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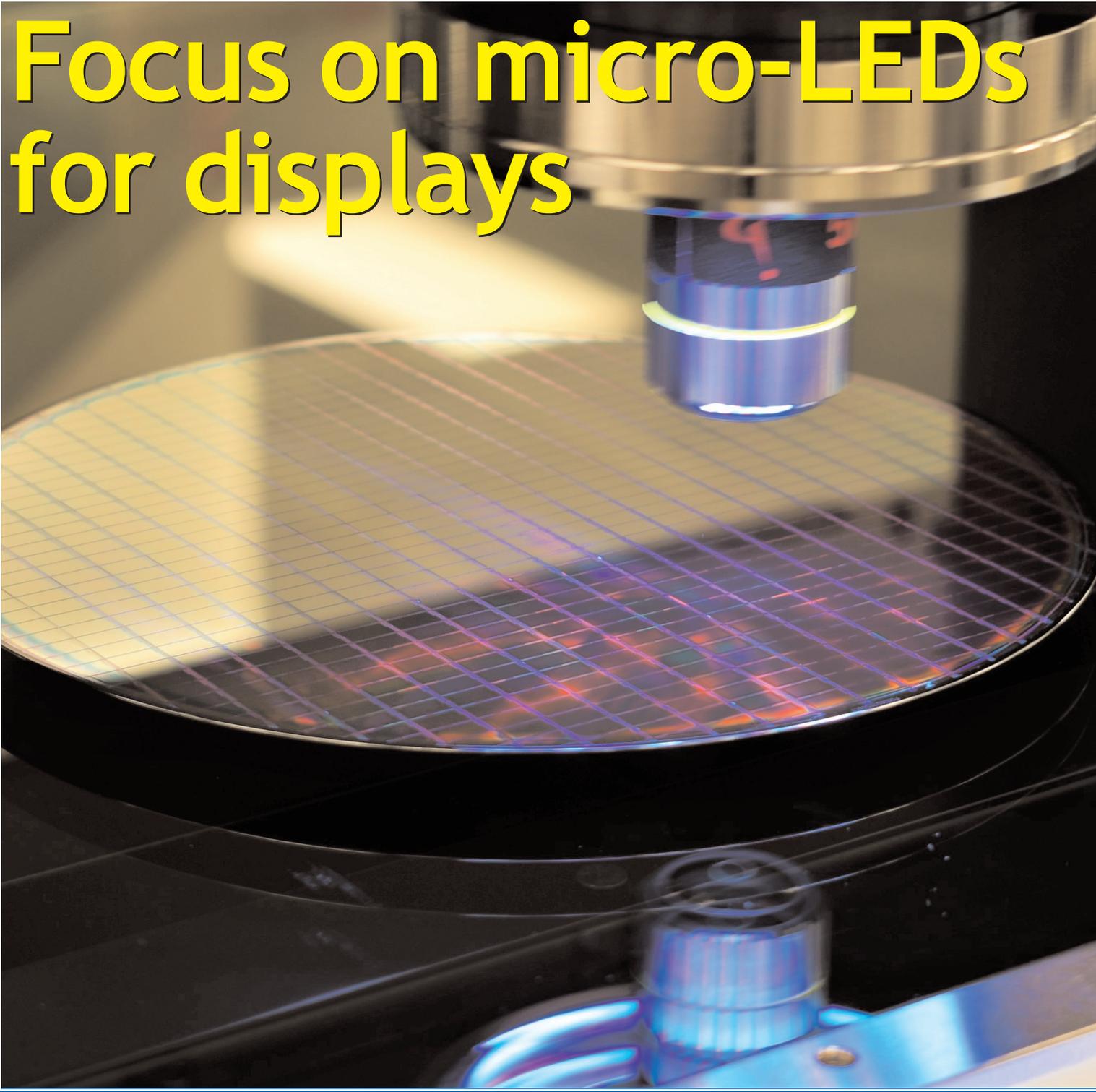
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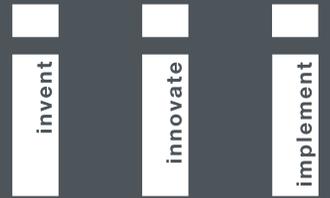
Vol. 15 • Issue 9 • November/December 2020

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Focus on micro-LEDs for displays

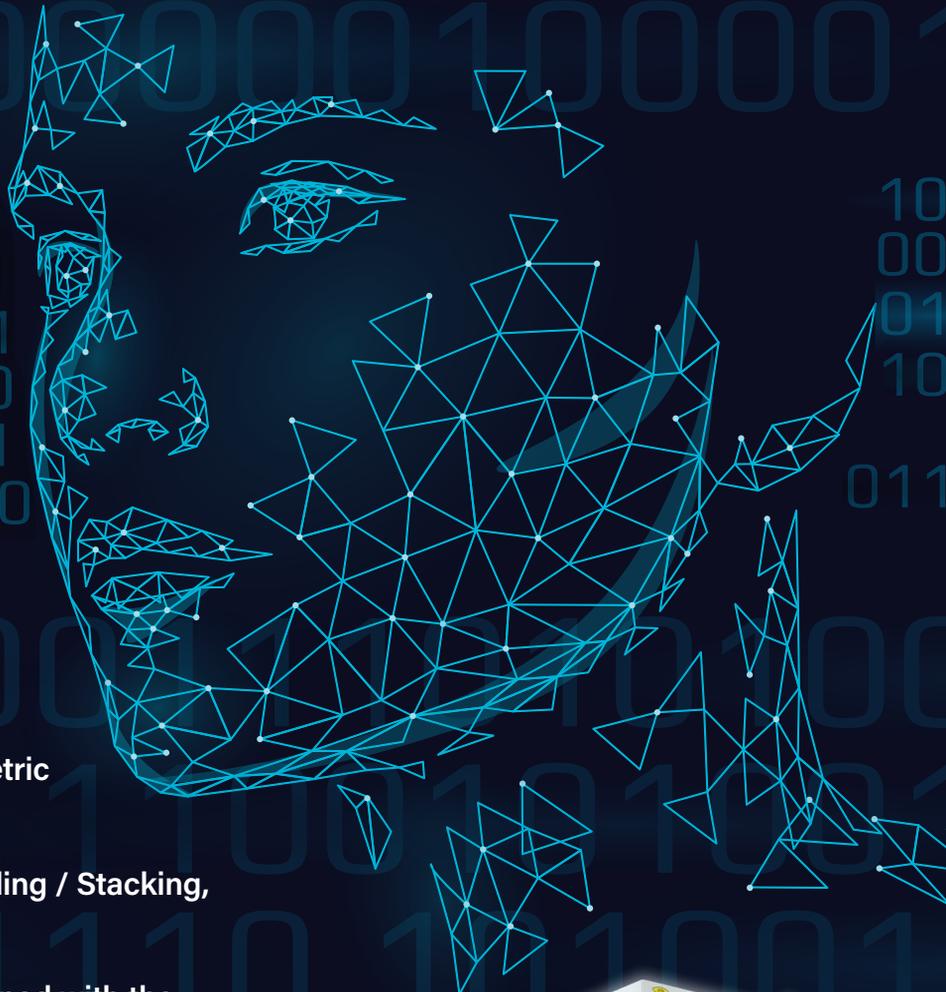


IQE founder relinquishing CEO role • NUBURU raises \$20m
Osram unveils its first UV-C LEDs • Kyocera acquiring SLD Laser



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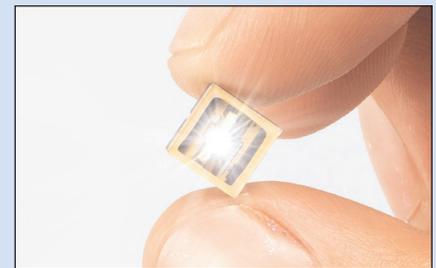
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p20 Japan's ROHM and China's UAES have established a joint laboratory for SiC technology in Shanghai.



p55 Aledia has manufactured what it says are the first micro-LED chips produced on 300mm silicon wafers.



p61 Japan's Kyocera has agreed to acquire US-based SLD Laser (formerly Soraa Laser Diode).



Cover: CP Display has opened its Micro-LED Innovation Acceleration Center in Arizona, the first fabrication plant dedicated to accelerating the time-to-market of sub-5µm-pixel monolithically integrated micro-LED displays to meet demand for mass-market AR/MR and smart wearable devices.. **p54**

UV-C LEDs a 'killer app' against virus?

As 2020 draws to a close the COVID-19 pandemic is still defying control. But now, after unprecedented speed of development, several vaccines are being approved and administered (including, in the last few days, those that are low cost and require mere refrigeration rather than continuous freezing, enabling widespread distribution). However, it will take several months to achieve anything approaching 'herd immunity' in any countries, and that's assuming that most citizens choose to be vaccinated. In the meantime, personal precautions and societal restrictions remain key to suppressing transmission of the SARS-CoV-2 virus.

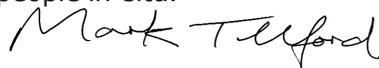
A downside of restrictions is the economic impact, through short-term disruption of supply chains and, in the mid term, the reduction of demand. This has particularly hit sectors such as transport and mobile consumer electronics. However, due to what is perhaps a permanent shift in lifestyle such as work-from-home and video-calling, sectors such as 5G, Wi-Fi 6 and fiber-optic communications are seeing greater demand.

This has partly driven the 30-35% sequential revenue growth in the September quarter for both RF IC makers Skyworks and Qorvo (exceeding even the increased guidance), outweighing the loss of revenue from Huawei due to the US-China trade dispute (see pages 8-13). Likewise, for photonic integrated circuit (PIC) firm NeoPhotonics, non-Huawei revenue for 400G-and-above products was up 91% year-on-year for the first three quarters of 2020, driven by a doubling in 400G ports being shipped (see page 76). Meanwhile, Lumentum's revenue grew 22.9% in Q3, with datacom chip production capacity increases being outstripped by the growing demand from data centers (offsetting delays in 5G deployments in China) — see page 78. Similarly, Emcore's revenue grew 23%, driven by demand for cable TV optical transmitters and components as MSOs "continue to expand their networks to break bottlenecks created by bandwidth demands for work-at-home and stay-at-home entertainment" (see page 84).

Currently, new variants of the virus with higher transmissibility are causing a resurgence of infections. It is assumed that the new vaccines will remain equally effective, but the best case is perhaps the need for regular renewal of vaccination as the virus mutates (as for seasonal 'flu). So, even with herd immunity to the established strain of the virus, prevention of transmission may remain key in order to suppress infection.

One prospect is the use of UV-C LEDs to provide sterilization of water, surfaces and air. Various reports have been issued regarding the effectiveness of UV-C LEDs to kill the SARS-CoV-2 virus, for example by Seoul Semiconductor subsidiaries Seoul Viosys and SETi (in the USA), and by US-based NS Nanotech. Most recently, for example, Seoul Viosys' Violeds technology has been applied to the moving handrails of escalators and moving walkways (see page 58). Meanwhile, Germany's Osram Opto has just launched its first UV-C LED (emitting at a wavelength of 275nm), representing the "beginning of a comprehensive portfolio of LEDs in the UV-C LED sector" (page 60). Applications include disinfection in air-conditioning systems (e.g. for vehicle interiors). In addition, NS Nanotech has partnered with AquiSense to develop what is claimed to be the first 'broadband' solid-state UV emitter, spanning from 400nm UV-A down to far-UV-C wavelengths of 200nm (page 52). The ability to tailor compound semiconductors for emission at short wavelengths — safe to eyes and skin — can be key to killing the airborne virus with people in-situ.

Mark Telford, Editor



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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices

(e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

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- feature articles (technology, markets, regional profiles);
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Semiconductor Today (ISSN 1752-2935) is published free of subscription charge

in a digital format 10 times per year by Juno Publishing and Media Solutions Ltd, Suite no. 133, 20 Winchcombe Street, Cheltenham GL52 2LY, UK. See: www.semiconductor-today.com/subscribe.htm

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Micro-LED chip revenue to reach \$2.3bn in 2024

Growth to be driven mainly by TV and large-sized display integration

Since the introduction of Sony's large-sized modular micro-LED display in 2017, other companies, including Samsung and LG, have successively made advances in micro-LED development, in turn generating much buzz for the technology's potential in the large-sized display market, according to market research firm TrendForce. Emissive micro-LED TVs are expected to arrive on the market between 2021 and 2022. Even so, many technological and cost-related challenges are yet to be solved, meaning that micro-LED TVs will remain ultra-high-end luxury products at least during the technology's initial stage of commercialization.

TrendForce reckons that micro-LED technology is likely to first enter the market in several applications, including small-sized head-mounted augmented reality (AR) devices, wearables such as smartwatches, high-margin products such as automotive displays, and niche products such as high-end TVs and large-sized commercial displays.

After this initial wave of products, micro-LED technology will subsequently also see gradual integration in mid-sized tablets, notebook computers and desktop monitors.

In particular, micro-LEDs will see the highest potential for growth in the large-sized display market, mainly since these products have a relatively low technological barrier.

Driven primarily by TV and large-sized display integration, micro-LED chip revenue is expected to reach \$2.3bn in 2024.

Taiwanese & Korean manufacturers working to overcome technical and cost-related roadblocks

The vast majority of micro-LED TVs and large-sized displays feature a traditional LED architecture of RGB LED chip packages paired with

passive matrix (PM) drivers. Not only is PM costly to implement but it is also limited in terms of how far the pixel pitch of the display can be decreased, making micro-LED technology viable for only commercial displays currently.

However, various panel manufacturers and display brands have in recent years developed their own active matrix (AM) solutions, which make use of an active pixel addressing scheme and feature thin-film transistor (TFT) glass backplanes. Furthermore, compared with PM, the IC design for AM is simpler, so AM requires less physical space for routing. All of these advantages make AM the more suitable solution for high-resolution micro-LED TVs.

Korean companies (Samsung/LG), Taiwanese companies (Innolux/AUO) and Chinese firms (Tianma/CSOT) have all now demonstrated their respective AM display applications. Regarding the LED light source, Samsung has partnered with Taiwan-based PlayNitride to create a full-color micro-LED display manufactured using semi-mass-transfer of RGB LED chips.

Micro-LED technology is likely to first enter the market in several applications, including small-sized head-mounted AR devices, wearables such as smartwatches, high-margin products such as automotive displays, and niche products such as high-end TVs and large-sized commercial displays

This process differs from the traditional method of LED display manufacturing, which utilizes RGB LED chip packaging technology instead. Conversely, Taiwan-based panel makers AUO and Innolux have pioneered a color-rendering technology that combines blue-light LED chips with quantum dots or LED phosphors.

On the other hand, the cost of micro-LED displays depends on the display resolution and chip size. As users demand higher-resolution displays going forward, micro-LED chip consumption will also skyrocket, forecasts TrendForce. TVs and LED displays in particular will dwarf other applications in micro-LED chip consumption. For example, a 75-inch 4K display requires at least 24 million RGB micro-LED chips for its subpixel array. Therefore, the manufacturing cost, which includes technologies such as semi-mass-transfer, and the material cost of micro-LED chips will remain very high for the time being, it is reckoned.

In light of this, TrendForce believes that technological and cost-related issues will remain the greatest challenge to the market availability of micro-LED TVs and large-sized micro-LED displays. As TVs trend toward large sizes and high resolutions in the future, manufacturers must confront increasing difficulties in micro-LED technologies, including mass transfer, backplanes, drivers, chips and inspection and repair, says TrendForce. Once these technological bottlenecks have been overcome, whether the cost of micro-LED manufacturing will undergo a corresponding, rapid drop will then determine the viability of the micro-LED as a mainstream display technology, the firm concludes.

www.trendforce.com

Micro-LEDs lighting way for display technologies?

While hindering progress, gaps in the supply chain and manufacturing capabilities present great opportunity

Micro-LED technology has been garnering interest for several years now, particularly since 2014 when Apple purchased the micro-LED-focused start-up LuxeVue. The implication that leading tech firms were racing to incorporate micro-LEDs into their highly desirable consumer tech prompted a flurry of speculation that micro-LEDs would be the 'next big thing' in TVs, smartphones, wearables and much more.

That hasn't happened – yet. But in the past few years the likes of Sony, LG and Samsung have demonstrated large-scale micro-LED screens, while other firms have brought various micro-LED prototypes to market, and still more have expressed plans to do so.

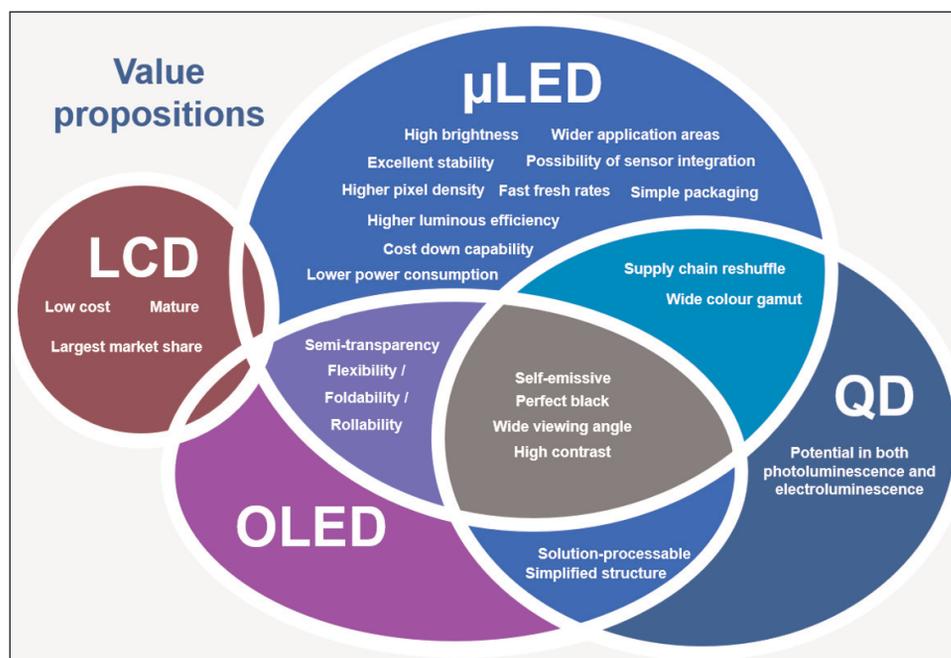
But the question of whether, and how, it will become the natural replacement for other LED technologies – including the currently dominant LCD and OLED – is somewhat complex.

In the new study 'Micro-LED Displays 2020–2030: Technology, Commercialization, Opportunity, Market and Players', market research firm IDTechEx reveals how gaps in the current supply chain and manufacturing capabilities may on one level be seen as hindering progress but are, simultaneously, generating great opportunity.

Micro-LED definition

Micro-LEDs act as pixels and are thus described as self-emitting. They use much smaller LED chips than their predecessors. There is no formally agreed definition, but generally a micro-LED chip is less than 100µm (i.e. LED emission area per pixel below 100µm x 100µm).

The size and nature of micro-LEDs convey several advantages when used in display screens. Their color gamut is superb, with perfect blacks and brightness above 1 million nits. A micro-LED screen can be exceptionally thin, with



Value propositions of various display technologies (Source: IDTechEx).

resolution as high as 6000PPI (pixels per inch), and has a wide viewing angle. Micro-LED screens also have a long lifespan, can be flexible and/or transparent, and can incorporate sensor technologies (such as biometric sensors to unlock the screen in a smartphone display).

Furthermore, unlike traditional LED screens which are huge and visibly lose resolution as the viewer gets closer, micro-LED displays retain their sharpness regardless. In addition, they can be used in a wide range of screen sizes (i.e. they are eminently scalable). The Figure illustrates the capabilities of micro-LED displays vis-à-vis

Unlike traditional LED screens which are huge and visibly lose resolution as the viewer gets closer, µLED displays retain their sharpness regardless. In addition, they can be used in a wide range of screen sizes

other display technologies.

But, given this situation, why are micro-LED displays not ubiquitous? **Why the wait for micro-LED?** As an emerging technology in the early stages of maturity, micro-LED displays are currently expensive and hard to make. For this to improve, and for the potential cost savings and efficiency gains of micro-LED to be fully realized, innovation and evolution of various techniques is required.

For example, processes that would scale up manufacturing would be advantageous to the market. So would better chip transfer, repair, inspection and light management techniques.

Meeting such challenges need not be particularly complex or risky: many components are based on existing and mature manufacturing processes. Thus, it may be seen as an opportunity open to many firms in relevant fields. If micro-LED manufacturing can be improved, a world of applications and thus, commercial potential, will open up, reckons IDTechEx.

www.IDTechEx.com/MicroLED

Qorvo's revenue grows a more-than-expected 34.6%

Growth driven by upgrades to 5G and Wi-Fi 6

For fiscal second-quarter 2021 (ended 3 October 2020) — which is a 14-week quarter (since fiscal 2021 is a 53-week year) — Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$1060.3m, up 34.6% on \$787.5m last quarter and 31.4% on \$806.7m a year ago (and above both the original guidance of \$925–955m and the 8 September update to \$1–1.03bn). “Following our updated guidance, customer demand continued to strengthen, and we were able to support some of that demand within the quarter,” says chief financial officer Mark Murphy.

“Strength was diversified across customers and supported by multi-year technology upgrade cycles, including 5G and Wi-Fi 6,” he adds. “Customers are requiring more and better RF in highly integrated form factors to enable their next-generation products.”

Mobile Products revenue up 61% sequentially

Mobile Products revenue was \$754m (71.1% of total revenue), up 61% on \$468m last quarter and up 21% on \$623m a year ago (and above the expected \$640m), driven by seasonal demand effects and the ramp of 5G smartphones. During the quarter, Qorvo increased volume shipments of bulk acoustic wave (BAW) filter-based antenaplexer solutions to multiple tier-one OEM smartphone makers. It also expanded shipments of integrated main-path solutions (including low-band, mid-/high- and ultra-high-band modules) across multiple tier-1 Android smartphone OEMs. Qorvo also saw broad-based content gains in Wi-Fi 6 in support of leading suppliers of smartphones, tablets, mesh networks, gateways, smart speakers and virtual reality (VR) headsets.

Infrastructure & Defense Products revenue up 66.3% year-on-year

Infrastructure & Defense Products (IDP) revenue was \$306m (28.9% of total revenue), down 4.1% on the record \$319m last quarter, as expected, but up 66.3% on \$184m a year ago, in support of the ongoing build-out of 5G networks and the roll-out of WiFi 6. WiFi revenue was broad-based across products and customers.

In wireless infrastructure, Qorvo was awarded multiple design wins in support of 5G massive MIMO base-station deployments, expanding its customer base for GaN amplifiers. Within that, the firm commenced shipments of GaN amplifiers supporting massive MIMO C-band base-station deployments, first in the USA and then other regions globally. Qorvo also launched high-performance BAW filters for 5G small cells and repeaters to enable 5G band 41 and Wi-Fi coexistence.

In wireless connectivity, revenue more than doubled year-on-year. Customer demand for front-end modules and BAW filters was especially strong in support of CPE and retail applications. Shipments to the leading connected home platform provider included WiFi 6 FEMs, BAW filters and multi-protocol SoCs. Also, for next-generation WiFi gateway, Qorvo was awarded the entire RF band in support of the leading North American multiple system operator (MSO), including the 2.5GHz and 5GHz FEMs and a variety of filter products.

In defense & aerospace, Qorvo was the exclusive RF recipient of the multi-year US government State-of-the-Art Heterogeneous Integrated Packaging (SHIP) program.

In power management, strong growth was driven by the transition to solid-state storage in client devices such as laptops and enterprise computing and data centers.

Demand has also been strong for motor control products as brushless motor technology, which continues to gain share in a broad range of consumer products. “Our Programmable Power Management business is performing very well across diverse markets as we help customers enhance product performance, reduce weight, improve reliability and bring products to market faster,” says president & CEO Bob Bruggeworth.

In automotive, Qorvo began sampling a second-generation automotive cellular V2X FEM that integrates the PA, LNA, switch and BAW coexistence filter to solve critical system-level challenges.

On a non-GAAP basis, gross margin has risen further, from 40.1% a year ago and 48.6% last quarter to 51.7% (above the forecasted 50%), due to better-than-expected mix and favorable manufacturing cost variances. “Our efforts to improve the portfolio, drive productivity and carefully manage inventories continue to yield favorable results,” says Murphy.

Operating expenses have grown further, from \$166.7m a year ago and \$178.7m last quarter to \$219m, due to the additional week, incentive compensation and other labor costs.

Net income is up from \$175.1m (\$1.50 per diluted share) last quarter and \$181.2m (\$1.52 per diluted share) a year ago to \$282m (\$2.43 per diluted share, above both the original guidance of \$1.90 and 8 September's update to \$2.14).

“Qorvo outperformed our updated guidance on revenue, gross margin and EPS,” notes Bruggeworth.

Cash flow from operations has grown from \$173.4m a year ago and \$214m last quarter to \$281m. Capital expenditure (CapEx) was \$43.6m. Free cash flow was hence \$237.4m (up from \$184m last quarter and \$135.4m a year ago). During the quarter, Qorvo repurchased \$105m of shares.

"We took steps to reduce our cost of debt and further improve our financial flexibility," says Murphy. Qorvo renewed its unsecured credit facility at more favorable terms and extended it to 2025. It also increased its term loan to \$200m and raised \$700m through a new issue of unsecured notes maturing in 2031. After the quarter closed, these proceeds and cash on hand were used to pay down the firm's notes maturing in 2026. The debt balance is now under \$1.8bn. Cash is about \$1.1bn. "Our leverage remains low," says Murphy. The firm's \$300m unsecured revolving credit facility remains untapped. "The weighted average maturity of our debt is 2029, and we have no material near-term maturities," he adds.

"With our financial flexibility, we can focus on advancing technology, supporting customers and making prudent organic and inorganic investments that support long-term earnings and free cash flow growth," says Murphy.

Over the last 12 months, free cash flow margin reached a milestone of about 25% of revenue, generating \$860m. Meanwhile, \$700m has been deployed for acquisitions and \$400m worth of stock has been repurchased, totalling \$1.1bn. Over the last six quarters, Qorvo has generated \$1.2bn in free cash flow, while buying \$1bn worth of companies [comprising five acquisitions] and repurchasing \$700m worth of stock. "Since inception, we've returned to shareholders 113% of our free cash flow, or \$3.1bn at an average [stock] price of \$63," notes Murphy.

To support the ongoing development of its ultra-wideband (UWB) products (following the acquisition in February of Decawave Ltd of Dublin, Ireland) and accelerate their adoption across mobile, IoT and automotive ecosystems, in the September quarter Qorvo acquired Paris-based UWB software and system solution provider 7Hugs Labs S.A.S. "This acquisition enhances Qorvo's software capabilities... 7Hugs brings a highly skilled team with vast experience in UWB applications and a

portfolio of intellectual property," says Murphy. "The combination of our hardware technology with their software expertise positions Qorvo to accelerate the development of broad ultra-wideband ecosystem expected to reach billions of devices in the coming years," he adds. "We see a wide array of applications emerging with ultra-wideband technology and have significant customer engagement on the design of new products and solutions. We expect UWB to contribute meaningfully to Qorvo over time."

Qorvo also signed a partnership agreement with design services company Sigma Connectivity to develop advanced UWB solutions and assist customers in the creation of applications. "We see adoption in smartphones as the catalyst for a broad ecosystem of connected devices. Similar to Bluetooth, smartphones will be the hub, connecting to multiple peripherals," forecasts Murphy.

"We project robust end-market demand to continue into the December quarter," says Murphy. For fiscal third-quarter 2021 (to end-December 2020), Qorvo expects revenue to be steady at \$1060m plus or minus \$15m. "Our December quarter revenue outlook reflects seasonal demand effects and demand for multi-year technology upgrade cycles," he adds. "In Mobile, demand for 5G is adding RF complexity and driving higher content." Mobile revenue is expected to grow to \$790m. In accordance with Department of Commerce regulations, in mid-September Qorvo suspended shipments to Huawei. Although it has recently received a license to ship certain mobile products, the firm has assumed no sales to Huawei in the December quarter while it works with the customer to

understand the impact of the license. IDP revenue is expected to fall to \$270m, reflecting the timing of base-station deployments.

Gross margin should rise to 52.5% in the December quarter, reflecting volume growth and ongoing efforts to improve the quality and efficiency of the business. "Specifically, we've invested early and adequately in the technologies that markets need, focused our product portfolio on where we can best serve customers, gained productivity across our operations and reduced our capital intensity," says Murphy.

Operating expenses are projected to fall to \$205m as Qorvo returns to a normal fiscal quarter length and other personnel costs decrease. Diluted earnings per share is expected to rise to \$2.65.

IDP revenue is forecasted to sustain strong double-digit year-on-year growth through the balance of the fiscal year, with infrastructure demand picking up in the March quarter. Continued strength in defense, WiFi and power management is expected due to durable underlying trends. "While considerable economic uncertainty remains with the ongoing effects of the pandemic, currently we expect end-market demand to support full fiscal year double-digit revenue growth [of 10–15%] for Qorvo," says Murphy.

"Our work to keep our inventories and cost structure low will help us sustain over 50% gross margin through the balance of the fiscal year [despite an expected drop of 150 basis points from fiscal Q3 to Q4 due to seasonally lower volumes]," he believes. "We think we're going to be able to sustain or expand gross margins as we go forward beyond fiscal 2021."

"We still project capital expenditures to remain below \$200m in fiscal 2021 and focus on areas that advance a differentiated position for Qorvo to best serve customer needs, such as BAW and GaN," says Murphy. "Currently, we expect free cash flow to be about \$900m [a record] this fiscal year."

www.qorvo.com

Work to keep our inventories and cost structure low will help us sustain over 50% gross margin through the balance of the fiscal year

Qorvo to create US-funded Heterogeneous Integrated Packaging RF production and prototyping center

SHIP program targets phased-array radar, unmanned vehicles, electronic warfare platforms and satcoms

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has been selected by the US government to create a State-of-the-Art (SOTA) Heterogeneous Integrated Packaging (SHIP) RF production and prototyping center. The SHIP program aims to ensure that microelectronics packaging expertise and leadership is available for both US defense contractors and commercial clients that require design, validation, assembly, test and manufacturing of next-generation RF components.

The exclusive SHIP Other Transaction Agreement (OTA), worth up to \$75m, was awarded to Qorvo by the Naval Surface Warfare Center (NSWC), Crane Division. The program is funded by the Office of the Undersecretary of Defense for Research and Engineering's (OUSD R&E) Trusted and Assured Microelectronics Program (T&AM). It is administered by the Strategic & Spectrum Missions Advanced Resilient Trusted System (S²MARTS)



Other Transaction Agreement (OTA), managed by National Security Technology Accelerator (NSTXL).

Under the SHIP program, Qorvo will design and deliver the highest levels of heterogeneous packaging integration. This is essential to meet the size, weight, power and cost (SWAP-C) requirements for next-generation phased-array radar systems, unmanned vehicles, electronic warfare (EW) platforms and satellite communications.

"This award reflects Qorvo's proven track record as a global leader in RF technology with over 35 years of experience," says James Klein, president of Qorvo's Infrastructure and Defense Products (IDP) group. "As part of this collab-

oration, Qorvo will expand its proven capabilities in Texas to create a SOTA facility that best serves the needs of the US government and commercial customers."

Qorvo's US-based capabilities include advanced manufacturing, packaging and testing for both high- and low-power applications ranging from DC to 100GHz. The firm holds a Defense Microelectronics Activity (DMEA) Category 1A trusted source certification for package assembly, test and wafer foundry services at its plant in Richardson, TX. Qorvo says that it further provides defense customers with greater value by applying high-yield manufacturing and scale expertise gained from serving the commercial market — to which it supplies more than 4 billion heterogeneous modules annually.

Qorvo acquires UWB software provider 7Hugs Labs

Qorvo has acquired Paris-based 7Hugs Labs S.A.S., a software provider for ultra-wideband (UWB) applications. The acquisition helps to strengthen Qorvo's UWB product offering for smartphones and other devices that increase the accuracy of a host of new location and communication services.

"The 7Hugs Labs team is a great addition to our Mobile Products business, providing the software talent and expertise to leverage the unique precision location capabilities of UWB," comments Eric Creviston, president of Qorvo's Mobile Products group.

"7Hugs Labs' proven software and software stack complement our UWB chipset offering and will help enable a host of new ultra-wideband applications in mobile, IoT and automotive markets," he adds.

"Our team is excited to take this next important step in software development as we build on our commercial success in the UWB market," says 7Hugs Labs' CEO & co-founder Simon Tchedikian. "Now, as part of Qorvo, we look forward to playing a larger role in helping the industry grow, expediting the integration of UWB in

ways that will truly transform our daily interactions with technologies."

7Hugs Labs was founded in 2014 and has been a trusted software partner for Decawave, which is now the UWB business unit (UWBU) within Qorvo's Mobile Product business. As part of Qorvo, the 35-member 7Hugs Labs team will help create complete UWB solutions — including chips, firmware and software — for a broad ecosystem that is expected to reach billions of devices in the coming years

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Skyworks' revenue grows a more-than-expected 30% in September quarter

Continued double-digit sequential revenue growth expected for December quarter

For full-year fiscal 2020 (ended 2 October), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$3356m, down slightly on fiscal 2019's \$3377m.

However, fiscal fourth-quarter 2020 revenue was \$956.8m, up 30% on \$736.8m last quarter and 16% on \$827.4m a year ago (and exceeding the \$830-850m guidance), driven by increasing adoption of the firm's mobile solutions and rising broad market momentum.

By business sector, revenue grew 30% sequentially and by double digits year-on-year in both Mobile (Integrated Mobile Systems and Power Amplifiers) and Broad Markets (up by almost \$70m to a record of \$295m, aided by "incredible diversification, with many new customers"). As for the previous two quarters, the split of total revenue was again 69% Mobile and 31% Broad Markets.

"During the quarter, our solutions powered a broad set of use cases. From the newest and most innovative smartphones to industrial IoT, automotive, cognitive audio and touchless commerce. Specifically, in Mobile, we accelerated the ramp of our Sky5 portfolio, while supporting leading 5G smartphone launches, including those from Samsung, Oppo, Vivo, Xiaomi, Google and other major tier-1s," says president & CEO Liam Griffin. Conversely, Huawei was slightly below expectations, at about 3% of total revenue.

"In IoT, we enabled touchless point-of-sale systems at Square, powered WiFi 6 access points for Amazon, ramped WiFi 6 solutions for advanced routers at NETGEAR and ASUS, and launched residential gateways at Verizon and Telecom Italia. We also supported Facebook's

newest Oculus AR/VR platform. And we further bolstered our position in low-latency cognitive audio solutions, powering wireless headsets at Logitech, Razor and Sony, among others," Griffin adds.

"In the industrial space, we introduced embedded connectivity modules enabling Fibocom's latest enterprise IoT architectures. We delivered critical medical applications at Boston Scientific and GE and also supported wireless utility metering at Itron and Census."

"In infrastructure, we secured multiple design wins in 5G wireless infrastructure deployments, powering next-generation MIMO base stations and small-cell installations."

"In automotive, we ramped telematic subsystems for BMW and Tesla and launched high-speed connected-car solutions for Daimler and leading OEMs in Japan and Korea."

"These engagements illustrate the diverse and expansive nature of our portfolio, supporting a broad array of customers and applications," summarizes Griffin.

On a non-GAAP basis, full-year gross margin has fallen further, from fiscal 2019's 50.6% to 50.2% for fiscal 2020. However, quarterly gross margin was 50.4% in fiscal Q4/2020, up on 50.1% last quarter and 50.3% a year ago, despite a headwind of 75-100 base points from the COVID-19 pandemic.

Quarterly operating expenses were \$147m (15.4% of revenue, cut from 18.9% last quarter), demonstrating leverage in the firm's operating model while continuing strategic investments in support of future growth.

Full-year net income has fallen from fiscal 2019's \$1076.7bn (\$6.17 per diluted share) to \$1041.3m (\$6.13 per diluted share). However, fiscal Q4/2020 net income was \$312.2m (\$1.85 per

diluted share, exceeding guidance by \$0.34), up from \$210.8m (\$1.25 per diluted share) last quarter and \$261.9m (\$1.52 per diluted share) a year ago.

"Skyworks significantly exceeded September quarter expectations in revenue and earnings per share, capping off a fiscal year that both tested and demonstrated the resilience of our business model," says Griffin.

"The Skyworks team executed exceptionally well despite a challenging environment, navigating the COVID-19 pandemic and headwinds from US-China trade relations," comments senior VP & chief financial officer Kris Sennesael.

In fiscal Q4/2020, cash flow from operations was \$267m (taking full-year operating cash flow to \$1.2bn). Capital expenditure (CapEx) was \$146m. Skyworks paid \$84m in dividends. Also, indicating its "conviction in the underlying strength of our business", the firm repurchased 1.7 million shares of its common stock at an average price of about \$140 per share for a total of \$231m. (During full-year fiscal 2020, Skyworks returned \$955m to shareholders via \$307m in dividends plus \$648m through the repurchase of 6.3 million shares.)

Overall, cash, cash equivalents and marketable securities fell from \$1162m at the end of last quarter to \$980m. Skyworks has no debt.

"We continue to deliver very strong free cash flow, and we continue to return all of that back to the shareholder... We've been very active from a buyback point of view," says Sennesael. "That still leaves us \$1bn of cash on the balance sheet with no debt, and so there is optionality from an M&A point of view."

"With 5G technology launches now well underway, we are ramping our innovative Sky5 solutions in a rap-

idly expanding set of end markets, from mobile to IoT, automotive and wireless infrastructure. Increased demand for reliable, ultra-fast wireless connections in our homes, businesses, schools and medical facilities is driving strong momentum throughout our product portfolio, positioning Skyworks for continued growth," continues Sennesael.

"We expect double-digit sequential revenue and earnings growth in the December quarter, fueled by content gains and product ramps across multiple 5G-enabled smartphone platforms and increased demand across our broad markets portfolio."

For fiscal first-quarter 2021, Skyworks expects of \$1040–1070m, up 10% sequentially and 18%

year-on-year (with sequential growth in both Mobile and Broad Markets). Specifically, Broad Markets should grow strongly, to a new record over \$300m. Mobile is expected to accelerate, driven by sequential growth for South Korea's Samsung as well as key China-based customers Oppo, Vivo and Xiaomi. No revenue for Huawei has been included despite the fact that Skyworks recently obtained a limited license from the US Department of Commerce to ship certain products to Huawei. "We are still figuring it out with the customer, which products they need, which products they want," says Sennesael.

Gross margin should rise slightly to 50.25–50.75% as the firm continues to drive profitability expansion.

"We still have some headwinds as a result of COVID-19 with social distancing, extra cleaning and sanitation, and some disruption in the supply chain here that is hitting us," notes Sennesael. "So, we expect over time to see further improvements there on the gross margin towards our target model of 53%."

With operating expenses of \$148m, diluted earnings per share should be \$2.06 (up 11% sequentially and more than 20% year-on-year).

Dividend payment

Skyworks' board of directors has declared a cash dividend of \$0.50 per share of common stock (payable on 10 December) to stockholders of record at the close of business on 19 November.

www.skyworksinc.com

Qorvo's CEO Bob Bruggeworth elected chair of SIA

The Semiconductor Industry Association (SIA) board of directors has elected Bob Bruggeworth, president, CEO & director of Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications), as its 2021 chair and Steve Mollenkopf, CEO & director of Qualcomm Inc, as its 2021 vice chair. SIA represents 98% of the US semiconductor industry by revenue and nearly two-thirds of non-US chip firms.

"Both engineers by trade, Bob and Steve are dedicated industry leaders and accomplished champions for chip technology," comments SIA president & CEO John Neuffer. "Their combined skills and experience will greatly benefit SIA in the year ahead as we work to advance semiconductor industry priorities in Washington and capitals around the world."

Bruggeworth served as president & CEO of RF Micro Devices from January 2003 to December 2014, prior to the merger of RFMD and TriQuint to form Qorvo. He was previously president of RFMD from June 2002 until January 2003. Before this, he was also vice presi-



dent and then president of RFMD's wireless products group. Prior to joining RFMD in September 1999, Bruggeworth held various leadership positions at AMP Inc (now TE Connectivity), serving most recently as VP of global computer & consumer electronics. He is an electrical engineer and a graduate of Wilkes University, Wilkes-Barre, PA.

The SIA is "a coalition that has never been more important to our industry — and our country — than it is now," comments Bruggeworth. "I'm eager to work alongside my colleagues on the SIA board to raise awareness about our industry and the tremendous importance of semiconductor technology to our country's economic strength and national security."

Bruggeworth delivered remarks at the 2020 SIA Leadership Forum & Award Celebration (a virtual event) on 19 November.

Mollenkopf joined Qualcomm in 1994 as an engineer and, during his tenure, has helped to make

Qualcomm a leader in foundational technologies, such as 5G, and the world's largest mobile chipset supplier. His technical and business leadership have been critical to the development and implementation of multiple industry-leading innovations and products. A published IEEE author, Mollenkopf holds patents in areas such as power estimation and measurement, multi-standard transmitter system, and wireless communication transceiver technology. He holds a Bachelor of Science in electrical engineering from Virginia Tech, and a Master of Science in electrical engineering from the University of Michigan.

"Amid an ongoing pandemic and global economic uncertainty, smart government policies are needed now more than ever to ensure sustained US leadership in semiconductor technology," says Mollenkopf. "Our industry speaks with one voice through SIA to promote policies that advance semiconductor innovation and the many chip-enabled technologies of the future."

www.qorvo.com

www.semiconductors.org

Imec's Advanced RF program to develop scalable, energy-efficient 6G device technology

Hybrid III-V/CMOS to enable operating frequencies above 100GHz

At the Japan installment of its ITF 2020 Technology Forum, imec of Leuven, Belgium launched the Advanced RF pre-competitive research program, which aims to lay the groundwork for next-generation mobile communications, focusing on creating a roadmap beyond 5G device technology.

One of the paths that imec will explore includes the use of a hybrid III-V/CMOS approach to energy-efficiently and cost-effectively accommodate the very high bandwidths enabled by radio frequencies above 100GHz. Focusing on concrete proof points, imec and its partners aim to present prototypes that show this approach's potential.

Imec says that, to realize the program's targets, it will tap into its broad expertise in the connectivity space — combining its system, circuit and network knowledge with its semiconductor know-how, both in the digital and analog domains.

With bandwidth demands doubling every two years and existing radio spectrum bands getting clogged up, the telecoms industry is looking continuously for novel technologies and approaches to anticipate future mobile communication requirements. Three generations of cellular networks have been introduced since the early 2000s — starting off with the roll-out of 3G, the commercial introduction of 4G in 2009, and today's deployment of 5G networks. Still, demand for bandwidth remains insatiable.

Single-link data rates of 100Gb/s, μ s latency and new, bandwidth-hungry apps

"There is still some discussion on 6G's exact characteristics and performance specs, as the actual standardization effort has yet to start," says Michael Peeters, VP of imec's R&D activities in the connectivity domain. "What is clear, though, is that next-generation wireless networks will largely out-smart their predecessors. Projected

features include a 100Gbit/s single-link throughput, micro-second (μ s) latency and a significantly higher energy efficiency — <1 nJ per bit."

"This will be crucial to enable concepts such as federated learning between artificial intelligence (AI)-enabled autonomous systems such as self-driving cars," he believes.

"Other use-cases include the deployment of very high-speed, ultra-reliable mobile hot spots in dense urban centers, the support of immersive augmented reality (AR) applications, and holography."

Tapping into higher radio frequencies in an energy and cost-efficient way

The quest for more bandwidth is inextricably linked with the use of higher radio frequencies: the higher the frequency, the more bandwidth that is available. Hence, while the 5G mobile networks that are on the verge of being deployed will initially operate in the 28GHz and 39GHz bands, future mobile networks will resort to frequencies above 100GHz to cater to the world's growing bandwidth demands. A similar shift to higher frequencies is happening outside of the cellular space as well.

"That is where we come across one of the main challenges to making affordable solutions a reality — as today's standard silicon device technology lacks the required transmit power and energy efficiency at higher radio frequencies," says Nadine Collaert, program director for imec's analog/RF activities.

"III-V materials — such as indium phosphide (InP) — might offer a way out, but do not yet lend themselves to be integrated onto a silicon platform. Hence, we will specifically look into hybrid III-V/CMOS approaches," she adds. "We will investigate how III-V materials can heterogeneously be combined with CMOS technology, how those materials perform in terms of reliability, which degradation mechanisms are at work, etc.

Building on those insights, we aim to create mobile device technology that efficiently and cost-effectively operates at 100GHz and beyond."

The networks that will use these mobile links will likely also need new approaches to the protocol stack from the physical to network layer. The default choice nowadays for high-bitrate air interfaces, orthogonal frequency-domain multiplexing (OFDM), may no longer be the right choice. More directional beams at higher frequencies can make more aggressive use of spatial multiplexing. Meshing and even stronger separation of data and control may become needed. Here, we will leverage the expertise we have built, e.g. on mmWave channel modelling, dense and short-distance meshing, and time-sensitive networking.

Prototype that shows benefits of hybrid III-V/CMOS approach

"It is widely recognized that future mobile networks will have to operate at frequencies above 100GHz to deliver data rates of 100Gb/s and more. So far, however, a clear and mature pathway to developing the underlying technology has been lacking," says CEO Luc Van den hove. "With our Advanced RF program, we aim to extend our impact beyond our pioneering role in the semiconductor space — providing insight and technology across the connectivity ecosystem, and not only when it comes to enabling 6G but also to accommodate the next generation of Wi-Fi communications."

Over the past few years, imec has already conducted research into this topic. One example includes their work in the Electronics Components and Systems for European Leadership joint undertaking (ECSEL JU) 'Taranto' project, resulting in the development of an integrated, compact 140GHz radio module that enables single-link data rates up to 80Gb/s in an energy-efficient way.

www.imec.be

Multi-year supply deal from GlobalFoundries for Soitec's 300mm RF-SOI wafers

FEM makers demanding 8SW RF-SOI for 5G sub-6GHz smartphones

GlobalFoundries (GF) of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) and engineered substrate manufacturer Soitec of Bernin, near Grenoble, France have announced a multi-year supply agreement for 300mm radio-frequency silicon-on-insulator (RF-SOI) wafers. Building on the long partnership between the two firms, the strategic agreement secures the supply of wafers that will allow GF to further expand its role in providing solutions for the next-generation mobile phone market.

The primary driver of the wafer supply agreement is the growth of GF's most advanced RF-SOI solution, 8SW RF SOI. With what is claimed to be best-in-class switches and low-noise amplifiers, the 8SW RF-SOI RF front-end module (FEM) platform is optimized to deliver the combination of performance, power

efficiency and digital integration required by the designers and suppliers of both existing and future 4G LTE and sub-6GHz 5G smartphones. The new platform is using the most advanced RF-SOI substrates developed by Soitec. GF's 8SW RF-SOI customers are said to include the top FEM providers for 5G sub-6GHz smartphones.

"Eight out of ten smartphones on the market today include GlobalFoundries-manufactured silicon, and the demand for our differentiated RF solutions continues to skyrocket as the industry transitions to 5G," says Dr Bami Bastani, senior VP & general manager for Mobile and Wireless Infrastructure at GF. "The 5G revolution would not be possible without GlobalFoundries and our industry-leading specialty RF solutions. Securing this critical supply of wafers from our long-standing partner Soitec enables GF to meet the ever-growing demand for our 5G solutions," he adds.

"Our engineered substrates provide the foundation for manufacturing high-performance and high-reliability semiconductor devices required by the electronics industry," says Soitec's chief operating officer Dr Bernard Aspar. "With our manufacturing facilities both in France and in Singapore, we have put in place the largest worldwide capacity with the most advanced engineered substrates to meet the needs of this fast-growing 5G market."

The new agreement builds on the existing partnership between GF and Soitec. In 2017, the two firms entered into a five-year supply agreement for fully depleted silicon-on-insulator (FD-SOI) wafers for GF's 22FDX platform. Manufactured in Dresden, Germany, GF's 22FDX platform has since realized \$4.5bn in design wins, with more than 350 million chips shipped to customers around the world.

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Blue phosphorus 2D semiconductor monolayer becomes metallic as a bilayer

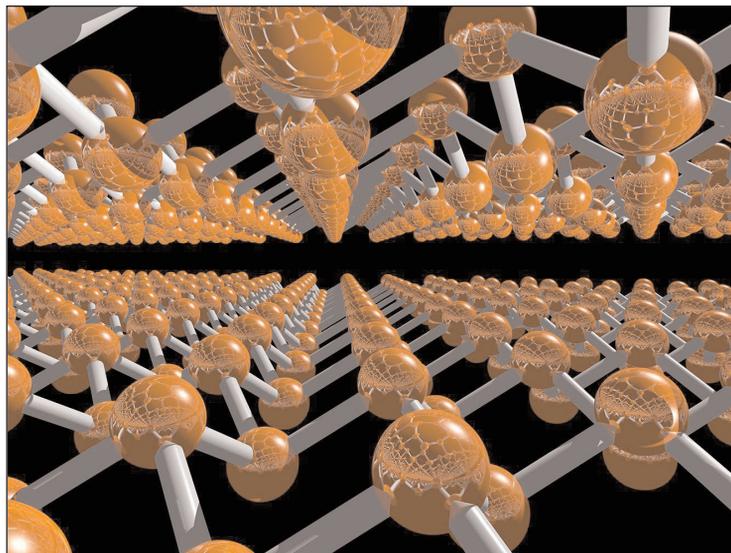
Semiconductor–metal transition could yield first single-element electronic/opto components

An interdisciplinary team led by professor Thomas Heine at Germany's Technische Universität Dresden and professor Gabriel Merino at the Mexican research institute Cinvestav Merida has discovered that blue phosphorus, an atomically thin synthetic semiconductor, becomes metallic as soon as it is converted into a double layer (Jessica Arcudia, et al, *Phys. Rev. Lett.* (2020) 125, 196401). The researchers are said to be first to describe the possibility of constructing nanoscale, highly efficient transistors consisting of only one element.

The chemical element phosphorus is considered to be one of the most essential elements for life. Phosphorus compounds are deeply involved in the structure and function of organisms. Every human carries about 1kg of it in the body. But even outside our bodies we are surrounded by phosphates and phosphonates every day: in our food, in detergents, fertilizers or in medicines.

Phosphorus occurs in several modifications that have extremely different properties. Under normal conditions, a distinction is made between white, purple, red and black phosphorus. In 2014, a team from the Michigan State University in the USA computationally predicted blue phosphorus, which could be produced experimentally two years later.

Due to its single-layer honeycomb-like structure, blue phosphorus is reminiscent of what is probably the best known two-dimensional (2D) material: graphene. Analogous to graphene, it was then also called blue phosphorene. This novel semiconductor material has since been investigated as an extremely promising candidate for optoelectronic devices.



Computer model of a two-layer buckled honeycomb structure of blue phosphorus. The compound is very stable and (due to the very small distance between the layers) has metallic properties. Copyright: Jessica Arcudia

In cooperation with Mexican scientists, Dresden chemist professor Thomas Heine has now made a unique discovery: by applying a topological concept they identified computationally a remarkably stable two-layer buckled honeycomb structure of blue phosphorene by means of highly precise calculations on high-performance computers. This two-layered compound is extremely stable. As the researchers surprisingly discovered, it has metallic properties due to the very small distance between the two layers.

Like all components, these devices must be supplied with power, which usually enters the material via metal electrodes. At the metal–semiconductor interface, energy losses are inevitable at such a Schottky barrier. Blue phosphorus is semiconducting as a single layer but it is predicted to be metallic as a double layer. Metallic 2D materials are very rare, and for the first time a pure elemental material has been discovered that exhibits a semiconductor–metal transition from the

monolayer to the double layer. Thus, an electronic or optoelectronic component for use in transistors or photo-cells can be realized from only one chemical element. Since there is no interface between semiconductor and metal in these devices, the Schottky barrier is greatly reduced and a higher effi-

ciency can be expected.

“Imagine you put two layers of paper on top of each other and suddenly the double sheet shines metallically like gold foil. This is exactly what we predict for blue phosphorene,” says Heine. “This work underlines the importance of interdisciplinarity in basic research. Using a topological-mathematical model and theoretical chemistry, we were able to design a new material on the computer and predict its physical properties. Applications in the field of nano- and optoelectronics are expected.”

For these results in basic research, first author Jessica Arcudia from Mexico has already been awarded the LatinXChem poster prize and the ACS Presidential Award. The young chemist was a guest student in the research group of Thomas Heine in 2018, where also her doctoral supervisor professor Gabriel Merino had worked previously.

<https://doi.org/10.1103/PhysRevLett.125.196401>
www.tu-dresden.de

UnitedSiC launches first 750V silicon carbide FETs

First Gen 4 devices offer 18mΩ and 60mΩ options

Power semiconductor maker United Silicon Carbide Inc (UnitedSiC) of Monmouth Junction, NJ, USA has launched the first four devices based on its Gen 4 SiC FET technology platform. As the first and only 750V SiC FETs currently available on the market, the Gen 4 devices enable what are claimed to be new performance levels, based on leading figures of merit (FoM), that benefit power applications across auto-motive, industrial charging, telecom rectifiers, data-center power factor correction (PFC), and DC-DC conversion as well as renewable energy and energy storage.

Available in options with on-resistance ($R_{DS(on)}$) of 18mΩ and 60mΩ, the new SiC FETs deliver what are claimed to be unmatched FoMs with reduced on-resistance per unit area, and low intrinsic capacitance. In hard-switching applications, the Gen 4 FETs exhibit what is reckoned to be the lowest $R_{DS(on)} \times E_{OSS}$ (mΩ-μJ), resulting in lower turn-on and turn-off loss. In soft-switching applications, their low $R_{DS(on)} \times C_{oss(tr)}$ (mΩ-nF) specification provides



lower conduction loss and higher frequency. The devices not only surpass existing competitive SiC MOSFET performance, whether running cool (25°C) or hot (125°C), but also offer the lowest integral diode V_F with excellent reverse recovery, delivering low dead-time losses and increased efficiency.

UnitedSiC says that, in expanding its range to 750V, the new devices offer more designer headroom and reduced design constraints. This

higher VDS rating also makes the FETs beneficial for 400/500V bus voltage applications, the firm adds. With a widely compatible gate drive of $\pm 20V$, $5V V_{th}$, all devices can be driven with 0V to +12V gate voltages. This means that they work with existing SiC MOSFET, silicon IGBTs and silicon MOSFET gate drivers.

"These devices help address the challenges facing engineers working across sectors with the highest voltage and power demands — from DC-DC conversion and on-board charging to power factor correction and solar inverters," says Anup Bhalla, VP engineering at UnitedSiC.

"We will be announcing many new Gen 4 devices over the next nine months which will further improve on cost-effectiveness, heat efficiency and design headroom," he adds.

"This will support all sectors in overcoming the challenges of mass adoption and to accelerate innovation."

Pricing for the new 750V Gen 4 SiC FETs (in 1000-unit quantities, FOB USA) range from \$3.57 for the 60mΩ UJ4C075060K3S to \$7.20 for the 18mΩ UJ4C075018K4S.

UnitedSiC expands SiC Schottky diode portfolio

UnitedSiC has launched four junction barrier Schottky (JBS) diodes to complement its FET and JFET transistor products.

With what is claimed to be the industry's best surge current performance, the UJ3D 1200V and 1700V devices are part of the firm's third generation of SiC merged-PiN-Schottky (MPS) diodes.

Possessing a $V_F \times Q_C$ figure of merit (FoM) that is at least 12-15% better than what diodes from other manufacturers can achieve, it is claimed, the SiC SB diodes are optimized for power system designs requiring elevated efficiency levels and ultra-fast switching speeds. Having a >8.8mm clearance between the anode and the cathode means

they are better at coping with high-pollution environments where voltage transients are likely to be present. In high-current situations, the novel PN junction arrangement featured enables the injection of additional charge carriers. Due to this, the diodes can withstand much higher surge currents than competing devices (up to 12x the rated current), it is reckoned.

There is a 1700V 25A-rated option, plus three 1200V devices in 10A-, 20A- and 50A-rated options. Fully compliant with the AEC-Q101 automotive standard, all SiC diodes come in a compact TO247-2L package format and in die form.

Applications that can benefit most from the new SiC diodes include fast-charge electric vehicle

(EV) charging access points, industrial motor drives, and solar energy inverters.

"Through the unique characteristics of the UJ3D1725K2, we can provide our customers with reliable, space-saving, cost-effective SiC diodes that have substantially better performance levels and assured quality, supported by high-volume manufacturing," says Anup Bhalla, VP engineering.

The UJ3D1725K2 resale price is \$6.47 (in 1000-unit quantities). The UJ3D1210K2, UJ3D1220K2 and UJ3D1250K2 resale prices are \$2.24, \$3.39 and \$9.55 (in 1000-unit quantities), respectively. All devices are available from authorized distributors.

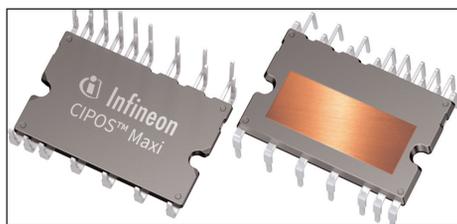
www.unitedsic.com

Infineon launches first 1200V transfer-molded silicon carbide integrated power module

Infineon Technologies AG of Munich, Germany has launched a 1200V transfer-molded silicon carbide (SiC) integrated power module (IPM), concluding its massive roll-out of SiC solutions for this year.

The CIPOS Maxi IPM IM828 series is claimed to be the industry's first in this voltage class. The series provides a compact inverter solution with what is said to be excellent thermal conduction and a wide range of switching speeds for three-phase AC motors and permanent magnet motors in variable-speed drive applications. Among others, these can be found in industrial motor drives, pumps drives and active filters for heating, ventilation and air conditioning (HVAC).

The CIPOS Maxi IPM integrates an improved 6-channel 1200V silicon-on-insulator (SOI) gate driver and



Infineon's CIPOS Maxi IPM.

six CoolSiC MOSFETs to increase system reliability, optimize PCB size and system costs. The new family member is packaged in a DIP 36x23D housing, making it the smallest package for 1200V IPMs with the highest power density and best performance in its class, it is reckoned. The IM828 series features an isolated dual-in-line molded housing for excellent thermal performance and electrical isolation. It meets EMI requirements and overload protection of

demanding designs.

The rugged 6-channel SOI gate driver of the SiC IPM provides built-in dead time to prevent damages from transients. It also offers under-voltage lockout (UVLO) at all channels and over-current shutdown protection functions. With its multi-function pin, the IPM allows high design flexibility for various purposes, says Infineon. Adding to the protection features, the IPM is equipped with an independent UL-certified temperature thermistor. The low-side emitter pins can be accessed for phase-current monitoring, making the device easy to control.

The CIPOS Maxi IM828 series can be ordered now. It comprises 20A IM828-XCC for power ratings of up to 4.8kW.

www.infineon.com/coolpic

Solar inverter uses full-SiC module with 1200V MOSFETs & diodes

Austria's Fronius International has launched the Symo GEN24 Plus solar inverter, whose Multiflow technology suits a wide range of applications supporting energy self-sufficiency. As well as providing power for direct use in the household it has an interface for energy storage systems. Also, the hybrid inverter is designed for water heating and charging electric cars, and can be connected to external systems.

The inverter uses CoolSiC MOS FETs from Infineon with an efficiency of over 98%. Combined with the high-voltage storage system from BYD, the Symo GEN24 Plus has achieved a record 94% System Performance Index (SPI) in the 10kW class (the only one in this combination to achieve Class A energy efficiency).

"SiC modules can be used to build very energy-efficient, robust, and reliable inverters. This technology enables a significant increase in switching frequency," says Andreas Luger, head of R&D

Power Electronics in the Solar Energy business unit of Fronius. "Compared to the previous generation, the functionality is significantly improved, while its size remains comparable."

"To maximize the advantages of SiC, engineers from Fronius and Infineon have jointly optimized the layout and chip assembly of the modules," says Peter Wawer, president of Infineon's Industrial Power Control Division. "Close communication between the development teams enabled system advantages that correspond to customer needs. Based on our tried and tested Easy module, the inverter's booster stages now use 1200V CoolSiC MOSFETs in combination with CoolSiC diodes. This full-SiC solution thus ensures maximum efficiency."

Full-SiC is also used for the battery stage. One Easy 1B 1200V with an on-resistance ($R_{DS(on)}$) of 45mΩ is used in the bidirectional DC/DC converter. The inverter stage implements a SiC hybrid solution

in an Easy 2B module, which has also been tailored to the needs of Fronius. The NPC1 topology combines silicon-based 650V TRENCH-STOP 5 IGBTs and rapid diodes with CoolSiC Schottky diodes. The modules are controlled in all stages with an EiceDriver IC gate driver.

Combining SiC MOSFET modules in the booster and battery input with hybrid modules in the inverter stage ensures the optimum ratio of efficiency and cost, it is said. As Infineon's SiC power semiconductors have a high power density, the Fronius Symo GEN24 Plus offers many functions such as backup power, storage connection, multi-MPP tracker and energy management. The inverter weighs only 24kg and has a small volume (594mm x 527mm x 180mm). Its active air-cooling can reduce the temperature of the power electronics, extending service life.

The inverter is available in the power classes 6, 8 and 10kW.

GTAT to supply silicon carbide boules to Infineon Infineon expanding material supply base for CoolSiC devices

GT Advanced Technologies (GTAT) of Hudson, NH, USA has signed a contract (with an initial term of five years) to supply silicon carbide (SiC) boules to Infineon Technologies AG of Munich, Germany, which is therefore adding a further element to secure its growing base material demand in this area.

Under the name CoolSiC, Infineon already markets what it claims is the industry's largest product portfolio for industrial applications and is rapidly expanding its offering towards consumer and automotive products.

"We are seeing a steadily increasing demand for SiC-based switches, especially for industrial applications. However, it has become clear that the automotive sector is quickly following suit," says Peter Wawer, president of Infineon's

Industrial Power Control Division. "With the supply agreement we have now concluded, we ensure that we will be able to meet the rapidly growing demand of our customers with a diversified supplier base. GTAT's high-quality boules will provide an additional source for competitive SiC wafers fulfilling the best-in-class material standards now and in the future. This supports our ambitious SiC growth plans, making good use of our existing in-house technologies and core competencies in thin-wafer manufacturing," he adds.

"GTAT will enable Infineon to achieve a secure, high-quality internal SiC wafer supply by applying their proprietary thin-wafer technology to GTAT's crystal," says GTAT's president & CEO Greg Knight. "The growth of SiC device adoption

is tied largely to the aggressive cost down of the substrate, and this agreement is a significant step towards achieving that goal."

SiC has mainly been used up to now in photovoltaic inverters, industrial power supplies, and the charging infrastructure for electric vehicles. This is where the advantages of SiC at the system level, compared with classical silicon solutions, have already come into play. Other industrial applications such as uninterruptible power supplies (UPS) and variable-speed drives are increasingly making use of silicon carbide technology. In addition, electric vehicles show enormous potential for application options, including the main inverters for the drive train and onboard battery charging units.

www.infineon.com/coolpic

Mitsubishi launches 4-terminal 1200V SiC MOSFETs Power consumption and size of power supply systems reduced

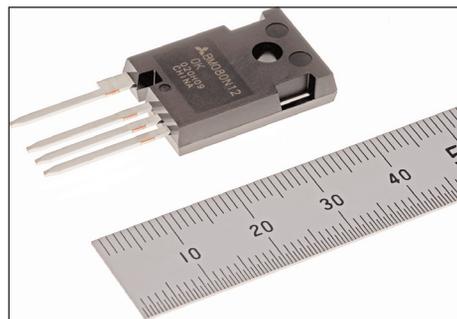
Tokyo-based Mitsubishi Electric Corp has launched the N-series of silicon carbide (SiC) metal-oxide-semiconductor field-effect transistors (MOSFETs).

The new power semiconductor devices have a 15.9mm x 41.0mm x 5.0mm TO-247-4 package (which separates the driver-source terminal from the power-source terminal, unlike conventional 3-pin packages).

The adoption of a four-pin package reduces parasitic inductance (a problem in high-speed switching), eliminating the gate-source voltage drops due to the current variations. This helps to reduce switching loss by about 30% compared with the existing TO-247-3 packaged products.

The SiC MOSFET exhibits a good figure of merit (FOM) of 1450mΩ-nC (on-resistance multiplied by gate-drain charge at 100°C junction temperature) and high self-turn-on tolerance

Using a higher carrier frequency (which determines the ON/OFF timing



Mitsubishi Electric's N-series 1200V SiC-MOSFET in a TO-247-4 package.

of switching in the inverter circuit) to drive the new devices helps to reduce switching-power loss, enabling smaller and simpler cooling systems as well as smaller reactors and other peripheral components, helping to reduce the power consumption and physical size of overall power-supply systems requiring high-voltage conversion.

The creepage distance (the shortest distance over the surface between two conductive parts) between the drain terminal and the

source terminal has been made wider than in TO-247-3-packaged products for more flexible application, including in outdoor installations where dust and dirt easily accumulate.

The new lineup of six models includes three models (the 80mΩ, 38A BM080N120K, the 40mΩ, 68A BM040N120K and the 22mΩ, 102A BM022N120K) for industrial applications (e.g. photovoltaic power systems) as well as three corresponding models (the BM080N120KJ, BM040N120KJ and BM022N120KJ) compatible with the Automotive Electronics Council's AEC-Q101 standards for applications in electric vehicles (EVs), such as for onboard chargers (OBCs).

Development of the new SiC products was partially supported by Japan's New Energy and Industrial Technology Development Organization (NEDO). Sample shipments started in November.

www.MitsubishiElectric.com

ROHM and UAES open joint lab in Shanghai

Chinese automotive manufacturer developing SiC power solutions

Power semiconductor maker ROHM Semiconductor of Kyoto, Japan, together with Chinese tier-1 automotive manufacturer United Automotive Electronic Systems Co Ltd (UAES), held an opening ceremony announcing the establishment of a joint laboratory for silicon carbide (SiC) technology at UAES' headquarters in Shanghai, China.

SiC power devices are increasingly being adopted in electric vehicles (EVs), infrastructure, environment/energy, and industrial equipment, since SiC-based products provide many advantages compared to silicon-based devices, such as significantly reduced loss during both switching and conduction, as well as supporting higher-temperature operation.

Since 2015, UAES and ROHM have collaborated via detailed technical exchange on automotive applications utilizing SiC power devices. Automotive products incorporating ROHM SiC power devices were released earlier this year.

The new joint lab contains key equipment required for device and application evaluation in automotive



UAES' deputy general manager Guo Xiaolu (right) and ROHM Semiconductor (Shanghai) Co Ltd's chairman Raita Fujimura (left) exchange gifts at the opening ceremony.

applications like on-board chargers (OBCs) and DC/DC converters. The firms reckon that this will allow them to strengthen their partnership and accelerate the development of SiC-based power solutions.

"With ROHM, which has been introducing SiC power devices since 2015, we have strengthened our collaboration, including top management. And, after many years of technical exchanges, we are pleased to announce the successful development and mass production

of SiC-equipped automotive applications this year," says UAES' deputy general manager Guo Xiaolu. "The establishment of this joint laboratory is a testament to the deepening relationship between our two companies, and we can look forward to further technical support through this new comprehensive facility," he adds.

As a supplier of SiC power devices, ROHM has a "proven track record of providing power solutions that combine peripheral components such as driver ICs," says Dr Kazuhide Ino, chief scientific officer & senior director of ROHM Co Ltd's Power Device business. "In the rapidly expanding automotive sector, as research tailored to customer needs and market trends becomes an important factor, we will continue to strengthen our partnership through this joint research lab and contribute to technical innovation in the automotive sector with power solutions centered on SiC."

www.rohm.com/products/sic-power-devices

www.uaes.com/servlet/portal/index.html

DENSO adopts SDK's 150mm silicon carbide epiwafers

Booster power modules to be used in fuel-cell electric vehicles

Tokyo-based Showa Denko K.K. (SDK, which produces petrochemicals, gas products, specialty chemicals, electronics, inorganics, aluminium, etc) says that its 6-inch (150mm)-diameter silicon carbide (SiC) epitaxial wafers have been adopted by automotive supplier DENSO Corp of Kariya, Aichi prefecture, Japan for their latest booster power modules for fuel-cell electric vehicles (FCEVs).

Launched in 2009, SDK's SiC epiwafers have been adopted by electronic device manufacturers for various devices including power supplies for servers of cloud com-

puting systems, quick-charging stands for EVs, and railcars. SDK says that DENSO has adopted its SiC epiwafers for their next-generation power modules after recognizing the track record of adoption by device manufacturers, high-grade epi specifications, low density of surface defects, and low frequency of basal plane dislocations.

Compared with existing mainstream silicon-based semiconductors, SiC-based power semiconductors can operate under high-temperature, high-voltage and high-current conditions, while

substantially reducing energy loss, notes SDK, enabling device makers to produce smaller, lighter, more energy-efficient power control modules. SiC power semiconductors are already used in on-board battery chargers (OBCs) and quick-charging stands for EVs, and railcars.

Demand is expected to grow with full-scale use in power control units (PCUs) for electric vehicles from 2025, when the SiC epiwafer market is hence expected to be about 100bn yen.

www.sdk.co.jp
www.globaldenso.com

EpiWorld qualifies Aixtron AIX G5 WW C system for production ramp-up

Chinese SiC epi foundry expanding to meet demand for power devices

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that its new SiC platform AIX G5 WW C has been qualified by pure-play silicon carbide (SiC) epitaxial wafer foundry EpiWorld International Co Ltd (a privately owned joint venture with investors in the USA, Japan and China) for high-volume manufacturing of SiC epitaxy products at its new production side in Xiamen, China. The vapor phase epitaxy (VPE) tool is the latest 8x150mm SiC Planetary Reactor platform from Aixtron.

EpiWorld aims to further expand its production capacity to meet increasing demand from customers. The firm has already completed 4- and 6-inch SiC epiwafer production lines for making 650V, 1200V and 1700V power devices.

A recently completed manufacturing center provides space for

rapid expansion to 400,000 6-inch epiwafers per year. EpiWorld currently has an annual capacity of over 60,000.

"In recent years, we have been qualified as a leading supplier of SiC epiwafers for power devices by various players in the automotive sector and therefore have a strong footprint in one of the most challenging industries," says EpiWorld's general manager Dr Gan Feng.

"We rely on Aixtron's proven system technology and are ready to move into high-volume production of our SiC epitaxial components with the AIX G5 WW C," Feng adds.

"The SiC epi reactor in the AIX G5 WW C system of Aixtron combines the performance of a single-wafer system with the cost advantages of a multi-wafer reactor," comments Feng. "The system guarantees EpiWorld highest throughput in the

industry at lowest production cost, while enabling excellent production quality."

"We are delighted to achieve the important production qualification milestone with one of the leading epi foundries with our new SiC platform to accelerate the further commercialization of silicon carbide," says Dr Frank Wischmeyer, Aixtron's VP marketing, Power Electronics.

"Our customer EpiWorld is well positioned to address the fast-growing market of SiC power devices in the Chinese automotive industry and beyond," he believes. "The enlarged production capabilities at EpiWorld will support the development of numerous high-end power electronics applications serving megatrends such as e-mobility or renewable energy."

www.epiworld-cn.com

www.aixtron.com/en/products/AIXG5WWC_p1333

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Altum RF wins two-year ESA contract

GaN Ka-band high-power amplifiers to be developed for VSATs

Altum RF of Eindhoven, The Netherlands (a supplier of high-performance RF to millimeter-wave solutions for next-generation markets and applications) has announced a two-year contract with the European Space Agency (ESA) under the ARTES (Advanced Research in Telecommunications Systems) Advanced Technology program to design and develop gallium nitride (GaN) Ka-band high-power amplifiers for very small aperture terminals (VSATs).

Starting in January, the project's objective is to develop Ka-band high-efficiency power amplifiers, using a cost-effective package solu-

tion. These high-power amplifiers are well suited for VSATs (two-way ground stations that transmit and receive data from satellites).

The "strategically aligned project" with ESA will "further strengthen our product growth and development plans over the next two years," says Altum RF's CEO Greg Baker. "This contract award also establishes the confidence ESA shows in our innovative design and solid execution capabilities," he adds.

"From a highly respected organization, the ESA contract recognizes the GaN design capabilities Altum RF has demonstrated and allows us to continue expanding our design and

development activities in the Eindhoven office," says Niels Kramer, managing director Europe & VP marketing.

"The ARTES Advanced Technology program is dedicated to the innovative technological development of the satcom industry and its applications," says Elodie Viau, ESA's director of telecommunication & integrated applications. "We are delighted to be able to assist Altum RF in developing this ground equipment — which represents a very promising new technology for future and evolving space-based telecommunication services."

www.altumrf.com

HRL targets first W-band N-polar GaN low-noise amplifier

ONR-funded project to improve receivers for radar, electronic warfare and communications

Targeting a disruptive improvement in radar, electronic warfare (EW) and communications capabilities, HRL Laboratories LLC of Malibu, CA, USA (a corporate R&D lab co-owned by The Boeing Company and General Motors) aims to develop what it reckons will be the first W-band, nitrogen(N)-polar gallium nitride low-noise amplifier (LNA), launching a new generation of defense-oriented electronics applications with a possible improvement of four times the output power in the W-band over HRL's existing technology.

HRL says that, by leveraging experience from designing many of the fastest electronics in existence, its team will design the new amplifier to enhance the range and sensitivity of sensors and high-frequency receivers far beyond existing specifications. Sponsored by the US Office of Naval Research (ONR), the initial project aims to demonstrate the design, fabrication and functional testing of an N-polar GaN millimeter-wave integrated circuit



that will enable the first W-band amplifier using GaN.

"HRL has been at the forefront of high-speed GaN electronics for decades. We demonstrated the world's fastest GaN transistors and we're applying that expertise to these new materials in a way that no other facility in the world can do," claims principal investigator Dr Dan Denninghoff. "In fact, we are the only foundry that can make GaN devices this fast, with vertically integrated material design and nanometer-scale device fabrication. We have the capability to go all the way from gases to circuits, and not just any circuits, but the highest-performing integrated circuits in the

world," he adds. "We hope to set another record with this amplifier."

The goal of the HRL team is to improve receiver amplifiers that could potentially give platforms

such as radar better performance than existing instruments. Aircraft could have enhanced communications ability, increasing safety in the air. Ocean-going platforms could also have game-changing potential benefits from this technology, it is reckoned, which interested the US Navy.

"ONR wants to see how good an integrated circuit we can make," says Denninghoff. "Previous demonstrations have been on small devices — no one has demonstrated monolithic microwave integrated circuits (MMIC) made with N-polar GaN material. We look forward to demonstrating this exciting technology."

www.hrl.com

TI launches first automotive GaN FET with integrated driver, protection and active power management

Dallas-based Texas Instruments Inc (TI) has expanded its high-voltage power management portfolio with the next generation of 650V and 600V gallium nitride (GaN) field-effect transistors (FETs) for automotive and industrial applications. With a fast-switching, 2.2MHz integrated gate driver, the new families of GaN FETs are said to help engineers to deliver twice the power density, achieve 99% efficiency and reduce the size of power magnetics by 59% compared with existing solutions.

TI developed the new FETs using its proprietary GaN materials and processing capabilities on a GaN-on-silicon substrate, providing a cost and supply-chain advantage over comparable substrate materials such as silicon carbide (SiC).

Vehicle electrification is transforming the automotive industry, and consumers are increasingly demanding vehicles that can charge faster and drive further. Engineers are hence being challenged to design compact, lightweight automotive systems without compromising vehicle performance. TI says that using its new automotive GaN FETs can help to reduce the size of electric vehicle (EV) onboard chargers and DC/DC converters by as much as 50% compared with existing silicon or SiC solutions, enabling engineers to achieve extended battery range, increased system reliability and lower design cost. In industrial designs, the new devices enable high efficiency and power density in AC/DC power-delivery applications where low losses and reduced board space are important, such as hyperscale and enterprise computing platforms as well as 5G telecom rectifiers.

"Wide-bandgap semiconductor technologies like GaN inherently bring firmly established capabilities to power electronics, especially for high-voltage systems," comments Asif Anwar, director of the Powertrain, Body, Chassis & Safety Service at Strategy Analytics. "Texas Instru-

ments leverages over a decade of investment and development to deliver a uniquely holistic approach – combining internal GaN-on-Si device production and packaging with optimized silicon driver technology to successfully implement GaN in new applications," he adds.

"Industrial and automotive applications increasingly demand more power in less space, and designers must deliver proven power management systems that operate reliably over the long lifetime of the end equipment," says Steve Lambouses, TI's VP for High Voltage Power.

"Backed by more than 40 million device reliability hours and more than 5GWh of power conversion application testing, TI's GaN technology provides the lifetime reliability engineers require in any market."

Double power density with fewer devices

In high-voltage, high-density applications, minimizing board space is an important design consideration. As electronic systems are getting smaller, the components inside them must also get smaller and sit closer together. TI's new GaN FETs integrate a fast-switching driver, plus internal protection and temperature sensing, enabling engineers to achieve high performance while reducing board space for their power management designs. This integration, plus the high power density of TI's GaN technology, enables engineers to eliminate more than 10 components typically required for discrete solutions, the firm reckons. Additionally, each of the new 30mΩ FETs can support up to 4kW of power conversion when applied in a half-bridge configuration.

Highest efficiency in PFC

GaN offers the advantage of fast switching, which enables smaller, lighter and more efficient power systems. Historically, the trade-off with gaining fast switching capability is higher power losses. To avoid this trade-off, the new GaN FETs feature TI's ideal diode mode to

reduce power losses, the firm says. For example, in power factor correction (PFC), ideal diode mode reduces third-quadrant losses by up to 66% compared with discrete GaN and SiC metal-oxide-semiconductor FETs (MOSFETs). Ideal diode mode also eliminates the need for adaptive dead-time control, reducing firmware complexity and development time. See the application note 'Maximizing the Performance of GaN with Ideal Diode Mode' at www.ti.com/lit/an/snoa932/snoa932.pdf.

Maximize thermal performance

Offering what is claimed to be 23% lower thermal impedance than the nearest competing packaging, the TI GaN FET packaging allows engineers to use smaller heat-sinks while simplifying thermal designs. The new devices provide maximum thermal design flexibility, no matter the application, with the ability to choose from either a bottom- or top-side-cooled package. In addition, the FETs' integrated digital temperature reporting enables active power management, allowing engineers to optimize system thermal performance under varying loads and operating conditions.

Package, availability and pricing

Pre-production versions of the four new industrial-grade, 600V GaN FETs are available now, only on TI.com, in a 12mm-by-12mm, quad flat no-lead (QFN) package. TI expects the industrial devices to ship in volume production in first-quarter 2021. Evaluation modules are available for purchase on TI.com starting at \$199. Multiple payment, line-of-credit and fast, reliable shipping options are available on TI.com.

Pre-production versions of the new LMG3522R030-Q1 and LMG3525R030-Q1 650-V automotive GaN FETs and evaluation modules are expected to be available for purchase on TI.com in first-quarter 2021. Engineering samples are available upon request.

www.ti.com/autogan

EPC strengthens European sales team

Stefan Werkstetter appointed as director, sales EMEA

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA has appointed Stefan Werkstetter as director of sales for EMEA (Europe, the Middle East and Africa). He will assist customers in the European market in the adoption of its enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for applications including DC-DC, light detection & ranging (LiDAR), motor control, and other power conversion systems.

Based near Munich, Germany,



Werkstetter has many years' experience working in the power electronics market, particularly the automotive and industrial automation sectors. In his new role he will focus on developing new and existing accounts with major OEM and key account customers based in Europe.

Werkstetter has a degree in electrical engineering and joins EPC

from Skeleton Technologies, where he was head of strategy. Prior to that, he spent many years working at Maxwell Technologies. His experience includes strategy, product management, business development, sales and applications engineering.

"I am looking forward to developing both new and existing business in EMEA," says Werkstetter. "There is great potential to assist customers in choosing to adopt GaN, and I'll be focussed on increasing these application and sales opportunities."

EPC's eGaN FET transistors used in BrightLoop's DC-DC buck converters

Smaller, lighter converters for performance e-motorsport vehicles

EPC2029 enhancement-mode gallium nitride (eGaN) FET transistors have been used by BrightLoop Converters of Paris, France (which develops and manufactures high-efficiency, high-reliability power converters) to greatly reduce the size, cost and improve the reliability of its latest BB SP DC-DC buck converters.

By switching from silicon transistors to gallium nitride, BrightLoop was able to increase the switching frequency of its design from 200kHz to 600kHz, while keeping the same efficiency. This design change increased power density by a factor of about two, resulting in lower cost by enabling the implementation of a smaller enclosure.

The EPC2029 is an 80V, 48A eGaN FET with a 1mm ball pitch. The wider pitch allows for the placement of additional and larger vias under the device to enable high current-carrying capability despite the extremely small 2.6mm x 4.6mm footprint.

Compared with a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2029 is

much smaller and has many times superior switching performance, claims EPC, making it suitable for applications such as BrightLoop's high-frequency BB SP DC-DC converter.

BrightLoop's converters are used primarily in motorsports and supercars, with other applications including commercial and off-highway vehicles. Future higher-power versions are coming next year to address the mild hybrid applications such as electrical starting assistance.

The BB SP is relevant in any dual-voltage architecture (14V/48V or 14V/24V), or where a certain load is available only with a voltage that is different from the regular network (for example, a 48V pump on a 14V car), in which case the conversion can be done by the BB SP locally, just in front of the load.

To make the use of BB SP interesting, it needs to have negligible losses and weight compared with the rest of the system. This is possible due to EPC's eGaN FETs. For example, a 48V actuator plus BB SP using GaN can be lighter

than the equivalent 12V actuator.

Due to BrightLoop's expertise in ultra-high-speed digital control, another important feature is the ability to implement a closed-control loop at 600kHz (the same as the switching frequency). The resulting bandwidth is so high that very little capacitance is required. So, electrolytic capacitors can be avoided, and only ceramic capacitors were used in the BB SP, further reducing the size and cost while dramatically improving reliability.

"Using EPC products has allowed us to design best-in-class solutions for automotive applications with converters that are drastically smaller and lighter than competition, such as the BB SP," comments BrightLoop's CEO Florent Liffra.

"This is a great example of where our eGaN FETs demonstrate real advantage over silicon FETs by delivering performance in a significantly smaller package and the extreme reliability that is needed in these ultra-fast supercars," says Wolfram Krueger, EPC's VP of sales for EMEA.

www.brightloop.fr/en

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Dell adopts Navitas' GaNFast ICs for laptop fast charger 90W available for laptop charging, plus 10W for smartphone

Navitas Semiconductor Inc of El Segundo, CA, USA says that Dell Technologies has adopted gallium nitride (GaN) technology for the first time, using its GaNFast power ICs.

The Dell USB-C Enhanced Power Adapter PA901 is a dual-output fast charger with 90W available via USB-C cable for high-power laptop charging, and an extra 10W via USB-A to simultaneously charge a smartphone. The adapter unleashes Dell ExpressCharge for a quick boost of up to 35% in just 15 minutes and will charge the Dell Latitude up to 80% in under an hour.

GaNFast power ICs integrate a GaN power (FET) with drive, control and protection to enable up to 3x more power in half the size and weight compared with silicon-based solutions, says Navitas. Over 9 million GaNFast power ICs have been shipped with zero failures.



GaNFast technology delivering the small size, low weight and cool operation that are critical for mobile fast charging, says Navitas' CEO & co-founder Gene Sheridan. "Dell's adoption of fast-charging GaN is another blow to the old, slow silicon chip," he adds. "Navitas' design, applications and quality teams passed a series of rigorous technology, performance and

reliability reviews with Dell to ensure a safe and successful adapter launch."

Two NV6117 GaNFast power ICs are used in the Dell adapter:

one for the critical conduction mode (CrCM) boost power factor correction circuit (PFC), and one for the DC-DC quasi-resonant (QR) flyback. The adapter was designed and built for Dell by Chicony Power Technology of Taipei, Taiwan, with support from local Navitas application engineering.

www.GaNFast.com

www.navitassemi.com

Navitas wins Semiconductor Design Innovation Excellence Award

GaNFast power ICs recognized at SemiExpo for high performance

At the awards gala of the third annual Shenzhen International Semiconductor and Emerging Applications Exhibition (SemiExpo 2020) in China (8-10 December), Navitas Semiconductor Inc of El Segundo, CA, USA was recognized by the China Communication Industry Association (CCIA) with the Semiconductor Design Innovation Excellence Award, presented to Navitas' Lolly (Hui) Ren by Shiying Xu, chairman of the Shenzhen Semiconductor and Display Industry Association.

Navitas was selected on the basis of the high performance of its GaNFast power ICs, which have been used in industries from mobile chargers to data centers,

solar inverters, electric vehicles (EVs) and mobility applications.

Founded in 2014, Navitas introduced what it claimed to be the first commercial gallium nitride (GaN) power ICs. The firm says that its proprietary 'AllGaN' process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs) with GaN analog and logic circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

"GaNFast has been adopted by many leading tech companies in the industry, including Xiaomi, OPPO, Lenovo and Realme in their

flagship fast chargers," says Charles (Yingjie) Zha, VP & general manager of Navitas China.

Also at SemiExpo, Navitas' Jason (Yupu) Tao introduced the high performance and environmental benefits of gallium nitride in his presentation 'Navitas GaNFast: A New Era in Fast Charging'.

In addition, visitors to the Navitas booth learned about the latest Navitas GaNFast devices and reference designs, which can achieve small size, low weight and high efficiency together with fast charging speeds for end products ranging from smartphones and tablets to laptops, monitors and gaming systems.

www.sz-semiconductor.com

VisIC and AB to co-develop high-voltage solid-state battery disconnect switch for electric drive systems

D³GaN developed for automotive-grade requirements

VisIC Technologies Ltd of Ness Ziona, Israel — a fabless supplier of power conversion devices based on gallium nitride (GaN) transistor devices for automotive high-voltage applications — is to collaborate with automotive battery disconnect switch maker AB Mikroelektronik GmbH of Salzburg, Austria to develop a D³GaN-based high-voltage solid-state battery disconnect switch with fast short-circuit detection (FSCD) for future e-mobility to fulfill the functional safety requirements.

AB is “a major player in high-power automotive applications with a strong experience in solid-state battery disconnect switches,” comments VisIC’s VP sales & marketing Ran Soffer. “This is a big advantage in developing the next step for a 400V battery switch” he adds. “Our effort to constantly serve our customers is raising the bar for high-voltage, high-current solutions for the EV market. Our focus for the EV industry using the D³GaN technology is enabling the future electric-drive technology to be aligned with the



Example: 48V solid-state battery disconnect.

market needs to reduce the electric drive cost and improve its efficiency with a reliable high-voltage automotive grad technology”.

VisIC says that the collaboration with AB on high-voltage battery disconnect switches will benefit from D³GaN’s capability for fast switching in safety-critical applications. In the event of a short circuit in the high-voltage bordnet, it is mandatory to detect and disconnect the battery as fast as possible. This requires a very fast power switch and management of the short current until the short circuit

is detected and disconnected.

The combination of VisIC D³GaN power switches with extremely low switching times and the VisIC’s FSCD patented circuit meets the requirements to realize a reliable high voltage, high current battery disconnect switch, and to support the functional safety implementation in HV battery disconnect application.

“AB Mikroelektronik’s experience in high-power integration using thick-film aluminium circuit boards and 48V battery disconnect switches will allow fast transfer to a high-voltage prototype,” reckons Dr Louis Costa, AB’s head of advanced development. “Our long-standing experience in aluminium packaging for high-power semiconductors will allow a fast transfer from existing solutions for 48V battery solid-state switches to a high-voltage prototype,” he adds. “We consider GaN as a promising candidate for future e-mobility applications due to its high-voltage and ultrafast switching capabilities.”

www.visic-tech.com

VisIC unveils 8mΩ power GaN switch for EV inverters

VisIC has announced its new 8mΩ low-on-resistance (Ron) product for electric vehicle (EV) inverter applications targeted at improving the efficiency and manufacturing cost of electric cars.

“The V8 product doubles the current capabilities and reduces resistance by a factor of 2.5 times over the previous generation of VisIC product,” says Ran Soffer, senior VP sales & marketing. “This will allow our customers to improve their inverter systems to be more efficient in size, power and cost for the target EV market,” he adds.

“The V8 product is another step in our long-term effort to provide a better solution based on our D³GaN technology,” continues Soffer. “The

work on the new product is done in close collaboration with our leading customers to bring meaningful improvement to the electric drive system which is the heart of the electrical vehicle. The higher power density can also be achieved in high-power traction invertors.”

The new product is rated at 8mΩ, 650V, 200A and provides significantly lower switching losses versus comparable insulated-gate bipolar transistor (IGBT) or silicon carbide (SiC) devices for the same current range. Customers can integrate the new die into both discrete packages and power modules with a variety of interconnect options. The new technology

enables power loss savings particularly in drive-cycle tests for high-current electric vehicle inverter systems, VisIC says.

Manufacturing a single die with a high current is a known challenge for wide-bandgap technologies (WBG), such as SiC and GaN, versus ubiquitous silicon dies, notes the firm. The development of 200A GaN dies has been made possible due to the design of the D³GaN platform as well as the manufacturing expertise of Taiwan-based foundry manufacturing partner TSMC. This will enable electric vehicles to benefit from the high-efficiency technology of GaN, leading to more cost-effective EV cars, adds VisIC.

Transphorm samples first SuperGaN brand Gen V FET

Lowest packaged on-resistance targets EV power conversion

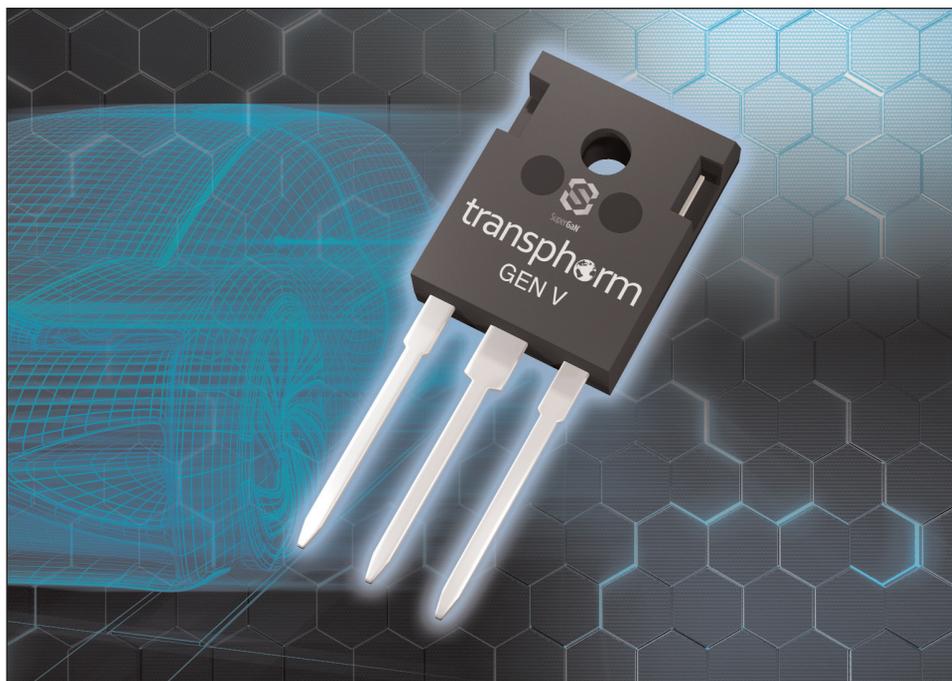
Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V and 900V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — is sampling its first Gen V device under its proprietary SuperGaN brand.

The TP65H015G5WS targets the electric vehicle (EV) market and provides what are claimed to be industry-leading performance enhancements, ease of designability, and optimized cost structure that is inherent to the SuperGaN device family. The firm claims that its Gen V GaN solution offers the lowest packaged on-resistance and delivers a 25% lower power loss over silicon carbide (SiC) in a standard TO-247-3 package, strengthening the potential of GaN in the EV power conversion market.

In March, automotive supplier Marelli announced a strategic partnership with Transphorm to collaborate on new GaN-based automotive/EV power conversion solutions, including on-board chargers (OBCs), DC-DC converters and powertrain inverters for electric and hybrid vehicles.

“Transphorm’s demonstration of achieving 10kW of power from a discrete packaged GaN device in a bridge configuration is further validation of the exciting promise of GaN for electric vehicle converters and inverters,” comments Dr Joachim Fetzer, CEO, Electric Powertrain Marelli. “As part of our previously announced partnership, we will continue to evaluate Transphorm’s industry-leading GaN devices and work together in support of a multi-year EV systems product roadmap,” he adds.

“We continue to innovate Transphorm’s SuperGaN FET technology, now offering the world’s lowest on-resistance in a standard TO-247-3 package in the market,



targeted for electric vehicles and other higher-power conversion applications,” says Transphorm’s COO & co-founder Primit Parikh. “This allows customers to drive into double-digit kilowatts with a single device, continuing to demonstrate GaN’s ability to provide higher performance, lower system cost and higher power density,” he adds. “Our Gen V GaN platform is creating new design opportunities for power levels that previously required paralleling, while still offering the greater than 99% efficiency.”

SuperGaN technology outperforms silicon carbide

The SuperGaN Gen V platform incorporates all the learnings from its Gen IV predecessor: patented reduced packaging inductance technology, ease of designability and drivability (V_{th} of 4V for noise immunity), and gate robustness of $\pm 20V_{max}$, along with a simplified and reduced assembly structure. In an article published in EEWORLD (‘Pushing the Boundaries of High Voltage GaN Power Conversion’) the TP65H015G5WS was compared to a similar on-resistance leading-edge SiC MOSFET in a standard TO-

247-3 package. The devices were both operated up to 12kW at 70kHz in a half-bridge synchronous boost converter, resulting in Transphorm’s GaN device demonstrating up to 25% lower losses.

Transphorm has begun sampling the SuperGaN Gen V FET, a 15m Ω 650V device, which is unavailable with existing single-chip E-mode GaN technology due to its gate sensitivity, says the firm. Matching the lowest R available from typical SiC MOSFETs in a discrete package, the solution is capable of driving more than 10kW depending on the target application, such as EV OBCs and powertrain inverters, power supplies for rack-powered data-center servers, uninterruptible industrial power applications, and renewable photovoltaic inverters. The TP65H015G5WS will also be available for die-level module solutions that enable further paralleling for even higher power.

The firm anticipates its Gen V FET device to receive JEDEC qualification in mid-2021, with AEC-Q101 qualification expected thereafter.

www.marelli.com
www.transphormusa.com/en/product/tp65h015g5ws

Transphorm expands multi-year development agreement with Yaskawa

GaN power devices to be used for industrial power conversion

Transphorm Inc of Goleta, near Santa Barbara, CA, USA has entered into an expanded, multi-year cooperation and development agreement with its long-term strategic partner Yaskawa Electric Corp of Kitakyushu, Japan, a manufacturer of low- and medium-voltage variable frequency drives, servo motors, machine controllers and industrial robots.

As part of the agreement, Yaskawa is making investments in Transphorm of \$4m, with the first tranche of \$1m provided by mid-December. The agreement is an expansion of the next phase of cooperation initiated in 2017 with Yaskawa's investment of \$15m in Transphorm.

Yaskawa intends to use Transphorm's GaN power device

products for industrial power conversion applications, commencing with servo motor and variable frequency drive applications. Power device development activity by

Transphorm under this agreement should benefit Yaskawa by enhancing its next generation of products for these applications.

"Transphorm greatly values its long-term relationship with Yaskawa as it has

These enhanced product features will make our new GaN products appealing for servo drives for robotics and motion control as well as a broader range of industrial and white-goods

helped to advance the development of Transphorm's GaN FET platforms, resulting in high-performance power devices for industrial and motor control applications as well as other focused markets," says co-founder & chief technology officer Umesh Mishra. "The device development under this contract will further enhance the specifications of Transphorm's products, while maintaining our best-in-class quality and reliability," he adds. "These enhanced product features will make our new GaN products appealing for servo drives for robotics and motion control as well as a broader range of industrial and white-goods applications."

www.yaskawa.co.jp/en
www.transphormusa.com

Transphorm's Q3 revenue almost doubles year-on-year Year-to-date loss cut to \$13.2m from 2019's \$17.7m

For third-quarter 2020, Transphorm — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage (HV) power conversion applications — has reported revenue of \$1.9m, up on \$1m a year ago. Revenue last quarter was \$6.3m, but that included \$5m in licensing revenue from manufacturing partner Nexperia. For the first nine months of 2020, revenue was \$9.4m, up from \$2m a year previously.

Operating expenses have risen from \$3.9m a year ago and \$4.2m last quarter to \$4.3m, with general & administrative (G&A) expenses more than doubling from \$1.27m a year ago to \$2.69m while sales & marketing expenses remained about \$0.55m and R&D expenses almost halved from \$2.04m to \$1.07m.

Net loss in Q3/2020 was \$6.7m (\$0.19 per share), up from \$2.3m (\$0.06 per share) last quarter and \$5.4m (\$0.19 per share) a year ago. However, for the first nine months of 2020, Transphorm's year-to-date net loss improved to \$13.2m (\$0.39 per share) from \$17.7m (\$0.63 per share) for the same period of 2019.

During the quarter, cash and equivalents fell further, from \$9.4m to \$4.4m.

"We continued to execute on our plans and make notable progress on our product development and design-win traction during the third quarter, despite the challenging environment," notes CEO Mario Rivas. During the quarter, Transphorm secured a new volume order with a strategic adapter customer.

"We have expanded our pipeline of customer engagements in the fast-charging power adapter market

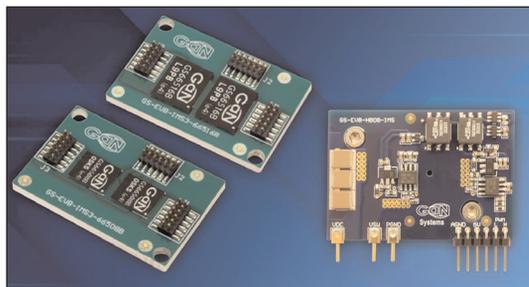
and also broadened our portfolio of high-voltage GaN power conversion devices, all of which continue to demonstrate excellent reliability in the field," says Rivas. During the quarter, Transphorm announced its latest high-voltage GaN quality and reliability (Q+R) data, including a failure in time (FIT) rate of <1 failure per billion hours on more than 10 billion field hours of operation. It also launched its second 900V GaN power FET device to production, for broad industrial and renewable energy applications, and released a 4kW analog-controlled bridgeless totem-pole GaN evaluation board for phase AC-to-DC power conversion solutions.

"Transphorm's strong patent and product portfolio, partnerships and government programs uniquely position the company for meaningful growth in the coming year," believes Rivas.

GaN Systems launches IMS3 platform for GaN E-HEMTs New half-bridge designs boost output by over 30%

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has launched its next-generation Insulated Metal Substrate (IMS3) platform for use with its GaN enhancement-mode high-electron-mobility transistors (E-HEMTs) in high-power, high-efficiency automotive, data-center and industrial applications.

The IMS3 platform features significantly improved heat transfer, which results in lower thermal temperatures and higher power density, making it a suitable reference for implementing smaller and lower-cost systems at the same power level or alternatively increasing output power by 30% in the same size, says the firm.



The platform consists of the IMS3 motherboard and a half-bridge power board, which is available in two power levels up to 3kW (GS-EVB-IMS3-66508B-RN) and up to 6kW (GS-EVB-HB-66516T-RN). The half-bridges are applied on a high-thermal-conductivity, ultralow-thermal-resistance IMS circuit board to achieve improved heat transfer. By applying high thermal conductivity, the IMS3 shows a 29% R_{th} case-to- heatsink thermal improvement. The boards

can be used with the new GS-EVB-HBDB-IMS optimized Half-Bridge isolated driver board and are also compatible with the GSP665HPMB-EVBIMS2 High Power Full-Bridge driver board.

"Our latest IMS evaluation platform featuring very high heat transfer, in combination with our GaNPX packaging technology and flexible design approaches, enables power system engineers to easily take full advantage of GaN and its benefits in providing more power while reducing system cost," says Peter Di Maso, director, product line management.

The GS-EVB-IMS3-66508B-RN, GS-EVB-HB-66516T-RN and GS-EVB-HBDB-IMS are available for purchase through GaN Systems' distributors.

GaN Systems and ON Semiconductor release 100V high-speed, half-bridge evaluation board Board enables evaluation of GaN for 48V applications

GaN Systems has announced a new 100V high-speed, half-bridge evaluation board (GS-EVB-HB-61008P-ON) in collaboration with power semiconductor IC supplier ON Semiconductor of Phoenix, AZ, USA. Available now through distribution partners, it is developed for existing and new PCB designs and allows power electronics designers to easily evaluate GaN for growing 48V market applications, including non-isolated step-down converters, non-isolated step-up converters, and half-bridge and full-bridge converters.

The evaluation board includes an OnSemi NCP51810 GaN driver and two GaN Systems GS61008P E-mode GaN power transistors connected in a high-side, low-side configuration and all necessary drive circuitry. It provides the flexibility of GaN transistor and driver combinations and can be applied

in any topology that requires the use of a high-side/low-side FET combination. When connected into an existing power supply, it can replace HS/LS drives and MOS-FETs. The evaluation board also offers configurable dead-time control and driver enable/disable functions.

One of the benefits is the evaluation board's small size and simplified yet robust design. Several pins are available to probe the circuit. HS and LS gate drives as well as SWN are accessible. Additional benefits include fast propagation delay of 50ns (maximum), increased efficiency and allowing paralleling, and control of rise and fall times for EMI tuning.

The OnSemi NCP51810 high-speed gate driver is designed to meet the requirements of driving E-mode GaN HEMT power switches in half-bridge power topologies.

Features include 150V, high-side and low-side gate driver, 200V/ns dV/dt rating, and protection functions such as an independent under-voltage lockout (UVLO) for high-side and low-side output stages.

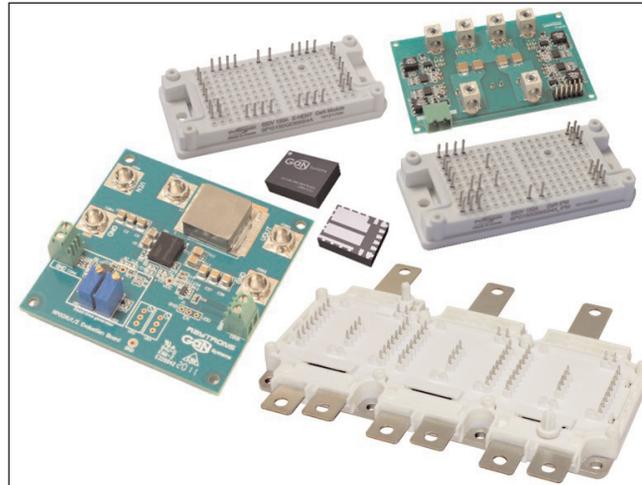
The GaN Systems GS61008P is an E-mode GaN-on-silicon power transistor, bottom-side-cooled that offers very low on-resistance, low gate charge, junction-to-case thermal resistance, and high-current capabilities for demanding high-power applications. Additionally, the transistor features a simple gate drive (0V to 6V), high switching frequency (>10MHz), fast and controllable fall and rise times, reverse current capability, and zero reverse recovery loss. These features combine to provide very high efficiency power switching, says GaN Systems.

www.onsemi.com
www.gansystems.com/evaluation-

GaN Systems adds integrated power module evaluation kits GaN modules meet industry-standard footprints

GaN Systems has announced the availability of four new integrated power module evaluation kits, designed to be easy to use and evaluate performance in high-power applications such as traction inverters, industrial motors, energy storage systems, photovoltaic (PV) inverters, and a variety of lower-power board and brick power supplies:

- The 100V Driver GaN DC/DC Power Stage Module provides high power density and efficiency for DC/DC topologies. The integrated module features a 7mΩ half-bridge power stage, ultra-low R- θ , high output power, and dual PWM (pulse width modulation) input with ultra-low dead time. Applications include 48V step-down converters, high-performance Class D audio systems, CPU/GPU/DDR, 48V-to-12V bricks and board-forward converter, ZVS, and buck/boost topologies. The module is also available mounted on an evaluation board for easy testing.
- The 650V 150A Half-Bridge IPM (intelligent power module) is designed with an industry-standard low-profile case with press-fit pins. The module provides an integrated gate drive, 10mΩ on-resistance ($R_{DS(on)}$), superior thermal perform-



ance, and ultra-small system form factor (82mm x 38mm). Designed for high-efficiency, high-frequency switching applications, the kit is suitable for PV inverters, energy storage systems (ESS), uninterruptible power supplies (UPS), and variable frequency drives (VFD).

- The 650V 150A Full-Bridge Module and Driver features are similar to the 650V 150A Half-Bridge IPM and offers the benefits of lower losses and cooler operating temperatures, high efficiency, increased power density, and reduced volume and weight. External optimized and isolated gate driver board is available for easy evaluation of the module. Applications include PV inverters,

ESS, UPS, VFD, automotive traction inverters, and on-board chargers (OBCs).

- The 650V 300A 3-Phase GaN Module and Driver is designed with an industry-standard form factor, featuring high performance and high power density to meet the requirements of automotive and industrial markets.

The module provides a high-thermal-conductivity base plate, press-fit pins for ease of assembly, and ZTA substrates for superior reliability. An external optimized and isolated gate driver board is available for easy evaluation of the module. Applications include high-efficiency 75kW traction inverter drives and motor drives.

GaN Systems says that the evaluation kits are popular with design engineers, and that the growing multitude of design resources make GaN easy to incorporate and take advantage of the benefits of high efficiency and smaller size and weight.

www.gansystems.com/evaluation-boards

Toyoda Gosei's GaN power devices chosen for Japan's CO₂ reduction project

Firm to work with Nagoya University and IKS

Toyoda Gosei Co Ltd of Kiyosu, Aichi Prefecture, Japan has been selected, together with the research group of professor Hiroshi Amano at Nagoya University and IKS Co Ltd, for the development of gallium nitride (GaN) power devices in the Japanese Ministry of the Environment's 'Project for the Accelerated Adoption and Spread of Innovative Components and Materials to Achieve CO₂ Reductions'.

Power devices are used for power

control in industry, mobility, home appliances and many other fields. But, with the spread of renewable energy and electric vehicles (EVs), higher-performance power devices are needed to reduce power loss when controlling high power loads.

Toyoda Gosei says it is leveraging its expertise in blue LEDs and using their main material, gallium nitride, in developing next-generation power devices that can efficiently control high power. In the Ministry

of the Environment project, the firm and its partners will accelerate development of GaN power devices for application to power conditioners for solar power generation and EVs with the aim of cutting power loss. They are also seeking to apply these improved power conditioners in micro-grids that serve distinct communities, which will contribute to CO₂ reductions in the entire power system.

www.toyoda-gosei.com

IGaN and A-PRO co-developing 650V GaN device on 200mm platform

Project aims to strengthen GaN mass-production and drive adoption in secondary battery market

Singapore-based IGSS GaN Pte Ltd (IGaN) — which develops and commercializes gallium nitride on silicon/silicon carbide (GaN-on-Si/SiC) epitaxial wafers and proprietary 8" (200mm) GaN fabrication technologies for power, RF and sensor applications — and A-PRO Semicon Co Ltd (a subsidiary of South Korea-based A-PRO Co Ltd's semiconductor business that manufactures GaN devices for power/RF electronics applications) have held their project kick-off meeting for a collaboration focused on producing 650V E-mode GaN power transistors.

This follows IGaN's US\$73m investment in building a GaN Epi Centre in Singapore, bringing to the partnership proven expertise in GaN epi production and the mass production of 8-inch (200mm) GaN fabrication technologies.

"In creating new synergies by combining IGaN's mass production

cost-effectiveness and defect control solutions in GaN production manufacturing with A-PRO Semicon's existing capabilities in the power conversion and secondary battery market, IGaN aims to drive technology innovation and GaN adoption in power/RF devices and modules/systems across A-PRO Semicon's ecosystem," says IGaN's CEO Raj Kumar.

"This exciting collaboration will see us leveraging IGaN's know-how to accelerate the production of E-mode GaN devices that have been developed so far, putting us on the path of strengthening our 8-inch commercialization strategy," says A-PRO Semicon's technical director Hyundon Song. "In extending our product portfolio, A-PRO Semicon can better serve our existing customer base, which includes many leading technology brands, and enable the sustainable expansion of

a global footprint," he reckons.

The partnership aims to tap into the power GaN market, which is expected to exceed US\$700m by 2025. Market research firm Yole Développement's Compound Semiconductor Quarterly Market Monitor for Q1/2020 termed 2020 as the 'Year of GaN', with a particular focus on the high-volume consumer fast charger market.

GaN is gradually being adopted in power and RF markets as a replacement for silicon in power electronics, as its wider-bandgap capabilities enable more efficient power conversion, so it can sustain higher voltages and allows current to run through a device faster.

Furthermore, device engineers can use GaN in similar voltage applications while maintaining a significantly smaller footprint, adds IGaN.

<http://en.aproele.com>
www.igssgan.com

SweGaN's chairman Mats Andersson hands over to vice chair Agneta Franksson

Andersson to remain active shareholder

SweGaN AB of Linköping, Sweden, which manufactures custom gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers (based on its unique QuanFINE growth technology) for telecom, satellite, defense and power electronics applications, says that its chairman Mats Andersson has stepped down, passing on the role to vice chair Agneta Franksson.

"As chairman, he [Andersson] brought a unique energy to the company and has been highly instrumental in SweGaN's rapid development over the past several years," comments CEO & co-founder Olle Kordina. "Mats will continue to support SweGaN as an active share-



holder, tapping his extensive network and expertise within Swedish and international telecoms," he adds.

"Agneta joined the SweGaN board in early 2020 and brings significant board experience. With a strong background within board work, she is well positioned to further strengthen our direction," he believes.

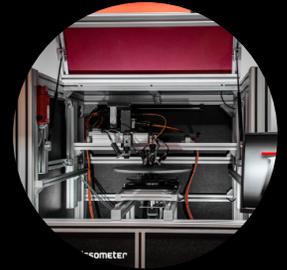
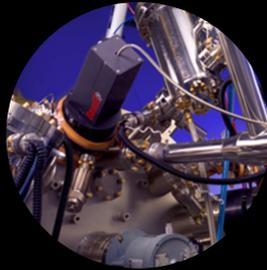
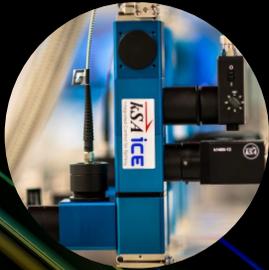
Franksson has an M.Sc. in Electrical Engineering and extensive experience from several CEO positions plus over 25 years' experience in R&D, business development and

sales. Since 2006, she has run her own management consulting company and has served on several boards of directors over the last 14 years. In addition, she is active in providing training at the Swedish Board Academy.

In September, SweGaN was named for the second year in a row to the Ny Teknik (New Technology) '33 List' of Sweden's most promising and innovative young companies, competing with 270 contenders. With what it says is rapidly increasing interest from customers in its patented QuanFINE growth technology, it expects significant volume orders in 2021.

www.swegan.se

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Paragraf, Rolls-Royce, TT Electronics and CSA Catapult working together in High-T Hall project

First supply chain for graphene Hall-effect sensors targets aerospace

Paragraf, which is developing graphene-based electronic sensors and devices, is helping to realise what is described as an industry first by implementing a supply chain for graphene Hall-effect sensors used in high-temperature power electronics, electric machines and drives (PEMD) within the aerospace sector.

The project High-T Hall — which started in July and is now due to run for one year — stems from the UK Research and Innovation's (UKRI) 'Driving the Electric Revolution' challenge and brings together Paragraf, Rolls-Royce, TT Electronics (Aero Stanrew) and the Compound Semiconductor Applications (CSA) Catapult. It aims to demonstrate how graphene-based Hall-effect sensors can operate reliably at high temperatures, paving the way for more efficient electric engines in aerospace and beyond.

Established by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), CSA Catapult is a not-for-profit organization (headquartered in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life in three technology areas — power electronics, RF & microwave, and photonics — as well as advanced packaging. It works across the UK in a range of industry sectors from automotive to medical, and from digital communications to aerospace.

Hall-effect sensors play a major role in monitoring current levels and magnetic fields in PEMD applications, which is critical to monitoring drive power consumption and machine speed and position. The deployment of conventional silicon Hall sensors is, however, restricted to environments with temperatures below 150°C and frequencies below

100kHz, which can constrain system-level design. The High-T Hall project aims to demonstrate that graphene-based Hall-effect sensors will operate reliably up to 180°C, and potentially even at temperatures of up to 230°C, allowing them to be mounted within the machine or power module enclosure. This can enable much greater flexibility in the design of new PEMD equipment aligned to silicon carbide (SiC) power devices and higher-performance, more compact electrical machines. The ability to monitor current levels more accurately and reliably should enable better overall system control, which will in turn reduce size and weight and help design more efficient electric engine systems.

The project could lead to better efficiency in all-electric engines and help to accelerate the adoption of e-planes and, more generally, electric vehicles, says Paragraf's co-founder Ivor Guiney. "Our graphene Hall-effect sensors have already proven to possess unique cryogenic properties, so their resistance to high temperatures will help demonstrate how uniquely versatile graphene devices are from a thermal standpoint."

As the lead partner in High-T Hall, Paragraf will design and manufacture custom Hall-effect sensors for integration into the systems of Rolls-Royce and TT Electronics. CSA Catapult will provide its packaging expertise to develop innovative packaging solutions and advanced assembly processes for realising the prototypes. Rolls-Royce and TT Electronics will test Paragraf's graphene Hall-effect sensors in aerospace PEMD applications, with the former pioneering the use of this technology in its upcoming gas turbine product portfolio. TT Electronics will use it to develop a range of modular current sensors for use in rugged aerospace electri-

cal systems to reduce Hall-effect sensor temperature-related errors.

"Rolls-Royce is committed to playing a leading role in reaching net zero carbon by 2050 and this includes championing sustainable power," says Stephen Dennison, Rolls-Royce's head of Electronics. "This project with Paragraf and the other partners will help develop a resilient supply chain that enables companies to source made-to-measure, innovative electronic components to enhance the efficiency and performance of power electronics, machines and drives."

"Now more than ever it's important we make a proactive effort to accelerate innovation within the aerospace supply chain," states Owen Rolfe, business development director at TT Electronics. "In this case, higher-temperature operation of these sensing solutions has the capability to deliver significant efficiency benefits to power electronics systems," he adds.

"The aim of project High-T Hall is to demonstrate an integrated UK supply chain solution for advanced Hall sensing within PEMD," says CSA Catapult's chief technology officer & acting CEO Martin McHugh. "This will address the issues PEMDs experience when switching frequencies across a broad range of temperature conditions," he adds. "We are very pleased to be involved in the sensor test platform and reliability testing on this project."

The use of a graphene-based Hall-effect sensors in high-temperature aerospace environments could not only be replicated in other industries such as automotive, it may also open new opportunities for other graphene-based electronics, beyond sensors, which can help to improve efficiency and performance even further in applications such as the engines of electric vehicles (EVs).

www.paragraf.com/graphene-hall-effect-sensors

ITRI and UK's CSA Catapult sign MoU

Organizations partner on compound semiconductor innovation

To promote compound semiconductor R&D, Taiwan's Industrial Technology Research Institute (ITRI) and the UK's CSA Catapult have signed a memorandum of understanding (MoU), representing a stepping stone for collaboration between two research organizations.

"The UK and Taiwan are natural partners in compound semiconductors," commented the Right Honorable Greg Hands, UK Minister of State for Trade Policy. "We have complementary strengths which, when combined, will bring the type of innovation leading us toward a more connected and greener world," he added.

"As one of the world-leading research institutes in semiconductors, ITRI was highlighted in a case study back in 2010 when Hermann Hauser made his recommendations for technology and innovation centers which became the Catapult Network," notes Dr Simon Edmonds, deputy executive chair & chief business officer of Innovate UK.

Since ITRI has long been working on semiconductor R&D, it has built solid foundation in electronics and optoelectronics, physics, chemistry and material science with frequent interaction and networking with Taiwan's semiconductor supply chain, remarks ITRI's president Dr Edwin Liu, and thus it has made the semiconductor industry the most important driving force of Taiwan's economy. The development of 5G, radio frequency, optical communication and automotive electronics applications in recent years has turned compound semiconductor technology into a new focus in the next generation of semiconductors. "The collaboration is expected to motivate new opportunities by combining CSA Catapult's technical strengths in semiconductor materials with ITRI's well-built semiconductor process capabilities," says Liu. As both research organizations aim to connect the R&D sector with indus-



ITRI and CSA Catapult signed an MoU to enhance collaboration on compound semiconductor technology.

try, he hopes that the alliance will invite more collaborations between semiconductor industries in the UK and Taiwan.

The advances in 5G and AI involve large amounts of data and a need for high-speed computing, making semiconductor material development even more important, notes Dr Chih-I Wu, ITRI vice president & general director of Electronic and Optoelectronic System Research Laboratories. Through the collaboration, ITRI aims to combine CSA Catapult's proficiency in epitaxy, design and system application with ITRI's assets in semiconductor research and process development, wide-bandgap power electronics, heterogeneous integration, advanced displays, sensors, and optical communication. "The two parties will focus on next-generation compound semiconductor research and expand the application of compound semiconductors in future 5G and smart Internet products," he adds.

"This MoU signifies a closer working relationship, advancing semiconductor research between two world-leading organizations," says Martin McHugh, chief technology

officer & acting CEO of CSA Catapult.

"Together, we look forward to developing advanced electronic products of the future, while forging long-lasting business relationships."

Following the long-term plans of national technology development, the Department of Industrial Technology (DoIT) of Taiwan's Ministry of Economic Affairs has recognized the importance of

compound semiconductor developments and has launched the 'Generation Å Semiconductor Project'. Previously, DoIT has invested in research related to the conversion from light to electricity, power electronics and high-speed radio frequency communications. ITRI says that it has also been striving to transfer compound semiconductor technologies to domestic optoelectronic industries, bridging the gap between lab and market.

With the existing DoIT technology R&D project's results as a cornerstone, ITRI and CSA Catapult will work together to develop technologies in wide-bandgap power electronics and communications, optoelectronic semiconductors, micro-LEDs, 3D sensing, silicon photonics, heterogeneous integration, and advanced packaging. It is hoped that the partnership can stimulate industry development, establish more connections between Taiwanese and UK industries, and further enhance exchanges and collaboration on both sides to promote high-tech industrial innovation.

www.csa.catapult.org.uk
www.itri.org/eng

GlobalWafers to take over Siltronic

Public tender offer of €125 per ordinary share approved by boards

A business combination agreement (BCA) has been signed under which Taiwan-based silicon wafer manufacturer GlobalWafers Co Ltd will make a voluntary public tender offer of €125 per ordinary share to shareholders of Siltronic AG of Munich, Germany (one of the world's largest manufacturers of hyperpure silicon wafers, with production sites in Asia, Europe and the USA) to acquire the firm.

The offer price represents a 48% premium to the 90-day volume-weighted average price of Siltronic's shares prior to 29 November (the public disclosure of advanced discussions between the firms) and a 10% premium to the closing price of the shares on 27 November Siltronic's last trading day prior to public disclosure).

The companies' product portfolios complement each other in many areas and form a basis to benefit from the long-term growth drivers in the wafer industry, it is reckoned.

This includes Siltronic's gallium nitride on silicon (GaN-on-Si) activities, which commenced as early as 2011 by joining the respective Imec Industry Affiliation Program (IIAP). A comprehensive GaN-on-Si technology platform was developed including GaN wafers for use in efficient power electronics as well as GaN-on-Si wafers for high-frequency applications (such as 5G) based on 6" and 8" wafer diameters. Siltronic also invested in research on this technology at the European Union (EU) level, joining

25 other partners in the 'Ultimate GaN' research project, strengthening Europe's abilities in power products and sustainable energy management.

"The Supervisory Board welcomes the planned combination of the two companies," says Dr Tobias Ohler, chairman of Siltronic's Supervisory Board.

The BCA includes guarantees of protection for Siltronic's German sites against closure and for their employees against compulsory redundancies until the end of 2024. The social partnership with German employee representatives as well as the existing collective bargaining agreements and works agreements will also be maintained. The Burghausen site will remain Siltronic's technology and R&D center. Sufficient investment budgets will be available to maintain and further develop existing production capacities. The Siltronic brand will also remain in the combined company. "The guarantees made to the sites and the workforce were very important to us, but also maintaining the strong Siltronic brand under the GlobalWafers umbrella," says Siltronic's CEO Dr Christoph von Plotho.

Siltronic will continue to manage its operating business with a high degree of strategic freedom. To fully exploit the potential of the merger, Siltronic's CEO, CFO and head of technology will assume additional management functions at GlobalWafers after completion of

the proposed deal. Siltronic's Supervisory Board will continue to be co-determined and will consist of 12 members. GlobalWafers aims to have appropriate representation on the Supervisory Board, which will continue to include three independent shareholder representatives.

Siltronic's general dividend policy, which provides for a payout ratio of about 40% of net income, will be continued for the 2020 fiscal year. The firm plans to propose a dividend of about €2 per share, to be distributed prior to completion of the merger.

Subject to review of the offer document and their legal obligations, Siltronic's Executive Board and Supervisory Board expect to recommend that shareholders accept GlobalWafers' tender offer.

Wacker Chemie AG, which currently holds about 30.8% of Siltronic's shares, has entered into a binding agreement (irrevocable undertaking) with GlobalWafers and will tender its entire Siltronic shares as part of the tender offer. The minimum acceptance threshold for the tender offer is 65%.

Closing of the transaction is subject to customary closing conditions, including the achievement of the minimum acceptance threshold and merger control and foreign investment approvals. The parties expect to complete the transaction in second-half 2021.

www.sas-globalwafers.com
www.siltronic.com

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LayTec's CEO & president Zettler stepping down

Designated CEO Blank and CTO Haberland to join management board

In-situ metrology system maker LayTec AG of Berlin, Germany says that, as part of an internal transition that has been ongoing for several months, co-founder Thomas Zettler is to step down as CEO & president at the end of this year. In alignment with a sustainable long-term plan for internal succession, Volker Blank and Kolja Haberland will join the management board, effective 1 January.

Designated CEO Blank has been working for LayTec since 2012. As co-founder, Haberland has been with LayTec since 1999 and will continue as chief technology officer. Both are familiar not only with the team but also with the needs of the markets and customers. With Blank and Haberland building on what LayTec has already achieved, the firm is confident that it will further strengthen its market position.



Co-founder, CEO & president Thomas Zettler hands over to Volker Blank and Kolja Haberland.

To support this process, Zettler will continue working for LayTec in an advisory role as vice president, strategic business development.

Blank has a diploma in physics from Goethe University Frankfurt am Main, where he worked on spectroscopy applications of ultra-broadband THz pulses. Since 2012, he has been

responsible at LayTec for sales in Taiwan and China and later in USA/Canada as well. In 2018, Blank was appointed as director of marketing & sales. He will continue heading LayTec's Sales & Marketing department as part of his CEO duties.

Haberland studied physics at the Technical University of Berlin, where in 2003 he obtained a PhD for his work on 'optical in-situ monitoring during epitaxial growth' —

LayTec's major field of application for many years. As co-founder he has been with LayTec from the very beginning and been working in several responsible positions. Haberland, in addition to his duties in the management board as CTO, will also remain head of R&D.

www.laytec.de





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AXT to merge BoYu and JinMei into Tongmei

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has announced a strategic plan to access China's capital markets in order to enhance its ability to support at scale the expected strong demand for compound semiconductor materials and to continue to boost its business and manufacturing operations in support of tier-1 customer requirements, as well as to replenish its cash with minimal dilution and further strengthen its financial structure.

AXT plans to merge two of its raw material companies into its wafer manufacturing company Beijing Tongmei Xtal Technology Co Ltd, subject to completion of definitive documentation and applicable laws. The two raw material companies Beijing BoYu Semiconductor Vessel Craftwork Technology Co Ltd (BoYu) and Nanjing JinMei Gallium Co Ltd and their related entities in China are performing well and add breadth of product diversity to Tongmei, says AXT.

BoYu manufactures pyrolytic boron nitride (pBN) crucibles that are used when growing single-crystal compound semiconductor ingots and used as effusion rings growing organic light-emitting diode (OLED) tools. JinMei produces 7N+ purified gallium and other specialty materials.

AXT aims to list shares of Tongmei on the Shanghai Stock Exchange's

Sci-Tech innovAtion boARd (the STAR Market), an exchange intended to support innovative companies in China. The process of going public includes several periods of review and is hence a lengthy process. Tongmei does not expect to accomplish this until mid-2022.

The listing of Tongmei on China's STAR market will not change the status of AXT as a US public company, which will continue to be listed on the Nasdaq Global Select Market under the symbol AXTI.

To qualify for a STAR Market listing, Tongmei is required to have multiple independent shareholders. The first major step in this process is engaging reputable private equity firms in China to invest funds. In exchange for about a 7.14% minority interest in Tongmei, private equity firms will invest about \$50m (see panel below).

AXT's ability to retain these investments is contingent on completion of the STAR Market listing. Tongmei would be required to sell a minimum of 10% of its equity in the public offering, bringing the total minority interest held publicly to 17.14%, or greater if Tongmei elects to increase the offering above 10%.

"Pursuing a listing on the STAR Market gives us the ability to replenish our cash and increase our market value for our shareholders with minimal dilution. Further, the additional capital will strengthen

our ability to compete for larger business opportunities," says CEO Morris Young.

"We have largely completed the relocation of our manufacturing lines and now our market-leading portfolio of materials is intersecting with what we believe to be some of the biggest, most influential technology trends of the next decade, such as 5G telecommunications, data-center connectivity, LED-based lighting and display, and laser-based sensing. In addition to these opportunities, we believe new applications across our portfolio are creating exciting incremental opportunities on the horizon," he adds. "Strengthening our balance sheet can give our customers greater confidence in our ability to support at scale the strong, expected demand for our strategic compound semiconductor materials."

"The combination of AXT's wafer manufacturing with BoYu's and JinMei's products and capabilities presents a compelling and well-rounded business model," believes Young. "They synergistically serve a diverse set of customers and markets," he adds. "The convergence of a strong market opportunity with state-of-the-art manufacturing capabilities and a diverse portfolio of products will make Tongmei an attractive company for the STAR Market and create incremental value for our shareholders."

www.axt.com

First-tranche private equity investment in Tongmei raises \$22.5m

The first tranche of the private equity investment in AXT's China-based wafer manufacturing firm Beijing Tongmei Xtal Technology Co Ltd has been fully funded, totaling about \$22.5m. Investors comprise three funds within the Haitong Private Equity Group: Liaoning Haitong New Energy Low-Carbon Industry Equity Investment Fund Co Ltd, Liaoning Haitong New Kinetic Energy Equity Investment Fund Partnership (Limited Partner-

ship) and Haitong Innovation Securities Investment Co Ltd.

The second tranche of about \$26.5m is expected to fund in January. The second tranche investment documents have not yet been executed.

"The applications and customer opportunities for which we have been preparing over the last two years are now taking shape. The materials we produce are proving to be an essential part of many of

the technologies that will define advancements in telecommunications, networking, healthcare, consumer products, and other verticals for many years to come," says CEO Morris Young. "Our success to date in positioning ourselves for an IPO of Tongmei on the STAR Market reflects the strong market demand for our products and our future growth, as well as our well-established presence in China," he believes.

AXT completes ramp of Osram shipments from Dingxing Osram demand now fully supported from new GaAs substrate plant

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has completed the ramp of its gallium arsenide substrate shipments for its major customer Osram from its new manufacturing facility in Dingxing, China. In March, Germany-based Osram finished its qualification of the new facility and began accepting a portion of its order volume from Dingxing, which it has continued to ramp throughout the year.

“We are very pleased to be able to fully support Osram’s requirements from our new, world-class manufacturing facility in Dingxing,” says CEO Morris Young. “The facility was designed from the ground up around modern manufacturing best practices, utilizing state-of-the-art

equipment and improved automation. It is also designed to efficiently scale to significant capacity expansion requirements, as our customers push the forefront of new, exciting, high-volume applications for gallium arsenide substrates” he adds. “We have greatly valued Osram’s partnership through the process of our relocation and we are excited to be able to support its growth across a breadth of established and emerging photonics fields.”

Dingxing is about 75 miles from Beijing. AXT began offering wafers from its new facility for customer qualification in 2019, and began customer site qualifications later that year.

The relocation process was prompted by the Beijing city government in 2015 selecting

Tongzhou for its new municipal headquarters. AXT had been manufacturing its GaAs substrate wafers in the Tongzhou district of Beijing since 2000. Along with many other businesses asked to relocate their manufacturing lines in order to create room and upgrade the district, AXT was instructed to relocate its GaAs manufacturing line. Hence, during fourth-quarter 2019, it transferred its GaAs crystal growth ingot production to its new manufacturing facility in Kazuo (a city about 250 miles from Beijing) and its wafer processing for GaAs was relocated to its new plant in Dingxing. AXT began offering wafers from Dingxing for customer qualification in 2019, and began customer site qualifications later that year.

www.axt.com

Umicore qualifying 6” germanium wafers for VCSELs Growing array size and cost driving transition from GaAs substrates

Umicore Electro-Optic Materials (EOM), which supplies germanium products and materials solutions, says that, in collaboration with leading commercial and academic partners, it has developed 6-inch germanium wafers for vertical-cavity surface-emitting lasers.

VCSELs are a key component in telecom and 3D sensor systems. Applications range from data-centers to face recognition systems and light detection & ranging (LiDAR)

time-of-flight sensors on mobile handsets and in-cabin sensing of autonomous vehicles. To increase the working distance of these sensors, VCSEL array sizes and costs are growing, which is a driver to transition from gallium arsenide (GaAs) to germanium wafers.

“For very demanding applications such as VCSELs, defect-free 6-inch germanium wafers show clear performance and process cost benefits in comparison with GaAs wafers,”

says Bendix De Meulemeester, director marketing & business development. “Umicore has invested years of research in the development of defect-free low-resistivity 6-inch germanium wafers, which are currently in the process of qualification,” he adds. “Production volumes are expected to ramp over the next few years as adoption across the VCSEL supply chain accelerates.”

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IQE expecting 20% revenue growth for full-year 2020 Record first-half revenue being followed by strong second half

In a trading update, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that, after a record first-half 2020 revenue performance, second-half 2020 has continued with positive momentum in both the Wireless and Photonics business units.

This has been evidenced by IQE receiving its largest military & defence sector purchase order to date from a major US customer, for both infrared and high-performance RF applications. With a combined value of over \$10m, the order is deliverable over the next nine months.

Wireless business unit

IQE says that strong year-on-year growth in 2020 for its Wireless business unit has been driven by:

- demand for gallium arsenide (GaAs) wafers for 5G handset power amplifiers fuelled by growing end-market demand for '5G ready' smartphones;
- sales of gallium nitride on silicon carbide (GaN-on-SiC) wafers for 5G infrastructure related to initial deployments of 5G base stations; and
- sales of high-performance GaN-on-SiC wafers for military RF applications.

Photonics business unit

Strong year-on-year growth in 2020 for the Photonics business unit has been driven by:

- consistently high demand for GaAs vertical-cavity surface-emitting laser (VCSEL) wafers for 3D sensing applications — IQE says that it retains a market-leading position in 3D sensing epitaxy and has been central to new applications being launched for this technology in its existing supply chains; and
- sales of high-performance gallium antimonide (GaSb) wafers for military & defence infrared applications.

Full-year outlook

For full-year 2020, IQE expects year-on-year revenue of growth of over 20% to at least £170m, exceeding the previous guidance (provided with the interim results on 8 September) of at least £165m. The firm also anticipates delivering a mid-single-digit £m adjusted operating profit.

With a reduction in capital expenditure in full-year 2020, along with a positive trading position and continued focus on cost control, net debt is expected to be low-single-digit £m, representing a significant

strengthening in the balance sheet position since the prior year-end balance of £16m net debt.

IQE anticipates that underlying demand for the technologies that its products enable will remain strong heading into 2021.

In particular, it expects that demand for 5G-related products (both handset and infrastructure) will continue to grow over the next few years as the mega-replacement cycle of 5G deployments gathers pace around the world.

In addition, IQE says that it has a leading portfolio of Photonics products, for 3D sensing and other applications, making it well positioned for growth.

"We are delighted to be reporting such a strong all-round financial performance, with anticipated revenue growth of over 20% for the full year, despite the ongoing uncertainty in the external environment," comments CEO Dr Drew Nelson. "I am exceptionally proud of the whole IQE team whose dedication and commitment has enabled us to operate without interruption throughout this period."

www.iqep.com

IQE's founder Drew Nelson to relinquish CEO role Advisory and ambassadorial role as board member & president

IQE has announced a new stage in its evolution as founder Dr Drew Nelson plans to step aside from his role as CEO once a successor has been found.

"I have been extremely proud and privileged to serve IQE and its shareholders as CEO for the last 30 years," says Nelson.

IQE says that this will enable a new CEO to lead it during its next phase, as it positions itself to capitalize on both its market position and the growth opportunities presented by the advent of 5G and the Internet of Things.

Nelson will remain as CEO until the right individual is appointed. Following any necessary handover period, he will become a board member with the title of president. As such, he will act in an advisory and ambassadorial role for the firm, which he co-founded in 1988.

"I want to thank Drew for his ongoing passion, commitment and contribution to IQE," says chairman Phil Smith. "Continuing as a board member once the new CEO is in place, he will be able to provide IQE with his expertise and industry knowledge."

Under his stewardship, IQE has grown to 650 staff and a footprint spanning Europe, the USA and Asia. Nelson has also been the driving force behind the establishment of the world's first compound semiconductor cluster (CS Connected) in South Wales, and he plans to devote more time to the further development of the CS Cluster.

Board update

On 5 November Mrs Carol Chesney FCA was appointed a senior independent director. She joined IQE's board in May 2019 and is chair of the Audit and Risk Committee.

IQE develops IQepiMo template technology for RF filters

IQE has announced the development of its IQepiMo template technology for RF filters and for any application requiring low-resistance buried electrodes. Built on its cREO (crystalline rare-earth oxide) technology platform, IQepiMo templates are available in diameters of up to 200mm. Trials are underway with potential customers and partners.

Low-resistance contacts are essential for the efficient operation of almost all electronic circuits. As dimensions shrink, the limitations of existing technologies are exposed, resulting in compromised device performance. This is especially true

of RF filters, which allow or prevent the transmission of selected signals or frequencies.

As 5G technology rolls out worldwide, the requirements for RF devices are becoming significantly more demanding, notes IQE. For RF bulk acoustic wave (BAW) filters, the higher frequencies of 5G translate into an electrical penalty for thinner electrodes that must be accommodated. IQepiMo is said to eliminate this electrical penalty by providing bulk-like metal resistance for very thin layers (down to 50nm). Also, IQepiMo templates enable higher-quality piezoelectric layers to be

fabricated from customers' existing processes, offering a clear path for improved-quality aluminium nitride (AlN) piezoelectric materials. As such, IQepiMo extends the capability of existing customer processes for next-generation applications.

"These templates will mean that customers, while using their existing processes, can fabricate higher-quality, better-performing BAW filters and eliminate the electrical penalty that had, until now, been inherent in the application of current technology to higher frequencies," says chief technology officer Dr Rodney Pelzel.

IQE founder, president & CEO awarded IOP Gold Medal

IQE's founder, president & CEO Dr Drew Nelson OBE has been awarded the Institute of Physics 'Katharine Burr Blodgett' Gold Medal. He has also been made a fellow of the UK's Institute of Physics (IOP).

Awarded for contributions to the application of physics in an industrial or commercial context, this

year's medal awarded to Nelson for "pioneering efforts in commercializing compound semiconductor materials and promoting the UK as the global leader in this field".

"I am extremely proud of the track record we have built at IQE and the leadership position we have developed in the global

compound semiconductor industry," says Nelson. "However, I recognize that none of this would be possible without the support of my colleagues at IQE."

Nelson is donating his prize of £1000 to a local charity supporting people from underprivileged backgrounds to go through university.

IQE develops IQGeVCSEL 150 technology

IQE has announced the development of IQGeVCSEL 150 technology for vertical-cavity surface-emitting lasers (VCSELs) on 6-inch (150mm) germanium substrates ("a critical step in the pathway to 200mm and 300mm VCSEL technology").

VCSELs are a key component in telecom and 3D sensing systems. Applications include high-speed data-center infrastructure; facial recognition, proximity sensing, and light detection & ranging (LiDAR) time-of-flight sensors on mobile handsets; in-cabin and environmental sensing for autonomous vehicles; and 3D image recognition. As demand for VCSELs grows and technical requirements become more stringent, there is the need to scale to larger wafer diameters and demonstrate a path for integration with leading-edge CMOS technology, notes the firm.

IQGeVCSEL 150 is a key development milestone in addressing this, it adds. Germanium substrates are readily available in diameters up to 200mm and provide a clear route for VCSEL growth on silicon substrates (through use of IQE's Ge-on-silicon templates) up to 300mm.

IQE says that, using this unique, patent-pending technology, it has demonstrated device performance parity between identical VCSEL structures grown on Ge and conventional gallium arsenide (GaAs). While conventional growth of VCSELs on 200mm GaAs substrates is currently virtually impossible, the use of Ge removes this limitation because Ge substrates allow for optimal strain management, resulting in a VCSEL wafer that is ~10x flatter compared with VCSELs on GaAs.

This not only simplifies the subsequent wafer fabrication process but results in a wafer that is up to ~3x more uniform. The improved wafer flatness provides additional design flexibility for thicker device architectures required to access longer-wavelength VCSELs. Finally, Ge substrates are available with zero defect density, resulting in higher-quality VCSEL epitaxial material compared with GaAs.

"Demonstrating device parity with GaAs but with a more uniform VCSEL wafer and improved flatness is a highly significant milestone, and we have begun sampling with partners and customers," says chief technology officer Dr Rodney Pelzel. "This provides clear line of sight to growth on larger-diameter wafers as well as VCSEL growth on silicon at 200mm and 300mm wafer sizes."

Veeco's revenue grows 14% in Q3/2020

MOCVD orders driven by RF & power devices and advanced photonics

For third-quarter 2020, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$112.1m, up 14% on \$98.6m last quarter and 2.8% on \$109m a year ago (and above the midpoint of the \$100–120m guidance).

"While maintaining all health and safety measures [during the COVID-19 pandemic], we continue to operate at normal capacity," notes CEO Bill Miller.

The Scientific & Industrial segment comprised 47% of total revenue (rising from 44% last quarter), led by ion beam system shipments to data-storage customers. "There has been significant activity in our data-storage market related to data-center and Cloud storage demand," says Miller.

"We're also seeing significant customer engagement in advanced-node semiconductor manufacturing, 5G RF and power electronics," he adds.

The Front-End Semiconductor segment (formerly part of the Scientific & Industrial segment, before the 2017 acquisition of lithography, laser-processing and inspection system maker Ultratech)

again contributed 18% of total revenue, driven by an ion beam deposition system shipped for making extreme ultraviolet (EUV) mask blanks. "We were encouraged by our laser annealing customer activity in the quarter [foundries and integrated device manufacturers] and expect laser annealing to become a bigger revenue contributor in the upcoming quarters," says Miller.

The Advanced Packaging, MEMS & RF filter segment — including lithography and Precision Surface Processing (PSP) systems sold to integrated device manufacturers (IDMs) and outsourced assembly & test firms (OSATs) for Advanced Packaging in automotive, memory and other areas — comprised 17% of total revenue (falling back from 22% last quarter), with a shift of systems into 5G RF filter and advanced packaging applications.

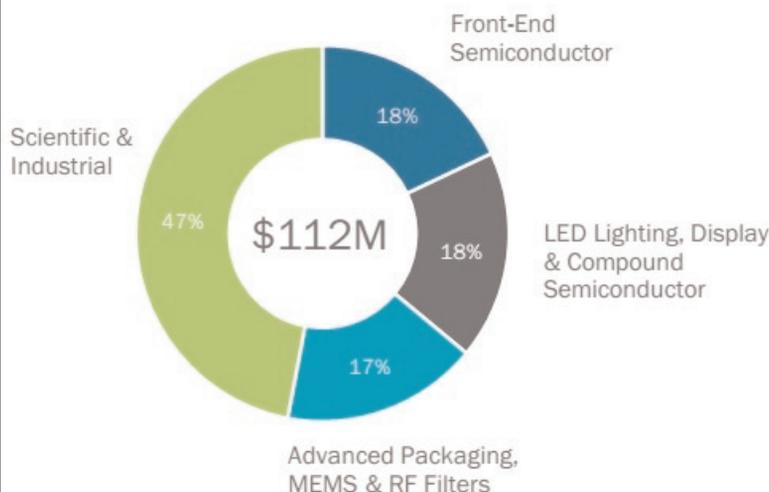
The LED Lighting, Display & Compound Semiconductor segment — which includes photonics, 5G RF, power devices and advanced display applications — comprised 18% of total revenue (up from 16% last quarter), driven by a broad number of applications for metal-organic chemical vapor deposition (MOCVD) systems including RF &

power devices, as well as advanced applications in photonics.

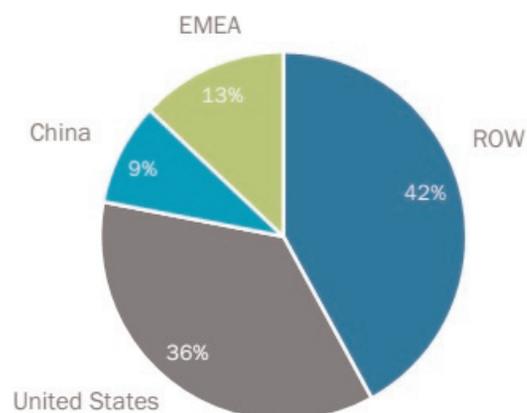
By region, the rest of the world (which includes Japan, Taiwan, Korea and South-east Asia) comprised 42% of revenue (rebounding from 26% last quarter), driven by sales of ion beam deposition systems to EUV mask blanks plus data-storage customers in South-east Asia. The USA rebounded from 30% to 36% of revenue, including sales of systems for data storage as well as advanced packaging and power electronics. Europe, the Middle East & Africa (EMEA) was 13% of revenue, comprising mainly sales to compound semiconductor customers. China shrank from 18% to 9% of revenue, as expected, since the regulatory environment is providing headwinds.

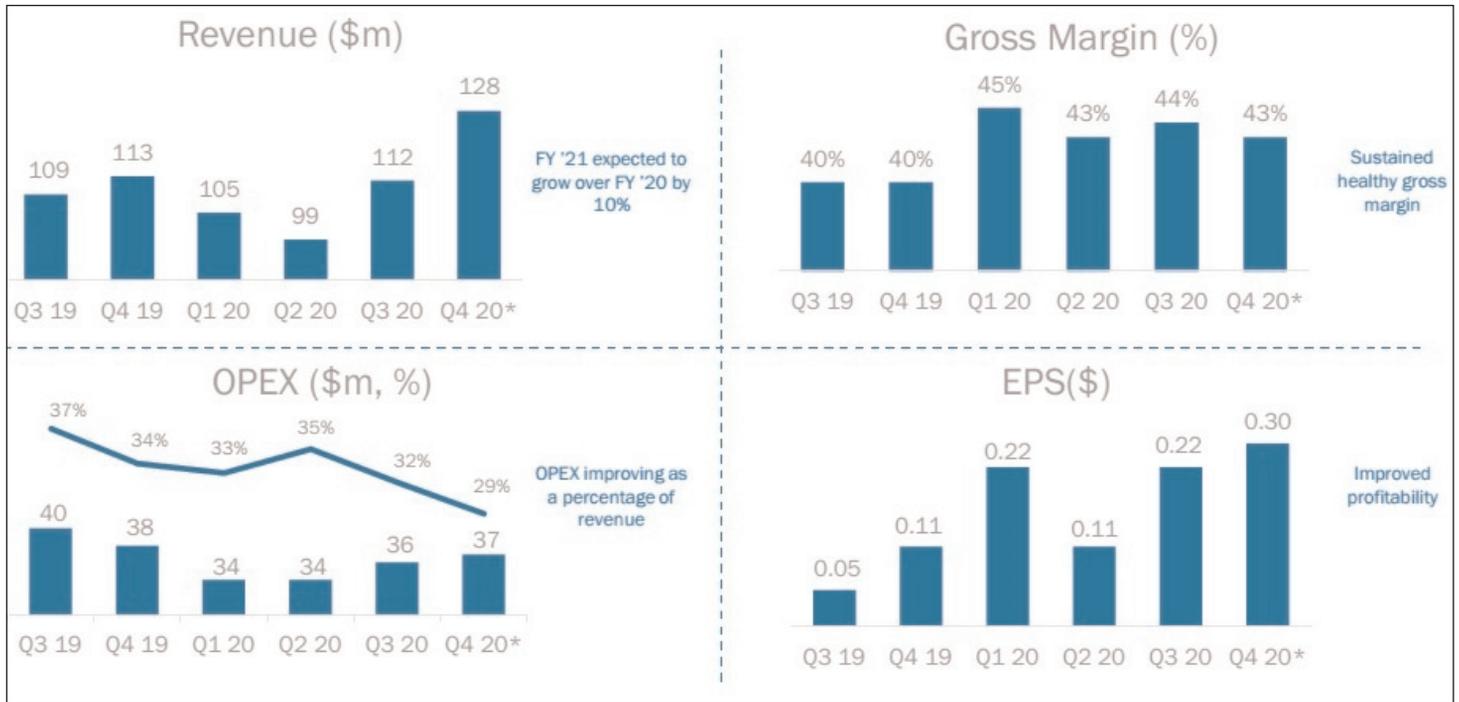
"MOCVD is at historically low revenue levels right now, driven by the fact that we decided to exit the commoditized China blue LED business. So over the last year and a half or so, we did a lot of work restructuring the business, and really focusing on new markets and new opportunities," notes Miller. "We're starting to gain some traction with the Propel system and for power & 5G RF with [South Korea-

Revenue by Market



Revenue by Region





based] A-Pro Semicon," he notes.

On a non-GAAP basis, gross margin has risen further, from 40.3% a year ago and 43% last quarter to 44.5%, exceeding the 42–44% guidance range.

Operating expenditure (OpEx) was \$35.7m, up from \$34.4m last quarter but cut from \$40m a year ago, and falling further from 37% of revenue a year ago and 35% last quarter to just 32%.

"We are pleased with our advancing profitability in the quarter, which was driven by our ion beam technologies sold into the Data Storage market," says Miller.

Operating income has risen from \$4m a year ago and \$8m last quarter to \$14.1m. "Our non-GAAP operating income improved significantly year-on-year [by \$10m, despite revenue being similar], demonstrating the early effectiveness of our transformation," says Miller. "Our sustained profitability is a result of the work we completed over several quarters to improve our operating model, such as expanding gross margins, and restructuring to reduce costs."

Likewise, net income rose further, from \$2.6m (\$0.05 per diluted share) a year ago and doubling from \$5.5m (\$0.11 per diluted share) last quarter to \$11m (\$0.22 per diluted share), towards the top of

the \$5–12m (\$0.10–0.26 per diluted share) guidance range.

Cash flow from operations was \$10m. Capital expenditure (CapEx) was \$1.4m. During the quarter, cash and short-term investments rose by \$9m, from \$301m to \$310m.

Long-term debt on the balance sheet has risen from \$317m to \$321m, representing the carrying value of \$382m in convertible notes.

From a working capital perspective, accounts receivable rose from \$67m to \$80m (as the firm increased shipments). Days sales outstanding (DSOs) rose slightly from 61 to 64 days. This was partially offset by accounts payable rising from \$26m to \$34m, driving up days payable outstanding (DPO) from 42 to 49 days. Inventory rose from \$137m to \$143m, resulting from investments made to increase shipments and provide evaluation systems to customers in support of Veeco's growth strategy in semiconductor and compound semiconductor markets.

"We have strong customer engagements... Entering the fourth quarter, we're in a strong backlog position," says Miller.

"In compound semiconductor markets, our MOCVD product is well positioned to address applications like power electronics, 5G RF, VCSELs [vertical-cavity surface-emitting lasers] and edge-emitting lasers

and micro-LEDs," believes Miller.

"We're experiencing an uptick in demand for MOCVD systems, certainly in the third quarter from order activity. We received multiple orders for high-volume Propel systems for power electronics, RF devices and early-stage micro-LED applications," he adds.

"What we're seeing now is the introduction of GaN power devices in consumer electronic products. For applications like fast charging, wireless charging is driving demand," says Miller. "There are also other customers trying to qualify GaN in the automotive market, not in the high-power silicon carbide (SiC) high-voltage areas [for electric vehicles] but for power management throughout automotive. Our product, the Propel single-wafer tool is pretty well positioned there," he believes.

"A-Pro Semicon based in Korea has selected Veeco's Propel HVM MOCVD system for GaN-based power and 5G RF semiconductor device manufacturing. Our single-wafer gallium nitride Propel system has been well received by leading customers for its proven high-performance capability," Miller continues.

"Aledia, a developer of next-generation advanced displays, has selected Veeco's Propel 300mm MOCVD system to manufacture 3D nanowire micro-LED displays. The

► system features a SEMI-compliant equipment front-end module with full automation and was chosen due to its excellent productivity and film quality," he adds.

"Osram Opto Semiconductors qualified our Lumina arsenide-phosphide MOCVD beta system to drive their next generation of advanced photonic devices. The performance Osram demonstrated reinforces our confidence in Lumina's capability. Also, we have an evaluation agreement in place with another leading customer [a beta system for micro-LED applications] which will further advance our ability to drive long-term growth."

"Given our visibility, we expect continued strength in our overall business and feel confident about our future performance," says Miller.

For fourth-quarter 2020, Veeco expects revenue to grow to \$120–136m. Gross margin should be flat to down, at 42–44%, reflecting additional service expenses to support customer eval-

uations. Operating income is expected to be \$14–22m. Net income should be \$11–19m (\$0.22–0.37 per share), despite OpEx being flat to up, to \$36–38m. "On a go forward basis, we expect to keep SG&A close to current levels, but are making strategic investments in R&D to support our growth initiatives," says chief financial officer John Kiernan.

"We will have a strong finish to 2020 and are optimistic about 2021," believes Miller. "Based on our current visibility and forecasted backlog, we expect revenue growth in full-year 2021 in the 10% range compared with full-year 2020," adds Kiernan.

"We're confident in our execution in the near-term based upon multiple customer engagements where the pull for production solutions is strong. This near-term growth stems from multiple product lines, and comes from the data-storage market, renewed demand in RF filters related to 5G, and continued

activity in the front-end semiconductor market," says Miller.

"With the first phase of our transformation behind us, we'll continue to focus solidly on the second phase of our transformation, growing the company organically in the semiconductor and compound semiconductor markets," says Miller.

"Consistent with our longer-term strategy for growing in semiconductor and compound semiconductor markets, we're making investments to solve our customers' most difficult challenges with our core technologies," he adds. "These investments include increased R&D and service spending, as well as inventory supporting evaluation tools at customer sites: evaluation agreements are in process for laser annealing systems for logic and memory applications, and MOCVD systems for early-stage micro-LED applications. This activity in high-value markets will be the catalyst for our growth in 2022 and beyond."

www.veeco.com

Veeco retiring \$125m of 2.70% senior notes due 2023 \$132.5m of new 3.50% notes due 2025 to be issued in exchange

Veeco has entered into a privately negotiated exchange agreement to retire \$125m of its outstanding 2.70% convertible senior notes due 2023 in exchange for the issuance of \$132.5m of its new 3.50% convertible senior exchange notes due 2025 and a cash payment to the holder of \$1.1m in respect of accrued and unpaid interest on the original notes to be exchanged. Following the exchange transaction, \$131.7m of the original notes will remain outstanding, with the terms unchanged.

The new notes will mature on 15 January 2025 and pay interest semi-annually at 3.50% per year. They have an initial conversion rate of 41.6667 shares of Veeco's common stock per \$1000 of new notes (equivalent to a conversion price of about \$24.00 per share),

subject to adjustment in certain events. The initial conversion price represents an approximately 58.6% premium over the closing sale price of Veeco's common stock on 11 November. Conversions of the new notes will be settled in cash, shares of common stock or a combination thereof, at Veeco's election.

The holder of the new notes may convert all or a portion of its notes at its option at any time prior to the close of business on the business day immediately preceding 15 October 2024, only upon the satisfaction of certain conditions and during certain time periods. On or after 15 October 2024 until the close of business on the second scheduled trading day immediately preceding 15 January 2025, the holder may convert its new notes at any time, without

condition.

The notes will not be redeemable by Veeco prior to 15 January 2023. On or after 15 January 2023, Veeco may redeem for cash all or any portion of the new notes if the last reported sale price of Veeco's common stock equals or exceeds 130% of the conversion price then in effect for at least 20 trading days (whether or not consecutive) during any 30 consecutive trading day period (including the trading day of such period) ending on, and including, the trading day immediately preceding the date on which Veeco provides notice of redemption at a redemption price equal to 100% of the new notes to be redeemed, plus accrued and unpaid interest to, but excluding, the redemption date (subject to certain limited exceptions).

www.veeco.com

Transphorm selects Veeco MOCVD platform for GaN-based power & 5G RF devices

Part of program to establish US production source of GaN epi

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that its Propel 300 HVM metal-organic chemical vapor deposition (MOCVD) system has been selected by Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage (HV) power conversion applications — for high-volume production of GaN-based RF (Department of Defense and commercial/5G) and power electronics epiwafers.

The system has been purchased under US DoD Office of Naval Research (ONR) contract number N68335-19-C-0107 from an OUSD (R&E) TAM/MINSEC program to establish a US-based dedicated production source of GaN epitaxy for high-performance RF and millimeter-wave electronics. The system was selected for its capability to deliver the cutting-edge process at high throughput and

what is claimed to be the lowest cost per wafer compared with other MOCVD systems.

"Being at the forefront of GaN-based power and 5G devices that offer efficiency and high power density requires world-class manufacturing solutions that are capable of scaling to mass production while offering flexibility to continuously innovate," comments Transphorm's chief technology officer & co-founder Umesh Mishra Ph.D. "Veeco's Propel HVM system is uniquely qualified to do that. The multi-reactor, single-wafer technology provides flexibility and exceptional throughput at a low cost of ownership."

The Propel system can be used for demanding GaN applications critical for next-generation communications infrastructure and highly efficient power devices. Its single-wafer reactor platform enables the process-

ing of 6- and 8-inch wafers or 2- to 4-inch wafers in a mini-batch mode. It accelerates production ramping due to faster recipe capabilities up to 50% quicker than when using traditional batch tools. In addition to Veeco's proprietary TurboDisc technology, the system also includes the firm's IsoFlange and SymmHeat technologies, which provide homogeneous laminar flow and uniform temperature profile across the entire wafer for optimal uniformity and repeatability.

"Transphorm's decision to adopt our high-volume MOCVD technology is proof of the system's uniformity, throughput, repeatability and cost of ownership advantages over batch technology," says Veeco's chief technology officer Ajit Paranjpe Ph.D. "We appreciate the collaboration with Dr Lee McCarthy, Dr Umesh Mishra and Dr Primit Parikh at Transphorm during their technology evaluation."

www.transphormusa.com
www.veeco.com/products/propel-hvm-gan-mocvd-system-for-power-5g-rf-and-photonics

We appreciate the collaboration with Dr Lee McCarthy, Dr Umesh Mishra and Dr Primit Parikh

Riber receives order for dual-chamber research system

European customer doing R&D on opto components for automotive applications

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that a Euro-

pean customer has placed an order worth several million euros for an MBE 412 research system, equipped with two growth chambers and one cluster, for R&D on

III-V-based optoelectronic components for the automotive industry.

The system will be delivered in 2021.

www.riber.com

Riber receives order from Asia for research MBE system

System to be used for ultra-pure III-V for low-temp transport studies

Riber says that it has received an order from "a leading academic research group in Asia" for a model C21 DZ research system.

Scheduled for delivery in 2021, the system will be used primarily to prepare ultra-pure layers of III-V materials for low-tempera-

ture transport studies, including quantum Hall-effect measurements.

www.riber.com

Aixtron's Q3/2020 up 21.9% year-on-year

Orders up 35.6%, driven by power electronics and laser applications

For the first nine months of 2020, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported total revenue (equipment plus after-sales) of €161.1m, down 13% on €184.6 a year previously. Of this, equipment fell from €148.1m to €129.5m (remaining 80% of total revenue), while services & spare parts fell from €36.5m to €31.7m. The COVID-19 pandemic had only a limited impact on business development, says the firm.

On a regional basis, revenue from Europe fell by 19% from €25.6m to

€20.7m (falling from 14% to 13% of total revenue) and the Americas fell by 48% from €30.2m to €15.6m (falling from 16% to 15.6% of total revenue). However, Asia fell year-on-year by just 3% from €128.8m to €124.9m (rising from 70% to 78% of total revenue).

"Operations continue to be not significantly affected by the course of the pandemic," says Aixtron. It adds that it took early preventive measures against the pandemic and strengthened these measures in third-quarter 2020.

Q3 revenue was €64.1m, up 14% on €56m last quarter and 21.9% on €52.6m a year ago, driven by high demand for gallium nitride (GaN)-based power electronics and laser technology for optical data transmission and 3D sensor systems.

Gross margin for the first nine months of 2020 was 39%, down from 40% the prior year. This is largely due to Q1/2020 gross margin of just 36%, although quarterly gross margin has since fallen back from 41% in Q2 to 40% in Q3. However, this was mainly because of a less favorable dollar exchange rate. Had the exchange rate been

the same as in Q2, gross margin would have recovered further, to 42%. Just under 50% of sales were denominated in US dollars (compared with less than the 70% in the past) because customers in China are less willing to use dollars.

Operating expenses in the first nine months of the year were up by 5.6% from 2019's €50.2m to €52.9m for 2020. This included R&D expenses rising from €40m to €41.2m (from 22% to 26% of revenue), while Aixtron invests in the ongoing development of next-generation metal-organic chemical vapor deposition (MOCVD) equipment.

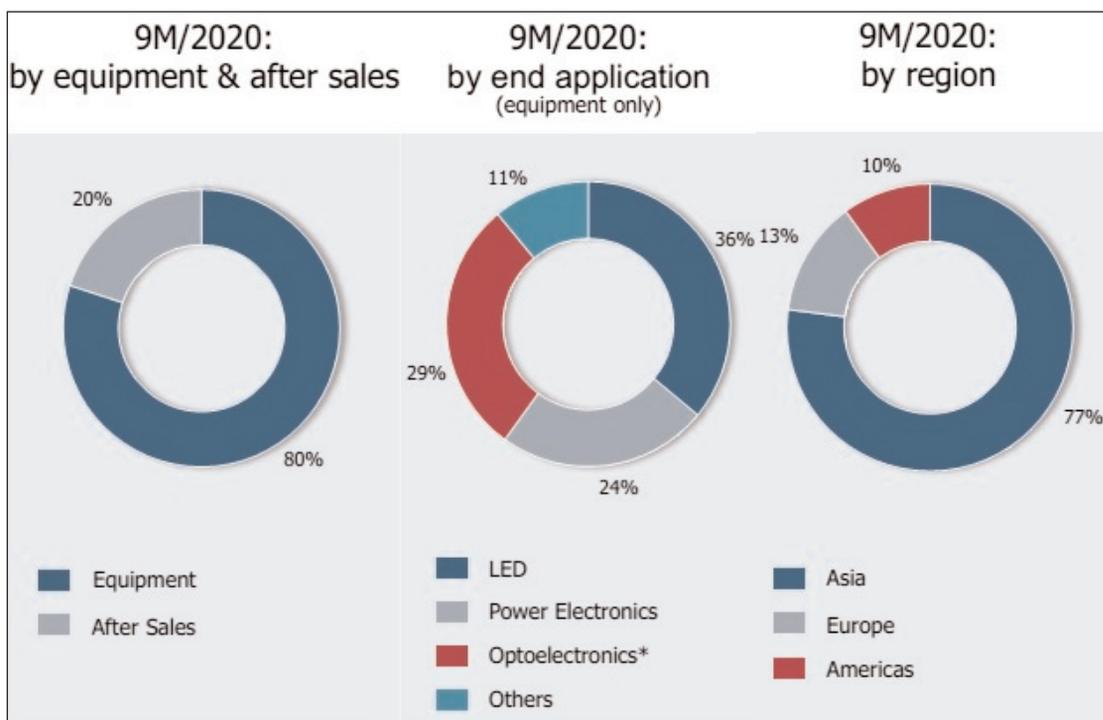
Operating expenses in Q3 were €17.6m, cut from €19.6m last quarter. Specifically, selling expenses fell by €0.9m from €2.8m to €1.9m (due mainly to lower external sales commission). R&D project costs fell by €1.6m from €14.2m to €12.6m, reflecting the current status of the organic light-emitting diode (OLED) project at South Korea-based subsidiary APEVA, where qualification of the Gen2 deposition system with the South Korean customer is nearing completion and a follow-up project has not yet started.

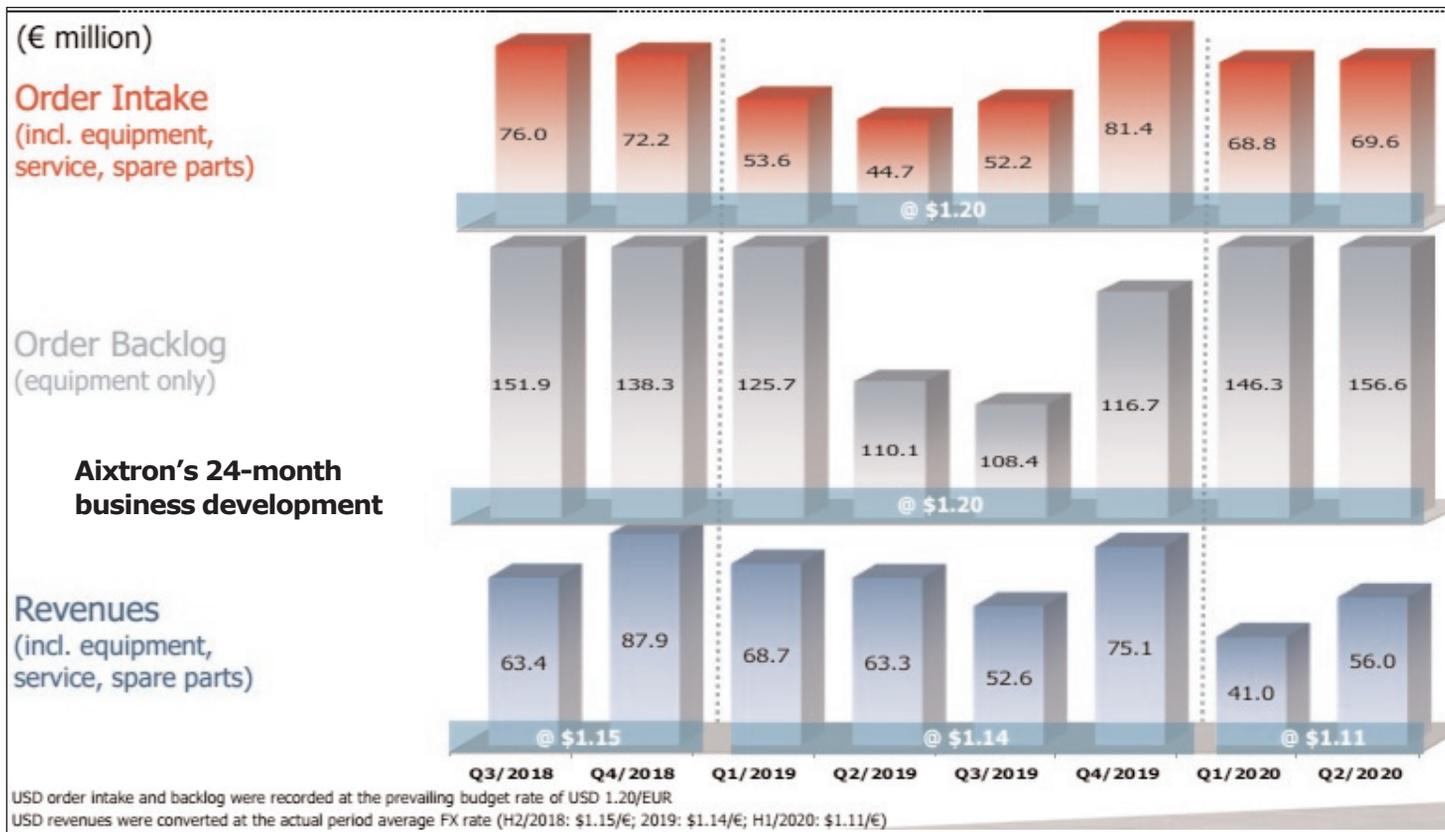
Due to the revenue growth and lower operating expenses, Aixtron more than doubled its operating result (earnings before interest and taxes) from €3.3m in Q2 (EBIT margin of 6% of revenue) to €8.2m (13% EBIT margin) in Q3, exceeding €5.5m (10% EBIT margin) a year ago.

Likewise, net income of €7.1m (11% of revenue) more than doubled from Q2's €3.3m (6% of revenue).

Because a lot of the trade receivables expected in the early part of 2020 were collected in Q4/2019 and because of the planned further build-up of inventory during Q3/2020 (from €91.2m to €101.6m, up from just €79m a year previously) ahead of increased shipments in Q4/2020, free cash flow worsened to -€3.3m for the first nine months of 2020, compared to -€2.4m a year prior.

Excluding the movements in and out of various investments, free cash flow was €5m in Q3 (an improvement on -€11.3m in Q2). During Q3, cash, financial investments & deposits hence rose from €288.6m to €292.8m, comprising €263m in short-term assets and €30m of cash on deposit within non-current assets.





Strong order growth year-on-year

Order intake (equipment plus after-sales) in the first nine months of 2020 were €209.3m, up 39% on €150.6m the prior year. This included €70.8m in Q3, up 35.6% on €52.2m a year ago and up 2% even on the strong €69.6m in Q2/2020, driven mainly by demand for power electronics and laser applications.

Order backlog (equipment only) at the end of September was €164.1m, up 5% on €156.6m at the end of Q2/2020 and up 51% on €108.4m a year previously. During Q3, customer deposits (contract liabilities for advance payments) rose further, from €61.1m to €63m, representing 38% of order backlog.

"In power electronics, we see solid demand for tools to produce GaN power devices. Adoption of these devices is growing in more and more applications, starting from mobile phone and laptop chargers. We also see applications in server and telecom power supplies as well as in automotive on-board chargers," notes president Dr Felix Grawert. "Furthermore, our customer base is growing as more and more players are entering the GaN power market.

For example, we are now serving all of the tier-1 foundries with our GaN products. In addition, and despite the high market share Aixtron has in GaN, we continue to convert customers from other vendors to our platform. In this quarter, we have been able to win Siltronic, one of the top five wafer makers, as a customer," he adds.

"In SiC, we see continuous demand from our long-term existing customer [a very major customer for the whole market] and we are making good progress with our qualification programs at our other customers. We have achieved the first full customer acceptance and, with this, an additional customer [targeting the automotive market... is the biggest volume market, and expected also to ramp very fast] in volume production on our SiC tool," Grawert continues. "We very shortly expect a repeat purchase order from this second customer because this customer is already now in full production with our tool and has just secured additional orders from its automotive customers... There is clearly a ramp planned based on our tool, as we are also the only vendor in this customer," he adds. "We have

our tool in other customers, where the qualification is ongoing. We are expecting to complete those qualifications within the next 1–2 quarters... We expect follow-on orders to come also from these other customers within the year 2021."

Overall, power electronics comprised about 50% of Aixtron's order intake in Q3.

"We also recorded continued good demand for our laser solutions, driven to a large degree by the need for optical data communications," says Grawert. For example, in October Finland-based laser maker Modulight ordered an AIX 2800G4-TM MOCVD system to scale up its epi-wafer production. Overall, lasers comprised about 35% of Aixtron's order intake in Q3.

"We continue to see a healthy pipeline for our LED equipment, in particular for the production of LEDs for fine-pitch or mini-LED displays and mini-LED backlighting units," adds Grawert.

"We're in our year-end push," says president Dr Bernd Schulte. "Aixtron's business development in the third quarter has shown that the demand for our innovative deposition systems remains at a high

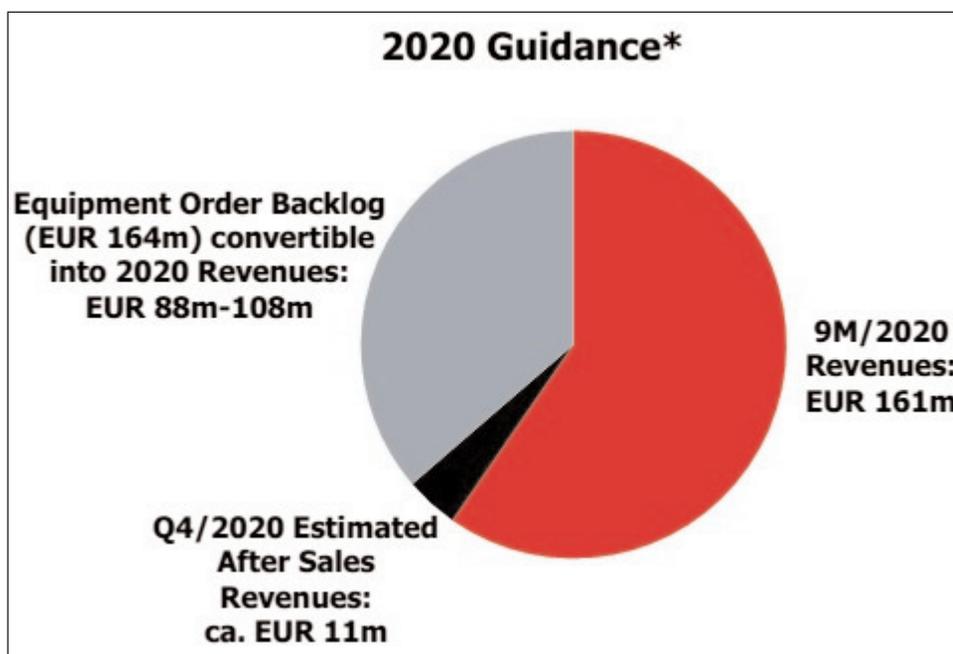
► level. Not only should our revenues continue to grow dynamically in the final quarter, but also our profits accordingly.”

For fourth-quarter 2020, Aixtron expects strong growth in both revenue (to €100–120m) and operating results. The firm hence expects inventories to fall substantially by the year end.

Full-year 2020 guidance

Based on (1) the order backlog, (2) the currently estimated low impact of the COVID-19 pandemic and (3) the budget exchange rate of \$1.20/€, for full-year 2020 Aixtron now expects order intake to be in a tightened range of €270–300m, within the original guidance range of €260–300m (up from €231.9m in 2019).

Aixtron reckons that €88–108m of its €164m equipment order backlog is convertible into revenue by end-2020. It also forecasts €11m in after-sales spares & services revenue in Q4. Added to the €161.1m in revenue from the first nine months of 2020, for full-year 2020 Aixtron now expects revenue of €260–280m (narrowing from the prior guidance of €260–300m), level to up on 2019's €260m. Guidance remains unchanged for gross margin of about 40% (down from 2019's 42%) and EBIT margin of 10–15% (compared with 2019's



15%). “We have not amended our EBIT guidance as some upcoming external events such as US elections and Brexit might lead to significant currency fluctuations, with the respective influence on our margins,” says Grawert. “Nevertheless, we believe that the mid-point of the EBIT range can be seen as our base case.”

Aixtron says that its executive board is monitoring the impact of the COVID 19 pandemic and ongoing trade disputes on the global economy and the movement of goods, in order to be able to assess any potential effects on its own

supply chain and production as well as on customer demand and thus on the firm's business development at any time and — if necessary — to initiate corrective actions.

“Aixtron's strength is also reflected in our continued high level of investment in the further development of our leading-edge technology,” says Grawert. “This allows us to make progress in continuing to align our product portfolio with the growing demands of our customers' future markets such as 5G mobile network expansion and e-mobility.”

www.aixtron.com

Aixtron appoints chief financial officer Christian Danninger to be Executive Board member

Aixtron's Supervisory Board has appointed Dr Christian Danninger as a new member of the firm's Executive Board in the role of chief financial officer (CFO), effective 1 July 2021 or earlier. The appointment is for a period of three years.

Danninger was most recently group CFO of Putzmeister Holding GmbH and CFO of Sany Europe GmbH (both Sany Group firms). The 41-year-old has extensive international experience in finance and accounting, compliance, law, IT and mergers & acquisitions (M&A). With a doctorate in law and master

in economics, his responsibilities in corporate and organizational development included the optimization of financial processes and reporting, the development and restructuring as well as the optimization of the organizational structures of various corporate divisions, and driving forward digitalization and human resources development.

As chief financial officer, Danninger will assume responsibility for finance & accounting, controlling, compliance, legal, human resources and investor relations at Aixtron no later than 1 July 2021. With his

appointment, the Supervisory Board considers the announced generation change in the Executive Board to be completed.

“As a proven financial expert with extensive experience in the machinery and equipment industry, Dr Danninger is an excellent addition to the Executive Board team to jointly drive the company's growth strategy,” believes Kim Schindelbauer, chairman of the Supervisory Board. “He will leverage his broad expertise on an operational and strategic level at Aixtron in a targeted manner.”

Aixtron participating in European pilot line for graphene and 2D materials

EC funds 2D-EPL as part of Graphene Flagship

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany and Aixtron Ltd (UK) are key partners in the 2D Experimental Pilot Line (2D-EPL) initiative of the Graphene Flagship (which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 649953). As one of the tool manufacturers, Aixtron will be responsible for developing the growth and transfer tools and processes necessary for graphene and related materials (GRM).

To scale up and integrate graphene and two-dimensional (2D) materials into semiconductor devices, Aixtron will develop a metal-organic chemical vapor deposition (MOCVD) reactor for growth of these materials directly on to large substrates up to 300mm using its proprietary Close Coupled Showerhead (CCS) technology. Direct growth allows industrial-grade 2D materials and their associated heterostructures to

be grown in-situ for front-end applications.

For effective back-end integration, Aixtron will investigate novel processes as well as develop a system for automated transfer of 2D material structures on to device wafers. These platforms will provide key capabilities for the pilot line in realizing large-scale integration of graphene and 2D materials into logic, memory, photonic and sensor devices.

2D-EPL spans whole value chain. The European Commission is providing €20m over four years for the 2D Experimental Pilot Line (2D-EPL), which started on 1 October. The project will establish a European ecosystem for prototype production of GRM-based electronics, photonics and sensors.

Comprising 11 partners, the 2D-EPL spans the whole value chain, including equipment manufacturers, chemical and material providers and pilot-processing lines. It aims to provide prototyping services to

not only the core Graphene Flagship project but also to external companies, research centers and academics in order to rapidly drive the adoption of graphene and 2D materials in wafer-scale devices.

"As a technology leader in semiconductor equipment for more than 30 years, our core expertise is to develop innovative solutions for complex material deposition — and deposition solutions for graphene and 2D materials are a key part of our product portfolio," says Michael Heuken, VP corporate research & development at Aixtron SE and professor at RWTH Aachen University. "These materials require very precise composition as well as thickness control down to one atomic layer, and we will leverage the technologies from our semiconductor production platforms to make this new class of materials a success for wafer-scale devices," he adds.

www.graphene-flagship.eu/pilot-line
www.aixtron.com

Lumcore orders Aixtron AIX 2800G4-TM systems

GaAs- and InP-based epiwafers to be produced for high-power lasers

High-power laser manufacturer Lumcore Optoelectronics Technology Co Ltd of Xi'an, China has ordered Aixtron AIX 2800G4-TM MOCVD systems for the production of gallium arsenide (GaAs)- and indium phosphide (InP)-based epiwafers.

"We at Lumcore are now taking the next important strategic step in the company's development," says Lumcore's chairman Xu Tianyou. "According to our assessment, Aixtron's product is the worldwide leading equipment in the production of high-end semiconductor laser epitaxial materials," he adds. "With highly com-



**Aixtron's
AIX 2800G4-TM
MOCVD system**

petitive high-power lasers, we can make a significant contribution to supporting China's development."

The AIX 2800G4-TM systems feature a graphite process chamber

and automated satellite loading at high temperatures, ensuring very high throughput and low particle count, says Aixtron. The high flexibility also enables Lumcore to produce epiwafers from 2-inches to 8-inches in diameter, depending on the requirements.

"With epiwafers grown on our systems, our customers are well prepared for the growing but increasingly competitive market for high-power laser applications in areas such as consumer electronics, automotive and communications," says Aixtron's president Dr Felix Grawert.

Picosun launches PicoOS unified control software

Picosun Group of Espoo, Finland, a provider of AGILE ALD (Atomic Layer Deposition) thin-film coating solutions for industrial manufacturing, has launched PicoOS, the new, full stack operating system and process control software for PICOSUN ALD equipment.

"PicoOS brings PICOSUN ALD equipment control to the modern era. It is designed for wafer fabs and industrial environments where the transition to Industry 4.0 is ongoing," says Dr Jani Kivioja, chief technology officer of Picosun Group. "Data-driven PicoOS enables future production solutions where machine learning, artificial intelligence, Internet of Things and other new digital inventions are utilized for optimum industrial efficiency."

Picosun's proprietary PicoOS software combines individual ALD mod-

ule, wafer handling and transfer system, and instrumentation control under one common graphical HMI (human-machine interface). This ensures easy, intuitive and user-friendly operation, maintenance and configuration of the whole PICOSUN ALD cluster.

PicoOS enables full factory integration via SECS/GEM protocol, process and system data logging down to 20ms rate, and real-time export of all data for continuous monitoring and further analysis.

The PicoOS operating system is specifically developed by Picosun's own in-house software team for the firm's fully automated production ALD systems Morpher and Sprinter, and it will be implemented in all future PICOSUN ALD tool platforms.

"PicoOS is designed to ensure the highest control precision and accu-

racy, the fastest service times, and the best user experience for our customers," continues Kivioja. "Having in-house control over all features and sub-components of our PICOSUN ALD solutions is a key part of our holistic service model."

PicoOS has a freely configurable and scalable editor for ALD process recipe and processing job creation and storage, and recipes can be edited or new ones created at any time during the ALD system operation. Configurable user levels and safety logic, instrumentation and interlocks guarantee safe use in day-to-day operations, and allow full access for tool management in maintenance situations. Maintenance procedures are sped up by specific clean-up and maintenance sequences inbuilt in the software.

www.picosun.com/picosun-picoos

Sprinter disrupts fast batch ALD on 300mm wafers

Picosun has launched Sprinter, a brand new, fully automated high-throughput ALD production module for 300mm wafers. Barrier, high-k and other films are deposited in Sprinter with perfect ALD for semiconductor (e.g. emerging memory, transistor, capacitor), display, and IoT component applications.

In Sprinter, single-wafer film quality and uniformity are upscaled to fast batch processing with the highest reliability and repeatability.

Compared to vertical furnace reactors typically used for batch ALD processing, Sprinter provides higher film quality with lower thermal budget, so it is suitable also for temperature-sensitive devices.

Sprinter combines very fast process times with smaller batch sizes than in vertical furnaces, which allows greater production flexibility and minimized risk without sacrificing throughput.

The core of the Sprinter is its disruptively designed reaction cham-

ber, where fully laminar precursor flows ensure perfect ALD deposition with no parasitic CVD growth. This minimizes the need for system maintenance.

"Picosun Sprinter meets directly the challenges in high-volume ALD manufacturing on 300mm wafers," says Jussi Rautee, CEO of Picosun Group. "We are happy to unveil this product to our new and existing customers in 300mm semiconductor markets, and offer them a truly disruptive, modern alternative to old technologies in batch ALD manufacturing."

The SEMI S2/S8-certified Picosun Sprinter module can be integrated into a customer's manufacturing line or cluster. It is also suitable for single-wafer manufacturing lines as it does not disturb the process flow. Sprinter is run with Picosun's new, proprietary PicoOS operating system and process control software.

"Together with Sprinter, we are launching also our PicoOS operating system," continues Rautee.

"Our own operating system and process control software, developed by our in-house software team, means the highest control precision and accuracy, the fastest service times, and the best reliability and quality for our customers."

Full stack PicoOS software allows control, operation and configuration of Picosun ALD equipment — either standalone systems or full production clusters — via one unified, intuitive and user-friendly graphical HMI ensures smooth connection between the system and the customer's factory automation via the SECS/GEM protocol.

Sprinter is available for process demos at Picosun facilities. Sprinter module sales starts in January, and the full Sprinter cluster with several ALD modules, central vacuum wafer handling unit and EFEM is available later in spring 2021.

www.picosun.com/product/picosun-sprinter

Plasma-Therm acquires OEM's PVD, RTP & etch business OEM Group focusing on wet chemical processing and ion implantation

Plasma-Therm LLC of St Petersburg, FL, USA (which makes plasma etch, deposition and advanced packaging equipment for specialty semiconductor and nanotechnology markets) has acquired the dry process equipment business of OEM Group of Phoenix, AZ, USA (which supplies new and re-manufactured semiconductor capital equipment and upgrades focused on emerging markets).

With the acquisition, Plasma-Therm has acquired all original OEM licenses and intellectual property rights for SFI Endeavor, AG Heatpulse, MRC Eclipse and Tegal brand equipment.

Plasma-Therm will continue to support existing customers through spare parts and upgrades, while offering new and refurbished tools to the wider market.

"The acquisition allows Plasma-Therm's award-winning customer service teams to support the large and global install base," says Plasma-Therm's CEO Abdul Lateef. "Additionally, PVD and RTP technologies align perfectly with our etch and deposition products and process solutions, which will further support the manufacturing and R&D needs and requirements of our customers," he adds.

"We are delighted to have had these outstanding products acquired by PlasmaTherm, ensuring a strong path to market for our newly developed Endeavor M series PVD platform, and the continued availability and support of the MRC Eclipse, AG Heatpulse, and Tegal products," comments OEM Group's CEO Michael Correra. "This acquisition allows OEM Group to strategically focus on our wet chemical process and ion implant technologies," Correra adds.

www.plasmatherm.com
www.oemgroupinc.com

Canon launching FPA-3030i5a lithography system for 50–200mm substrates

Upgrade from FPA-3030i5+ reduces CoO, targeting SiC and GaN

Canon USA Inc says that in March its parent company Canon Inc will begin sales of the FPA-3030i5a, the newest entry in its lineup of i-line (365nm-wavelength) lithography systems supporting manufacturing of devices including compound semiconductors. The new system is also designed to help to reduce the cost of ownership (CoO).

The FPA-3030i5a stepper is designed to process small substrates between 50mm (2-inches) and 200mm (8-inches) in diameter. It supports not only silicon wafers but also common compound semiconductor materials such as silicon carbide (SiC) and gallium nitride (GaN), which helps to enable the manufacturing of various devices that are expected to see increased demand in the future, such as high-power devices for automobile electrification and high-bandwidth video processing and communication devices for 5G communications.

The FPA-3030i5a stepper hardware and software have been upgraded from its predecessor, the FPA-3030i5+ stepper (released in

June 2012), to help reduce CoO. The FPA-3030i5a inherits the imaging performance of the FPA-3030i5, achieving exposure resolution of 0.35 μ m line-width patterns while providing robust alignment options and increased productivity. The new system employs a high-speed wafer feeding system that can be configured to handle a variety of wafer materials and sizes including compound semiconductors with diameter of 50–200mm.

The FPA-3030i5a uses a new off-axis alignment scope to illuminate and measure wafer alignment marks. By not observing the marks through the projection lens, the alignment system can employ a wide range of illumination wavelengths to help optimize alignment conditions. FPA-3030i5a steppers equipped with the optional Through-Silicon Alignment (TSA) system can also utilize infrared light to view through substrates to enable backside alignment processes. The new alignment system also shortens alignment mark measurement time.

The reduced alignment time, high-speed feeder system and upgraded software allow the FPA-3030i5a to achieve 123 wafers per hour (wph) output for 200mm (8-inch) wafers, which is about a 17% productivity improvement compared to its predecessor. The new stepper also features a new chamber temperature control system that maintains the lithography system in a clean environment and constant temperature level. The new design helps to reduce power consumption by about 20% compared with the predecessor model and, through such improvements, the system helps to reduce CoO.

Through the introduction of the FPA-3030i5a and the implementation of advanced functions, system owners are able to manufacture specialty power and communication devices using a wide range of wafer materials including silicon and compound semiconductors such as SiC and GaN ranging in size from 50mm to 200mm, summarizes Canon.

www.usa.canon.com

LCIF2 invests in Kubos in £760,000 round

Funding to boost development of commercial proof of concept

In its fifth deal as manager of the Low Carbon Innovation Fund 2 (LCIF2), Turquoise (the UK merchant bank specializing in energy, environment and efficiency) is investing in Kubos Semiconductors Ltd of Cambridge, UK as part of a £760,000 round.

Recently shortlisted by the 2020 Cambridge Independent Science and Technology awards as a finalist in the 'start-up of the year' category, Kubos was formed in 2017 to develop and commercialize its proprietary cubic GaN intellectual property (IP). The firm has an exclusive license to the technology, which was originally developed in partnership with the Department of Materials at the University of Cambridge and Anvil Semiconductors.

Kubos' cubic GaN growth technology is reckoned to have the potential to circumvent some of the key limitations in conventional GaN-based LED devices. In particular, the removal of internal electric fields and a narrower bandgap mean that cubic GaN can deliver

more efficient green and amber LEDs, overcoming the so-called 'green gap' problem (where a significant drop in efficiency is seen in green and amber devices compared with their blue and red counterparts). This can facilitate improved displays and also light bulbs that can be varied to mimic the natural changes in daylight through the day. The main applications are in general lighting, micro-LED displays, automotive, street lighting and digital signage. Kubos plans to license the technology to major LED makers.

"Kubos LED technology will represent a massive improvement in lighting and displays efficiency, significantly reducing energy consumption and accounting for less CO₂ emissions," comments Axel de Mégille, director at Turquoise. "This investment fits very well in the investment strategy of LCIF2 into technologies helping to reduce greenhouse gases (GHGs)," he adds.

"This investment will enable us to

further our development program to deliver a commercial proof of concept and start engaging with potential customers," says Kubos' CEO Caroline O'Brien. "LCIF2 will also enable us to strengthen our links with local and national government".

Funded by the European Regional Development Fund (ERDF, an investment program part financed by the European Union) and with the UK Ministry of Housing, Communities and Local Government as the Managing Authority, LCIF2 is a venture capital fund investing in eligible small- to medium-sized businesses based in England, particularly the areas covered by its local government backers, developing products and services that will have a beneficial environmental impact. LCIF2 has received £10.9m (for co-investment alongside private monies) from the ERDF as part of the European Structural and Investment Funds Growth Programme 2014–2020.

www.kubos-semi.com

AquiSense and NS Nanotech partner

First solid-state UV emitter to span 200–400nm wavelengths

AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) has partnered with NS Nanotech of Ann Arbor, MI, USA on the development of what is said to be the first solid-state broadband UV research device. It will be powered by what is claimed to be the first UV lamp that is solid-state and emits wavelengths from 200nm to 400nm, developed by NS Nanotech. The device is critical for research into key disinfection wavelengths such as 220nm (far UV-C), 254–280nm (UV-C) and 290–400nm (UV-A and -B).

A startup with patented technology developed at the University of

Michigan and McGill University, NS Nanotech claims that its new nitride semiconductor chips are the first solid-state devices to emit far-UVC light at wavelengths ranging from 200–222nm.

The collaboration between AquiSense and NS Nanotech aim to offer researchers reliable, low-footprint tools, as part of AquiSense's PearlLab Beam product line: one device to test all wavelengths within the full UV spectrum and another focused on the 220nm (far-UV) region.

"This partnership signifies a shift in how we can research spectral impacts of UV on various mediums and organic material," says AquiSense's CEO Oliver Lawal.

"Due to the early stages of far-UV-C, much more research is needed on its effects as a disinfectant; we wanted to provide that research tool so we can more effectively expand into consumer markets if far-UV-C is found to be unequivocally safe. Expect this product to be ready to purchase in the coming year," adds Lawal.

"We believe our technology will revolutionize how we disinfect our world and we're excited to get this technology into the hands of researchers to quantify the safety and effectiveness of this breakthrough," says Victor Hsia, VP of sales & business development at NS Nanotech.

www.nsnanotech.com

AquiSense's PearlAqua Micro to be tailored for Mitsubishi UV-C LED water disinfection for Japanese residential market

Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) has announced a unique version of its PearlAqua Micro product specifically for Tokyo-based Mitsubishi Electric Corp (MELCO, a subsidiary of Mitsubishi Corp). The partnership provides AquiSense's patented ultraviolet light-emitting diode water treatment technology for MELCO's residential Eco Cute hot-water systems.

On the basis of their low energy consumption, long service life and small footprint, MELCO spent over two years evaluating UV-C LED technology solutions from over a dozen suppliers for its CO₂ heat-

pump hot water supply system. AquiSense was selected as the long-term supplier based on what is said to be leading product performance, high-volume manufacturing capability and competitive pricing. The new product from AquiSense, based on its PearlAqua Micro platform, offers a high-level microbial disinfection barrier in hot water reuse. Unlike competing units, where pathogens remain throughout the water recycling process, the new UV LED disinfection acts as a barrier preventing contamination from future cycles, it is claimed.

AquiSense says the partnership shows that MELCO has committed to deploying mercury-free UV-C LED technology in its products for

decades to come, providing AquiSense substantial production growth for an extended period.

"This partnership signifies a huge adaptation of UV-C LED technology in the residential market," says Jun Miyauchi, AquiSense's Asian regional sales director. "Not only is this the world's largest UV-C LED supply contract to date, it is likely larger than all previous contracts combined."

Production is already underway, notes AquiSense's CEO Oliver Lawal. "This again reinforces our position that UV-C LED technology offers unique benefits that expand the application use of chemical-free disinfection."

www.aquisense.com

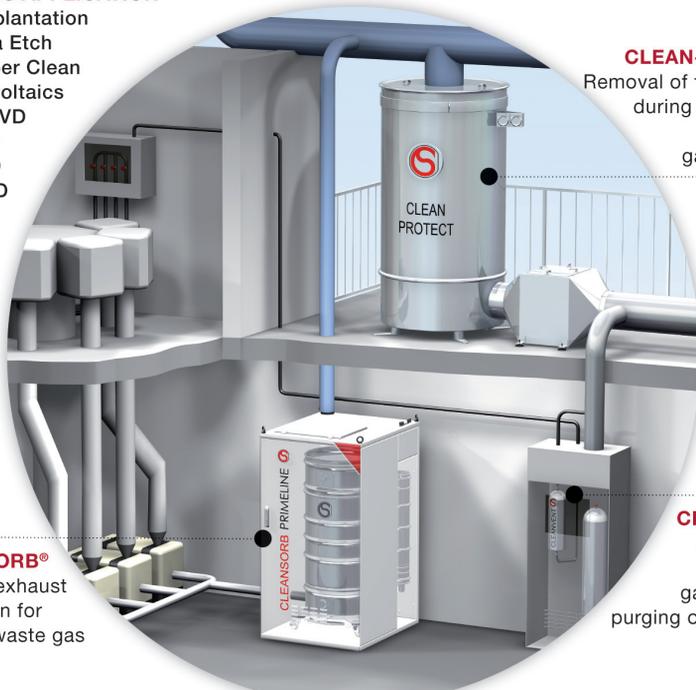
www.MitsubishiElectric.com



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www.csclean.com

Compound Photonics opens Micro-LED Innovation Acceleration Center in Arizona

Hub to provide process development for assembly, bonding, integration and pilot production

Compound Photonics US Corp (CP Display) of Vancouver, WA, USA — a provider of compact high-resolution micro-display technologies for augmented- and mixed-reality (AR/MR) applications — has opened its Micro-LED Innovation Acceleration Center (MiAC) in Chandler, Arizona, said to be the first fabrication plant dedicated to accelerating the time-to-market of sub-5 μm -pixel monolithically integrated micro-LED displays to meet the rising demand for mass-market AR/MR and smart wearable devices.

“Arizona’s advanced manufacturing industry continues to grow rapidly thanks to investments from innovators like Compound Photonics,” commented Arizona Commerce Authority’s president & CEO Sandra Watson.

“Micro-display has been a critical component that determines form factor, size, power consumption and optical performance of mainstream AR glasses,” notes CP’s co-CEO Richard Jackson. “CP has been in the forefront of delivering a cutting edge of sub-3 μm -pixel display drive technology & platform with a track record of bringing production-worthy products to market,” he adds. “By aligning with our partners’ expertise, equipment and resources at MiAC, together we will accelerate micro-LED process advancement to be ready to scale for commercialization.”

With over \$20m investment since 2018, MiAC will facilitate collaboration between CP and its industry partners in a single high-tech workspace. The approximately 15,000ft², Class 100 cleanroom provides direct access to specialized fabrication and metrology equipment to facilitate advanced process development for micro-LED assembly, bonding, integration and pilot production. Equipped with optical and electro-mechanical labs,



the facility also enables prototyping for complete optical systems. MiAC is strategically located close to major global semiconductor manufacturers and universities with access to optics and process engineering talent.

MiAC provides the infrastructure to showcase CP’s proprietary, small-pixel, epi-substrate-agnostic micro-LED integration. The process scheme is to monolithically integrate GaN-based micro-LED array epi-wafers with CMOS backplane array wafers incorporating CP’s recently unveiled Intellipix drive technology platform. By leveraging CP’s experience in making 3 μm -pixel high-performance micro-display and its strategic partners’ new generation of manufacturing solutions — ranging from chemical-mechanical polishing/

MiAC provides the infrastructure to showcase CP’s proprietary, small-pixel, epi-substrate-agnostic micro-LED integration

planarization (CMP), hybrid wafer bonding, metrology and packaging — the collaboration at MiAC aims to accelerate the integration of emerging fine-pixel-pitch micro-LED arrays into compact micro-display modules. This multi-disciplinary approach is intended to streamline innovation and development cycle time to rapidly yield operable micro-display modules with the required performance for AR/MR near-eye applications.

CP’s new Chandler-based MiAC is ready now, and more strategic partners should join the workspace. The first samples of CP’s 0.26”-diagonal 1080p-resolution backplane configured as a spatial color RGB micro-LED display integrated with display driver IC to accept industry-standard MIPI input are expected to be introduced at MiAC by summer 2021. A grand opening ceremony will be held on 14 January, with CP’s executives and strategic partners as well as local business leaders providing keynote addresses. www.compoundphotonics.com

Aledia produces first micro-LED chips on 300mm silicon wafers

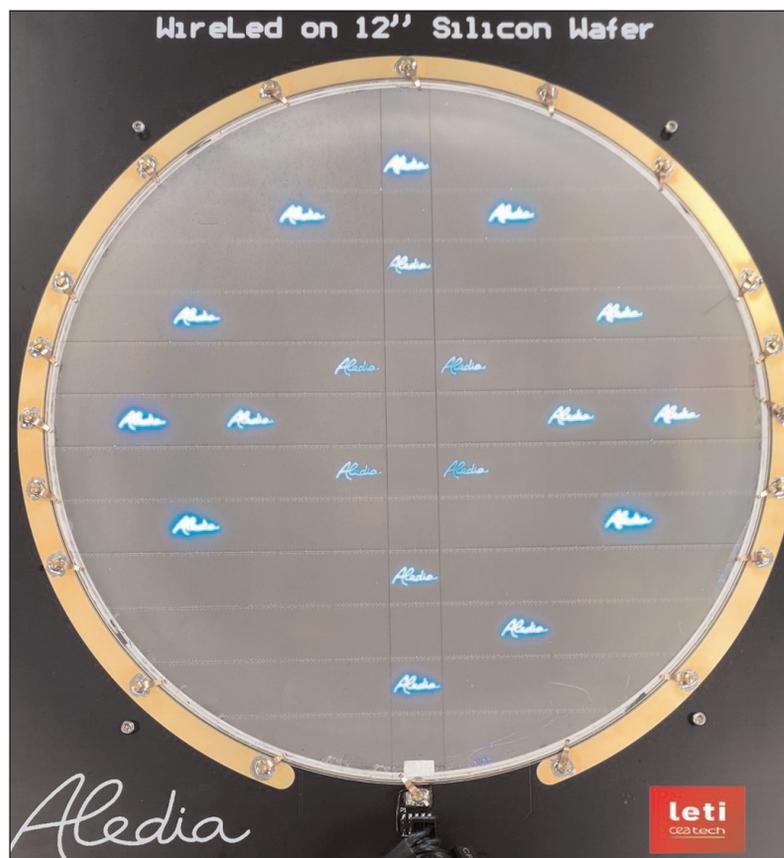
Leti pilot lines used, prior to 200–300mm foundry manufacturing

Aledia S.A of Echirrolles, near Grenoble, France (a developer and manufacturer of 3D micro-LEDs for display applications based on its gallium nitride nanowires-on-silicon platform) has manufactured what it says are the first micro-LED chips produced on 300mm (12") silicon wafers.

The firm, which developed its technology on 200mm (8") silicon wafers over the past eight years, will produce the chips on both 200mm and 300mm wafers. The larger wafers provide better economic payoff and cost-effective integration with smaller-node electronics, which are only available on 300mm silicon wafers. Aledia was spun out of Grenoble-based micro/nanotechnology R&D center CEA-Leti in 2012, and the work on 300mm wafers has been performed by joint Aledia and CEA-Leti teams.

"Producing micro-LEDs on large-area 300mm silicon wafers is a world's first, and opens this technology to huge potential-volume-manufacturing capabilities," believes CEO & co-founder Giorgio Anania. "The larger size allows 60–100 smartphone displays to be made on a single 300mm wafer, versus approximately four-to-six using the present LED industry-standard, 4" sapphire substrate," he adds. "Thanks to Aledia's unique nanowire LED technology (3D LED), this can be done with commercially available processes and equipment, since it uses standard-thickness (780µm) silicon wafers."

Traditional planar 2D micro-LEDs are produced by depositing layers of GaN crystal on sapphire wafers of 100–150mm (4–6") diameter, with most production currently being on 100mm (4") wafers. Aledia's micro-LED technology grows GaN nanowires on top of large-area silicon. This 3D nanowire technology does not create any of



"The use of large-area silicon wafers and microelectronics foundries are the only way to deliver the huge volumes demanded by end-user markets," believes Anania. "For example, if only the large-screen TVs of 60" in diagonal and larger transitioned

the stresses seen on 2D chips, which build up as the wafer size is increased, and so allows the use of very large-size wafers, says Aledia. In addition, the silicon-based technology allows production in conventional foundries, which can be ramped up to high-volume production with extremely high yield.

"We are very pleased to have helped Aledia push forward the state of the art of 3D LED manufacturing using our 300mm silicon processing line. We believe large-area silicon wafers are the best manufacturing platform in the world today for displays, and give big advantages in manufacturability," says CEA-Leti's CEO Emmanuel Sabonnadière. "3D nanowire micro-LEDs have the potential to make serious penetration into large-display markets. CEA-Leti is very active today in supporting the display industry's transition to micro-LED technology," he adds.

to silicon nanowire technology to obtain better image quality and lower manufacturing costs, this would require 24 million 300mm wafers per year, volumes that can only be delivered by the silicon industry and supply chains. Smartphones, laptops and tablets would be on top of that," Anania says.

Aledia's technology is protected by 197 patent families, making it the leading French startup company in France in filed patents, it is reckoned.

The work is sponsored by the European Commission (EC) Horizon 2020 grant agreement 954553 for the project SPEED ('Smart Pixel Emitters For Display' — H2020-EIC-SMEInst-2018-2020), which runs from 1 August 2020 to 31 July 2022.

www.aledia.com
www.cordis.europa.eu/project/id/954553

Porotech launches first native red InGaN LED epiwafer for micro-LEDs

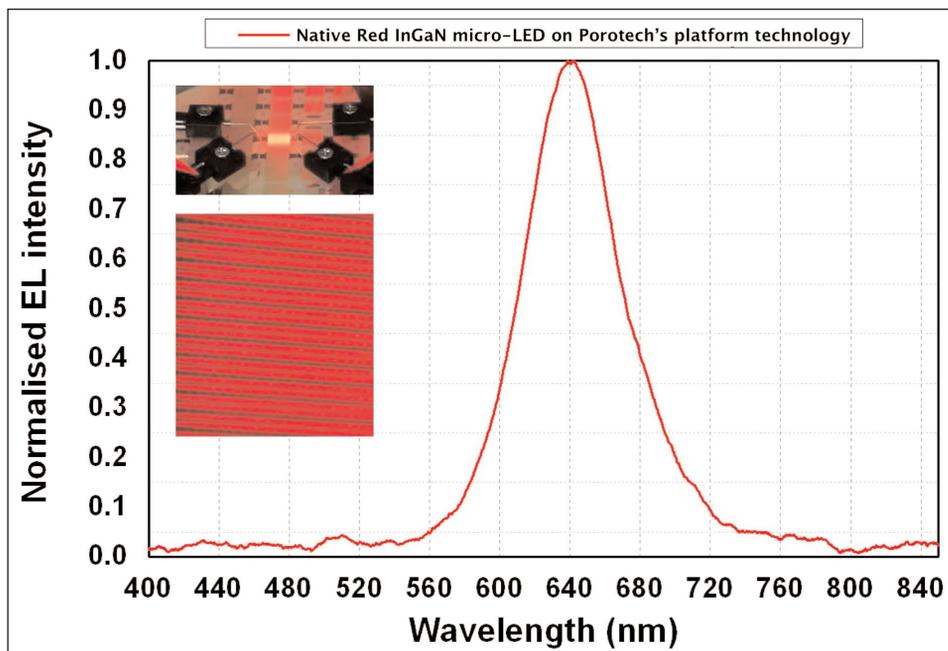
Cambridge spin-off unveils its first product

Gallium nitride (GaN) material technology developer Porotech (a spin-out from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge) has announced the launch of its first product, which is reckoned to be the first commercial native red indium gallium nitride (InGaN) LED epiwafer for micro-LED applications.

Micro-LED display technology offers a huge improvement on standard display panels due to its optimum brightness, efficiency and image definition, as well as improved lifetime. These benefits are crucial for near-to-eye applications such as augmented reality (AR) and head-mounted displays — a market predicted to be worth tens of billions of dollars over the next five years. They are also key for a range of other applications — from large-area displays and TVs to mobile phones and wearable devices such as smartwatches. But, until now, achieving the necessary high-efficiency, ultra-fine-pitch red pixels has been a challenge.

Traditional red LEDs are largely based on aluminium indium gallium phosphide (AlInGaP) materials. So, they show a drastic efficiency drop as the device size decreases due to their large carrier diffusion lengths and high surface recombination velocity.

Porotech says that its unique production process has enabled the creation of a new class of porous GaN semiconductor materials and structures that provide enhanced functionality. Porous GaN could be regarded as a semiconductor composite of solid GaN and air. It enables Porotech to engineer a wide range of material properties (optical, mechanical, thermal and electrical) and consequently offers an entirely new material platform for semiconductor devices to be built upon.



“Micro-LED displays using GaN-based material technology are widely seen as the only technology that can deliver displays bright and efficient enough to meet the requirements of AR,” says CEO & co-founder Dr Tongtong Zhu. “With AR glasses expected to one day replace smartphones — or at least reduce our interaction with the devices in our pockets — development of advanced materials to improve performance is crucial,” he adds.

“Integration of AlInGaP red and indium InGaN green and blue LED displays in a module with micron-scale pixels is extremely challenging as high surface recombination velocities in AlInGaP devices make this material unsuitable for efficient micro-LEDs. Our breakthrough extends the emission range of InGaN LEDs to meet the performance needs of the red display, whilst delivering the ability to scale wafer size, required by micro-LED

Red LEDs are largely based on AlInGaP materials... They show a drastic efficiency drop as the device size decreases

semiconductor display technology.”

GaN is applicable across electronics and optoelectronics — from efficient power transistors and lasers to quantum devices, sensors and solar cells — and the introduction of porous architectures can extend its capability in all these realms, reckons Porotech. The firm says that its product fits within existing industry standards and processes. The proprietary technology is robust but also flexible enough to be tailored to the needs of different applications. The native red InGaN micro-LEDs have a wavelength of 640nm at a current density of 10A/cm², as well as improved performance over conventional AlInGaP and colour-converted red LEDs at very small pixels and pitches.

Earlier this year, Porotech secured a £1.5m seed round investment co-led by Cambridge Enterprise (the commercialization arm of the University of Cambridge) and IQ Capital Partners, with the additional participation of Martlet Capital and a syndicate of angel investors from Cambridge Angels and Cambridge Capital Group.

www.porotech.co.uk

www.gan.msm.cam.ac.uk

SemiLEDs' quarterly revenue falls 12%

For its fiscal full-year 2020 (to end-August), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of \$6.07m, up 3% on fiscal 2019's \$5.9m. However, fiscal fourth-quarter 2020 revenue was \$1.4m, down 12% on \$1.57m last quarter.

Full-year gross margin has recovered further, from just 8% in fiscal 2019 to 26% for fiscal 2020. However, quarterly gross margin fell

back from 27% last quarter to 8% in fiscal Q4/2020.

Despite that, operating margin has improved further, from -66% a year ago and -47% last quarter to -28% for fiscal Q4/2020. This helped full-year operating margin to recover from -62% in fiscal 2019 to -34% for fiscal 2020.

Net loss for fiscal Q4/2020 was \$62,000 (\$0.02 per diluted share), cut from \$513,000 (\$0.14 per diluted share) last quarter and

\$881,000 a year ago (\$0.25 per diluted share). Full-year net loss has been reduced from \$3.57m (\$1.00 per diluted share) in fiscal 2019 to \$544,000 (\$0.15 per diluted share) for fiscal 2020.

Cash and cash equivalents (excluding restricted cash) have risen further from \$1.4m at the end of fiscal 2019 and \$2.5m at the end of last quarter to \$2.8m at the end of fiscal 2020.

www.semileds.com

Luminus launches XFM-5050 UVC LEDs Single device delivers 250mW at 275nm for disinfection & sterilization

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — has introduced its new XFM-5050 UVC LED series that is said to set new benchmarks for output, and lower the \$/mW by another 20% compared with previous Luminus UVC LEDs.

The series offers 2-, 3- and 4-chip options with nominal power levels of 120, 180 and 240mW of disinfection power. With the industry

rapidly transitioning from mercury lamps to LEDs and new applications emerging that require higher power from smaller LEDs, XFM-5050 can deliver more than 400mW at maximum drive current from a 5mm x 5mm package. At this new level of power, price and reliability, even challenging applications such as municipal/industrial water purification are within reach, it is reckoned.

"Effective UVC applications require the right combination of wavelength, intensity and reliability, and

the market demands all three at a cost that enables LED adoption," says Murali Kumar, director of specialty marketing. "Earlier this year we dropped the cost per milliwatt to \$0.10 with the XBT-3535. Lowering the cost an additional 20% and increasing output comes just in time to support the rising demand for UVC LED solutions."

The XFM-5050 series is sampling now, with production volumes starting early in 2021.

www.luminus.com

Lumileds boosts flux of key LUXEON C and CZ colors

Lumileds LLC of San Jose, CA, USA has announced increases in flux from the PC Amber, Lime and Royal Blue emitters in its LUXEON C and CZ Color Lines.

The 17% leap in flux of PC Amber in LUXEON C LEDs supports more efficient, safer and easier-to-design lighting for first-responder vehicles, tow trucks and construction vehicles, says the firm. Lumileds claims that its unique Lime LEDs deliver the highest efficacy of any LED — 149lm/W — and are a critical element for the best tunable white and color mixing solutions. Royal Blue flux has been increased by 4%, supporting broader use in entertainment and architectural applications.

"The LUXEON Color lines are known for having the greatest color selection and now they provide even higher luminous output, so fixtures will require fewer LEDs to achieve their target brightness in a smaller overall footprint," says product marketing manager LP Liew.

The LUXEON C and CZ Color lines facilitate color mixing by having the same focal length on every color to prevent halos and to ensure uniform output levels across light beams.

The LUXEON CZ Color LEDs feature a dome-less design to deliver narrow beam angles and what is claimed to be 50% higher punch than competing LEDs. The low dome on LUXEON C provides the highest light extraction from a very small source, resulting

in more compact fixture designs, says the firm.

Driven at 350mA, the LUXEON C achieves luminous output of 110lm in PC Amber, 149lm in Lime and 552mW in Royal Blue; the LUXEON CZ delivers 88lm in PC Amber, 138lm in Lime and 432mW in Royal Blue.

Both Color lines feature small overall footprint of 2.0mm x 2.0mm for dense packing, low thermal resistance that reduce heat-sink requirements, and hot testing to ensure color consistency in real-world operating conditions. Colors of the LUXEON C and CZ lines include Violet, Royal Blue, Blue, Cyan, Green, Lime, Mint, PC Amber, Amber, Red-Orange, Red, Deep Red and Far Red.

www.lumileds.com

Seoul Semi obtains injunctions against Philips brand lighting affiliates

German court orders recall and destruction of products

South Korean LED maker Seoul Semiconductor Co Ltd says that the German District Court of Düsseldorf has issued two permanent injunctions against certain cell-phone and lighting products affiliated with Philips brand lighting.

The court ordered a permanent injunction against lighting products manufactured by Klite Lighting, a subsidiary of Signify (formerly Philips Lighting), and a recall of those products sold after March 2017 with the destruction of those

products in the patent litigation against Leuchtstark Vertriebs GmbH. In other recent litigation against Klite's products, Seoul also obtained a permanent injunction, a recall of infringing products sold after October 2017 and destruction of those products. This follows two other cases in the USA, where Seoul obtained permanent injunctions against the sales of Philips branded LED TV products.

In separate patent litigation filed against Conrad Electric (one of

Europe's largest electronics retailers), the court ordered a permanent injunction and a recall of infringing cell-phone products sold after October 2017 because they infringed Seoul's patent.

Seoul says that, for the past three years, it has prevailed in about 30 patent litigations across the USA, UK, Germany, Japan, China and Korea. The table shows a list of Seoul's patented technology asserted in enforcement actions.

www.SeoulSemicon.com

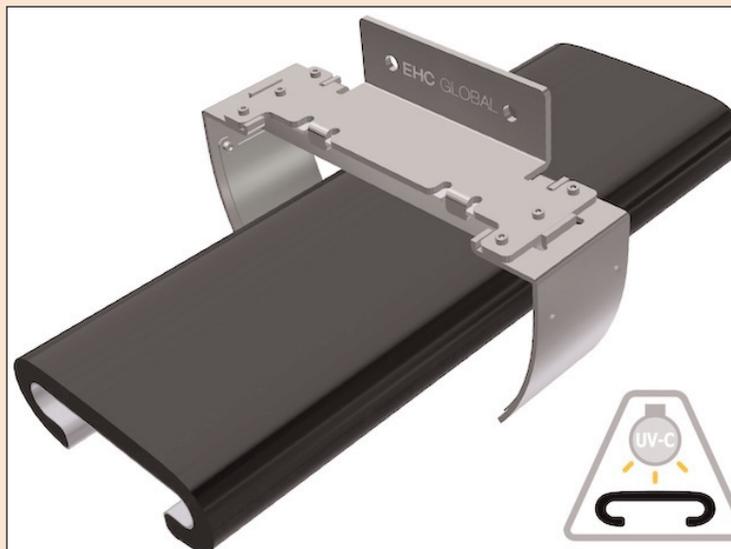
Violeds technology used for handrail sterilization

Installations applied on escalators and moving walkways

Ultraviolet LED product maker Seoul Viosys Co Ltd (a subsidiary of South Korean LED maker Seoul Semiconductor Co Ltd) says that its Violeds technology has been applied to an escalator handrail sterilization solution that is being supplied to global escalator and elevator OEMs by EHC Global Inc, a Canadian-based manufacturer of integrated solutions for the vertical transportation industry.

Providing disinfection on the surface of handrails using UV LED light, it is designed to match the speed, area and distance of the handrail to disinfect 99.9% of harmful viruses and bacteria in the areas exposed to the light.

EHC's handrail sterilization solutions with Violeds technology have already been installed on escalators and moving walks around the world in a wide range of environments including airports, public transit systems, commercial buildings, shopping malls, department stores, healthcare facilities, sports venues, museums and government buildings. EHC recently supplied Violeds technology applied escalator handrails to Ted Stevens Anchorage International Airport in



EHC Safety+ Handrail Sterilizer with Violeds technology.

Alaska in the USA and James Armstrong Richardson International Airport in Winnipeg, Canada.

"In response to the growing demand for vertical transportation solutions incorporating clean, anti-bacterial and disinfection technologies, EHC has implemented the Violeds UVC disinfection module by Seoul Viosys," says EHC Global's VP of sales Patrick Bothwell. "Thousands of installations have already been completed and we anticipate continued demand in

2021 and beyond." "As the COVID-19 pandemic continues, interest in the prevention of multi-use facilities is greatly increasing," says Seoul Viosys. Violeds has been proven to disinfect 99.9% of new coronavirus,

for elevators and escalators in public facilities such as airports, hospitals, shopping malls, sports stadiums, and even in air conditioning systems, the firm adds.

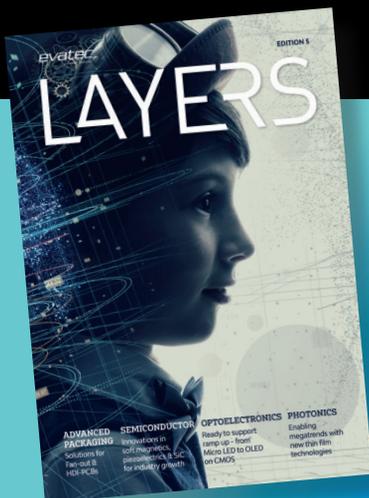
Violeds technology has been adopted for 2021 models by the world's top three brands of electrical goods such as refrigerators, drying machines and washing machines, and Violeds products are in mass production.

www.seoulviosys.com
www.ehc-global.com

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Giving our customers the lead through mass production of high performance TCOs, metals and DBRs with the best cost of ownership is our daily business. However, leveraging our know how to help customers develop new more demanding processes or ramp up production of next generation Optoelectronic devices like Micro LED or OLED on CMOS is where we add value too, and in this edition of LAYERS you can also read about solutions we can offer for exactly that.

Stefan Seifried, Head of BU Optoelectronics

Osram unveils its first UV-C LEDs

Oslon UV 3636 emits at 275nm for disinfection applications

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched its first UV-C LED, the Oslon UV 3636, representing the beginning of a comprehensive portfolio of LEDs in the UV-C LED sector.

Irradiation with UV-C light can eliminate 99.9% of viruses and bacteria on surfaces, in the air and in drinking water. It causes chemical bonds in the RNA or DNA helix of pathogens to break down, so they are no longer able to multiply and are thus rendered harmless. UV-C light has been used for many years to disinfect air or water – but often with very large lamps based on conventional light technologies.

A major advantage of modern LED-based UV-C solutions is the compact size of the light sources. Due to their space-saving dimensions, the LEDs can be installed

easily on the final application for direct interaction with the substance being sanitized, for example significantly reducing germs in faucets and disinfecting the air in air-conditioning systems before it is blown into car interiors. Direct integration of the light sources also has the advantage of ensuring that the high-energy, short-wave UV-C light does not reach the surrounding area, and therefore does not pose a risk to people. In addition, unlike conventional lighting technologies, LEDs are very robust and insensitive to external shocks.

With an emission wavelength of 275nm and compact dimensions of 3.6mm x 3.6mm, the new Oslon UV 3636) is suitable for disinfection applications. A low-power version produces 4.5mW of output power at a drive current of 30mA; a mid-

power version produces 42mW at 350mA.

“Thanks to their compact footprint and different optical power classes, UV-C LEDs enable completely new designs and applications,” says Christian Leirer, product manager for UV-C. “The Oslon UV 3636 is the first product in a series of innovations from Osram Opto Semiconductors in the UV-C range. A high-power UV-C LED will be launched in early 2021.”

Osram has been active in the UV area for many years and says that it has developed knowledge of UV technology through participating in various research projects with partners from industry and research, in particular the UNIQUE and UV-Power projects, as well as IPCEI on Microelectronics.

www.osram.com/os/applications/uv-c

Osram launches Ostune white LEDs for automotive ambient lighting

With car interiors becoming increasingly important in the latest generation of vehicles and undergoing a fundamental image change (leading to corresponding effects on design and integrated applications), Osram Opto Semiconductors says that its Ostune LED family now brings technical advances and insights from the general lighting industry to the car.

The first two products cover a wide color temperature range and enable OEMs to offer distinctive light variants for their ambient lighting: from bluish cool white to reddish warm white. The LEDs offer a coloring rendering index (CRI) of more than 90, the highest CRI currently available for automotive applications, it is reckoned.

From high-performance LEDs for headlights to infrared versions for driver monitoring and RGB solutions for interior lighting, LEDs are increasingly penetrating the automotive market. However, in the



field of ambient lighting, halogen lamps are still often used today – which not only require significantly more energy but also considerably more installation space.

The Ostune E1608 and E3030 extend Osram’s broad portfolio for automotive interior lighting by offering a wide color temperature range of 2700–6500K. In addition, they provide an energy-efficient and space-saving alternative to conventional technologies for many applications: from interior lighting and reading lights to mirror and footwell lighting. Due to the broad color range and ability to

choose from many small bins, users can easily and precisely define their desired white tone and make it a fixed design element across vehicles, says Osram. As well as the compact dimensions of 1.6mm x 0.8mm x 0.6mm (E1608) and 3.0mm x 3.0mm x 0.65mm (E3030), the products offer what is claimed to be outstanding color rendering in the car interior. The E1608 covers the lower brightness range up to over 7 lumens, and the E3030 the upper range up to over 70 lumens.

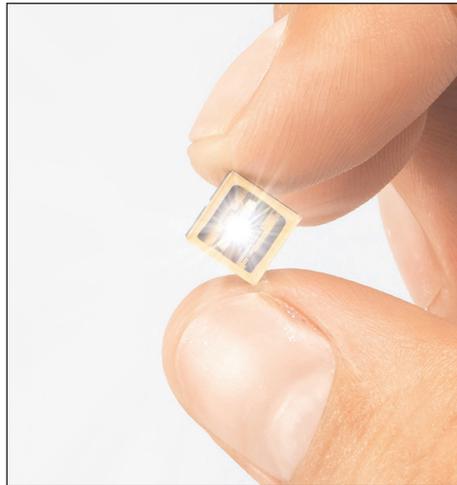
“Ambient lighting is becoming increasingly important with each new generation of vehicles,” says Hermann Senninger, marketing manager for Automotive Interior at Osram Opto. “With our Ostune product family, completely new designs are now possible, transforming the atmosphere in the interior from a functional workplace to a cozy living room simply by adjusting the color temperature.”

Kyocera acquiring Soraa spin-off SLD Laser

Fine ceramic component maker targets synergies with GaN expertise

Kyocera Corp of Kyoto, Japan (which manufactures fine ceramic components) has agreed to acquire SLD Laser of Goleta, near Santa Barbara, CA, USA (formerly Soraa Laser Diode Inc), which plans to begin operating as a Kyocera group company upon approval of regulatory authorities regarding national anti-trust and investment regulations.

Soraa Laser was spun off in 2013 from Soraa Inc of Fremont, CA, USA — a developer of solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates — and was co-founded by Dr Shuji Nakamura (the 2014 Nobel Laureate in Physics), Dr Steve Denbaars, Dr James Raring



and Dr Paul Rudy.

With 169 staff (as of 31 August) and facilities in both Santa Barbara and Fremont, CA, SLD Laser develops, manufactures and markets

high-efficiency, high-luminance GaN laser-based products for automotive & mobility, specialty lighting, consumer, and industrial applications. The firm's laser light sources have safety certifications from both ANSI/UL (American National Standards Institute/Underwriters Laboratories Inc) and IEC (the International Electrotechnical Commission). SLD Laser is also ISO 9001 certified and automotive compliant to IATF 16949.

Kyocera says that it targets synergies by integrating SLD Laser's GaN expertise with its own production technologies and R&D capabilities in fine ceramic-related businesses.

www.SLDLaser.com

<https://global.kyocera.com/prdct/fc>

Excelitas launches Generation 2 905nm high-volume pulsed laser diode

Power boosted by 20%, targeting range finding and LiDAR

Excelitas Technologies Corp of Waltham, MA, USA (which provides customized photonic solutions to OEMs) has introduced its enhanced Generation 2 905nm high-volume pulsed semiconductor laser diode. Featuring a multi-layer monolithic chip design, the second-generation product provides higher efficiency (3W/A) for further ranging and reduced power consumption, as well as an improved gallium arsenide (GaAs) structure to offer typically 85W pulsed peak power when driven at 30A for an increase of more than 20% compared with the first-generation product.

Suitable for industrial and consumer range finding and light detection & ranging (LiDAR) applications involving time-of-flight measurements, the enhanced pulsed laser diode design includes an optical emitting area of 225µm x 10µm by emission of three laser lines, offering high output power in a small



emitting area.

The laser chips are fabricated using metal-organic chemical vapor deposition (MOCVD) in a TS 16949 certified high-volume facility.

Features and benefits include:

- increased output power by more than 20%: a customer's range finder can measure greater distances, or the same distance with reduced power consumption;
- triple-cavity design: provides three times the level of optical

power compared with a single-cavity design;

- plastic TO package: cost-effective solution for high-volume applications.

"Our technology enhancements make this the highest-quality, highest-efficiency plastic-packaged pulsed laser diode on the market at 905nm, delivering a robust, cost-effective solution for design engineers working with time-of-flight measurements for industrial and consumer distance measurement applications," claims Denis Boudreau, product leader, Detection, at Excelitas.

Available for purchase now, Generation 2 905nm high-volume pulsed semiconductor laser diodes come standard in a plastic TO package, with future SMD and metal TO iterations available in 2021.

www.excelitas.com/product/tpg2ew1s09-905nm-generation-2-triple-cavity-225-mm-plastic-pld

ROHM develops VCSEL module technology

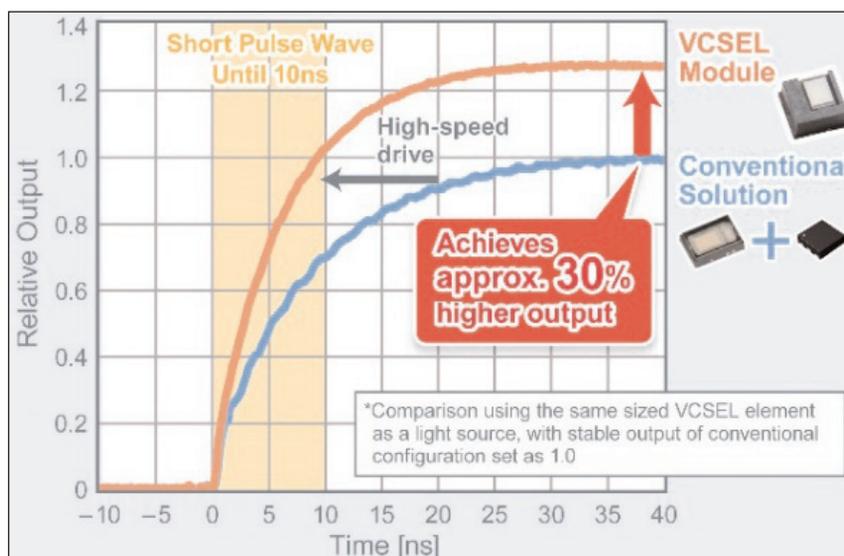
Output of spatial recognition and ranging systems boosted by 30%

Japan-based ROHM says that its newly developed vertical-cavity surface-emitting laser (VCSEL) technology achieves greater accuracy in spatial recognition and distance measuring systems by using time-of-flight (TOF) systems.

VCSEL module technology has become popular in recent years with the adoption of laser light sources for spatial recognition in tablets and facial recognition in smartphones. Also, with the emergence of automated guided vehicles (AGVs) and industrial inspection systems utilizing gesture and shape recognition, demand for VCSELs is expected to rise.

Meanwhile, for applications that require automation, shorter pulse drive and higher output for the light source are required to achieve higher-accuracy sensing.

Conventionally, in VCSEL-equipped laser light sources, both the VCSEL and the MOSFET for driving the light source are individually mounted on the board. Consequently, the wiring length (parasitic inductance) between products has an unintentional effect on the light source output and drive time, making it difficult to



Laser output for new technology versus conventional configuration.

achieve a light source that provides the high output and short pulses needed for high-accuracy sensing.

ROHM says that its new VCSEL module technology makes it possible to modularize the VCSEL and MOSFET elements into a single package. By minimizing the wiring length between elements, the performance of each element is maximized, resulting in a light source capable of short pulse drive (under 10ns) that reduces susceptibility to external noise from sunlight while enabling up to 30% higher output over conventional solutions, reck-

ons ROHM. As a result, when evaluating its VCSEL module technology in spatial recognition and ranging systems consisting of a control IC, TOF sensor (light receiving element) and laser

light source (VCSEL module), the amount of light reflected to the TOF sensor is increased by 30% over conventional configurations, contributing to improved accuracy in TOF systems, claims ROHM. In March, ROHM plans to release its new VCSEL module for AGVs in the industrial market and facial recognition systems for mobile devices requiring high-accuracy sensing. The firm will also continue to develop high-output lasers for light detection & ranging (LiDAR) in vehicles and other applications.

www.rohm.com/eu

Ushio adding 400mW 404nm laser to violet range

Cost-effective laser targets increased demand from non-industrial use

Ushio Inc of Tokyo, Japan has further expanded its violet light product portfolio by starting production of a new 404nm laser diode.

Offering 400mW of continuous wave (CW) output power (with an absolute maximum rated output of 500mW) within Ushio's standard MG (TO-56) 5.6mm-diameter CAN package and operating at temperatures of 0–30°C, the HL40093MG aims to meet demand for a violet laser diode (with emission wavelengths of

398–410nm) suitable for industrial applications and beyond.

Ushio says that its 404nm laser diode products are often used as light sources in direct imaging lithography systems, for exposing the high-definition circuit patterns on boards. Recently, demand for 404nm laser diodes from other non-industrial applications, such as evolving smartphones and high-definition 3D printers, has increased, notes the firm. This has driven it to launch a cost-effective

laser diode to meet greater demand from both existing and emerging markets.

With beam divergence of 13° horizontal and 45° vertical, the HL40093MG shares the optical and electrical characteristics, as well as pin layout, with the HL40053MG laser diode, providing another affordable option for existing HL40053MG users, as well as newcomers to using 404nm laser diodes.

www.ushio.eu

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CSC launches first quantum photonic component foundry

Three-year project to use standard techniques to scale up manufacture

Part-funded by the UK Quantum Technologies Challenge, via UK Research and Innovation, QFoundry (QFoundry) is a three-year, £5.7m project that will use standard semiconductor techniques to scale up the manufacture of quantum components that are critical to a wide range of novel quantum systems.

Quantum technologies are on the brink of emerging from the laboratory into a wide range of industrial and consumer products. Advanced quantum phenomena are being harnessed to create disruptive technologies in areas ranging from ultra-secure communications to highly sensitive imaging and healthcare diagnostics.

As new applications emerge, widescale market adoption of quantum systems will require a robust, commercial-grade source of quantum photonic components, often based on semiconductor devices. The adoption of foundry manufacturing will accelerate mass-market traction, it is reckoned.

Initial areas of focus of QFoundry include vertical-cavity surface-emitting lasers (VCSELs) for commercial-grade atomic clocks and

atomic magnetometers, and single-photon emitters and detectors for quantum communications, computing, imaging and sensing applications.

The consortium is led by The Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK. It also comprises Amethyst Research, Bay Photonics, Compound Semiconductor Applications Catapult, CSconnected Ltd, Cardiff University, Integrated Compound Semiconductors (ICS), IQE, Microchip Technology, National Physical Laboratory (NPL), Toshiba Europe, University of Cambridge and University of Sheffield. The consortium will deliver a national open-access quantum semiconductor device foundry.

Members of the consortium have already delivered proof-of-concept quantum devices, and they aim to build on collective capability to create the foundations for robust, scalable quantum component manufacturing in the UK to reduce barriers to commercialization of

quantum technologies.

"Widescale adoption of quantum systems need a robust, reliable and volume supply of semiconductor components to integrate into products to deliver a return on investment on the science," says CSC director Wyn Meredith. "QFoundry can perhaps be described as the missing piece in the pathway to commercialization, and the project will lay the groundwork towards a new UK quantum component industry," he expects.

"This is part of the UK National Quantum Technologies Programme, which is set to make a £1bn investment over its lifetime," notes Roger McKinlay, challenge director for the Quantum Technologies Challenge. "This impressive team illustrates that the UK can lead in the manufacture of quantum devices, not just the development of the technology," he adds. "This is not just good business in its own right but also part of a virtuous cycle in which world-class fabrication is underpinning further leading developments in quantum computing, communications, imaging in sensing."

<http://uknqt.epsrc.ac.uk>

SMART Cymru supporting CSC to develop manufacturing process for low-cost, high-spec lasers

High-specification compound semiconductor laser sources are used in high-bandwidth fiber-optic networks as well as in light detection & ranging (LiDAR) markets for navigation and obstacle avoidance by autonomous cars and robots. These lasers require high-quality, high-power light from a distributed feedback (DFB) laser.

For the market to grow to accommodate the number of devices needed, the technology needs to be commoditized to drive a cost reduction of ~10x. In a new SMART Cymru project, Compound

Semiconductor Centre Ltd (CSC) will develop a proof of concept of a high-power DFB laser design, as well as a method of production that replaces a time-consuming, expensive electron-beam lithographic step with a cheap and fast imprint stamping process to produce the embedded gratings in the DFB laser structure.

If successful, this project will deliver a new 'value-add' material-scale product that will increase yield, and reduce production lead-times and costs for DFB laser manufacturing.

The CSC was founded in 2015 as a joint venture between Cardiff University epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK, with the mission of accelerating the commercialization of compound semiconductor materials and device research and realising a tangible economic return on the UK investment in this key area of enabling technology. Based in Cardiff, CSC is a milestone towards developing a compound semiconductor technology cluster in South Wales.

www.compoundsemiconductorcentre.co

Sivers Photonics receives £325,000 Innovate UK funding for SPIDAR

Project to develop quantum-based LiDAR for vehicle safety

Sivers Photonics (formerly CST Global of Glasgow, Scotland, UK, and a subsidiary of Sivers Semiconductors AB of Kista, Sweden) — which develops and manufactures products for optical fiber networks, sensors and optical fiber communications (Li-Fi) — has received £324,800 of funding from UK Government agency Innovate UK for its part in SPIDAR ('Single Photon Infrared Imaging, Detection and Ranging'), a quantum project to develop range-finding and 3D imaging systems for driver-assisted and autonomous vehicles.

The total SPIDAR project grant is worth £3.62m, split between Sivers Photonics and project partners

Toshiba Research, Network Rail Infrastructure, Thales UK, Bay Photonics, Heriot-Watt University, Horiba Mira, IQE, University of Cambridge, University of Edinburgh and the University of Glasgow.

"The SPIDAR project will develop single-photon, infrared imaging, detection and ranging technology," says Sivers Photonics' managing director Billy McLaughlin. "This technology will be used to sense the proximity of objects and other vehicles for driver safety and self-driving vehicle applications; a market valued at \$556bn by 2026 [according to the report 'Global Autonomous Vehicle Market' from Allied Market Research]," he adds.

"Cameras are used to detect single photon light particles in the infrared region of the electromagnetic spectrum," McLaughlin continues. "The distance to the detected object or range is the measured time from the photon's emission to the object and back again. The photon detector delivers sub-nanosecond precision, detecting single photons from the faintest possible reflections. This technology enables a far greater detection range for 3D cameras than is currently available, enhancing both safety and effectiveness when deployed in real-life applications like vehicle safety."

www.sivers-semiconductors.com

Sivers Photonics appoints sales director at Glasgow HQ

Former CST Global targets expansion into optical communications, sensing and wireless markets

Sivers Photonics has appointed Graeme Urquhart as sales director, based at its headquarters in Glasgow, Scotland, UK.

"Graeme brings extensive international sales management and business development experience in complex markets," comments Sivers Photonics' managing director Billy McLaughlin. "He will increase sales service and support levels to our existing customers



New sales director Graeme Urquhart.

and drive Sivers Photonics continued expansion into optical communications, sensing and wireless markets."

Prior to joining Sivers Photonics, Urquhart was business

development director at Novosound, a Scottish technology start-up developing thin-film ultrasound sensors for non-destructive testing (NDT) markets. Previously he spent 14 years at Scottish engineering firm Linn Products, as EMEA business development manager. He holds a degree in Law from Glasgow Caledonian University and has an MBA from Strathclyde Business School.

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NUBURU completes \$20m Series B funding round

NUBURU Inc of Centennial, CO, USA, which specializes in high-power industrial blue lasers, has raised \$20m in Series B funding to accelerate development of its high-brightness AI Series industrial product line and to expand its presence in the energy-storage, e-mobility and 3D printing markets.

Co-led by industrial technology investment firm Anzu Partners and by Thomas Wilson (chair, president & CEO of The Allstate Corporation), the round brings NUBURU's total funding to nearly \$50m. Wilson, along with Ron Nicol, former senior partner and managing director of the Boston Consulting Group (BCG), will join Anzu managing partners David Michael and David Seldin on the board of directors.

NUBURU says that its blue lasers provide speed and quality control for metal processing operations, such as welding and additive manufacturing in growing industries such as e-mobility and automotive, where materials such as copper, stainless steel and aluminum are increasingly critical. Previous technologies are inflexible, slow and produce poor-quality metal joints, but the firm says that its industrial

blue lasers leverage a fundamental physical advantage to produce defect-free welds up to four times faster than the traditional approaches, together with the flexibility inherent to laser processing.

The funding follows the executive appointments of Dr Guy Gilliland as chief executive officer and Chris Baldwin as chief financial officer. NUBURU reckons that, paired with the additional funding, their experience growing global technology companies sets it up for additional product innovation and progression into new markets in the coming year.

"NUBURU lasers drive superior manufacturing speed and quality in fast-growing sectors such as consumer electronics, batteries and electric vehicles," says Gilliland. "This new funding allows us to advance our Denver-based automated production facility and accelerate development of our ultra-high-brightness product family," he adds.

"Feedback we've received from our customers has been overwhelmingly positive and proven that our high-power and high-brightness blue lasers are a compelling option for processing aluminum, brass, gold and other challenging metals," says

founder & chairman Dr Mark Zediker. "We are now scaling operations to respond to this strong customer interest in migrating their processes to our blue laser technology."

Wilson, who co-led the investment round and will join NUBURU's board, is also chairman emeritus of the US Chamber of Commerce. Nicol is a senior advisor with BCG following a 30-year career where he led its global technology practice. He has advised many of the world's largest electronics manufacturing firms. Nicol also has a degree in physics from the US Naval Academy. NUBURU reckons that their corporate development expertise and senior advisory roles will aid it as it expands its customer base.

"NUBURU's differentiated blue laser technology solves key challenges in electronics manufacturing and is also positioned to address many other applications ranging from life sciences to the aerospace sector," comments Nicol. "As blue technology continues to mature, NUBURU has a head start with its application expertise and strong IP portfolio that position the company for continued success," reckons Wilson.

www.nuburu.net

NUBURU appoints CEO and CFO

NUBURU has appointed Dr Guy Gilliland as chief executive officer and Chris Baldwin as chief financial officer.

Gilliland has over 20 years of management experience from the Boston Consulting Group (BCG), where he led the firm's global and North American technology practices and advised several of the world's largest telecoms, technology, electronics and photonics companies. Gilliland has a background in laser physics and served as a postdoctoral fellow at the IBM T.J. Watson Research Center and a faculty member at Arizona State University and Emory University.

"NUBURU's blue light laser technology is poised to transform the

production of high-volume electronics, EVs and batteries, while also accelerating the world of metal 3D printing," says Gilliland. Founded in 2015, NUBURU's standard AO laser and extreme-brightness AI laser are said to enable gains in speed and quality for metal machining and processing. "Our powerful technology platform advances what is possible in high-volume materials processing and delivers vital productivity and resolution improvements to metal additive manufacturing," he adds.

Baldwin has nearly 30 years of financial management experience across the photonic, telecom and medical device industries. He was

most recently CFO at Axsun Industries, a developer and supplier of MEMS-based photonic engines for medical imaging and industrial spectroscopy, and helped in its sale to Excelitas Technologies in 2019.

"Guy Gilliland and Chris Baldwin bring a combined 50 years of global technology experience and have each served as senior leaders in high profile companies within each of their core industries," comments NUBURU's founder & board chairman Mark Zediker Ph.D. "Their appointments will set NUBURU up for continued growth and innovation as we look to increase adoption of our technology across key markets."

Hitachi High-Tech acquires VLC Photonics

Optical component manufacturer adds photonic integration engineering, design & test

Tokyo-based Hitachi High-Tech Corp has acquired Spanish photonic integrated circuit (PIC) design house VLC Photonics S.L. (a spin-off of the Universitat Politècnica de València that has experience with various material platforms including silicon photonics, indium phosphide, silicon nitride, PLC and polymer). As a subsidiary, VLC will continue to provide photonic integrated circuit engineering services as part of Hitachi High-Tech's broader range.

Integrated into wafer materials such as silicon, indium phosphide and silicon nitride, PICs have optical functions with immediate applications in transceivers for optical communications. Internet traffic continues to grow rapidly due to the data arising from social media, video streaming

services, working from home, IoT and the overall digitization of our economy and environment. In the optical communications market, higher speeds and increased bandwidth are required to satisfy this growing demand. Meanwhile, as demand rises, the market has also had to manage issues of power consumption, size and cost reduction, and manufacturing scalability. Photonic integration provides the means to address all these requirements in a more holistic way than the traditional approach of assembling optical systems from discrete parts.

Hitachi High-Tech says that, as a long-term provider of components and services to the optical communications industry, it is aware of the increasing need of customers for

greater integration and innovation. As an independent provider of PIC design, test and engineering services, VLC can help it to serve the new requirements of its existing customers as well as providing a base for the development of new service provisions, adds the firm.

Besides optical communications, PICs are also becoming a critical platform in many industrial sectors such as automotive sensing, environmental testing, health sciences and quantum technology.

Going forward, Hitachi High-Tech aims to provide not only a more complete one-stop service but also engineering services that leverage the strengths of both companies.

www.vlcphotonics.com

www.hitachi-hightech.com/global

JePPIX opens up Pilot Line services for indium phosphide photonic integrated circuit production

Commercial production based on mature PDKs

The JePPIX (Joint European Platform for Photonic Integration of Components and Circuits) Pilot Line has launched design and manufacturing services for indium phosphide (InP) photonic integrated circuit (PIC) production, offering commercial InP PIC production based on mature process design kits (PDKs) that are embedded in industry-standard design environments.

Open now for companies that need to prepare for commercial production, the JePPIX Pilot Line provides a single point of contact for all the services needed for InP PIC product qualification, including:

- functional PIC modelling with manufacturing tolerances;
- design for test (DFT);
- design for manufacturing; and
- automated die testing with customizable scripting and test services.

JePPIX brings together the European photonic integrated circuit supply chain as a coherent force to advance and promote PIC technology. It promotes and facilitates an open-access, horizontal and generic foundry model that aims to keep pace with the market, bringing in new users, enabling specialization, and facilitating the supply chain agility required for new sectors.

To accelerate the use of InP PICs, the European Union's Horizon 2020 research and innovation program has supported the pilot line through the InPulse project, funded under grant agreement no. 871345.

Value of indium phosphide PICs

JePPIX says that InP PICs offer benefits as they are small in size, low weight and have a very low power consumption. Moreover, the possibility to integrate lasers, detectors, interferometers,

photodetectors, modulators, filters, waveguides and other (electro-)optical technologies all on a single chip has a huge impact on the material resources that are needed, circuit-level reproducibility and the overall cost of the system.

Application areas

According to JePPIX, photonic integrated circuits offer advantages over traditional approaches for implementing optical functionalities in a wide array of application domains, providing the engines for high-performance metrology, quantum technology, microwave signal processing and light detection & ranging (LiDAR). This offers huge potential for markets such as optical communication, automotive, life sciences, agriculture & food, environmental monitoring, defence and security, it adds.

www.jepix.eu

POET launches LightBar remote laser light sources TOSA incorporates four continuous-wave lasers for transceiver and data-center switch applications

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has completed and tested its designs for a line of high-performance remote laser light source products for 400G FR4, 800G and co-packaged optics (CPO) applications in cloud data centers.

For makers of conventional and silicon photonics-based optical transceivers, the LightBar product line offers a fully aligned, tested and multiplexed laser light source attached to an output fiber, eliminating the difficult and costly step of four laser alignments in optical transceivers. For makers of next-generation network switches that require the combination of switch components and optical components in a single package (CPO), using LightBar products can reduce heat generation within the package, which is a common cause of

component failure. When used as a remote laser source, the LightBar is expected to improve overall system reliability for both transceiver and CPO applications by offering the ability to replace failed laser assemblies in the field, without disturbing other components and sub-assemblies. Laser failures have proven to be the cause of a large majority of sub-assembly failures in both optical transceivers and co-packaged optics applications.

LightBar products are configured as a transmit optical sub-assembly (TOSA) incorporating four continuous wave (CW) lasers into the waveguide matrix of POET's proprietary Optical Interposer, meeting the CWDM4 and FR4 technical specifications. The 400G version is upgradeable to 800G with the incorporation of additional components. The LightBar is completely customizable and can support a wide range of output power from 15mW to 60mW, depending on the application.

In all cases, LightBar incorporates POET's proprietary designs and assembly features that deliver what is claimed to be an industry-leading laser coupling efficiency of >80% (power loss = <1.0dB), while maintaining wafer-scale integration capability — said to be significantly better than the best results observed with competing integrated approaches. Better coupling efficiency allows the use of lower-power, more reliable lasers to achieve the same output. POET will begin sampling the LightBar product line to customers in first-quarter 2021. Following qualification with customers, the firm expects to begin volume production in fourth-quarter 2021.

According to LightCounting, the market for 400G optical transceivers in all formats will grow from an estimated \$0.5bn in 2021 to over \$3bn by 2025. The market for optical connectivity (chips in co-packaged optics) is forecasted to exceed \$4bn in 2028.

POET appoints Glen Riley to board

POET has appointed Glen Riley to its board of directors. His experience includes over 30 years in leadership roles spanning both the semiconductor and optoelectronics industries.

Most recently, he was general manager of the Filter Solutions business unit at Qorvo, responsible for developing highly integrated RF modules used in flagship smartphones. Prior to the merger of RFMD and TriQuint that formed Qorvo, he held multiple leadership roles at TriQuint, including managing director of international headquarters in Singapore, general manager of the gallium arsenide (GaAs) foundry business, and general manager of Optoelectronics.

Riley was previously CEO of

Opticalis, an early-stage optoelectronics company focused on the development of high-density wavelength division multiplexing (WDM) products. He held prior roles as VP & general manager of the Optoelectronic business at Agere Systems, and president of Asia-Pacific sales & marketing at Lucent Technologies Microelectronics Group.

"Glen is an excellent addition to POET's board, bringing extensive executive experience from leading semiconductor and optoelectronics companies," comments POET's executive chairman & CEO Dr Suresh Venkatesan. "He has highly relevant experience in the development and advancement of market-leading solutions, in particular

his past work with new technology solutions that helped to increase the capacity of existing fiber-optic networks for less than half the cost of traditional solutions," he adds. "We look forward to Glen's contribution of valuable experience and insight as we continue to advance toward commercialization of the POET Optical Interposer platform."

Riley is a member of the advisory board at Resonant, a publicly traded company that designs and develops advanced acoustic filters for 5G RF solutions. He graduated as valedictorian with a B.S. degree in Electrical Engineering from the School of Engineering at the University of Maine and completed The General Manager Program at Harvard Business School.

POET halves loss in Q3/2020

Product development progress fuels prospects

For third-quarter 2020, POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has reported a net loss of \$3.5m (\$0.01 per share), up from \$2.9m (\$0.01 per share) a year ago but cut from \$6.2m (\$0.02 per share) last quarter.

The loss included R&D costs level with last quarter at \$1.3m. This is up from \$0.5m a year ago, reflecting a redistribution of R&D activities and costs that were previously accounted for by Singapore-based subsidiary Denselight Semiconductors Pte Ltd and reported as a discontinued operation after 1 January 2019, when the organization operated as a single entity. Since Denselight was divested on 8 November 2019, these costs are now accounted for solely by POET.

Non-cash expenses included stock-based compensation of \$1.1m and depreciation & amortization of \$0.21m, compared with \$0.85m and \$0.19m, respectively, last quarter and \$0.8m and \$42,000, respectively, a year ago.

During the quarter, POET had debt-related finance costs of \$244,000 (compared with \$229,000 last quarter and \$321,000 a year ago). Of this, \$141,000 was non-cash (compared with \$130,000 last quarter and \$110,000 a year ago).

On a non-IFRS basis, cash outflow from operations has risen from -\$1.3m a year ago and -\$1.7m last quarter to -\$2.9m.

Nevertheless, POET ended Q3/2020 with cash and cash equivalents of \$9.4m, compared with \$1.4m at the end of 2019.

Business highlights in Q3 include:

- signing a development and supply agreement with a leading European optical systems company to design optical engines for a 400G data-center application;

- proving out all features and production methods for the Optical Interposer platform to achieve production-ready status; and
- extending the final expiry date of 12,545,350 warrants with an exercise price of CN\$0.75 from 30 September to 17 November (no warrants were exercised prior to expiry).

"During the third quarter, we made extraordinary progress on our product development efforts on the Optical Interposer platform, and in several instances, exceeding our own internal performance metrics. We intend to release this data publicly once we have collected additional data from our product tests with potential customers," says CEO Dr Suresh Venkatesan.

Since Q3, POET has completed the signing of a definitive agreement with Sanan Integrated Circuit Co Ltd of Xiamen City, Fujian province (a subsidiary of Sanan Optoelectronics Co Ltd, China's first 6-inch pure-play compound semiconductor wafer foundry) for the formation of Super Photonics Xiamen Co Ltd, a joint venture with a value of \$50m. "We are actively engaged with our strategic partner Sanan IC under the newly formed JV aimed at the development and manufacturing of optical solutions for the data communications and telecommunications markets," Venkatesan adds.

POET also announced that director & former executive chairman David Lazovsky is resigning from the board at the end of November to dedicate himself full-time to his most recent venture, Inorganic Intelligence. "I would like to take this opportunity to thank Dave for his several years of service to POET, including serving as executive chairman for three years," says Venkatesan. "Dave was instrumental in helping to guide the company's strategy and provided insightful aid in discussions with potential strategic partners."

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POET releases multi-product mask set to production

Tape-out sent to foundry

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has launched its first multi-product wafer (MPW) mask set for production. The MPW comprises multiple products, including custom designs for specific applications and customers.

The MPW tape-out, which commits product designs to manufacturing, incorporates all the new features of the Optical Interposer announced in late October and is largely in-line with the product roadmap presented at the firm's Annual General Meeting in August. Included are designs for two variants of 100G CWDM4 optical engines for two different customers, a 100G design for an LR4 transmit optical sub-assembly (TOSA), a 400G receive optical sub-assembly (ROSA) and a 400G FR4 externally modulated laser (EML)-based optical engine, and three different designs for light engines, including two operating in the O-band for datacoms applications and another in the C-band for sensing and computing applications. The tape-out also includes various test structures for evaluation and incorporation in future product designs.

New features announced previously and now incorporated into the Optical Interposer enhance critical performance, manufacturability and versatility of the platform.

To improve the overall performance of the Optical Interposer in transmitting light without significant losses, POET produced waveguide designs that minimized or eliminated reflections of light at the interface of the laser and the waveguide, a problem that is common in photonic device integration. In addition, the firm incorporated several features that minimize losses as light travels through the device, including its latest generation of Mach-Zehnder interferometry (MZI)-based multiplexers, which reduce the loss of signal from this device to less than 20% (<1.0dB), which is believed to be industry-leading performance for this type of device. Improved spot-size converters, able to match different diameters (modes) of light beams (for more efficient coupling between devices), were implemented with losses of less than 10% (<0.5dB), far exceeding best-in-class, it is claimed. To connect efficiently to off-the-shelf components, such as top-entry photodetectors and vertical-cavity surface-emitting lasers (VCSELs), POET incorporated improved vertical mirrors into the Optical Interposer, expanding the overall versatility of the platform. The firm designed unique fiber-attach-units (FAUs) with matching passive alignment structures on the Optical Interposer that facilitates alignment while providing a low-loss attachment of POET's optical

engines in customers' transceivers. Finally, new designs of fiducials on both the Optical Interposer and POET-designed lasers better enable sub-micron accuracy for mechanical pick-and-place assembly of components.

"The tape-out that we sent to our silicon fabrication foundry today represents the culmination of many months of design and development work by our team of highly experienced and dedicated engineers and consultants," says chairman & CEO Dr Suresh Venkatesan. "We have made tremendous progress in the past few months, refining designs, calibrating our simulation models and preparing for the fabrication of prototype designs of optical engines and sub-assemblies," he adds. "Once fabricated, the Optical Interposer wafers will be sent to POET Singapore or Super Photonics Xiamen (our joint venture with Sanan IC) for component assembly, test and packaging of alpha prototypes. We intend to use these prototypes to sample prospective customers and to collect additional data that will conclusively demonstrate to customers the superior performance of POET's optical engines. We look forward to announcing specific products over the course of the next several weeks as we continue on our path to the commercialization of POET's Optical Interposer platform."

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POET unveils first flip-chip directly modulated lasers

Wafer-scale processing yields lowest-cost, smallest-size 100G CWDM4 optical engine

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has completed and tested its high-speed directly modulated laser (DML) designs using a distributed feedback (DFB) structure and flip-chipped these lasers onto its Optical Interposer platform, which also incorporates several other industry-first accomplishments, it is claimed.

The flip-chip assembly technique enables a true single-chip, fully integrated Optical Engine to be produced at wafer scale, resulting in what is reckoned to be the lowest-cost, smallest-size 100G CWDM4 Optical Engine (with a form factor of 9mm x 6mm), while including banks of four lasers, four monitor photodiodes, four high-speed photodiodes, a multiplexer, demultiplexer, taps for power monitoring and features supporting a self-aligned fiber attach unit.

“Without being able to flip-chip the lasers, we would be unable to assemble Optical Engines at wafer scale, which is the single most

important driver of cost,” says chairman & CEO Suresh Venkatesan. “Wafer-scale processing enables the production of high unit volumes at low incremental costs, ultimately allowing us to reduce the cost of building photonics devices by 25–40% compared to conventional approaches,” he adds. “Following our successful demonstration of this flip-chip assembly process, POET can now readily incorporate these lasers and other active devices into derivative optical engine configurations, supporting data communications applications such as 200G CWDM4, 100G CWDM6 and 100G LR4, telecom applications such as 5G, as well as other applications that could benefit from the small size and low cost of our platform technology.”

Four DML lasers are commonly used in 100G transceiver applications (a key initial target market for POET’s Optical Interposer), enabling high-speed optical communication in the 2–10km range. Operating at speeds of 25Gb/s, POET’s family of four DML lasers of different wavelengths comprise the first known commercial 25G DFB-type DML lasers to utilize a flip-chip

process to passively align and bond to electronic and optical circuitry on the interposer platform, while maintaining optimal performance. Given the estimated total available market (TAM) for 100G transceivers of about \$2.5bn, POET believes that its recently formed joint venture SuperPhotonics Xiamen can achieve annual revenue of over \$100m within this single market segment in the 2024–25 time frame.

Flip-chip assembly of electronic devices on circuit boards, MEMS (micro-electro-mechanical systems) and other devices is a manufacturing process for achieving electrical interconnection (2D, 2.5D and 3D) in semiconductor architectures. To achieve the benefits of the planar architecture of POET’s Optical Interposer that facilitates wafer-scale processing, flip-chipping of lasers was an important development milestone, requiring POET to demonstrate that it could simultaneously optimize the radio-frequency performance of the flip-chipped DML laser on interposer while preserving a low RIN (relative intensity noise) measurement both before and after assembly.

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AOI's post-COVID rebound continues

...but Q4 hit by Chinese customers' inventory adjustments

For third-quarter 2020, Applied Optoelectronics Inc (AOI) of Sugar Land, TX, USA — a designer and manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable TV broadband, fiber-to-the-home (FTTH) and telecom markets — has reported revenue of \$76.6m, up 17.5% on \$65.2m last quarter and 66% on \$46.1m a year ago.

"We recorded good growth in each of our three major business segments," notes founder, president & CEO Dr Thompson Lin.

However, revenue was at the low end of the \$76-83m guidance range as AOI began to see some slowing in orders from certain data-center customers in the later part of Q3, related to inventory normalization as previous orders are digested (following the surge in demand in first-half 2020 that was driven by the shift to working from home).

Data-center product revenue was hence \$55.3m (72% of total revenue), up only 5% on \$52.5m last quarter and up 63% on \$34m a year ago. Of data-center revenue, just 28% was from 40G transceiver products and as much as 68% was from 100G products (for which revenue rose 13% sequentially and nearly 350% year-on-year).

Cable television (CATV) product revenue was \$11.6m (15% of total revenue), up 90% on \$6.1m last quarter and 32% on \$8.8m a year ago. "We began shipping newly designed line extender amplifier products in the quarter and plan to ship initial quantities of system amplifier products in Q4," says chief financial officer & chief strategy officer Dr Stefan Murry.

Telecom product revenue was \$8.9m (12% of total revenue), up 44% on the record \$6.2m last quarter and more than tripling (up 209%) from \$2.9m a year ago, driven by increased demand for 5G mobile deployments in China.

FTTH product revenue has rebounded from just \$1000 last quarter to more than double the \$39,000 a year ago, but is still just \$67,000.

"Results were broadly in line with our expectations and reflect continued progress on our revenue and customer diversification efforts," says Murry.

The top 10 customers comprised 84.9% of revenue (down from 88.3% a year ago) and the top five represented 75% of revenue (down from 82%). This included two 10%-or-greater customers (both in the data-center segment), contributing 40% and 10% of revenue, respectively. Three other customers each contributed 5-10% of revenue (two in the data-center segment and one in CATV). This compared with two 10%-or-greater customers and just one 5-10% customer a year ago.

During the quarter, AOI had seven design wins with six customers. Two of the design wins were in the CATV segment, three in the data-center segment, and one in the telecom segment.

On a non-GAAP basis, gross margin was 27.4%, down on 28.8% a year ago but up from 23.1% last quarter (and above the guidance range of 25-26.5%) due to cost-reduction benefits coupled with a favorable product mix (particularly in the telecom segment, for which gross margin continued to expand, rising by 230 basis points sequentially).

Operating expenses have risen from \$18.4m a year ago and \$20.6m last quarter to \$22.3m, but cut as a percent of revenue from 39.9% a year ago and 31.6% last quarter to 29.1%, reflecting efficient expense management.

Net loss was \$1.4m (\$0.06 per basic share), cut from \$2.9m (\$0.15 per basic share) a year ago and \$5m (\$0.24 per basic share) last quarter, and towards the top

end of the guidance range of \$0.6-4.6m (\$0.03-0.20 per basic share).

Cash used for operations was \$6.1m (more than halving from \$15.5m last quarter). Capital expenditure (CapEx) was \$3.5m, including \$1.2m in production equipment & machinery and \$2.2m in construction & building improvements (below expected, as the firm continues to tightly manage CapEx, despite resuming spending on its new factory in Ningbo, China following the COVID-related pause in construction in Q2/2020).

Regarding its at-the-market share offering announced in February, AOI has so far raised gross proceeds of \$23.2m (including \$8.9m in Q3). The firm intends to use the proceeds for continued investment, including new equipment and machinery for production and R&D.

Overall, during the quarter, cash, cash equivalents, short-term investments and restricted cash hence fell by just \$0.8m, from \$58.9m to \$58.1m.

Inventory rose from \$97.3m to \$111.4m, driven mainly by the buildup of raw material and semi-finished goods inventory, which AOI is preparing prior to year-end and in anticipation of the Lunar New Year holiday in China.

For fourth-quarter 2020, AOI expects revenue to drop to \$50-55m and net loss to rise to \$4.5-5.8m (\$0.19-0.25 per share), despite gross margin growing further, to 28.5-29.5% (driven by the cost-reduction benefits and continued favorable product mix).

"Recently we have been informed by several of our China telecom customers that 5G deployment there has been paused by several large network operators as they re-plan their supply chains following the disruption caused by Huawei's component shortages," says Murry. "We anticipate that revenue will be down sequentially in Q4. However, we believe that growth will resume

in Q1," he adds. "Overall, we remain optimistic about telecom spend in 2021 as we believe that China deployments will resume with vigor after the Lunar New Year."

Regarding CATV products: "Demand from North American MSOs [multi-service operators] for HFC [hybrid fiber coaxial] equipment appears to be stronger than it has been in several years and we currently expect this demand to continue for at least the next several quarters as MSOs upgrade their networks, particularly to address congestion in the return path," says Murry.

Regarding the data-center market, AOI expects near-term headwinds in Q4 as some hyperscale customers adjust their inventories back down to more normal levels. "Several of them anticipated more supply chain disruption during COVID than actually occurred. So they prepared extra inventory in anticipation that there would be some problems. Those problems maybe didn't materialize as much as they thought they might," says Murry. "In the next few quarters, as

inventory at our customers returns to normal levels, we will resume revenue growth in this segment," he believes. "We continue to have good relationships with our data-center customers... The fundamental needs for higher bandwidth within hyperscale data centers will drive long-term growth, particularly during this time as our customers remain focused on improving network performance in light of the increased traffic related to the shift towards working from home."

"We recently secured our second technical qualification for a 400G product with a sizable tier-2 data-center operator who is an existing customer, and we are encouraged by the customer interest we continue to see for this product," says Lin. "This qualification will be recorded as a design win once we receive an order from this customer for the 400G product, which we expect will happen in this quarter [Q4]," he adds.

As AOI continues to tightly manage its CapEx plans, it has now reduced its expectation for full-year 2020 CapEx from \$42m to about \$22m. This is due mostly to a

reduction in equipment purchases and building improvements as it works with customers to anticipate the timing of the 400G ramp next year. "We will continue to re-evaluate our spending needs as our plans evolve," says Murry.

"Looking ahead, while we expect headwinds in the fourth quarter as our hyperscale data-center customers adjust their inventory levels downward, and we see effects of what we believe to be a temporary pause in 5G deployments in China, we believe our customer relationships and market share position remains strong, while the continued demand for higher bandwidth will drive long-term growth," says Lin.

"The recent notable highlight in our FTTH segment is our involvement working on the 25GS-PON MSA [multi-source agreement] alongside Nokia and three Asia-Pacific service providers," says Murry. The MSA "positions us well in the next-generation PON ecosystem, and we believe this could be a long-term growth driver for our fiber-to-the-home segment."

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Ayar Labs raises \$35m in Series B funding

Ayar Labs of Santa Clara, CA, USA (which was founded in 2015) has completed a \$35m Series B financing round co-led by Downing Ventures and BlueSky Capital. New investors include Applied Ventures LLC, Castor Ventures, Downing Ventures (UK) and SGIInnovate (Singapore), expanding the investor base with strategic ecosystem and global investors. Existing investor participation includes BlueSky Capital, Founders Fund, GlobalFoundries, Intel Capital, Lockheed Martin Ventures, and Playground Global.

With the new investment, Ayar aims to accelerate product development and commercialization of its in-package optical interconnect (I/O) solution, as well as grow the firm's footprint internationally.

Ayar's patented approach uses industry-standard silicon processing techniques to develop high-speed, high-density, low-power optical-based interconnect 'chipllets' and lasers, with a 1000x improvement in interconnect bandwidth density at 10x lower power driving the replacement of traditional electrical-based I/O.

Optical I/O (OIO) is said to solve the major computing bottlenecks in interconnect bandwidth, power consumption and reach. Removing these bottlenecks enables new system architectures that can bring improvements in power, performance, area and cost beyond the limits of traditional Moore's Law scaling in important applications such as artificial intelligence, high-performance computing, cloud, telecoms, and aerospace.

"Over the last year, we have continued to invest and grow our organization, and have demonstrated a number of technology firsts while securing additional customer and ecosystem relationships," says CEO Charles Wuischpard. "The investment interest from new and existing strategic and financial investors despite these difficult global times allows us to continue executing our long-range plan for making Ayar Labs Optical I/O a ubiquitous computing solution," he adds.

"Ayar Labs represents the future of interconnects which have eventual applicability to every electronic

device on earth," comments Warren Rogers, partner & head of ventures at Downing Ventures. "We have the highest confidence that, when their optical I/O technology is applied to computing, the industry can accelerate even faster than Moore's Law and redefine the boundaries of computing," he adds.

"We've been an investor in Ayar Labs since the beginning and have been looking for opportunities to increase our ownership in the company," notes Blue Sky Capital's managing director, Madison Hamman "We believe in their patented technology and execution of a plan that makes it a core building block of future computing systems," he adds.

"In the near future, the need for higher bandwidth will lead to short-distance connections within data centers to be optical in nature," remarks Hsien-Hui Tong, executive director, venture investing, at SGIInnovate. "We believe that Ayar Labs has market-leading technology in the area of in-package optics that will potentially revolutionize the industry."

www.ayarlabs.com

Ultra-dense optical interconnects on GF's silicon photonics process

As part of a multi-year technology and manufacturing partnership, Ayar has demonstrated its patented monolithic electronic/photonic solution on the next-generation photonics solution of GlobalFoundries (GF) based on its 45nm platform. This is reckoned to be an industry first and milestone in providing chip-to-chip optical connectivity at scale for data-hungry applications such as artificial intelligence (AI), high-performance computing (HPC), cloud, telecoms and aerospace.

The two companies began working together in 2015 with a commitment to collaborate and commercialize differentiated silicon photonics solutions for green-field applications that would require extreme bandwidth den-

sity (high data throughput in a small physical package) at low latency and high energy efficiency.

"Ayar Labs has been perfecting our micro-ring based monolithic electronic/photonic solution for nearly a decade," says Ayar's CEO Charles Wuischpard. "But the true commercial potential is realized when coupled with a 300mm semiconductor fabrication process that delivers the performance, reliability and cost advantages that we and our customers require," he adds.

"Ayar Labs is an important partner of GlobalFoundries," comments Anthony Yu, VP of silicon photonics at GF. "As collaborators, we've incorporated their requirements for PDK [process design kit] and process optimizations while pro-

viding early access to our next-generation process," he adds.

"Together, we will unlock a larger market opportunity and realize chip-to-chip optical I/O solutions that will enable higher bandwidth and faster connection for high-performance computer applications."

Over the last 18 months, Ayar Labs has been working with select semiconductor manufacturers, systems builders and end users on co-design partnerships. The firm is now announcing an expanded sampling program of its next-generation chiplet developed on GF's latest silicon photonics manufacturing process that will be available to a broader group by request at www.ayarlabs.com/starterkit.

www.globalfoundries.com

Vector receives £280,000 Innovate UK grant LOCAL project to validate PCSEL technology for datacoms

Vector Photonics Ltd of Glasgow, UK has received a £280,000 government grant to support the project LOCAL (Lasers for Communications Applications), validating its unique photonic-crystal surface-emitting laser (PCSEL) all-semiconductor laser technology for use in datacoms applications. The grant comes from Innovate UK's Sustainable Innovation Fund, run in collaboration with the University of Glasgow (from

which Vector was spun out).

"The government grant clearly demonstrates the strategic importance of our PCSEL technology to the UK and the worldwide photonics industry," says CEO Neil Martin.

"LOCAL allows Vector Photonics to focus on Cloud data-center applications — a huge growth

LOCAL will see Vector's PCSELS used in data-center transceivers

market driven by the proliferation of mobile devices, Internet of Things (IoT) and the 5G roll-out."

LOCAL will see Vector Photonics' PCSELS used in data-center transceivers. However, PCSEL technology is said to be equally applicable to light detection & ranging (LiDAR), mobile consumer, biometric and sensing markets, where semiconductor lasers enable critical new functionality.

Vector Photonics unveils 1310nm/25G chip at ECOC PCSEL-based chip targeted at data centers

At the European Conference on Optical Communication (ECOC 2020) virtual exhibition (6–10 December), semiconductor laser start-up Vector Photonics Ltd of Glasgow, Scotland, UK announced a 1310nm/25G chip (aimed specifically at data centers) as the first commercial development of its photonic-crystal surface-emitting laser (PCSEL) technology.

"ECOC is Europe's largest exhibition of fiber-optic communications

and photonics-related technologies. This makes it the ideal platform from which to announce our 1310nm/25G PCSEL chip development and to state our intention to target data-center applications as a priority," says CEO Neil Martin.

"The data-center market is rapidly growing, driven by the increasing use and demand for mobile devices, Internet of Things (IoT) and 5G," he adds. "It is also a market where we can validate our

technology against the IEEE 802.3 standard for datacoms chips, selling them through multiple, global sales channels once successful."

The data-center PCSEL project, known as LOCAL (Lasers for Communications Applications), has received a £280,000 Sustainable Innovation Fund government grant from Innovate UK, in collaboration with the University of Glasgow (from which Vector was spun out).

www.vectorphotonics.co.uk

Vector Photonics appoints development engineer Aim is to drive PCSEL lasers into data-center applications

Vector Photonics Ltd has appointed Dr Calum Hill as development engineer, based at its Glasgow office.

Hill has laser system design and development expertise, with a track record of innovative product design and new product introduction (NPI). He will assist Dr Richard Taylor and the technical team in taking its photonic-crystal surface-emitting laser (PCSEL)-based semiconductor laser technology into prototype and full production for datacoms customers.

Hill comes from Laser Quantum, where he introduced laser technology to the company and steered laser product development. As well



Calum Hill, Vector's new development engineer.

as taking new laser systems to market, he also established an entirely new supply chain for the business. Prior to that, Hill was at U2t Photonics UK, where he designed and characterized complex, gallium arsenide/aluminium gallium arsenide (GaAs/AlGaAs) waveguides for high-speed optical modulators using Python modelling software.

Hill has an MPhys in Physics from the University of St Andrews and an Engineering Doctorate (EngD) from the Centre for Doctoral Training in Applied Photonics at Heriot-Watt University, where he developed environmentally stable, near-infrared mode-locked fiber lasers for radar and LiDAR applications, in collaboration with Thales UK.

Hill was a UK Finalist in the Three Minute Thesis competition, Scottish Finalist in Famelab, and was Space School ambassador for Careers Scotland, traveling to NASA to represent young, gifted and talented Scottish engineers.

NeoPhotonics' year-to-date non-Huawei 400G-and-above revenue up 91% year-on-year

For third-quarter 2020, NeoPhotonics Corp of San Jose, CA, USA — a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — has reported revenue of \$102.4m, up 11% on \$92.4m a year ago but down 1% on \$103.2m last quarter.

"We're dealing with the challenges of the global pandemic and with the revised restrictions in August from the Department of Commerce's Bureau of Industry and Security (BIS) pertaining to [China-based] Huawei," notes chairman & CEO Tim Jenks.

Largest customer Huawei Technologies contributed 44% of revenue (down from 52% last quarter). The next four largest customers contributed 39% collectively. In Q3, NeoPhotonics gained a third 10%-or-greater customer (all for 400G-and-above products).

"The trends in our highest-speed-over-distance products are favorable in terms of accelerating growth and in our building and expanded customer base," believes Jenks. "Keeping in mind that the number of 400G ports being shipped each year is approximately doubling, we are simultaneously gaining market share at the highest speeds."

In the first nine months of 2020, year-on-year revenue growth was 20%. However, excluding Huawei, year-to-date revenue from 400G-and-above products in particular grew 91% year-on-year, reaching 44% of total revenue in Q3.

"We are pleased to report another strong non-GAAP profitable quarter, driven by our highest-speed products," says Jenks.

On a non-GAAP basis, gross margin grew further, from 29% a year ago and 33.2% last quarter to 33.6% (at the top of the original 30–34% guidance range). Within this, product margin was 36.9%, up slightly

from 36.3% last quarter due to a favorable product mix. Other cost-of-sales charges of 3.2 percentage points comprised about 2 points of under-utilization and 1 point of warranty and other minor charges.

Operating expenses have grown from \$22.3m a year ago and \$23.6m last quarter to \$24.5m (24% of revenue), lower than the expected \$25–26m due to early execution of cost-reduction programs.

Operating income was \$9.9m (operating margin of 9.7% of revenue, just under the operating model of 10%, reflecting continued strong execution throughout the firm). This is down from \$10.7m (10.4% margin) last quarter but up on \$4.4m (4.8% margin) a year ago.

Net income was \$6.2m (\$0.11 per diluted share, near the top of the \$0.03–0.13 guidance range), down from \$8.7m (\$0.16 per diluted share) last quarter but up from \$5.4m (\$0.11 per diluted share) a year ago.

Cash generated from operations has risen from \$9m a year ago and \$9.6m last quarter to \$15m. CapEx (capital expenditure) was \$4m. During the quarter, NeoPhotonics paid down \$1m of debt. Cash and cash equivalents, short-term investments and restricted cash hence rose by \$10m to \$123m. "This cash level puts us in a good position to continue to invest for the growth that we see in 64 and 96GBaud lasers components and 400ZR and 400ZR+ modules," says chief financial officer Beth Eby.

In response to the expanded restrictions on Huawei, in October NeoPhotonics said it will manage its business without relying on future revenue contributions from Huawei. "We took decisive actions to better align our capacity and production infrastructure with expected demand," says Jenks. This involves tightening production operations, accounting for Huawei-specific assets and inventory, consolidating indium phosphide (InP) production

and implementing an approximately 4% reduction in force.

The cost of making these changes was estimated to be \$12.1m through 2021 (\$1.1m in severance costs and \$11m in inventory and idle asset charges), but this is now due to be just \$10.9m. Of this, \$9.4m was recorded in Q3/2020, comprising severance charges of \$0.9m, an equipment write-down of \$4.1m, and an end-of-life-related inventory write-down of \$4.4m (\$1.3m less than estimated, due to lower material cancellation charges).

When fully realized, restructuring allows for breakeven at quarterly revenue of \$80m, based on the current product mix. "We will continue to invest in the growth drivers of our business, including lasers, 64GBaud components and 400G modules," says Eby. "We expect the continued rapid growth of products for 400G and beyond to drive revenue growth from this point forward."

For Q4/2020, with no contribution from Huawei, NeoPhotonics expects revenue of \$64–70m, growing by 16% sequentially on the \$58m (excluding Huawei) in Q3, and growing by considerably more for 400Gb/s-and-above products. "We are seeing increases in design wins, backlog, higher volumes and resulting share gains in our highest-speed-over-distance solutions with a broad range of customers," says Jenks.

However, reflecting lower volumes overall and hence higher under-utilization charges (in both the Japan and China factories), gross margin is expected to drop sharply to 22–26%. Loss per share should be \$0.13–0.23, with operating expenses of \$24–25m, as continued spending reductions are offset by a planned non-recurring engineering (NRE) payment for investment in 400ZR developments.

"We expect to complete our 400ZR collaboration at the lead cloud customers by Q1/2021 [after

beginning qualification in Q1/2020]. We expect initial volume applications for 400ZR to be with major cloud providers for metro data-center interconnects. These will be new volume customers for us beyond our network equipment manufacturer customer base," says Jenks. "However, with 400ZR+ capability for longer distances, there is also an opportunity for new use cases to emerge beyond natural data-center interconnects into edge use, 5G backhaul and longer-distance regional interconnects," he adds.

"We will rapidly grow the business excluding Huawei by supporting the highest-speed-over-distance solutions at 400G-and-above for telecom equipment providers, and expand our business by ramping our 400ZR

and 400ZR+ coherent modules to Cloud and hyper-scale data-center customers," believes Jenks.

"As this market heats up, we will see increasing revenue from an expanded customer group beyond our two historically largest customers. With the industry-leading equipment companies leveraging NeoPhotonics products for their 400G-and-faster systems, our growth is strong with these customers," says Jenks.

"We typically achieve higher-than-average gross margins from our highest-speed products. As these products become an increasing fraction of our revenue mix, we believe we will see a favorable trend in our margins."

"Given our design wins, customer forecast and the rate of industry

growth at the highest speeds, we are looking forward to seeing our revenue without Huawei grow at 40–50% over the next year," continues Jenks.

NeoPhotonics expects to get back to non-GAAP operating profit in Q3 and GAAP operating profit in Q4 of 2021 (without revenue from Huawei). "We'll be continuing the trend of delivering year-over-year growth in revenue and profitability," believes Eby. "With our increasing momentum in 400G-and-above design wins across major network equipment manufacturers as well as the 400ZR and 400ZR+ opportunities in 2021 and beyond, we remain optimistic that industry trends continue to move in NeoPhotonics favor."

www.neophotonics.com

Class 60 coherent modulator & receiver for 100+Gbaud symbol rates

NeoPhotonics has added Class 60 versions of its CDM (coherent driver-modulator) and Micro-ICR (micro-intradynic coherent receiver) to its suite of high-bandwidth coherent components, addressing the next generation of 100+Gbaud systems to meet ongoing growth in demand for bandwidth, especially between cloud data centers.

Optical performance improvement due to increased baud rates enables customers to pack more data over longer distances for better economics, lower cost per bit, lower operating expenses and lower power consumption, all under the same hardware envelope as NeoPhotonics' existing Class 40 components.

The new Class 60 coherent components extend the highest-speed-over-distance performance of the firm's existing Class 50 products by increasing the 3dB bandwidth from 50GHz to 60GHz. The Class 60 suite improves on the Class 40 components, and allows increasing symbol rates from 64+Gbaud to 100+Gbaud. These components work together to enable users to implement single-wavelength data transmission near 1 Terabit per

second over data-center interconnect (DCI) distances, and long-haul 400–500Gbps transmission.

Higher symbol rates increase data capacity while maintaining superior optical signal-to-noise ratio (OSNR) and reach performance, enabling the highest-speed-over-distance use. The new components are available in compact form-factor packages for pluggable modules and compact daughter cards. The Class 60 CDM and micro-ICR are mechanically compatible to their Class 40 counterparts, and are a natural upgrade path for achieving 100+Gbaud in order to support 800Gbps-and-above data rates per wavelength applications.

The Class 60 suite comprises:

- the polarization-multiplexed coherent driver-modulator (CDM), with a co-packaged indium phosphide (InP) modulator with four linear, high-bandwidth differential drivers, designed for low V-Pi, low insertion loss and a high extinction ratio — the compact package is designed to be compliant with the form factor of the OIF Implementation Agreement #OIF-HB-CDM-01.0;
- the high-bandwidth micro-intradynic coherent receiver (Micro-ICR),

designed for 100+Gbaud (more than tripling the rate of standard 100G ICRs) — the compact package is designed to be compliant with the OIF Implementation Agreement OIF-DPC-MRX-02.0.

The components are designed to work together with NeoPhotonics 'Nano' ultra-narrow-linewidth external-cavity tunable laser, which roughly halves the size of compared with existing micro-ITLAs (integrated tunable laser assemblies) while featuring "industry-leading" linewidth and low phase noise with low electrical power consumption.

"NeoPhotonics has supported our customers by being first to volume production of our products at each new speed node," says chairman & CEO Tim Jenks. "We are pleased to now offer Class 60 coherent modulators and receivers which, along with our ultra-narrow-linewidth external-cavity 'nano' tunable laser, provide a whole suite of components enabling customers to increase the data rate per wavelength to 1 Terabit and beyond. We are continuing to extend the bandwidth of our InP coherent integration platform to serve the highest-speed-over-distance applications "

Lumentum's quarterly revenue grows 22.9%, yielding record margins and EPS

Annual targets raised to 50% gross margin and 30% operating margin

For fiscal first-quarter 2021 (ended 26 September 2020), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has reported revenue of \$452.4m, up 22.9% on \$368.1m last quarter and 0.6% on \$449.9m a year ago, and near the top of the guidance range of \$430–455m.

This is despite sales to China-based Huawei Technologies declining again, to less than 10% of total revenue, given the further restrictions on licenses for exporting to Huawei announced by the US Department of Commerce in August.

Commercial Lasers segment revenue was \$23.9m (just 5.3% of total revenue), down 36.8% (more than the expected 25%) on \$37.8m last quarter and down 29.3% on \$33.8m a year ago. "Given our customer mix, this decline was related to manufacturing weakness outside of China," notes president & CEO Alan Lowe. "It will be several quarters before we get back to the revenue levels we saw in fiscal 2020."

Optical Communication segment revenue was \$428.5m (94.7% of total revenue), up 29.7% on \$330.3m last quarter (due to 3D sensing seasonality and growth in telecoms and datacoms) and up 3% on \$416.1m a year ago (as a result of growth in telecoms and particularly in the datacoms chip business). Specifically:

- Industrial & Consumer revenue was \$167.2m, almost level with \$168m a year ago but more than doubling from \$73.9m last quarter, and significantly higher than guidance, due particularly to vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing.

"Revenue mix was different than we had contemplated in our guidance due to the changes throughout the quarter," notes Lowe. "Our

assumptions for 3D sensing proved conservative and demand for our 3D sensing products accelerated." Strength in 3D sensing sales more than offset lower-than-anticipated Commercial Laser and Telecom sales.

- Telecom & Datacom revenue was \$261.3m, up 2% on \$256.4m last quarter and 5% on \$248.1m a year ago (or up 4% and 14% respectively, excluding low-margin product lines that have been discontinued, such as the lithium niobate (LiNbO₃)-based optical component wafer fab in San Donato, Italy divested in December 2019).

Telecom transmission was the largest contributor to growth. Sales were strong for indium phosphide (InP)-based coherent transmission modules and components, including ACO (analog coherent optics) and DCO (digital coherent optics) modules and 600G and 800G modulators. Sales of reconfigurable optical add/drop multiplexer (ROADMs) grew from last quarter, but were still down year-on-year. In particular, contentionless MxN ROADMs grew by over 30% quarter-on-quarter to a new high, highlighting the increasing shift to this technology in new customer systems. Nevertheless, there were some push outs in telecom customer orders. There were also reductions in customer forecasts due to COVID-19 impacting the timing of new deployments in addition to customer inventory management. These contributed to lower-than-expected telecom sales.

"During the first quarter, we made a lot of progress on new products," says Lowe. "On the transmission side we began sampling our 400G DCO transmission modules. On the transport side, we continued to proliferate a contentionless MxN and high-port-count ROADM technologies [previously led by customers in China] with C-, L- and extended C-band versions to enable customers'

next-generation systems globally," he adds. "On certain key new telecom products, however, demand exceeded our ability to supply and we are working hard to expand output."

In Datacoms, prior-quarter trends continued, with chip sales up 6% (capacity-constrained, as demand outstrips increases in production). "We did see some delays in the demand for our datacom chips for 5G deployment [front-haul related], mostly in China. But that is easily taken up by strong demand in hyperscale cloud data centers," says Lowe. "We have seen a shift in near-term customer forecast so that lower projected 5G demand is offset by continued strength in demand for our market-leading chips for data centers. We have adjusted our wafer start plans accordingly."

On a non-GAAP basis, gross margin has risen further, from 45.8% a year ago and 47.2% last quarter to a record 52%, driven by an improvement in product mix and acquisition synergies (following the acquisition of San Jose-based optical communications component and module maker Oclaro Inc in December 2018). "This record gross margin performance demonstrates the improvements we've made in our financial model," says chief financial officer Wajid Ali.

Optical Communication segment gross margin was 52.5%, rising further from 46.6% last quarter (due to a better product mix with higher chip-related revenue) and 46.1% a year ago (due to a more favorable product mix, improved telecom and datacom margins, and acquisition synergies).

Commercial Laser segment gross margin fell from 52.9% last quarter to 43.5% (due to the significantly reduced manufacturing volumes), although this is still up slightly on 42% a year ago.

Operating expenses remained about \$82.7m (18.3% of revenue,

down from 22.4% last quarter), a little lower than normal run rates due to the COVID-19 pandemic reducing travel, trade show and other expenses. Specifically, selling, general & administrative (SG&A) expense remained about \$36.8m and R&D expense was \$45.9m.

Driven by gross margin growth (since OpEx was level), operating income was a record \$152.5m (operating margin of 33.7% of revenue), up from \$91.4m (24.8% margin) last quarter and \$122.7m (27.3% margin) a year ago.

"For the first time, we achieved gross margin in excess of 50% and operating margin above 30%. This performance demonstrates the strength and resilience of our business and financial model," says Lowe.

Likewise, net income was a record \$139.2m (\$1.78 per diluted share), up from \$91.7m (\$1.18 per diluted share) last quarter and \$111.4m (\$1.44 per diluted share) a year ago.

"We started fiscal 2021 on a strong note, achieving record non-GAAP gross margin, operating margin and earnings per share in the first quarter," notes Lowe.

During the quarter, total cash and short-term investments rose \$56.9m, from \$1553.8m to \$1610.7m.

Lumentum has \$1.5bn in convertible notes and no term debt. Of the convertible notes, \$450m is due in 2024 and \$1.05bn is due in 2026. The total associated cash interest expense is about \$6m per year.

"We are well positioned financially, with a strong margin model, high levels of cash and low interest expense as well as long-maturity financing," says Ali. "Strong growth in our accounts receivable during fiscal Q1 should lead to even stronger cash generation in fiscal Q2," he adds.

"Long-term market trends are very favorable, as the world is increasingly shifting to digital and virtual approaches to work, education and life, which drives increasing demand for our differentiated products and technologies," says Lowe.

For fiscal second-quarter 2021 (to end-December 2020), Lumentum expects revenue to grow to

	FY19	FY20	LTM*	Prior Targets**	New Targets (Annual)
Revenue	\$1,565	\$1,679	\$1,681		
Gross Margin %	39.5%	46.5%	48.1%	40-45%	50%
Opex % of revenue	19.0%	19.9%	19.8%	<18%	20%
Operating Margin %	20.5%	26.6%	28.4%	22-28%	30%

Revised mid-term target financial model (non-GAAP) compared with prior targets announced in March 2018 in connection with the acquisition of Oclaro. Targets were exceeded for the last twelve months (LTM). Lumentum expects continued improvements in product mix, efficiency and operating leverage, while making strong investments in new products and technology.

\$465–485m, despite Huawei declining further (and to less than 5% of total revenue beyond fiscal Q2).

Sequential growth is forecasted in both telecoms and datacoms. The strongest growth will come from telecom transport, driven by growth in next-generation ROADMs (with non-Huawei business in the rest of the world outside China expected to grow dramatically over the next 18 months while Lumentum continues to add production capacity). "We're also seeing strength in the higher-speed coherent components like our 600G and 800G modulators and tunable lasers," notes Lowe. "Growth is being driven from a product standpoint across high-end ROADMs and the newest coherent components," confirms Chris Coldren, senior VP of strategy & corporate development.

The Industrial & Consumer and Commercial Lasers segments are both expected to be flat to up modestly quarter-on-quarter. "We've seen strong demand through August and September, and it carried through October. So it's more of a front-end-loaded quarter," says Lowe. "We expect some of the demand that would typically be consumed in the December quarter to roll into the March quarter," he adds.

Despite a rise in OpEx (due mainly to R&D as Lumentum invests in new products and technology), operating margin should be 32–34% and diluted net income per share

\$1.72–1.90. "We're expecting our cash flow to be significantly better in fiscal Q2 versus Q1," says Ali.

"When we announced the acquisition of Oclaro, we put forth a target financial model with a gross margin range of 40–45% and an operating margin range of 22–28% [with OpEx <18% of revenue]," notes Ali. "For the trailing 12 months from the end of fiscal Q1/2020 to the end of fiscal Q1/2021, we exceeded this target model."

"We will continue to grow margins over time due to further improvements in product mix, efficiency and operating leverage. As such, we are now increasing this annual target in our mid-term financial model [to gross margin of 50% and operating margin of 30%, with OpEx of 20% of revenue]," he adds. "We don't expect to exceed these new targets for the current fiscal year due to 3D sensing seasonality as well as regulatory restrictions on sales to Huawei impacting the second half of the fiscal year," Ali cautions.

"Our backlog for datacom chips remains very robust and demand continues to outstrip our wafer fab capacity. In the short-term, we're going to be constrained on those data-center chips... We are going to continue to get some incremental improvement through yields and productivity," says Lowe. "We are continuing to aggressively expand our wafer fab capacity based on long-term demand trends and

► expectations. We're expecting to double the wafer capacity over the next 18–24 months... Probably middle of next calendar year, we'll see a step up of installed capacity to be able to take advantage in the second half of the year," he adds "Some of the newer chips are bigger and so they consume more real estate on a wafer. It may not be a doubling of units but it would be a doubling of wafers, as the newer 200G chips are actually larger and there are fewer chips per wafer."

"On the new product front, we are working closely with our lead customers on their needs for future 800G-and-above datacom transceivers. To this end, we have recently demonstrated high-performance 200G PAM4 [4-level pulse amplitude modulation] externally modulated lasers (EMLs) for such applications," continues Lowe.

In the Industrial & Consumer segment: "Our unmatched experience in shipping hundreds of millions of VCSEL arrays per year continues to put us in a leadership position in the market," believes Lowe. "Since we became an independent public company five years ago, we have shipped approximately \$1.5bn of 3D sensing revenue. We have a larger addressable opportunity over this product cycle. This is due to the significant increase in 3D sensing content for consumer device we are now shipping," he adds.

"We are optimistic about 3D sensing demand in the coming quarters and years. In addition to increasing content, we believe there's potential for a strong consumer upgrade cycle driven by new features, including 5G, augmented and virtual reality (AR/VR) and computational photography. Further, we believe there's potential for market share shifts at our customer's level, which could be beneficial to us," says Lowe.

"On Android, we continue to make very good progress on new opportunities. However, we are taking a conservative approach to Android revenue in our near-term projections to the COVID-19 and geopolitical factors."

"Even further ahead, we have multi-year product and technology roadmaps aligned with our consumer electronics customers. These include unique technologies to increase the integration of other components, enable under-screen 3D cameras, produce higher-density and larger arrays to enable higher-performance 3D imaging, as well as to create new lasers to increase our opportunity within other consumer mobile devices," he adds.

"We are also focused on planting seeds for growth in markets beyond consumer electronics. We have unmatched and invaluable experience in 3D sensing lasers for consumer electronics applications and broad industry-leading

photonic capabilities used across other markets. We believe this gives us a competitive advantage as we pursue emerging long-term opportunities outside of consumer electronics."

"In the past quarter, our VCSEL arrays have completed the important AEC automotive qualification through a module partner, and we expect initial deployments of these products to be in automobile in-cabin applications. We are also now sampling high-power VCSEL arrays into LiDAR for last-mile vehicle applications. According to our customers, these last-mile applications could be one of the largest LiDAR opportunities in the next several years. In addition, we are also sampling or are in qualification with major tier-1 auto suppliers for broader automobile opportunities that we'll deploy and develop over time," Lowe continues.

"We are making progress in the security and access control markets. We are already shipping in volume for facial recognition on payment kiosks. We are engaged with providers of security and access control systems who are looking to add 3D sensing to enable touchless or contactless high-security access control. These applications are also accelerating due to public health & safety concerns," Lowe concludes.

www.lumentum.com

Lumentum acquires TriLumina assets

Optical component maker gains VCSEL technology for automotive, industrial and consumer 3D sensing applications

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has acquired certain technology assets (including patents and other intellectual property) of TriLumina Corp of Albuquerque, NM, USA..

Terms of the transaction have not been disclosed.

TriLumina's laser illumination technology includes flip-chip, back-emitting near-infrared vertical-cavity surface-emitting laser (VCSEL) arrays for use in a wide range of automotive, industrial and consumer 3D sensing applications, including automotive safety and driver assistance systems and light detection & ranging (LiDAR), and other emerging applications.

Lumentum designs and manufactures optical and photonic products for optical networking and laser applications. Its optical components and subsystems are part of virtually every type of telecom, enterprise and data-center network. The firm's lasers enable manufacturing techniques and diverse applications including next-generation 3D sensing capabilities.

www.trilumina.com

Lumentum announces availability for sampling of first 100G PAM4 directly modulated lasers

Cavity design enables lower cost for 400G hyperscale data-center speed

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has added to its datacom laser chip portfolio with the 100G PAM4 (53Gbaud) directly modulated laser (DML) for hyperscale data-center applications. Complementing Lumentum's existing 100G PAM4 externally modulated laser (EML) products, the new directly modulated laser offers transceiver designers a lower-cost alternative.

In response to the rapid growth of intra-data-center traffic and the resulting need for higher speed, capacity and reliability, Lumentum has begun sampling its 100G PAM4 DMLs to customers seeking a cost-

effective approach for 400G DR4 and future 800G PSM8 transceiver module applications.

"This latest advancement helps to significantly reduce the cost of 400G DR4 modules in data-center infrastructures," says Walter Jankovic, senior VP & general manager, Datacom. "The 100G PAM4 DML goes beyond servicing the current need for cost-effective and innovative indium phosphide (InP) laser solutions at mass volume by enabling future intra-data-center interconnects as the industry moves to 800G."

The newly developed 100G PAM4 DML joins Lumentum's portfolio of laser chips that enable a wide-range of MSA-compliant transceiver modules operating at multiple data

rates and wavelengths. Manufactured with Lumentum's internal wafer production capabilities, the 100G PAM4 DML leverages InP technology, using a sophisticated cavity design to operate with the same high-bandwidth performance of an EML in 100G and 400G applications but in a small, simple and cost-effective footprint. The latest DML can lower the cost of 400G DR4 compared with existing laser alternatives, says the firm. Additionally, 800G PSM8 modules can benefit from the capabilities of the new 100G PAM4 DML, which is important as data centers transition to these modules in future top-of-rack and leaf layer applications, adds Lumentum.

www.lumentum.com

Source Photonics launches 100G ZR4 QSFP28 transceiver

Cost-efficient 80km DCIs while reducing complexity and power

Source Photonics Inc of West Hills, CA, USA (which provides optical connectivity products for data centers, metro and access networks) has launched its 100G ZR4 QSFP28 transceiver for 80km high-speed data-center interconnects and routing applications. Leveraging the widely deployed 4 x 25G NRZ optics, 100G ZR4 QSFP28 is the latest addition to the firm's 100G product lines among its 100/200/400G portfolio of single-mode transceivers for data-center and routing applications.

Cloud traffic continues to drive data-center growth and the industry requires cost-effective and high-bandwidth interoperable solutions, says Source Photonics. The 100G ZR4 QSFP28 is a cost-optimized and low-power transceiver supporting 100G Ethernet for extended reach up to 80km transmission that provides point-to-point network connectivity solutions between data

centers or central offices without the need to deploy either complicated, power-hungry and expensive coherent solution or legacy CFP/CFP2 interfaces. The 100G ZR4 QSFP28 alleviates the fiber shortage bottlenecks and enables hyperscale cloud operators to scale their network.

The transceiver is in QSFP28 form factor (the smallest for the 100G 80km solution). It is fully compliant with the industry standard QSFP28 and related MSA described in the latest SFF-8665/8636, and digital diagnostic functions are available through an I2C interface. It also complies with IEEE 802.3 100GBASE-ZR4-related specifications. In addition, the module supports standard KR4 FEC (forward error correction) baud rates, which will help receive-side detect and correct bit errors and improve the overall quality of the link. The 100G ZR4 QSFP28 transceiver is

capable of operating over up to 80km point-to-point links without the need for optical amplification and dispersion compensation.

Source Photonics showcased a product demonstration of the 100G ZR4 QSFP28 transceiver for 80km optical transmission in its virtual booth, in addition to live booth activities, and video content during the European Conference on Optical Communications (ECOC 2020) Virtual Exhibition (7-9 December).

Source Photonics is currently sampling its 100G ZR4 QSFP28 product, in addition to its latest 100G ER4 and 400G ER8 transceivers. The firm is in full production of its other products for data-center and routing applications such as 100G LR4/ER4 Lite, 100G DR1/FR1/LR1, and 400G DR4/FR4/LR4/LR8 transceivers.

www.ecoco2020.org

www.sourcephotonics.com

OIF launches 800G Coherent and Co-Packaging Framework IA projects

New board members/positions, officers and Working Group chairs

Following its Q420 Technical and MA&E Committee meetings (held virtually on 2–6 November), the Optical Internetworking Forum (OIF) has announced the start of two new projects — 800G Coherent and Co-Packaging Framework — the availability of a new FlexE for 400ZR white paper, and newly elected board members/positions and working group representatives.

New projects

The 800G Coherent project's scope is to define interoperable 800G coherent line specifications for campus and data-center interconnect (DCI) applications. The resulting Implementation Agreement (IA) will:

- define single-lambda 800G coherent line interfaces for two applications:
 - (1) amplified, single-span DWDM links up to 80–120km and
 - (2) unamplified, fixed-wavelength links of 2–10km;
- support Ethernet client(s) (minimum 100GE) up to 800G aggregate bandwidth.

"The next standardized coherent rate beyond 400ZR will be technically challenging, with many factors to be considered," notes OIF vice president Tad Hofmeister, technical lead, Optical Networking Technologies at Google. "With the 800G Coherent IA, OIF is in a unique position to take a leadership role in defining interoperable 800G coherent line interfaces for various applications."

The Co-Packaging Framework IA (announced on 10 November) will study the application spaces and relevant technology considerations for co-packaging of communication interfaces with one or more application-specific integrated circuits (ASICs). A primary objective of this specification is to identify new opportunities for interoperability standards for possible future work

at the OIF or other standards organizations. Upon completion, the work will be summarized in a Framework IA.

White paper

A new OIF white paper addressing 400ZR applications requiring multiplexing of lower-rate Ethernet signals (e.g. 100GE) and how to leverage FlexE for this service multiplexing is now available.

The OIF 400ZR IA includes mapping of 400G Ethernet signals as defined in IEEE 802.3, but not lower-rate services such as 100G Ethernet. The white paper describes utilizing the OIF FlexE Implementation Agreement multiplexing of lower service rates, such as 100G and 200G Ethernet to a 400G frame that can be carried by 400ZR devices

Example profiles are provided to guide interoperability in common scenarios.

Election results

Board of directors:

- Ian Betty, Ciena, continues to serve on the board and was appointed as president;
- Mark Filer, Microsoft, was elected to the board (two-year term);
- Tad Hofmeister, Google, contin-

ues to serve on the board and was re-appointed as vice president;

- Mike Li, Intel, was re-elected to the board (one-year term);
- Jeffery Maki, Juniper Networks, was elected to the board (one-year term);
- Gary Nicholl, Cisco, was re-elected to the board (two-year term) and appointed as secretary/treasurer;
- Nathan Tracy, TE Connectivity, was re-elected to the board (two-year term) and appointed as VP of marketing.

Officers:

- Klaus-Holger Otto, Nokia, was elected as technical committee chair;
- Karl Bois, Hewlett Packard Enterprise, was elected as technical committee vice chair;
- Lyndon Ong, Ciena, was re-elected as Market Awareness & Education Committee co-chair, Networking;
- Richard Ward, Intel, was elected as Market Awareness & Education Committee co-chair, Physical and Link Layer;
- Dave Brown, Nokia, continues to serve as director of communications.

Technical Committee:

- Michael Klempa, Amphenol, was elected as Physical and Link Layer Interoperability Working Group chair (two-year term);
- Jeffery Maki, Juniper Networks, was re-elected as Physical Layer User Group Working Group chair (two-year term).

"I'm looking forward to serving OIF members as president of this vital organization and thank all those who have served and continue to serve," says new president Ian Betty. "OIF's role continues to be critical in making great strides in interoperability solutions for today's and tomorrow's challenges."

www.oiforum.com/

Acacia wins ECOC Industry Award for 400G pluggable coherent solutions with 3D siliconization technology

Expertise in silicon PICs and low-power DSPs recognized

Acacia Communications Inc of Maynard, MA, USA (which develops and manufactures high-speed coherent optical interconnect products) says that its family of 400G pluggable coherent solutions has won the optical integration (Silicon Photonics) category of the first-ever ECOC Exhibition Industry awards, announced at the European Conference on Optical Communications (ECOC 2020) Virtual Exhibition (7–9 December).

Utilizing Acacia's 3D siliconization technology, the 400G pluggable module family features an expansive list of interoperability solutions (400ZR, OpenZR+, Open ROADMSA and CableLabs Coherent Optics Physical Layer Specification) in QSFP-DD, OSFP and CFP2-DCO pluggable form factors for cloud data-center (DCI) interconnects and service provider networks. The 400G pluggable coherent solutions were designed to enable network operators to address increasing bandwidth demand through a simplified network architecture to help reduce both capital and operational expenditures.

"For more than a decade, Acacia has been executing on its vision to unleash the full potential of silicon technology in optical interconnects and this award is a testament to our efforts," says Acacia's VP of

marketing Tom Williams. "By utilizing our 3D siliconization technology, Acacia has been able to move beyond traditional optics manufacturing, utilizing semiconductor processes that are designed to enable these 400G coherent pluggable modules to scale to address higher-volume applications."

400G pluggable modules represent a key architectural change in high-bandwidth data-center interconnects because they can be plugged directly into switches and routers offering the same density for both coherent DWDM and client optics in the same chassis. As bandwidth demands continue to grow, these solutions are designed to help cloud providers increase the capacity of the optical interfaces that connect their data centers around the globe. The use of coherent optics in switches and routers can simplify architectures, resulting in reductions in capital and operational expenditures, says Acacia. The same technology can be combined with higher performance standards for the potential to drive more traditional transport applications toward CFP2-DCO solutions.

"Congratulations to Acacia for winning one of only six awards being given in honor of ECOC's 25th anniversary," says Emma Harvey, commercial director of the

ECOC Exhibition's organizer Nexus Media Events. "Our judges determined that Acacia's 400G pluggable coherent solutions emphasize technology and product commercialization and highlighted significant achievements in advancing the business of optical communications and silicon photonic integration."

3D siliconization technology

Acacia's 400G pluggable coherent solutions leverage its 3D siliconization technology that takes advantage of the firm's expertise in high-performance silicon photonic integrated circuits (PICs) and low power digital signal processors (DSPs). Acacia's 3D siliconization applies integration and 3D stacking techniques to enable a single device that includes the high-speed opto-electronic functions necessary for coherent communications. This device, which includes the DSP, photonic integrated circuitry, drivers and transimpedance amplifiers (TIAs), is manufactured using standard electronics packaging processes. Advantages of 3D siliconization include the reduction of electrical interconnects and improved signal integrity, leading to improvements in performance, cost, reliability, power consumption, and size, claims Acacia.

www.ecoco2020.org

www.acacia-inc.com

MACOM showcases high-data-rate products at ECOC

At the European Conference on Optical Communications (ECOC 2020) virtual conference (7–9 December), MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) highlighted its portfolio of data-center products, including the following:

- Flip-chip quad-channel driver and transimpedance amplifier (TIA) for 400G ZR: The linear modulator driver and TIA are high-performance quad-channel flip-chip devices for operation at symbols rates up to 64GBaud. The products offer the low power consumption and the flexibility required to enable next-generation 400G ZR modules.
- PAM4 100G to 800G transim-

pedance amplifiers: The portfolio includes a 4x28GBaud TIA and a 1x28GBaud TIA for 53Gbps applications. These products are suitable for high-density optical interconnect solutions and are intended for 50G, 100G, 200G, 400G and 800G receivers using multi-level modulation such as PAM4.

www.ecoco2020.org

www.macom.com/opto

Emcore's revenue grows 23% in September quarter

CATV MSOs buying linear EMLs to meet bandwidth demand

Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — has reported revenue of \$110.1m for full-year fiscal 2020 (to end-September), up 26% on \$87.3m for fiscal 2019.

Fiscal fourth quarter 2020 revenue was \$33.5m (the largest quarterly revenue since December 2014), up 23% on \$27.3m last quarter and 37.9% on \$24.3m a year ago (and above the \$29–31m guidance).

Aerospace & Defense (A&D) segment revenue was \$14.5m, up just 3% on \$14m last quarter, driven by increased revenue for Quartz MEMS (micro-electro-mechanical system) navigation products — acquired through buying Systron Donner Inertial (SDI) of Concord, CA, in June 2019 — and Defense Opto-electronics product lines.

Broadband segment revenue was \$19m, up 44% on \$13.3m last quarter, driven by robust demand for Cable TV optical transmitters and components as multi-service operators (MSOs) continued to expand their networks to break bottlenecks created by bandwidth demands for work-at-home and stay-at-home entertainment.

"More and more MSOs are demanding linear EMLs [linear externally modulated laser]," notes CEO Jeff Rittichier. "We are the only people in the world that can make them," he adds. "Linear EMLs are the largest part of our cable TV business."

"From an operational standpoint, the supply chain and operations teams were well ahead of the COVID-19-driven shortages that required a lot of work to overcome in previous quarters [specifically, shortages of custom linear components that were in short supply because of COVID breakouts in packaging operations in Taiwan and in Malaysia]. We experienced only a modest number of challenges with

our supply chain throughout Asia," says Rittichier. "Nevertheless, the pandemic continued to increase the general level of friction in ongoing business activities, particularly with customer development schedules and new programs, forcing us to adjust our plans."

On a non-GAAP basis, full-year gross margin grew significantly to 33% in fiscal 2020 (up from 23% for each of the two previous fiscal years), driven partly by cost reductions, improved production yields and better inventory management. Inventory levels remained similar to last year's, even though revenue was up.

Fiscal Q4 gross margin was 38%, up from 34% last quarter due to the combination of revenue growth and operational improvements. Driven by a less favorable product mix, A&D's gross margin fell back somewhat to 32%, from last quarter's spike of 36% (which had been boosted by non-recurring credits). However, this was offset by Broadband gross margin rising from 33% to 42%, driven by the Cable TV revenue growth, over-absorption of production overhead costs, and a favorable product mix.

"The transition of our CATV manufacturing operations to [Shenzhen-based electronics manufacturing services (EMS) provider] Hytera's Bangkok facility has made significant progress, although the move of the last laser module line continues to face a fluid schedule... in the fourth fiscal quarter, we were still largely an in-house operation," notes Rittichier. "Transmitter yields in Bangkok are at target, but we need to see some improvement in laser module yields to get them to the Beijing standard before we finish the move," he adds. "Our working capital efficiency continued to improve with production increases in Bangkok."

Operating expenses have been cut further, from \$12.4m (51% of

revenue) a year ago and \$10.1m (37% of revenue) last quarter to \$9.7m (29% of revenue). This was due to selling, general & administrative (SG&A) expenses falling (largely a result of ongoing expense management activities), as R&D expenses were flat sequentially.

"Solid execution in Q4/20 resulted in revenue growth of 23% sequentially and continued gross margin expansion, enabling us to achieve positive GAAP earnings and very strong non-GAAP profitability metrics," says Rittichier.

Operating income was \$2.9m (operating margin of 9% of revenue), an improvement from a loss of \$0.7m (-3% margin) last quarter. "Not only was this our first positive result since the fiscal 2018 first quarter, it was also a \$3.6m or a 12% swing from just the quarter before," notes chief financial officer Tom Minichiello.

Likewise, net income was \$2.9m (\$0.10 per share), compared with net losses of \$0.7m (\$0.03 per share) last quarter and \$7.7m (\$0.27 per share) a year ago.

Cash from operations was \$1.6m (up from last quarter's \$0.7m of operating cash flow), while cash from financing activities was \$300,000. Capital expenditure (CapEx) was \$1.1m. Free cash flow was hence \$800,000. During the quarter, cash (net of the \$6.5m loan payable) therefore rose by \$0.8m, from \$23.2m to \$24m.

For fiscal first-quarter 2021 (ending 31 December 2020), Emcore expects revenue of \$32–34m.

"We're expecting to see a strong performance from Cable TV, QMEMS and our Defense Optoelectronic product lines," says Rittichier. In particular, Defense Opto's new millimeter-wave Q- and V-band products are gaining traction in the market across military and commercial applications. "However, we continue to be cautious about

annual slowdowns that we see with various customs authorities, which have delayed shipments over quarters and in the past," he adds. Operating expenses should again be under \$10m (and \$9.5-10m per quarter going forward).

Gross margin should be similar to fiscal Q4/2020's. "There's not a wholesale movement in Q1 of product being built in Thailand. So that effect, which really happens as the primary facility for manufacturing becomes Bangkok, that's when it really manifests itself," says Rittichier. "Transmitters will virtually all be over there in some point in the March quarter and then laser modules early in the June quarter."

"Looking ahead, despite the ongoing challenges of the COVID-19 pandemic, we expect to continue to execute well in all areas of the business, including Broadband where we see orders for our Cable TV products extending well into the June 2021 quarter," says Rittichier.

"The strong Cable TV demand is continuing to require us to maxi-

mize total production output and minimize potential losses to that volume from yield fallout," says Rittichier. "The Thai government is starting to allow foreign workers back into the country after negative COVID tests at a 2-week quarantine," he adds. "We're beginning the process of getting our engineers in EA [Emcore Asia, in Beijing] set up to travel to Thailand for 3-month assignments, which will strengthen our Thai team and allow us to finish the job sometime in early in the June quarter. Our Thai manufacturing engineering team continues to get stronger and improve their effectiveness, but adding the highly experienced EA engineers into the mix will have a positive impact."

"There is sufficient product demand to justify parallel operation at both facilities, enabling us to hedge the risk of a switchover before we're ready," continues Rittichier. "Our customers expect certainty in their ship dates, and a two-facility operation provides that. As more operations move from

Beijing to Thailand, we expect to see upward pressure on gross margins in Cable TV," he adds.

"While we don't know the MSOs' calendar year 2021 spending plans in their entirety until January, Emcore's Cable TV products had a strong order book well into the June quarter. Although we remain cautious of the ultimate duration of the upgrade cycle, we're confident that we'll complete our move to variable-cost manufacturing while orders are strong," Rittichier says.

"On the demand side, there are no major architectural changes in the Cable TV networks that are imminent, as MSOs continue to rely on proven linear optics technology to meet their needs," notes Rittichier. "Any migration to DAA [distributed access architecture] Remote PHY keeps pushing further out to the right. In the meantime, development work continues at Emcore on Remote PHY Shelf products, which are built on a proven linear optics backbone."

www.emcore.com

Emcore shipping Optiva Q/V-band fiber-optic links Transmitter and receiver modules launched at Satellite 2020

Emcore is now shipping its Optiva Q/V-band fiber-optic links for applications from 2MHz to 60GHz.

Introduced at Satellite 2020 in Washington DC in mid-March, the transmitter and receiver modules are suitable for antenna remoting, interfacility links, electronic warfare systems, broadband delay lines, signal processing systems and other high-dynamic-range applications.

Optiva Q/V-band unamplified microwave fiber-optic transmitter and receiver pairs are said to eliminate the performance and cost penalty of block up/down-conversion. At the heart of the system is Emcore's high-performance, ultra-low RIN (relative intensity noise) source laser technology combined with high optical input power capable photodiodes. Optiva Q/V-

band links feature microprocessor-based transmitter control for laser and modulator bias, along with link gain for consistent high-performance, low-bias operation and higher SFDR (spurious-free dynamic range) of $>102\text{dB-Hz}^{2/3}$ at 60GHz.

"Emcore is the only major fiber-optic transmission equipment supplier producing native Q/V-band-capable fiber-optic links," says David Wojciechowski, VP & general manager of Defense Optoelectronics. "Our products deliver a major improvement in cost and performance compared to currently available solutions with a simplified communications architecture, fewer points of failure, and increased overall uptime for these extreme high-frequency applications," he claims.

"Our Optiva Q/V-band fiber-optic links represent a significant breakthrough in microwave transmission technology," reckons Defense Optoelectronics product line manager Nan Wang. "By leveraging our advanced engineering capabilities and vertically integrated manufacturing facility, Emcore provides cutting-edge, high-performance fiber-optic transmitter and receiver products demanded by our customers."

Optiva Q/V-band fiber-optic links are SNMP compliant with DWDM operation that increases transport capacity without increasing fiber count. They can be housed in the same chassis and monitored by the same NMS (network management system) as other Optiva cards, enabling a full redundancy system in a single chassis.

NREL and UNSW raise two-junction solar cell efficiency record to 32.9%

First record-efficiency multi-junction cell to use strain-balanced structure

The US Department of Energy's National Renewable Energy Laboratory (NREL) and the University of New South Wales (UNSW) in Australia have achieved record energy conversion efficiency for two-junction solar cells, creating a cell with two light-absorbing layers that converts 32.9% of sunlight into electricity (Myles A. Steiner et al, 'High Efficiency Inverted GaAs and GaInP/GaAs Solar Cells With Strain-Balanced GaInAs/GaAsP Quantum Wells', *Advanced Energy Materials*, 13 December 2020).

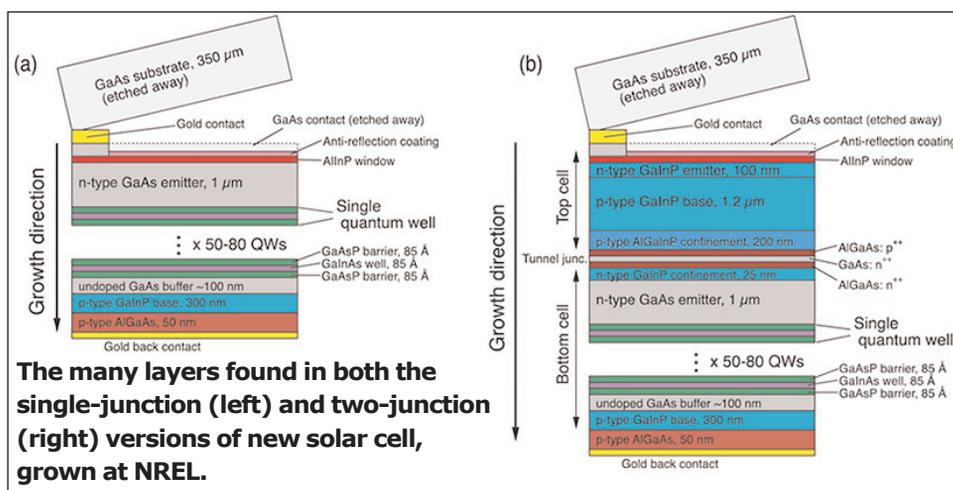
Key to the cell's design is a series of more than 150 ultrathin layers of alternating semiconductors that create quantum wells in the cell's bottom absorber, allowing it to capture energy from a key range of the solar spectrum. While the new record only improves modestly on the previous 32.8% efficiency record, it is the first record-efficiency multi-junction solar cell to use a strain-balanced structure — a design that holds promise for further improvements.

The cells have a gallium indium phosphide (GaInP) layer for their top junction and a bottom junction of gallium arsenide (GaAs) striated with 80 stacked layers of quantum wells.

Quantum wells offer possibilities

The inclusion of so many quantum wells in the bottom junction lowers that junction's effective bandgap, increasing the wavelength of light it can absorb. Capturing longer wavelengths enables the tandem cell to absorb more energy from the solar spectrum, making the cell more efficient.

Traditionally, quantum wells have primarily been used in lasers, LEDs and electronics for telecommunications. As part of the development process, the NREL team produced a single-junction cell that demonstrated a very high external radi-



ative efficiency (>40%) — the efficiency with which the cell converts electricity to light when run in reverse. While the team was not trying to build an LED device, their high-quality quantum wells demonstrated some potential in this area too.

Strain balancing unlocks new record

Previous work has attempted to use quantum wells to adjust the bandgap of solar cell junctions, but it has not produced any record-efficiency cells, in part because it is difficult to grow many layers of high-quality quantum well material. If the layers become too thick or the mechanical strain within the crystal lattice is not properly balanced, the cell develops defects.

For the record cell, the team alternated layers of gallium indium arsenide — in compression — and gallium arsenide phosphide — under tension. By carefully controlling the thickness of these layers, the strain of the compressive and tensile forces balances between layers. An array of lasers was used to measure the curvature of the wafer throughout the growth process, allowing the researchers to detect and adjust for strain in the crystal lattice.

"This work will lead to higher-efficiency solar cells for one-sun appli-

cations, which could be a significant driver of the widespread adoption of these cells," says Myles Steiner, a senior scientist on the NREL team.

"Now, a key challenge ahead is to learn how to manufacture these cells in a cost-competitive manner."

Globe-spanning collaboration

The development of the cell design grew out of a close collaboration between part of the High-Efficiency Crystalline Photovoltaics research group at NREL and a team at the University of New South Wales (UNSW). In fact, Steiner spent three months in early 2020 in New South Wales with his Australian collaborators, working on the project as part of a grant from the Fulbright Scholars Program.

"Our partnership brought together NREL's long-standing expertise in epitaxial growth and UNSW's work in solar cell modeling, which helped us to collaborate effectively at a distance," says Nicholas Ekins-Daukes, who led the UNSW team. "I was impressed with how quickly we were able to develop the first composite, strain-balanced semiconductor material to outperform a conventional solar cell."

<https://doi.org/10.1002/aenm.202002874>

www.nrel.gov

www.pv.unsw.edu.au

www.onlinelibrary.wiley.com/doi/

5N Plus secures multi-year First Solar supply contracts Lower volumes anticipated in the earlier period of the contract

Engineered materials and specialty chemicals producer 5N Plus Inc of Montreal, Québec, Canada has secured multi-year contracts for the supply of semiconductor materials for the manufacture of cadmium telluride (CdTe) thin-film photovoltaic (PV) modules by First Solar Inc of Tempe, AZ, USA. The terms of the contracts are structured asymmetrically, with lower volumes anticipated in the earlier period of the contract.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II–VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

5N Plus has been a key supplier of semiconductor materials to First Solar since 2007 and over this period several long-term contracts have been signed and executed. During this period 5N Plus has become the leading supplier of engineered semiconductor compounds to the thin-film renewable energy industry, it is claimed.

5N Plus' semiconductor materials are incorporated in First Solar's Series 6 module, which is said to have a carbon footprint that is up to six times lower and a water footprint that is up to 24 times lower than crystalline silicon PV panels. Given that a large portion of 5N Plus' production activity related to these semiconductor compounds is powered by renewable energy, Series 6 modules produced with 5N Plus semiconductor thin-film materials deliver the lowest carbon

solar available, it is claimed.

"5N Plus recognizes that economics will largely govern the rate of growth in renewable energy sector. Consistent with this view, the company has continued to invest in process and product technologies, aiming to optimize the balance between cost and performance of its engineered semiconductor compounds used in thin-film solar technology," says Nicholas Audet, executive VP – Electronic Materials. "The specialty semiconductor market continues to be a natural growth space for our company as we further expand our portfolio of advanced engineered materials based on unique value propositions desired by our customers across a broad spectrum of applications," he adds.

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InAs QD lasers on SOI

Researchers in China have claimed the first electrically pumped devices.

Researchers based in China claim the first electrically pumped indium arsenide quantum dot in gallium arsenide matrix (InAs/GaAs QD) narrow-ridge Fabry-Perot (FP) lasers on silicon-on-insulator (SOI) substrates [Wen-Qi Wei et al, Optics Express, vol28, p26555, 2020].

The team from Beijing National Laboratory for Condensed Matter Physics, University of Chinese Academy of Science, and Songshan Lake Materials Laboratory, hope to contribute to the development of monolithic integration of III-V laser sources into silicon photonics integrated circuit (Si PIC) chips.

The researchers comment: "Integration of III-V materials on Si combines the superior optoelectronic properties of III-V materials and the compatibility with currently mature manufacturing processes offered by CMOS foundries." They add: "Overall, the realization of electrically pumped III-V FP lasers on SOI will enable the great potential integration opportunity for on-chip silicon photonic telecom transmitters."

In future work, the team hopes to develop direct butt coupling into SOI-based silicon waveguides through selective-area growth of InAs/GaAs QD lasers inside

SOI templates with pre-patterned trenches.

The material was grown by molecular beam epitaxy (MBE) in two systems — one for silicon and the other for III-V growth. The 8-inch-diameter SOI substrate consisted of 3 μ m buried oxide (BOX) insulator (SiO₂) and 340nm silicon top layer patterned with U-shape trenches in the [110] direction of the silicon crystal structure.

The substrate was diced into 3.2cmx3.2cm pieces and deoxidized in dilute hydrofluoric acid. The first MBE process consisted of 420nm of silicon at 600°C, resulting in a coalesced sawtooth surface with {111} facets on voids over the U-shaped trenches (Figure 1).

The III-V buffer structure was grown at two temperatures: 380°C for a 40nm nucleation layer and 540°C for the main material. The nucleation layers consisted of 10nm AlAs and 30nm GaAs. This was followed by 360nm of high-temperature GaAs and a series of InGaAs/GaAs and InAlAs/GaAs strained-layer superlattices (SLSs) to filter out threading dislocations to a level of 9.6x10⁶/cm².

The active region of the laser consisted of seven layers of InAs QDs in a GaAs matrix, forming a dot-in-well (DWELL) structure. The DWELL was grown at 430°C, while the surrounding cladding and contact layers were

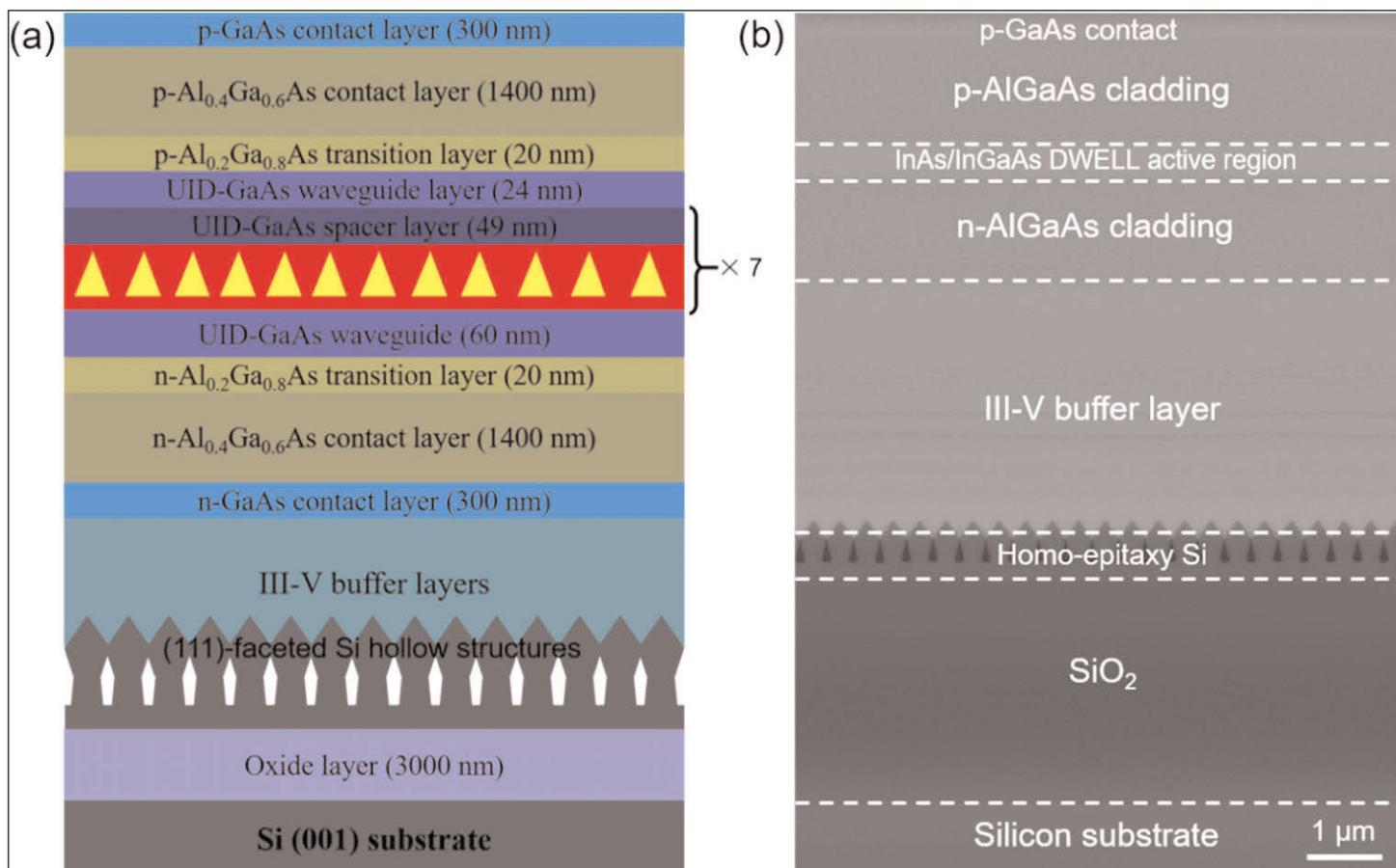


Figure 1. Schematic (a) and SEM image (b) cross sections of InAs QD laser structure on SOI substrate.

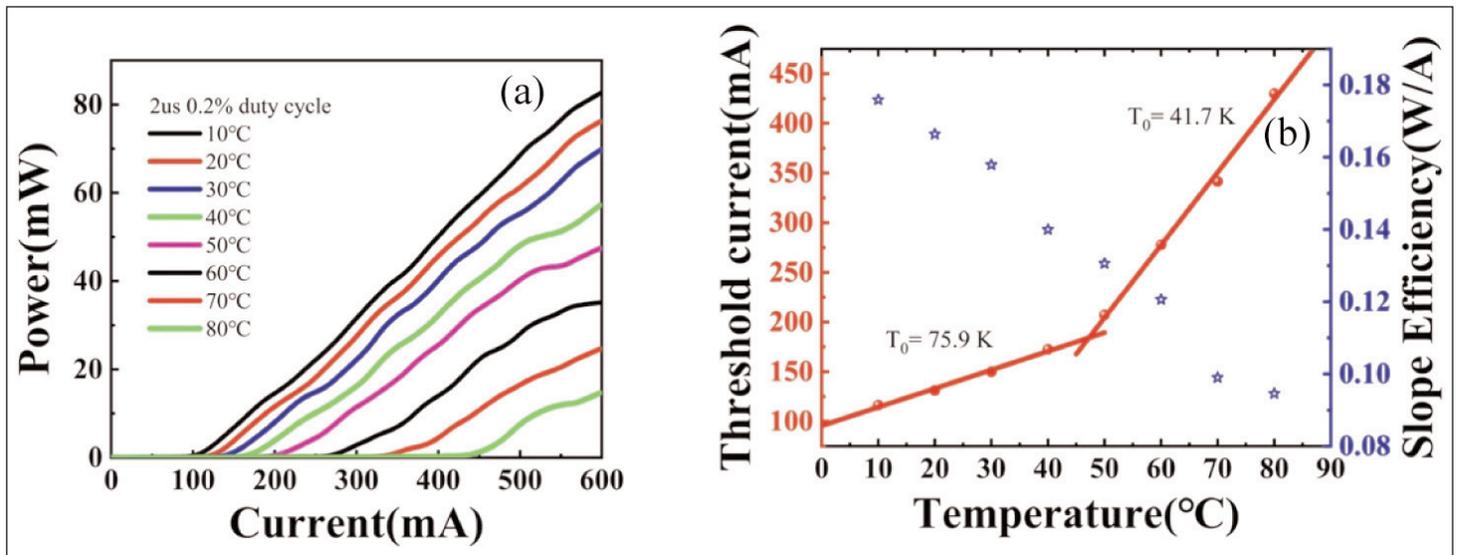


Figure 2. (a) Temperature-dependent light output power-current characteristics of InAs/GaAs QD laser under pulsed operation. (b) Threshold current and slope efficiency versus temperature.

grown at 580°C and 540°C, respectively. In photoluminescence spectra, the wavelength peak occurred at 1298nm. A comparison structure grown on GaAs substrate had a peak at 1275nm, the difference being attributed to “substrate temperature variation”.

Narrow-ridge lasers were fabricated parallel and perpendicular to the underlying v-groove structures. Dry and wet etch were carried out to achieve smooth sidewalls of the ridges and mesas. The top ridge mesa reached down to about 100nm above the active region.

The contacts were annealed nickel-germanium-gold/gold and titanium/platinum/titanium/gold for the n- and p-sides, respectively. The substrate was thinned to 100μm thickness before cleaving into laser bars. The cleaved mirror facets were not coated with anti-reflective layers.

The threshold for continuous wave (CW) operation of a 4μm×1mm bar was 140mA at 0°C, increasing to 175mA at 5°C and 10°C.

The threshold was reduced to around 50mA for the 0–10°C temperature range in 100ns pulsed operation with 5% duty cycle, allowing heat dissipation and therefore avoiding thermal degradation of performance. As the temperature increased to 60°C, the threshold increased to 90mA for pulsed injection.

For CW performance, the heat build-up was largely attributable to the thermally insulating nature of the SiO₂ component of the SOI substrate.

The output powers in pulsed mode was less than 5mW at 200mA injection. For 0°C CW operation, the output power was just over 4mW at the same current. The maximum output power reached in pulsed mode was 6.5mW at 240mA.

The team hopes that high-reflection coatings and facet passivation could improve output power and lower thresholds.

The characteristic temperature T_0 , reflecting changes

in threshold current, was 184.2K below 30°C, reducing to 58.1K above that due to heat dissipation problems. The 184.1K value was higher than for previously reported 1.3μm and 1.5μm QD Fabry–Perot lasers grown on silicon substrates.

The slope efficiency of the device is described as ‘poor’ at 0.034W/A at room temperature (20°C). The researchers suggest “high internal loss, resulting from high doping level in the AlGaAs cladding layers” was to blame for this.

The laser emissions were multi-mode, with the main peak just above threshold being from the 2nd excited state with a wavelength of 1210nm. As the current injection increased to 130mA, the 1st excited state peak at 1240nm rose in strength.

Operation with 2μs pulses at 0.2% duty cycle enabled increased temperature operation at 80°C, but with increased threshold of 130mA at room temperature. The maximum room-temperature output power was 75mW under these conditions. In the 0–40°C range, T_0 was 75.9K, reducing to 41.7K for 40–80°C.

The researchers see thermal dissipation as being the main barrier to progress. The team comments: “By implementing thick metal contacts with externally bonded heat-sink such as thermal shunt design, it would significantly help reducing the heat accumulation inside the laser chips, which could strongly contribute to better device performance. Ultimately, by selectively growing III–V lasers on the bottom silicon of SOI substrate, the generated heat from laser devices could be effectively dissipated into the substrate, rather than isolated by the BOX layer.”

Another possibility for improved thermal dissipation, mentioned by the team, is selective-area growth of InAs QD lasers within the SOI trenches, allowing heat transfer to the more conductive silicon substrate. ■

<https://doi.org/10.1364/OE.402174>

Author: Mike Cooke

BiTeSe optoelectronic functional device

Researchers realize 'OR' gate, memory and optical signal decoding operations.

Hebei University in China has used bismuth telluride selenide ($\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$) to realize a range of optoelectronic functions [Hong Wang et al, IEEE Electron Device Letters, volume 41, Issue 10 (October 2020), p1504–1507]. The material has a two-dimensional structure with a narrow bandgap of 0.16eV. The researchers suggest that it may be possible to combine information communication, calculation and storage functions in one device in the future.

A 20nm $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ film was fabricated by pulsed laser deposition (PLD) on $\sim 30\text{nm}$ native silicon dioxide (SiO_2) on p-type silicon substrate (Figure 1). A 0.1mm-diameter circular palladium (Pd) electrode was added

with DC magnetron sputtering. The electrode was thin enough (60nm) to allow light to pass through. The $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ film was naturally n-type with an area of 1cm^2 .

The bandgaps of the $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$, SiO_2 and Si layers are nominally 0.16, 8.9 and 1.1eV, respectively. Optical illumination generates freely moving electron-hole pairs — the electrons move toward the Pd electrode where they are trapped, leaving a positive charge at the $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}/\text{SiO}_2$ interface. At the same time the SiO_2 barrier is lowered, even without illumination, reducing the resistance to current flow through the structure with a positive bias on the Pd electrode.

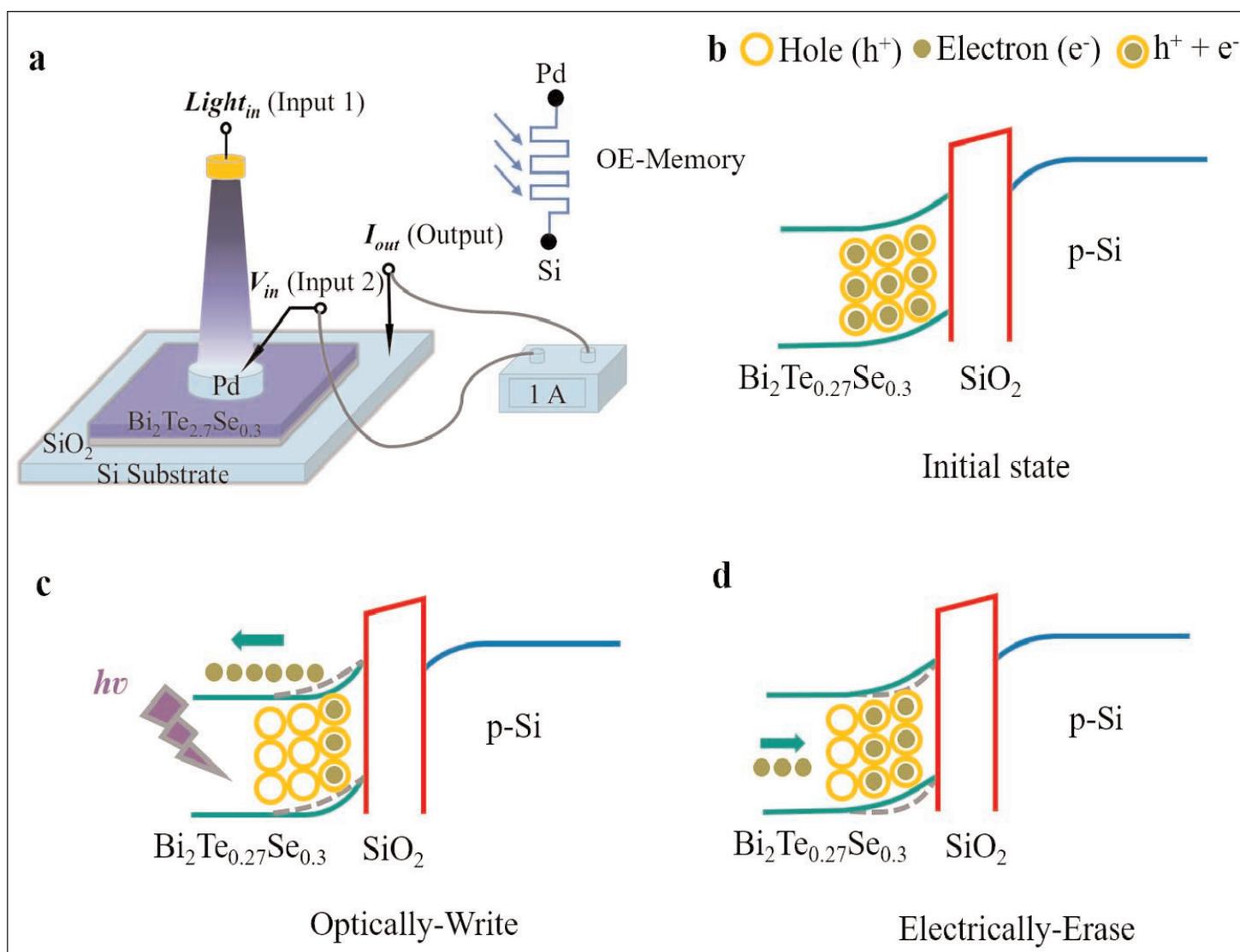


Figure 1. (a) Schematic illustration of Pd/ $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ / SiO_2 /Si device. Band diagrams of (b) initial state, (c) and under optical writing and (d) electrical erasing conditions.

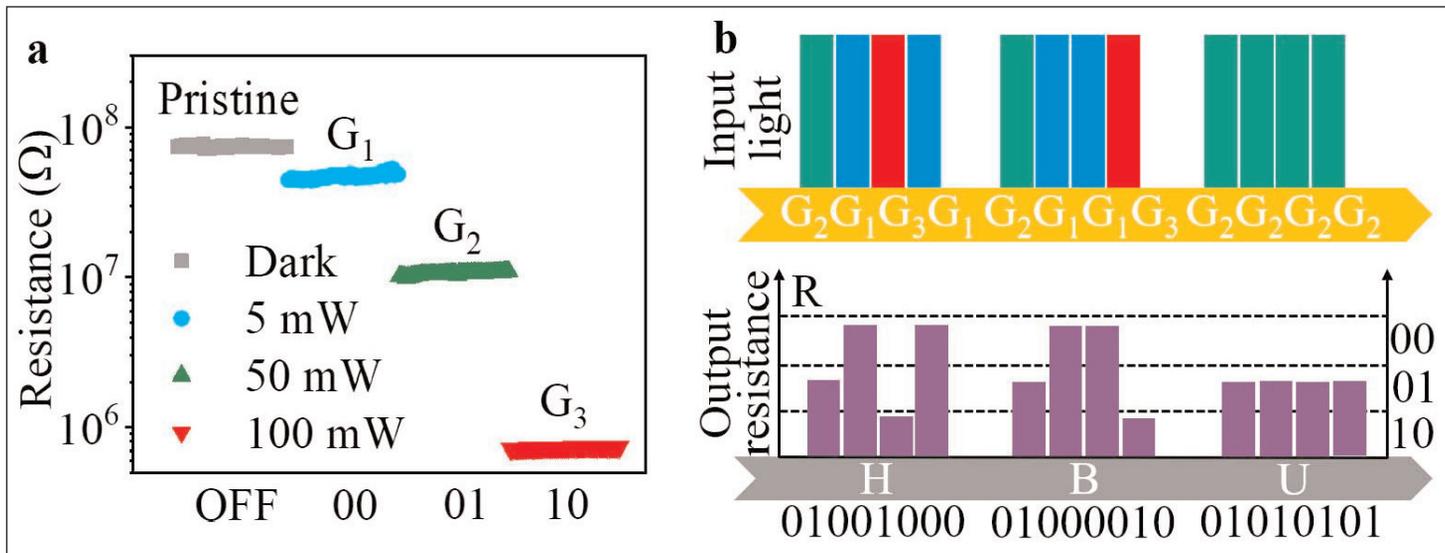


Figure 2. (a) Decoding of '00', '01' and '10' bit pairs with light pluses at intensities of 5 (G₁), 50 (G₂) and 100mW (G₃), respectively. (b) 'HBU' demodulation in eight-bit ASCII. 'HBU' data did not need a code for '11'.

The erasure of the memory state is achieved with negative bias on the Pd electrode pushing electrons back to recombine at the Bi₂Te_{2.7}Se_{0.3}/SiO₂ interface, raising the barrier and increasing electrical resistance.

The researchers used the structure to achieve 'OR' gate functionality with a 100mW light pulse as one input and a 2V electrical pulse as the other. The zero output state consisted of a current pulse through the structure of around 8x10⁻⁹A, while separate optical and electrical pulses gave 8x10⁻⁷A and 9x10⁻⁷A, respectively. Optical and electrical pulses combined gave 1x10⁻⁶A.

The team also looked at the potential for non-volatile resistive memory, realizing three resistance states

— 298 kΩ, 4000 kΩ and 20,000kΩ — with different optical write powers (100mW, 50mW and 5mW). The data retention time was in excess of 10⁴ seconds (just under 3 hours).

The researchers also report the use of the structure to demodulate an optical input into an electrical signal. The team successfully decoded a three-letter ASCII data stream — 'HBU' standing for 'Hebei University' — encoded on a purple light beam (Figure 2). Three resistance levels were used to encode bit pairs, giving four signals per letter, or twelve signals in total. ■

<https://doi.org/10.1109/LED.2020.3017166>

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Simultaneous emission–detection

Researchers explore the potential for monolithic GaN-based IoT systems.

Researchers in China and Japan have been exploring the simultaneous emission–detection capabilities of multiple quantum well (MQW) III–nitride diode arrays [Yongjin Wang et al, Applied Physics Express (2020), volume 13, p101002]. The hope of the team from Nanjing University of Posts and Telecommunications and Zhengzhou University in China and Nagoya University in Japan is to develop advanced monolithic III–nitride information systems for Internet of Things (IoT) deployment, based on such multi-function devices.

III–nitride diodes have the capability to both emit and detect light. The researchers have successfully combined these capabilities, performing these functions at the same time.

The team comments: “By integrating with programmed circuits, multi-functioning MQW–diodes open up feasible routes toward a wide range of exciting applications from automatic brightness control to touchless shared user terminals and simultaneous illumination–imaging system. In particular, the shared user terminals communicate with each other via light and thus provide non-contact reader/writer interfaces, offering protective actions to avoid the cross-contamination due to touch with conventional handwritten terminals and to help prevent the spread of viruses. These monolithically integrated devices benefit from the simplicity of a single growth and fabrication process, and this integrated on-chip system could produce better performance with advances in the material growth and device fabrication.”

The MQW–diode arrays were fabricated using 2inch-diameter III–nitride on sapphire material (Figure 1). The n-type

gallium nitride (n-GaN) contact layer was exposed using inductively coupled plasma reactive-ion etch to a depth of 750nm. Indium tin oxide (ITO) transparent conductor material was applied onto the p-GaN contact layer through evaporation techniques, and then annealed. A lift-off process was used to deposit and pattern the chromium/platinum/gold metal used for the n- and p-electrodes.

The devices in 4x4 arrays were electrically isolated by trenches filled with 230nm-thick silicon dioxide insulation. Bonding pads and metal lines were formed from titanium/platinum/gold. The individual MQW–diodes measured 1mmx1mm.

The electroluminescence peak at 442nm wavelength had a 36nm overlap with the tail of the photoresponse spectrum (Figure 2). Communication between two array elements achieved a 2k bit per second rate with pseudorandom binary sequence (PRBS) modulation.

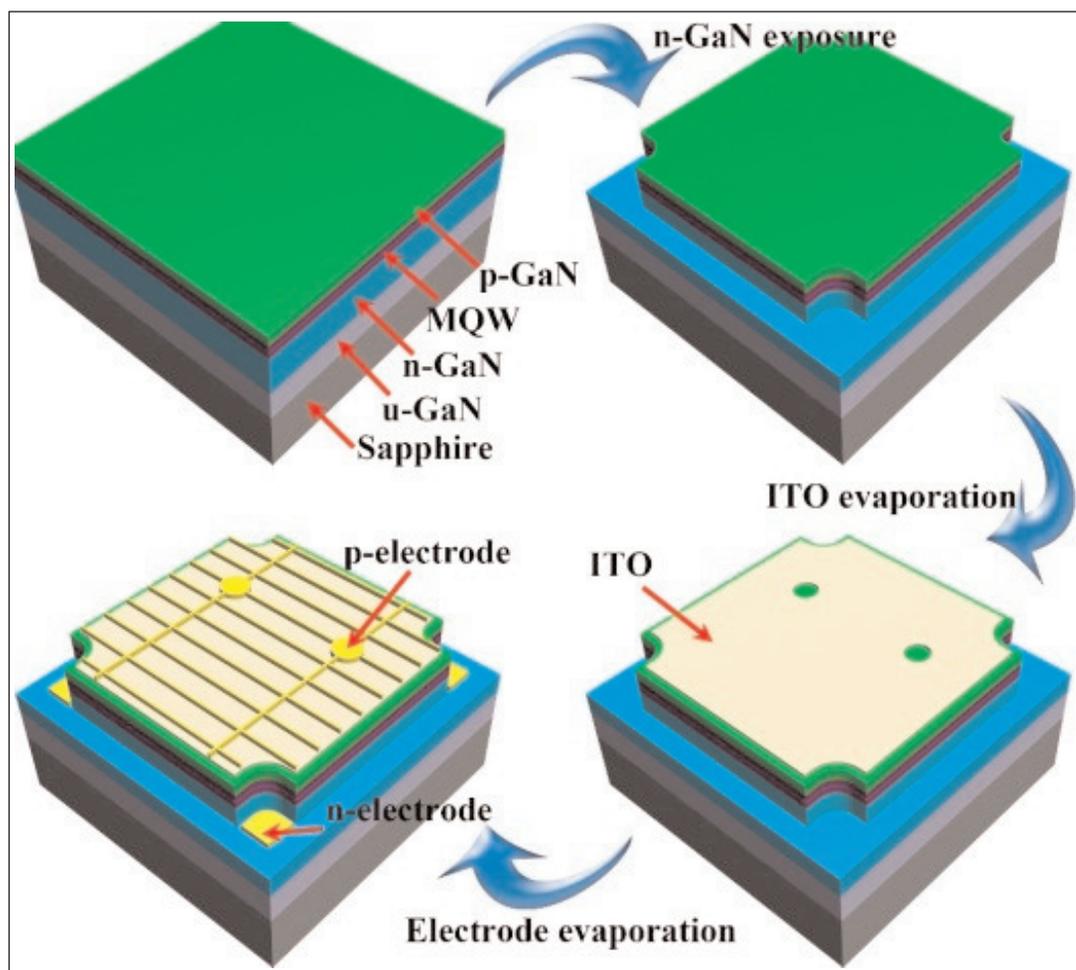


Figure 1. Fabrication process flow of MQW–diode array.

The peak-to-trough voltage difference for the binary pulse modulation was 1.6V. The detected signals were about 1.5mV high.

The researchers realized an automatic light brightness control setup where a 405nm laser pointer could issue a coded sequence of pulses that would be detected by the array, and then interpreted by control circuitry that would adjust the light output to the desired level, considering ambient light conditions through feedback.

Another demonstration involved using the array to recognize characters from images projected on the diodes with potential for a touchless-terminal application (Figure 3).

The team is developing circuitry to effectively extract photocurrents while the devices are also simultaneously operating as LEDs. "We can envision that a large MQW-diode array can realize the simultaneous illumination-imaging system with improved performance," the researchers say. In their paper, they describe preliminary experiments demonstrating the potential of this with their 4x4 array combined with optical imaging and electronic/software processing systems.

Yongjin Wang reports: "The simultaneous illumination-imaging system has three operation modes: illumination, imaging, and a simultaneous illumination-imaging operation. It means the micro-LED screen can display

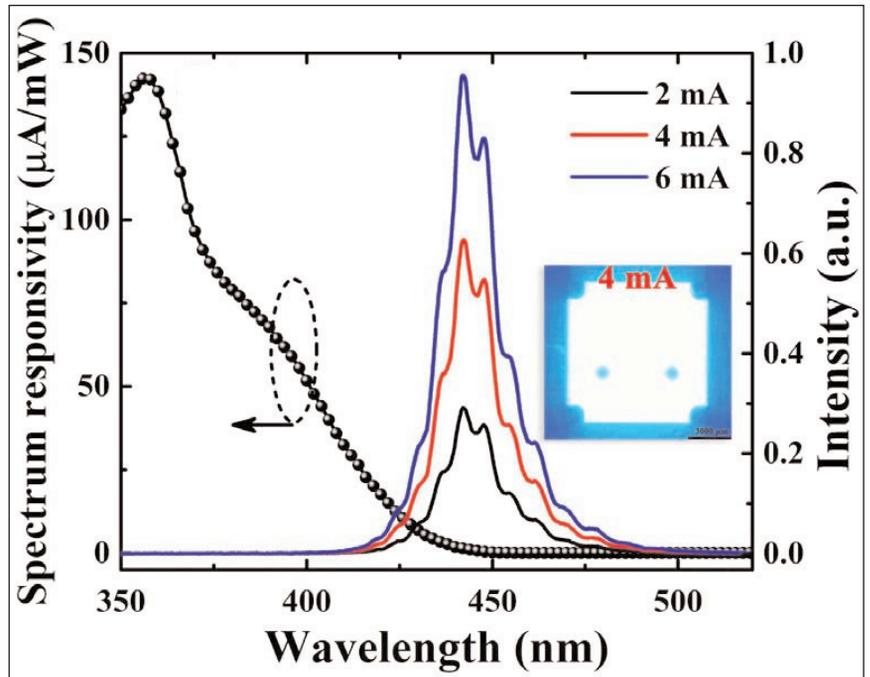


Figure 2. Measured EL and responsivity spectra, and inset emission at 4mA injection.

and image at the same time." He adds that changes in environmental light conditions creates a photocurrent inside the chip, allowing a feedback signal to control the operation. ■

<https://doi.org/10.35848/1882-0786/abb786>

Author: Mike Cooke

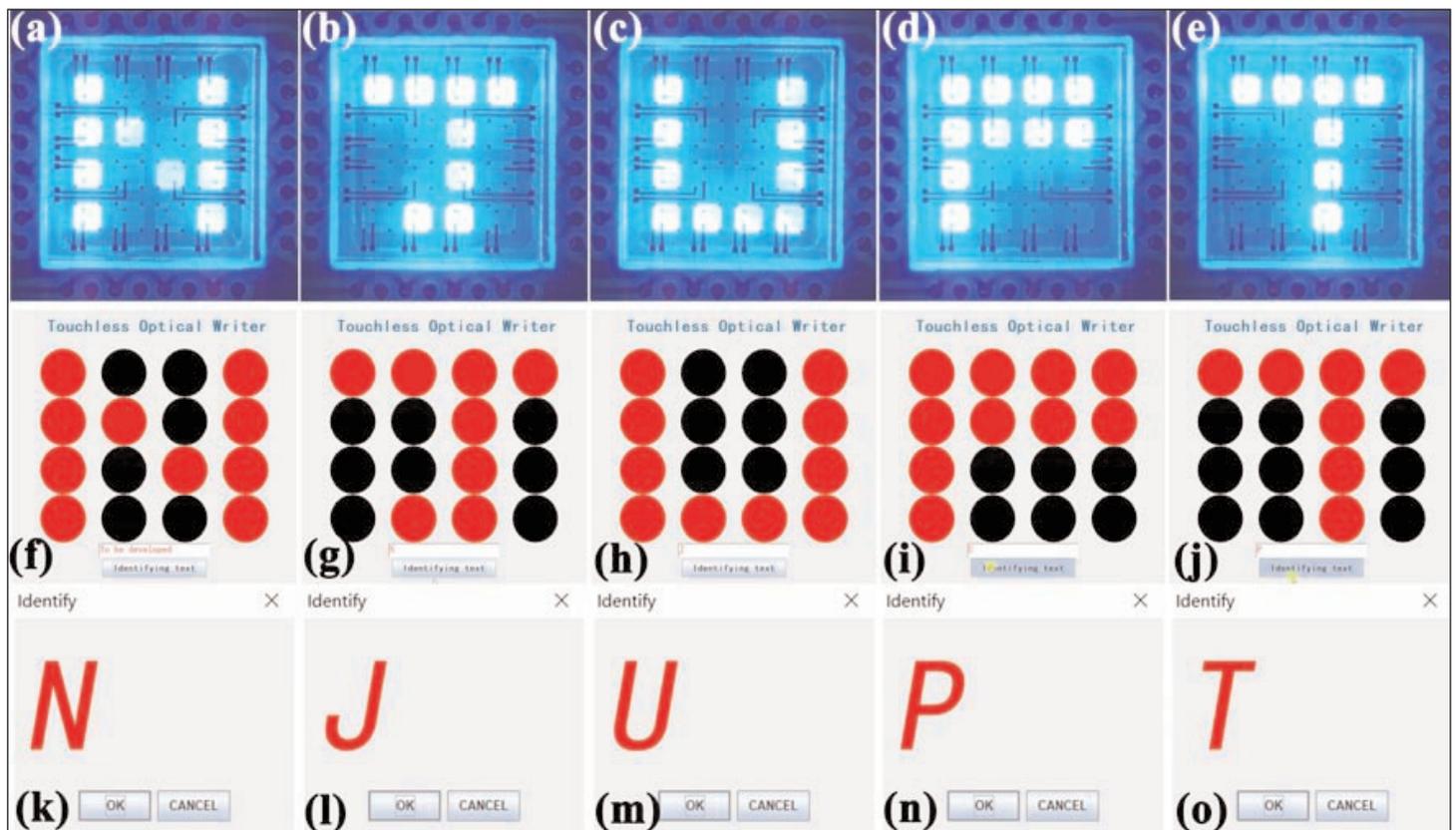


Figure 3. (a)–(e) Light-activated emission pattern; (f)–(j) Corresponding pattern displayed on user interface; (k)–(o) corresponding output character sequence.

Apple's μ LED supply chain to disrupt display industry?

CMOS micro-drivers could eliminate TFT backplanes, says **Yole Développement**.

Over \$5bn has already been spent on micro-LED development (as of first-quarter 2020), estimates Yole Développement in its report 'MicroLED Displays — Market, Industry and Technology Trends 2020'. Despite the global COVID-19 pandemic, money is still flowing into the micro-LED ecosystem, with the impact on the global industry varying according to the application.

"For many companies, interest in micro-LEDs lies beyond just the ability to offer the latest display technology," asserts Eric Virey PhD, Yole's principal analyst, Technology & Market, Displays. "Intellectual property (IP) analyses indicate that Apple is planning to forgo TFT (thin-film transistor) backplanes, instead opting for silicon CMOS micro-drivers," he adds. "The implications go far beyond a technological choice. Apple's micro-LED supply chain would eliminate reliance on display makers such as Samsung or LG".

Apple can source micro-drivers and micro-LED chips from foundry partners and assemble those components in-house or with other partners to create unique displays. Although it currently has more pressing battles to fight, the same logic applies to Huawei, with the possible added benefits of a 100% domestic display supply chain that does not rely on restricted US technology.

The key players and inflexion points vary from one application to another. Apple will lead on smartwatch applications and Samsung on TVs, which will evolve smoothly from luxury products in excess of \$100,000 towards high-end consumer devices, expects Yole.

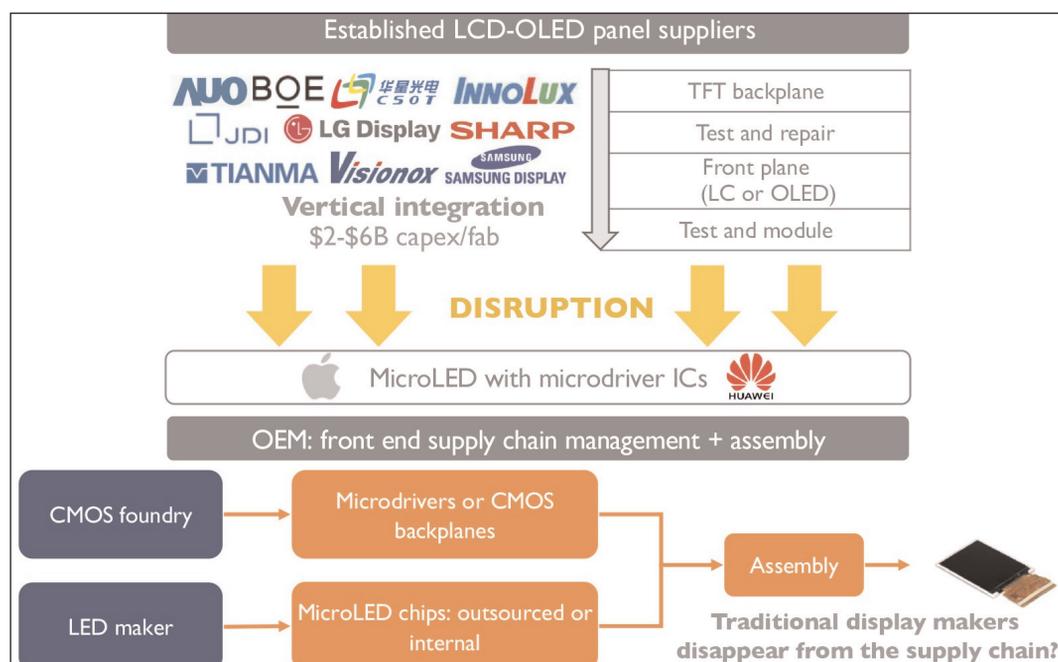
For Samsung's TV division Samsung Visual Display (SVD), micro-LEDs would confer the ability for it to compete against organic light-emitting diodes (OLEDs) in the high-end, large TV segment with a technology that does not rely on panels from China or its friendly enemy Samsung Display Co Ltd (SDC). SVD's micro-LED technology still uses LTPS

(low-temperature polysilicon) TFTs but, thanks to its modular design, only requires smartphone-sized tiles that could be sourced from existing G6 fabs.

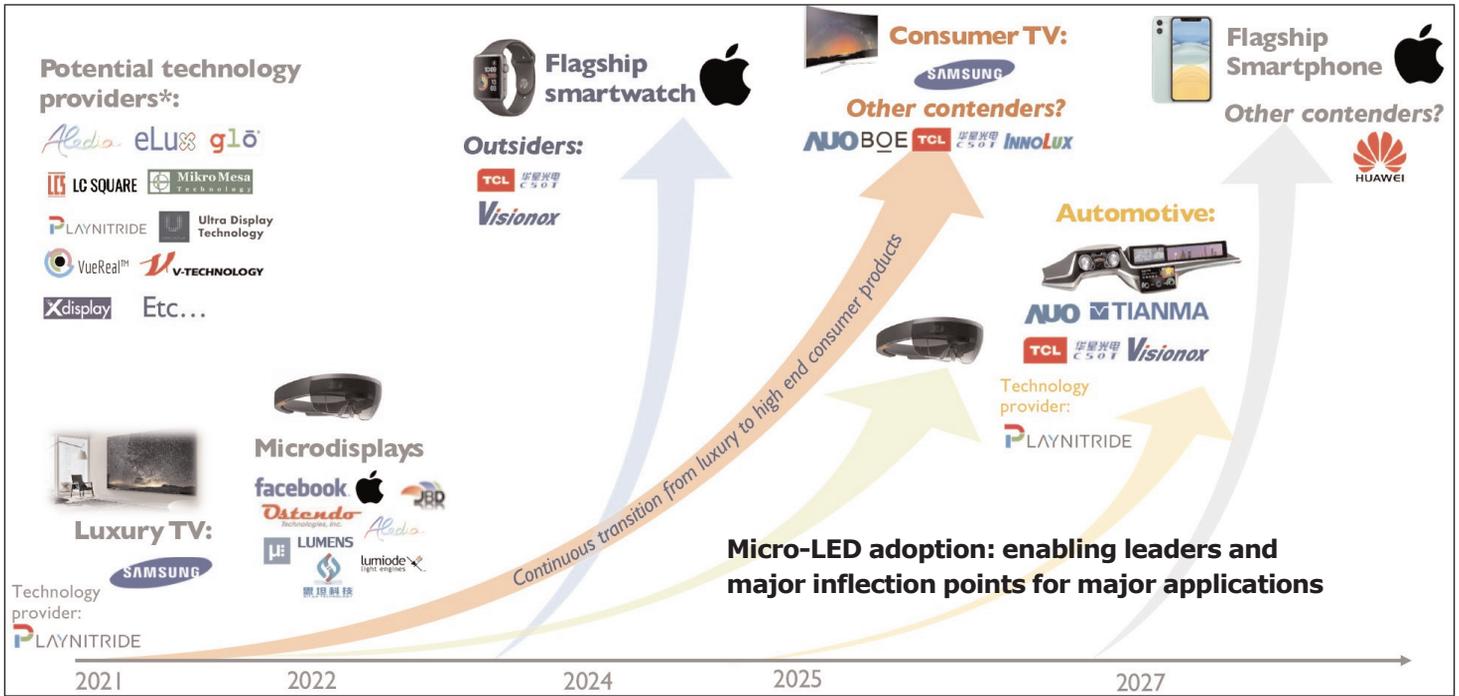
Other display makers such as BOE or CSOT want to leverage their existing TFT infrastructure. Samsung Display is developing QNEDs, its own flavor of micro-LEDs that could fast track the technology and leverage most of its quantum dot (QD)-OLED investments.

For AUO, micro-LEDs could be a matter of survival. The firm has been successfully managing cash by limiting capital expenditure (CapEx) and focusing on high-added-value products. But China won the LCD war and the firm never significantly invested in OLED capacity, making it difficult to pursue this strategy in the long term. Micro-LEDs represent AUO's best shot at remaining relevant in high-end automotive and TV panels, without requiring the massive CapEx of an OLED fab. The firm has already shown various automotive prototypes and could demonstrate TV prototypes in 2021.

The availability of standard tools and processes enabled the commoditization of LCDs and will soon do so for flexible red/green/blue (RGB) OLEDs. Despite progress in micro-LED technology, however, roadblocks remain, including power efficiency, transfer and assembly, yield management, driving. Challenges lie in the yield, manufacturability and cost effectiveness of those solutions.



How micro-LEDs and micro-drivers can disrupt the display supply chain.



The lack of micro-LED process maturity and the proliferation of technology paths hinders the development of high-volume manufacturing tools and the development of the supply chain. However, this complexity is a welcome barrier to entry for companies such as Apple or Samsung. Both have the financial and technological strength to develop end-to-end solutions internally and acquire missing technology building blocks as needed.

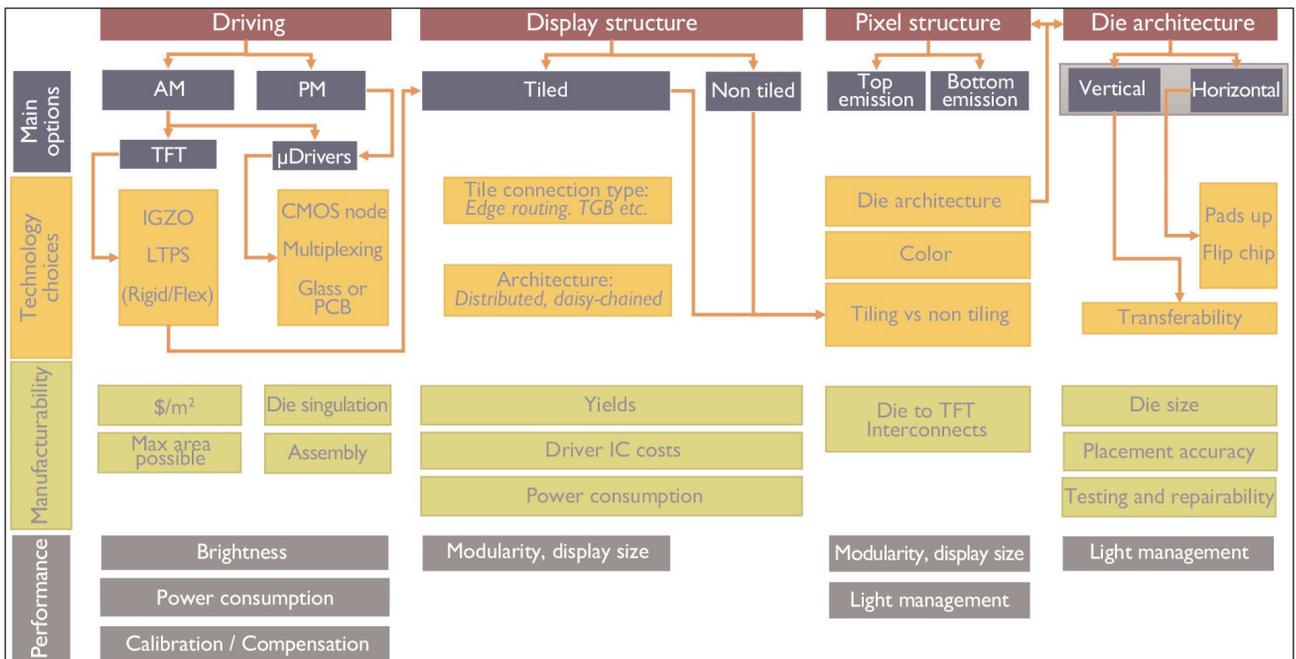
Latecomers or smaller companies are eager to see micro-LED processes converge and off-the-shelf tools become available. Equipment makers such as Toray Engineering, TDK, V-Technology, Besi, SET and others are making the first attempts, while technology providers such as Playnitride, XDC and many others can license key processes and components.

For high-volume consumer applications, economics are driving die size to below 5µm, with stringent yield requirements for which traditional LED fabs are not suited. A paradigm shift is

required towards a semiconductor-like manufacturing mindset with high efficiency, automation, end-to-end defect prevention and management strategies, says Yole.

This is creating an additional push toward the adoption of larger-diameter substrates. Going from 6" to 8" is especially desirable, as it grants access to battle-tested, retrofitted semiconductor equipment. This also increases the appeal for gallium nitride on silicon (GaN-on-Si) platforms that are readily available in 8" and already looking toward 12". Although they are more challenging, 8" sapphire and gallium arsenide (GaAs) platforms however remain credible options. ■

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Multiplicity of micro-LED display design and architecture options.

Green and orange LEDs on porous gallium nitride

UCSB shows that a less rigid material creates a relaxed InGaN pseudo-substrate for high indium uptake in regrowth.

University of California Santa Barbara (UCSB) in the USA has been using a gallium nitride porosification process to increase the wavelength of indium gallium nitride (InGaN) micron-scale light-emitting diodes (μ LEDs) [Shubhra S. Pasayat et al, Appl. Phys. Lett., vol117, p061105, 2020]. The porous GaN is less rigid, allowing overlying InGaN 'pseudo-substrate' (PS) layers to be less strained.

The relaxed InGaN in turn increases indium uptake during regrowth processes through the 'composition pulling effect', creating higher-indium-content layers and hence longer emission wavelengths. Composition pulling is ascribed to the reduced lattice mismatch between the InGaN growth front and the underlying InGaN pseudo-substrate, compared with InGaN grown directly on GaN. The work resulted in green (500–565nm)- and even orange (590–625nm)-emitting devices.

The researchers see the potential for applications from near-eye head-mounted to large-area self-emitting displays. Also,

smaller device sizes often allow for faster switching speeds for GHz-level modulation bandwidth in visible light communications (VLC). "Owing to their small form factors, μ LEDs are also being considered to possess immense potential in medical applications and mask-free lithography," the team adds.

The UCSB group has also recently

reported on use of the same concept for producing high-aluminium-content AlGaIn pseudo-substrate films, which may lead to better-performing very-short-wavelength deep-ultraviolet-emitting devices [Shubhra S. Pasayat et al, Appl. Phys. Lett., vol117, p062102, 2020].

For the InGaN μ LEDs, the UCSB team performed metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The GaN layers used trimethyl-gallium as the metal precursor, while for InGaN triethyl-gallium and trimethyl-indium were used. The nitrogen source was ammonia. Silicon doping for n-type conductivity came from disilane (Si_2H_6).

The first steps consisted of growing 2.8 μm of unintentionally doped (UID) GaN buffer, followed by 800nm of $5 \times 10^{18}/\text{cm}^3$ Si-doped GaN (GaN:Si) and a 100nm UID GaN cap.

A 2mmx2mm die from the material was dry etched into square tiles with dimensions from 8 μm x8 μm up to 20 μm x20 μm . The target etch depth was 550nm.

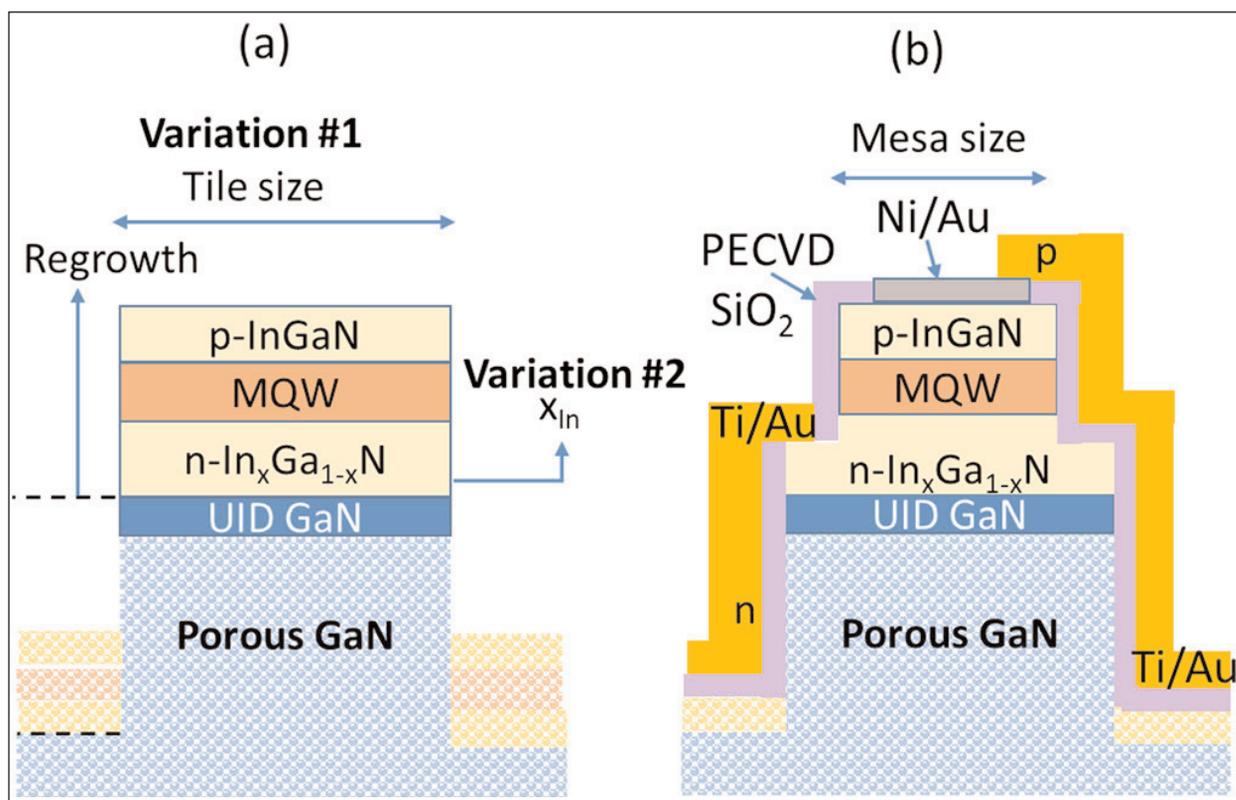


Figure 1. Cross-sectional schematic of regrown green micro-LED structure (a) and (b) post-fabrication.

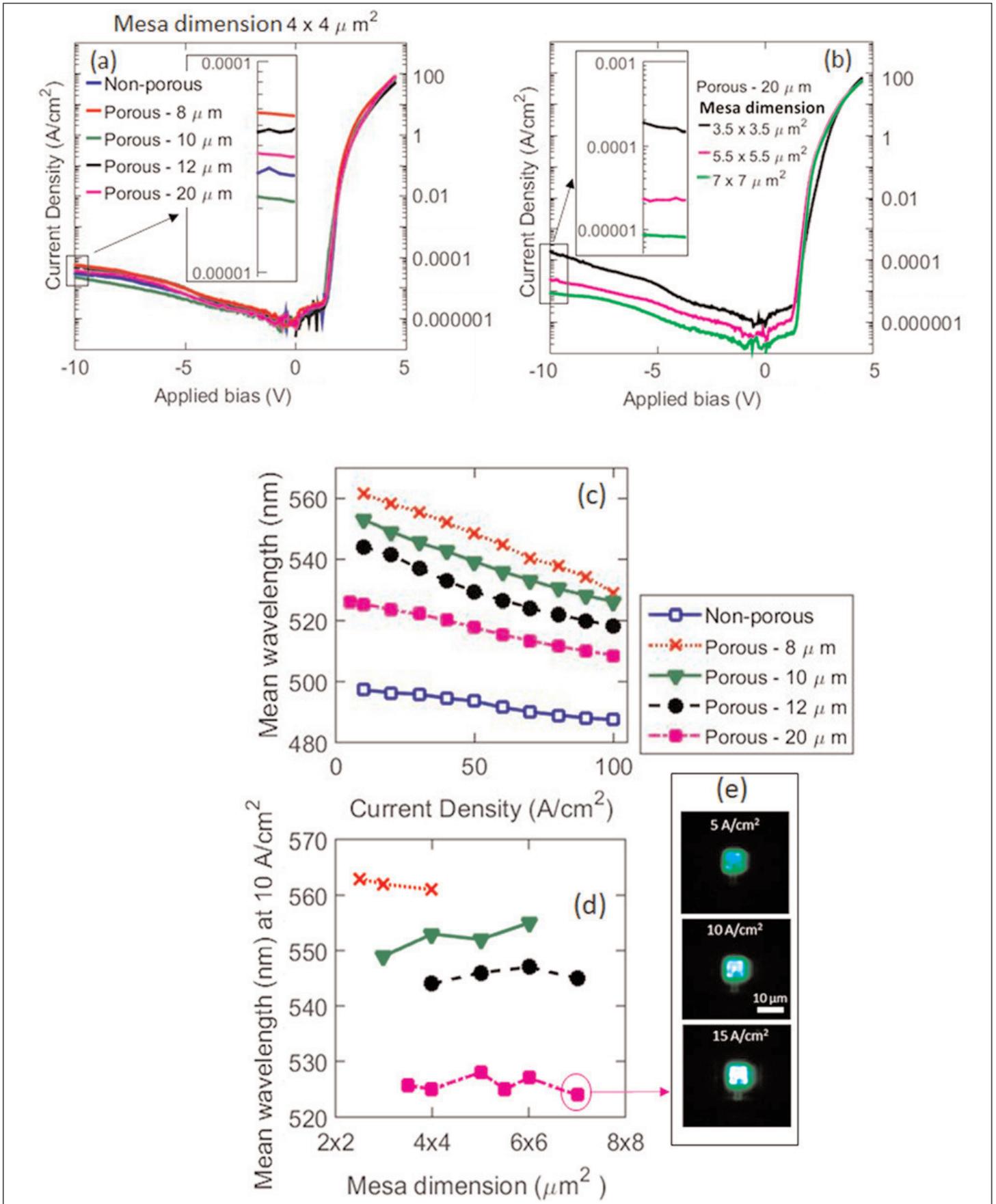


Figure 2. Current–voltage characteristics of (a) $4 \mu\text{m} \times 4 \mu\text{m}$ mesa μLEDs fabricated on various-sized tiles and on unpatterned non-porous material, and (b) for various-sized mesa / microLEDs fabricated on $20 \mu\text{m}$ tiles. (c) Mean EL wavelength dependent on current density, for $4 \mu\text{m} \times 4 \mu\text{m}$ mesa μLEDs fabricated on various-sized tiles and on unpatterned non-porous region. (d) Mean EL wavelength dependent on device dimensions fabricated on various-sized tiles at $10 \text{ A}/\text{cm}^2$ injection. (e) EL images of $7 \mu\text{m} \times 7 \mu\text{m}$ μLED on $20 \mu\text{m}$ tile at varied current injection.

Electrochemical (EC) etching porosified the GaN:Si layer. Some parts of the die were protected from the electrochemical process to allow the growth of reference InGaN material. The electrochemical etch used a metal contact on the exposed GaN:Si layer as the anode, a platinum cathode, and 0.3M oxalic acid electrolyte.

The porous material was subjected to MOCVD regrowth, producing LED structures (Figure 1): 180nm of $\text{In}_x\text{Ga}_{1-x}\text{N}:\text{Si}$, 10nm of unintentionally doped GaN, a multiple quantum well (MQW), 120nm of magnesium-doped $\text{In}_{0.04}\text{Ga}_{0.96}\text{N}:\text{Mg}$, and 16nm of heavily doped $\text{p}^{++}\text{In}_{0.04}\text{Ga}_{0.96}\text{N}:\text{Mg}$. The x-parameter for the 180nm InGaN layer was either 4% or 9% In.

The MQW consisted of three 3nm nominal $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ wells capped with 2nm of aluminium gallium nitride ($\text{Al}_{0.1}\text{Ga}_{0.9}\text{N}$), and 10nm of UID GaN. The p-type Mg-doped layers were grown on the last well of the sequence.

The LED structure was fabricated with reactive ion etch isolation of the structure, followed by plasma-enhanced chemical vapor deposition (PECVD) of silicon dioxide insulation. Contacts were formed using wet etch and deposition of nickel/gold p-contacts and titanium/gold n-contacts. The researchers point out that the LED fabrication was “basic”, and that many enhancements could improve light output performance.

The team first looked at the mean wavelength of the electroluminescence (EL) from $4\mu\text{m}\times 4\mu\text{m}$ -area LEDs on tiles of various dimensions with a base InGaN layer of 4% indium content (Figure 2). As the tiles became smaller, the wavelength red-shifted: with $10\text{A}/\text{cm}^2$ injection current density the wavelength for $20\mu\text{m}\times 20\mu\text{m}$ tiles was 525nm, while $8\mu\text{m}\times 8\mu\text{m}$ -tile μLEDs produced 561nm radiation. The researchers estimated the indium content to be 0.22 and 0.245, respectively. A μLED on the non-porous region of the die emitted at an even shorter wavelength of 497nm, giving an estimated indium content of 0.2, the target value for the growth process.

The researchers explain: “The higher degree of relaxation in the n-InGaN layer on smaller tiles resulted in a higher n-InGaN in-plane lattice constant and led to an increased indium uptake during the growth of the InGaN MQW active region of the LEDs due to the composition pulling effect, resulting in the red-shift of the EL peak.”

The turn-on voltages were in the range 3–3.5V for reasons that are not yet well understood. One would hope that longer-wavelength devices would have a lower turn-on voltage, reflecting the narrower bandgap. Lower turn-on voltages are an important factor in power efficiency.

The emission wavelengths were largely independent of the size of the μLED mesa, showing no clear trends. The researchers believe this indicates uniform indium incorporation across the tiles.

The external quantum efficiency (EQE) of the devices was less than 0.44% at $100\text{A}/\text{cm}^2$, with the largest values being from the largest μLEDs on the $20\mu\text{m}$ tiles. The light was only measured on the sapphire side of the device within an approximate 60° half-angle exit cone. “This geometry was preferred over the measurement of packaged devices in an integrating sphere as it more accurately imitated how micro-LEDs are used in displays,” the team writes.

The better efficiency of the larger μLEDs suggests losses from the perimeter of the active area through surface recombination effects. The team comments: “Etched surfaces are known to possess crystallographic defects, impurities, nitrogen vacancies, and dangling bonds that can introduce trap states within the bandgap, which can act as non-radiative recombination centers.”

Another effect was a blue-shift with increasing current, particularly in devices on the smaller tiles. The researchers comment: “As the indium incorporation in the InGaN wells of the MQW active region increased with decreasing tile size, the barriers of the MQWs

The higher degree of relaxation in the n-InGaN layer on smaller tiles resulted in a higher n-InGaN in-plane lattice constant and led to an increased In uptake during the growth of the InGaN MQW active region of the LEDs

were still composed of AlGaIn and GaN, giving rise to higher piezoelectric fields in the LED active region and, hence, a higher quantum-confined Stark effect (QCSE). This blue-shift can be lowered by using InGaIn as barrier material in the MQWs.”

Using a 9% indium-content 180nm InGaIn base layer reduced the turn-on voltage to around 2V at the cost of up to three orders of magnitude increased reverse-bias leakage. The EL wavelength was 616nm, ‘orange’, at $60\text{A}/\text{cm}^2$, while the EQE was around 0.001% at $100\text{A}/\text{cm}^2$. The estimated indium content in the wells was 0.3. A comparison device with a 4%-indium base layer had an emission wavelength of 536nm at $60\text{A}/\text{cm}^2$.

The team reports: “Compared to the green-emitting μLEDs , as the indium composition increased in the n- $\text{In}_x\text{Ga}_{1-x}\text{N}$ base layer as well as the quantum well for the orange-emitting μLED , enhanced v-defect formation led to the introduction of a lot of leakage pathways. This led to an enhanced leakage current in the orange μLED .”

Although the EQE of the orange-emitting device was pitifully low, the researchers believe it “demonstrates the potential of this technology for the fabrication of strain-relaxed color-tunable μLEDs .” ■

<https://doi.org/10.1063/5.0011203>

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Turning point in RF GaN patenting over last 2 years

Patent activity is being driven by China, and IP is moving further down the value chain, says **Knowmade**.

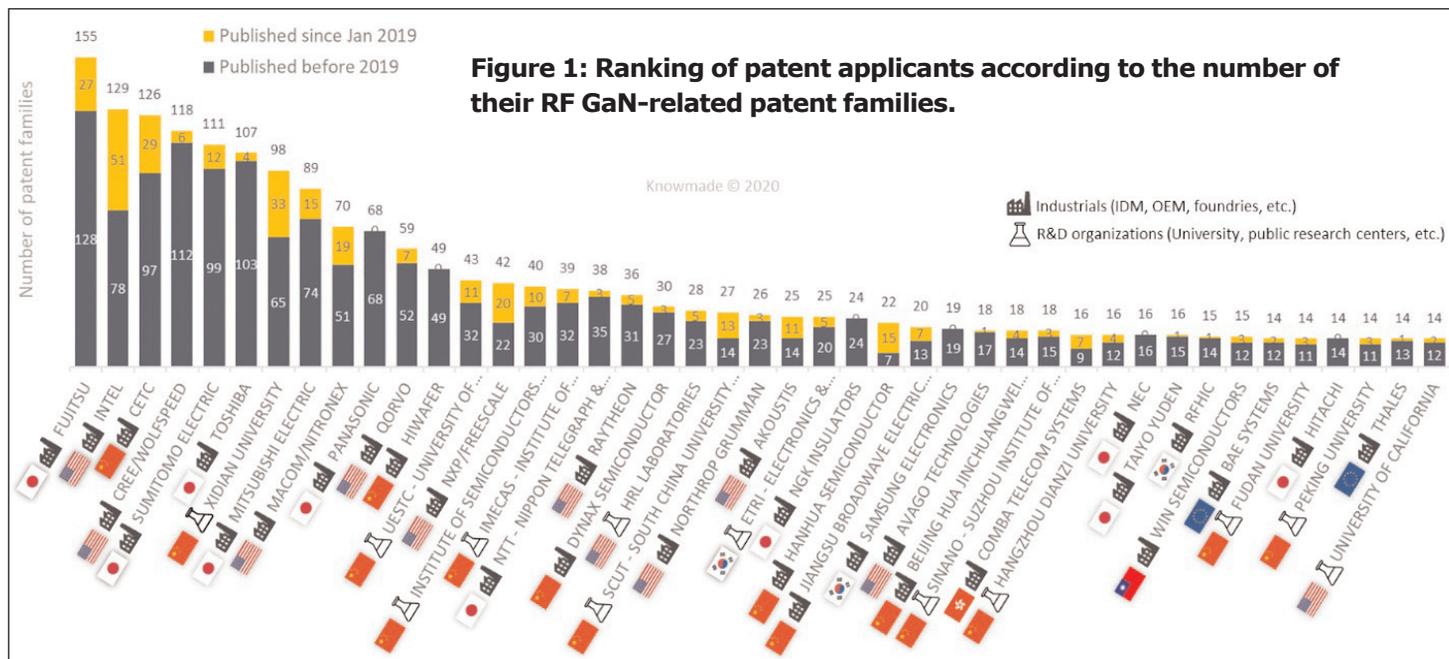
The radio frequency (RF) gallium nitride (GaN) market is seeing impressive growth, driven mainly by telecom and military applications. Yole Développement forecasts that the GaN RF market will rise at a compound annual growth rate (CAGR) of 12% from \$740m in 2019 to more than \$2bn in 2025. According to market analysts, both the COVID-19 pandemic and the US-China trade conflict have started to change the landscape of the semiconductor industry. However, the virus outbreak is likely to have minor consequences for GaN deployment. Leading Chinese telecom operators' 5G construction goals remain unchanged and development continues. Furthermore, the US-China conflict is likely to have a positive impact on Asian integrated device manufacturers (IDMs) and foundries, as well as European players.

In this context, patent analysis and technology intelligence firm Knowmade (a partner of Yole Développement) has released a new RF GaN patent landscape report, covering the whole value chain from epitaxial structures to RF devices, circuits, packages, modules and systems. The company selected and analyzed more than 6300 patents, representing more than 3000 patent families (inventions) filed by more than 500 different organizations. "This 2020 edition comprises 2x more patent families and more than 100 new players compared to

the 2019 edition," says Knowmade's CEO & co-founder Nicolas Baron.

The first RF GaN patent applications were filed in the 1990s. The level of activity took off in 2004 and accelerated significantly from 2015. Today, IP dynamics are driven by two major factors: (1) China, and (2) the shift of IP further down the value chain, says the report.

Chinese patenting activity has been accelerating since 2015. Over the last two years, there has been a remarkable increase in patents coming from China, with many Chinese newcomers entering the RF GaN IP landscape. In 2019-2020, the Chinese organizations represented more than 40% of the patent applicants (American = 23%, Japanese = 10%, European = 3%). "The rise in RF GaN patents from Chinese companies follows a more general trend as the country transitions from a manufacturing to an innovation-driven economy," says Baron. "This trend also reflects the situation in the RF industry, with a Chinese market that is showing exploding demand for commercial wireless telecom applications and Chinese companies already developing next-generation telecom networks. Moreover, following the US-China trade war, numerous China-based companies are trying to develop GaN RF for 5G infrastructures internally", he adds.



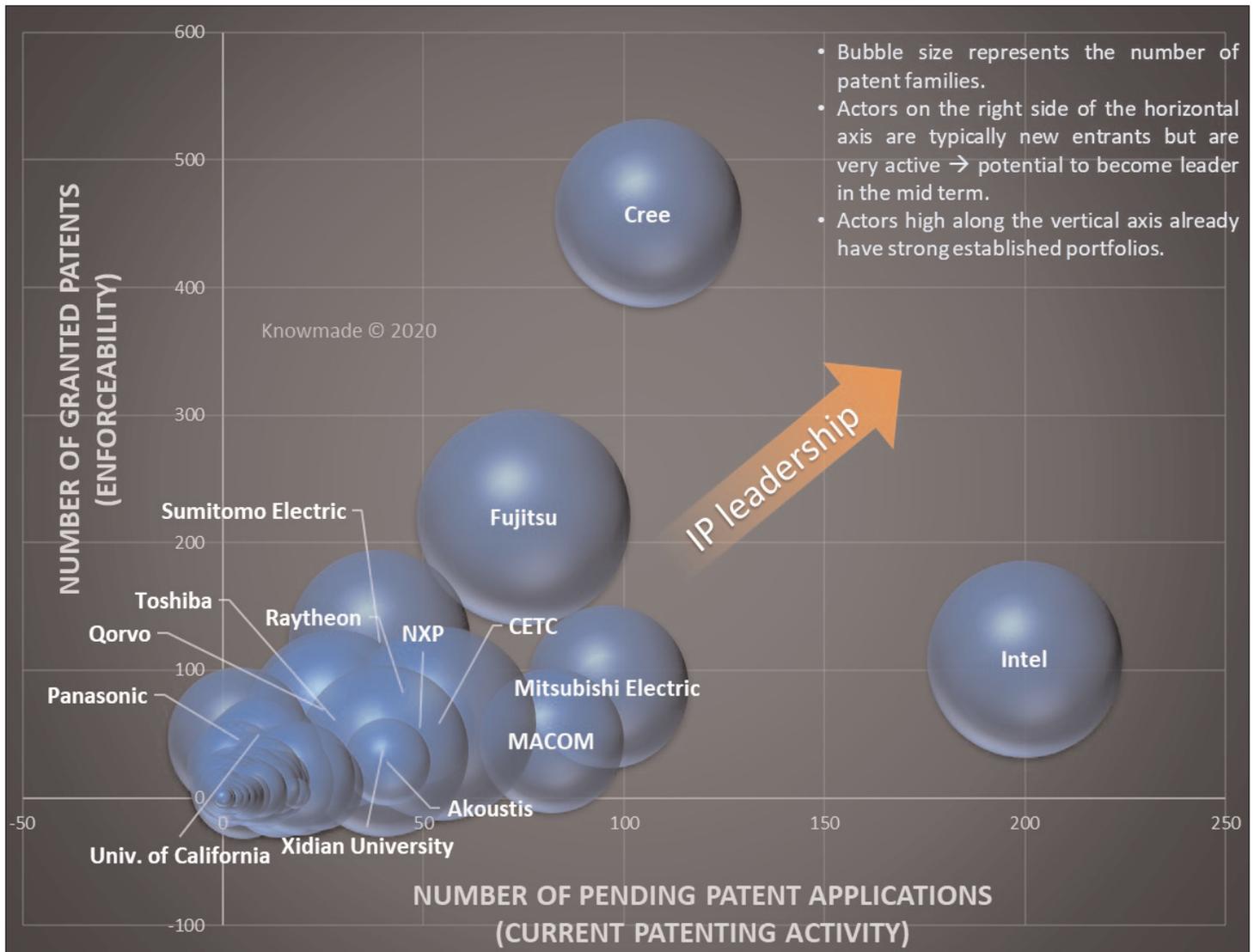


Figure 2: IP leadership of RF GaN patent applicants.

The RF GaN patent landscape is currently dominated by American and Japanese companies such as Cree, Fujitsu, Sumitomo Electric, Mitsubishi Electric, Intel, MACOM, Toshiba, Qorvo and Raytheon. The IP competition has been strongest in the USA, as demonstrated by a much greater number of granted patents (1200+) versus China (640+), Japan (440+) and Europe (250+). However, patenting activity is now focused on China.

Cree has the strongest IP position thanks to numerous fundamental patents, especially for gallium nitride on silicon carbide (GaN-on-SiC) technology. Over the past five years, inventive activity at Cree, Sumitomo Electric and Toshiba stalled, says Knowmade. These IP leaders have developed broad patent portfolios covering a wide range of RF GaN technology nodes. "The reduced IP activity could be a sign of confidence in their already robust RF GaN patent portfolio," comments Baron.

Intel and MACOM have greatly increased their IP activity since 2017, especially for GaN-on-silicon technology. Intel is currently the most active patent applicant in the RF GaN field, with a record level of activity in patenting new inventions over the last couple of

years that could, in the future, position it ahead of Sumitomo Electric, Fujitsu or Cree in terms of IP leadership, reckons Knowmade.

In China, CETC and Xidian University have the most prolific inventive activity. Other players such as HiWafer, Dynax, Hanhua and China's top public research entities UEST, IMECAS, SCUT and Institute of Semiconductors have built sizeable RF GaN IP portfolios, and numerous new players are entering the IP landscape (Boxin, Reactor Microelectronics, TUS - Semiconductor, Hatchip, Nexgo, Bosemi, HC Semitek, A-INFO, RDW, Chippacking, China Mobile, Gaxtrem, etc).

"The China IP rise should be taken seriously as it changes the landscape in which international companies operate," says Baron. While China currently emphasizes quantity over quality, many RF GaN patents from top Chinese organizations are up to international quality standards (CETC, Xidian University, HiWafer, Dynax etc). Further, some Chinese companies that have global ambitions (e.g. Dynax, Hanhua, Zhuhai Crystal Resonance, ZTE, Huawei, CCT, Nexgo) are filing or acquiring patents in key countries. Also, foreign companies

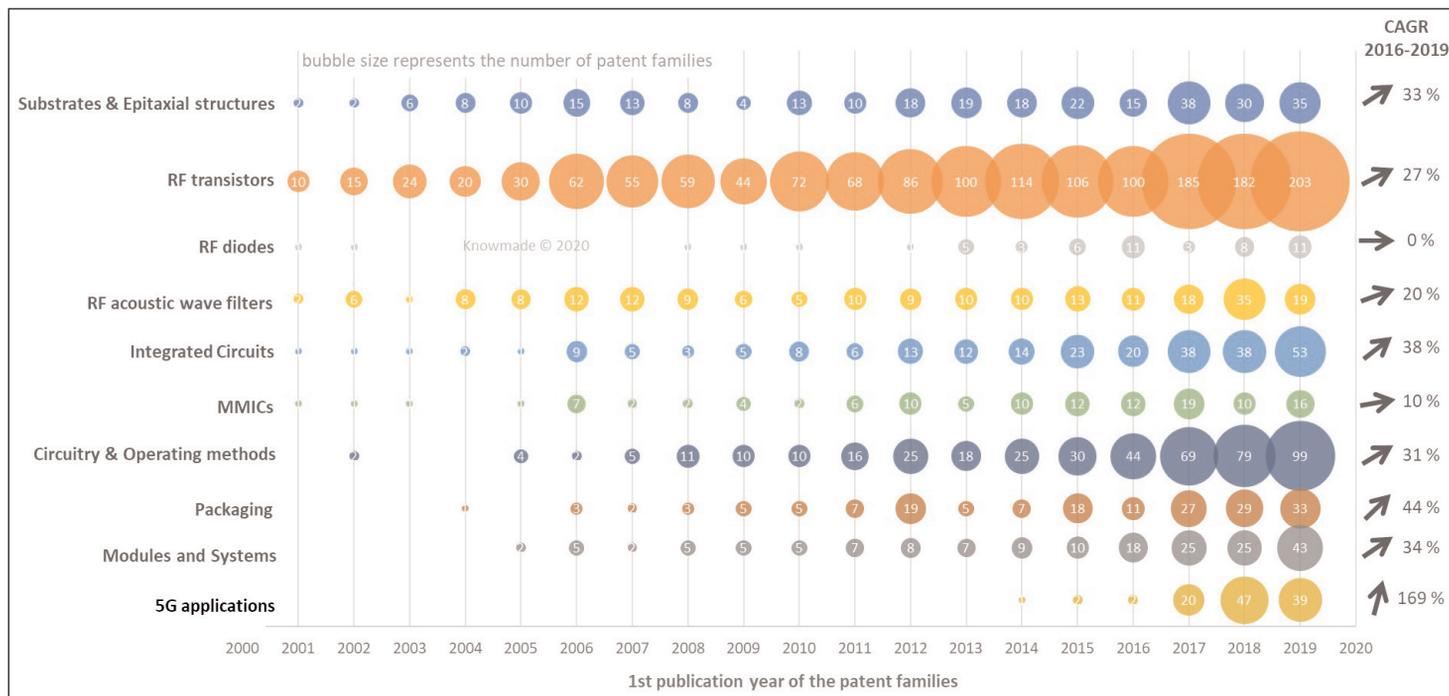


Figure 3: Time evolution of RF GaN-related patent publications for the main segments.

(such as Mitsubishi Electric, NXP) are now increasingly applying for patent protection in China. For domestic or foreign businesses operating in China, this increases the risk of patent infringement, which also becomes hard to manage.

European RF players Thales, BAE Systems, Infineon, Ampleon, Ericsson etc are only playing a small part in current RF GaN IP dynamics. In Taiwan, the foundries WIN Semiconductors, TSMC and GlobalWafers entered the RF GaN IP landscape first in the mid-2010s, followed by others such as Vanguard International Semiconductor (VIS) and Wavetek in 2018. South Korean entities are not very active in terms of patent filings. Korea’s Electronics and Telecommunications Research Institute (ETRI) has continued to file few new patents every year over the past decade. In 2016, RFHIC acquired GaN-on-diamond-related patents from Element Six. More recently, we have seen the entry of Wavice, U-Tel and Wavepia.

Over the last few years, the level of creativity to address all the technology and manufacturing roadblocks for GaN RF devices has been impressive. “More recently, IP developments are accelerating on topics further down the value chain to address manufacturing and technology issues related to monolithic integration, packaging, RF circuits and modules/systems. This trend is expected to accelerate as more mature RF products implement GaN technology,” says Baron. Current patenting activity suggests that manufacturing and technology issues still need to be resolved in the monolithic integration of different RF semiconductor devices; thermal management at the epi-stack, semiconductor device and package levels; linearity at the device and circuit levels; and protection, matching and distortion compensation at the circuit level.

In this 2020 edition of its report, Knowmade details the RF GaN IP landscape and recent patents of note related to GaN-on-SiC, GaN-on-silicon, GaN-on-diamond and GaN-on-sapphire. They describe IP activity related to RF transistors (HEMT, HBT, E-mode, etc), RF diodes (varactor, RTD, IMPATT, etc) and RF acoustic wave devices (SAW, TC-SAW, FBAR, BAW-SMR). Also, the report includes a section dedicated to GaN-based MMIC-related patents. Analysts highlight patents dealing with manufacturing and technology issues still of interest to IP players (heat dissipation, monolithic integration, linearity, impedance matching etc) and/or targeting μ W/mmWave frequency ranges or 5G telecom applications.

GaN-related patenting activity is prolific; an increasing number of players are entering the sector and the GaN IP landscape is evolving. On the one hand, some GaN startups and pure-play companies remain on the lookout for promising business opportunities and are developing transverse GaN IP portfolios to address not only RF applications but also power electronics. On the other hand, RF companies from outside the GaN industry, and OEMs, are seeking to take leading positions in RF GaN by developing patents claiming the use of GaN technology in RF modules/systems. There are now enough companies with transverse portfolios, and enough enforceable patents worldwide that address most technology issues through the whole value chain, to say that the freedom to operate of active entities is shrinking, and to predict that complex licensing and legal battles will likely arise once GaN RF devices enter high-volume commercial markets. Now the questions are: will Chinese IP shape the future of the GaN RF industry? And, which IP owners will be the GaN RF leaders in the 5G, post-COVID world? ■

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Power module market growing at 9.1% CAGR over 2019–2025

The packaging sector is growing at a 10.7% CAGR to \$2.71bn in 2025, driven by EV/HEV applications, says Yole.

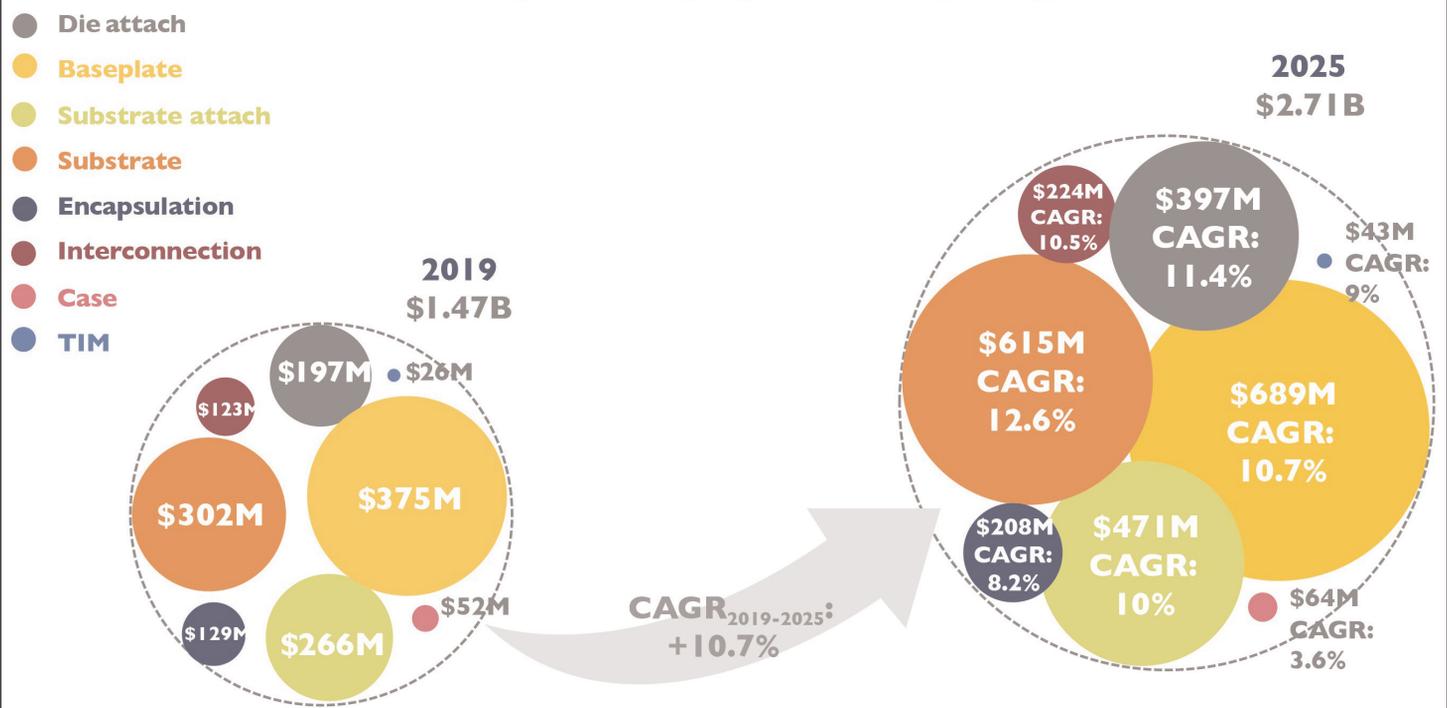
The market for power modules (one of the key elements in power converters and inverters) is rising at a compound annual growth rate (CAGR) of 9.1% over 2019–2025, to \$7.6bn, according to the annual power electronics report 'Status of the Power Module Packaging Industry' by Yole Développement.

In the past, packaging needs were driven by industrial applications, but today they are increasingly driven by electric and hybrid electric vehicles (EV/HEVs). "EVs are driving the growth of power module packaging, as going to mass production of EV/HEV changes the rules of game," says Shalu Agarwal, technology & market analyst at Yole. "Technology alone is not enough; low cost is increasingly important." In fact, by 2025 EV/HEVs will become the biggest power module market, at almost \$3.4bn. This promising

outlook is hence also beneficial for the power module packaging material market, which will grow at a CAGR of 10.7% from \$1.47bn in 2019 to \$2.71bn in 2025.

In 2019, packaging materials comprised about 31% of power module costs. The largest packaging materials market segment was for baseplates, followed by substrates. The next biggest segment was substrate-attach, followed by die-attach materials. Major technical choices in these segments can therefore rapidly impact the overall power module packaging market. For example, the market share for silver nitride as a substrate is increasing, driven especially by EV/HEVs. This technology is pricier than more conventional aluminium oxide substrates, and the CAGR for the substrate market is hence 12.6% — higher than for other market segments — between 2019 and 2025.

2019-2025 power module packaging market forecasts - Split by packaging solution



2020 Chinese players* are expanding their capabilities

(Source: Status of the Power Module Packaging Industry 2020 report, Yole Développement, 2020)



Global power module packaging giants.

*Non-exhaustive list of companies



Chinese players are also expanding their capabilities, production capacities and technological knowledge.

The huge business opportunity in the power device market is attracting interest from various players in the power electronics and automotive supply chains. With a strong focus on power modules, changes in business models and a constant re-shaping of the supply chain are expected, especially in the very dynamic power module packaging market.

Automotive tier-1 part suppliers and car-making original equipment manufacturer (OEMs) are becoming increasingly involved in the design and manufacturing of power modules. As power module packaging of semiconductor devices is a relatively new concept for system and car makers, it takes time to develop a power module with high performance and low manufacturing costs, notes Yole.

Some tier-1s and OEMs thus prefer to focus directly on newer silicon carbide (SiC) MOSFET technology, instead of facing competition from power module makers with strong experience in already well-established silicon insulated-gate bipolar transistor (IGBT) automotive power modules. This focus on SiC power module development has been strengthened by the adoption of SiC modules in traction inverters in Tesla Model 3 and BYD Han vehicles.

Chinese companies want to have as local a supply chain as possible. Subsidies are given by the government to support this. Many Chinese companies develop power module packaging solutions, mainly still using power dies supplied by European, Japanese and US companies. Most Chinese packaging companies focus on power modules for industrial applications, which are based on more conventional packaging solutions and have thus less exacting requirements on packaging

know-how. Here Chinese companies, which often have difficulty competing on a technological basis, can offer cost-competitive products.

However, Chinese players are moving very fast. With the help of leading material suppliers and equipment makers they are evaluating and testing different innovative solutions, such as sintered SiC dies, targeted primarily at EV/HEV applications.

Power module packaging technology is about more than just wire bonding, soldering and encapsulation. The packaging technologies — especially for applications with strong demand for power density, performance and reliability — are very complex and require specific know-how. In particular, continuous improvements in module materials and packaging design is needed, especially to fully benefit from the technology advantages of silicon carbide and gallium nitride. Many newcomers in power module packaging have underestimated the packaging complexity and are struggling to bring their packaging concepts to commercial production. Initially they targeted performance and reliability.

Nowadays, many players must refocus their development efforts on manufacturing processes and material choices in order to achieve 'good enough' performance and reliability while achieving acceptable manufacturing yield and throughput, enabling them to reduce manufacturing costs. External partners with the required knowhow are therefore more than welcome to speed up the development and bring products to market earlier, Yole says. ■

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Tel: +1 925 245 5817
Fax: +1 925 449-4096

www.temescal.net

Veeco Instruments Inc

100 Sunnyside Blvd.,
Woodbury, NY 11797, USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231

www.veeco.com

**7 Wafer processing
materials****Kayaku Advanced Materials Inc**

200 Flanders Road,
Westborough, MA 01581, USA
Tel: +1 617 965 5511

www.kayakuam.com

Praxair Electronics

(see section 5 for full contact details)

Versum Materials

8555 S. River Parkway,
Tempe, AZ 85284, USA
Tel: +1 602 282 1000

www.versummaterials.com

**8 Wafer processing
equipment****Evatec AG**

Hauptstrasse 1a, CH-9477 Trübbach,
Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001

www.evatecnet.com

EV Group

DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600

www.EVGroup.com

EV Group is a technology and market leader for wafer processing equipment. Worldwide industry standards for aligned wafer bonding, resist processing for the MEMS, nano and semiconductor industry.

Logitech Ltd

Erskine Ferry Road,
Old Kilpatrick, near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Plasma-Therm LLC

(see section 6 for full contact details)

SAMCO International Inc

532 Weddell Drive,
Sunnyvale, CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd

Ringland Way,
Newport NP18 2TA, UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG

Schleißheimer Strasse 90,
85748 Garching, Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Synova SA

Ch. de la Dent d'Oche,
1024 Ecublens, Switzerland
Tel +41 21 694 35 00
Fax +41 21 694 35 01
www.synova.ch

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054, USA
Tel: +1-408-748-0100
Fax: +1-408-748-0111
Contact Person: Cathy W. Hung
Email: sales@tecdia.com
www.tecdia.com

Veeco Instruments Inc

(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd

Ermine Business Park,
Huntingdon,
Cambridgeshire PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com

PLANSEE High Performance Materials

6600 Reutte, Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

10 Gas and liquid handling equipment

Cambridge Fluid Systems

12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG

Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24000
Fax: +49 89 96 2400122
www.cs-clean.com

Entegris Inc

129 Concord Road,
Billerica, MA 01821, USA
Tel: +1 978 436 6500
Fax: +1 978 436 6735
www.entegris.com

IEM Technologies Ltd

Fothergill House, Colley Lane,
Bridgwater,
Somerset TA6 5JJ, UK

Tel: +44 (0)1278 420555
Fax: +44 (0)1278 420666
www.iemtec.com

Versum Materials

8555 S. River Parkway,
Tempe, AZ 85284,
USA
Tel: +1 602 282 1000
www.versummaterials.com

11 Process monitoring and control

Conax Technologies

2300 Walden Avenue,
Buffalo, NY 14225,
USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
www.conaxtechnologies.com

k-Space Associates Inc

2182 Bishop Circle
East, Dexter, MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

KLA-Tencor

One Technology Dr,
1-2221I, Milpitas, CA 95035,
USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG

Seesener Str.
10-13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de



LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)

Bregstrasse 90,
D-78120 Furtwangen im
Schwarzwald, Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker

Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker.com

KLA-Tencor

160 Rio Robles, Suite 103D,
San Jose, CA 94538-7306, USA
Tel: +1 408 875-3000
Fax: +1 510 456-2498
www.kla-tencor.com

13 Characterization equipment

J.A. Woollam Co. Inc.

645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc

575 McCorkle Boulevard,
Westerville, OH 43082, USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Riff Company Inc

1484 Highland Avenue, Cheshire,
CT 06410, USA
Tel: +1 203-272-4899
Fax: +1 203-250-7389
www.riff-co.com

Tektronix Inc

14150 SW Karl Braun Drive,
P.O.Box 500, OR 97077, USA
www.tek.com

15 Assembly/packaging materials

ePAK International Inc

4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak

31398 Huntwood Avenue,
Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc

(see section 3 for full contact details)

Materion Advanced Materials Group

2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

CST Global Ltd

4 Stanley Boulevard,
Hamilton International Technology
Park,
Blantyre, Glasgow G72 0BN, UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

PI (Physik Instrumente) L.P.

16 Albert St . Auburn ,
MA 01501,
USA
Tel: +1 508-832-3456,
Fax: +1 508-832-0506
www.pi.ws
www.pi-usa.us

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak

10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikcpak.com

18 Chip foundry

CST Global Ltd

4 Stanley Boulevard, Hamilton
International Technology Park,
Blantyre,
Glasgow, G72 0BN,
UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

RENA Technologies NA

3838 Western Way NE,
Albany, OR 97321,
USA
Tel: +1 541 917 3626
www.rena-na.com

20 Facility consumables

PLANSEE High Performance Materials

6600 Reutte,
Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

W.L. Gore & Associates

401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Brumley South Inc

422 North Broad Street,
Mooresville, NC 28115, USA
Tel: +1 704 664 9251
Email: sales@brumleysouth.com
www.brumleysouth.com

As an ISO 9001 registered global leader in the remanufacturing of wafer inspection systems, Brumley South Inc specializes in designing, installing and supporting upgrades for ADE, Nanometrics, Dryden and KLA-Tencor Surfscan tools, polystyrene latex sphere calibration standards, particle deposition systems, and semiconductor parts and service.



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Class One Equipment Inc

5302 Snapfinger Woods Drive,
Decatur, GA 30035, USA
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Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Riff Company Inc

1484 Highland Avenue,
Cheshire, CT 06410, USA
Tel: +1 203-272-4899
Fax: +1 203-250-7389
www.riff-co.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054 ,
USA
Tel: +1-408-748-0100
Fax: +1-408-748-0111
Contact Person: Cathy W. Hung
www.tecdia.com

24 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies

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CA 95126, USA
Tel: +1 408 289 9555
www.alshultz.com

SEMI Global Headquarters

San Jose, CA 95134,
USA
Tel: +1 408 943 6900
www.semi.org

Yole Développement

69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

SEMI Global Headquarters

3081 Zanker Road,
San Jose,
CA 95134, USA
Tel: +1 408 943 6900
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10–15 January 2021

(postponed from 13–18 September 2020)

23rd European Microwave Week (EuMW 2020)

Utrecht, The Netherlands

E-mail: eumwreg@itnint.com

www.eumweek.com

14–18 February 2021

IEEE International Solid- State Circuits Conference (ISSCC 2021)

San Francisco, CA, USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

17–18 February 2021

PHOTONICS+ Virtual Exhibition & Conference, in partnership with EPIC

E-mail: photonicsplus@fleet-events.de

www.photonicsplus.com/epic

12–15 March 2021

(postponed from 22–25 July 2020)

International Congress on Advanced Materials Sciences & Engineering (AMSE)

Vienna, Austria

E-mail: eve@istci.org

www.istci.org/amse2021

17–19 March 2021

LASER World of PHOTONICS CHINA 2021

Shanghai, China

E-mail: info@world-of-photonics-china.com

www.world-of-photonics-china.com/en

21–25 March 2021

(postponed to 9–13 June 2021)

IEEE Applied Power Electronics Conference and Exposition (APEC 2021)

Phoenix, AZ USA

E-mail: registration@apec-conf.org

www.apec-conf.org

25–27 March 2021

International Conference on Nano Research and Development (ICNRD-2021) – Breakthrough and Innovation in Nano Science and Technology

Grand Copthorne Waterfront Hotel, Singapore

E-mail: laura@icnrd.com

www.istci.org/icnrd2021

28 March – 1 April 2021

(postponed to 6–10 June 2021)

Optical Networking and Communication Conference & Exhibition (OFC 2021)

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.com

www.ofcconference.org

15–16 April 2021

EPIC Annual General Meeting 2021

Radisson Blu Hotel Lietuva, Vilnius, Lithuania

E-mail: neringa.norbutaite@epic-assoc.com

www.epic-assoc.com/epic-annual-general-meeting-2020

18–21 April 2021

(postponed from 26–29 April 2020)

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2nd International Conference on UV LED Technologies & Applications (ICULTA 2021)

Berlin, Germany

E-mail: contact@icultra.com

www.ICULTA.com

20–22 April 2021

(postponed from 21–23 April 2020)

24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2021) – now a virtual, online event

Four Points by Sheraton (LAX) Los Angeles, CA, USA

E-mail: info@tjgreenllc.com

www.tjgreenllc.com/cmse

9–14 May 2021

2021 Conference on Lasers & Electro-Optics (CLEO)

San Jose Convention Center, San Jose, CA, USA

E-mail: CLEO@compusystems.com

www.cleoconference.org

11–14 May 2021

10th World Congress of Nano S&T 2021

Venetian Macao Resort Hotel, Macao, China

E-mail: esther@bitcongress.com

www.bitcongress.com/nano2021-macao

6–10 June 2021

(postponed from 28 March –1 April 2021)

Optical Networking and Communication Conference & Exhibition (OFC 2021)

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.com

www.ofcconference.org

9–13 June 2021

(postponed from 21–25 June 2021)

IEEE Applied Power Electronics Conference and Exposition (APEC 2021)

Phoenix, AZ USA

E-mail: registration@apec-conf.org

www.apec-conf.org

20–24 June 2021

International Congress on Photonics in Europe – co-located with LASER World of PHOTONICS

ICM (Internationales Congress Center München), Germany

E-mail: info@photonics-congress.com

www.photonics-congress.com/en

21–24 June 2021

LASER World of PHOTONICS 2021

Messe München, Munich, Germany

E-mail: info@world-of-photonics.com

www.world-of-photonics.com/en

22–24 June 2021 (postponed from 9–11 Feb 2021)

Strategies in Light 2021

Santa Clara Convention Center, Santa Clara, CA, USA

E-mail: registration@endeavorb2b.com

www.strategiesinlight.com

4–9 July 2021 (postponed from 14–19 June 2020)

20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)

Stuttgart, Germany

E-mail: info@icmovpexx.eu

www.icmovpexx.eu

1–5 August 2021

SPIE Optics + Photonics 2021 – Conference and Exhibition

San Diego Convention Center, San Diego, CA, USA

Abstract deadline: 20 January 2021

E-mail: customerservice@spie.org

www.spie.org/opstm

1–3 September 2021

CIOE 2021 (23rd China International Optoelectronic Exposition)

Shenzhen World Exhibition & Convention Centre, China

E-mail: cioe@cioe.cn

www.cioe.cn/en

12–17 September 2021 (postponed to 2022)

19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2021-2022)

Davos, Switzerland

E-mail: info@icscrm2021.org

www.icscrm2021.org

13–15 September 2021

ECOC 2021 (47th European Conference on Optical Communication)

Bordeaux Exhibition Centre, Bordeaux, France

E-mail: sales@ecocexhibition.com

www.ecocexhibition.com/ecoc-exhibition-2021

10–14 October 2021

27th International Semiconductor Laser Conference (ISLC 2021)

Potsdam, Germany

Abstract deadline: 14 May 2021

E-mail: islc@fbh-berlin.de

www.islc2021.org

10–15 October 2021

24th European Microwave Week (EuMW 2021)

ExCel, London, UK

E-mail: eumwreg@itnint.com

www.eumweek.com



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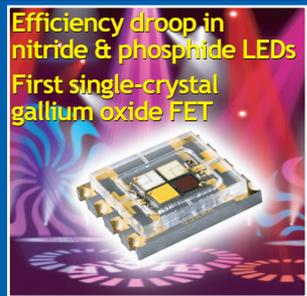


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