

## Wolfspeed selling RF unit to MACOM as it focuses on 200mm SiC ramp-up



Infineon adds to SiC fab in Kulim • Blue Laser Fusion raises \$25m  
First 4" AlN substrate • UK grant for Kubos • Comptek raises €8m



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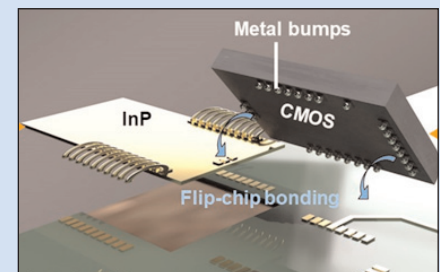
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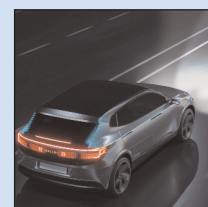
**p14** University of Arkansas has begun construction of the US national Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC).



**p15** Infineon is expanding its plant in Malaysia — over and above the original investment announced in February 2022 — by building the world's largest 200mm silicon carbide power fab.



**p82** At IMS 2023, NTT and Tokyo Institute of Technology reported the first wireless data transmission via beamforming in the 300GHz band.



Cover image: Now in volume production, ams OSRAM's EVIYOS 2.0 multi-pixel LED enables adaptive, dynamic headlight operation and image projection in automotive forward lighting, selectively illuminating the road ahead to maximize the driver's view in high-beam mode without dazzling oncoming drivers. **p46**

## Focusing on silicon carbide ramp-up

Last issue we reported news of billions being invested in silicon carbide power semiconductor device manufacturing by the likes of Wolfspeed, onsemi, Infineon, STMicroelectronics, Sanan, Rohm and Renesas, targeting industrial and automotive applications in particular.

As the transition from silicon power devices accelerates, the unprecedented demand for silicon carbide is highlighted by the latest investment in August, as Germany-based Infineon is to expand its fab in Kulim, Malaysia — beyond the original investment announced in February 2022 — by building “the world’s largest 200mm-wafer silicon carbide power fab”, backed by customer commitments covering €5bn of new design wins in automotive and industrial applications plus €1bn in pre-payments (see page 15).

The demand is shown by fiscal full-year revenue (to end-June) for Wolfspeed of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) power-switching and gallium nitride (GaN) RF devices — growing by 24% year-on-year, due to strength in both its materials and power device product lines (see pages 18–19).

In October 2022, Wolfspeed outlined its \$6.5bn plans to construct “the world’s largest state-of-the-art greenfield silicon carbide footprint”, which includes the largest 200mm SiC materials facility at the John Palmour Manufacturing Center for Silicon Carbide (JM) in Siler City, NC (which broke ground early this year) and the 200mm-wafer Mohawk Valley Fab in Macy, NY, for making SiC power devices (which was opened in April 2022). However, difficulties in ramp-up led to revenue of just \$1m from the Mohawk Valley Fab this June quarter. Relying on its existing capacity-constrained 150mm-wafer SiC device fab in Raleigh, NC meant that Wolfspeed’s revenue grew up just 3% in the June quarter, while the lower yields and higher unit costs on 150mm wafers — as well as the low 200mm fab utilization — have impacted profit margins.

In addition, since Mohawk Valley began revenue-generating production in the June quarter, factory start-up and under-utilization costs are now no longer excluded from the non-GAAP net loss, which hence tripled from the prior quarter (causing the stock price to drop sharply, despite the fundamentals being no different).

Also, Wolfspeed’s revenue from RF devices continues to be weaker than originally expected, due to recession-related pullback in 5G wireless demand.

With the firm having so far raised \$5bn of the \$6.5bn capital needed for its SiC expansion plans, on 22 August it announced an agreement to divest its Wolfspeed RF business for \$125m to MACOM Technology Solutions of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies), which will assume control of the firm’s 100mm GaN-on-SiC wafer fab in Research Triangle Park, NC, two years after finalizing the sale (see page 20). “Given the significant growth we’ve seen in automotive, industrial and renewable energy markets, we believe this is the right time to further focus on scaling our Power device and materials businesses to meet this accelerated demand,” says Wolfspeed’s president & CEO Gregg Lowe.

This marks a complete transformation for the firm initially known as Cree, focused on making GaN-based LEDs (on SiC substrates), to what will be a purely SiC-based materials and power electronics device maker.

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COMPOUNDS & ADVANCED SILICON



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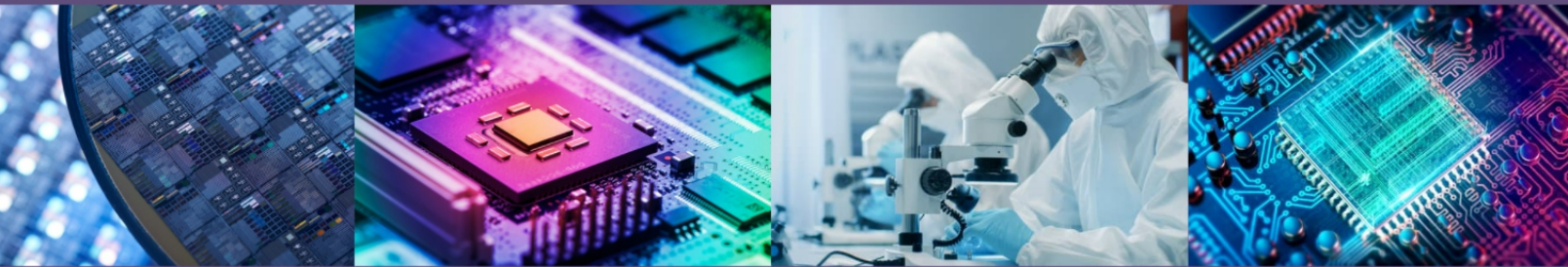
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## US DOE releases 2023 Critical Materials Assessment Supply chain security evaluated for clean energy technologies

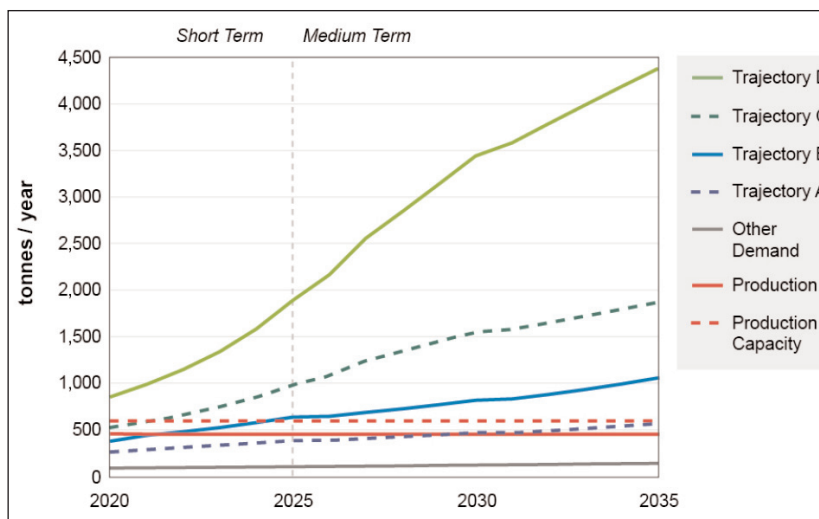
The US Department of Energy (DOE) has released its 2023 Critical Materials Assessment, which evaluated materials for their criticality to global clean energy technology supply chains and has hence determined the 2023 DOE Critical Materials List of energy-specific critical and near-critical materials through 2035.

The Assessment focuses on key materials with high risk of supply disruption that are integral to clean energy technologies. The final list includes aluminium, cobalt, copper, dysprosium, electrical steel (grain-oriented steel, non-grain-oriented steel, and amorphous steel), fluorine, gallium, iridium, lithium, magnesium, natural graphite, neodymium, nickel, platinum, praseodymium, terbium, silicon, and silicon carbide.

Gallium continues to be critical due to its use in light-emitting diodes. In addition, the use of gallium has increased both in magnet manufacturing and in semiconductors including gallium arsenide (GaAs) or gallium nitride (GaN), the Assessment notes.

The Figure shows four different demand scenarios for gallium from 2020 to 2035 against current gallium production and production capacity. Energy applications considered for gallium were LED lighting, magnets in electric vehicles (EVs) and wind turbines, solar cells, and power electronics.

There is a wide gap among the four trajectories due to different technology trends. LED demand is steadily growing for both low and high trajectories. Gallium demand for magnets in EVs and wind is highly variable because of the difference between low and high intensities. In the case of solar, because the adoption of copper indium gallium diselenide (CIGS) is shrinking, trajectories A and B



assume no CIGS market share between 2020 and 2035, while trajectories C and D assume 5% CIGS market share within the same time frame. Overall, demand for gallium in energy applications is the dominant use of gallium. Other demand not considered in the report includes the use of gallium in consumer electronics and telecommunications. As the Figure shows, 'other demand' is insignificant.

Production data were obtained from the United States Geological Survey (USGS). Of this data, high-purity refined gallium production was identified as the material form of interest due to the requirement that most semiconductor applications feature 6N purity or higher (IARC). To compute total high-purity gallium production capacity, the primary high-purity gallium production capacity 325mt was summed with the secondary high-purity gallium production capacity 273mt (USGS). Regarding current production, because recycling output is not available, an assumed 86% capacity utilization rate was used to derive production from capacity. This number, 232mt, was then added to primary high-purity gallium production, 220mt, to compute the total supply of high-purity gallium.

chains needed to manufacture our most promising clean energy generation, transmission, storage and end-use technologies, including solar panels, wind turbines, power electronics, lighting, and electric vehicles," says Alejandro Moreno, acting assistant secretary for the DOE's Office of Energy Efficiency and Renewable Energy (EERE). "Ultimately, identifying and mitigating material criticality now will ensure that a clean energy future is possible for decades to come."

Because material and technology markets are global, the Critical Materials Assessment has a global scope, placing US domestic interests in that context. For each of the critical materials identified, the DOE says it will develop an integrated strategy to address material-specific risks.

The 2023 Critical Materials Assessment was managed and funded by EERE's Advanced Materials and Manufacturing Technologies Office (AMMTO) and was conducted by Argonne National Laboratory and Idaho National Laboratory, in consultation with members of the DOE Critical Minerals and Materials Science and Energy Technology Team.

[www.energy.gov/cmm/critical-minerals-materials-program](http://www.energy.gov/cmm/critical-minerals-materials-program)

"As our nation continues the transition to a clean energy economy, it is our responsibility to anticipate critical material supply

# Micro-LED chip market to almost double to \$27m in 2023, driven by large displays and wearables

## Japanese watchmakers and Western auto-makers to drive 136% CAGR to \$580m in 2027

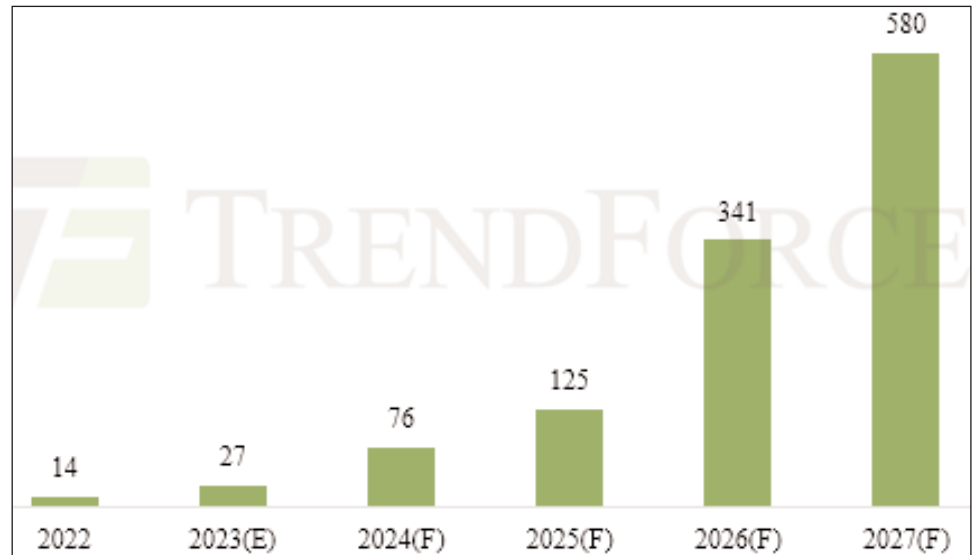
Driven by the mass production of large displays and wearable devices, the micro-LED chip market will grow by 92% year-on-year from \$14m in 2022 to \$27m in 2023, while rising at a compound annual growth rate (CAGR) of about 136% between 2022 and 2027 to \$580m due to the scaling of existing application shipments and the introduction of new applications, forecasts market research firm TrendForce.

Alongside the consistent growth in chip values, ancillary industries — such as transfer and testing equipment, glass and CMOS backplanes, and both active- and passive-matrix drive ICs — are poised for synchronous expansion, adds the firm.

This year, Samsung has unveiled an 89-inch 4K display and plans to further take advantage of the seamless splicing of micro-LEDs by introducing 101-inch and 114-inch models. South Korean brand LG Electronics is set to begin mass production of its 136-inch 4K model, utilizing a larger 22.3-inch backplane and cost-effective 16  $\mu\text{m}$  x 27 $\mu\text{m}$  chips, by the end of 2023.

Leading panel maker BOE has taken a similar trajectory, with launches aimed at bolstering growth of the overall industry. The firm launched its P0.9 active-matrix display in second-quarter 2023 and plans to release the P0.51 active-matrix display in fourth-quarter 2023. Additionally, BOE intends to introduce a turnkey solution in 2024. For brands interested in micro-LEDs, this not only diversified production acquisition channels but also contributes to the accelerated development of the overall industry.

Wearables are a key application for micro-LED this year. Pivoting from its traditional LCD operations, AUO has produced the world's first 1.39-inch micro-LED watch panel. In addition to initially providing it to



European luxury watch maker Tag Heuer, other major companies specializing in sports wearables and Japanese watch brands are all potential adopters of micro-LED wearable devices in the future, says TrendForce.

Apple's rollout of a 2.12-inch micro-LED display for the Apple Watch has been deferred from 2025 to 2026 due to supply chain adjustments. However, production operations for the micro-LED variant are already in motion, signifying possible integration into Apple's broader product range, including headsets, smartphones and automotive applications.

Booming development in recent years has provided growth opportunities for innovative automotive displays like micro-LEDs. However, due to the prolonged verification processes inherent to the auto sector, tangible mass production of micro-LED displays for vehicles might only materialize post-2026. TrendForce believes that instrument displays with high demand for reliability and brightness, technically advanced head-up displays (HUD), and transparent displays with numerous connections to autonomous driving technology are all primary avenues

for micro-LED displays to enter the automotive sector. Auto-makers from Europe, the USA and Japan are showing considerable enthusiasm toward adopting micro-LED technology.

Micro-LED displays continue to compete with technologies like LCOS (liquid-crystal on silicon), micro-OLED (organic light-emitting diode) and LBS (laser beam scanning) when it comes to augmented reality (AR) headsets. Industry leaders like Meta, Google and MIT continue to assess and assist in R&D on micro-LEDs for micro-projection displays, attracted by its balanced performance in terms of brightness, energy consumption, pixel density and light engine size.

On 5 September (9:30–17:00) at the NTUH International Convention Center in Taipei, Taiwan, TrendForce is hosting the 'Micro-LED Forum 2023', featuring senior research VP Eric Chiou, alongside industry representatives from Mojo Vision, ITRI, Lumus, Unikorn Semiconductor, Porotech, Nitride Semiconductor, Tohoku University, Coherent, InZiv, AUO and Tianma, sharing developments in micro-LED technology and its manifold applications.

<https://seminar.trendforce.com/LEDforum/2023/US>

## Qorvo's June-quarter revenue down less than expected, as Android consumer-related inventory consumption offset by growth in defense & aerospace and automotive September-quarter revenue to grow by over 50%

For its fiscal first-quarter 2024 (ended 1 July 2023), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$651.2m (down 37% on \$1035.4m a year ago but up 2.9% on last quarter's \$632.7m).

This was well above the mid-point of the \$620–660m guidance range, despite the macro-environment. Relative strength in areas like defense & aerospace and automotive was offset by inventory consumption across consumer markets and weak demand in 5G infrastructure. However, channel inventories of the firm's components in the Android ecosystem was reduced by a further 20% (following greater than 20% reductions in the prior two quarters). "We have made significant progress clearing channel inventories," notes president & CEO Bob Bruggeworth. "Qorvo continues to under-ship to end-market demand."

By business segment, revenue (compared with last quarter) comprised:

- Advanced Cellular Group (ACG) \$412m (down only slightly from \$418m, despite fiscal Q1 being the lowest seasonal point for Qorvo's largest customers);
- High-Performance Analog (HPA) \$140m (up 5% on \$133m);
- Connectivity & Sensors Group (CSG) \$99m (up 21% on \$82m).

On a non-GAAP basis, gross margin was 42.9% (down from 50% a year ago but up from 41.3% last quarter). This outperformed the expected 41.5% due to higher production levels and product mix, despite a headwind of about 800 basis points from under-utilization after factory production levels improved only modestly.

Operating expenses were \$232.7m, up from \$227.4m last quarter due to investments in multi-year customer programs, investments in core systems and other productivity initiatives, and the return of incentive compensation based on expectations for improved financial performance. However, OpEx was down slightly from \$233.8m a year ago, and less than the expected \$237m or so.

Operating income was \$46.7m (operating margin of 7.2% of revenue), down from \$284.4m a year ago but up from \$33.8m last quarter.

By operating segment, operating margin was 11% for ACG, 17% for HPA and –20% for CSG (a notable sequential improvement). However, the Qorvo Biotechnologies business reduced CSG operating income by about \$2m. "We are currently in the process of seeking strategic alternatives for this business," notes senior VP & chief financial officer Grant Brown.

Net income was \$33.6m (\$0.34 per diluted share), down from \$238.4m (\$2.25 per diluted share) a year ago but up from \$25.7m (\$0.26 per diluted share) last quarter and more than double the expected \$0.15 per diluted share.

Operating cash flow was \$44.9m, down from \$65.4m last quarter. Capital expenditure on purchases of property and equipment has risen from \$34.1m to \$39.5m. Free cash flow was hence just \$5.4m, down from \$31.3m last quarter.

During the quarter, Qorvo repurchased \$100m worth of its shares (at an average price of \$96.81 each). The firm also completed the sale of its Farmers Branch campus. Overall, cash and equivalents hence fell from \$809m to \$744m. As of quarter-end, Qorvo had about \$2bn of debt outstanding with no near-term maturities.

"Qorvo exceeded the mid-point of our June quarterly guidance for revenue, gross margin and EPS [provided on 3 May] while also continuing to reduce channel inventory," notes Brown. "The team is executing very well, working closely with our suppliers and customers while navigating a challenging macroenvironment."

Net inventory balance rose by \$121m to \$917m, driven by the seasonal ramp at Qorvo's largest customer. "We are introducing new products and technologies to increase our content in customer designs and broaden our exposure in new and existing markets," notes president & CEO Bob Bruggeworth.

During the quarter, design wins in HPA were diversified across customers and markets and included large defense programs extending multiple years.

In Connectivity and Sensors, design activity spanned a variety of applications including highly integrated IoT connectivity solutions, Wi-Fi 7 RF front ends and force-sensing touch sensors. "We have a broad range of growth drivers in CSG and we are pleased with our increasing design activity in new growth areas like sensors and ultra-wideband," says Bruggeworth.

"Over time, we see HPA and CSG contributing increasingly to growth, diversification and margin expansion," he adds.

In Advanced Cellular, design activity continued to be favorable across all leading smartphone OEMs. "We are growing our content and next-generation 5G smartphones at our largest customers and we are capturing new content in the Android ecosystem as 4G units transition to 5G and enter our SAM [serviceable available market]," says Bruggeworth. "In calendar 2023,



approximately 45% of Android smartphones will be 5G and we expect Android 5G smartphone unit growth to post double-digit CAGR for several years," he adds.

Strategic highlights during the quarter

### ● **Connectivity & Sensors Group (CSG)**

In automotive applications, Qorvo was selected by an automotive tier-one to supply ultra-wideband (UWB) connectivity for an upcoming EV launch by US-based maker. "We are pleased with this win and the growing content opportunity in automotive where the ultra-wideband content inside the car will typically include five to seven placements plus one placement in each key fob," says Bruggeworth.

Qorvo also secured multiple touch sensor design wins (totaling multiple billions of dollars) enabling force-level detection in a range of smart interior applications including center console, door panel, steering wheel and display.

In Automotive Connectivity, Qorvo was selected by a leading automotive antenna supplier to provide cellular V2X front-end modules (FEMs) and bulk acoustic wave (BAW) coexistence filters for use by a major European-based OEM.

Qorvo also expanded its automotive footprint with an automotive radar design win to supply a receive amplifier for a major US-based automotive OEM. The firm's automotive opportunities include DC-to-DC converters, onboard chargers, smart interiors, RF front ends for 5G, Wi-Fi and V2X connectivity, radars and ultra-wideband secure car access for key fobs and inside cars.

In Wi-Fi, Qorvo secured several Wi-Fi 7 design wins with access point providers for its Wi-Fi 7 BAW filters enabling full coverage of 2.4GHz, 5GHz and 6GHz bands. The firm also began sampling tier-one customers for its next-generation Wi-Fi 7 FEMs which paired with multiple chipsets. "In our Connectivity Systems business, we were among the first

to achieve Matter 1.1 certification for our concurrent connect integrated solutions for gateways and devices," says Bruggeworth. "This expands our market opportunity and support of top smart home ecosystem customers whose installed base exceeds \$150m home networks," he adds.

### ● **High-Performance Analog (HPA)**

In silicon carbide, Qorvo booked a multi-million dollar customer order for silicon carbide (SiC) power devices supporting artificial intelligence (AI) servers and other data-center applications. "The design-win funnel for Qorvo's silicon carbide power devices is increasing and we continue to expand our supply base to support our customers," says Bruggeworth. In addition to the previously announced supply agreement with SK Siltron, the firm also has agreements in place with Wolfspeed and Coherent.

For defense communications, Qorvo began sampling the industry's first 2–18GHz integrated transmit & receive Tx/Rx front-end module, delivering 10W of transmit power. This highly integrated wideband solution integrates the power amplifier (PA), switch, low-noise amplifier (LNA) and limiter, and leverages Qorvo's advanced packaging and process technologies to maximize power efficiency in a miniaturized footprint. "The form factor and functional density of our solution is especially critical given the trend in our defense & aerospace business of one-to-many," says Bruggeworth.

"In addition to manned aircraft, there will be many more drones. In addition to large keyhole satellites, there will be many more low Earth orbit (LEO) satellites. These future communication systems and system upgrades incorporate more electronics, requiring greater integration across higher volumes."

"For broadband applications, we extended our leadership in DOCSIS 4.0 with customer sampling of our 1.8GHz hybrid power doubler," says Bruggeworth. "This solution

delivers more RF power with lower power consumption than competing solid-state solutions," he claims.

In Cellular Infrastructure, Qorvo released a highly integrated 3.4–3.8GHz, 8W power amplifier module (PAM) that simplifies 5G massive MIMO system design. The firm also began sampling what is claimed to be the industry's first C-band discrete BAW band-pass filter for 5G small-cell radios.

### ● **Advanced Cellular Group (ACG)**

With Android smartphone OEM customers, Qorvo began sampling its newest highly integrated power amplifier duplexer (PAD), which combines in a single-placement low-, mid- and high-(LMH) band main-path functionality that is currently offered in two placements. This new architecture reduces surface area by 40% to simplify design and decrease time-to-market for massive 5G phones, says the firm. This follows Qorvo's announcement last quarter that it had begun sampling a mid/high-band PAD that combines the main-path and diversity receive content for the mid and high bands. Both placements leverage a broad range of Qorvo process technologies, including its newest BAW and SAW filters.

Qorvo also commenced customer sampling of its next-generation antenna tuners, providing smartphone OEMs with what is claimed to be best-in-class linearity, the industry's smallest solution size, and compatibility with all major chipsets.

### **Outlook**

Considering the current demand environment, further consumption of channel inventory and seasonal factors, for fiscal second-quarter 2024 (to end-September 2023) Qorvo expects revenue to grow sequentially by over 50%, to \$1bn plus or minus \$15m, driven primarily by content gains at the firm's largest customer. Gross margin should rise to 45–46%.

Operating expenses are expected to increase to about \$240m. ➤

► “In addition to growth-oriented investments across our product and technology portfolios, we are also targeting enterprise-wide productivity initiatives. We’re simplifying and rationalizing processes and upgrading the core systems we use to run the business,” notes Brown. “We will present these productivity investments as non-GAAP other operating expenses. These multi-year efforts will support future growth and enhanced profitability as we upgrade, modernize and standardize around the latest tools and best practices.”

Diluted earnings per share are expected to rise to \$1.75 in fiscal Q2/2024.

“We expect our inventory balance will decrease in the September quarter as we support a seasonal ramp [of new products] at our largest customer,” says Brown.

“In terms of channel inventory, the environment continues to improve. We anticipate channel inventories will continue to decline

this quarter,” says Brown. “Later this calendar year, we expect Android channel inventories will normalize,” he adds. “Outside of the Android ecosystem, there are smaller pockets of channel inventory. They will take longer to digest.”

During fiscal second-half 2024 (to end-March 2023), Qorvo expects sequential declines in gross margin during Q3 and again in Q4, primarily related to utilization and mix. Operating expenses for Q3 and Q4 are expected to be \$240–245m per quarter, with variability related to the timing of product development spend, investments in core systems and related productivity initiatives, incentive compensation based on expectations for improved financial performance, the timing of the Biotechnology business disposition as well as other items.

“We forecast fiscal 2024 revenue will be above fiscal 2023 and expect to benefit from strong dollar content growth at our largest customer,” says Brown. Gross margin

is expected to be about 44% (down from fiscal 2023’s 46.3%).

“As we clear the channel inventory across Android and as utilization returns to a level in which we’re shipping to end-market demand, we should have a clear path back towards the 50% gross margins we’ve enjoyed in the past,” says Brown. Issues are two-fold, he adds. “There is the inventory we have on hand, which is already burdened with the cost of that under-utilization in the past. Then there is the forward-looking utilization within the current quarter as we meet future demand or build product for future demand. Both of those can weigh on the quarter and are in that 800 basis points. The under-utilization of the current period, if it’s extreme, can hit as period charges and we’ve experienced some of those as well. As we re-synchronize our factories to end-market demand, we should have a clear path back.”

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# Skyworks' June-quarter revenue down 13% year-on-year due to ongoing inventory digestion for Android

## Revenue to rebound by 13% sequentially in September quarter

For fiscal third-quarter 2023 (to end-June), Skyworks Solutions Inc of Irvine, CA, USA (which makes analog and mixed-signal semiconductors) has reported revenue of \$1071.2m, down 7% on \$1153.1m last quarter and 13% on \$1232.6m a year ago.

Skyworks' largest customer Apple remained about 64% of total revenue.

Mobile Products comprised about 59% of total revenue, with broad content gains across the firm's largest customer's product portfolio being offset by ongoing weakness in demand from the Android smartphone ecosystem as those OEMs continue to reduce their inventories.

Broad Markets comprised about 41% of total revenue, with another strong contribution from the automotive, infrastructure and industrial markets. Specifically, automotive applications posted double-digit year-on-year revenue growth.

On a non-GAAP basis, gross margin has fallen further, from 51.2% a year ago and 50% last quarter to 47.5%, driven mostly by temporary factory under-utilization as the firm right-sizes its inventory levels.

Operating expenses have been cut further, from \$257.5m a year ago and \$190m (16.5% of revenue) last quarter to \$182m, outperforming the targeted \$183–187m, given the ongoing focus on managing discretionary expenses.

Net income has fallen further, from \$393.6m (\$2.44 per diluted share) a year ago and \$323.1m (\$2.02 per diluted share) last quarter to \$276.3m (\$1.73 per diluted share, although this exceeds the \$1.67 guidance).

Operating cash flow was \$305.7m (taking the year-to-date operating cash flow to a record \$1.491bn). Capital expenditure has been cut further, from \$125.1m a year ago and \$45.3m last quarter to \$31.3m.

Free cash flow was hence \$274m. The first three quarters of fiscal 2023 generated record free cash flow of \$1.35bn and record free cash flow margin of 38%.

During the quarter, Skyworks paid \$98.7m in dividends and repaid \$500m of its 2023 notes at maturity.

Overall, cash, cash equivalents and marketable securities hence fell from \$1061.4m to \$739.5m.

### Quarterly business highlights

In mobile and Internet of Things (IoT) applications, Skyworks:

- secured 5G content for Android smartphones across all tiers with Google, Samsung, Oppo, Vivo and Xiaomi;
- delivered Sky5 platforms for the 5G broadband customer premise equipment (CPE) of leading North American carriers;
- supported the launches of Wi-Fi 7 tri-band routers with NETGEAR and TP-Link;
- powered Bell's Wi-Fi 6E Giga Hub home gateway;
- continued to gain design-win momentum with its 5GHz cognitive wireless audio system-on-chip solutions, supporting Samsung's Q-Symphony soundbars.

Across infrastructure and industrial applications, Skyworks:

- enabled 5G small-cell deployments with a top North American operator;
- ramped timing solutions for artificial intelligence (AI) data centers at a leading cloud provider.

**Skyworks expects 13% sequential revenue growth to \$1.19–1.24bn. However, reflecting the cyclical impact of lower factory utilization while the firm is reducing its internal inventories, gross margin will remain 47–48%**

In automotive applications, Skyworks:

- captured designs for telematics applications across a broad range of domestic and China-based OEMs;
- extended its engagements by leveraging its power isolation portfolio with a North American electric vehicle (EV) supplier.

"Our targeted investments in next-generation technologies are generating solid momentum going into the second half of calendar year 2023," reckons chairman, CEO & president Liam K. Griffin.

### Revenue to grow 13% in September quarter

For fiscal fourth-quarter 2023 (to end-September), considering the seasonal impact from major product launches, Skyworks expects 13% sequential revenue growth to \$1.19–1.24bn. However, reflecting the cyclical impact of lower factory utilization while the firm is reducing its internal inventories, gross margin will remain 47–48%.

Operating expenses are expected to be \$178–182m, down 6.5% year-on-year as the firm continues to optimize operating efficiencies while making the necessary investments in technology and product development "to further enhance our leadership position in Mobile and drive diversification and growth in our Broad Markets business," says senior VP & chief financial officer Kris Sennesael.

Diluted earnings per share is expected to rise 21% sequentially to \$2.10.

"Given our conviction in Skyworks' long-term strategic outlook and consistent strong cash generation, we announced a 10% increase in our quarterly dividend to \$0.68 per share [from \$0.62 per share]," says Sennesael. The dividend is payable on 19 September to stockholders of record at the close of business on 29 August.

[www.skyworksinc.com](http://www.skyworksinc.com)

# Sivers receives \$375,000 award under DARPA NGMM program in collaboration with PseudolithIC

## PseudolithIC's heterogeneous integration technology to combine with Sivers' RF SOI beamforming chipsets

Chip and integrated module supplier Sivers Semiconductors AB of Kista, Sweden says that its US subsidiary Sivers Semiconductors Inc has received an award worth \$375,000 (about 4MSEK) under the US Defense Advanced Research Projects Agency (DARPA) Next-Generation Microelectronics Manufacturing (NGMM) program in collaboration with PseudolithIC Inc of Santa Barbara, CA, USA. The program aims to develop three-dimensional heterogeneously integrated (3DHI) technologies. PseudolithIC and Sivers will specifically investigate 3DHI systems for millimeter-wave (mmWave) applications in the 5G, SATCOM and defense sectors.

Three-dimensional heterogeneous integration involves the heterogeneous integration of disparate mat-

erials and components, enabled by advanced packaging that leverages all three dimensions. The DARPA NGMM program is a complementary effort to the US CHIPS Act, a \$52.7bn program designed to invigorate American semiconductor research, development, manufacturing and workforce development. Sivers and Pseudolithic will specifically focus on the heterogeneous integration of Sivers' high-performance radio-frequency silicon-on-insulator (RF SOI) beamformers with III-V front ends for millimeter-wave 5G, SATCOM and defense applications.

"One of our major goals with the acquisition of MixComm (today part of Sivers Wireless), was to get a better footprint in the US market. I cannot see any better acknowledgment than getting this award

from the DARPA NGMM program," says Sivers Semiconductors' group CEO Anders Storm. "Working in this project on the next-generation mmWave applications in the 5G, SATCOM and for the defense sectors is a fantastic step for Sivers," he adds.

"We are excited to team PseudolithIC's innovative heterogeneous integration technology with the proven performance of Sivers' RF SOI beamforming chipsets," comments PseudolithIC's CEO Dan Green. "This combination of silicon and III-V technology will enable access to the millimeter-wave spectrum with performance and scale surpassing any single, monolithic technology."

Sivers expects all revenue from the award to be recognized in 2023.

[www.sivers-semiconductors.com](http://www.sivers-semiconductors.com)

## Bastani joins Sivers Semiconductors as strategic advisor

### Industry veteran to provide guidance on semiconductor, photonics, 5G and SATCOM ecosystems

Sivers Semiconductors AB of Kista, Sweden says that Dr Bami Bastani has joined it as a strategic advisor to the board and management to further strengthen the firm's focus on the US and global markets and to provide guidance related to the semiconductor, photonics, 5G and SATCOM ecosystems.

Bastani has over four decades of extensive experience in the industry, most recently as senior VP & general manager at GLOBALFOUNDRIES, where he led the high-growth Mobile and Wireless Infrastructure business unit. He transitioned to senior VP & senior advisor to the CEO in August 2022 through March 2023. He has also served on the board of directors of the Global Semiconductor Alliance (GSA).

Bastani's leadership roles have spanned multiple industries that include semiconductor components (Intel, National Semiconductor), system-on-a-chip (Fujitsu Micro, Trident Microsystems), systems and software (Meru Networks including WiFi as a Service -WAAS-on-the-Cloud) and manufacturing services (GLOBALFOUNDRIES). He has also served as the growth and turnaround CEO of several public companies, including ANADIGICS, Trident Microsystems, and Meru Networks.

"Bami Bastani is a strategically important addition to our team and fits perfectly with the company's strategy to develop and expand our business," says Sivers Semiconductors' chairman Tomas Duffy. "I look very much forward to work

with Bami and the board to further strengthen our position in the US."

Bastani is "an industry veteran who offers in-depth knowledge directly relevant to the Sivers ecosystem and strategic market presence," comments group CEO Anders Storm. "Bami will support our continued growth journey, especially in the US which will further strengthen our position," he adds.

"Sivers is uniquely positioned in photonics, 5G and SATCOM, all of which are critical to the mega trends in connectivity for data centers, point-to-point high-speed data transitions, edge-to-edge connectivity for AI and autonomous vehicles, to mention a few examples," comments Bastani,

# Arkansas begins construction of US national Multi-User Silicon Carbide Research and Fabrication Facility

## MUSiC to enable government, businesses and universities to prototype in silicon carbide

The University of Arkansas (U of A) has begun construction of the US national Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC). Capable of silicon or silicon carbide chip fabrication, the new semiconductor research and fabrication facility will enable the government, businesses of all sizes, and universities to prototype in silicon carbide, introducing a capability that does not presently exist in the USA.

The unique facility will offer low-volume prototyping for high-volume manufacturing, bridging the gap between traditional university research and the needs of private industry. The aim is to accelerate both workforce development and technological advancement in semiconductors by providing a single location where chips can go from developmental research to prototyping, testing and fabrication.

With MUSiC, the university could “begin training the next generation at a variety of degree levels to provide well-trained and educated talent for onshoring semiconductor manufacturing that domestic suppliers offshored in the late 90s and early 2000s,” says principal investigator Alan Mantooh, Distinguished Professor of electrical engineering. “Our training will be equally applicable to silicon and silicon carbide and other materials.”

Construction coincides with the CHIPS America Summit on 17 August, an invitation-only event for research, industry and governmental leaders from across the nation to discuss CHIPS and Science Act semiconductor-related opportunities.

The summit features Adrienne Elrod, director of external & government affairs for the US Department of Commerce’s CHIPS Program Office. US Representative Steve Womack and Arkansas



**Artist’s rendering of the national Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC).**

Secretary of Commerce Hugh McDonald are also participating.

### **Existing and expanding research foundation**

In addition to the MUSiC facility, the U of A is also home to the first Energy Frontier Research Center in Arkansas, as part of a team of researchers who received \$10.35m from the US Department of Energy. The Center for Manipulation of Atomic Ordering for Manufacturing Semiconductors is dedicated to investigating the formation of atomic orders in semiconductor alloys and their effects on various physical properties. This research program aims to enable reliable, cost-effective and transformative manufacturing of semiconductors.

Researchers at the U of A previously established the MonArk NSF Quantum Foundry to accelerate the development of quantum

materials and devices. In collaboration with Montana State University and other member universities, the foundry supports the study of 2D materials — consisting of a single layer of bonded atoms — by aiding researchers and facilitating the exchange of ideas across academia and industry. The project leads the fabrication of 2D material quantum devices and their characterization, using low-temperature electronic transport and optoelectronic techniques.

The U of A reckons that its existing and expanding research foundation means that it’s uniquely positioned to take advantage of the recent CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act, which is providing about \$280bn in funding to stimulate domestic research and manufacturing of semiconductors.

As a result of manufacturing and production shortages of essential computer chips during the pandemic, which are overwhelmingly manufactured overseas, the federal government has prioritized the onshoring of this critical technology.

<https://research.uark.edu>

**The university could begin training the next generation at a variety of degree levels... Our training will be equally applicable to silicon and SiC**

# Infineon expanding Kulim fab investment with €5bn second phase for Module Three

## World's largest 200mm SiC power fab anchored by €5bn in design wins plus €1bn in prepayments

Infineon Technologies AG of Munich, Germany is to significantly expand its fab in Kulim, Malaysia — over and above the original investment announced in February 2022 — by building the world's largest 200mm-wafer silicon carbide (SiC) power fab. The planned expansion is backed by customer commitments covering about €5bn of new design wins in automotive and industrial applications as well as about €1bn in pre-payments.

Over the next five years Infineon will invest up to €5bn in Kulim during a second construction phase for Module Three. The investment will lead to an annual SiC revenue potential of about €7bn by the end of the decade, together with the planned 200mm SiC conversion of the existing fabs in Villach, Austria and Kulim. This manufacturing base will support Infineon's SiC market share target of 30% towards the end of the decade. Infineon says it is confident that its SiC revenue in the fiscal year 2025 will come in ahead of the target of €1bn.

"The market for silicon carbide shows accelerating growth, not only in automotive but also in a broad range of industrial applications such as solar, energy storage and high-power electric vehicle (EV) charging," says CEO Jochen Hanebeck. "With the Kulim expansion, we will secure our leadership position in this market," he reckons. "With the industry's leading scale and a unique cost position, we are leveraging our competitive position of best-in-class SiC trench technology, the broadest package portfolio and unrivaled application understanding. These factors are the areas of differentiation and success in the industry."

Infineon has been awarded new design wins of about €5bn along



Rendering of Infineon's manufacturing site in Kulim, Malaysia.

with about €1bn in prepayments from existing and new customers. In the automotive sector this comprises six OEMs (including three from China). Among the customers are Ford, SAIC and Chery. In the area of renewable energies, customers include SolarEdge and three leading Chinese photovoltaic and energy storage systems companies. In addition, Infineon and Schneider Electric agreed on a capacity reservation including prepayments for power products based on silicon and silicon carbide. The prepayments will contribute positively to Infineon's cash flow in the coming years and shall be fully repaid in connection with the agreed sales volumes by 2030 at the latest.

"Malaysia is putting in maximum efforts to meet its national target to decarbonize its economy and achieve net zero by 2050," said Malaysia's Prime Minister The Right Honourable Dato' Seri Anwar bin Ibrahim, who expresses his appreciation for Infineon's commitment to creating a significant wide-bandgap hub in the country. "Infineon's vision on green technology and sustainability puts it right

at home in Malaysia."

"Infineon's expansion of their world-class silicon carbide facility in Kulim marks a significant milestone in

Malaysia's

pursuit of developing advanced manufacturing capabilities, creating high-skilled employment opportunities and positioning the country at the forefront of enabling green technologies, which are crucial to achieving our global sustainable development goals," comments His Hon. Tengku Datuk Seri Utama Zafrul Aziz, the Minister of Investment, Trade and Industry (MITI). "The innovative power semiconductor technologies manufactured in the SiC power fab will also bolster Malaysia's position as a key player in the world's semiconductor ecosystem, with a growing role specifically in the sustainable technology supply chain," he adds. "I look forward to our long-term partnership for the further development of Malaysia's green technologies ecosystem."

Infineon notes that sustainability is also a key element in the planning, construction and operation of the fab, adding that the building is designed in a way that allows Infineon to make responsible use of resources such as electricity and water.

[www.infineon.com](http://www.infineon.com)

## Mitsubishi Electric to ship samples of NX-type full-SiC power semiconductor modules for industrial equipment

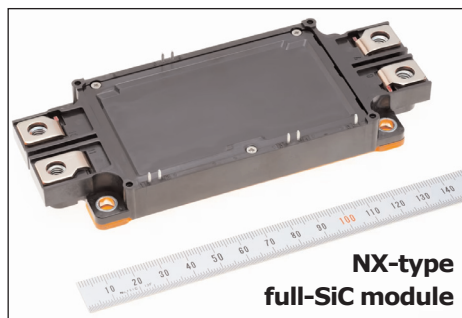
### Internal inductance cut by 47% versus silicon IGBT-based module

Tokyo-based Mitsubishi Electric Corp has begun shipping samples of its new NX-type full-SiC (silicon carbide) power semiconductor module for industrial equipment.

Mitsubishi Electric began releasing power semiconductor modules incorporating SiC chips in 2010. The new module features a low-loss second-generation SiC chip and an electrode structure optimized with laminated electrodes to achieve reduced internal inductance of 9nH, 47% lower than that of the existing module.

Reduced internal inductance suppresses voltage surges in order to protect equipment, allowing fast switching while also lowering switching loss and power loss.

The low-loss second-generation SiC chip incorporates junction field-effect transistor (JFET) doping technology (which increases device density by increasing impurity



**NX-type  
full-SiC module**

density in the JFET area). Compared with the existing module (the CM600DX-34T of the 1700V/600A NX-type silicon IGBT module T-series), this reduces power loss by about 72%, contributing to more efficient equipment. Reduced power loss helps to reduce heat generation, allowing the use of smaller and lighter-weight coolers.

With a voltage rating of 1700V and current rating of 600A (and dimensions of 62mm x 152mm x 17mm), the new FMF600DXE-34BN module is expected to contribute to the

realization of more efficient, smaller and lighter-weight industrial equipment.

Also, the NX-type package compatibility allows the new module to easily replace the current version. Despite inclusion of the SiC chip, the external dimensions and pin configurations are compatible with the NX-type module, facilitating easy replacements that can help to speed up the design of new equipment.

Development of the SiC module was partially supported by Japan's New Energy and Industrial Technology Development Organization (NEDO).

Mitsubishi Electric says that it will continue to expand its lineup of power semiconductor modules to further contribute to more efficient, smaller and lighter industrial equipment.

[www.ims-ieee.org/ims2023](http://www.ims-ieee.org/ims2023)  
[www.MitsubishiElectric.com/](http://www.MitsubishiElectric.com/)

## ROHM Semiconductor receives Continental's Supplier of the Year award

Continental Automotive of Hanover, Germany has honored Japan-based ROHM Semiconductor with its 'Supplier of the Year 2022 Award' for "particularly exemplary performance".

Since 2008, Continental has conducted an annual analysis to identify exceptional contributions in customer satisfaction and at all levels of quality, supply, engagement and purchasing conditions. This is the sixth time in the last 15 years that ROHM has received this award.

Taking place on 2 August at the historic Herzogssaal in Regensburg, Germany, the award ceremony was the first onsite event after three years of virtual presentations due to the pandemic.

"We are eager to continue our strong collaboration and shape the technological transformation in the



**At the award ceremony in Regensburg (from left to right): Jürgen Braunstetter, senior VP of supply chain management at Continental; Peter Popp, head of automotive purchasing at Continental; Heiko Metzger, automotive sales director at ROHM; Marek Vyskocil, VP purchasing electronics at Continental; Kai-Uwe Brinkmann, senior VP purchasing electronics at Continental; Sebastian Rodemeyer, global key account manager at ROHM; Continental's CEO Nikolai Setzer and ROHM Semiconductor Europe's president Wolfram Harnack.**

Automotive market earlier together," stated Peter Popp, head of automotive purchasing at Continental.

"We have a long history with Continental," noted Wolfram Harnack, president of ROHM Semiconductor Europe of Willich near Dusseldorf, Germany. "ROHM strives to build long-term and sustainable partnerships with its customers and to continuously contribute to their product quality and customer satisfaction."

[www.continental-corporation.com](http://www.continental-corporation.com)  
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# Wolfspeed's margins fall further while 200mm silicon carbide device fab ramp-up lags

## 20% utilization by mid-2024 to yield \$100m quarterly revenue from 200mm fab, then return to 50% margins

For its fiscal full year (to end-June), Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has reported revenue growth of 24%, from \$746.2m in 2022 to \$921.9m for 2023, due to the strength in both materials and power device product lines.

Fiscal fourth-quarter revenue of \$235.8m exceeded the \$212–232m guidance, due mainly to favorable timing related to product shipments out of the Durham production facilities (which are constrained by running at full capacity for power devices). However, this was up just 3% on both last quarter's \$228.7m and \$228.5m a year ago. RF revenue continued to be weak, as expected, while revenue from the new Mohawk Valley silicon carbide device fabrication facility in Marcy, NY (opened in April 2022 to produce SiC power devices on larger, 200mm wafers) was just \$1m.

On a non-GAAP basis, quarterly gross margin has fallen further, from 36.5% a year ago and 32.3% last quarter to 29% (at the low end of the 29–31% guidance). This was impacted by lower yields and higher costs on the firm's taller 150mm SiC boules as well as a heavier mix of products for high-volume automotive customers that were initially slated to be produced in the Mohawk Valley 200mm SiC device fab but had to be run on the smaller-diameter 150mm wafers in the Durham fab. Fiscal full-year gross margin has hence fallen from 2022's 35.6% to 32.6% for 2023.

Net loss from continuing operations was \$52.8m (\$0.42 per diluted share), more than tripling from \$16m (\$0.13 per diluted share) last quarter and doubling from \$26m (\$0.21 per diluted share) a year ago. This also

exceeded the expected \$21–29m (\$0.17–0.23 per diluted share). However, the non-GAAP loss now includes \$39.5m (\$0.26 per share) of impact from factory start-up costs, related primarily to Mohawk Valley and includes early-phase start-up costs related to the firm's materials expansion, primarily for the JP materials facility (John Palmour Manufacturing Center for Silicon Carbide) in Siler City, NC.

Likewise, fiscal full-year net loss has grown from 2022's \$115.4m (\$0.96 per diluted share) to \$180.7m (\$1.45 per diluted share) for 2023, but this was impacted by \$160.2m of factory start-up and under-utilization costs.

"When a new facility begins revenue-generating production, the operating costs of that facility that were previously expensed as start-up costs [excluded from non-GAAP results] will instead be primarily reflected as part of the cost of production within the cost of revenue, net line item [and hence included in non-GAAP results] in our statement of operations," says Lowe. "For example, our new silicon carbide device fabrication facility in Marcy, New York began revenue-generating production at the end of fiscal 2023 and the costs of operating this facility going forward will be primarily reflected in cost of revenue, net in future periods," he adds.

"We are making these changes in our presentation to align with the Securities & Exchange Commission, which has clarified its guidance related to non-GAAP measures for public companies," says chief financial officer Neill Reynolds.

Net cash used in operating activities was hence \$51.9m (up from \$11m last quarter). Capital expenditure (CapEx) has risen further, from \$55.4m a year ago and \$233.9m last quarter to \$402.9m. Free cash

outflow was hence \$454.8m (up from \$245m last quarter and \$86.2m a year ago).

Nevertheless, in late June Wolfspeed announced a \$1.25bn secured note financing from an investment group led by Apollo Global Management Inc, with an accordion feature for up to an additional \$750m. Cash, cash equivalents and short-term investments hence rose during fiscal Q4/2023 from \$2248.2m to \$2955m.

"Last October, we outlined our [\$6.5bn] plans to construct the world's largest state-of-the-art greenfield silicon carbide footprint," says CEO Gregg Lowe. "Since then, we've secured \$5bn of the capital necessary to achieve these goals, allowing us to finish out the fit out of Mohawk Valley, expand our materials capacity at Durham, and break ground on the world's largest 200mm silicon carbide materials facility at the John Palmour Manufacturing Center for Silicon Carbide in Siler City, North Carolina," he adds.

"As far as our more immediate strategy to increase 200mm materials production at Building 10 on our Durham campus, we have now installed more than 75% of the crystal growers in that facility... and producing excellent quality material, which is translating into very nice and very excellent defect-density wafers," says Lowe. "Epi at 200mm is also excellent, and we are ramping that."

Customer design-ins were \$1.6bn in fiscal Q4, amounting to \$8.3bn for full-year 2023. The cumulative total is now more than \$19bn over the last four years.

"We have made great strides in diversifying our device customer base across the automotive, industrial and energy sectors, with flagship agreements with key OEMs and tier-1s, including Jaguar

Land Rover, Mercedes, BorgWarner, and ZF," says Lowe. "We are also continuing to see growth in the traditional industrial and energy segments as customers make the transition to silicon carbide. We are seeing many opportunities in solar and energy systems, motor drives, UPS, heat pumps, air conditioning, and many more. The growth in these segments is primarily driven by the need for higher energy efficiency. In addition, emergent industrial applications such as e-mobility, electric vertical take-off and landing (VTOL) aircraft, are also integrating Wolfspeed silicon carbide within their initial designs to reduce system weight and improve range," he adds.

"Our customer wins to date give us the confidence in the growth of our addressable market and our ability to capture meaningful share of the device market between now and the end of the decade," says Lowe.

For its fiscal first-quarter 2024 (to end-September), Wolfspeed targets revenue of \$220–240m, with power device revenue from the Durham fab remaining capacity-constrained at about \$100m per quarter. RF revenue will be flattish for fiscal first-half 2024 (before perhaps a modest pickup in the second half).

Gross margin is expected to fall to 10–18% in fiscal Q1, since this will now include about \$37m of under-utilization costs (–16% of gross margin) as the Mohawk Valley fab (which will be capable of generating \$2bn in revenue at full capacity) continues to ramp up production. "We have three products that are currently fully qualified at the Mohawk Valley fab, and we have eight additional products that now pass all reliability testing and are working through the final end of qualification for that," says Lowe. "As we transition Mohawk Valley from pre-production to an active production facility in the first quarter of fiscal 2024, these costs will be categorized as under-utilization costs and will be part of cost of

goods sold," he adds.

"We expect underlying gross margin performance, excluding under-utilization, to improve modestly in the quarter as we continue to serve more automotive customer mix out of the Durham fab," stresses Reynolds.

Operating expenses should rise to about \$120m in fiscal Q1. However, this will include about \$8m of factory start-up costs in connection with the materials expansion efforts (primarily related to the JP materials facility in Siler City, NC). Excluding start-up costs, OpEx increases quarter-over-quarter are driven by higher employee-related expenses.

Net loss is hence expected to rise to \$75–94m (\$0.60–0.75 per diluted share).

"We still have some work to do at Mohawk Valley as we scale device production, and expect a modest increase in device revenues in the first half of fiscal 2024, with a steeper increase in revenue beginning in the second half of 2024," says Lowe.

Given that growth will be governed by how quickly Wolfspeed ramps up 200mm substrate capacity and, in turn, the Mohawk Valley fab, for fiscal full-year 2024 Wolfspeed hence continues to expect revenue of \$1–1.1bn (reduced in May by 35% from the \$1.6bn forecast given at last's October Analyst Day).

CapEx should be about \$2bn, mostly related to the build-out at JP. "Customers are continuing to select Wolfspeed for their future silicon carbide device needs, so we must remain keenly focused on scaling our materials and device capacity in fiscal 2024," concludes Lowe.

**Customers are continuing to select Wolfspeed for their future silicon carbide device needs, so we must remain keenly focused on scaling our materials and device capacity in fiscal 2024**

From a materials perspective, in early July Wolfspeed has signed a 10-year wafer supply agreement with automotive semiconductor device maker Renesas Electronics Corp. "The agreement includes a \$2bn customer deposit, which is one of the largest deposits I have ever seen in my 30-plus years in semiconductors. This will secure a capacity corridor as they begin to ramp silicon carbide device production beginning in 2025," says Lowe. "Securing this key customer was possible because of our forward-thinking investments in material capacity at the Durham campus and with the construction of the JP. We will be uniquely positioned to drive the industry transition from 150mm to 200mm silicon carbide wafers, which will help address some of the supply–demand mismatch which currently exists today and potentially open up new markets for silicon carbide applications in the industrial and energy sectors," he adds.

"Fully built out, the JP will add 10 times more capacity compared to our current operations in Durham, significantly increasing the world's total supply of silicon carbide materials," says Lowe. "The building foundation is in place, and we've now started construction on the shell of the building. We remain on track to begin producing wafers at the site in the second half of calendar 2024," he adds.

"While we are still aligned on previous expectations that we will reach 20% utilization out of Mohawk Valley by the end of fiscal 2024, it will be the second half of the calendar year 2024 before we see \$100m of quarterly revenue from the fab that the 20% utilization would represent. This accounts for the time between fab starts and shipments to our customers," notes Reynolds. "As we shift to higher levels of production out of Mohawk Valley, we anticipate future improvements in gross margin [to over 50%, as unit economics are better than the Durham fab]."

[www.wolfspeed.com](http://www.wolfspeed.com)

# Wolfspeed selling RF business to MACOM for \$125m

## Wolfspeed focusing on US capacity expansion to support silicon carbide power device and materials businesses

Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has agreed to sell its radio frequency business (Wolfspeed RF) to MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies) for about \$75m in cash (subject to a customary purchase price adjustment) plus 711,528 shares of MACOM common stock, valued at \$50m based on its 30 trading day average through 21 August.

“Given the significant growth we’ve seen in automotive, industrial and renewable energy markets, we believe this is the right time to further focus on scaling our Power device and materials businesses to meet this accelerated demand,” says Wolfspeed’s president & CEO Gregg Lowe. “This transaction also represents a tremendous opportunity for our RF team to grow and operate at scale, leveraging MACOM’s diverse customer base, RF engineering leadership and operational efficiencies.”

As well as its product development pipeline, Wolfspeed RF has expertise supporting a gallium nitride (GaN) on silicon carbide product portfolio optimized for next-generation

telecommunications infrastructure, military and other commercial applications. Serving a broad customer base of aerospace, defense, industrial and telecommunications customers, Wolfspeed RF most recently generated annualized revenue of about \$150m. Leveraging MACOM’s diverse customer base and operational expertise, Wolfspeed RF is reckoned to be well positioned to continue to deliver products at scale.

“The RF team’s engineering capabilities, technology and products are a perfect fit with MACOM and our strategy,” comments MACOM’s president & CEO Stephen G. Daly.

**Given the significant growth we’ve seen in automotive, industrial and renewable energy markets, we believe this is the right time to further focus on scaling our Power device and materials businesses to meet this accelerated demand. This transaction also represents a tremendous opportunity for our RF team to grow and operate at scale**

MACOM will assume control of Wolfspeed’s 100mm GaN wafer fabrication facility in Research Triangle Park, North Carolina (the RTP Fab) approximately two years after closing the transaction to accommodate Wolfspeed’s relocation of certain production equipment. Prior to that, the shares of MACOM’s stock that Wolfspeed receives at closing will be subject to restrictions on transfer.

The acquisition also includes design teams and associated product development assets in Arizona, California and North Carolina, as well as back-end production capabilities in California and Malaysia. In addition, MACOM will be assigned or licensed an intellectual property portfolio including more than 1400 patents associated with the RF business.

A workforce of about 280 is expected to join MACOM at closing, with additional employees joining when the RTP Fab conveys.

Subject to the expiration of the waiting period under the Hart–Scott–Rodino Antitrust Improvements Act of 1976 (HSR) and satisfaction of customary closing conditions, the transaction is expected to close by the end of 2023. The acquisition is expected to be immediately accretive to MACOM’s non-GAAP earnings.

[www.macom.com](http://www.macom.com)  
[www.wolfspeed.com](http://www.wolfspeed.com)

## Wolfspeed adjusts September-quarter revenue outlook from \$220–240m to \$185–205m

Based on the agreement to sell Wolfspeed RF, the operations of the RF business will be classified as discontinued operations. Wolfspeed is hence updating its guidance to reflect continuing operations only.

For fiscal first-quarter 2024

(to end-September), Wolfspeed targets revenue from continuing operations of \$185–205m (compared with \$220–240m previously).

Non-GAAP net loss from continuing operations remains unchanged from 16 August’s business outlook of \$75–94m (\$0.60–0.75 per

diluted share). This excludes \$63–69m of estimated expenses (net of tax) related to stock-based compensation expense, amortization of debt issuance costs, net of capitalized interest, project, transformation and transaction costs and loss on Wafer Supply Agreement.

# US DOE renews funding for PowerAmerica Institute

## Continued investment in WBG technologies to accelerate more powerful, energy-efficient power electronics

The US Department of Energy (DOE)'s Advanced Materials and Manufacturing Technologies Office (AMMTO) has announced renewed funding for PowerAmerica, a public-private research initiative established in 2014 that is the DOE's first Clean Energy Manufacturing Innovation Institute.

PowerAmerica will receive an initial \$8m, with potential funding across four more fiscal years to follow, to continue advancing domestic manufacturing of wide-bandgap (WBG) semiconductors for power electronics to aid economy-wide decarbonization and electrification.

WBG semiconductors enable power electronics that are used in a range of applications — including industrial equipment, data centers, consumer devices, and electric vehicles. Silicon carbide (SiC) and gallium nitride (GaN) WBG semiconductor technology makes the power electronic modules significantly more powerful and energy efficient than those made from conventional semiconductor materials, namely silicon. These high-performance power electronics can increase electric vehicle driving range; help to integrate renewable

energy into the electric grid; and lead to significant energy savings.

"The work PowerAmerica — and its 82 member organizations spanning industry, academia and national labs — is doing to galvanize commercialization of high-performance power electronics is invaluable to our clean energy future," comments AMMTO director Chris Saldaña.

"PowerAmerica has catalyzed an innovation ecosystem that touches nearly every sector up and down each supply chain."

Based in Raleigh, NC, USA, PowerAmerica has commercialized over 10 WBG technologies over five years. So far, 40% of PowerAmerica's 60 projects have reached or are set to reach commercial status.

Not only is PowerAmerica innovating semiconductors that surpass operational limitations of traditional silicon-based designs but it also focuses on training the future workforce of the USA's manufacturing sector through its education and workforce development (EWD) program. Since launching in 2014, PowerAmerica has trained more than 400 masters and PhD students, 300 short-course attendees, 1800 tutorial participants, and 9000

K-12 students in STEM programs, including 2000 participants of hands-on trainings. This is particularly important in addressing the acute workforce shortage that the power electronics industry faces, and scaling up PowerAmerica's existing EWD program is a proposed focus of the new federal funding.

The latest federal funding builds upon initial federal funding of \$70m, in addition to \$81m in cost share from its member partners, for a total of \$151m.

PowerAmerica is one of seven Clean Energy Manufacturing Innovation Institutes supported by two of the DOE's Energy Efficiency and Renewable Energy program offices: the Advanced Materials and Manufacturing Technologies Office (AMMTO) and Industrial Efficiency and Decarbonization Office (IEDO). In addition, PowerAmerica is one of the 16 member institutes of Manufacturing USA, a national network of manufacturing innovation institutes for advanced manufacturing through large-scale public-private collaboration on technology, supply chain, and education and workforce development.

[www.poweramericainstitute.org](http://www.poweramericainstitute.org)

# MACOM appoints Wayne Struble as senior VP, Advanced Semiconductor Technology

MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies) has appointed Wayne Struble as senior VP, Advanced Semiconductor Technology.

Struble has served as a MACOM Distinguished Fellow of Technology since joining the firm in 2010. He is an expert in RF, microwave and millimeter-wave integrated circuit design, semiconductor device modeling and testing, compound semi-

conductor process development and wireless communication system design. During his 40-year career, Struble has made technical contributions to the semiconductor industry in the areas of gallium arsenide (GaAs) and gallium nitride (GaN) circuit design and process development, published more than 25 technical papers and holds more than 50 patents in the field of RF and microwave semiconductors. He earned a B.S. in Electrical Engineering and an M.S. in

Electrical Engineering from Michigan Technological University.

"Wayne has the rare capability of understanding the complex relationship between semiconductor material science, circuit topologies and IC performance," comments president & CEO Stephen G. Daly. "He is a true innovator, and I am excited to see him take on this leadership role in which he will collaborate with and inspire our engineering teams."

[www.macom.com](http://www.macom.com)

# Navitas' revenue grows 35% in Q2/2023

## Operating expenses and losses cut; customer pipeline exceeds \$1bn

For second-quarter 2023, gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA has reported revenue of \$18.1m (exceeding the \$16–17m guidance range), up 35% on \$13.46m last quarter. This is also up 110% on \$8.6m a year ago, although this is aided by the acquisition in August 2022 of silicon carbide power semiconductor device designer and manufacturer GeneSiC Semiconductor Inc of Dulles, VA, USA.

"As the only pure-play, next-gen, power semi company, our leading-edge GaN and SiC technologies are delivering extraordinary growth in both near-term revenue and our customer opportunity pipeline across all key markets including electric vehicles (EV), renewable energy, data-center, appliance/industrial and mobile segments," says CEO & co-founder Gene Sheridan.

Cumulative shipments now exceed 100 million GaN and 12 million SiC devices.

On a non-GAAP basis, gross margin was 41.5% down from 41.6% a year ago but up from 41.1% last quarter.

Operating expenses have been cut slightly, from \$17.8m last quarter to \$17m.

Net loss was \$8.65m (\$0.05 per share), cut from \$10.9m (\$0.07 per share) last quarter.

Despite this, cash and cash equivalents rose from \$100.8m to \$177.7m during the quarter, after completing a \$2m equity offering.

Specific market highlights in Q2/2023 are listed as follows:

### ● *Electric vehicles (EV):*

Strong growth in both on-board and roadside fast chargers, with new EV consortium plans for 30,000 fast chargers in the USA alone, creating additional demand for high-voltage GeneSiC products. The number of customer pipeline projects is up by more than 50%.

### ● *Data center:*

Artificial intelligence (AI) processing demands have been doubling every 3.4 months. Pipeline projects are up by more than 50%. The latest AI processors, such as NVIDIA's GH200, consume up to 1000W of power. There is a significant opportunity for GaN power ICs to meet these dramatic increases in the required power, efficiency and density. A new 3.2kW GaN IC-based server power supply platform delivers what is claimed to be industry-leading power density of 100W/in<sup>3</sup> and over 96% efficiency to surpass the EU's 'Titanium' specification.

### ● *Solar/ESS (energy storage systems):*

Despite some market softness, the firm is experiencing a rapid increase in GaN and SiC adoption in solar inverters and energy

storage systems, with attach rates doubling, now up to 60%. The customer pipeline revenue per solar/ESS customer project has more than doubled.

### ● *Appliance/Industrial:*

The major trend to electrification is leading to a doubling of customer pipeline projects based on demand for high-efficiency, motor drive applications including dish-washers, refrigerators, washing machines, air conditioners, heat pumps, factory automation, robotics and HVAC systems.

### ● *Mobile:*

Despite global consumer softness, the firm is experiencing significant growth in China and South Korea for mainstream models at Xiaomi, Oppo, Samsung and dozens of others as Navitas' GaN-based chargers have achieved system-cost parity with silicon chargers.

During Q2/2023, Navitas' customer pipeline rose by 30% from \$760m to over \$1bn, with growth in both the number of customer projects and revenue potential across all target markets.

For third-quarter 2023, Navitas expects revenue to grow to \$21m plus or minus 2%. Given expected continued strength in the lower-margin mobile market, gross margin is expected to be relatively flat on Q2. Operating expenses should rise to \$18.5–19.5m.

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# Navitas' CRPS185 3200W 'Titanium Plus' server power platform meets demands of AI data-centers

## GaN integrated power ICs deliver high-speed, high-efficiency power in 40% smaller size than silicon solutions

Gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA says that its CRPS185 3200W 'Titanium Plus' server reference design not only surpasses the stringent 80Plus Titanium efficiency requirements but also effectively satisfies the increasing power demands of AI data-center power.

The rapid development and deployment of artificial intelligence (AI) including OpenAI's ChatGPT, Microsoft's Bing with AI, and Google's Bard, has penetrated all aspects of people's lives. New power-hungry AI processors like NVIDIA's DGX GH200 'Grace Hopper' demand up to 1600W each, and are driving power-per-rack specifications from 30-40kW up to 100kW per cabinet. Meanwhile, with the global focus on energy conservation and emission reduction, as well as the latest European regulations, server power supplies must exceed the 80Plus 'Titanium' efficiency specification.

Navitas says that its reference designs dramatically accelerate customer developments, minimize time-to-market, and set industry benchmarks in energy efficiency, power density and system cost, enabled by GaNFast power ICs. These system platforms include complete design collateral with fully tested hardware, embedded software, schematics, bill-of-materials, layout, simulation and hardware test results.

In this case, the 'Common Redundant Power Supply' (CRPS) form-factor specification was defined by the hyperscale Open Compute Project, including Facebook, Intel, Google, Microsoft, and Dell. Now, Navitas' CRPS185 platform delivers a full 3200W of power in only 1U (40mm) x 73.5mm x 185mm



(544cc), achieving 5.9W/cc, or almost 100W/in<sup>3</sup> power density. This is a 40% size reduction versus the equivalent legacy silicon approach and easily exceeds the Titanium efficiency standard, reaching over 96.5% at 30% load, and over 96% stretching from 20% to 60% load, creating a 'Titanium Plus' benchmark, critical for data-center operating models.

The CRPS185 uses the latest circuit designs including an interleaved CCM (continuous conduction mode) totem-pole PFC (power factor correction) with full-bridge LLC. The critical components are Navitas' new 650V GaNFast power ICs, with robust, high-speed integrated GaN drive to address the sensitivity and fragility issues associated with discrete GaN chips. Additionally, GaNFast power ICs offer extremely low switching losses, with a transient-voltage capability up to 800V, and other high-speed advantages such as low gate charge ( $Q_g$ ), output capacitance ( $C_{OSS}$ ) and no reverse-recovery loss ( $Q_{rr}$ ). As high-speed switching reduces the size, weight and cost of passive components in a power supply, Navitas estimates that GaNFast power ICs save 5% of the LLC-stage system material cost, plus \$64 per power supply in electricity over three years.

Compared with traditional 'Titanium' solutions, the Navitas CRPS185 3200W 'Titanium Plus' design running at a typical 30% load can reduce electricity consumption by 757kWh, and decrease carbon dioxide emissions by 755kg over three years (equivalent to saving 303kg of coal). Not only does it help data-center clients achieve cost savings and efficiency improvements but it also contributes to the environmental goals of energy conservation and emission reduction.

In addition to data-center servers, this solution can also be widely used in applications such as switch/router power supplies, communications, and other computing applications.

"The popularity of AI applications like ChatGPT is just the beginning. As data-center rack power increases by 2x-3x, up to 100kW, delivering more power in a smaller space is key," says Charles Zha, VP & general manager of Navitas China. "We invite power designers and system architects to partner with Navitas and discover how a complete roadmap of high-efficiency, high-power-density designs can cost-effectively and sustainably accelerate their AI server upgrades."

[www.navitassemi.com](http://www.navitassemi.com)

# Transphorm's quarterly revenue grows 14% year-on-year to \$5.9m, boosted by Government contract revenue

## Return to sequential product revenue growth due in September quarter

For its fiscal first-quarter 2024 (to end-June 2023), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — has reported revenue of \$5.883m, up 14.1% on \$5.16m a year ago, and up 84% on \$3.192m last quarter due to the delay in securing a new government contract with the \$15m National Security Technology Accelerator (NSTXL) to manufacture GaN epiwafers under the ECLIPSE project, recognizing revenue of \$2.9m during the quarter.

There was hence roughly an equal split between Government contract revenue (which was up \$2.2m year-on-year) and Product revenue (which was down slightly from \$3.2m last quarter to about \$3m).

Nevertheless, the firm has achieved continued capacity increases, with record monthly epiwafer output from its epiwafer operations in Japan, and released two additional reactors for process development at GlobalWafers' epiwafer operations.

Gross margin was 36%, up from just 5% last quarter, and exceeding the expected 30–34%.

On a non-GAAP basis, operating expenses were \$6.83m, up from \$5.43m a year ago but cut from \$7.55m last quarter.

Net loss was \$4.5m (\$0.08 per share), up on \$4.23m a year ago but cut from \$7.24m (\$0.13 per share) last quarter, and outperforming the expected \$0.10–0.13 loss per share.

During the quarter, cash, cash equivalents and restricted cash fell by \$12.7m, from \$16m to \$3.3m. But this was due mainly to Transphorm, in April, fully repaying its \$12m loan from Nexperia (and ending its exclusivity for Nexperia in the four-wheeler electric vehicle segment).

Also, this does not include gross proceeds of \$7.94m (\$7.6m net) from the rights offering concluded at the end of July. “We are now beginning our previously announced strategic review of Transphorm with the goal of maximizing shareholder value, encompassing potential strategic and/or traditional equity or debt financing, US- and Asia-based licensing opportunities, and M&A opportunities,” says the firm.

Highlights during the quarter were:

### High-power segment update

- Total design-ins for higher power (300W–7.5kW) grew by 25% from the prior 60 in June to over 75 (with over 30 in production), with traction in segments such as micro-inverter and computing.

- Multiple 1.5–7.5kW-range Titanium-rated power supplies with Transphorm GaN in production validate opportunities in AI computing and data-center power, enabling higher efficiencies and higher power densities, from power gaming graphics cards to data-center power supply units (PSUs), with fundamental patents for the underlying GaN topology.

- Transphorm achieved the industry milestone of demonstrating up to 5µs short-circuit withstand time (SCWT) using a patented approach, and in collaboration with Yaskawa Electric Corp, proving the firm's ability to meet the required SCWT capabilities of rugged power inverters such as servo motors, industrial motors, and electric vehicle power-trains

**We are now beginning our strategic review... encompassing potential strategic and/or traditional equity or debt financing, US- and Asia-based licensing opportunities, and M&A opportunities**

served traditionally by silicon insulated-gate bipolar transistor (IGBTs) or silicon carbide (SiC) MOSFETs — a total addressable market (TAM) for GaN of over \$3bn.

- Transphorm is working on multiple 300W–2kW charger platforms at leading Asia-based electric 2- and 3-wheeler companies, including a top-3 market leader company in India.

- The firm demonstrated a 600W battery-charging solution with Super GaN FETs achieving over 1% efficiency gain (14% loss reduction) versus silicon superjunctions while reducing power device count by 25% in a smaller GaN device versus a silicon device — cheaper than silicon, with higher performance.


- The position in the automotive EV market was strengthened through 1200V FET advancements: a simulation model was released and is receiving interest from both tier-1 automotive OEMs and ODMs.

### Low-power segment update

- Design-ins for power adapters and fast chargers (<300W) grew by 10% from the prior update of over 90 in June to over 100 (with over 30 in production).

- Multiple notebook charger designs, including inbox wins, are now shipping for several of the top-5 OEMs, with production at tier-1 ODMs.

- Traction was achieved with the firm's SiP strategy with versatility in using the same Transphorm FET for 65W and 100W adapter designs, a crossover not possible with competing E-mode GaN.

- Transphorm secured a system-in-package (SiP)-based design win that is expected to ramp to multi-million units annually, starting in fiscal second-half 2024, at leading OEMs supplying diversified consumer power accessory products. 



## Return to sequential product revenue growth in September quarter

Transphorm has continued to grow its 5-year pipeline opportunity — by 3% from the previous update of \$440m in June to over \$450m now. With traction in design-ins and design wins of the past few quarters, and opportunities nearing production, the firm expects to resume sequential product revenue growth in

fiscal second-quarter 2024 (to end-September 2023).

“Our differentiated and highly patented products/platforms for the high-power segments are gaining momentum in key targeted market areas — computing, energy & industrial and EVs,” president, CEO & co-founder Primit Parikh.

“The net proceeds from our rights offering, together with an anticipated non-dilutive debt financing, will enable

us to continue to execute on our long-term growth plans and, along with the strategic review process, allow for enhancing and maximizing shareholder value,” he adds.

“A combination of our wins in the market, our pipeline and our strengthened balance sheet all will enable us to maximize growth in the future,” concludes chief financial officer Cameron McAulay.

[www.transphormusa.com](http://www.transphormusa.com)

## Transphorm’s GaN first to hit short-circuit robustness milestone key for motor drives

### Collaboration with Yaskawa leverages Transphorm’s normally-off platform

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — has demonstrated up to 5µm short-circuit withstand time (SCWT) on a GaN power transistor with a patented technology. The achievement is claimed to be the first of its kind on record. It proves Transphorm GaN’s ability to meet the required short-circuit capabilities of rugged power inverters such as servo motors, industrial motors, and automotive powertrains served traditionally by silicon insulated-gate bipolar transistors IGBTs or silicon carbide (SiC) MOSFETs — a total addressable market (TAM) for GaN of over \$3bn over the next five years.

The demonstration was developed with support from Transphorm’s 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). It is reckoned that this makes GaN a highly attractive power conversion technology for servo systems, as it allows for higher efficiency and reduced size compared with

incumbent solutions. To do that, GaN must pass stringent robustness tests — of which, short-circuit survivability is the most challenging. In case of short-circuit faults, the device must survive extreme conditions with both high current and high voltage. The system can take up to a few microseconds to detect the fault and shut down the operations. During this time, the device must withstand the fault on its own.

“If a power semiconductor device cannot survive short-circuit events, the system itself may fail. There was a strong perception that GaN power transistors could not meet the short-circuit requirements needed for heavy-duty power applications such as ours,” says Motoshige Maeda, department manager of Fundamental R&D Management Department, Corporate Technology Division, Yaskawa. “Having worked with Transphorm for many years, we believed that perception to be unfounded and have been proven right today,” he adds. “We’re excited about what their team has accomplished and look forward to demonstrating how this new GaN feature can benefit our designs.”

The short-circuit technology has been demonstrated on a newly designed 15mΩ 650V GaN device.

Notably, that device reaches a peak efficiency of 99.2% and a maximum power of 12kW in hard-switching conditions at 50kHz. The device demonstrated not only performance but also reliability, passing high-temperature high-voltage stress requirements.

“Standard GaN devices can withstand short-circuit for only a few hundredths of nanoseconds, which is too short for fault detection and safe shut-down. However, with our cascode architecture and key patented technology, we were able to demonstrate short-circuit withstand time up to 5µm with no additional external components, thus retaining low cost and high performance,” notes Transphorm’s chief technology officer & co-founder Umesh Mishra.

“We understand the demands of high-power, high-performance inverter systems,” he adds. “We have a long history of strong innovation, and we’re proud to say that experience helped us bring GaN to the next level.”

The full description explaining the SCWT achievement, the demonstration analysis, and more is expected to be presented at a major power electronics conference next year.

[www.yaskawa.co.jp/en](http://www.yaskawa.co.jp/en)  
[www.transphormusa.com](http://www.transphormusa.com)

# Odyssey signs letters of intent with customers for early-access sampling program

## Vertical GaN power device maker's foundry business gains two new customers in Q2/2023

Odyssey Semiconductor Technologies Inc of Ithaca, NY, USA — which develops high-voltage vertical power switching components based on proprietary gallium nitride (GaN) processing technology — says that, in second-quarter 2023, two letters of intent with customers were signed for its early-access sampling program. At least one additional signed letter of intent is in process and, due to summer holidays in Europe, is expected to be signed by September.

“Lead customers have collaborated along the way and have remained committed to product evaluations. Feedback on products delivered in Q1/2023 validated the performance metrics expected from vertical GaN for power applications,” says CEO Mark Davidson. Additional product samples will be delivered no later than Q4/2023. “While we develop improvements to the products, we are actively engaged in multiple product definition conversations with leading electric vehicle (EV) automotive customers, as well as industrial

motor and renewable energy customers,” he adds.

“We must show additional customer traction in Q3 as we need to raise money by the end of the quarter,” says Davidson. “We remain confident in the product development problems getting solved, the quantity and quality of intellectual property being created, and the patience and interest that remains from customers.”

Odyssey says that it is continuing to take product sample requests. Customers can request information and samples of the 650V and 1200V vertical GaN power devices at [info@odysseysemi.com](mailto:info@odysseysemi.com).

Odyssey's foundry on-boarded two new customers in Q2/2023. While only \$8000 has been invoiced, these initial product runs will be completed in Q3/2023 with invoicing of about +\$100,000. More importantly, says the firm, each customer represents large opportunities with recurring revenue from multiple fabrication runs. Odyssey is converting a \$2m pipeline for foundry services to new

business as it continues to pursue new opportunities.

Odyssey reckons that its approach to vertical GaN will offer even greater commercial advantages over silicon than silicon carbide (SiC) or lateral GaN. Vertical GaN offers a 10x advantage over silicon carbide at performance enabling smaller and lighter power systems and cost levels unattainable by competing technologies, it is claimed.

Odyssey notes that the market it is pursuing is large and fast growing. The 650V segment is the larger market currently, expected to grow at a compound annual growth rate (CAGR) of 20%. The 1200V product market segment is expected to grow faster, at a 63% CAGR, and is forecasted to become the larger market in the second half of this decade. Collectively, the 650V and 1200V power device market is forecasted by market research firm Yole Group to grow at a combined CAGR of 40% to more than \$5bn in 2027.

[www.odysseysemi.com](http://www.odysseysemi.com)

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# GaN Systems and ACEpower partner to drive gallium nitride adoption in Chinese EV market

## Future initiatives encompass joint development of high-power-density GaN-powered OBCs rated at 6.6kW and 11kW

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has partnered with ACEpower — a Chinese designer and manufacturer of power supplies, electric vehicle (EV) charging modules, and OBC (onboard charger) products — to expedite the widespread adoption of GaN technology in electric vehicles. By harnessing GaN Systems' power semiconductors, extensive expertise in EV power electronics, and ACEpower's track record in high-power system design and high-volume manufacturing capabilities, the partnership is expected to accelerate the GaN-based electric vehicle power market in China.

GaN power semiconductors play a pivotal role in realizing the compact size, lightweight, and high efficiency demanded by the next generation of high-performance electric vehicles. By harnessing GaN Systems' automotive-grade, high-performance GaN power transistors alongside ACEpower's deep expertise in the power electronics industry, the companies are combining their

distinctive capabilities to unlock the full potential of GaN performance advantages. In addition to other areas, the partnership will focus on topology optimization and advanced integrated power modules, and high-frequency magnetics design to enhance crucial electric vehicle efficiency and power density significantly.

"Our longstanding relationship with GaN Systems, coupled with their unrivaled expertise in high-reliability, automotive-qualified GaN semiconductors — a vital component for electric vehicles — brings great business opportunities in the fast-growth Chinese EV market," says ACEpower's CEO Albert Wang. "Together, we are committed to driving innovation that will revolutionize electric vehicles, particularly in efficiency and power density, delivering substantial benefits to the industry."

The combination tackles fundamental challenges related to traditionally larger, heavier, inefficient and costlier power systems based on legacy silicon power transistors. GaN power transistors enable higher efficiency and power density at a faster switching speed for

onboard chargers, DC/DC converters, and traction inverters. These advances translate into faster charging, extended driving range, and reduced overall system costs.

"Today's announcement marks a significant leap in our cooperative efforts with ACEpower to drive GaN adoption in the Chinese electric vehicle market," says GaN Systems' CEO Jim Witham. "This collaboration paves the way for disruptive and game-changing advancements in next-generation electric vehicles," he reckons. "Building upon our strong industry relationships with key players such as BMW, Toyota and Vitesco, GaN Systems and ACEpower are poised to make a substantial impact in accelerating GaN adoption across the electric vehicle platform."

GaN Systems and ACEpower's shared aim extends to capturing substantial market value in emerging sectors such as data centers and electric vehicles. Future initiatives encompass the joint development of high-power-density GaN-powered OBCs rated at 6.6kW and 11kW for electric vehicles.

[www.gansystems.com](http://www.gansystems.com)

# Mitsubishi Electric buys stake in Novel Crystal Technology

## Ga<sub>2</sub>O<sub>3</sub> wafer technology to speed development of power semiconductors

Tokyo-based Mitsubishi Electric Corp has taken an equity position in Novel Crystal Technology Inc of Saitama, Japan, which develops and sells gallium oxide wafers. Gallium oxide ( $\beta$ -Ga<sub>2</sub>O<sub>3</sub>) is a promising candidate for use in superior energy-saving power semiconductors that Mitsubishi Electric intends to develop at an accelerated pace in support of global decarbonization.

As one of the first companies to develop, manufacture and sell gallium oxide wafers for power

semiconductors, Novel Crystal Technology has manufacturing technology that Mitsubishi Electric will use in its production of gallium oxide power semiconductors.

Mitsubishi Electric say that it has been contributing to energy saving in power electronic products by producing semiconductors made of silicon and silicon carbide (SiC). Recent advances have been achieved with silicon carbide and gallium nitride wafers, but gallium oxide wafers are expected to help achieve even

higher breakdown voltages and lower power dissipation.

Mitsubishi Electric now expects to accelerate its development of gallium oxide power semiconductors by combining its own expertise in the design and manufacture of low-energy-loss, high-reliability power semiconductors with Novel Crystal Technology's expertise in the production of gallium oxide wafers.

[www.novelcrystal.co.jp/eng](http://www.novelcrystal.co.jp/eng)  
[www.MitsubishiElectric.com/semiconductors](http://www.MitsubishiElectric.com/semiconductors)

# Fraunhofer IAF-led GaN4E-moBiL project targets bidirectional charging for EVs

## New GaN-based charging technology to make EVs usable as 'batteries on wheels' mobile power storage units

Funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) as part of the Elektro-Mobil program, the three-year research project 'GaN4E-moBiL — GaN power semiconductors for electro-mobility and system integration through bidirectional charging' was launched in mid-July, led by Fraunhofer Institute for Applied Solid State Physics IAF and joined by consortium partners the University of Stuttgart, Robert Bosch GmbH and Ambibox GmbH.

The consortium's goal is to demonstrate an intelligent and cost-effective bidirectional charging system using new semiconductor devices, device concepts and system components.

Bidirectional charging allows electric vehicles (EVs) to be both charged with electricity from renewable sources and discharged as needed during periods when no wind or solar energy is being produced. E-cars can thus serve as mobile electricity storage units

Consumers could use this electricity for other electrical devices or supply it to the power grid, increasing the flexibility of the energy system and contributing to energy security. However, previous technical approaches do not meet the demands for cost and efficiency, says Fraunhofer IAF. There is a lack of intelligent and cost-effective bidirectional charging systems to connect batteries, the grid, local generators and consumers with high efficiency and high power density, it adds.

"Our project aims to connect batteries, renewable energies and electrical consumers in an economical and flexible way," says GaN4E-moBiL project coordinator Dr Stefan Mönch, a power electronics researcher at Fraunhofer IAF. "Through bidirectional charging solutions, the previously unused



**Consortium partners Fraunhofer IAF, University of Stuttgart, Robert Bosch and Ambibox met in Freiburg for the official kick-off of the GaN4E-moBiL project.**

batteries of parking electric vehicles will make a greater contribution to increasing the flexibility of the energy system and avoiding CO<sub>2</sub> emissions in the future," he adds.

"In future, efficient, small-scale and intelligent charging infrastructures in electro-mobility will contribute to overcoming social challenges", says Dr Etienne Tchoula, R&D director at Ambibox.

To ensure that bidirectional charging can be used on a broad scale, the GaN4E-moBiL consortium is therefore researching innovative charging technologies, specifically developing new semiconductor, device and system technologies for the 800V class.

### **Previous solutions are expensive, inefficient or too complex**

To date, initial bidirectional medium-power DC wallboxes for batteries up to 800V use power semiconductor devices that are not yet optimal for this application: They are either efficient but expensive (silicon carbide) or low-cost but less efficient (silicon). Currently available 650V transistors made of gallium nitride on silicon (GaN-on-Si) are inexpensive and efficient, but require a complex circuit due to

insufficient voltage rating.

To integrate as many batteries as possible bidirectionally, the cost, efficiency and compactness of charging solutions must be significantly improved, says Fraunhofer IAF. For this purpose, the GaN4E-moBiL project partners are researching new semiconductor solutions as a first step. They aim to realize a new cost-effective GaN technology on alternative substrates (for example sapphire) enabling low-cost and efficient 1200V transistors. On this basis, they are developing new system components (bidirectional charging cable and charger) and investigating their reliability for significantly increased operating hours.

At the end of the project, demonstrators should be able to fill the R&D gap that currently exists between cost, efficiency, compactness, functionality, power class and voltage class (800V batteries). Furthermore, the consortium aims to promote knowledge transfer between universities, research institutions and industry, train young scientists and secure national know-how in the field of electro-mobility.

[www.iaf.fraunhofer.de](http://www.iaf.fraunhofer.de)

# Comptek secures €8m in Series A funding round

## Funding to support scale-up, development and industrialization of passivation technology for opto and power electronics

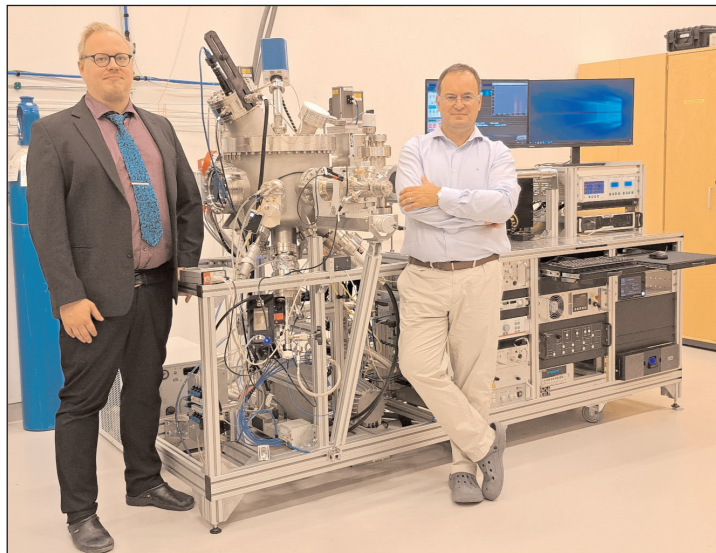
Comptek Solutions Oy of Turku, Finland (which specializes in III-V compound semiconductor quantum surface engineering) has closed its Series A funding round, consisting of an €8m equity investment with the participation of a key strategic partner in the consumer electronics industry, the Horizon Europe European Innovation Council (EIC) Fund, and Italian venture capital firm LIFTT S.p.A., which is focused on early-stage investments in startups and SMEs with high growth impact and ESG.

Complementing the €2.45m grant awarded in 2022 by the EIC Accelerator, the involvement of the new investor group should provide support in areas such as scale-up growth, advancing its technological innovation progress, and accelerating the pace of industrialization and implementation of its technology for next-generation applications in optoelectronics and power electronics.

The Series A funding round extends beyond the inaugural seed-funding efforts, which oversaw the firm's technology development and execution of its business model and market-entry strategy worldwide.

Founded in 2017 by chief technology officer Jouko Lång and chief executive officer Vicente Calvo Alonso, Comptek Solutions was spun out of the University of Turku, where its core technology Kontrox was developed by Lång together with other material scientists and semiconductor engineering researchers who constitute the firm's core R&D team to-date. Kontrox tackles the problem of native oxidation in compound semiconductors, enabling improvements in the power efficiency of semiconductor components and optimizing their manufacturing processes.

"Comptek Solutions has proven to be a leading innovator in the rapidly growing market for compound



**Comptek Solutions' founders CTO Jouko Lång (left) and CEO Vicente Calvo Alonso (right).**

semiconductor devices with the unique passivation technology they have," comments EIC Fund board chair Svetoslava Georgieva. "We are pleased to support Comptek's journey as they bring disruptive solutions to fill the gap in the market on a global scale. Their technology can be instrumental in faster adoption of crucial technologies such as 5G/6G communications, AR/VR, mobility, IoT, and quantum computing," she adds.

"Passivation is an essential factor of advanced

**With the proceeds from this recent financing round, we will accelerate the growth of our team and technology portfolio to provide the most efficient passivation solutions for other core fields of applications such as power electronics, where key European manufacturers have already committed to collaborating**

reduce production costs," he adds.

"Closing this investment round is a very important stepstone in our path towards wider market entry and scale-up of the company," says Vicente Calvo Alonso. "In these first years, despite limited resources, we have made crucial developments to validate our technology and its fit into important semiconductor applications such as optoelectronics and power electronics. Thanks to our commitment to continued R&D excellence and creating value for customers through our technology and innovation, we have generated a solid customer base and are now set to roll out our first full turnkey solutions for passivation of edge-emitting lasers using the company's proprietary passivation technique and custom-built equipment," he adds. "With the proceeds from this recent financing round, we will accelerate the growth of our team and technology portfolio to provide the most efficient passivation solutions for other core fields of applications such as power electronics, where key European manufacturers have already committed to collaborating with us."

[www.comptek-solutions.com](http://www.comptek-solutions.com)

optoelectronic chip manufacturing, and Comptek Solutions is a key driver in this crucial niche," comments LIFTT's project manager Pierluigi Freni. "Their solution disrupts the value chain by introducing a novel processing technology that enables unprecedented levels of chip efficiency and helps to significantly

## Indium Corp to supply high-quality gallium acetylacetonate

Indium Corp of Clinton, NY, USA is to supply high-purity gallium acetylacetonate ( $\text{Ga}(\text{acac})_3$ ), an organometallic coordination complex with gallium at the center surrounded by three acetylacetonate ligands that, due to its versatility and stability, has applications in materials science, organic chemistry and catalysis.

Through heating and decomposition,  $\text{Ga}(\text{acac})_3$  can be used to produce a highly pure and uniform thin-film version of gallium oxide ( $\text{Ga}_2\text{O}_3$ ). This unique variation of  $\text{Ga}_2\text{O}_3$  finds common use as an ultrawide-

bandgap ( $\sim 4.8\text{eV}$ ) semiconductor in power electronics applications.

Indium Corp says its  $\text{Ga}(\text{acac})_3$  can be combined with sulfur to synthesize gallium sulfide ( $\text{Ga}_2\text{S}_3$ ) quantum dots with a bandgap of about  $3.30\text{eV}$ .

The resulting  $\text{Ga}_2\text{O}_3$  quantum dots are well suited for use in photonics and optoelectronics.  $\text{Ga}(\text{acac})_3$  can also be used to prepare quantum dots of gallium arsenide (GaAs), gallium phosphide (GaP), and gallium indium phosphide (GaInP), with potential applications in quantum photonics.

Additionally,  $\text{Ga}(\text{acac})_3$  serves as a thermally stable replacement for trimethyl gallium (TMG) in high-temperature deposition processes. It decomposes at higher temperatures and is not pyrophoric like TMG, making it safer to handle. The crystalline powder form of  $\text{Ga}(\text{acac})_3$  adds to its ease of handling compared with the liquid state of TMG.

Indium Corp notes that, with purity starting at 99.99%, it can optimize its  $\text{Ga}(\text{acac})_3$  to the specific needs of its customers.

[www.indium.com](http://www.indium.com)

## Ares Strategic Mining detects germanium and gallium at US fluorspar mine

Following assaying conducted by inspection, verification, testing and certification services company SGS, Ares Strategic Mining Inc of Vancouver, BC, Canada (which owns the only permitted fluorspar mine in the USA) says it has detected germanium and gallium at its 5982-acre Lost Sheep Fluorspar Project in the Spor Mountain area, Juab County, Utah (about 214km south-west of Salt Lake City).

In 2018 the US government classified fluorspar as a Critical Mineral, "deemed critical to US national security and the economy."

Fluorspar remains the only non-metallic Critical Mineral, which is 100% imported in the entire USA. Fluorspar's classification as a Critical Mineral in the USA translates to a faster permitting period, enabling mining operations to initiate more quickly than operations for conventional minerals, Ares notes.

As the firm is focused on returning fluorspar manufacturing to North America, Ares is currently concentrating on building processing facilities to achieve production at its operation. However, it plans to explore the rare-earth discovery when it conducts further drilling.

The minerals were located through an RC drilling program, and further work using core drilling will be used to develop a better understanding of the rare earths at the Spor Mountain project.

Germanium ores are rare and most germanium is a by-product of zinc production and from coal fly ash. China produces around 60% of the world's germanium, according to European industry association Critical Raw Materials Alliance (CRMA), with the rest coming from Canada, Finland, Russia and the USA. China exported 43.7 metric tons of unwrought and wrought germanium last year, according to Chinese customs. About \$39m worth of germanium was consumed last year, up 10% from 2021, according to the US Geological Survey (USGS).

Gallium is found in trace amounts in zinc ores and in bauxite, and gallium metal is produced when processing bauxite to make aluminium. About 80% is produced in China, according to the CRMA. China exported 94 metric tons of gallium in 2022, up 25% on the prior year, according to Chinese customs. US imports of gallium

metal and gallium arsenide (GaAs) wafers in 2022 were worth about \$3m and \$200m, respectively, according to USGS.

China has hence been the USA's principal source of both germanium and gallium. However, since 1 August, both rare-earth minerals have been restricted from export from China without a permit from the authorities.

"It's an extremely interesting find to locate both germanium and gallium at our fluorspar project, right at the time when the trade war is promising to interfere with the supply of minerals vital to the production of microchips and electronics needed to sustain the tech industry," says Ares' CEO & president James Walker. "We are currently building our production facility in Utah, and upgrades could be incorporated into the operation to retrieve the minerals, provided further investigation justifies the expanded recovery operation," he adds. "As we continue our construction work, we will investigate this discovery, examining the possibility of commercialization."

[www.aresmining.com/post/ares-strategic-mining-](http://www.aresmining.com/post/ares-strategic-mining-)

## Grant for Centre for Integrative Semiconductor Materials Wolfson's £500,000 award to support design, procurement and deployment of Advanced Semiconductor Wafer Analytical Capability

Swansea University in south Wales, UK has received a grant from the Wolfson Foundation (an independent charity with a focus on research and education) that will provide a boost to its Centre for Integrative Semiconductor Materials (CISM).

The £500,000 award will support design, procurement and deployment of a unique 'cluster instrument' the Advanced Semiconductor Wafer Analytical Capability (ASemi-WAC), which will be housed at CISM and be part of a project to create a nationally significant Semiconductor Analytical Suite (SAS) for use by researchers and industrial partners.

It is reckoned that this will grow the university's capability in the provision of semiconductor expertise and deliver a dramatic expansion in research breadth, depth and excellence, with a particular focus on semiconductor technology for

enabling Net Zero, and also for emerging applications of semiconductor devices in healthcare.

"Swansea University has a nationally significant and internationally recognised critical mass in semiconductor research and innovation which is fuelled by the emergence and rapid growth of our regional semiconductor industry," says CISM's director professor Paul Meredith. "The award for our ASemi-WAC proposal is vitally important as it will support us in playing a major part in the much-heralded UK Semiconductor Strategy as part of the CSconnected Cluster of partners," he adds.

"The UK needs to invest urgently in semiconductor technologies as their importance to industries as varied as healthcare and energy becomes ever more evident," says the Wolfson Foundation's

chief executive Paul Ramsbottom. "The ASemi-WAC project at Swansea can play an exciting role in this R&D effort, and we are delighted to be supporting it — and to be funding in Swansea again," he adds.

"Semiconductor science and engineering has long been an area of research excellence at Swansea University," says vice-chancellor professor Paul Boyle. "This award from the Wolfson Foundation will enable us to build upon our existing strengths and deliver the world-class innovation which is urgently required in this field, and which is vital for economic growth, job opportunities and the advancement of energy science in south Wales and the UK."

[www.wolfson.org.uk](http://www.wolfson.org.uk)

[www.swansea.ac.uk/campus-development/developing-bay/key-projects-bay/cism](http://www.swansea.ac.uk/campus-development/developing-bay/key-projects-bay/cism)

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## AXT's Q2 sees InP revenue bottom out, but GaAs rebounds Indium phosphide inventory digestion to affect next few quarters

For second-quarter 2023, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of \$18.6m, down slightly on \$19.4m last quarter but more than halving from \$39.5m a year ago.

By product category, InP revenue is believed to have bottomed out, at \$4.6m, down on \$7.1m last quarter and \$15.7m a year ago. This reflects the expected market softening after starting to decline about 6 months ago, particularly in the data-center, consumer and telecoms infrastructure markets.

GaAs revenue was \$5.4m, less than half the \$12.2m a year ago but rebounding slightly from \$5m last quarter. "We saw continued modest improvement in Q2 as key applications such as high-power lasers and IoT devices continued their recovery, particularly in China," says co-founder, CEO & chairman Dr Morris Young. "Gallium arsenide was the first of our materials to experience the micro-downturn, beginning in Q3 of last year," he notes. "We actually already have seen two quarters of improvement, although very, very slight."

Germanium substrate revenue fell back from \$1.4m last quarter to \$1m, down on \$3.9m a year ago.

In addition, revenue was \$7.6m from the two consolidated raw material joint venture companies: BoYu (which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic LEDs) and JinMei (which supplies high-purity materials including gallium and germanium, as well as InP poly and other materials). Due to both increased demand and rising prices, this was up on \$5.9m last quarter and almost equal with \$7.8m a year ago. "Since relocating to our Kazuo campus, both supply chain companies have been able to increase capacity to meet demand," notes Young.

Of total revenue in Q2/2023, the proportion from the Asia-Pacific region has rebounded from 68% last quarter to 75%, while Europe has fallen from 18% to 16% and North America from 14% to 9%.

The proportion of total revenue contributed by the top five customers has fallen further, from 35% a year ago and 28% last quarter to 24%. Again, no customer comprised more than 10%.

"Though the macro-environment continues to impact our growth near-term, the trends that have driven our revenue and customer expansion remain very much intact," notes Young.

On a non-GAAP basis, gross margin has fallen further, from 39.4% a year ago and 26.9% last quarter to just 9.8%, driven by (1) sales volume, (2) product mix, and (3) the raw material business having lower margin due to working through higher-priced inventory, especially since raw material sales exceeded 40% of total revenue.

"With the reduction in overall revenue, we have continued to take steps to reduce our operating expenses to align with the current environment," notes chief financial officer Gary Fischer. Operating expenses have hence been cut further, from \$9.1m a year ago and \$8.7m last quarter to \$7.8m.

Net loss was \$4.2m (\$0.10 per share), up from \$2.4m (\$0.06 per share) last quarter and compared with net income of \$6.7m (\$0.16 per share) a year ago.

Depreciation & amortization was \$1.8m. Capital expenditure (CapEx) was \$750,000. During the quarter, cash and cash equivalents and investments fell from \$53.6m to \$49.6m. However, this was due mainly to a repayment of a bank loan totaling \$7.2m, offset by a favorable reduction in net inventory of \$4.6m, from \$91.7m to \$87.1m.

Of the net inventory, 44% is raw materials, 52% is work-in-progress (WIP), and only 4% is finished

goods. "We continue to do well on recycling of indium phosphide and believe that this will be an important cost advantage for us as the market recovers," says Fischer. "We continue to expand our recycling program and are focused on improving our efficiency and accelerating our return to profitability," says Young.

For third-quarter 2023, AXT expects revenue of \$16.5–19.5m, with further growth in gallium arsenide. However, there is continued weakness in indium phosphide. "In first-half 2023, we saw considerable inventory digestion [in data-center applications] and believe that it is still ongoing," says Young.

OpEx should rise slightly, by \$100,000–200,000. Net loss is expected to rise slightly to \$0.11–0.13 per share.

"As we look ahead to the coming quarters, we believe we will see improvement in our gross margin as a result of several factors," says Fischer. "In the near term, we expect to see improvement in the gross margin contribution from our raw material joint ventures as they have worked through much of their higher-priced inventory. We expect JinMei to begin production in Q3 on our new gallium arsenide recycling program which, like our indium phosphide recycling program, should have a positive impact on gross margin. Further, indium phosphide revenue should begin to recover over the coming quarters [normalizing at \$9–10m per quarter after inventories are worked down, after Q4/2023]," he adds.

"Beyond the near term, we remain confident that we can get back to the mid-30% range as the environment strengthens through higher overall volume, a recovery in indium phosphide mix and the benefits of our recycling programs, along with continued efficiency improvements throughout the business," Young says.

[www.axt.com](http://www.axt.com)



# AXT's China subsidiary applies for export license

Regarding the announcement on 3 July by China's Ministry of Commerce (MOFCOM) and General Administration of Customs (GAC) that control measures would be imposed from 1 August on the export of gallium- and germanium-related semiconductor raw materials, AXT's

China-based wafer manufacturing subsidiary Tongmei has applied for export licenses. "We have not been given a time-frame for the expected length of the permitting process," notes co-founder, CEO & chairman Dr Morris Young. "We have been in close contact with our customers

through this time and are working with them to minimize any disruption," he adds. However, JinMei's exports outside of China comprised less than 2% of their sales in Q2. "We do not expect a meaningful direct impact to our revenue of the new regulations," concludes Young.

## Update on Tongmei's listing on the STAR Market

On 10 January 2022, AXT's China-based wafer manufacturing subsidiary Beijing Tongmei Xtal Technology Co Ltd applied to list its shares in an initial public offering on the Shanghai Stock Exchange's Sci-Tech innovAtion boARd (STAR Market) and the application was accepted for review.

Subsequently, Tongmei responded to several rounds of

questions received from the Shanghai Stock Exchange (SSE). On 12 July, the SSE approved the listing of Tongmei's shares. On 1 August 2022, the China Securities Regulatory Commission (CSRC) accepted Tongmei's IPO application for review. The STAR Market IPO remains subject to review and approval by the CSRC and other authorities.

"Shortly after Chinese New Year, we were asked to address two primary issues," says CFO Gary Fischer. "We are close to a resolution."

AXT says that going public on the STAR Market includes several periods of review and is a lengthy process, but Tongmei hopes to accomplish this in the coming months.

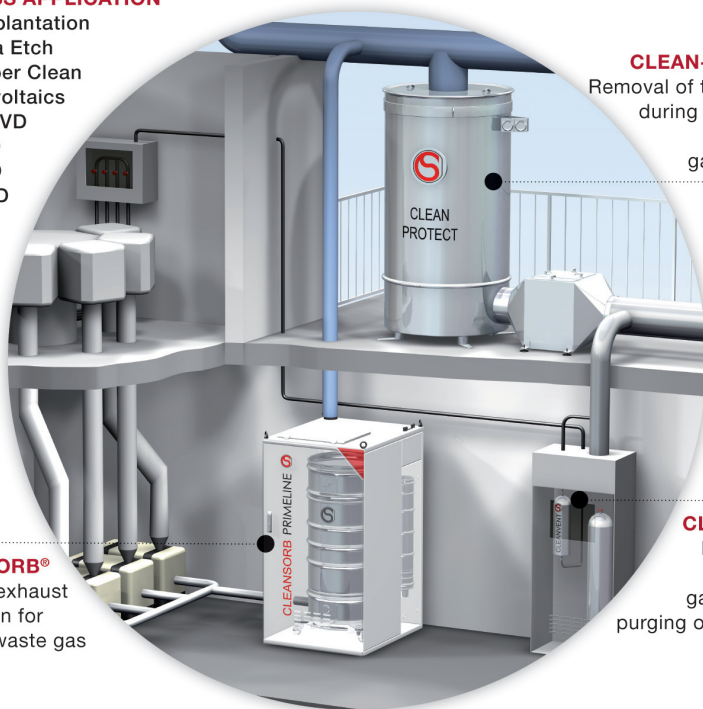
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## **IQE expects first-half 2023 revenue of at least £52m** **Pre-close update within May's £50–56m guidance,** **though down from first-half 2022's £86.2m**

In an unaudited pre-close update for first-half 2023, epiwafer and substrate maker IQE plc of Cardiff, Wales, UK says that trading was in line with management expectations. Revenue is expected to be at least £52m, in line with market guidance

and within the firm's £50–56m guidance provided on 17 May. This compares with revenue in first-half 2022 of £86.2m.

The company says that it is continuing to effectively navigate the challenging macroeconomic

environment, by managing costs and implementing its diversification strategy.

IQE will report full (unaudited) interim results for first-half 2023 on 8 September.

[www.iqep.com](http://www.iqep.com)

## **New Space Enterprise Lab opens at** **CSA Catapult in South Wales**

### **Lab to provide collaborative technology, resources and expertise to space organizations and academic institutions across Wales and the Western Gateway**

The latest addition to the UK's Satellite Applications Catapult's network of Space Enterprise Labs (SEL) has opened at the Compound Semiconductor Applications (CSA) Catapult in Newport, South Wales, providing companies and academics access to the latest collaborative technology, resources and expertise.

The services at the Space Enterprise Labs enable the virtual delivery of "meetings, business sprints, user engagement spark sessions and other services, such as virtual whiteboards and built-in video conferencing" for everyone within the UK space sector to utilize.

The Space Enterprise Labs were created in response to the changing needs of space organizations since the global pandemic and a need to collaborate virtually with stakeholders in many locations. They are free to use and open to existing space organizations and academic institutions across the UK. Located across the country, Space Enterprise Labs provide users with Zoom licenses, virtual reality headsets and access to Microsoft Surface Hubs as well as a modern, professional and safe working environment.

CSA Catapult is applying compound semiconductor technologies to space applications, supporting a network of space-based

businesses and organizations across the country. Specifically, compound semiconductors enable a number of space-based applications where harsh environments, temperature range and reliability are all major considerations, which enables CSA Catapult's expertise in advanced packaging and harsh environmental and reliability testing to be utilized.

"We are delighted to be launching the Space Enterprise Labs as we continue to support the growth of the space sector across the UK," says Satellite Applications Catapult's chief operations officer Lucy Edge.

"These unique facilities embrace the new hybrid way in which we all now engage, while also offering a safe and secure environment to foster UK-wide space innovation and discussion. Businesses across the UK will now be able to collaborate across a range of high-tech,

**Compound semiconductors enable a number of space-based applications where harsh environments, temperature range and reliability are all major considerations**

high-innovation subjects, to bring ideas and customers together more effectively," she adds.

"We are delighted to be able to host a Space Enterprise Lab here at CSA Catapult to support a growing network of space organizations and academic institutions across the UK," comments CSA Catapult's CEO Martin McHugh. "We hope this innovative new service will encourage more companies to work collaboratively with us," he adds. "We have a broad technical offering and experience in supporting companies developing space applications."

With the addition of SEL Newport, there is now a total of 12 Space Enterprise Labs across the country, including:

- SEL Daresbury (Liverpool City Region);
- SEL Edinburgh (Midlothian);
- SEL Glasgow (Lanarkshire);
- SEL Leeds (West Yorkshire);
- SEL Exeter (Devon);
- SEL Harwell (Oxfordshire);
- SEL Leicester (Leicestershire);
- SEL NETPark (County Durham);
- SEL Penryn (Cornwall);
- SEL Portsmouth (Hampshire);
- SEL Westcott (Buckinghamshire).

[www.csa.catapult.org.uk](http://www.csa.catapult.org.uk)

[www.sa.catapult.org.uk/sel](http://www.sa.catapult.org.uk/sel)

[www.spaceenterprise.uk](http://www.spaceenterprise.uk)

## CVD Equipment appoints Ashraf Lotfi to board

### Power electronics device industry expertise to aid strategic focus

CVD Equipment Corp of Central Islip, NY, USA (a designer and maker of chemical vapor deposition, physical vapor transport, gas and chemical delivery control systems, and other equipment and process solutions for developing and manufacturing materials and coatings) has appointed Dr Ashraf Lotfi to its board of directors, which has also approved an expansion of the number of directors from the current level of five to six.

"His extensive semiconductor and power electronics device industry expertise, and proven track record of bringing innovative technologies to market, will be invaluable as we execute our core strategy focused on the 'electrification of everything,'" comments chairman Lawrence J. Waldman.

Lotfi is currently a venture partner with Deep Sciences Ventures and

serves on the board of Lotus Microsystems ApS. He previously served as VP and a Fellow at Intel Corp. Prior to Intel, he was power chief technology officer for Altera Corp, serving its Enpirion Power Business as well as the broader field-programmable gate array community. Altera was acquired by Intel in 2015. Prior to Altera, he was president & CEO of Enpirion Inc, which he founded in 2002.

From Enpirion's inception, Lotfi led its strategic direction with what is reckoned to be a unique industry-first vision to create the ultimate power converter-on-chip, creating ubiquitous DC-DC conversion at the silicon level. In 2013, he led Enpirion's merger into Altera to realize his vision of highly integrated power management closely coupled to digital silicon loads. Prior to founding Enpirion, he was director

of Advanced Power Research at Bell Laboratories.

"His in-depth knowledge of the power electronics market and his track record of scaling the Enpirion Power Business will allow him to immediately contribute to our management team and board of directors as we pursue the pipeline of customer opportunities in our key strategic markets of high-power electronics, battery materials/energy storage and aerospace & defense," says CVD Equipment's president & CEO Manny Lakios.

"Its long history and solid IP capabilities, particularly in silicon carbide, the essential enabling technology for electrification, form a strong basis for continued growth and participation in critical parts of vital applications and growth markets," says Lotfi about CVD Equipment.

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# Veeco's Q2 record semiconductor revenue drives growth

## Full-year margin and profit forecast raised

For second-quarter 2023, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$161.6m, down on \$164m a year ago but up 5% on \$153.5m last quarter, and near the top end of the \$145–165m guidance range.

Growth was driven by the Semiconductor segment (Front- & Back-End, and EUV Mask Blank systems and Advanced Packaging) contributing record revenue of \$106m (65% of total revenue), up 14% on \$93m (60% of revenue) last quarter and up 9% on \$97.5m (59.5% of revenue) a year ago, led by record laser annealing shipments. "We continue to execute our Laser Annealing growth strategy in advanced-node logic and memory by winning new customers and applications," notes CEO Bill Miller. Specifically, Veeco:

- shipped LSA systems and won follow-on orders from a tier-1 customer for high-bandwidth memory,

- enabling artificial intelligence;
- received LSA orders from tier-1 logic customers for their most advanced nodes; and
- made further progress towards shipping evaluation systems for nanosecond annealing (NSA) and ion beam deposition (IBD) for advanced-node semiconductor applications.

The Compound Semiconductor sector (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, laser diodes) contributed \$24m (15% of total revenue), down from \$31.1m (19% of revenue) a year ago but up slightly from \$21m (14% of revenue) last quarter, driven by system shipments for photonics applications.

The Data Storage segment (equipment for thin-film magnetic head manufacturing) contributed \$14m (9% of total revenue), down from \$22m (14% of revenue) last quarter and \$21.5m (13.1% of revenue) a year ago.

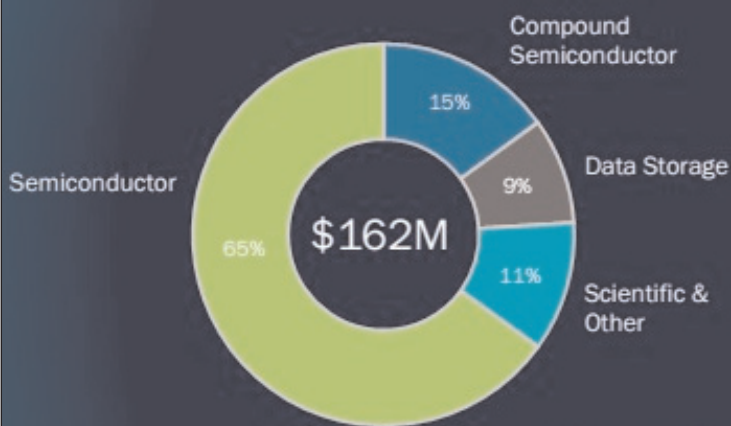
The Scientific & Other segment (research institutions and other applications) contributed \$17m (11% of total revenue), down slightly from \$18m (12% of total revenue) last quarter but up from \$13.8m (8.4% of total revenue) a year ago.

By region, the Asia-Pacific (excluding China) rose from 25% of total revenue last quarter to 36% in Q2/2023, due to a significant increase in semiconductor system sales, while China fell back from 40% to 31% of revenue, following last quarter's spike in shipments of LSA system for trailing-edge semiconductor nodes. The USA rose from 20% to 22% of revenue, while Europe, Middle-East & Africa (EMEA) fell from 15% to 11% of revenue.

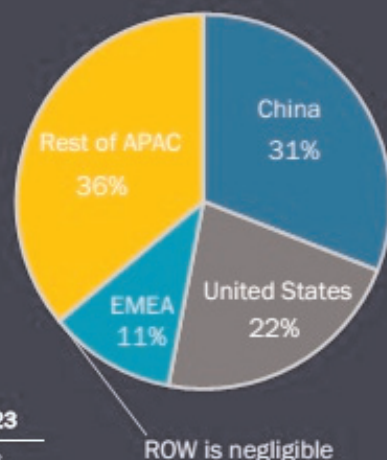
On a non-GAAP basis, gross margin was 42.7%, up from 41.5% last quarter and 40.3% a year ago, and above the expected 42%, boosted by a favorable product mix as well as lower spending in service and operations. ➤

### Q2 2023 Revenue by Market & Region

Revenue by Market



Revenue by Region



Revenue Trend (\$M)	Q2 22	Q1 23	Q2 23
Semiconductor	98	93	106
Compound Semi	31	21	24
Data Storage	22	22	14
Scientific & Other	14	18	17
<b>Total</b>	<b>164</b>	<b>154</b>	<b>162</b>

Operating expenses have risen from \$43.2m a year ago and \$43.3m last quarter to \$44.8m. "We continue to focus on cost management while maintaining investment for growth," says chief financial officer John Kiernan.

Net income was \$20.6m (\$0.36 per diluted share), up from \$16.9m (\$0.30 per diluted share) last quarter, and exceeding the guidance range of \$14–20m (\$0.26–0.34 per diluted share).

Cash flow from operations has fallen further, from \$14m last quarter to \$11m. Capital expenditure has almost halved from last quarter, to \$4m.

During the quarter, cash and short-term investments rose \$34m to \$287m, driven mainly by \$24m of net proceeds from a refinancing (completing a private offering of \$230m of 2.875% convertible notes due in 2029 while repurchasing \$206m of the outstanding 3.5% convertible notes due in 2025 and 3.75% convertible notes due 2027).

Long-term debt rose hence from \$254.7m to \$274m, representing the carrying value of about \$282m of convertible notes.

Inventory rose by \$19m to \$244m, and days of inventory (DOI) from 213 to 225 days, due to continued investment in the firm's evaluation program and to support revenue growth in second-half 2023.

"We expect opportunities for our technologies to grow as customers continue to adopt our products for their most advanced-node devices used for high-performance computing and artificial intelligence," says Miller.

For third-quarter 2023, Veeco expects revenue of \$155–175m, with Semiconductor down slightly (after Q2's record), Compound Semiconductor flat, Data Storage bouncing back by more than doubling (to about \$30m), and the Scientific & Other segment flat.

Gross margin should be 42–43%. Despite operating expenses rising slightly to \$45–47m, net income should be steady at \$17–23m (\$0.30–0.40 per diluted share).

Based on current backlog and expected growth trajectory in second-half 2023, for full-year 2023 Veeco has reiterated its revenue outlook of \$630–670m (relatively flat on 2022's \$646.1m), despite China comprising just 30% of total revenue after declining in second-half 2023. However, the firm has raised its projection for gross margin from

**Integration of our SiC CVD technology is progressing well [after acquiring Epiluvac] and customer engagement remains healthy**

41–42% to 42–43%. Together with a reduction in net interest expense and a lower projected tax rate. Veeco has raised its projection for diluted earnings per share (EPS) from \$1.15–1.35 to \$1.30–1.50 (compared with \$1.57 for 2022).

"Our opportunity in the compound semiconductor market is driven by demand for epitaxy equipment for power electronics applications, including silicon carbide and gallium nitride, in addition to photonics applications such as micro-LED," says Miller.

"Integration of our silicon carbide CVD technology is progressing well [following the acquisition of Epiluvac AB of Lund, Sweden at the end of January] and customer engagement remains healthy," says Miller. "We expect the demo-ready system by year-end, in anticipation of several evaluations with tier-1 customers next year. We believe our innovative system design offers an opportunity for a differentiated solution and are optimistic our sales, service and manufacturing infrastructure can position us to gain share in this high-growth market," he adds. "We also remain committed to our opportunities in GaN and micro-LED, as long-term fundamentals and these markets remain positive."

[www.veeco.com](http://www.veeco.com)

## Riber's half-year revenue grows 32% year-on-year to €12.2m as systems revenue almost triples

### Orders remain high, at €30.5m, maintaining full-year revenue forecast

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems and evaporation sources — has reported first-half revenue growth of 32%, from €9.2m in 2022 to €12.2m for 2023. Of this, 26% came from Europe, 62% from Asia and 12% from North America.

MBE Systems revenue almost tripled (rising by 192%) from €2.9m to €8.5m (with deliveries rising from just one to four machines). Services & Accessories sales have fallen by 42% from €6.3m to €3.6m.

#### **Growth in Systems orders offsets drop in Services & Accessories**

The order book at end of June came to €30.5m, roughly level year-on-year with €30.6m a year ago.

The Systems order book is up by 3%, from €23m to €23.7m (comprising nine machines, including four production machines). The Services & Accessories order book is down by 11% from €7.6m to €6.7m.

#### **Full-year outlook maintained**

In view of the strong order book (with a high proportion of machines deliverable by the end of this year), Riber's outlook for full-year 2023 remains unchanged, i.e. revenue of about €40m (up 44% on 2022's €27.8m), with an improvement in profitability.

Riber expects that, in a buoyant semiconductor market, it will continue to take new orders during second-half 2023.

[www.riber.com](http://www.riber.com)

# Silicon carbide and gallium nitride power electronics applications grow to 83% of Aixtron's first-half revenue

## Full-year outlook raised after highest quarterly order intake since 2011

For second-quarter 2023, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €173.5m, more than doubling from the dip to €77.2m last quarter and up 69% on €102.5m a year ago. This drove first-half revenue up 31% year-on-year, from €191.1m in 2022 to €250.7m for 2023.

The continuously growing demand for efficient power electronics applications was supplemented by a large portion of the export licenses outstanding in the prior quarter having now been granted. Over €50m of the €70m in systems waiting for shipment at the end of Q1 has now been shipped and turned into revenue, confirming expectations that the pace of granting export licenses is now returning to normal.

Of total first-half revenue, 82% came from equipment sales (up from 78% a year ago), while 18% came from after-sales service & spare parts (down from 22% a year ago).

Metal-organic chemical vapor deposition (MOCVD)/chemical vapor deposition (CVD) equipment for making gallium nitride (GaN)- and silicon carbide (SiC)-based power electronics devices continued rising strongly, to 83% of equipment

revenue, up from just 29% a year previously (with SiC comprising the largest share). MOCVD equipment for making optoelectronics devices (telecoms/datacoms and 3D sensing lasers for consumer electronics, solar and wireless/RF communications) has fallen from 24% of equipment revenue a year ago to just 12% (mostly for lasers for optical data transmission and 3D sensing). MOCVD equipment for making LEDs fell from 43% of equipment revenue a year ago to just 5%.

By region in first-half 2023, 50% of revenue came from Asia (down from 70% in first-half 2022), 29% from Europe (up from 16%) and 21% from the Americas (up from 14%).

Quarterly gross margin has grown further, from 37% a year ago and 40% last quarter to 42%, taking first-half gross margin from 39% in 2022 to 42% for 2023.

First-half operating expenses have risen by 34% from €42.3m in 2022 to €56.5m for 2023, as quarterly OpEx rose further, from €20.6m a year ago and €27.6m last quarter to €28.9m in Q2/2023. This is driven by R&D spending (on existing systems, and on developing new system generations) rising from €27.3m in first-half 2022 to €39m in first-half

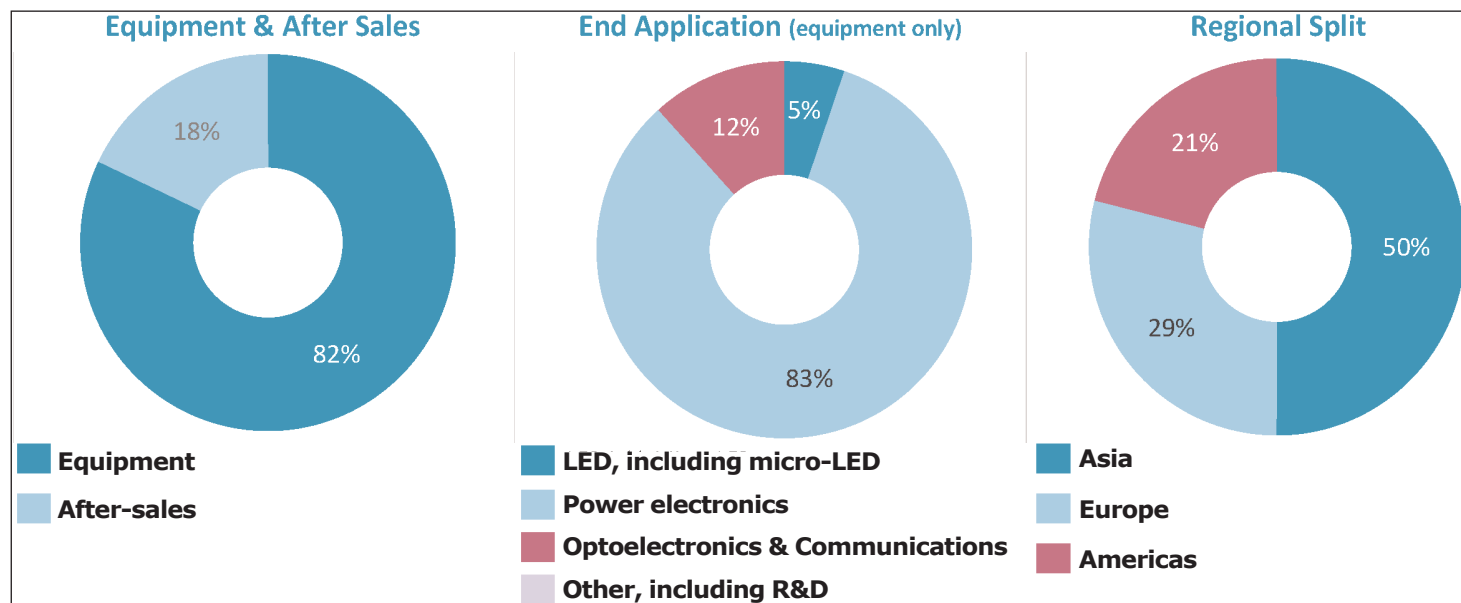
2023, as well as increased staffing (full-time equivalent) rising by 31% from 772 at the end of June 2022 to 1014 at end-June 2023.

### Quarterly profits more than double year-on-year

Second-quarter 2023 operating result (earnings before interest and taxes) was €44.6m (EBIT margin of 26%), up on €17.2m (17% margin) a year ago. This drove first-half EBIT up from €31.4m (16% margin) in 2022 to €48.1m (19% margin) for 2023.

First-half net profit rose from €31.1m (€0.28 per share) in 2022 to €43.9m (€0.39 per share) for 2023. Q2/2023 net profit of €40.4m (€0.36 per share) was up from €17.3m (€0.16 per share) in Q2/2022.

Free cash flow was -€82m in Q2/2023, compared with +€1.9m a year ago. However, this was driven primarily by outflows to build up inventory from €224m to €333m to prepare for the very high expected business volumes in second-half 2023. "We are very carefully managing our inventories to enable us to offer acceptable delivery times to our customers," notes chief financial officer Dr Christian Danninger. "Our balanced approach has allowed us to ship to our customers supporting their capacity expansion plans."



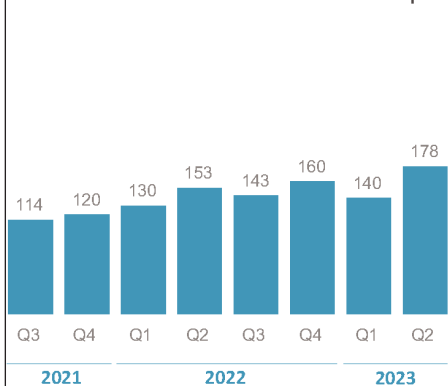
**Order Intake**

(incl. equipment & after sales)<sup>1</sup>

@ \$1.25 @ \$1.20 @ \$1.15

1 USD order intake and backlog were recorded at the prevailing budget rate (2021: \$1.25/€; 2022: \$1.20/€; 2023: \$1.15/€)

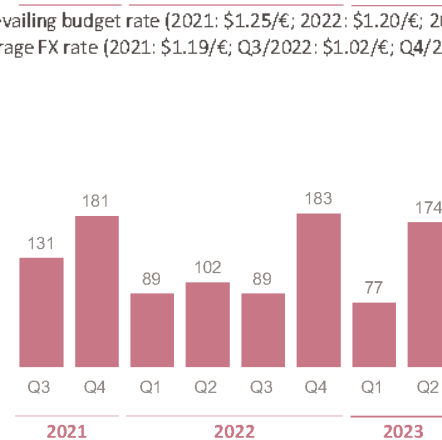
2 USD revenues were converted at the actual period average FX rate (2021: \$1.19/€; Q3/2022: \$1.02/€; Q4/2022: \$1.00/€; Q1/2022: \$1.07/€; Q2/2023: \$1.09/€)



**Revenues**

(incl. equipment & after sales)<sup>2</sup>

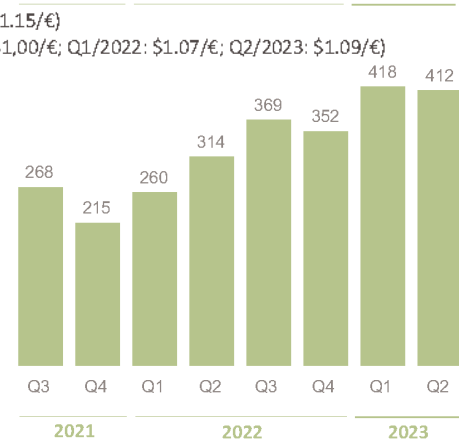
@ \$1.19 @ \$1.06 @ \$1.08



**Order Backlog**

(equipment only)<sup>1</sup>

@ \$1.25 @ \$1.20 @ \$1.15



Together with a dividend payment of €34.8m paid in May, during first-half 2023 cash and cash equivalents (including other current financial assets) hence fell from €325.2m to €210.4m. Of this, €133m has been invested into funds following a very conservative diversification strategy.

**Equipment order backlog up 31% year-on-year**

First-half order intake rose by 12% year-on-year from €282.8m in 2022 to €317.7m for 2023. Q2 order intake was €177.8m, up on €139.9m last quarter, and the highest quarterly order intake since 2011.

Equipment order backlog is hence up 31% year-on-year, from €314.4m to €412.5m at the end of June.

Growth was driven by continued high demand from the addressed end-markets and in particular for efficient power electronics based on GaN and SiC, which accounted by far for the largest share of the order intake. "Customers are ordering equipment for large proj-

ects to build high-volume manufacturing capacity," notes CEO Dr Felix Grawert. Aixtron is currently supporting several major customers in setting up production facilities and enabling these important semiconductor companies to manufacture SiC and GaN devices in high volumes. The ground for this is set by the new G10 family of products: the G10-SiC, the G10-AsP and the G10-GaN, which will follow later this year.

"We expect this momentum to continue in the years to come," says Grawert. "A very strong indication of this can be found in e-mobility, where SiC is the preferred material system. Moreover, we already know that our systems for SiC [the G10-SiC] will by far be the top-selling products in our portfolio in 2023," he adds.

**Full-year guidance raised for orders and revenue**

Due to the unabated strong demand, for full-year 2023 Aixtron has

raised its forecast for order intake from €600–680m to €620–700m (up 11% on 2022's €585.9m), based on the budgeted exchange rate of \$1.15/€ (versus \$1.20/€ in 2022).

Based on the first-half revenue of €250.7m, plus equipment order backlog (convertible into 2023 revenue) of €300–330m as of end-June, joined by a forecasted €30m in new order intake convertible into revenue in 2023, plus a forecasted €50m in after-sales revenue, the forecast for full-year revenue has been raised from €580–640m to €600–660m (up about 36% on 2022's €463.2m).

Aixtron still expects full-year gross margin of 45% and an EBIT margin of 25–27%.

"Led by the global megatrends of electrification, digitalization and sustainability, we expect the strong demand for wide-bandgap materials such as SiC and GaN to last and continue," says Danninger.

[www.aixtron.com](http://www.aixtron.com)

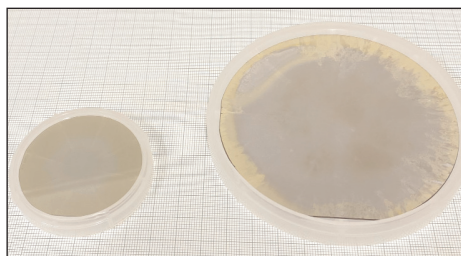
FY/2023 Guidance		Revenue Guidance FY/2023	
<b>Total Order Intake</b>	EUR 620m – 700m (from EUR 600m – 680m)		
<b>Revenues</b>	EUR 600m – 660m (from EUR 580m – 640m)		
<b>Gross Margin (%)</b>	Around 45% (unchanged)		
<b>EBIT Margin (%)</b>	25% – 27% (unchanged)		

## Crystal IS and Asahi Kasei produce first 4" AlN substrate Commercialization to quadruple device output of existing 2" facility

Crystal IS Inc of Green Island, NY, USA — a subsidiary of Tokyo-based Asahi Kasei that makes proprietary ultraviolet light-emitting diodes (UVC LEDs) — has produced what it claims is the first reported 4-inch (100mm)-diameter single-crystal aluminium nitride (AlN) substrate, demonstrating the scalability of its processes for growing AlN bulk single crystals to meet production demands.

Aluminium nitride substrates have low defect densities, high UV transparency, and low impurity concentrations. AlN is attractive for a variety of applications, such as UVC LEDs and power devices, due to its ultra-wide bandgap and very high thermal conductivity. The 4-inch substrate produced shows a usable area of over 80% based on existing requirements for UVC LEDs.

"This accomplishment signifies that aluminium nitride is commercially viable for new industries beyond just UVC LEDs," comments



**Crystal IS' existing 2"-diameter AlN substrate used for commercial UVC LED production (left) and the first 4"-diameter AlN substrate (right).**

Dr Naohiro Kuze, executive fellow, Research Laboratory of Advanced Science and Technology, Asahi Kasei.

Founded in 1997 to develop native aluminium nitride substrates, Crystal IS manufactures UVC LEDs on its commercial process for 2-inch diameter substrates. These LEDs enable what is claimed to be industry-leading reliability and performance at the ideal germicidal wavelengths of 260–270nm for the disinfection of water, air and surfaces. The existing capacity of the facility can meet the volume requirements

for consumer devices using UVC LEDs based on the existing 2-inch production line.

"This indicates the scalability of our processes to deliver quality devices on aluminium nitride," says Crystal IS' president & CEO Eoin Connolly.

Crystal IS currently produces thousands of 2-inch substrates annually to support the production of its Klaran and Optan product lines. The commercialization of 4-inch AlN substrates will quadruple the device output of the existing footprint of the firm's facility. It should also enable the development of new applications on AlN substrates as it integrates into existing fabrication lines for power and RF devices using alternative materials.

Crystal IS presented the progress on 4-inch substrates at the 23rd American Conference on Crystal Growth and Epitaxy in Tucson, Arizona (13–18 August). [www.crystalconference2023.com](http://www.crystalconference2023.com)  
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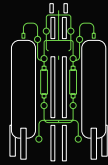
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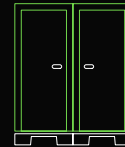
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## Instrument Systems joins MicroLED Industry Association

### Light measurement firm supporting development and implementation of $\mu$ LED display technologies

Light measurement technology firm Instrument Systems GmbH of Munich, Germany (which was founded in 1986 and has been a subsidiary of Konica Minolta Group since 2012) has become a member of the MicroLED Industry Association (MIA), supporting the development and implementation of  $\mu$ LED display technologies.

Instrument Systems has been involved in setting global standards for high-precision spectroradiometric measurements in the LED industry since 1986. The firm is involved in standardization committees and associations (such as DIN, CIE) and cooperates with the metrology institutes. Joining the MIA is a logical

continuation of these activities for the purpose of sharing knowledge and advancing new technologies worldwide, says CEO Dr Markus Ehbrecht.

Founded in 2022 to accelerate the implementation of  $\mu$ LED display technologies, the MicroLED Industry Association brings together companies, researchers and organizations active in the  $\mu$ LED industry, and provides a forum for solving common technology problems, promoting collaboration and sharing information, resources and tools. The association aims to ensure that the  $\mu$ LED display industry communicates uniformly and jointly solves technology problems.

With its light meters and spectrally optimized cameras, Instrument Systems offers solutions for the precise optical measurement of  $\mu$ LEDs. The camera-based 2D systems LumiTop 4000 and LumiTop X150 enable fast, highly accurate and traceable optical measurements for  $\mu$ LED arrays and displays. Combined with a high-precision CAS 140D spectroradiometer, adaptive live calibrations can be realized, based on the spectral properties of the test specimen. In addition, the measurement can be synchronized with the power source of the  $\mu$ LED to achieve high speeds and reproducibility.

[www.microledassociation.com/](http://www.microledassociation.com/)

## CrayoNano to supply CrayoLED UV-C LEDs for AquiSense's water disinfection systems

### Contract offers opportunities to increase value beyond minimum

CrayoNano AS of Trondheim, Norway — which develops and makes semiconductor components based on patented and proprietary nanomaterials technology — has signed a commercial frame contract to supply UV-C LEDs worth about NOK4m over the next 12 months to AquiSense Technologies LLC of Erlanger, KY, USA (which designs and makes UV-C LED water, air and surface disinfection systems). The contract offers additional opportunities to increase the value



beyond the minimum amount. "Over the past nine months, AquiSense has tested and validated

the CrayoLED UV-C LEDs to our high-quality standards for use in water disinfection systems for point-of-entry and point-of-use products," says AquiSense's CEO Oliver Lawal. "We are very happy to welcome CrayoNano as a supplier as the collaboration allows AquiSense to substantially grow our business globally across market segments, including the industrial and consumer markets," he adds.

[www.crayonano.com](http://www.crayonano.com)  
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# Kubos' gains £700,000 Innovate UK grant to develop 5%-efficient red micro-LEDs

## First customer order follows new patents for cubic GaN process and product technology

Micro-LED material technology company Kubos Semiconductors Ltd (which was spun out of the University of Cambridge in 2017) has won a £700,000 Future Economy Investor Partnerships (FEIP) grant from UK government innovation agency Innovate UK. The funding is subject to completing aligned investment led by the Development Bank of Wales. The firm has also been granted its first process technology patents and has received its first customer order.

The grant is for a 24-month project to achieve 5% efficiency for red micro-LEDs by deploying the company's proprietary KubosLED cubic-phase gallium nitride (GaN) process. Achieving the project's goal will make micro-LEDs viable in augmented/virtual-reality (AR/VR) applications by approximately doubling the efficiency achieved with other process technologies, it is reckoned. Poor red micro-LED efficiency is currently one of the main factors constraining the AR/VR market.



**Kubos' CEO  
Caroline O'Brien.**

"We've only recently joined the FEIP and Kubos is the first company we have supported, and they have been awarded this grant," notes Carl Griffiths, technology seed fund manager for DBW. "Kubos has demonstrated it has the right focus on deep tech, the right profile and momentum to secure the funding. Their exciting new technology has a clear purpose, and the market opportunity is vast," he comments.

Following completion of the funding round in the autumn, Kubos — as a fabless semiconductor company — will open a development office in Wales. This will enable it to continue to benefit from years of collaboration with the South Wales compound semiconductor cluster, specifically the Compound Semiconductor Centre (CSC, a partnership between Cardiff University and Cardiff-based

epiwafer & substrate maker IQE plc) and the Institute of Compound Semiconductors at Cardiff University, where the Kubos LEDs are processed and tested.

Kubos' core cubic GaN process and product technology patent has now been granted in China, Japan, Singapore and the USA. Its patent portfolio has also been extended to include granted patents for silicon carbide epitaxy, which is used by Kubos as a growth substrate.

The firm has also won its first customer for its KubosLED material in red micro-LEDs. "We see huge demand for our technology every time we engage with potential customers and are delighted to have won our first major customer and secured further funding to ensure we reach our technology goals," says CEO Caroline O'Brien. "These achievements underline the fact that KubosLED material technology is the leading contender to clear a major bottleneck that's been holding back AR/VR adoption."

[www.kubos-semi.com](http://www.kubos-semi.com)

## Luminus' CEO Dr Decai Sun retires Executive VP of marketing & sales Mark Pugh appointed CEO

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — says that, after 11 years of service, chief executive officer Dr Decai Sun is retiring, and executive VP of marketing & sales Mark Pugh has taken over as CEO.

Sun started Lightera Corp in Silicon Valley in 2012 with funding from Sanan Opto. Lightera acquired Luminus in 2013, merging the two firms with Sun becoming CEO. Under his leadership, Luminus became a profitable LED component company, with a broad range of

applications worldwide. He moved Luminus from Boston to Sunnyvale in 2014 and recently built the worldwide team to more than 200 employees.

Mark Pugh has been a pioneer in the optoelectronics industry for over 30 years, with leadership roles in business development, marketing and executive management. His career began with Hewlett Packard in the Optoelectronics Division, working with LEDs and infrared devices. This eventually led to an opportunity to represent HP in a new joint venture with Philips that later became Lumileds. In 2007,

Pugh co-founded Xicato, with the goal to replace halogen lights with LED modules that had industry-leading quality-of-light and all the benefits of LEDs. In 2015, he joined Luminus Devices as executive VP of marketing & sales, and the firm quickly tripled in sales and turned profitable.

"We will continue to further expand our broad product offering of photonics solutions as well as leverage our Sanan group relationship to grow our customer base in new markets with new and compelling semiconductor technologies," says Pugh.

[www.luminus.com](http://www.luminus.com)

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The high performance UCS300-SC provides unmatched cleaning capabilities to ensure maximum productivity and a contamination free surface every time

# ams OSRAM launches intelligent multi-pixel EVIYOS 2.0 LED for precision adaptive headlights

## Marelli's new h-Digi microLED based on the EVIYOS 2.0

After 10 years of continuous engineering development, ams OSRAM GmbH of Premstätten, Austria and Munich, Germany has launched EVIYOS 2.0 in volume production, a new type of intelligent multi-pixel LED that enables fully adaptive, dynamic headlight operation and image projection in automotive forward lighting.

EVIYOS 2.0 can selectively illuminate the road ahead to maximize the driver's view in high-beam mode without creating the glare typically experienced by other road users. With a pixel pitch of 40µm, the chip's 25,600 individually controllable LEDs can also project high-resolution images on to the road surface, for example to display warning symbols to the driver or other road users, or to guide the driver past obstacles.

Use of EVIYOS 2.0 is said to improve road safety by increasing the time for drivers to react to hazards that would be invisible or partially hidden with conventional headlights. The superior view of the road also promises to transform the driver's experience of the road at night, making night driving easier and safer.

Until now, many automotive safety features have been designed to keep the driver and passengers inside the vehicle safe. With EVIYOS 2.0, through the ability to project images on the road at night, the car communicates in new ways both to the driver but also to others in the car's surroundings. For example, headlights based on EVIYOS 2.0 can project a snowflake symbol on to the road surface to warn of icy or slippery conditions, helping to heighten awareness of danger and hence reducing the risk of accidents.

"High-resolution adaptive forward lighting

is set to become the next big differentiator for vehicles from the world's premium brands," says Wolfgang Lex, senior VP automotive. "EVIYOS 2.0 is the enabler of the most precisely controllable forward lighting systems, and is a major new value creator for the automotive industry."

### Monolithic architecture produces homogeneous light output

The design of EVIYOS 2.0 draws on multiple innovations in chip design and fabrication. The 25,600 pixels are fabricated in a monolithic µ-LED chip array, which enables ams OSRAM to achieve what is claimed to be exceptionally high uniformity of color and brightness.

EVIYOS 2.0 consists of the multi-pixel emitter and a driver that individually controls the operation of each of the 25,600 LEDs. In Adaptive Driving Beam systems, the multi-pixel headlamp is mounted in a lensed headlamp assembly, and combined with an intelligent camera for scanning the scene in front of the vehicle. This enables the headlamp in high-beam mode to dynamically switch off enough LEDs to avoid glare for other road users while maximizing the driver's view of the road. Dynamic control of individual LEDs also enables the headlight to project accurately along curves, extending the driver's view of the road ahead.

EVIYOS 2.0 is a high-output, high-efficiency automotive light source that enables energy saving in vehicles: only those LEDs are energized that are required to maximize the driver's view safely, so light is not wasted.

The LED chip has a compact 40mm<sup>2</sup> footprint to ease integration in sleek headlamp assemblies and is available with a 1:4 (25,600 pixels) or 1:3 (19,200 pixels) aspect ratio.

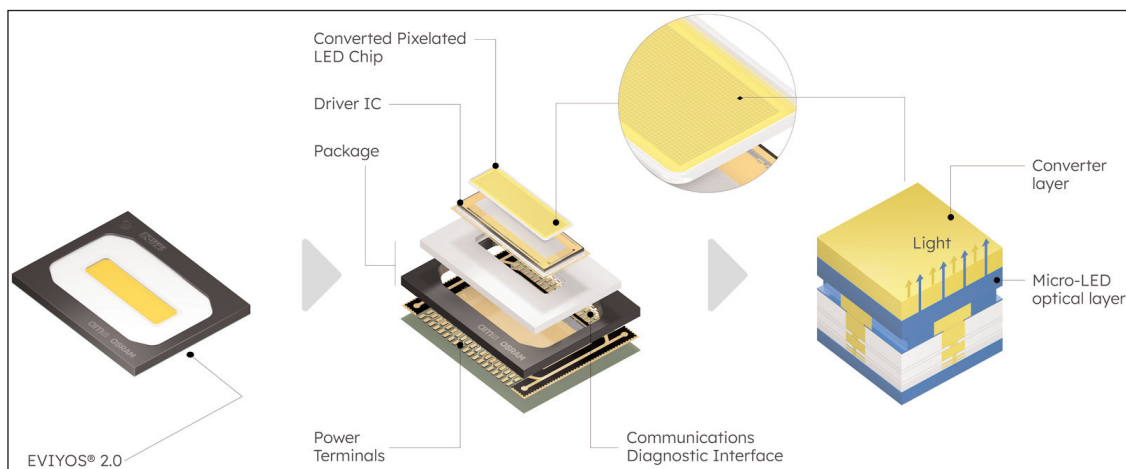
### First design implementation with Marelli: micro-LED module using EVIYOS 2.0

Several global car makers and tier-1 suppliers are designing EVIYOS 2.0 into new product concepts.

For example, Marelli has announced its first multi-pixel LED headlight module to be based on EVIYOS 2.0: the h-Digi microLED.

"The h-Digi microLED platform module based on the ams OSRAM EVIYOS 2.0 enables us to develop solutions for global carmakers providing more safety and comfort for drivers at night," notes Didier Thalgott, senior VP at Marelli's Automotive Lighting & Sensing Division. "In addition, thanks to its compactness, improved power consumption and affordable pricing, the system opens doors to applying the technology also in mid-level car segments."

[www.ams-osram.com/products/product-families/eviyos](http://www.ams-osram.com/products/product-families/eviyos)



# ams OSRAM's OSIRE E3731i RGB LED allows dynamic color and motion effects across hundreds of LEDs

## License-free Open System Protocol for communication with any microcontroller reduces implementation cost and complexity of dynamic interior automotive lighting

ams OSRAM GmbH of Premstätten, Austria and Munich, Germany has introduced new technology that is said to greatly simplify the implementation of dynamic, color- and intensity-changing arrays of hundreds of RGB LEDs in car interior lighting.

The new OSIRE E3731i RGB LED features a digital core that enables low-latency communication over a standard serial bus interface with any microcontroller. ams OSRAM has also developed a new Open System Protocol (OSP) running on the OSIRE E3731i. Using OSP, any microcontroller can transmit instructions to modulate brightness and color individually to each LED. OSP is available for use license- and royalty-free by any car, LED, lighting system or microcontroller manufacturer.

By using the OSIRE E3731i LED and OSP, automotive manufacturers can realize novel dynamic lighting effects in the car interior. Up to 1000 LEDs can be connected in a daisy chain, controlled via one microcontroller.

"Dynamic lighting promises to add value to cars by combining changes in color and brightness with pulsing, breathing or moving light effects, for decorative or functional purposes," says senior product manager Hermann Senninger. "The OSIRE E3731i and OSP enable dynamic interior lighting to be implemented



**OSIRE E3731i  
RGB LED**



with a simpler architecture, fewer components, less wiring and at lower system cost. These benefits are attracting customers already, and we expect to see the product deployed in production vehicles soon."

Intelligence built in to every LED ams OSRAM says that development of the new intelligent LED draws on its capabilities in optical technology and IC design and fabri-

cation. The OSIRE E3731i is a high-performance RGB LED co-packaged with an IC that features three LED drivers, a serial bus interface supporting the OSP, a temperature sensor and on-chip memory.

Each intelligent RGB LED is characterized at the factory, and its optical performance data are stored in the LED's on-chip memory. This is said to make it easier for automotive manufacturers to perform end-of-line calibration of interior lighting systems, and to achieve very high optical uniformity and consistency across arrays of hundreds of OSIRE E3731i LEDs.

The OSIRE E3731i is now qualified to the latest AEC-Q102 Annex 3 standard.

[www.ams-osram.com/products/leds/multi-leds/osram-osire-e3731i-krtbi-d2lm31-31](http://www.ams-osram.com/products/leds/multi-leds/osram-osire-e3731i-krtbi-d2lm31-31)

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# NUBURU wins NASA contract to demonstrate power beaming in space using blue laser technology

## Reducing size and weight of surface power management equipment for the moon and Mars

NUBURU Inc of Centennial, CO, USA — which conducts research, development, design and manufacturing of high-power, high-brightness industrial blue lasers — has been awarded a contract by the US National Aeronautics and Space Administration (NASA) to demonstrate the feasibility of power beaming in space using the firm's proprietary blue laser technology. Through NASA's Small Business Innovation Research (SBIR) funding initiative, NUBURU has been selected to create a qualified solution that mitigates the high costs associated with transporting copper or aluminium wires that are critical to provide power to lunar or planetary bases in remote locations.

"Power beaming is one of the only effective and economical solutions to the power management challenges facing NASA and other

space operators today," says NUBURU's CEO Mark Zediker.

"Powered by our blue laser technology, the system we are developing will provide a unique solution that dramatically reduces the size and weight of the equipment needed to meet regular mission needs."

During the initial phase of the project, NUBURU will focus on establishing the scientific, technical and commercial merit and feasibility of its technology. The firm then aims to create a commercially viable product to tackle this ongoing problem and continue to develop innovative space-qualified hardware.

In addition to tackling the core business challenges associated with power transmission, NUBURU's laser technology can provide visual guidance to astronauts due to the scatter off either the fine regolith

powder suspended above the moon's surface or the Rayleigh scattering off the Martian atmosphere, creating a guided highway across these surfaces. NUBURU's blue laser power beaming system will also be equipped with a high-bandwidth laser communication link, ensuring laser safety and enabling data transmission between widely spaced habitats.

NASA's SBIR program funds the research, development and demonstration of innovative technologies that fulfill NASA needs as described in the annual solicitations and have significant potential for successful commercialization. This three-phase process begins with a six-month idea generation period followed by a two-year prototype development phase that then leads to commercialization.

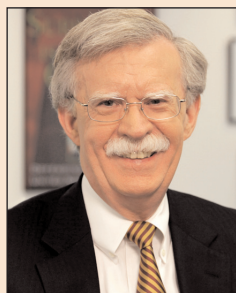
[www.nuburu.net](http://www.nuburu.net)

## NUBURU appoints John Bolton to board

### Former US National Security Advisor to bolster strategic and commercial development with defense expertise

NUBURU Inc of Centennial, CO, USA — which was founded in 2015 and develops and manufactures high-power industrial blue lasers — has appointed attorney, diplomat, consultant and political commentator John Bolton to its board of directors, providing strategic insight to support efforts to expand its presence in the defense, energy and aerospace markets as well as guidance on the impact of international relations and regulations on the firm's business and customer base.

Bolton was the US National Security Advisor to former President Donald Trump and the United States Ambassador to the United Nations from 2005 to 2006.



**John Bolton, now on NUBURU's board of directors.**

He has spent many years of his career in public service and held high-level positions in the Administrations of Presidents Ronald Reagan, George H. W. Bush and George W. Bush. As an attorney, Bolton was in private practice in Washington DC from 1974 to 2018, except when he was in government service. He graduated with a BA, summa cum laude, from Yale College and received his JD from Yale Law School.

"Through his extensive defense and diplomacy background, John will contribute key insights to inform NUBURU's strategic presence in the defense and energy markets," comments NUBURU's co-founder, CEO & director Mark Zediker.

"NUBURU's innovative technology is at the forefront of disrupting the metal machining and processing industry with its high-performance blue lasers," says Bolton. "I see great potential for this innovative and proven technology to become further embedded in the energy and defense industries, and I look forward to helping establish the company as a key player in this sector."



## Blue Laser Fusion raises \$25m in seed round funding Santa Barbara-based start-up targets first prototype MegaJoule pulse laser in 2025, for commercial-ready fusion reactor by 2030

Blue Laser Fusion Inc (BLF) of Palo Alto, CA, USA has raised \$25m in its first series seed round funding. Major investors are the two Japan-based venture capital firms JAFCO Group Co Ltd and SPARX Group Co Ltd (Mirai Creation Fund III).

Blue Laser Fusion was founded in 2022 by University of California, Santa Barbara (UCSB) professor Shuji Nakamura Ph.D. (the 2014 Nobel Laureate in Physics), Waseda University Ventures (WUV) general partner Hiroaki Ohta Ph.D., and Silicon Valley-based attorney Richard Ogawa.

With over 200 claims in patent applications, BLF has developed a proprietary novel laser fusion technology that is reckoned to be capable of achieving the world's first nuclear fusion for energy generation for power grids. The

firm's laser technology enables a MegaJoule pulse energy laser with a fast repetition rate to achieve commercial fusion. BLF plans to complete its first prototype in 2025, and then demonstrate a commercial-ready fusion reactor by 2030.

The new funding will be used to expand R&D operation in the Santa Barbara area as well as in Tokyo to develop its prototype commercial reactor.

For sustainable and environmentally friendly operation, Blue Laser Fusion plans to adopt a safe hydrogen-boron fuel HB11, which is not radioactive, is free from harmful neutrons, yields safe helium elements, and is a naturally abundant mineral.

"HB11 is the perfect fuel for fusion and has no harmful neutron or tritium elements, as conventional fusion technologies," notes chief

technology officer Hiroaki Ohta. "We are pleased to be working with our group of world's top scientists and experts to not only ignite a fusion reaction with HB11 but maintain the reaction to create clean renewable energy," he adds.

"Fusion is the ultimate energy source, and its successful commercialization will be a huge leap towards achieving clean and abundant energy for everyone," comments Keisuke Miyoshi, president & CEO and partner of JAFCO. "Advances in laser inertial technology, including Blue Laser Fusion's ability to execute the next generation of laser technology, provide the basis for a very exciting and promising path to the ultimate sustainable energy source."

[www.materials.ucsb.edu](http://www.materials.ucsb.edu)

[/people/faculty/shuji-nakamura](http://people/faculty/shuji-nakamura)

## NUBURU more than doubles revenue in Q2 to \$1.1m

For second-quarter 2023, NUBURU Inc has reported revenue of \$1.05m, more than doubling from \$0.47m last quarter and compared with just \$0.04m a year ago, driven by product deliveries to commercial customers Essentium and GE Additive.

Deliveries to Essentium were part of a multi-year partnership focused on metal 3D printing for the aerospace, automotive and defense markets. The firm also delivered the first blue area printing head as part of the Small Business Innovation Research (SBIR) Phase II contract awarded in 2022 by AFWERX (an innovation arm of the US Department of the Air Force) to GE Additive for testing.

"This is underpinned by the progress we've made in introducing additional product lines within our core technology portfolio," says CEO & co-founder Dr Mark Zediker.

During Q2, NUBURU announced:

- the BL-1000 series 1kW blue laser to target large, fast-growing

electric vehicle battery production, metal 3D printing and consumer electronics markets;

- a contract from NASA to demonstrate feasibility of power beaming using a blue laser, showcasing the breadth of applications for NUBURU's IP-protected technology;

- a private placement from existing and new investors, increasing June's capital raise to \$9.2m.

"With the recent product launch of our new NUBURU BL Series Laser, our market positioning for long-term growth continues to develop," says Zediker. "In tandem with the accelerating market demand we recognize for sustainable welding and 3D printing technologies, we've also witnessed an increased interest in our products by blue chip customers such as NASA."

Operating expenses have almost doubled from \$2.7m to \$5m, due mainly to one-time professional fees associated with legal, compliance and accounting matters following

the business combination and transitioning to being a public company, plus regular general and administrative costs associated with the firm's status as a public company and increased costs for R&D of tooling and supplies related to the development of the BL product line.

EBITDA has gone from -\$3.75m a year ago and -\$4.6m last quarter to -\$6m.

Net cash used in operations has risen from \$2.83m a year ago and \$4.05m last quarter to \$4.65m.

Driven by the increase in production capabilities to support additional product lines, capital expenditure has risen from \$0.083m a year ago and \$0.345m last quarter to \$0.48m.

Free cash flow has hence worsened, from -\$2.9m a year ago and -\$4.4m last quarter to -\$5.1m.

Despite this, cash and cash equivalents rose during the quarter from \$1.52m to \$6.6m due to the funds raised in the private placement.

# BluGlass highlights GaN laser orders for quantum sensing & surgical applications, and improvements to DFB lasers

BluGlass Ltd of Silverwater, Australia — which develops and makes gallium nitride (GaN) blue laser diodes based on its proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology — has given an update on activities in its fiscal fourth-quarter 2023 (to end-June).

## Enhanced GaN lasers showcased

At the Laser World of Photonics conference in Munich, Germany at the end of June, BluGlass presented enhanced performance data for its GaN lasers. Since the launch of its first laser products in January, BluGlass has significantly improved light emission, power conversion efficiencies and voltage across its violet (405nm and 420nm) and blue (450nm) wavelengths. The 450nm lasers saw the largest improvement, with power conversion efficiencies for single-mode and multi-mode devices up by more than 55% and 42%, respectively. Enhancements broaden target applications to include quantum computing, robotics and biotechnology.

In addition to improving existing products, BluGlass has expanded its GaN laser portfolio, introducing an ultraviolet 397nm alpha prototype. UV lasers offer increased power and precision and are used in applications such as disinfection technologies, quantum sensing and medical devices. Higher-power single-mode 405nm and 420nm devices are in development, along with single-mode and multi-mode 450nm and longer-wavelength devices spanning 470nm, 488nm and 525nm.

"Industry conferences are key to securing new customer orders, increasing awareness of our growing GaN laser portfolio, flexible packaging solutions, and custom manufacturing capability. We continue to engage with potential customers and partners across our target verticals (quantum, biotech,

display (AR/VR), industrial, defence and R&D)," says CEO Jim Haden.

"These higher-performing devices enable use in more demanding applications while meeting customer needs for wavelength and form-factor flexibility," he adds.

"Discussions with these companies are progressing, and we expect many of these will convert to sales, supported by increased adoption of GaN lasers in advanced applications."

## New customer orders

During the quarter, BluGlass continued to grow its customer book, securing new purchase orders from a quantum photonics pioneer and a leading medical device manufacturer. Customer orders now encompass BluGlass' entire GaN laser product suite, now being tested for eventual deployment in various applications including novel quantum sensing, machine vision, 3D printing, and surgical applications. BluGlass expects to secure new orders this quarter to be shipped in line with industry-standard 8–12-week shipping timeframes.

"Customers continue to test, integrate and qualify BluGlass' lasers in their own product development and applications. These steps pave the way to securing larger, recurring orders. We are engaged with multiple customers and are working diligently to convert these to long-term agreements while engaging with additional prospective customers and partners," says Haden.

"We are receiving positive feedback on our laser performance from our collaborative customers, who have been impressed by our momentum, fuelled by both continuous and breakthrough design enhancements. Their valuable feedback is guiding our efforts to improve aspects of our fabrication and packaging to better meet their specific product needs. Progressing agreements from initial discussions through to qualification and full-scale manufacturing often takes multiple months, and sometimes even years for novel,

advanced and high-power applications, but early engagement is necessary to become 'designed-in' in our customers' products," he adds.

"Vertical integration further supports qualification and adoption of our GaN lasers, enabling us to provide wavelength and form-factor flexibility with emphasis on quality, consistency and performance."

## Vertical integration nearing completion

During the quarter, BluGlass transferred core downstream manufacturing processes from four contract manufacturers to its Silicon Valley production facility in Fremont, CA, USA. The firm is now in the final stages of integrating its remaining contract manufacturer, responsible for thinning, cleaving and n-metalization processes.

While creating a new manufacturing supply chain is complex, BluGlass says that it has transitioned most core processes to Fremont. A few production and repeatability challenges in parts of the fabrication process temporarily impacted availability of the firm's GaN lasers during the quarter. These challenges, which impacted laser consistency, were related to photolithography processes, metalization, and packaging processes for non-TO Can packages.

Manufacturing equipment component unavailability at Fremont resulted in stepper photolithography equipment for single-mode products being offline for an extended period during the quarter. The stepper is back online and preventative measures have now been implemented, including stockpiling spare parts, and securing specialist servicing and maintenance suppliers. New manufacturing processes, including secondary qualification and uniformity calibration, have significantly reduced variability in photolithography steps.

BluGlass is also working with its partners and suppliers to address bonding inconsistencies. Wafers

manufactured with improved packaging designs and operational controls will be available in mid-September.

"While it is common to experience some challenges in vertically integrating manufacturing processes, and converting to a new material class, we have quickly identified and rectified issues as they have arisen. New manufacturing processes and enhanced operational controls are reducing variability, and we are now implementing iterative improvements to enhance the repeatability and performance of our GaN lasers," notes Haden. "As we continue to refine our manufacturing supply chain, we are implementing standard cavity lengths and product runs to further enhance consistency and product availability. We have invested in additional engineering team members at Fremont to support these improvement and subsequent mitigation efforts, and have ordered commercial reliability equipment to scale our testing capability and delivery of products to customers," he adds.

"Vertical integration provides enormous technical and commercial benefits in both the short and long term for BluGlass, improving quality and performance of our launched lasers while accelerating learning cycles and development of new and next-generation products," Haden believes. "Operational control and manufacturing capability is also critical to establishing ourselves as a partner-of-choice and addressing key customer challenges, such as packaging flexibility and greater GaN laser availability."

#### **Improvements to DFB laser demonstration**

BluGlass progressed its development of visible GaN distributed feedback (DFB) lasers, demonstrating substantial performance improvements with collaboration partner University of California Santa Barbara (UCSB). In its latest DFB development, BluGlass demonstrated increased side-mode suppression ratio by over 50%, delivering advanced single-frequency performance at 450nm, and using its proprietary

RPCVD technology extended to longer-wavelength blue devices up to 478nm.

Visible DFB lasers are not commercially available. However, there is growing need for this highly promising laser technology to provide narrow spectral width and high spectral purity in more compact form factors in order to facilitate advanced quantum applications.

#### **Gallium export restrictions**

In July, China announced that it will impose new export restrictions on gallium nitride, commencing 1 August. BluGlass has been in contact with its primary gallium suppliers, who have indicated no short-term impact to supply. The firm says it is monitoring the situation closely with its suppliers and will update the market should there be any material change.

#### **Financials**

Customer revenue for fiscal Q4/2023 was \$209,000; comprised primarily of foundry services for a European wafer developer and initial payments for laser product orders. Cash at end of June was \$4.26m, before receipt of the firm's significant fiscal-year 2023 R&D rebates, totalling ~\$7m and expected to be received in September. This significant cash injection, combined with expected business operations, will provide an extended cash runway, says the firm.

Inclusive of salaries, materials and fabrication costs, R&D expenses were \$3.189m (comprising \$3.137m for laser diode product development and \$0.052m for RPCVD development). These costs reflect additional resources at the Silicon Valley fab as BluGlass vertically integrates core manufacturing processes while exiting contract manufacturers.

Payments to related parties in fiscal Q4 were \$163,000, comprising chair and non-executive director fees.

#### **Outlook**

BluGlass says that it enters fiscal 2024 fully focused on delivering against its product and commercialization roadmaps, improving

yield and performance, qualifying products in customer applications, onboarding additional customers, and securing larger purchase orders of its GaN lasers. At the same time, the business will complete integration of its external wafer fab contract manufacturers into its Silicon Valley fab and establish regional distribution agreements in key laser jurisdictions including Europe and the USA.

"While our priority remains validating our product performance and qualifying BluGlass lasers in customer applications, we are also progressing the development of higher-powered lasers in our core wavelengths (405–450nm) and next-generation products. Ongoing manufacturing refinements will continue to enhance laser performance and yield, enabling us to bring better-quality lasers to market much faster. Our discussions with potential customers have highlighted the genuine need for an agile manufacturing partner to address unmet market needs and deliver brighter, better-performing and longer-wavelength devices," says Haden.

"We are also leveraging our RPCVD technology to bring to market novel solutions with collaboration partners. These include our development of green GaN vertical-cavity surface-emitting lasers with Ganvix and visible DFB lasers with UCSB. These solutions are not commercially available, enabling us to further differentiate ourselves in the GaN laser market," he adds.

"Specializing in visible lasers with packaging and manufacturing flexibility, BluGlass' market position is unique," reckons Haden. "Our recent customer engagement continues to confirm the growing need for an agile and dedicated provider in this market, and the increasing importance of visible laser diodes to enable future technologies. Our product strategy remains focused on solving customers' challenges and being a GaN laser partner-of-choice."

[www.bluglass.com.au](http://www.bluglass.com.au)

## Coherent ships 200 billionth VCSEL emitter for sensing

### Sensing to expand into new applications such as smart watches and in smart glasses, plus in-cabin sensing and automotive LiDAR

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA (formerly II-VI Inc before it acquired Coherent in July 2022) says that it has now shipped more than 200 billion vertical-cavity surface-emitting laser (VCSEL) emitters to date for sensing applications.

"In 2013, we began working on two-dimensional VCSEL arrays for 3D sensing in smartphones," says Dr Giovanni Barbarossa, chief strategy officer & president, Materials Segment. "We scaled our production

capabilities from 3-inch to 6-inch wafers in 2017, just in time to help enable the market launch of the first smartphones with facial biometrics," he adds. "We believe sensing applications based on semiconductor lasers will continue to expand into new and exciting applications such as in smart watches for health monitoring and in smart glasses for extended reality. VCSELs will also continue to enable a growing market for in-cabin sensing and LiDAR in automotive."

Coherent says that it continues to innovate in sensing through vertical integration of differentiated technologies. It recently announced a new VCSEL module technology that enables ultra-compact pattern projectors, flood illuminators, and tightly integrated sensing subsystems. This patented module technology relies on an innovative flip-chip assembly of backside-emitting VCSEL arrays on application-specific integrated circuits and supports the integration of photodetector arrays.

## Coherent appoints Christopher Dorman as executive VP, Lasers Business

### General manager of Glasgow facility now responsible for Lasers Segment

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA says that Dr Christopher Dorman has been named executive VP, Lasers Business. He is responsible for the Lasers Segment across the markets of precision manufacturing, semiconductor & display capital equipment, life sciences, and scientific instruments, driving operational excellence and customer focus.

"Dr Dorman's 21-year tenure with Coherent and his recognized expertise in laser technology make him the perfect choice to lead multiple businesses within our Lasers Segment," reckons chair & CEO Dr Vincent D. Mittera Jr.



**Christopher Dorman.**

"Dr Dorman established the blueprint for our world-class facilities for laser design and manufacturing in Glasgow, Kaiserslautern and Lübeck, and in his new role he will continue to drive revenue and cash generation for our lasers business."

Dorman was most recently senior VP & general manager based in Coherent's facility in Glasgow, Scotland. He joined Coherent in 2002 as a product manager and has held various

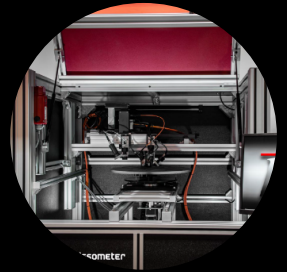
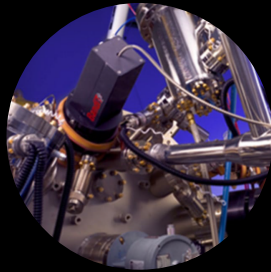
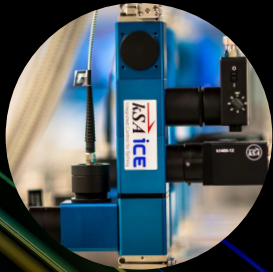
positions as a general manager and vice president.

Dorman graduated from Oxford University with an MA (Oxon) in Physics and holds a Ph.D. in Lasers and Quantum Physics from Imperial College, London. He is currently chair of the UK Photonics Leadership Group, chair of Photonics Scotland, a visiting professor to the University of Strathclyde, and a Fellow of the Institute of Physics. He was recognized by Queen Elizabeth II with an OBE (Officer of the Most Excellent Order of the British Empire) for services to photonic and laser technology and exports in the 2019 Birthday Honours list.

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# Mitsubishi Electric demos light source module for high-capacity optical communication in space

## Quick, low-cost demonstration uses nanosatellite developed through industry–academia collaboration

Tokyo-based Mitsubishi Electric Corp has demonstrated laser optical frequency control using a new light source module, a key component of a projected high-capacity laser optical communication network to be deployed in outer space.

The module, which produces a 1.5 $\mu$ m-wavelength signal, was installed in the OPTIMAL-1 nanosatellite (measuring 10cm x 10cm x 34cm) developed through an industry–academia collaboration led by ArkEdge Space Inc and joined by Pale Blue Inc, SEIREN Co Ltd, the University of Fukui, the School of Engineering at The University of Tokyo, and Mitsubishi Electric. OPTIMAL-1 was released from the Japanese Experiment Module 'Kibo' aboard the International Space Station (ISS) on 6 January. The use of a nanosatellite enabled the demonstration to be carried out faster and at lower cost than using a conventional large satellite.

Mitsubishi Electric has been developing space-based optical technologies that are expected to increase data capacity (by ten times or more) as well as communication speeds and distances compared with systems that use radio waves.

Satellite images are increasingly being used for purposes such as assessing conditions in post-disaster areas and the state of remote forestry resources. Existing radio-wave satellite communication systems are limited in terms of capacity, speed and distance, so

new optical systems offering improved communications capabilities are required for faster and higher-resolution assessments from space. Advanced systems that use laser signals are expected to be increasingly adopted not only for their superior communications capabilities but also for using wavelengths shorter than radio waves, which allows the use of relatively small and easily installed terrestrial antennas.

Features include:

- **The first optical frequency control test in space with a 1.5 $\mu$ m-wavelength laser light source module.**

Laser communication between satellites requires correction of the Doppler effect, which causes the laser optical frequency to change due to satellites moving at different speeds relative to each other. The new light source module was deployed in the world's first demonstration of a laser frequency being adjusted by up to 60GHz in space, sufficient for Doppler effect compensation.

- **Nanosatellite developed in industry–academia collaboration enables quick, low-cost demonstration.**

By using a nanosatellite developed through an industry–academia collaboration project, the demonstration in space required only about one-third the time and one-hundredth the development cost of previous demonstrations in space performed by Mitsubishi Electric with large satellites.

"The development of nanosatellites has been gaining momentum in recent years," notes ArkEdge Space Inc's CEO Takayoshi Fukuyo. "Nanosatellites weighing just a few kilograms can be developed and launched for low cost, so they are expected to be used in new applications, such as widespread observations of Earth using numerous satellites. The successful demonstration of the light source module aboard the OPTIMAL-1 is expected to advance the deployment of nanosatellites."

"Conditions in outer space, including radiation, vacuum and temperatures, create harsh environments for equipment, so demonstrating the capability to operate in space is crucial for the development of satellites," says University of Fukui associate professor Yoshihide Aoyanagi. "I hope the successful demonstration of the OPTIMAL-1 will lead to further progress in industry's use of nanosatellites."

### **Future development**

Mitsubishi Electric will propose the demonstrated technology for use in large-scale space development projects. The firm also intends to promote nanosatellites as an important demonstration platform for space-related R&D conducted through industry–academia collaborations. Mitsubishi Electric says that it will continue to pursue technological development aimed at the early realization of space-based laser optical communications.

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# OIF announces External Laser Small Form-Factor Pluggable Implementation Agreement

## ELSFP paves way for advances in co-packaged optics applications

The Optical Internetworking Forum (OIF) has unveiled the External Laser Small Form-Factor Pluggable (ELSFP) Implementation Agreement (IA), defining a front-panel pluggable form factor tailored to co-packaged optical systems and other multiple laser external laser source applications.

The ELSFP IA introduces the first multi-sourced future-proof front-panel pluggable external laser source form factor to address the evolving needs of the industry. This IA is said to offer benefits including definitions for the placement of laser sources at the front panel, the coolest section of the system, enhancing system reliability and allowing for efficient 'hot-swap' field replacement when necessary.

The ELSFP uses a multi-fiber blind-mate optical connector positioned at the rear of the module. This strategic design mitigates potential eye-safety risks, particularly in applications where high

optical powers are involved. Each ELSFP can supply optical power to one or more optical engines, all seamlessly managed by OIF's Common Management Interface Specification (CMIS).

The IA also defines interoperability for mechanical, thermal, electrical and optical parameters as well as establishing standard power ranges and fiber configurations to focus the industry's development. The final feature unique to ELSFP is the pass-through option, which allows systems architects to maximize face-plate real estate, solidifying ELSFP's position as a versatile and adaptable solution for various optical networking applications.

"By providing a front-panel pluggable external laser source form factor, we're empowering network operators and equipment manufacturers with a cutting-edge solution that not only improves reliability but also paves the way for future innovations," says Jeff Hutchins of Ranovus, OIF board member and

Physical & Link Layer (PLL) Working Group Co-Packaging vice chair.

"The ELSFP's flexible design accommodates the ever-changing needs of the industry, enabling seamless integration with OIF's 3.2T co-packaged optical module project and beyond."

While the ELSFP project was originally envisioned to complement the 3.2T co-packaged optical module, its forward-looking design makes it easily extensible to address future requirements.

"The ELSFP has already garnered a favorable industry reception through its potential to propel external laser source applications forward, as evidenced by strong collaboration among OIF members both in writing the IA and the substantial engagement in numerous interoperability demonstrations facilitated by OIF," comments Cisco's Jock Bovington, editor of the OIF ELSFP IA.

[www.oiforum.com/wp-content/uploads/OIF-ELSFP-01.0.pdf](http://www.oiforum.com/wp-content/uploads/OIF-ELSFP-01.0.pdf)

## OIF's largest ever multi-vendor interoperability demo Demos highlight work on 400ZR+; co-packaging solutions; CEI-112G & CEI-224G; and CMIS implementations

In booth #304 at the European Conference on Optical Communication (ECOC 2023) in Glasgow, Scotland, UK (2-4 October), the Optical Internetworking Forum (OIF) is showcasing its largest-ever multi-vendor interoperability demonstration, involving 39 companies participating in live and static demos highlighting advances in four key technology areas: 400ZR+ optics; co-packaging solutions; Common Electrical I/O (CEI) channels; and Common Management Interface Specification (CMIS) implementations.

The collaborative efforts of OIF's network operator, system vendor,

component vendor and test equipment vendor members are on display at ECOC, illustrating their contributions in driving the adoption of technologies for both present and future networks. OIF member companies participating in the demo are: Adtran; Alphawave Semi; Amphenol; Applied Optoelectronics Inc; Broadcom Inc; Cadence Design Systems Inc; Casela Technologies; Ciena; Cisco Systems; Coherent; Credo Technology Group; Eoptolink; EXFO; Fujitsu Optical Components; Hisense Broadband; Infinera; Juniper Networks; Keysight Technologies; Linktel Technologies;

Lumentum; MACOM Technology Solutions; Molex; MultiLane Inc; NEC Corp; Nokia; O-Net Technologies; Precision Optical Transceivers Inc; Quantifi Photonics; Samtec; Semtech; Senko Advanced Components; Sicoya; Source Photonics; Sumitomo Electric Industries; Synopsys; Telefonica S.A.; VIAVI Solutions and Wilder Technologies. The interoperability demo is supported by participating companies Telefonica and LightRiver. Telefonica is the hosting consulting network operator, and LightRiver is a host for technology-specific pre-demonstration integration testing.

[www.ecocexhibition.com](http://www.ecocexhibition.com)

# POET creates optical interposer platform for 1.6T transceivers using 200G-per-lane technology

## Customer sampling of 200Gbps-per-lane 1.6T T&R optical engines targeted for first-half 2024

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the Optical Interposer, photonic integrated circuits (PICs) and light sources for the data-center, telecom and artificial intelligence (AI) markets — has announced its development of an optical interposer platform for 1.6T transceivers and beyond using 200G-per-lane technology for next-generation data-center and AI networks.

Migrating from 100G per lane to 200G per lane doubles the bandwidth with the same face-plate density as 100G per lane, lowers the overall system power consumption and reduces the solution cost. Cloud and other service providers can continue to reap the benefits of pluggable transceivers in their networks and deploy pluggable solutions at bandwidths of 1.6T (and beyond) with 200G-per-lane technology utilizing POET's enhanced interposer-powered optical engines.

"Moving to 200Gbps per lane is a critical step for the industry to sustain the bandwidth demands of the cloud and AI networks," says chairman & CEO Dr Suresh Venkatesan. "An integration platform like the POET Optical Interposer is an absolute requirement at such high speeds to connect optical and electrical components and at the same time meet performance and power requirements," he adds. "We have augmented the Optical Interposer platform in several important ways to extract the native bandwidth of components without inducing the losses and interferences that are common in other integration schemes. We are working with several industry leaders and integrating their high-bandwidth components on our platform to demonstrate 200G performance."

Enhancements to the Optical Interposer now support 200Gbps-per-lane speed for both the transmitter and the receiver.

The transmit optical engine has been modified for externally modulated lasers (EML), EML drivers and monolithically integrated multiplexers for single-mode fiber applications for up to 10km reach. The receive optical engine can now incorporate the next-generation higher-speed photodiodes, trans-impedance amplifiers and monolithically integrated low-loss polarization-insensitive demultiplexers for 1.6T transceivers and beyond.

The newly designed Optical Interposer architecture enables seamless wafer-scale passive assembly of externally modulated lasers from multiple suppliers, providing maximum flexibility for customer requirements. Among the new features of the Optical Interposer, the most important include:

- novel transmission line designs to supply low-loss, high-speed electrical interconnects with bandwidth greater than 75GHz, a requirement of next-generation high-speed lasers and drivers;

**We have augmented the Optical Interposer platform in several important ways to extract the native bandwidth of components without inducing the losses and interferences that are common in other integration schemes**

- adaptations to support the integration of conventional surface-mount device (SMD) components, which improve RF performance that is crucial at such high speeds;
- new, proprietary demux architectures and assembly techniques to allow passive, wafer-level assembly of the next generation of high-speed photodiodes;
- through-silicon-vias (TSVs) on the Optical Interposer platform for the integration of high-speed electrical and optical components while eliminating wire bonds — one of the primary sources of signal noise and interference in transceivers.

The overall effect of these improvements to the Optical Interposer platform is to achieve superior performance in a power-optimized solution at 200G per lane that can be included in 1.6T pluggable transceivers. The small-form-factor of POET Optical Engines makes the solution scalable to 3.2T pluggable transceivers in existing industry standard form factors.

POET expects to complete the design of 1.6T transmit and receive optical engines with 200Gbps-per-lane technology based on the new generation of Optical Interposer designs by early 2024. It plans to demonstrate these products at major tradeshows and to begin customer sampling by first-half 2024.

Additional information about POET's developments in 200G-per-lane 1.6T optical engines is being featured at the European Conference on Optical Communication (ECOC 2023) on 2 October in Glasgow, Scotland, UK, where POET's senior vice president Raju Kankipati is discussing the 'Semiconductorization of Photonics using Silicon Optical Interposers'.

[www.poet-technologies.com](http://www.poet-technologies.com)



# POET cuts losses further in Q2/2023

## Alpha versions of POET Infinity optical chiplet delivered for testing by two lead customers

For second-quarter 2023, POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer, photonic integrated circuits (PICs) and light sources for the data-center, telecom and artificial intelligence (AI) markets — has reported non-recurring engineering revenue (NRE) of \$177,000, down from \$181,000 last quarter but up on \$120,000 a year ago. This comprised NRE contract services provided to multiple customers (one of which continued to contract services from last year) relating to unique projects that are being addressed utilizing the capabilities of the POET Optical Interposer.

Net loss has been cut from \$5.3m (\$0.14 per share) last quarter to \$4.4m (\$0.11 per share). This included R&D costs of \$2m, cut from \$2.3m last quarter.

Cash flow from operations was -\$4m, more than -\$3.4m a year ago but cut from -\$4.4m last quarter.

During the quarter, POET received \$1.6m from the exercise of warrants and stock options, contributing to \$7.9m received for the first three quarters of 2023.

"We continue to execute on our roadmap, while also accelerating certain aspects of it through increased customer engagements," says CEO & chairman Dr Suresh Venkatesan.

On 14 June, the firm announced alpha sample readiness of POET Infinity, a chiplet-based transmitter platform for 400G, 800G and 1.6T pluggable transceivers and co-packaged optics solutions.

"The company now has five product lines that we are actively sampling and engaged with at new and existing customers. POET Infinity, POET Starlight, POET LightBar,

POET Legacy and POET ONE have emerged as foundational products for us and are providing the opportunity for expanded discussions with customers," says Venkatesan. "Our AI product line features competitively priced and scalable optical engines for high-speed Ethernet-based transceivers and packaged light sources for CXL 3.0-type interfaces. Within the datacom and telecom markets, we have delivered alpha versions of the POET Infinity optical chiplet solution to two lead customers for testing. These customers aim to develop industry-leading 800G 2xFR4 QSFP-DD and OSFP transceiver solutions," he adds. "To further support our team's engineering and commercialization achievements, we have increased our sales and marketing activities."

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# Lumentum's quarterly revenue falls 3.3% as customer inventory digested

## Return to year-on-year growth in Telecom & Datacom shipments expected in 2024

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes optical and photonic products for optical networks and lasers for industrial and consumer markets) has reported full-year revenue growth of 3.2% from \$1712.6m in fiscal 2022 to \$1767m for fiscal 2023 (ended 1 July).

The Optical Communications segment grew by 2.6% from \$1518.5m to \$1557.8m, while the Commercial Lasers segment grew by 7.8% from \$194.1m to \$209.2m.

This was despite fiscal second-half 2023 (and the rest of calendar 2023, it is expected) being impacted by customers digesting large stocks of inventory that they had built up during IC component supply shortages that have since eased.

Fiscal fourth-quarter 2023 revenue was hence \$370.8m, down 3.3% on \$383.4m last quarter and 12.3% on \$422.1m a year ago, although this was above the midpoint of the \$350–380m guidance.

The Commercial Lasers segment contributed \$50.3m (13.6% of total revenue), down 1.8% on \$51.2m a year ago but up 4.1% on \$48.3m last quarter. Specifically, sequential revenue growth was 35% in ultra-fast lasers (driven particularly by new applications in solar cell processing, leading to market share gain) and over 25% in fiber lasers, offset partially by lower solid-state laser shipments for mainly semiconductor applications.

The Optical Communications segment contributed \$320.5m (86.4% of total revenue), down 4.4% on \$335.1m last quarter and 13.6% on \$370.9m a year ago. Of this:

- Industrial & Consumer revenue of \$33.6m was down on \$41.8m last quarter and \$88.8m a year ago, as expected, due to smart-phone seasonality and end-market demand. Full-year revenue fell by

\$ in millions	Q4 FY23	Q3 FY23	Q4 FY22
<b>Revenue</b>	<b>\$370.8</b>	<b>\$383.4</b>	<b>\$422.1</b>
Optical Communications	320.5	335.1	370.9
<i>Telecom &amp; Datacom</i>	286.9	293.3	282.1
<i>Industrial &amp; Consumer</i> <sup>(1)</sup>	33.6	41.8	88.8
Commercial Lasers	50.3	48.3	51.2
<b>Gross Margin (Non-GAAP)</b>	<b>36.7 %</b>	<b>40.8 %</b>	<b>50.4 %</b>
Optical Communications	36.1 %	40.8 %	49.8 %
Commercial Lasers	40.6 %	40.4 %	54.5 %

54% year-on-year due to market share normalization in 3D sensing as a result of an additional competitor joining the market.

- Telecom & Datacom revenue of \$286.9m was down 2% on \$293.3m last quarter (due to customer inventory digestion) but up 2% on \$282.1m a year ago. Full-year revenue grew by 31%.

Although revenue for tunable access modules was down sequentially as expected, strength in metro access and fiber-deep applications drove revenue up 57% to a new record in full-year 2013 (during which manufacturing capacity has been doubled to address the expected return to quarterly growth in fiscal 2014 as the customer base expands and existing customers complete near-term transitions from 10G to the firm's new 25G tunable access module).

There was sequential growth in quarterly revenue for narrow-linewidth tunable lasers and reconfigurable optical add/drop multiplexers (ROADMs) across several leading customers and across all major categories of ROADMs, including low-port-count, high-port-count and contentionless MxN platforms. With fiscal Q4 revenue for ROADMs up 30% sequentially and 21% year-on-year, full-year

ROADM revenue grew 22%, driven by the adoption of these advanced ROADM architectures. "Our ultra-narrow-linewidth tunable lasers and our advanced ROADMs are key enablers of our customers' next-generation network architectures that are just starting to be deployed," notes president & CEO Alan Lowe.

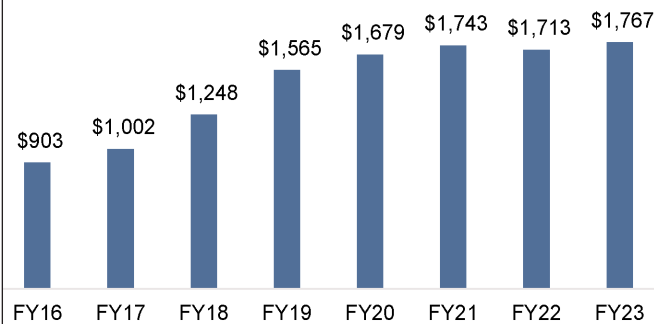
During fiscal Q4, there were three greater-than-10% customers (all in the Telecom market, with no 10% customers in the Consumer market).

Due mainly to the lower revenue, the product mix and the factory under-utilization, on a non-GAAP basis quarterly gross margin has fallen further, from 50.4% a year ago and 40.8% last quarter to 36.7% in fiscal Q4 (dragging full-year gross margin down from 51.6% to 43.2%). By segment:

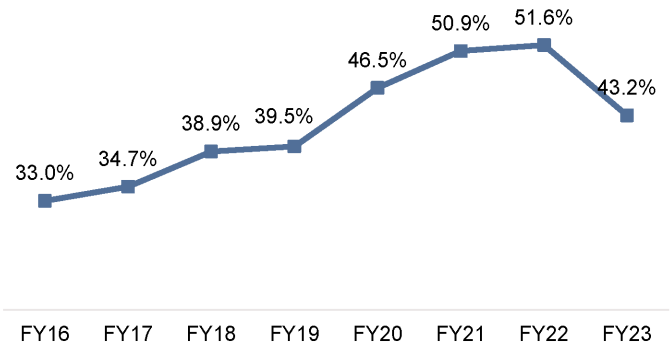
- Optical Communications gross margin has fallen further, from 49.8% a year ago and 40.8% to 36.1%, due mainly to the lower revenue and the impact of product margins from NeoPhotonics Corp (acquired in August 2022).
- Commercial Lasers gross margin was 40.6%, down from 54.5% a year ago but up slightly from 40.4% last quarter.

Operating expenses were \$102.4m (27.6% of revenue), cut from \$104.9m (27.4% of revenue)

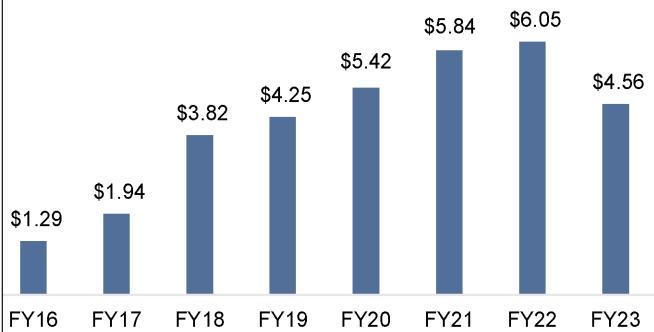
## Net Revenue (M)



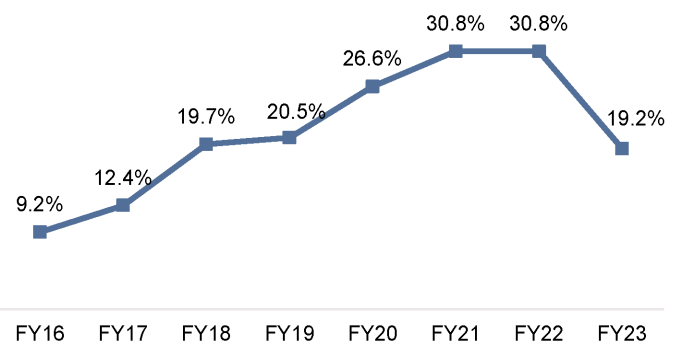
## Non-GAAP Gross Margin (% of revenue)



## Non-GAAP Earnings Per Share



## Non-GAAP Operating Margin (% of revenue)



last quarter. "In the near-term, we are focused on expense controls while maintaining crucial R&D to continue to drive the forefront of innovation as we partner with our customers," says Lowe.

Quarterly operating margin has fallen further, from 28.8% of revenue a year ago and 13.4% margin last quarter to 9.1% margin. Full-year operating income fell from 30.8% margin to 19.2% margin.

Likewise, net income has fallen further, from \$105m (\$1.47 per diluted share) a year ago and \$51.8m (\$0.75 per diluted share) last quarter to \$40.2m (\$0.59 per diluted share), although this is above the midpoints of the \$0.45–0.65 guidance. Full-year net income fell from \$449.2m (\$6.05 per diluted share) in fiscal 2022 to \$315.3m (\$4.56 per diluted share) for fiscal 2023.

Cash from operations for full-year fiscal 2023 was \$179.8m, of which \$49.2m was generated in fiscal Q4.

In June, Lumentum issued \$603.7m worth of convertible notes due in 2029. Of the net proceeds of \$599.4m (after deducting \$4.3m of

net issuance costs), Lumentum used \$132.8m to repurchase \$125m of its convertible notes due in 2024 and \$125m to repurchase common stock.

During the quarter, total cash, cash equivalents and short-term investments hence rose by \$346.4m, from \$1667.2m to \$2013.6m.

"As we make progress on the integration of NeoPhotonics products into our global manufacturing footprint and attain synergies without impacting customer deliveries, we plan to carry elevated inventories over the short-term," says chief financial officer Wajid Ali. "However, we expect inventories to decline by approximately \$30m exiting calendar year 2023 as we continue to focus on cash generation," he adds.

"The current customer inventory correction cycle will continue through the balance of the calendar year and, therefore, our shipments will be below end-market demand," believes Lowe. "During this transition period, we are tracking ahead of our previously announced synergy plans, while we continue to deliver on our new product and

technology roadmaps."

For its fiscal first-quarter 2024 (to end-September 2023), Lumentum expects revenue to fall to \$300–\$325m, with Telecom & Datacom and Commercial Lasers down sequentially due primarily to customer inventory reductions.

"We expect overall Commercial Lasers demand to be softer over the next several quarters due to customer inventory digestion and macro factors impacting end markets," says Lowe. "We expect continued rapid growth in new applications for our ultrafast lasers to partially offset these near-term headwinds [e.g. in fiber lasers]," he adds.

In what have historically been strong quarters seasonally, Industrial & Consumer is expected to be roughly flat sequentially (and down more than 60% year-on-year) in both the September and December quarters, due to lower revenue for 3D sensing applications as a result of the current end-market demand environment, pricing, and the impact of the additional competitor on a certain socket opportunity. ➤

► Telecom customers are saying that they want to reduce inventory to normal levels. “The confidence that they have in our ability to produce what they need when they need it, and that the component suppliers — including semiconductors — are going to be there when they need it, gives them confidence that they can live with even less inventory than originally anticipated,” notes Lowe. “We are shipping into our customers less than they are shipping out to the carriers which, in turn, should take care of that problem and more normalize as we get into calendar 2024 [after “depressed” shipments during second-half 2023].”

After entering its inventory-correction phase earlier (in the September 2022 quarter), Datacoms should return to sequential growth in the September 2023 quarter.

“We probably ratcheted back our capacity more than we should have on Datacom. That’s now in full force to accelerate the output of our Datacom chips,” says Lowe. “We expect to see sequential growth in our Datacom chip business through the balance of this year as well as into calendar 2024... as hyperscale customers prepare to ramp artificial intelligence (AI) capacity,” he adds. “Within the next eight quarters, could we get back to \$240–260 annually [for Datacoms revenue]? We are putting capacity in place to do that... We are in the midst of going to larger wafers to address the demand we have seen in the long-term.”

With factory under-utilization lingering through calendar second-half 2023, September-quarter operating margin is expected to be just 1–4%. Diluted earnings per share should fall to \$0.20–0.35.

“We do expect a return to growth in Telecom & Datacom shipments in calendar 2024 compared to calendar 2023, as customer inventory levels are reduced and our shipment rate is more in sync with end-market demand,” says Ali.

“Our synergy plan that we communicated at our March investor

event at OFC [the Optical Fiber Communication conference] is proceeding ahead of schedule in terms of operating expense reductions,” notes Ali. “We will exit certain manufacturing facilities at the end of this calendar year [in November–December], which will deliver significant cost-of-goods-sold synergies over the subsequent quarters [from the January time-frame]. Overall, we remain on track to the total synergy plan of \$80m in annualized savings that we articulated previously [over the next 18 months], and we have achieved over half of the savings in fiscal year 2023,” he adds.

“With generational upgrades in the backbone of the network and increased customer activity for AI in the data center, we expect year-over-year Telecom and Datacom growth in calendar 2024,” says Lowe.

“Our focus is on serving a hyperscale cloud market, primarily to our transceiver customers that we supply to also certainly supply into the enterprise end-markets,” says Chris Coldren, senior VP & chief strategy & corporate development officer. “So, again, we’re supplying EMLs [externally modulated lasers] as the largest product line, and that’s primarily

**Mid- to long-term fundamentals are solid for our business as we serve the exponential growth in network bandwidth in the artificial intelligence, machine learning, mobile, carrier and cloud computing markets. New industrial applications are emerging for our imaging and sensing products, and our commercial lasers are expanding into high-growth applications beyond our traditional markets**

playing now into the transition to 800G,” he adds. During fiscal Q4/2023, Lumentum demonstrated the industry’s first 800G ZR module technology. “We will also have 200G-per-lane EML shipments ramping up in calendar 2024 ramping [since internal qualification has now been completed], and that’s for a next generation of 800G transceivers and then the eventual transition to 1.6 terabits per second [with customer qualifications currently underway].”

Lumentum is seeing strong demand for its high-power continuous wave (CW) lasers for customers utilizing silicon photonic to build 800G transceivers.

To further address the connectivity requirements for AI and machine learning clusters, Lumentum has also started to deliver high-speed vertical-cavity surface-emitting lasers (VCSELs) for short-reach connections between servers and switches in these systems, and it expects to ramp up these shipments meaningfully in calendar 2024.

“We highlighted the VCSELs ramping so that we have a broader product portfolio as well as CW lasers to intersect the 800G and 1.6-terabit silicon photonic based approaches,” Coldren says.

“Mid- to long-term fundamentals are solid for our business as we serve the exponential growth in network bandwidth in the artificial intelligence, machine learning, mobile, carrier and cloud computing markets,” summarizes Lowe.

“New industrial applications are emerging for our imaging and sensing products, and our commercial lasers are expanding into high-growth applications beyond our traditional markets,” he adds.

“We are confident we can get back to the levels of revenue we have had in the past,” says Lowe. “With our model, the operating leverage is pretty immense. We should see significant bounce back when we get up to that \$400–450m, even \$500m in revenue. That’s doable in the not-too-distant future.”

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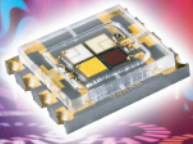


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# First Solar selects Louisiana for its fifth US manufacturing facility

## Investment in \$1.1bn, 3.5GW plant to create over 700 new direct manufacturing jobs in the state

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has selected the Acadiana Regional Airport in Iberia Parish, Louisiana as the location for its fifth fully vertically integrated manufacturing facility in the USA (announced at the end of July). Believed to be the single largest capital investment in the area's history, the facility represents an investment of up to \$1.1bn in expanding the USA's capacity to produce its own photovoltaic solar modules. Expected to be completed in first-half 2026, it is forecast to grow the firm's nameplate manufacturing capacity by 3.5GW to reach about 14GW in the USA in 2026.

First Solar's investment in Louisiana is expected to create over 700 new direct manufacturing jobs in the state. The company — which is already believed to be the largest employer in the USA's solar manufacturing sector, with over 2500 staff across the country — expects to have over 4000 direct employees in the country by 2026, including 850 new manufacturing jobs expected to be created in Alabama and Ohio and over 100 new R&D jobs planned in Ohio.

First Solar is unique among the world's ten largest solar manufac-

turers for being the only US-headquartered company and not manufacturing in China. Its tellurium-based semiconductor material, which allows it to avoid any dependence on Chinese crystalline silicon supply chains, is the second most common photovoltaic technology available today.

"We are pleased to partner with Louisiana as we lean into our commitment to creating enduring value for America by expanding our solar manufacturing footprint and the domestic value chains that enable it," says CEO Mark Widmar. "As we evaluated our options, Louisiana's ability to deliver the talent we need stood out, thanks to its extensive workforce development initiatives and the presence of academic institutions such as the University of Louisiana at Lafayette, which now features a world-class solar energy lab," he adds.

"We expect the plant to mirror the commitment to Responsible Solar evident at every First Solar manufacturing facility, which are among the cleanest, safest, and most diverse in the industry," claims Widmar.

Since the start of this decade, First Solar has embarked on a \$4.1bn manufacturing expansion strategy that has seen it grow from

about 6GW of global nameplate capacity in 2020 to 13GW operational today, with about 12GW of nameplate capacity expected to come online in the USA and India between second-half 2023 and 2026. In addition to the Louisiana facility, First Solar commissioned its third Ohio factory earlier this year and is expected to complete its new facility in Alabama and the expansion of its existing Ohio footprint in 2024. It also expects its new facility in India to begin commercial production in second-half 2023. Additionally, the firm is investing up to \$370m in a dedicated R&D innovation center in Perrysburg, Ohio, which is expected to be completed in 2024.

The new Louisiana facility will produce First Solar's Series 7 modules, which are expected to be manufactured with 100% US-made components identified in the current domestic content guidance issued by the US Department of Treasury. First Solar anticipates that, once the new factory is completed and ramped, Series 7 modules will account for over two thirds of its annual domestic nameplate capacity. Series 7 modules currently produced at the firm's Ohio facility are already manufactured with US-made glass and steel.

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# First Solar issues 2023 Sustainability Report unveiling onsite third-party social audits

## US and Vietnam operations achieve platinum status, but four service providers at Malaysia facility fall short

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has released its 2023 Sustainability Report and established a new industry benchmark for transparency by making public details of onsite third-party social audits conducted across its global manufacturing footprint in what is believed to be an industry first.

First Solar is also believed to be the first among the world's largest solar manufacturers to have conducted third-party social audits across its operational global manufacturing footprint.

First Solar says that its integrated manufacturing process helps to eliminate risks and traceability challenges associated with outsourcing and the multiple supply tiers of conventional crystalline silicon solar manufacturing.

As the only major solar manufacturer that is a member of the Responsible Business Alliance (RBA), First Solar conducted three onsite third-party RBA Validated Assessment Program (VAP) audits at its manufacturing facilities in the USA, Malaysia and Vietnam. While the firm's US and Vietnam operations achieved the highest-possible rating of platinum status, the audits uncovered the fact that four service providers at its Malaysia facility fell short of First Solar's standards. Details of the findings and First Solar's corrective actions are included in the company's 2023

Sustainability Report. The Malaysia facility is expected to have its VAP closure audit in fourth-quarter 2023. The purpose of proven third-party social audits like the RBA VAP social audits is not to rubber-stamp compliance but to identify and remedy existing and potential issues to help improve the lives of workers across the supply chain.

"We have chosen to highlight the audit findings openly, not only because of our commitment to transparency and Responsible Solar, but to raise awareness of modern slavery risks that hide in plain sight and to illustrate the value of an independent third-party social audit conducted in a credible, comprehensive manner," says CEO Mark Widmar. "The solar industry will anchor the global transition to a sustainable energy future, and we believe that it must do so responsibly," he adds "Our industry's work to power the energy transition and enable the fight against climate change does not serve as credits to offset its social and human rights obligations."

The report also highlights that First Solar's new factory in Tamil Nadu, India, which is scheduled to begin commercial production in second-half 2023, is expected to be the world's first net-zero water withdrawal solar manufacturing facility. Located in a region of high baseline water stress, the facility is designed to minimize its impact on local water resources and will rely

entirely on tertiary treated reverse osmosis water from the city's sewage treatment plant and have zero wastewater discharge.

"As we continue our journey to growth we are doubling down on our commitment to Responsible Solar and meaningfully contributing to the fight against climate change," says Widmar. "This includes designing our manufacturing facilities and products with sustainability in mind."

Compared with 2021, in 2022 First Solar lowered its greenhouse-gas emissions intensity by 11%, manufacturing energy intensity by 8%, manufacturing waste intensity by 28%, and manufacturing water intensity by 20%. The firm also secured an 'AA' rating from MSCI ESG Research in 2022, the highest in the solar industry, and a CDP Climate Change 'A-' rating.

First Solar claims that its PV modules have the lowest carbon and water footprint of any commercially available PV module today, and that it is the first PV manufacturer to have its product included in the Electronic Product Environmental Assessment Tool (EPEAT) global registry for sustainable electronics. The firm has also pioneered a high-value recycling program, which provides closed-loop semiconductor recovery for use in new modules, while also recovering other materials including aluminium, glass and laminates.

[www.firstsolar.com/en-Emea/Responsible-Solar/Governance](http://www.firstsolar.com/en-Emea/Responsible-Solar/Governance)

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# UbiQD expands collaboration with First Solar on quantum dot-enhanced solar modules

## Newly developed quantum dot composites present opportunities to boost efficiency

Nanotechnology firm UbiQD Inc of Los Alamos, NM, USA has entered into a joint development agreement with cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA to collaborate further on developing the potential to incorporate fluorescent quantum dot technology in advanced solar modules. The two firms have been conducting exploratory work since early 2022, and the initial results have supported the new, more formalized joint-development effort.

Since quantum dot (QD) nanoparticles exhibit high-efficiency photoluminescence over a wide range of tunable colors, they are effective at optimizing light spectra.

UbiQD has launched several greenhouse products under its UbiGro brand that adjust the spectrum of sunlight to enhance crop growth. Now, the firm is engineering these materials for potential applications in utility-scale solar, with the aim of significantly increasing the efficiency of existing PV technologies.

"As we work towards developing the next generation of photovoltaics, we are exploring a range of enhancements that could allow us to convert more sunlight into energy," says First Solar's chief technology officer Markus Gloeckler. "We are interested in the potential use of quantum dots in optimizing the absorption of light and look forward to continuing our work with

UbiQD on exploring this possibility," he adds.

"With First Solar's domain expertise and leadership position in multi-gigawatt-scale solar, we are excited to be working together on the potential to enhance panel efficiency using quantum dot technology," says UbiQD's CEO Hunter McDaniel. "If successful, this application in solar modules will be a perfect example of the broad applicability of our core technology. With emerging applications in food and energy, these novel nanomaterials are proving to be a key tool in humanity's urgent response to climate change and further sustainable economic development."

<https://ubiqd.com>

# Matrix to procure 2.1GW of First Solar PV modules

## Agreement spans delivery in 2024–2027 for projects in USA and Spain

First Solar Inc of Tempe, AZ, USA has entered into a framework agreement for new customer Matrix Renewables of Madrid, Spain, the TPG Rise-backed global renewable energy platform, to procure about 2.1GW<sub>DC</sub> of its cadmium telluride (CdTe) thin-film photovoltaic modules, for delivery in 2024–2027 for projects in the USA and Spain. Matrix Renewables was created and backed by global alternative asset manager TPG and its \$17bn investing platform TPG Rise.

Across the USA, Matrix owns more than 6GW of projects in various stages of development across four different regions (CAISO, MISO, ERCOT and WECC) and continues to expand its pipeline and team to capitalize on the large demand for renewable energy in the USA. Including Matrix's presence in Spain, Italy and Chile, Matrix's footprint has already surpassed

13GW of solar power, battery storage and green hydrogen projects globally.

"As a purpose-driven company, and as part of our supply chain strategy of partnering with technology market leaders, we are thrilled to be working with First Solar to supply our projects in the US market, and a number of our Spanish projects, with responsibly produced ultra-low-carbon PV modules," says Matrix's president Luis Sabate. "With this deal, we're getting access to solar technology without compromising on competitiveness or performance."

"Matrix is the latest in a number of large IPPs [independent power producers], in the US and internationally, that are choosing to partner with First Solar not just on the strength of our technology and competitiveness but also because we share the same values," says First Solar's chief commercial officer

Georges Antoun. "This latest order underscores our belief that a growing number of developers are recognizing the value of Responsible Solar and of working with a partner that delivers on its commitments."

First Solar is investing about \$1.3bn in expanding its US manufacturing footprint from over 6.5GW<sub>DC</sub> of annual nameplate capacity currently to about 10.9GW<sub>DC</sub> by 2026. In addition to the \$1.1bn expected investment in a new 3.5GW<sub>DC</sub> facility in Alabama, the firm has also embarked on a \$185m expansion of its existing manufacturing footprint in Ohio. First Solar has also announced an investment of up to \$370m for a dedicated R&D innovation center in Perrysburg, Ohio, which is expected to be completed in 2024.

[www.matrixrenewables.com](http://www.matrixrenewables.com)  
[www.firstsolar.com](http://www.firstsolar.com)



## 5N Plus solar cells powering Chandrayaan-3 AZUR's cell technology used in Indian Space Research Organisation lunar exploration mission

5N Plus Inc of Montreal, Québec, Canada says that solar cell technology produced by its subsidiary AZUR SPACE Solar Power GmbH is being used in the third Indian Space Research Organisation (ISRO) lunar exploration mission.

"AZUR solar cell technology is in high demand, and we are especially excited to have it included in the Chandrayaan-3 mission as it powers all aspects of the travel, landing and exploration," says president & CEO Gervais Jacques. "The 3G30-

Advanced is AZUR's latest qualified solar cell product and provides the highest end-of-life efficiencies in space," he claims. "With various configurations in production, our AZUR R&D team continues to exceed client expectations with their ability to address challenging conditions with unique solutions."

Launched on 14 July, Chandrayaan-3 consists of a propulsion module that takes a lander and rover to the moon. The mission, which began its orbit of the moon

on 5 August, comprises a soft landing on the moon and exploration of the moon's surface with the rover to better understand its composition through experiments and observation. Expected to land near the lunar south pole region on 23 August, AZUR supplied the 3G30 solar cells for the propulsion module (758W), the lander (738W) and the rover (50W).

[www.isro.gov.in/Chandrayaan3.html](http://www.isro.gov.in/Chandrayaan3.html)  
[www.azurspace.com](http://www.azurspace.com)  
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## Hasselt University and imec spin-off EnFoil unveils thin, flexible CIGS solar panels

### Initial talks with industry to produce panels and integrate them onto the roofs of trucks

Hasselt University (UHasselt) and Leuven-based nanoelectronics research center imec have unveiled the new spin-off EnFoil of Genk, Belgium, which offers pliable, robust solar panels only a few millimeters thick that can be integrated on various surfaces. Initial talks between EnFoil and industry leaders to produce the solar panels and integrate them onto the roofs of trucks are ongoing.

Standard silicon solar panels on rooftops already play an important role but cannot be placed on every surface due to their weight or shape. UHasselt and imec have been investigating new types of solar cells that are easier and cheaper to integrate onto surfaces beyond roofs.

Until now, to integrate solar cells on the surfaces of trucks, buildings or tents, consumers were limited to standard, typically flat products of a pre-defined size, and handled the integration themselves. "This mainly limited the technology to exclusive construction projects, or as an expensive opt-ins for cars. With EnFoil, we aim to change this,"

says EnFoil's chief technology officer Marc Meuris. "We intend to make custom solar foils in any size and shape at a large scale (mass-customization)," he adds. "The solar foils will be directly installed or further integrated into our customers' products. The production will be done locally and we will guarantee the feasibility and integration of the final products."

**More sustainable and reliable**  
EnFoil ('Energy Enabling Foil') combines technologies and processes that are patented and developed within UHasselt and imec. The thin-film solar cells are based on copper indium gallium diselenide (CIGS) technology. "This technology offers lightweight, flexibility and impact resistance, which is crucial for many new applications," says professor Bart Vermang of imo-imomec, imec's associate lab at UHasselt. "The solar cells achieve almost the same efficiency as standard panels," he adds.

**Ready for production**  
EnFoil is in ongoing discussions with the industry to bring its solar

foil to market. "A wide array of applications will be possible, such as integrating the solar cells on swimming pool covers or roof tiles," says Meuris. "Currently, we mostly focus on the logistics sector, aiming to integrate our materials on roofs and sidewalls of trucks to power their sensors and track & trace systems. It would save the battery and, under abundant sunlight, the battery could even be charged."

#### ERC grant

The project has already received support from the European Research Council through an ERC Proof of Concept. Worth €150,000, the grant aims to bring new technologies to market. With this, UHasselt will recruit a researcher who will continue to work with EnFoil on product development. "The ERC jury includes several industry experts," notes Vermang. "We therefore see this grant as great recognition and a sign that the industry believes in our product and sees the potential to bring it to the market."

[www.enfoil.com](http://www.enfoil.com)

# Improving micron-scale AlGaInP red LED performance

Enhanced sidewall treatments give the lowest size-effect drop in EQE to date.

University of California Santa Barbara (UCSB) in the USA and Seoul Viosys Co Ltd of South Korea have used a combination of thermal annealing, chemical treatment, and passivation, to reduce performance degradation in micron-scale aluminium gallium indium phosphide (AlGaInP) red light-emitting diodes (LEDs) [Applied Physics Express, v16, p066503, 2023]

The researchers report: "The devices with sidewall treatments demonstrated a reduction in external quantum efficiency (EQE) of 20%, corresponding to the lowest efficiency drop due to the size effect in AlGaInP  $\mu$ LEDs to date."

Micron-scale LEDs are being developed for display applications. Although nitride-based InGaN LEDs are used to cover the green and blue parts of the visible color range, InGaN red LEDs suffer from much reduced efficiency and low light output powers. Normal red LEDs use other material systems such as AlGaInP.

Unfortunately for micron-scale applications such as displays, the reduced-size AlGaInP LEDs suffer from more severe efficiency degradation than nitride-based devices.

This mainly arises from 'sidewall damage' from the mesa etching part of the LED fabrication process. This damage has a larger impact on smaller devices due to the greater ratio of sidewall surface area to device volume — or, alternatively but equivalently, sidewall perimeter to device area.

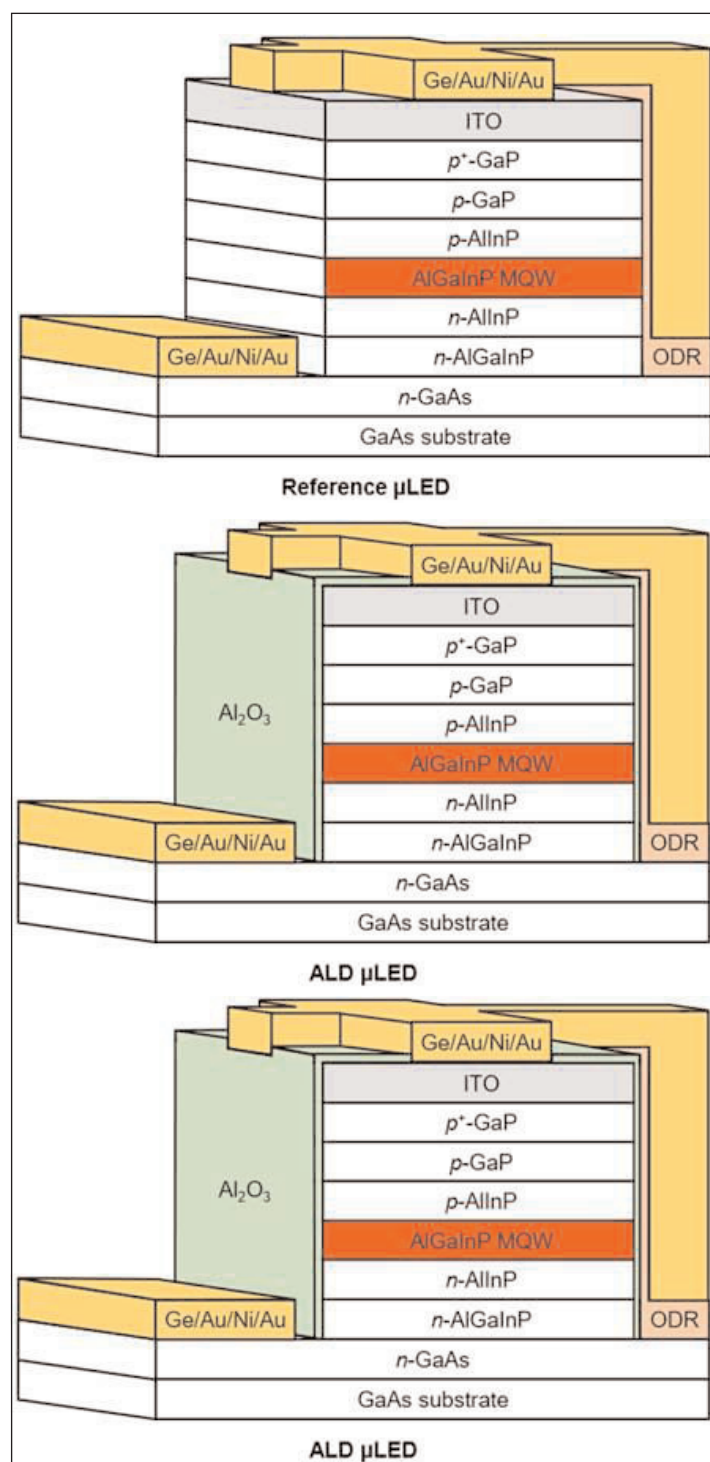
Damaged sidewalls form sites where carriers more easily dissipate their energy through Shockley–Read–Hall (SRH) recombination, rather than perform the desired LED function of recombining electrons and holes into photons. AlGaInP devices suffer from further factors of a longer minority carrier diffusion length, and faster surface recombination velocity, compared with other LED materials systems, which means that the carriers can more easily end up at the sidewalls, avoiding photo-production.

The devices (Figure 1) were fabricated from one commercial 4-inch AlGaInP wafer produced for LED production. The active light-emitting region of the epitaxial material comprised 40 AlGaInP quantum wells in InGaP barrier layers.

The material was diced into 1.5cmx1.5cm squares for LED fabrication. A 110nm indium tin oxide (ITO)

transparent ohmic conductor was first applied to the p-GaP contact layer by electron-beam evaporation.

Various-sized square device mesas of sides from 20 $\mu$ m to 100 $\mu$ m were etched using reactive chlorine/nitrogen ions. A major problem with reactive-



**Figure 1. AlGaInP devices with no sidewall treatments (reference), with ALD sidewall passivation, and with chemical treatments and ALD sidewall passivation.**

ion etching is that it creates highly defective sidewalls.

The researchers tackled the sidewall damage by a combination of annealing, chemical treatment, and passivation. The chemical treatment consisted of 310°C rapid thermal annealing in nitrogen for 5 minutes and 60°C ammonium sulfide ((NH<sub>4</sub>)<sub>2</sub>S) exposure for 10 minutes. The passivation came from atomic layer deposition (ALD) of aluminium oxide (Al<sub>2</sub>O<sub>3</sub>).

Devices were completed by applying an omnidirectional reflector (ODR) and electrical isolation materials, and metal electrodes. The ODR consisted of a three-period silicon dioxide/tantalum pentoxide (SiO<sub>2</sub>/Ta<sub>2</sub>O<sub>5</sub>) structure. The electrical isolation was Al<sub>2</sub>O<sub>3</sub>. The contact metals consisted of annealed germanium/gold/nickel/gold (Ge/Au/Ni/Au).

The researchers also produced reference devices without any attempt to repair the sidewall damage, and devices with only passivation, but no chemical treatment step.

ALD passivation improved the electrical current-voltage performance of the LEDs, reducing series resistance and leakage currents. The reference device without passivation also had a higher subthreshold current.

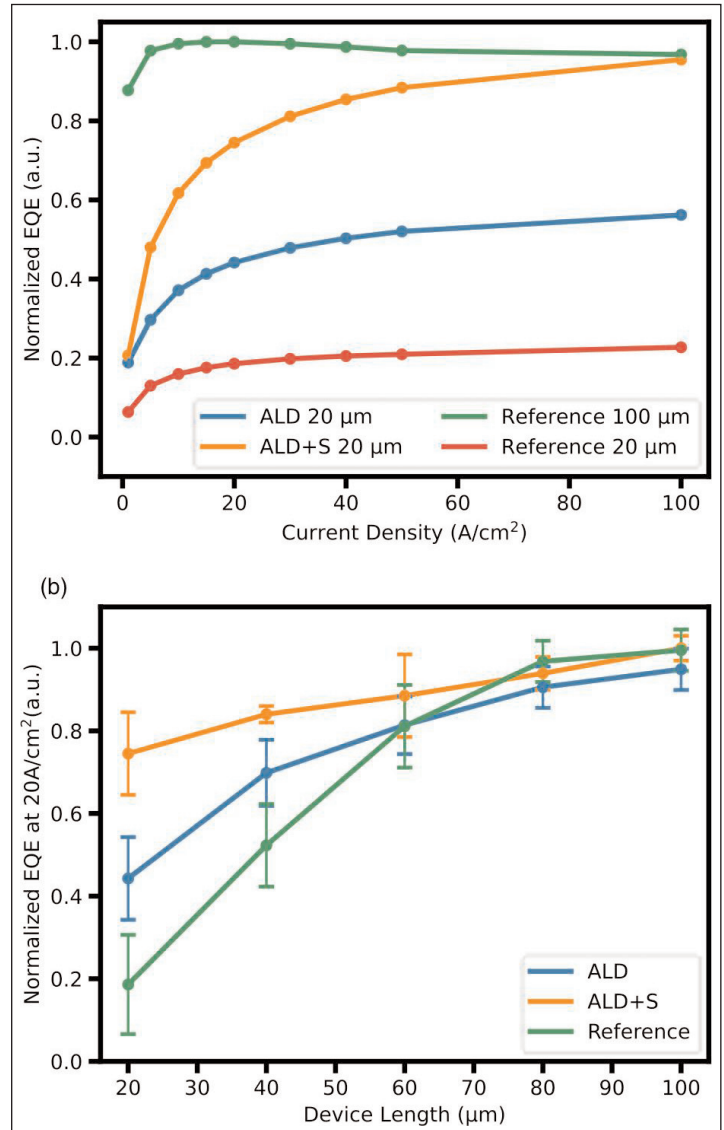
While the annealing and chemical treatment had no visible effect on the electrical performance, the light output power and external quantum efficiency were significantly increased. For 20-μm-side devices, the light output was 5x that for the reference LEDs without any sidewall treatments at 5A/cm<sup>2</sup> injection. The effect of chemical treatment over just applying the ALD passivation was 1.9x at 100A/cm<sup>2</sup>.

The researchers also found a significant effect on performance from applying thermal annealing before the ammonium sulfide treatment. In particular, the EQE improved by 160% and 40% at 5A/cm<sup>2</sup> and 100A/cm<sup>2</sup>, respectively.

The team comments: "The purpose of thermal annealing was to remove residual oxygen at the surfaces before the chemical treatment with ammonium sulfide, and the thermal annealing condition was insufficient for nitridation to occur. The large enhancement in optical power was attributed to the reduction in SRH non-radiative recombination centers at the active region, resulting in an improvement in internal quantum efficiency."

At 100A/cm<sup>2</sup> injection, the fully treated and passivated 20-μm-side device showed comparable performance to the larger 100-μm-side reference without any sidewall measures (Figure 2). The 20-μm-side devices without chemical treatment and the reference were reduced in EQE by 50% and 80%, respectively.

At 20A/cm<sup>2</sup> injection, the reduction in EQE relative to the largest 100-μm-side LEDs was around 20% for the fully treated device. "The 20% reduction in EQE indicates that additional optimizations in the sidewall treatments are necessary to achieve fully size-independent EQE performance, yet this work demonstrates AlGaInP μLEDs



**Figure 2. (a) On-wafer EQE performance of AlGaInP LEDs and (b) on-wafer EQE measurements of AlGaInP devices with and without thermal annealing before treating with ammonium sulfide with various side mesas.**

efficiency can be significantly improved with proper sidewall treatment techniques," the team writes.

The devices showed similar EQE degradation effects from increasing the operating temperature up to 80°C. The researchers explain: "The thermal degradation in EQE of AlGaInP devices was attributed to the direct-indirect bandgap transition and carrier overflow due to the smaller band offset compared to III-nitride-based devices. This suggested that the thermal degradation in EQE is limited by the intrinsic material properties and epitaxial design and sidewall defects do not contribute to additional EQE loss."

At 80°C, the light output power from the fully treated 20-μm LEDs was 20% and 15% greater than that from the same sized reference and passivation-only devices, respectively. ■

<https://doi.org/10.35848/1882-0786/acdf3c>

Author: Mike Cooke

# Monolithic integration of III-V lasers & silicon photonics

**Researchers claim the first demonstration of coupling such laser light into on-chip waveguides.**

**R**esearchers based in France, Italy and Ireland claim the first demonstration of III-V semiconductor lasers grown on a patterned silicon photonics platform with light coupled into a waveguide [Andres Remis et al, *Light: Science & Applications*, v12, p150, 2023].

The team from University of Montpellier in France, Polytechnic University of Bari in Italy, and Tyndall National Institute and Munster Technological University, both in Ireland, report a butt-coupling efficiency of about 10% and an upper value for the insertion loss of 10dB. The gallium antimonide (GaSb)-based lasers emitted at a wavelength around 2.3 $\mu$ m. Such wavelengths have applications that include trace-gas sensing and the light-version of radar, LIDAR.

The researchers are seeking to overcome the roadblock for monolithic integration of lasers with low-cost, large-scale, fully integrated photonic integrated circuit (PIC) chips. The alternative approach is heterogeneously integrating separately-grown III-V epitaxial material, using wafer bonding techniques. The team comments: "Note that a recent comparison of epitaxial and heterogeneously integrated GaSb-based lasers revealed superior performances of epitaxial lasers in terms of threshold current density and maximum operating temperature. We thus expect the same to be true for the lasers studied here that are grown on a PIC."

The group also hopes that the techniques used "can be extended to any semiconductor materials system provided the anti-phase domain problem can be solved, which is the case with most III-V systems nowadays, and the various processing steps are established, which does not pose fundamental issues." Further, the availability of 300mm epitaxy systems raises the prospect for scaling up to large-diameter silicon wafer sizes and mass production of low-cost laser-powered PICs.

The platform for the silicon PICs consisted of silicon nitride (SiN) sandwiched between silicon dioxide (SiO<sub>2</sub>) cladding (Figure 1), processed at Tyndall National Institute in Ireland. The substrate was 100mm-diameter silicon. The bottom cladding was achieved through thermal oxidation of the substrate, and the top by plasma-enhanced chemical vapor deposition (PECVD).

The wafer was then patterned and etched to produce a series of waveguides with 300 $\mu$ m S-bend offset and

16mmx2.5mm recessed areas where the GaSb lasers were to be grown and fabricated. The researchers took extra care for the recess etching so that the III-V growth surface was not damaged by the etching. About 95% of the etching was by reactive-ion etch, but the last 5% was carried out by a slower hydrofluoric acid wet etch.

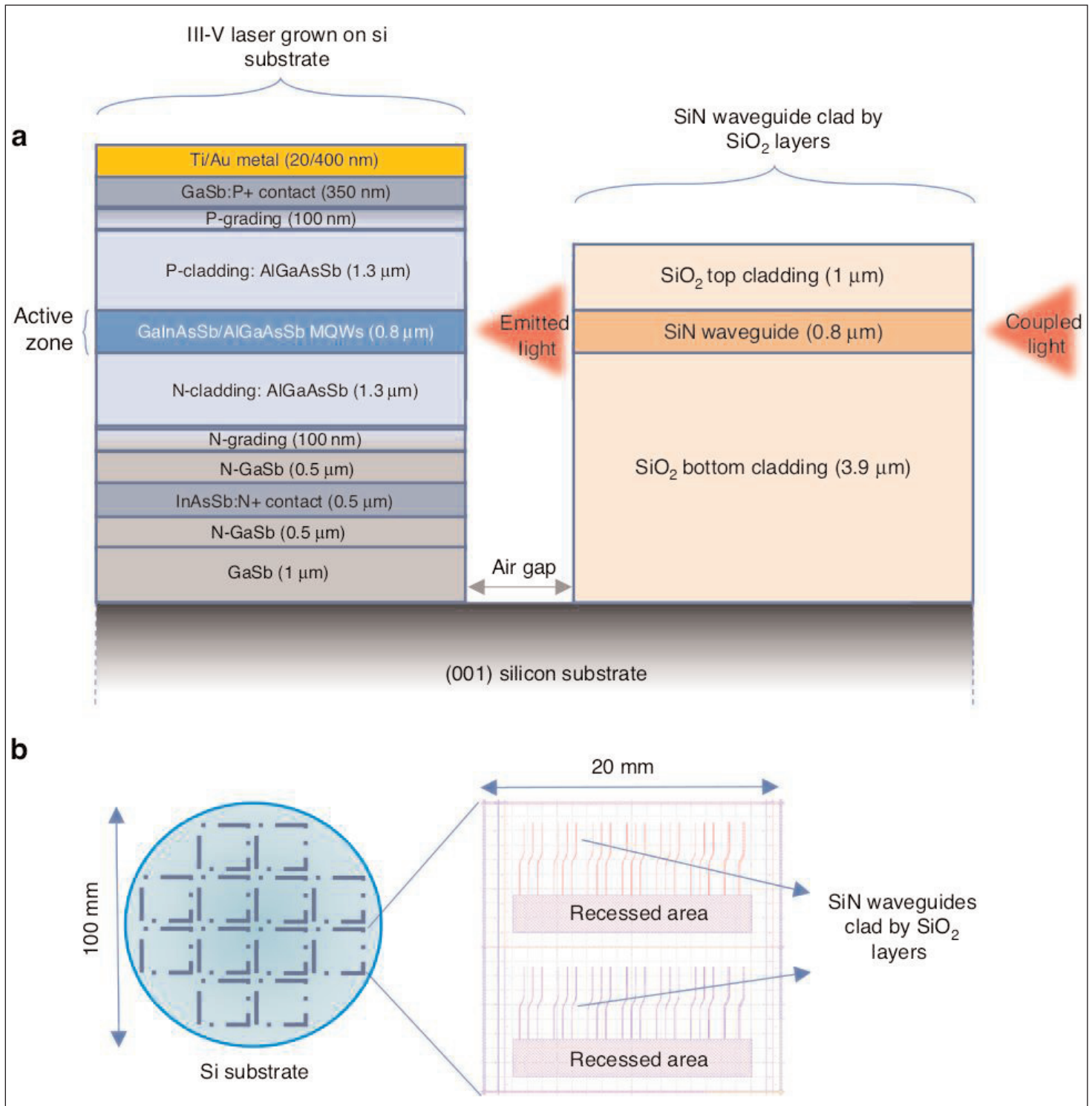
The researchers explain: "A one-step dry etch would have invariably damaged the silicon surface. In contrast, hydrofluoric acid wet etching being isotropic, wet etching of the entire thickness of the stack would have resulted in a concave dielectric facet."

For the III-V epitaxy, the group used its previous work to avoid anti-phase boundary (APB) defects, burying them in the 1 $\mu$ m GaSb buffer layer. The buffer was grown in two steps on 20mmx20mm dies from the patterned PIC wafer by solid-source molecular beam epitaxy (MBE): 50nm at 400°C and the remainder at 500°C. Before the growth, native oxide was removed from the silicon surface by vacuum annealing in the MBE chamber at 1000°C. While the buffer was being grown, the researchers periodically inspected the materials to ensure an APB-free GaSb surface while preserving the silicon PIC integrity.

The laser structure itself was grown in a separate MBE reactor. The active region consisted of two gallium indium arsenide antimonide (GaInAsSb) quantum wells (QWs) confined by aluminium gallium arsenide antimonide (AlGaAsSb) barriers. The researchers estimate the threading dislocation density in the laser material at the order of 107/cm<sup>2</sup>. The root-mean-square surface roughness was as low as 2.5nm, according to atomic force microscopy (AFM).

Device fabrication began with removal of polycrystalline III-V residue deposited on the PIC dielectrics during MBE by a wet etch, involving citric and hydrofluoric acids, hydrogen peroxide, and water. The single-crystal laser material was coated with photoresist to protect it during this etch processing. The laser material was then fabricated into ridge-waveguide laser diodes. The facets were formed by etching rather than cleaving.

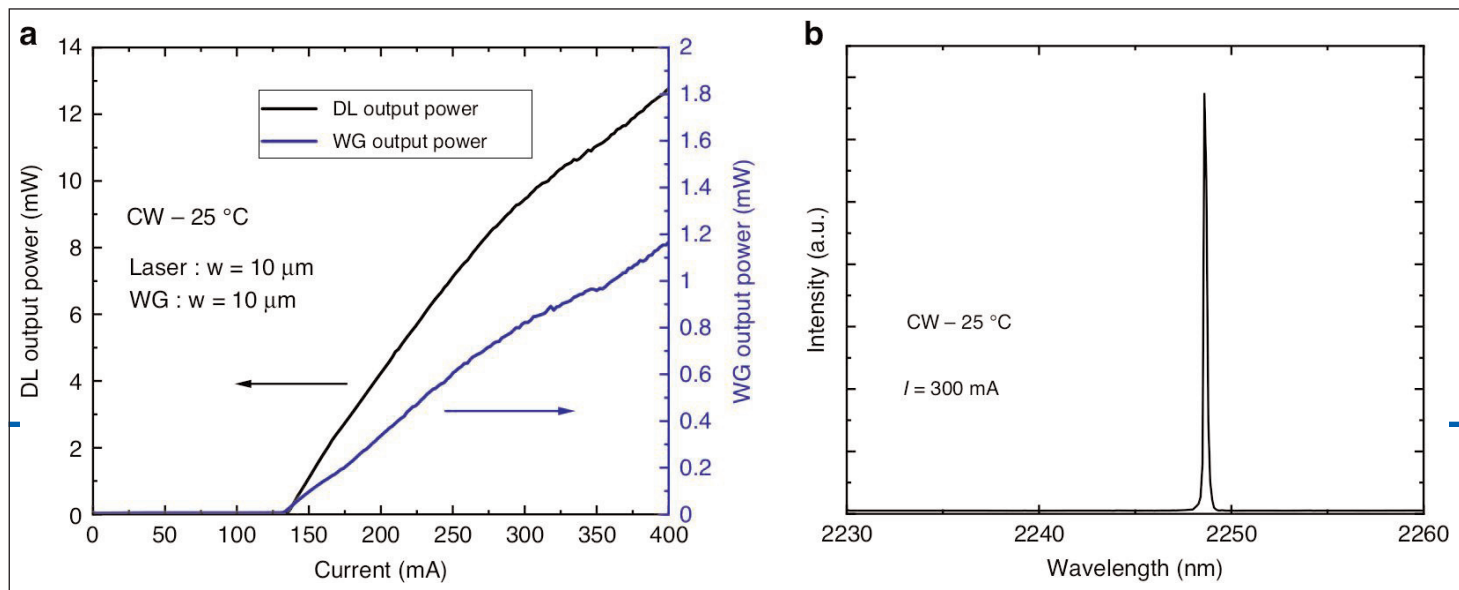
Each 20mmx20mm die was cleaved into two chips for testing. The chips contained eight laser diodes with 10 $\mu$ m x 1.5mm ridges. The air gap between the laser facet and waveguides was around 15 $\mu$ m.



**Figure 1. (a) Final device cross-section. (b) Schematic of silicon photonics PICs.**

The turn-on voltage for the lasers was around 1V with various threshold currents in the range 135–150mA in continuous wave operation at room temperature. The series resistance was around  $3\Omega$ . The output power from the back facet at 400mA injection was in the range 7–10mW. Away from room temperature, the threshold for one device increased from 163mA to 283mA between 20°C and 80°C. The characteristic temperature for this increase ( $T_0$ ) was 110K. The researchers see these results as consistent with other reports of GaSb laser diodes on silicon.

The researchers then tested the butt-coupling of the laser light into the appropriate 10 $\mu\text{m}$ -wide waveguide (Figure 2). The coupling efficiency was about 10%. Since such waveguides typically have a low propagation loss of 0.1–2.5 dB/cm in the wavelength range of the laser light, the researchers consider most of the power loss between the source laser and detection at the end of the waveguide to be insertion loss from the butt-coupling. “We thus conclude that the upper value for the insertion losses in our system is 10dB,” the team reports.



**Figure 2. a** Light output powers versus current for back facet of laser diode (black, left scale) and from waveguide (blue, right scale). **b** Emission spectrum recorded from laser diode at room temperature, CW operation, at  $\sim 2\times$  threshold current.

The insertion loss could be improved by reducing the air-gap between the laser and waveguide to less than  $2\mu\text{m}$ , according to simulations. Unfortunately, the team does not believe the gap can be reduced below  $3\mu\text{m}$ , due to fabrication considerations.

An alternative approach could be to fill the gap with a material with a higher refractive index ( $n$ ) than air ( $n = 1$ ). The researchers comment: "Filling the gap with amorphous silicon ( $n = 3.44$ ) or chalcogenide

materials ( $n \sim 2.5$ ) would allow a coupling efficiency higher than 50%, but filling a narrow gap with these materials might prove cumbersome. In contrast, filling the gap with polymers such as PMMA or BCB ( $n \sim 1.5$ ), which is easy to do given their liquid state before polymerization, would already give a coupling efficiency as high as 40%." ■

<https://doi.org/10.1038/s41377-023-01185-4>

Author: Mike Cooke

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# Co-doping boost for quantum dot lasers on Si(001)

Researchers report significantly enhanced thresholds and thermal stability up to 115°C.

China's Key Laboratory of Semiconductor Materials Science and the University of Chinese Academy of Sciences claim significantly enhanced performance of indium arsenide (InAs) quantum dot (QD) lasers on silicon (Si) by spatially separated co-doping [Shuai Wang et al, *Optics Express*, v31, p20449, 2023].

The researchers attribute much of the improved performance as being due to "effective passivation of non-radiative recombination centers around the QDs by n-type direct doping" in the active light-generating region of the device (Figure 1). This region consisted of a stack of five indium gallium arsenide (InGaAs) wells separated by p-doped (beryllium) GaAs barriers. The InAs QDs were grown in the wells doped with silicon at  $4.4 \times 10^{10}$  dots/cm<sup>2</sup> density.

The researchers comment on the effect of n-doping the QDs: "The carrier loss is reduced and the mode gain of the QD lasers is improved especially for the situation under high injection current and operating temperature."

Previously, modulation p-doping of the barriers in QD lasers has been found effective in compensating for

hole loss during device operation, resulting in improved differential gain, temperature stability, and small-signal modulation response. However, one drawback is an increased threshold current due to higher non-radiative Auger recombination rates, negatively impacting power consumption.

Doping the QDs n-type has resulted in lower threshold current density, higher slope efficiency, smaller linewidth enhancement factor, and a narrower near-field lasing spot. Co-doping with p-type barriers and n-type dots has been shown to reduce power consumption and improve thermal stability. Deploying the co-doping technique on silicon substrates has the potential to compensate for the reduced material quality (increased defects) of III-V epitaxial layers.

The researchers comment: "This work shows the great promise of co-doping technique for enhancing silicon-based QD laser performances towards lower power consumption, higher temperature stability, and higher operating temperature, to boost the development of future low-cost and high-performance silicon photonic chips."

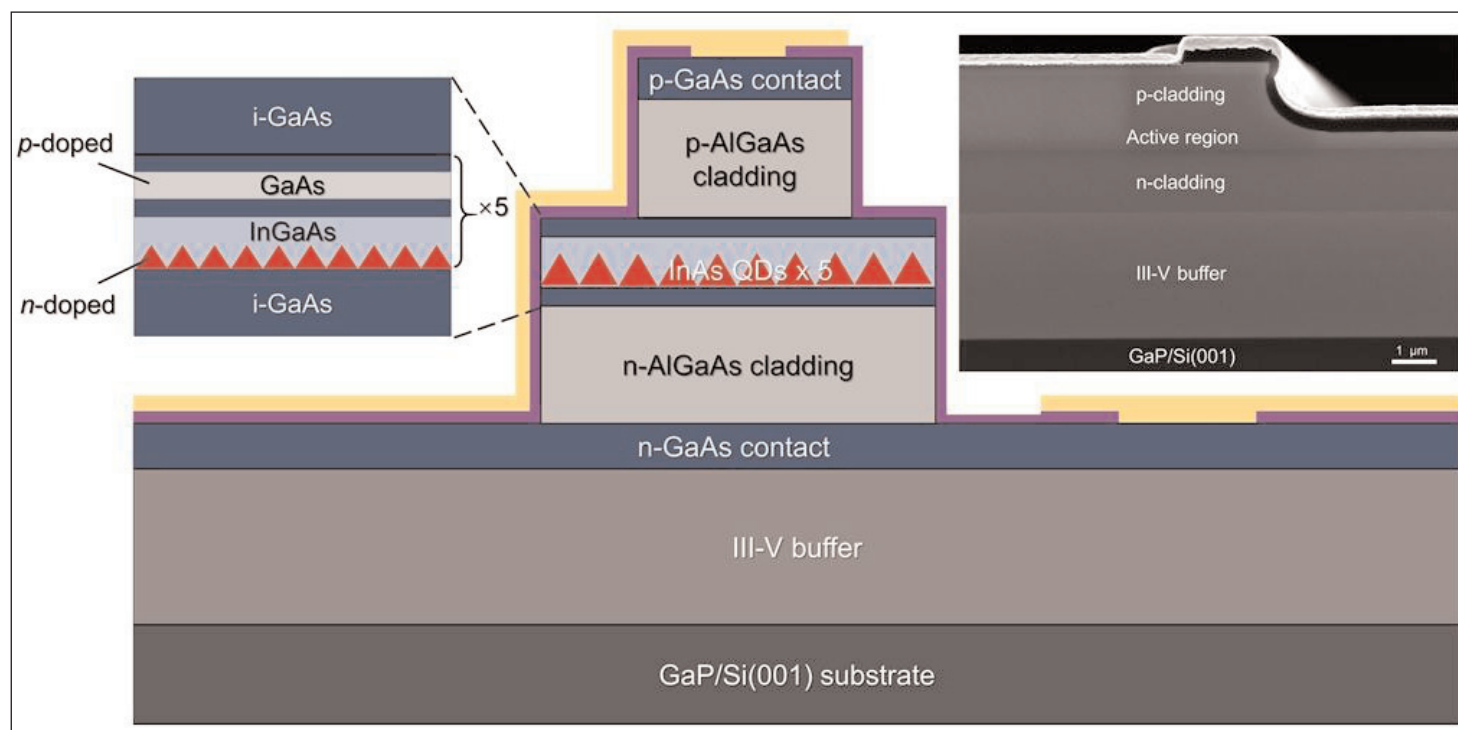


Figure 1. Silicon-based InAs/GaAs QD laser structure. Top-left inset: schematic of separated co-doping in QD active region; top-right: scanning electron microscope (SEM) image of front facet.



The laser material structure was grown by solid-state molecular beam epitaxy (MBE) on gallium phosphide (GaP) on Si(001) templates with a view to avoiding anti-phase boundary defects.

The 2700nm III-V buffer consisted of 1600nm GaAs, 200nm dislocation filter (DFL), and 900nm GaAs spacer layer. The DFL contained ten groups of superlattice strain layers (10nm  $\text{In}_{0.14}\text{Ga}_{0.86}\text{As}$ /10nm GaAs). Cyclic annealing improved the crystal structure. The threading dislocation density was estimated as being as low as  $8.7 \times 10^6/\text{cm}^2$ .

The waveguide layers were GaAs, and the cladding was aluminium gallium arsenide ( $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ ).

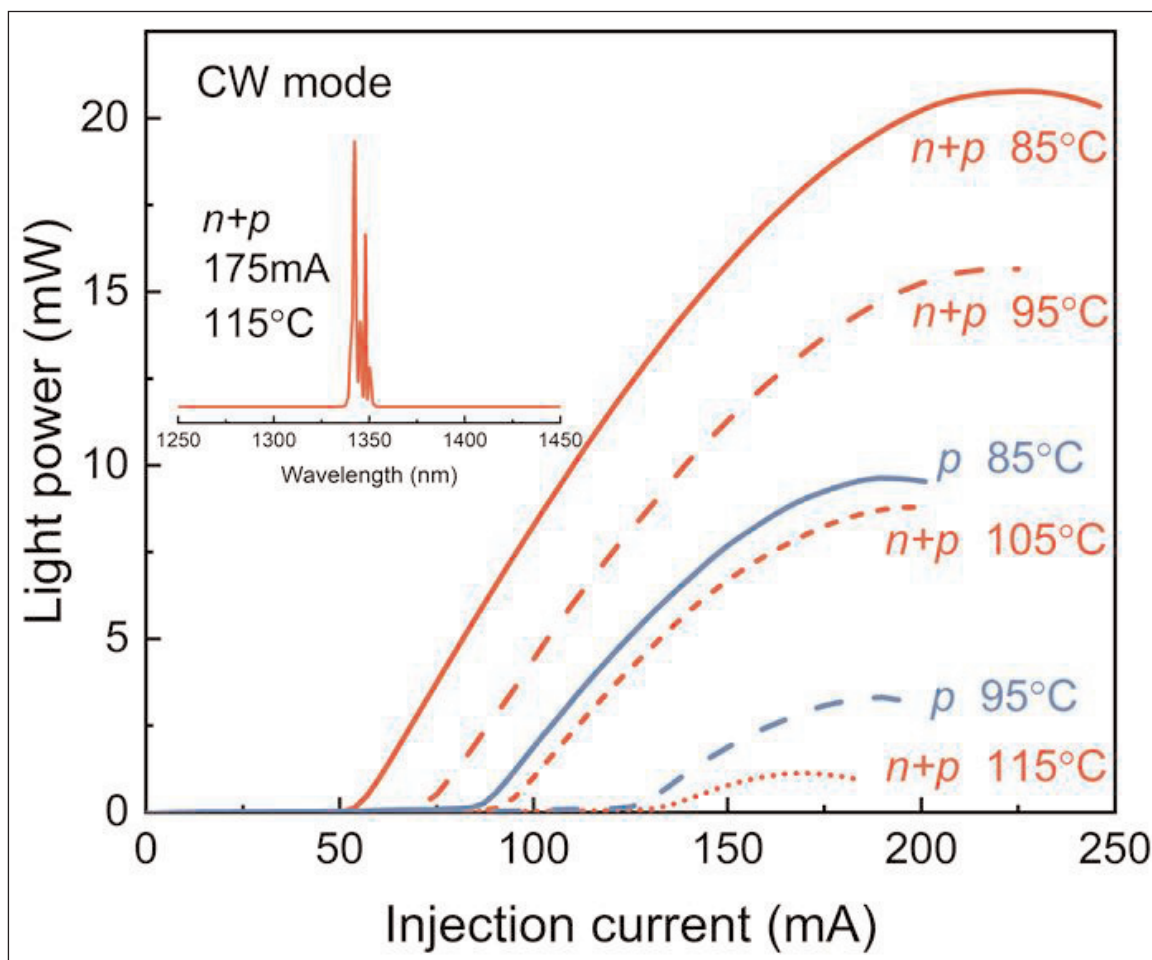
A reference material was also grown without n-doping of the QDs. The doping concentrations were around  $1 \times 10^{18}/\text{cm}^3$ . For the barrier p-type doping this corresponded to about 13.6 holes/dot; for the smaller volume of dots, the doping gave around 1.6 electrons/dot, it is estimated.

The epitaxial materials were fabricated into standard  $6\mu\text{m} \times 1\text{mm}$  ridge-waveguide laser diodes (LDs). The cleaved facets were coated with 97% reflective dielectric stacks consisting of silicon dioxide and tantalum pentoxide ( $\text{SiO}_2/\text{Ta}_2\text{O}_5$ ) layers.

The  $\text{p}^+\text{n}$  co-doped QD laser achieved a threshold current of 28.1mA ( $468\text{A}/\text{cm}^2$ ) in continuous wave (CW) operation at room temperature ( $25^\circ\text{C}$ ). The p-only diode had a 40.3mA ( $672\text{A}/\text{cm}^2$ ) threshold. Other reported p-only QD laser diodes have reached thresholds as low as  $266\text{A}/\text{cm}^2$ , suggesting room for improvements and optimizations.

The maximum power output reached 69mW in the co-doped laser diode, while the p-only device reached 55mW. The saturation currents were 375mA and 335mA, respectively. The slope efficiency of both devices was around 0.27W/A below 200mA injection.

The ground-state laser wavelengths were 1305nm



**Figure 2. CW light output power-current curves of p-doped alone and co-doped QD lasers above  $85^\circ\text{C}$ . Inset: optical spectrum of co-doped**

(at 40mA) and 1296nm (50mA) for the  $\text{n}^+\text{p}$  and p-only doped laser diodes, respectively.

The thermal performance of the laser diodes was assessed in pulsed mode between  $15^\circ\text{C}$  and  $115^\circ\text{C}$ . At the highest temperature, the co-doped device had a 102mA threshold, compared with 267mA for the p-only laser diode. The maximum power output from the co-doped diode was 8mW at  $115^\circ\text{C}$ . The characteristic temperatures for the thresholds ( $T_0$ ),  $15$ – $85^\circ\text{C}$ , were 102K and 87K for the co-doped and p-only devices, respectively. The corresponding characteristics for the slope efficiency ( $T_1$ ),  $15$ – $55^\circ\text{C}$ , were 556K and 513K.

The researchers report that the  $\text{n}^+\text{p}$  laser diode maintained ground-state lasing with a peak wavelength of about 1342.2nm under 175mA CW operation at  $115^\circ\text{C}$  (Figure 2), adding: "To the best of our knowledge, this result is better than the highest CW operating temperature reported so far for p-doped alone QD lasers grown on offcut silicon (not CMOS compatible) of  $108^\circ\text{C}$  and is close to the best value on offcut silicon (not CMOS compatible) of  $119^\circ\text{C}$ ."

The team expects improvements from optimized material quality, doping concentrations, device processes, and packaging techniques. ■

<https://doi.org/10.1364/OE.492096>

Author: Mike Cooke

# GeSn VCSE p-i-n diodes bonded on 200mm silicon

**A multiple quantum well vertical-cavity surface-emitting p-i-n diode structure enhances light emission from germanium–tin on silicon by factors of up to 8.**

**R**esearchers based in Singapore, the USA and China claim the “first demonstration” of 200mm (8-inch) wafer-scale germanium tin (GeSn) multiple-quantum-well (MQW) vertical-cavity-surface-emitting (VCSE) p-i-n structures and diodes [Qimiao Chen et al, ACS Photonics, published online 8 May 2023]. The team from Singapore’s Nanyang Technological University, China’s State Key Laboratory of Superlattices and Microstructures, and Applied Materials Inc in the USA, see the achievements as setting the stage for “laser or light-emitting diode (LED) applications in silicon photonics by wafer bonding and layer transfer techniques”.

The researchers also believe that the devices could be easily scaled up to production of 300mm (12-inch) wafers, since the MQW was grown on 300mm silicon (Si) substrates. VCSE lasers (VCSELs) are widely used as compact size devices with circular emission profile, low beam divergence, high bandwidth, and high coupling efficiency to fiber-optic cables. Fabrication is compatible with mass manufacturing using wafer-scale techniques.

Further, such devices being fabricated on silicon potentially opens the way to optoelectronic Nirvana, combining mainstream complementary metal-oxide-semiconductor (CMOS) electronics and laser light transmitted by silicon waveguides.

But we’re not there yet. Group IV alloys like GeSn have indirect bandgaps without some serious massaging. Materials with indirect bandgaps generally have low potential for light emission. In the case of GeSn the narrowest energy gap is between what are called L valleys placed at non-zero quasi-momentum in the conduction band down to the heavy-hole band with a peak at zero quasi-momentum. There are four such L valleys. The direct  $\Gamma$  valley (zero quasi-momentum) has a larger energy gap. The photon has effectively zero momentum, and electron–hole transitions to a photon, requires near zero change in quasi-momentum.

The difference between the gaps can be altered by (tensile) strain and band-filling. Thermal fluctuations can also increase the density of electrons in the  $\Gamma$  valley.

The MQW structures were grown using reduced-pressure chemical vapor deposition (RPCVD).  $\text{Ge}_{0.92}\text{Sn}_{0.08}$ /Ge wells/barriers were grown on a 1 $\mu\text{m}$  Ge buffer and 470nm p<sup>+</sup>-Ge contact layers (Figure 1).

The precursors were di-germane ( $\text{Ge}_2\text{H}_6$ ) and tin tetrachloride ( $\text{SnCl}_4$ ). The structure was finished off with a 330nm n<sup>+</sup>-Ge contact layer.

The well thicknesses were kept below critical, so the growth was ‘pseudomorphic’ — i.e. the strain ( $\sim 1.6\%$ ) did not relax through generation of misfits or threading dislocations. With this compressive strain the GeSn was still nominally indirect, with a calculated bandgap between the L valleys and the heavy-hole band of 549meV. Direct transitions from the  $\Gamma$  valley would release an energy 604meV, hopefully to a photon. As the L valleys fill with carrier injection, one expects thermionic effects to allow more electrons to be excited into the  $\Gamma$  valley, and some light to be emitted. Such excitation increases with temperature — at room temperature the thermal energy scale is around 26meV (Boltzmann’s constant  $\times$  300K), about half the gap between the L and  $\Gamma$  valleys.

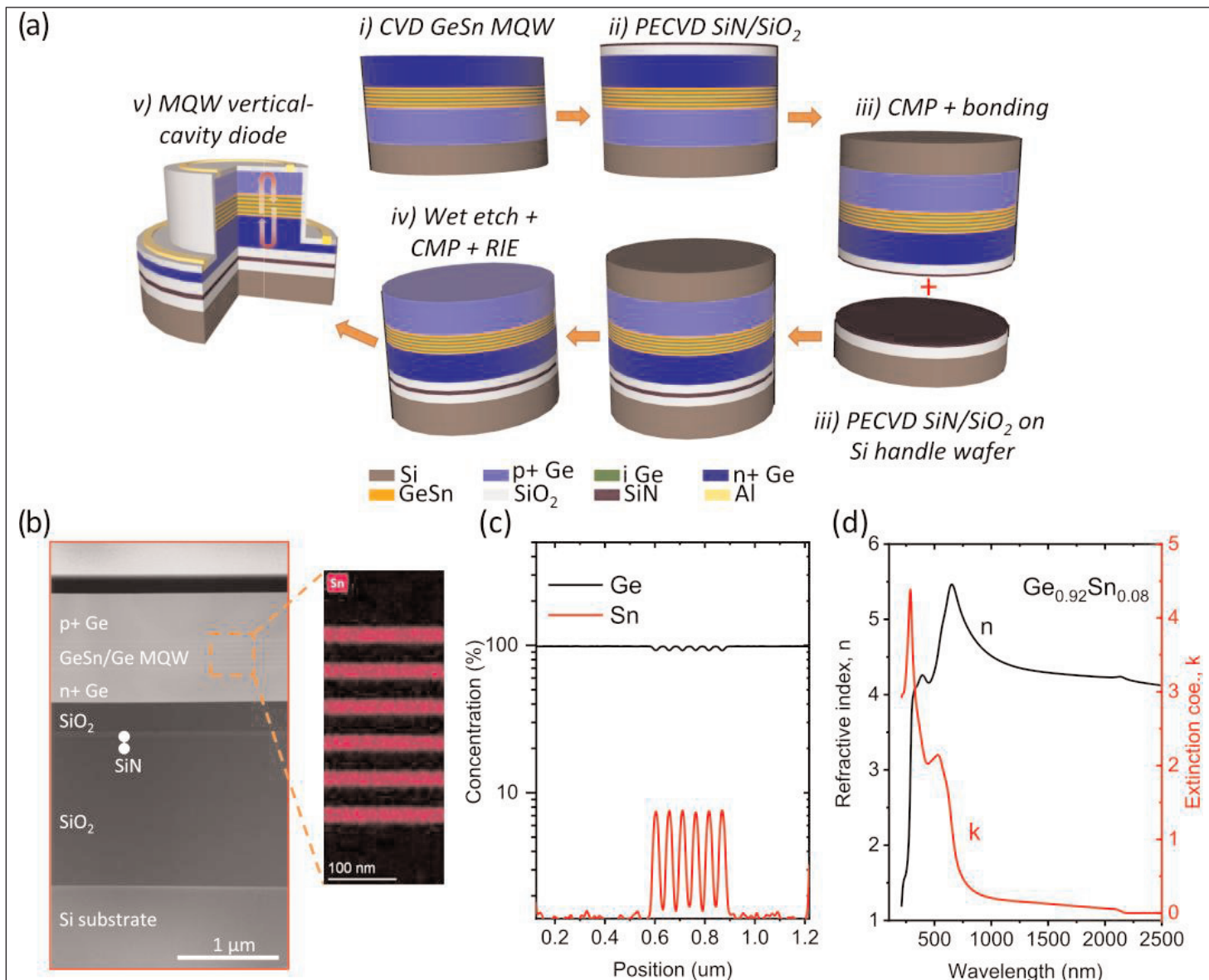
The researchers comment: “It can be anticipated that further increasing Sn content in GeSn QW, relaxing the compressive strain or incorporating Si and Sn into the barrier layer can increase the directness of GeSn QW and carrier confinement in the GeSn QW. It thereby can further increase the optical gain due to more electrons occupied in  $\Gamma$  valley so as to achieve population inversion with reduced injection current densities.”

A 6-period MQW structure with 21nm wells separated by 32nm barriers was bonded to a 200mm silicon handle wafer. The 300mm donor wafer was prepared by dicing to 200mm, and plasma-enhanced chemical vapor deposition (PECVD) of 1486nm silicon dioxide ( $\text{SiO}_2$ ) and 27nm silicon nitride (SiN). The final handle wafer was also prepared with 27nm SiN and 287nm  $\text{SiO}_2$ .

The bonding was at room temperature, followed by 300°C annealing in nitrogen atmosphere for 4 hours. The donor wafer and Ge buffer layers were removed by tetramethylammonium hydroxide (TMAH) etching, chemical mechanical polishing (CMP) and reactive-ion etching (RIE).

The  $\text{SiO}_2$ /SiN dielectric bonding layers also served as a bottom reflector of the vertical-cavity structure.

Transmission electron microscopy (TEM) with energy-dispersive x-ray (EDX) mapping suggested the VCSE structures had a cavity length of 1083nm.



**Figure 1. (a) Fabrication flow of GeSn/Ge MQW vertical-cavity surface-emitting structures and diodes on Ge-on-insulator (GOI) substrate. (b) Cross-sectional TEM with EDX mapping and (c) EDX line scan. (d) Optical constants from spectral ellipsometry.**

Photoluminescence studies of the VCSE structure showed stronger emission relative to reference MQWs on the donor wafer. Also, the main peak of the VCSE came at 2148nm, which is 171nm longer than for the reference emissions.

The researchers comment: "Since the VCSE structure and reference samples have the same GeSn/Ge MQW structure, the difference is more likely due to the vertical micro-cavity effect rather than quantum-confined effect."

The maximum PL enhancement of the VCSE structure over the reference was more than 8x at 2177nm. Simulations suggested that the MQWs were at an anti-node of the optical field in the Fabry-Pérot cavity.

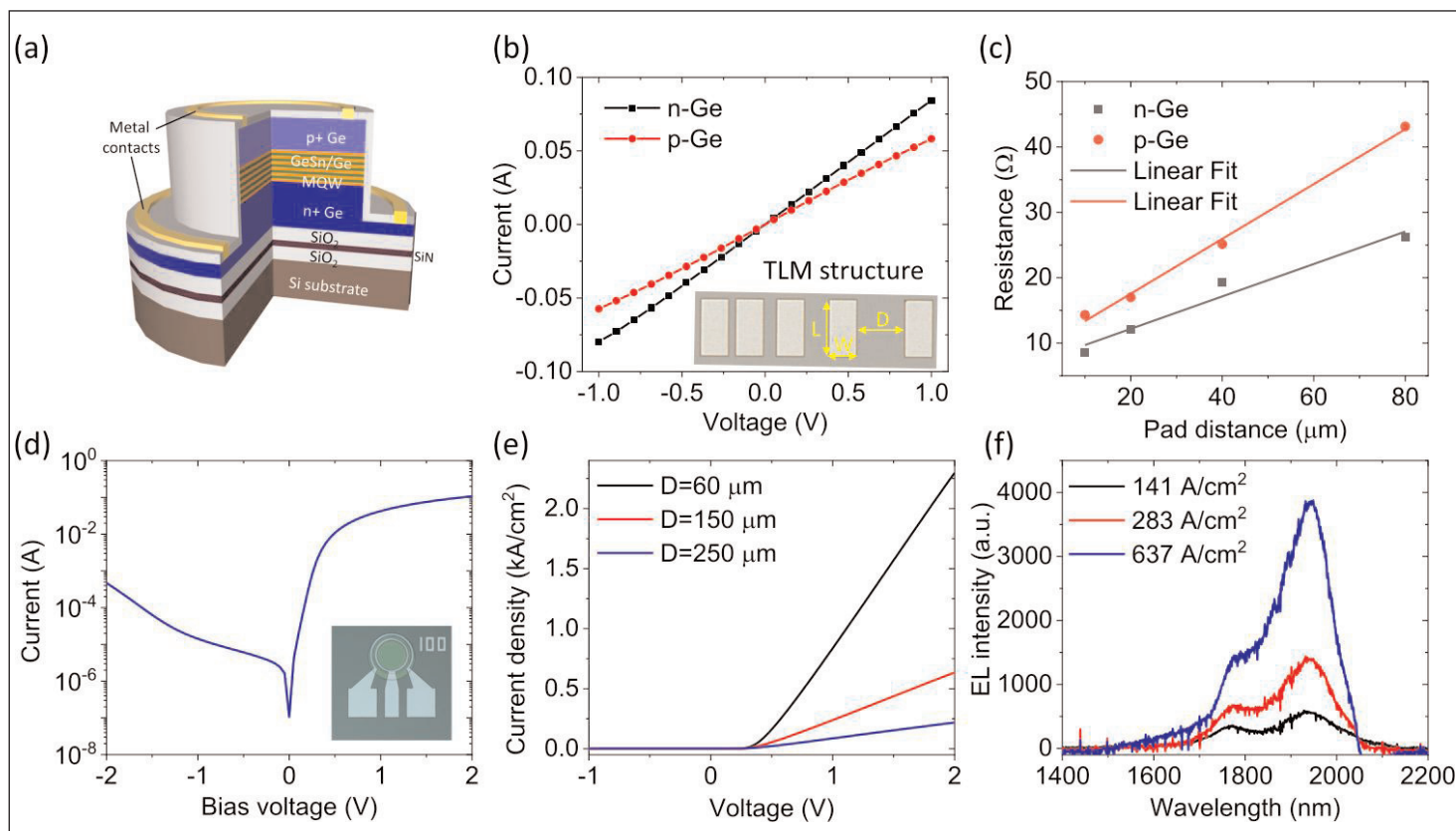
The team comments: "Based on the simulation, the active GeSn/Ge MQW layer is spatially and spectrally aligned with the single-longitudinal-mode cavity of the MQW VCSE structure, which is the reason for the

enhancement of the light emission from the MQW VCSE structure."

The PL enhancement increased as the temperature was increased from 4K to 300K (roughly room temperature). The researchers attribute this to a red-shift of the spontaneous emission spectrum from the MQW into the cavity resonance.

The team suggests that the enhancement would be even higher at temperatures above 300K. "This temperature-dependent feature of the MQW VCSE structure is preferred for high-efficiency light sources that are often heated by high injection currents," the researchers write. "As the device is heated with the increasing injection current, the spontaneous emission spectrum shifts to align with the cavity mode to provide optimum light source performance."

VCSE p-i-n diodes were fabricated with a double-mesa structure, using CMOS compatible processing tech-



**Figure 2. (a) 3D schematic of GeSn/Ge MQW VCSE photodiode. (b) Current-voltage curves of transmission line method structures on n-Ge and p-Ge with pad distance of 20 μm. Inset: optical microscope image. (c) Extracted total resistance for n- and p-contacts with different pad distance. (d) Electrical characterization of GeSn/Ge MQW VCSE photodiode with mesa diameter of 250 μm. Inset: typical fabricated MQW VCSE diode. (e) Current density-voltage curves of diodes with different mesa diameters. (f) Electroluminescence spectra of 60 μm-diameter diode with different injection current densities.**

niques (Figure 2). The structures were passivated with 400 nm PECVD SiO<sub>2</sub>. The metal contacts consisted of titanium/titanium nitride/aluminum (Ti/TiN/Al). The contacts were rapidly thermally annealed to improve the ohmic contact between the n-Ge and the metal electrodes.

Under forward bias, smaller-diameter devices were found to respond with higher current density, suggesting more uniform current spreading. The emission spectrum wavelength of the devices apparently cuts off just above 2000 nm (2 μm), due to the reduced sensitivity in this range of the liquid-nitrogen-cooled indium gallium arsenide photodetector array.

Electrically pumped lasing was not observed at

637 A/cm<sup>2</sup>, which exceeds the calculated radiative current density needed for positive optical gain. The team comments: "This suggests that non-radiative recombination and cavity losses within the device may be contributing to a higher injection current density requirement for lasing. To realize electrically pumped lasing from the VCSE diodes, future research can focus on several potential solutions, including improving material quality to suppress the non-radiative recombination, optimizing the cavity to reduce the cavity loss, or tuning the Sn(Si) concentration or strain in GeSn/Ge quantum wells to enhance gain." ■

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# AlScN ferroelectric FETs for monolithic 3D NVM integration

A new structure could increase device density and boost data processing speeds.

Researchers in the USA, Korea and Saudi Arabia report on the performance of field-effect transistors (FETs) using aluminium scandium nitride (AlScN) ferroelectric (FE) to give non-volatile memory (NVM) operation [Kwan-Ho Kim et al, Nature Nanotechnology, published online 22 May 2023].

The team from University of Pennsylvania in the USA, Hanyang University ERICA in South Korea, Pennsylvania State University in the USA, King Abdulaziz University and King Abdullah University of Science and Technology in Saudi Arabia, and University of Tokyo in Japan comment: "The stable memory performance of the FE-FETs, combined with their scalability and low-temperature integration, make a promising case for vertical heterointegration with silicon CMOS logic transistors."

The researchers see such monolithic three-dimensional (M3D) integration of NVM with complementary metal-oxide-semiconductor (CMOS) logic ('compute-in-memory') as overcoming data processing bottlenecks arising from placing the various levels of memory at varying distances with different communication speeds.

The ferroelectric potential of AlScN has only recently been realized, making it an interesting competitor to more established materials such as hafnium zirconium oxide (HZO) with a higher remnant polarization ( $P_r$ ) of more than  $110\mu\text{C}/\text{cm}^2$  and lower processing temperature.

The ferroelectric (FE) transistors (Figure 1) were fabricated on platinum/silicon dioxide/silicon (Pt/SiO<sub>2</sub>/Si) and aluminium (111)/sapphire (Al/Al<sub>2</sub>O<sub>3</sub>) 4-inch templates. The metal template layers were used as back-gates of the transistor, and for controlling the AlScN polarization field. The coercive field ( $E_c$ ) of the deposited AlScN was  $-4.5/5.1\text{MV}/\text{cm}$ , according to metal-AlScN-metal structural capacitor studies.

The channel material was the transition-metal dichalcogenide molybdenum disulfide. The researchers comment: "Selecting atomically thin monolayer MoS<sub>2</sub> as the FE-FET channel provides a key advantage by exploiting the high  $P_r$  of AlScN as an FE gate dielectric

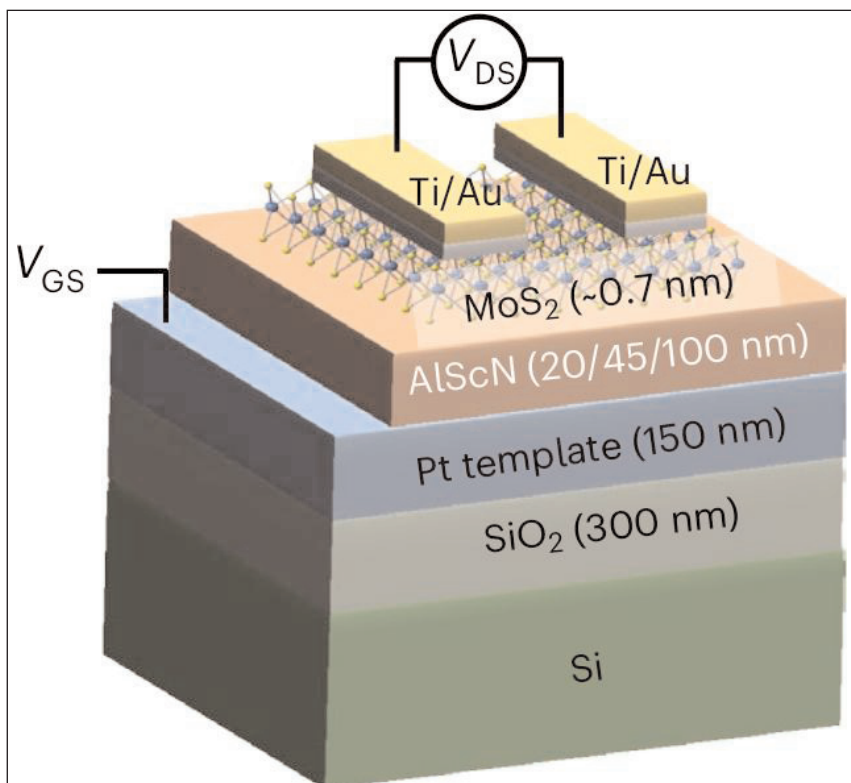


Figure 1. Schematic of MoS<sub>2</sub>/AlScN FE-FET.

because of the ability of MoS<sub>2</sub> to support high carrier densities, which is critical for a high ON-current density and high-speed operation as well as alleviating short-channel effects."

The researchers explain the operation of the devices: "Under a positive (negative) gate voltage above  $E_c$ , the FE polarization is switched in the direction pointing towards the channel (opposite of the channel), and consequently, electrons are accumulated (depleted) in the channel, causing a low-threshold-voltage (LVT) (high-threshold-voltage (HVT)) state."

The AlScN was applied using 150kHz pulsed DC co-sputtering of the metals with nitrogen at 350°C chamber temperature. The relatively low temperature falls within the thermal budget of standard CMOS electronics back-end-of-line (BEOL) processing (usually metal interconnection of the front-end-of-line (FEOL) devices and passivation/insulation). The team was careful to avoid the formation of oxide on the AlScN, which would otherwise seriously degrade the FE-FET performance.

The large-area molybdenum disulfide (MoS<sub>2</sub>) was deposited as a single layer on two-inch sapphire, using three different chemical vapor deposition (CVD) methods. The Mo was sourced from MoO<sub>x</sub> or the metal-organic molybdenum hexacarbonyl (Mo(CO)<sub>6</sub>). The sulfur precursor was variously S powder or hydrogen sulfide (H<sub>2</sub>S). The MoS<sub>2</sub> was then transferred onto the AlScN during transistor fabrication in a wet process.

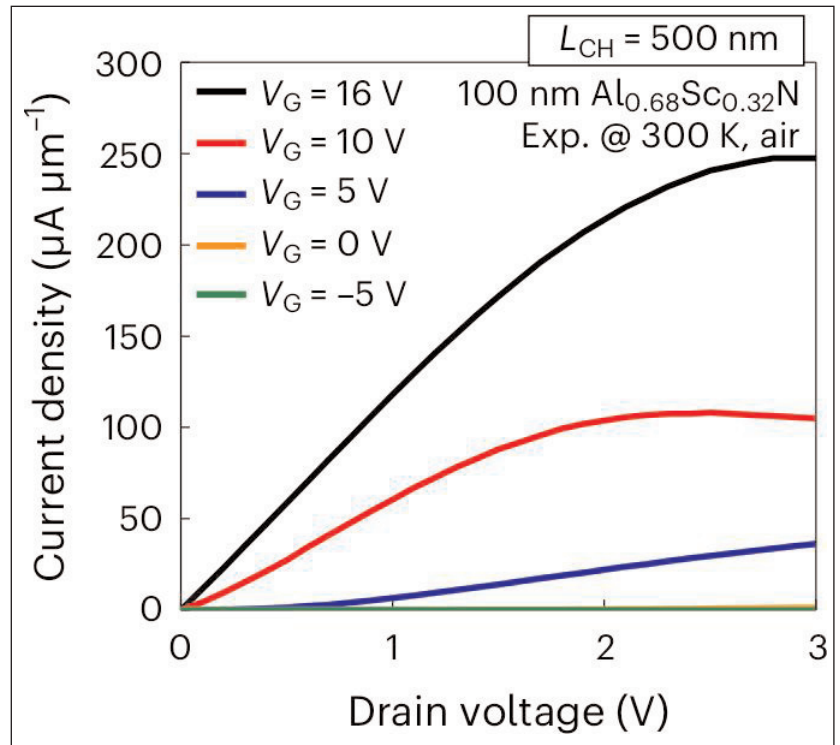
A 500nm long-channel device on 100nm Al<sub>0.68</sub>Sc<sub>0.32</sub>N had a very large memory window (MW) of 18V, along with an ON/OFF current ratio of 10<sup>7</sup>.

The ON-current density at 1V drain bias (V<sub>DS</sub>) was 71μA/μm. At 3V V<sub>DS</sub> the ON-current density reached 252μA/μm. The team comments: "To the best of our knowledge, this is among the highest current density values obtained without any channel doping or contact resistance engineering in a 2D channel FET, further highlighting the importance of high-P<sub>r</sub> FE materials like AlScN."

The FE switching voltage for the maximum MW could be reduced by thinning the AlScN layer and increasing the Sc content. A smaller switching voltage is needed for low energy consumption and M3D integration of the FE-FETs with Si CMOS. The MW was reduced to 5–6V with a 20nm Al<sub>0.68</sub>Sc<sub>0.32</sub>N FE layer.

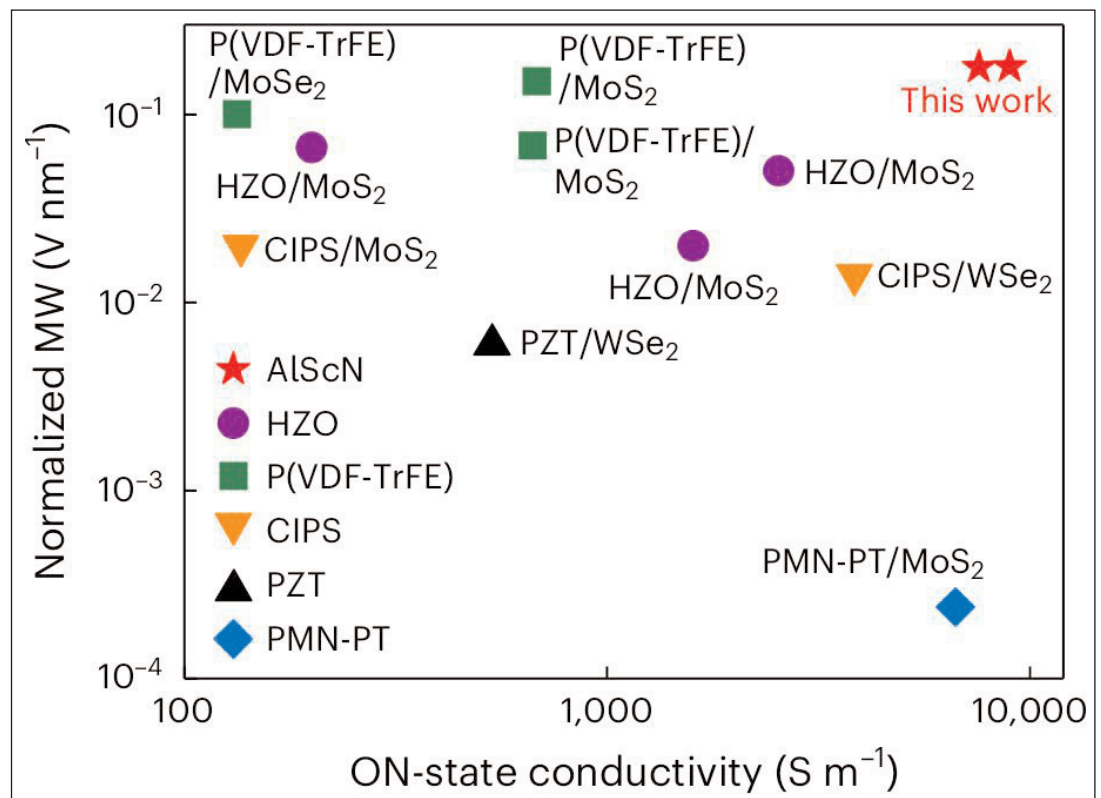
Aggressive channel length (L<sub>CH</sub>) scaling down to 78nm with 45nm AlScN FE layer resulted in an 8V MW, and an ON/OFF ratio greater than 10<sup>6</sup>. The team comments that sustaining performance after such aggressive scaling is due to "the high P<sub>r</sub> value of AlScN, which noticeably keeps the OFF-current low".

Comparing the normalized MW and ON conductivity of the long- and short-channel devices with other reports (Figure 3), the researchers comment that their FE-FETs "are among the highest compared with other 2D channel FE-FETs." They also note the closeness in performance of their long- and short-channel devices (the two stars in the figure).

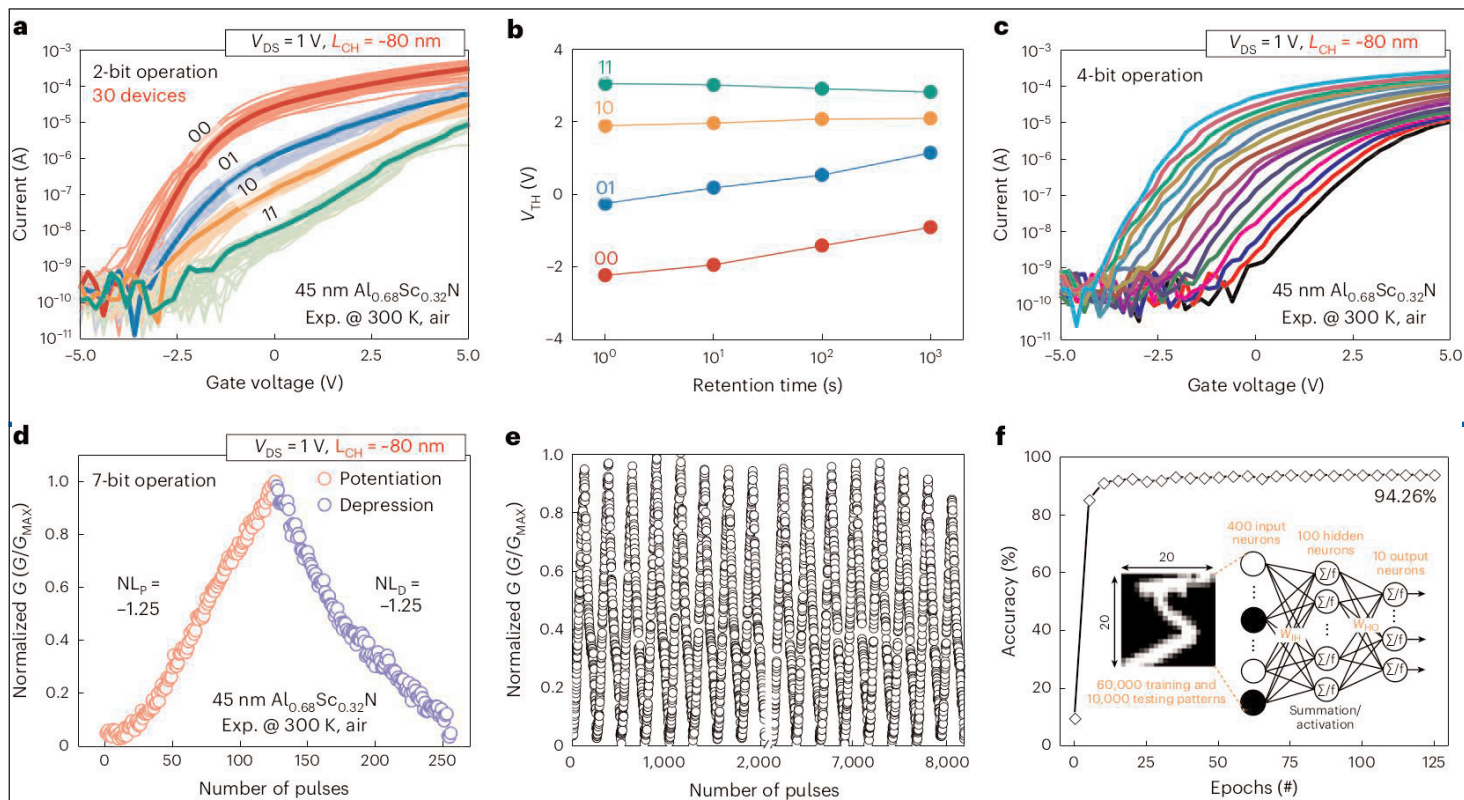


**Figure 2. Linear-scale output characteristics of a representative 100nm Al<sub>0.68</sub>Sc<sub>0.32</sub>N/MoS<sub>2</sub> FE-FET at various gate voltages (V<sub>G</sub>).**

The programming (PRG) and erasing (ERS) pulses were 500ns/34V and 40ms/12V, respectively. FE materials, such as AlScN, often have a trade-off



**Figure 3. Comparison of normalized MW and ON-state conductivity from reported 2D channel FE-FETs with various FE materials. Left and right red stars correspond to 45nm and 100nm AlScN/MoS<sub>2</sub> FE-FETs, respectively.**



**Figure 4. a. Two-bit operation measured from 30 scaled FE-FETs after 10–12V/40ms PRG or ERS pulses. b. Retention of 2-bit  $V_{TH}$  states up to 1000s. c. Four-bit operation with 9–12V/40ms pulses. d. Normalized 7-bit LTP/LTD curves obtained from scaled FE-FET. e. Cycle-to-cycle variations of LTP/LTD curve for over 30 cycles (total, over 8000 input pulses). f. Recognition rate as function of the number of training epochs based on the LTP/LTD curve in d, and inset schematic of 400x100x10 MLP-based ANN.**

between pulse width and amplitude.

Retention of the HVT and LVT states of the FE material was extrapolated to have a 10-year scale to maintain a MW of more than 3V. The researchers add: "Aside from time-dependent retention, the devices also exhibit stable switching endurance for more than 10,000 cycles and maintain the ON/OFF ratio when a pulse with 10V amplitude and 40ms width is used."

Given the large MW, the team also explored AlScN's potential for multi-bit memory operation for increased effective data density per NVM cell (Figure 4). The researchers comment: "Although the device performance of individual FE-FETs has reached or surpassed floating-gate FETs in flash technology, multi-bit demonstrations in FE-FETs are still in their infancy even for HfO<sub>x</sub>-based FE-FETs and has never been demonstrated before for nitride FE materials."

**Although the device performance of individual FE-FETs has reached or surpassed floating-gate FETs in flash technology, multi-bit demonstrations in FE-FETs are still in their infancy even for HfO<sub>x</sub>-based FE-FETs and has never been demonstrated before for nitride FE materials**

The multi-bit operation was achieved by applying different numbers, widths and amplitudes of pulses to achieve various  $V_{TH}$  states. The team comments: "To the best of our knowledge, this is the first demonstration of multi-state programming in FE nitrides and in BEOL-compatible FE-FETs at this scale. These results suggest the foundation for a scalable M3D integration of memory with logic."

The team also looked at a scheme for using the device as an artificial synapse in a 7-bit operation mode using 15V/150 $\mu$ s 4kHz pulses for long-term potentiation (LTP) and -1 to -15V/150 $\mu$ s for long-term depression (LTD). The corresponding non-linearities ( $NL_{P/D}$ ) were found to be -1.25.

The device parameters were used in a multi-layer perceptron (MLP)-based artificial neural network (ANN) simulation with 400 input, 100 hidden and 10 output 'neurons' connected by artificial synapses.

The researchers report: "The Modified National Institute of Standards and Technology dataset of black-and-white handwritten digit patterns with a size of 20x20 was used for training (60,000) and testing (10,000). As a result, the maximum accuracy based on the LTP/LTD curve reached a very high value of 94.26% (96.19% for software-based simulation)."

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# NTT achieves 300GHz-band high-speed data transmission with beamforming

**NTT and the Tokyo Institute of Technology have established a foundation for the instantaneous transmission of ultra-high-capacity data to 6G mobile devices.**

**A**t June's 2023 IEEE MTT-S International Microwave Symposium (IMS) in San Diego, CA, USA, Tokyo-based NTT Corp and researchers at the Tokyo Institute of Technology said that they have demonstrated a phased-array transmitter module to enable instantaneous ultra-high-capacity data transmission to mobile receivers. The researchers achieved the first wireless data transmission via beamforming in the 300GHz band, which is expected to be utilized in the realization of sixth-generation (6G) communications.

## Research background

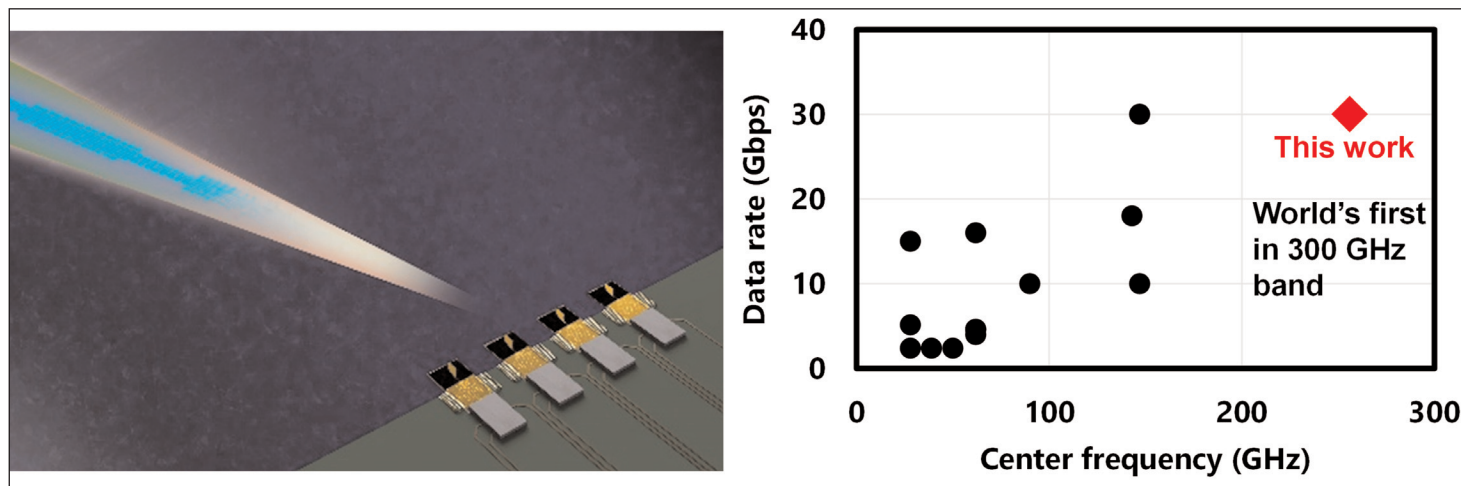
In 6G wireless communications systems, ultra-high-speed wireless communications are expected to be achieved by utilizing the 300GHz band, which has the advantage of being able to use a wide frequency range. On the other hand, it faces the problem of large path loss during signal propagation through space. Beamforming technology is being studied to overcome this problem.

Beamforming concentrates and directs radio energy toward the receiving device. In 5G wireless systems that use radio waves in the 28GHz and 39GHz bands, beamforming has been realized with CMOS integrated circuits. On the other hand, CMOS ICs alone lack sufficient output power in the 300GHz band. Combining

CMOS ICs with III-V compound semiconductor ICs, capable of high output power, is therefore being attempted around the world to achieve beamforming in the 300GHz band. However, because high output power is prevented by the large energy loss occurring inside the III-V IC and in the connection between the III-V IC and the CMOS IC, high-speed wireless data transmission by beamforming has not been achieved until now.

## Research results

NTT has developed indium phosphide (InP) ICs that integrate its proprietary high-output power amplifier circuit and antenna circuit. This is enabled by NTT's proprietary InP-based heterojunction bipolar transistor (InP HBT) technology. Tokyo Tech has succeeded in fabricating a highly scaled CMOS IC containing frequency conversion and control circuits. NTT and Tokyo Tech have now developed a compact four-element phased-array transmitter module by mounting the CMOS IC and InP IC on the same printed circuit board. With a steering range of 36°, maximum data rate of 30Gbps and communication distance of 50cm, this transmitter module has achieved the first high-speed wireless data transmission in the 300GHz band using beamforming (Figure 1).



**Figure 1: (Left) Beamforming using phased-array wireless device. (Right) Comparison of previously reported transmission with beamforming wireless devices and this achievement.**

**Figure 2: The newly developed 300GHz-band phased-array transmitter and the transmission experiment.**

### Key technical points

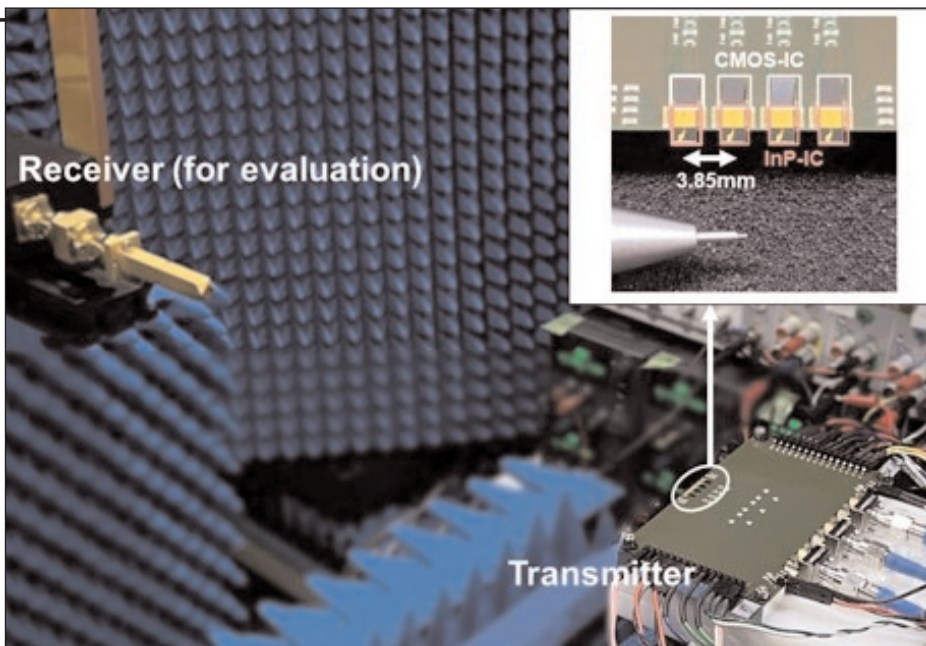
The following two technologies made the beamforming and high-speed wireless data transmission possible.

#### 1. Design of 300GHz-band high-output power amplifier circuit

NTT and Tokyo Tech have designed a power amplifier circuit that achieves high output power in the 300GHz band and realized its fabrication by using NTT's proprietary InP HBT technology. For the power amplifier circuit, high output power is achieved by combining electrical power output from multiple amplifier elements using a low-loss power combiner. The circuit amplifies the signals output from the CMOS IC and radiates the radio wave to the receiving device from the antenna packaged on the same chip.

#### 2. High-frequency band low-loss mounting technology

Conventionally, to connect different types of ICs for the 300GHz band, each IC is mounted on a waveguide module, and the modules are connected together. However, this approach has the problem of energy loss when radio waves pass through the waveguides. NTT and Tokyo Tech's achievement is said to overcome this problem through flip-chip bonding of the CMOS IC and the InP IC and connecting them using metal bumps of several tens of microns in size. This packaging approach reduces connection loss and achieves high output power (Figure 3).



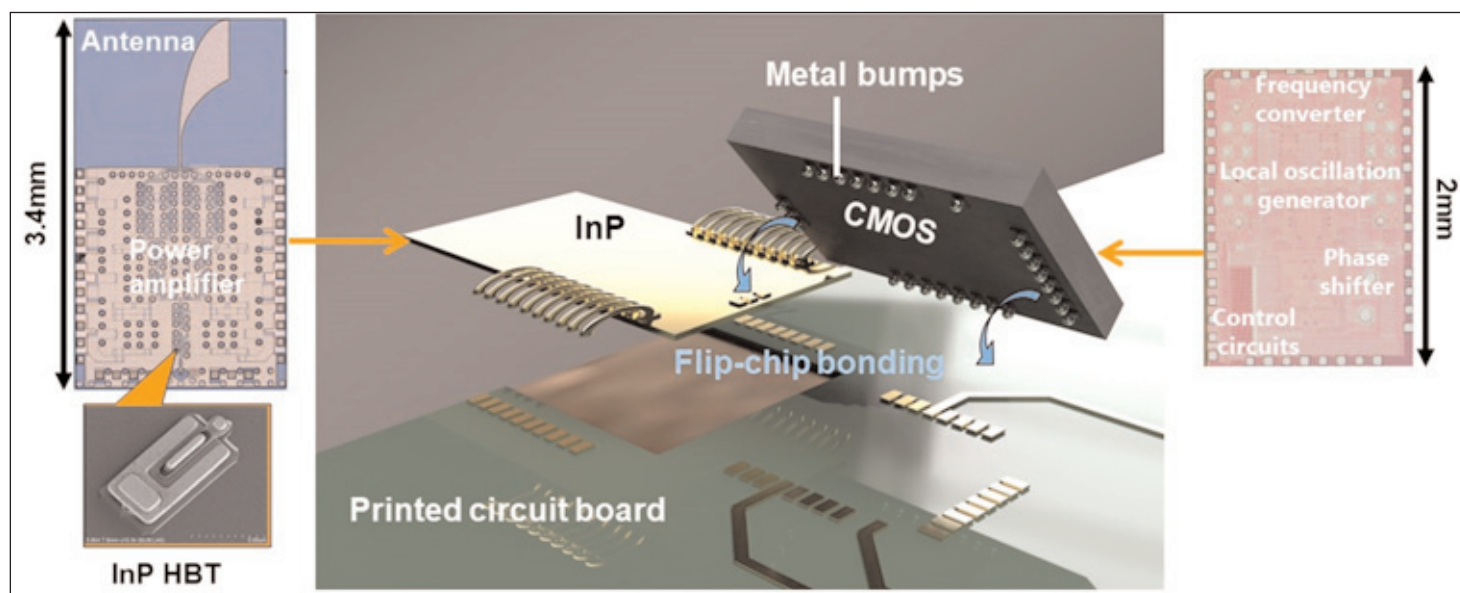
### Future research

Short-distance mobile communication devices are expected to be deployed in 6G networks in the future. NTT and Tokyo Tech's technology promises to expand these applications, such as interactive kiosks and femtocells. The developed technology demonstrated one-dimensional beamforming. NTT and Tokyo Tech are working on demonstrating two-dimensional beamforming with a 2D array and extending the communication distance by increasing the number of arrays. NTT and Tokyo Tech are also engaged in the development of receiver modules to meet the needs of 6G applications, and in the practical implementation of wireless communication with transmission capacity ten-fold greater than is available currently. ■

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**Figure 3: Exploded-view diagram of 300GHz band phased-array transmitter and photo of the chip.**

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[www.kymatech.com](http://www.kymatech.com)

**MARUWA CO LTD**

3-83, Minamihonjigahara-cho,  
Owariasahi, Aichi 488-0044, Japan  
Tel: +81 572 52 2317  
[www.maruwa-g.com/e/  
products/ceramic](http://www.maruwa-g.com/e/products/ceramic)

**sp3 Diamond Technologies**

2220 Martin Avenue,  
Santa Clara, CA 95050, USA  
Tel: +1 877 773 9940  
Fax: +1 408 492 0633  
[www.sp3inc.com](http://www.sp3inc.com)

**Sumitomo Electric  
Semiconductor Materials Inc**

7230 NW Evergreen Parkway,  
Hillsboro, OR 97124, USA  
Tel: +1 503 693 3100 x207  
Fax: +1 503 693 8275  
[www.sesmi.com](http://www.sesmi.com)

**The Fox Group Inc**

200 Voyageur Drive, Montreal,  
Quebec H9R 6A8, Canada  
Tel: +1 925 980 5645  
Fax: +1 514 630 0227  
[www.thefoxgroupinc.com](http://www.thefoxgroupinc.com)

**III/V-Reclaim**

Wald 10, 84568 Pleiskirchen,  
Germany  
Tel: +49 8728 911 093  
Fax: +49 8728 911 156  
[www.35reclaim.de](http://www.35reclaim.de)

**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  
E-mail: sales@tecdia.com  
[www.tecdia.com](http://www.tecdia.com)

**Wafer Technology Ltd**

34 Maryland Road, Tongwell,  
Milton Keynes, Bucks, MK15 8HJ, UK  
Tel: +44 (0)1908 210444  
Fax: +44 (0)1908 210443  
[www.wafertech.co.uk](http://www.wafertech.co.uk)

Wafer Technology  
Ltd is a UK based  
producer of III-V  
materials and  
epitaxy-ready  
substrates  
offering the widest  
product range in the business.



WAFER TECHNOLOGY LTD.

**Wafer World Inc**

1100 Technology Place, Suite 104,  
West Palm Beach,  
FL 33407,  
USA  
Tel: +1-561-842-4441  
Fax: +1-561-842-2677  
[www.waferworld.com](http://www.waferworld.com)

**4 Epiwafer foundry****Albemarle Cambridge Chemical Ltd**

Unit 5 Chesterton Mills,  
French's Road, Cambridge CB4 3NP,  
UK  
Tel: +44 (0)1223 352244  
Fax: +44 (0)1223 352444  
[www.camchem.co.uk](http://www.camchem.co.uk)

**Intelligent Epitaxy Technology Inc**

1250 E Collins Blvd,  
Richardson, TX 75081-2401,  
USA  
Tel: +1 972 234 0068  
Fax: +1 972 234 0069  
[www.intelliepi.com](http://www.intelliepi.com)

**IQE**

Cypress Drive,  
St Mellons,  
Cardiff  
CF3 0EG, UK  
Tel: +44 29 2083 9400  
Fax: +44 29 2083 9401  
[www.iqep.com](http://www.iqep.com)



IQE is a leading global supplier of  
advanced epiwafers, with products  
covering a diverse range of  
applications within the wireless,  
optoelectronic, photovoltaic and  
electronic markets.

**OMMIC**

2, Chemin du Moulin B.P. 11,  
Limeil-Brevannes, 94453,  
France  
Tel: +33 1 45 10 67 31  
Fax: +33 1 45 10 69 53  
[www.ommic.fr](http://www.ommic.fr)

**Soitec**

Parc Technologique des Fontaines,  
Chemin des Franques, 38190  
Bernin, France  
Tel: +33 (0)4 76 92 75 000  
[www.soitec.com](http://www.soitec.com)

**The Fox Group Inc**

200 Voyageur Drive, Montreal,  
Quebec H9R 6A8, Canada  
Tel: +1 925 980 5645  
Fax: +1 514 630 0227  
[www.thefoxgroupinc.com](http://www.thefoxgroupinc.com)

**5 Deposition  
materials****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](http://www.williams-adv.com)

**Matheson Tri-Gas**

6775 Central Avenue,  
Newark, CA 94560, USA  
Tel: +1 510 793 2559  
Fax: +1 510 790 6241  
[www.mathesontrigas.com](http://www.mathesontrigas.com)

**Nouryon Functional Chemicals B.V.**

Zutphenseweg 10, 7418 AJ  
Deventer,  
The Netherlands  
Tel: +31 652 478554  
<https://hpmo.nouryon.com>

**Praxair Electronics**

542 Route 303,  
Orangeburg, NY 10962,  
USA  
Tel: +1 845 398 8242  
Fax: +1 845 398 8304  
[www.praxair.com/electronics](http://www.praxair.com/electronics)

**Vital Thin Film Materials**

**(Guangdong) Co Ltd  
(Vital Materials subsidiary)**  
18G, 18th Floor, Shenzhen Free  
Trade Centre, No.111 Taizi Road,  
Nanshan District,  
Shenzhen, Guangdong, China 518067  
Tel: (+86) 0755-21651348  
sales@vitaltfm.com

[www.vitalfm.com](http://www.vitalfm.com)

Vital Materials is the world's leading producer of rare metals



as well as the **Thin Film Materials** first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

## 6 Deposition equipment

### AIXTRON SE

Dornkaulstr. 2,  
52134 Herzogenrath,  
Germany  
Tel: +49 2407 9030 0  
Fax: +49 2407 9030 40  
[www.aixtron.com](http://www.aixtron.com)

### ETC (LPE subsidiary)

Via Falzarego, 820021 Baranzate (Mi), Italy  
Tel: +39 02 383 41 51  
Fax: +39 02 383 06 118  
[www.lpe-epi.com](http://www.lpe-epi.com)

### Evatec AG

Hauptstrasse 1a,  
CH-9477 Trübbach,  
Switzerland  
Tel: +41 81 403 8000  
Fax: +41 81 403 8001  
[www.evatecnet.com](http://www.evatecnet.com)

### FHR Anlagenbau GmbH (Vital Materials subsidiary)

Am Hügel 2, D-01458  
Ottendorf-Okrilla, FHR  
Germany  
Tel: +49 35205 520-0  
E-mail: [sales@fhr.de](mailto:sales@fhr.de)  
E-mail: [sales@vitalchem.com](mailto:sales@vitalchem.com)  
[www.fhr.biz](http://www.fhr.biz)

Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor

substrates, and a strategic partner of the world's largest thin film solar manufacturer.

### LPE S.p.A.

Via Falzarego, 8  
20021 Baranzate (Mi), Italy  
Tel: +39 02 383 41 51  
Fax: +39 02 383 06 118  
[www.lpe-epi.com](http://www.lpe-epi.com)

### PLANSEE High Performance Materials

6600 Reutte,  
Austria  
Tel: +43 5672 600 2422  
[info@plansee.com](mailto:info@plansee.com)  
[www.plansee.com](http://www.plansee.com)

### Plasma-Therm LLC

10050 16th Street North,  
St. Petersburg, FL 33716,  
USA  
Tel: +1 727 577 4999  
Fax: +1 727 577 7035  
[www.plasmatherm.com](http://www.plasmatherm.com)

### Riber

31 rue Casimir Périer, BP 70083,  
95873 Bezons Cedex,  
France  
Tel: +33 (0) 1 39 96 65 00  
Fax: +33 (0) 1 39 47 45 62  
[www.riber.com](http://www.riber.com)

### SVT Associates Inc

7620 Executive Drive,  
Eden Prairie, MN 55344,  
USA  
Tel: +1 952 934 2100  
Fax: +1 952 934 2737  
[www.svta.com](http://www.svta.com)

### Temescal, a division of Ferrotec

4569-C Las Positas Rd,  
Livermore, CA 94551,  
USA  
Tel: +1 925 245 5817  
Fax: +1 925 449-4096  
[www.temescal.net](http://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](http://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](http://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](http://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](http://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](http://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](http://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](http://www.samcointl.com)

**SPTS Technology Ltd**

Ringland Way, Newport NP18 2TA,  
Wales, UK  
Tel: +44 (0)1633 414000  
Fax: +44 (0)1633 414141  
[www.spts.com](http://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](http://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](http://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](http://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](http://www.goodfellow.com)

**PLANSEE High Performance Materials**

6600 Reutte,  
Austria  
Tel: +43 5672 600 2422  
info@plansee.com  
[www.plansee.com](http://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](http://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](http://www.cambridge-fluid.com)

**CS CLEAN SOLUTIONS AG**

Fraunhoferstrasse 4,  
Ismaning, 85737,  
Germany  
Tel: +49 89 96 24000  
Fax: +49 89 96 2400122  
[www.csclean.com](http://www.csclean.com)

**Entegris Inc**

129 Concord Road,  
Billerica, MA 01821, USA  
Tel: +1 978 436 6500  
Fax: +1 978 436 6735  
[www.entegris.com](http://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](http://www.iemtec.com)

**Vacuum Barrier Corporation**

4 Barton Lane,  
Woburn, MA 01801,  
USA  
Tel: +1 781 933 3570  
Fax: +1 781 933 9428  
[www.vacuumbarrier.com](http://www.vacuumbarrier.com)  
**VACUUM BARRIER VBC**  
CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators

deliver low-pressure LN2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN2 pipe eliminates two-phase flow to all use points.

**Versum Materials**

8555 S. River Parkway,  
Tempe, AZ 85284, USA  
Tel: +1 602 282 1000  
[www.versummaterials.com](http://www.versummaterials.com)

## 11 Process monitoring and control

**Conax Technologies**

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Buffalo, NY 14225,  
USA  
Tel: +1 800 223 2389  
Tel: +1 716 684 4500  
[www.conaxtechnologies.com](http://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](http://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](http://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](http://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.

**Vacuum Barrier Corporation**

4 Barton Lane, Woburn, MA 01801, USA

Tel: +1 781 933 3570

Fax: +1 781 933 9428

[www.vacuumbARRIER.com](http://www.vacuumbARRIER.com)

**VACUUM  
BARRIER VBC**  
CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN<sub>2</sub> pipe delivers LN<sub>2</sub> at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN<sub>2</sub> to each use point for on-demand supply. Combine with SEMIFLEX Triax LN<sub>2</sub> pipe eliminates two-phase flow to all use points.

**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](http://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](http://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](http://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](http://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](http://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](http://www.riff-co.com)

**Tektronix Inc**

14150 SW Karl Braun Drive,  
P.O.Box 500, OR 97077, USA

[www.tek.com](http://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](http://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](http://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](http://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](http://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](http://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](http://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](http://www.pi.ws)

[www.pi-usa.us](http://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](http://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.quikicpak.com](http://www.quikicpak.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](http://www.cstglobal.uk)



**United Monolithic Semiconductors**

Route departementale 128,  
BP46, Orsay, 91401,  
France  
Tel: +33 1 69 33 04 72  
Fax: +33 1 69 33 02 92  
[www.ums-gaas.com](http://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](http://www.rena-na.com)

**Vacuum Barrier Corporation**

4 Barton Lane, Woburn, MA 01801,  
USA  
Tel: +1 781 933 3570  
Fax: +1 781 933 9428  
[www.vacuumbARRIER.com](http://www.vacuumbARRIER.com)

**VACUUM BARRIER VBC**  
CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN<sub>2</sub> pipe delivers LN<sub>2</sub> at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN<sub>2</sub> to each use point for on-demand supply. Combine with SEMIFLEX Triax LN<sub>2</sub> pipe eliminates two-phase flow to all use points.

**20 Facility consumables****PLANSEE High Performance Materials**

6600 Reutte,  
Austria  
Tel: +43 5672 600 2422  
info@plansee.com  
[www.plansee.com](http://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](http://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](http://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](http://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](http://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.


**Class One Equipment Inc**

5302 Snapfinger Woods Drive,  
Decatur, GA 30035,  
USA  
Tel: +1 770 808 8708  
Fax: +1 770 808 8308  
[www.ClassOneEquipment.com](http://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](http://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](http://www.tecdia.com)

**24 Resources****Al Shultz Advertising Marketing for Advanced Technology Companies**

1346 The Alameda,  
7140 San Jose, CA 95126, USA  
Tel: +1 408 289 9555  
[www.alshultz.com](http://www.alshultz.com)

**SEMI Global Headquarters**

San Jose, CA 95134,  
USA  
Tel: +1 408 943 6900  
[www.semi.org](http://www.semi.org)

**Yole Développement**

69006 Lyon,  
France  
Tel: +33 472 83 01 86  
[www.yole.fr](http://www.yole.fr)

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**3–6 September 2023**

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incorporating:

**SPIE Remote Sensing**

**SPIE Security + Defence**

RAI Amsterdam,

Amsterdam, Netherlands

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

[www.spie.org/conferences-and-exhibitions/sensors-and-imaging](http://www.spie.org/conferences-and-exhibitions/sensors-and-imaging)

**4–8 September 2023**

**European Conference on Power Electronics and Applications (EPE'23 ECCE Europe)**

Aalborg Kongres & Kultur Center,

Aalborg, Denmark

**E-mail:** [epe2023@aau.dk](mailto:epe2023@aau.dk)

[www.epe2023.com](http://www.epe2023.com)

**6–8 September 2023**

**CIOE 2023:**

**The 24th China International Optoelectronic Exposition**

Shenzhen World Exhibition & Convention Center,

Shenzhen, China

**E-mail:** [cioe@cioe.cn](mailto:cioe@cioe.cn)

[www.cioe.cn/en](http://www.cioe.cn/en)

**6–8 September 2023**

**SEMICON Taiwan 2023**

TaiNEX 1&2, Taipei,

Taiwan

**E-mail:** [semicontaiwan@semi.org](mailto:semicontaiwan@semi.org)

[www.semicontaiwan.org](http://www.semicontaiwan.org)

**17–22 September 2023**

**International Conference on Silicon Carbide and Related Materials (ICSCRM 2023)**

Hilton Sorrento Palace Conference Centre,  
Sorrento, Italy

**E-mail:** [info@icscrm-2023.org](mailto:info@icscrm-2023.org)

[www.icscrm-2023.org](http://www.icscrm-2023.org)

**17–22 September 2023**

**26th European Microwave Week (EuMW 2023)**

Berlin Messe, Germany

**E-mail:** [eumwreg@itnint.com](mailto:eumwreg@itnint.com)

[www.eumweek.com](http://www.eumweek.com)

**1–5 October 2023**

**European Conference on Optical Communication (ECOC 2023)**

Glasgow, Scotland, UK

**E-mail:** [postmaster@theiet.org](mailto:postmaster@theiet.org)

<https://ecoc2023.theiet.org>

**14–16 October 2023**

**SPIE/COS Photonics Asia 2023**

Beijing International Convention Center,  
Beijing, China

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

[www.spie.org/conferences-and-exhibitions/photonics-asia](http://www.spie.org/conferences-and-exhibitions/photonics-asia)

**14–17 November 2023**

**SEMICON Europa 2023**

Messe München, Munich, Germany

**E-mail:** [semiconeuropa@semi.org](mailto:semiconeuropa@semi.org)

[www.semiconeuropa.org](http://www.semiconeuropa.org)

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**14–18 October 2023**

**2023 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)**

Monterey, CA, USA

**E-mail:** cs@cshawevent.com

[www.bcicts.org](http://www.bcicts.org)

**24–26 October 2023**

**SPIE Photonex 2023**

Scottish Event Campus (SEC), Glasgow, UK

**E-mail:** customerservice@spie.org

[www.spie.org/conferences-and-exhibitions/phonex](http://www.spie.org/conferences-and-exhibitions/phonex)

**29 October – 2 November 2023**

**IEEE Energy Conversion Conference & Expo (ECCE 2023)**

Music City Center, Nashville TN, USA

**E-mail:** ECCE2023TPC@GMAIL.COM

[www.ieee-ecce.org/2023](http://www.ieee-ecce.org/2023)

**9–13 December 2023**

**69th annual IEEE International Electron Devices Meeting (IEDM 2023) – ‘Devices for a Smart World Built Upon 60 Years of CMOS’**

Hilton San Francisco Union Square Hotel, CA, USA

**E-mail:** iedm-info@ieee.org

[www.ieee-iedm.org](http://www.ieee-iedm.org)

**13–15 December 2023**

**SEMICON Japan 2023**

Tokyo Big Sight, Tokyo, Japan

**E-mail:** semicon@sakurain.co.jp

[www.semiconjapan.org](http://www.semiconjapan.org)

**27 January – 1 February 2024**

**SPIE Photonics West 2024**

The Moscone Center, San Francisco, CA, USA

**E-mail:** customerservice@spie.org

[www.spie.org/conferences-and-exhibitions/photronics-west](http://www.spie.org/conferences-and-exhibitions/photronics-west)

**18–22 February 2024**

**2024 IEEE International Solid- State Circuits Conference (ISSCC 2024)**

San Francisco, CA USA

**E-mail:** Issccinfo@yesevents.com

[www.isscc.org](http://www.isscc.org)

**25–29 February 2024**

**IEEE Applied Power Electronics Conference (APEC 2024)**

Long Beach CA, USA

**E-mail:** apec@apec-conf.org

<https://apec-conf.org>

**7–11 April 2024**

**SPIE Photonics Europe 2024, co-located with SPIE Optical Systems Design 2024**

Palais de la Musique et des Congrès, Strasbourg, France

**E-mail:** customerservice@spie.org

[www.spie.org/conferences-and-exhibitions/photronics-europe](http://www.spie.org/conferences-and-exhibitions/photronics-europe)

**20–23 May 2024**

**2024 CS MANTECH: International Conference on Compound Semiconductor Manufacturing Technology**

JW Marriott Starr Pass Resort,

Tucson, AZ, USA

**E-mail:** registration@csmantech.org

[www.vlssymposium.org](http://www.vlssymposium.org)

**12–23 June 2024**

**2024 IEEE Symposium on VLSI Technology and Circuits**

Hilton Hawaiian Village Waikiki Beach Resort,

Honolulu, HI, USA

**E-mail:** vlsi@vlssymposium.org

[www.vlssymposium.org](http://www.vlssymposium.org)

**16–21 June 2024**

**2024 IEEE/MTT-S International Microwave Symposium (IMS 2024)**

Washington DC, USA

**E-mail:** exhibits@horizonhouse.com

[www.ims-ieee.org/about-ims/past-and-future-ims](http://www.ims-ieee.org/about-ims/past-and-future-ims)

**9–11 July 2024**

**SEMICON West 2024**

Moscone Center, San Francisco, CA, USA

**E-mail:** semiconwest@semi.org

[www.semiconwest.org](http://www.semiconwest.org)

**22–26 September 2024**

**ECOC 2024: European Conference on Optical Communication**

Frankfurt am Main, Germany

**E-mail:** michelle.dampier@nexusmediaevents.com

[www.ecocexhibition.com/future-dates](http://www.ecocexhibition.com/future-dates)

**16–20 February 2025**

**ISSCC 2025: IEEE International Solid- State Circuits Conference**

San Francisco, CA USA

**E-mail:** issccinfo@yesevents.com

[www.isscc.org](http://www.isscc.org)



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