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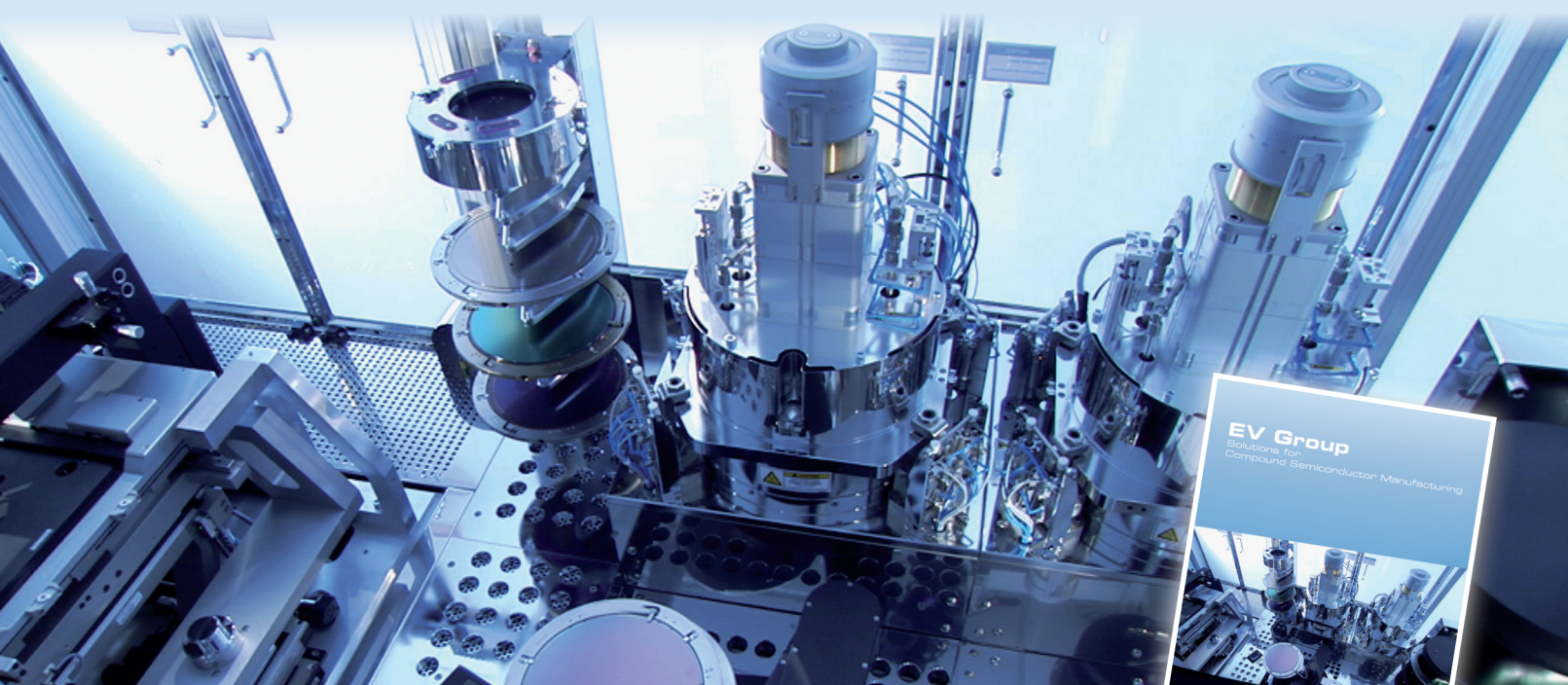
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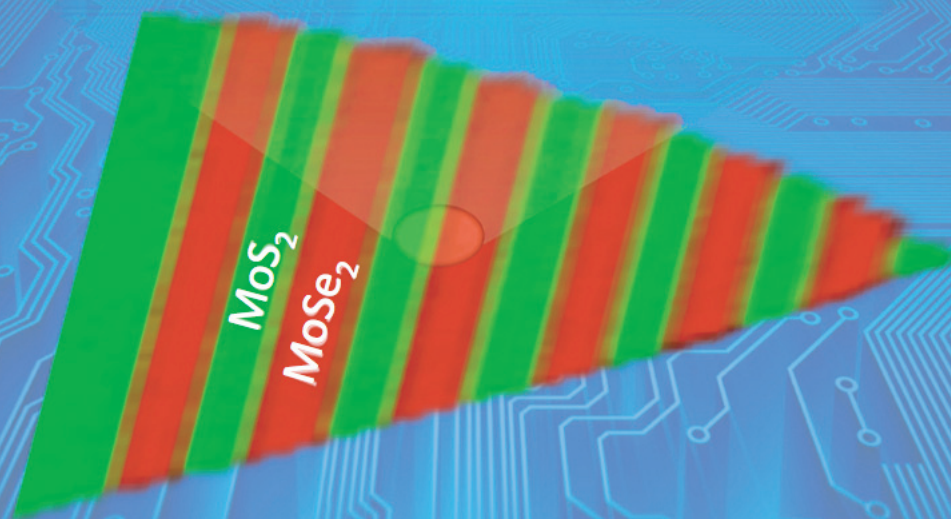
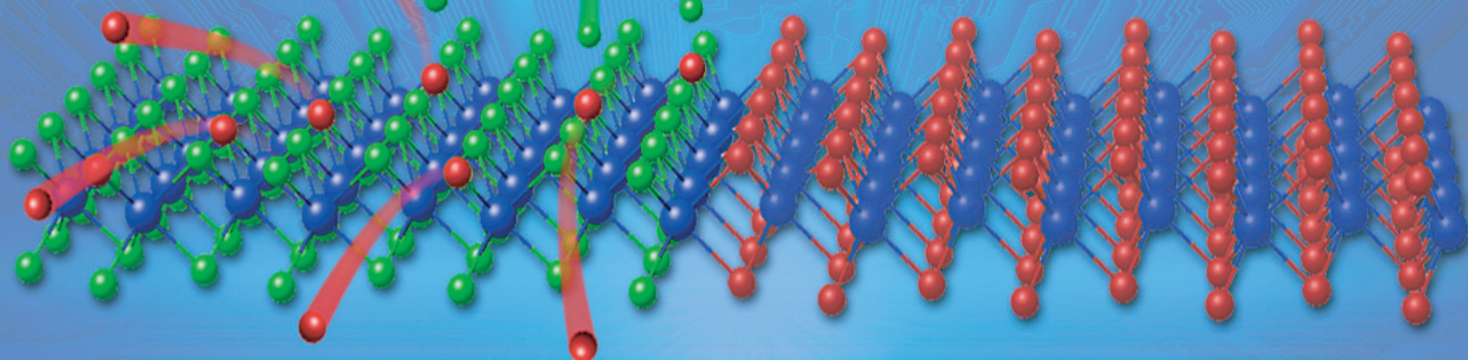
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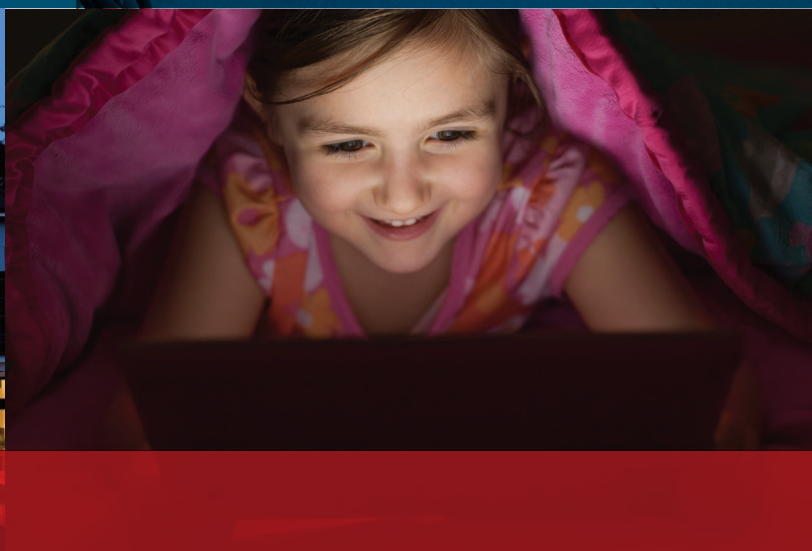
Vol. 10 • Issue 5 • June/July 2015

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Scalable heterojunction arrays in 2D monolayers



Cree acquires SiC firm APEI • IQE and Cardiff establish JV
Leti & EVG launch NIL program • CEC to buy Bridgelux



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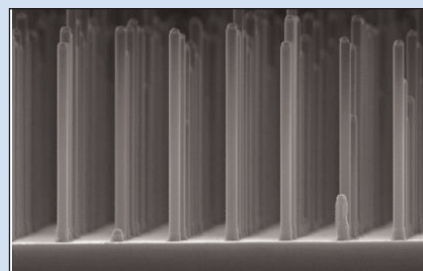
Veeco's New TurboDisc EPIK700 GaN MOCVD System

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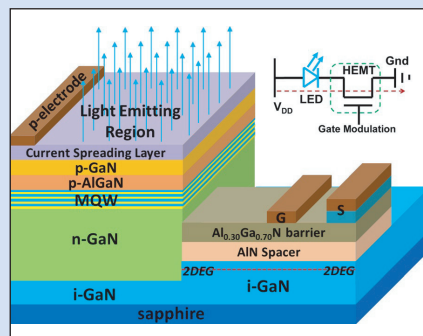
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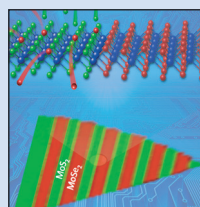
p41 EVG ramps nanoimprint lithography into high-volume manufacturing with HERCULES NIL track system.



p66 GaP nanowires boost solar fuel cell efficiency tenfold while using 10,000 times less material.



p86 Schematic of HEMT-LED device and (inset) equivalent circuit diagram.



Cover: The USA's Oak Ridge National Laboratory ORNL has fabricated scalable arrays of heterojunctions within nanometer-thick 2D crystalline monolayers. E-beam lithography and pulsed laser vaporization selectively converts MoSe_2 into MoS_2 . Other materials and structures are also to be explored. **p18**

Growing photonic integration

Too late to be included in the news pages but just before this issue closes comes news that, as part of US president Obama's National Network for Manufacturing Innovation (NNMI), the US Department of Defense's \$110m investment to establish the country's first Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) has been awarded to the consortium led by the Research Foundation for the State University of New York (SUNY, which had been in competition with two other finalists the University of Central Florida and the University of Southern California). The SUNY-led consortium involves 20 universities and laboratories (e.g. University of California Santa Barbara) plus 55 industrial partners including epiwafer foundry IQE and many of the USA's key chip makers and users such as Intel, IBM, HP and TI as well as Infinera (which makes optical communications network equipment based on its own indium phosphide-based photonic integrated circuits (see next issue for full details).

Also too late for this issue's news pages, citing "considerable growth over the last 2 years" in the InP market driven by fiber-to-the-home (FTTH) network deployments worldwide, substrate maker AXT has acquired fellow Silicon Valley-based InP substrate maker Crystacomm, whose LEC-based growth technology (having been a leading developer of 6" diameter InP) will complement AXT's VGF growth technology at its facilities in China (see www.semiconductor-today.com/news_items/2015/jul/axt_300715.shtml). In addition, on page 31 in a trading update for first-half 2015, epiwafer foundry and substrate maker IQE says that its photonics business is seeing strong and sustainable revenue growth driven by a wide array of end-markets including data centres and optical communication.


In the meantime, on pages 56–60 of this issue we report news from the Laser World of Photonics 2015 event, which saw many product launches and demonstrations of products for industrial applications. This coincides with JDSU spinning off its Communications and Commercial Optical Products (CCOP) business as the separate public company Lumentum as of the beginning of August.

Also, on pages 76–79 we report research on lasers emitting at about 3µm for mid-infrared spectroscopy applications, and on pages 80–82 we report on research to improve optical confinement in gallium nitride (GaN)-based 450nm blue lasers, targeting not only projector and data storage applications but possibly ultimately general lighting applications. In addition, on pages 84–85 we cover research that has boosted power output from GaN LEDs by growing layers of carbon nanotubes to create a patterned sapphire substrate before deposition of the nitride LED epilayers.

The adoption of GaN LEDs for general lighting applications is highlighted by market research firm IHS, which forecasts that LED lamps are growing from 30% of total global lamp revenue to 67% in 2022 (see page 6). Such growth is contributing to a total market for GaN-based devices that Transparency Market Research reckons is rising at a compound annual growth rate of over 15%. LEDs comprise 82.5% by volume and 68% by value of the GaN device market. However, the rest comprises the burgeoning RF and power device sectors (as highlighted by LED maker Cree registering in May for an initial public offering of its Power and RF subsidiary (which will be bolstered by Cree just acquiring SiC power module firm APEI (page 20),

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

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

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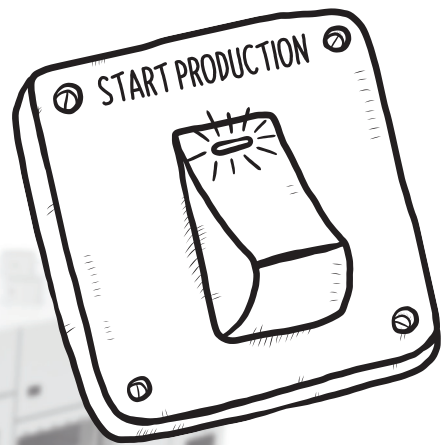
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Large lighting makers continue to transition to LEDs LED lamps to grow from 30% of lamp revenue in 2014 to 67% in 2022

As a proportion of total global lamp revenue, LED lamp revenue grew from 25% in 2013 to 30% in 2014 and is forecast to reach 67% in 2022 as the lighting market continues to transition to LED technology, according to a research note from Fabian Hoelzenbein, market analyst for Lighting & LEDs at market research firm IHS Technology.

A growing market for LED technology lighting means a shrinking market for halogen, compact fluorescent lamp (CFL) and other traditional technologies, and the larger lighting companies have struggled to adapt their businesses accordingly. At the same time, smaller and more specialized LED-only companies have entered the market, further increasing the pressure on the incumbent players, notes IHS.

Market leader Philips managed to increase its share in the LED lamp market, from 14% in 2013 to 17%

in 2014. Runners-up Osram, Panasonic and Toshiba roughly maintained their market shares of 8%, 6% and 6%, respectively, while GE increased from 3% in 2013 to 6% in 2014. Hefty losses in the traditional technology lamp market, however, meant that all top-five lamp manufacturers lost market share overall.

The luminaire market is a lot more fragmented than the lamp market. Philips is the worldwide market leader, with 6% of the market, and the top 10 manufacturers combined comprise just 22% of the market. Overall though, the luminaire market looks a bit brighter than the lamp market, at least for the top players. The top five companies — Philips, Acuity, Panasonic, Zumtobel and Cooper — all held on to their respective market shares in 2014. However, the pull of LED technology is also felt in the luminaire market.

LED luminaire revenue market share grew from 21% in 2013 to 23% in 2014, and is expected to reach 53% in 2022. IHS says that the big winner is Philips, whose LED luminaire market share increased from 4% in 2013 to 10% in 2014. Acuity Brands, which is focused on the American market, saw its share increase from 4% in 2013 to 6% in 2014. Acuity Brands holds 19% of the overall LED luminaire market (up from 16% in 2013). Philips is more concentrated, with 12% of the European, Middle East & Africa (EMEA) market and 10% of the Asia-Pacific (APAC) market.

It remains to be seen how leading lighting manufacturers will follow the market as it moves towards LEDs, says IHS. However, a strong focus on the luminaire market seems to help ease this transition ... at least for the moment, the firm concludes.

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LED grow-light market rising at nearly 27% CAGR to \$1.9bn by 2020

The light-emitting diode (LED) grow-light market will rise at a compound annual growth rate (CAGR) of 26.93% from 2015 to more than \$1.9bn by 2020, according to the report 'LED Grow Light Market by Wattage, Type of Installation (New, Retrofit), Spectrum (Partial, Full), Application (Indoor Farming, Commercial Greenhouse, Vertical Farming, Turf & Landscaping, Research, and Others), and Geography — Forecast to 2020' from the firm MarketsandMarkets.

The LED grow-light market is expected to witness a high-growth phase in applications such as vertical farming, commercial greenhouse, and indoor farming. LED

grow-lights were used initially for indoor farming, but with increasing awareness about their benefits (such as energy efficiency, no need for a ballast, and low heat emission) large-scale adoption has begun in vertical farming and commercial greenhouse applications. Also, the rising trend for indoor farming, government regulations favoring LED lighting, and the requirement for energy-efficient and long-lasting lighting technology as a supplement to natural lighting in plant growth, are all driving growth in the LED grow-light market.

Europe is estimated to account for the major share of the market, whereas the Asia-Pacific (APAC) region is expected to see the

fastest growth and overtake North America.

The new opportunities will not only drive the LED grow-light market in the coming years but will also lead to the opening up new market segments, forecasts the report.

The major players in the market are listed as Alta LED Corp (USA), Bridgelux Inc (USA), Cree Inc (USA), Everlight Electronics Co Ltd (Taiwan), General Electric Company (USA), Heliospectra AB (Sweden), Illumitex Inc (USA), Lumigrow Inc (USA), Osram Licht AG (Germany), and Royal Philips Electronics N.V. (The Netherlands).

www.marketsandmarkets.com/Market-Reports/led-grow-light-market-237907331.html

Infrared component market to grow from \$1.3bn in 2014 to \$1.5bn in 2020

Over the past 10 years, visible LEDs have been adopted widely in many different applications, as prices have fallen and new technologies have been developed to make full use of them. The infrared LED market is now also experiencing a similar increase, states a research note by Mike Hornung of the technology team at market research firm IHS Inc.

The market for infrared ambient light and proximity sensors was expected to continue growing very quickly in the near future. However, it is now expected to slow down significantly, as the market for sensors in tablets and smartphones begins to saturate. Nevertheless, the market for infrared components is still expected to grow from \$1.3bn in 2014 to \$1.5bn in 2020.

So where is this growth coming from? The answer lies in the market for infrared LEDs, photodiodes, and phototransistors, notes IHS.

Infrared LEDs have in the past been used in a variety of applications, mostly in remote controls for

consumer goods. But over the past few years there has been a huge increase in the popularity of consumer do-it-yourself (DIY) security cameras. Each of these has a number of rings of IR LEDs to provide night-vision capabilities so that, in each camera sold, there could be anywhere from 10 to 50 IR LEDs. Their gain in popularity has had a major impact on the market in China, where most of these cameras are manufactured, says IHS.

Despite gains in security cameras, the real growth potential lies in the automotive market, reckons the firm. Over the past 10 years, many leading automotive manufacturers have increased the number of sensors and 'smart' capabilities into their vehicles. Many newer technologies — such as rain, light and tunnel sensors — now come standard on many vehicles. Other applications of IR devices in cars include proximity, parking, lane detection and driver drowsiness sensors. The IR LED market is therefore growing

strongly in the automotive sector, with a compound annual growth rate (CAGR) of 11% forecast from 2014 to 2020.

Also, in automotive applications, each IR LED might be paired with a number of photodiodes or phototransistors to act as sensors. The success of the IR LED market is hence inherently linked to the success of the photodiodes and phototransistor market.

Over the next six years, with the emergence of more smart technologies and the focus of many consumers on safety and security, the market for IR LEDs, photodiodes and phototransistors can only increase, reckons IHS. However, the market for visible LEDs is over 10 times the size of the market for IR LEDs. So, whatever happens to the IR LED market, the effects on the wider optoelectronics industry will still be dictated by the behavior of the visible LED market, concludes the market research firm.

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LED lighting to reach 32% of office lamp revenue in 2015 LED lamps to comprise \$1.2bn of \$3.5bn total market

LED lighting is forecast to reach 32% of total lamp revenue in office lighting in 2015, according to the latest projection by market research firm IHS Inc. Global revenue for office lamps is projected to be \$3.5bn, of which \$1.2bn is expected to be LED. The remainder is mostly fluorescent lighting.

LED lighting is gaining popularity in high-end installations in developed countries. Also, lighting designers are increasingly eschewing fluorescent lighting in their projects, in favor of LEDs.

The key factors used to make decisions about office lighting installations are the following: upfront cost, running cost (i.e. electricity cost) and the ease and frequency of maintenance. LED

lighting does well in most of these categories. However, one notable exception is the initial installation cost, which is higher than other technologies. In office lighting projects installed in 2014, maintenance accounted for 18% of project cost, compared with 51% for equipment, 25% for installation, and 6% for design and engineering.

Increasing use of LED lighting is only part of the story, as the lighting industry is also a shifting toward smart lighting. Smart-lighting solutions are only used in a small number of offices globally, but there are many different types of systems available. According to one US-based lighting designer, "occupancy and vacancy sensing is essential and, depending on where

you are in the country, also daylight sensing". Smart lighting is most commonly introduced to meet legislative requirements to save energy. Where such regulations do not exist, its penetration rate is currently still very low, comments IHS.

Technology challenges also exist in office lighting, but none are insurmountable, says the market research firm. One of the biggest issues today is dimming, with a wide variety of control standards available. Until organizations have a more coherent collaboration, the market will remain inhibited, IHS reckons. It would be beneficial to the industry to improve this in the next few years, it concludes.

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GaN devices market growing at CAGR of 15.1%

The global gallium nitride (GaN) industrial devices market is rising at a compound annual growth rate (CAGR) of 15.1% from \$481.8m in 2014 to \$1315m in 2021, forecasts Transparency Market Research. By volume, the market is expected to grow at a CAGR of 17.5% from 1099.6 million units in 2014 to 3427.2 million units by 2021.

The report divides the GaN industrial devices market by type into two segments: power devices and optoelectronics. By revenue, optoelectronics was the largest contributor in 2014, accounting for 78% of the overall market, driven by the widespread implementation of these devices in light-emitting diodes and laser diodes.

By application, the report classifies the GaN industrial devices market

into three sub-segments: RF, LEDs and power devices.

The LED segment was the largest contributor, both in terms of value and volume in 2014, accounting for market shares of 68% and 82.5%, respectively, due to the extensive usage of GaN-based LED devices in traffic signal lamps, vehicle lamps and liquid-crystal displays (LCDs) among others. Moreover, there have been two major developments in GaN-based LEDs: GaN-based devices on foreign substrates and LEDs based on bulk GaN substrates.

The GaN high-electron-mobility transistor (HEMT) market is divided into seven segments: WiMAX/LTE, wireless phone infrastructure base transceiver station (BTS), CATV, V-SAT, satellite, defense, and others. By revenue, the wireless phone

infrastructure BTS segment was the largest contributor in 2014, accounting for 26% market share. Rising adoption of GaN HEMT technology is leading to an increase in the number of base transceiver station installations, notes the report.

In terms of value, North America accounted for the largest share of the global market in 2014 in terms of revenue (31.1%), due mainly to the high penetration of GaN-based transistors into military and defense applications. The penetration of GaN industrial devices is fueled by increasing demand for LEDs in computers, laptops, mobile tablets, gaming devices and televisions, notes the report. Europe accounted for the second largest market share (28.9%).

www.transparencymarketresearch.com

Semiconductor laser market growing at 7.1% CAGR

The semiconductor laser market will rise at a compound annual growth rate (CAGR) of 7.1% from \$4.8bn in 2013 to \$7.7bn by 2020, says Transparency Market Research.

With growth in its end-application markets, the market is expected to grow significantly due to rising awareness of the advantages over conventional lasers, e.g. that they are small in size, require just milliwatts of power, and are more efficient (making them the optimum choice for the manufacturing of laser-based systems). Their compact size and low cost also makes them ideal for small electronic devices such as CD, DVDs and other optical data storage devices. Also, improving global economic conditions and the financial position of industrial and commercial users are expected to spur demand for semiconductor lasers.

By type, the market is segmented into fiber-optic lasers (FOL); vertical-cavity surface-emitting lasers (VCSEL); compact disc lasers (CDL); high-power diode lasers (HPDL); red lasers; violet lasers; green lasers; and blue lasers.

Accounting for 44.4% of revenue in 2013, fiber-optic lasers are expected to maintain their dominance, as they are replacing light-emitting diodes due to their ability to carry multiple signals over single fiber with multiple wavelengths.

High-power diode lasers are expected to grow the fastest, at a CAGR of 8.6% over 2014–2020, driven primarily by the increasing use of semiconductor lasers in fiber-laser pumping (to meet demands for high power and high brightness with reduced manufacturing cost). Rising demand for high-power diode lasers used in material processing, defense, solid-state laser pumping and consumer electronics manufacturing is also expected to boost demand for high-power diode lasers (with particularly huge potential in industrial and material processing applications, it is reckoned).

Emerging technologies such as green, blue and violet lasers should gain market share steadily through continuous development in output power and brightness. In particular,

blue and green lasers are replacing red lasers in optical storage, consumer electronics manufacturing and printing applications.

Applications of semiconductor lasers include optical storage devices, lithography, healthcare, defense and R&D, sensors, displays, printing, communications and industrial machinery manufacturing.

Accounting for 32.2% of revenue (commonly used in transmission and amplifying devices), the largest application segment is communications (including optical fiber communications, telecoms, free-space communications, underwater communications and satellites).

By region, the Asia-Pacific is both the largest and fastest-growing (from 37.5% of revenue in 2013), driven mainly by the communications sector in major countries such as China, India, South Korea, Japan, and Australia. Europe and North America are expected to see steady growth throughout 2014–2020, due to improving economic conditions in these regions' major countries.

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Skyworks' quarterly revenue rises a more-than-expected 38% year-on-year to \$810m

Integrated mobile systems revenue grows 120% as power amplifiers fall to 24% of revenue

For its fiscal third-quarter 2015 (ended 3 July), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has reported revenue of \$810m, up 6.3% on \$762.1m last quarter and up 38% on \$587m a year ago (and exceeding guidance of \$800m).

Compared with last quarter, power amplifiers have fallen from 31% to 24% of revenue, while broad markets have risen slightly again from 22% to 23%, and integrated mobile systems have risen from 47% to 53%. Integrated mobile systems was again the fastest-growing sector, up 120% year-on-year, highlighting the shift to higher-margin system solutions (ongoing across the firm's customer base). The broad market products category again grew over 20% during the quarter (well ahead of the diversified analog market), fueled by the spread of connectivity through a broad range of end-markets.

"As the world becomes more interconnected, we are capitalizing on powerful secular growth trends, including the rising adoption of streaming media services, the proliferation of connectivity in emerging markets, and the Internet of Things — all of which are driving growth well in excess of the broader semiconductor market," says chairman & CEO David J. Aldrich.

"The common thread across all of these market trends is the need for seamless access to content and the ability to transmit large amounts of data to the cloud, efficiently, reliability, anytime and anywhere," notes Aldrich. "Technology leaders like Google, like Facebook, Amazon, Netflix and others all recognize this and are prioritizing mobility with their corporate strategies... These market dynamics translate into much more complex architectures and higher-performance speci-

cations, providing an opportunity for Skyworks to offer differentiated solutions with high barriers to entry. We accomplished this by leveraging our combination of core technology expertise, integration capabilities and systems leadership," he adds.

"Our solutions have become mission critical within the overall value chain, facilitating deeper strategic relationships with our customers, a more defensible business model with enhanced financial returns," continues Aldrich.

On a non-GAAP basis, gross margin has risen further, from 45.4% a year ago and 46.7% last quarter to 49% (exceeding guidance of 48%), driven by gains from accretive new product launches, enhancements in the filter business, and improved operational efficiencies.

Operating expenses have risen again, from \$97m last quarter to \$101.3m (higher than the expected \$99.5m), driven by R&D expenses rising from \$63m to \$65.1m and selling, general & administrative (SG&A) expenses rising from \$34m to \$36.2m.

Despite this, operating income rose further, from \$179.1m a year ago (operating margin of 30.5%) and \$258.9m last quarter (margin of 34%) to \$295.4m (margin of 36.5%). Likewise, net income has risen again, from \$160.8m a year ago (\$0.83 of diluted earnings per share) and \$224.6m last quarter (\$1.15 per diluted share) to \$262.5m (\$1.34 per diluted share, \$0.06 better than the guidance of \$1.28 per diluted share).

Cash flow generated from operations has rebounded from \$155m last quarter to \$222m. After doubling last quarter, capital expenditure rose from \$84m to \$108m. Despite distributing \$72m to shareholders through dividend and stock repurchase activity, cash and cash equivalents rose during the quarter from

just over \$1bn to over \$1.1bn (with no debt).

As announced on 18 June, Skyworks' board of directors declared a cash dividend of \$0.26 per share of common stock, payable on 27 August to stockholders of record at the close of business on 6 August (doubling the quarterly dividend from \$0.13 per share).

"Looking ahead, we see tremendous opportunity to leverage our capabilities across a broadening set of markets and applications," says Aldrich.

Design wins in fiscal Q3/2015 highlight success in capturing new high-value system-level opportunities. Recent broad market wins include ZigBee analog front-end solutions within Home Depot's smart lighting platform; multiple analog designs with its extended automotive telematics line-up, supporting Subaru's 2016 models (complementing prior telematics wins at Ford and at Audi); and a customized system-in-a-package including processor and all supporting analog content across Google's refreshed smart-home portfolio. Skyworks has also won analog ICs within Gemalto's machine-to-machine modules (supporting industrial and transportation verticals) and secured over \$14 of new content in a femtocell design alongside a leading system-on-chip (SoC) partner.

In the mobile sector, Skyworks delivered a complete system portfolio (comprising a suite of six devices, including a transmit chain, an antenna tuning and switching functions) to support Huawei's Honor smartphone platform. The firm also expanded participation in Xiaomi's smartphone portfolio (adding antenna switch and connectivity modules for LTE models targeting India). In addition, it ramped a carrier-aggregation-enabled version of the SkyOne Mini, ►

▶ along with diversity modules in ZTE's quad-core Star-II LTE mobile platform. Skyworks also enabled Meizu's 4G LTE smartphone portfolio with SkyLiTE solutions supporting Mediatek's latest-generation octa-core chipset.

"These design wins illustrate the diverse pipeline of rich content opportunities that we are servicing today," comments Aldrich. "They highlight our competitive edge in applications that require complex systems capabilities," he adds. "We are successfully leveraging our systems portfolio to strengthen our competitive position," says executive VP & chief financial officer Donald W. Palette.

For fiscal fourth-quarter 2015, Skyworks expects revenue of \$875m (up 22% year-on-year). Gross margin should be about 50% (versus 45.9% a year previously), driven by the continued adoption of integrated solutions and precision analog products, integration efficiencies and ongoing operational initiatives. Operating expenses are expected to rise again, to \$104–105m, driven primarily by incremental investments in engineering and development teams (expanding the firm's footprint within new verticals and the serviceable market opportunity, as well as further enhancing integration capabilities). Operating margin is

expected to rise to more than 38%. From this new baseline of profitability, diluted earnings per share should grow to \$1.51.

"We continue to recommend modeling 55% incremental gross margin from the new Q4 baseline, providing additional runway for margin improvement ahead," comments Palette.

"We maintain a high level of confidence in our growth trajectory through 2016 and beyond," he adds. "Having just guided over \$6 in earnings per share on an annualized basis, we continue to accelerate our progress towards our \$7 EPS target."

www.skyworksinc.com

Imec presents post-FinFET research at VLSI Symposium Nanowire FETs and quantum-well FinFETs for 7nm-and-beyond logic

At the 2015 Symposia on VLSI Technology and Circuits in Kyoto, Japan (15–19 June), nano-electronics research center Imec of Leuven, Belgium reported its latest results on nanowire field-effect transistors (FETs) and quantum-well (QW) FinFETs towards post-FinFET multi-gate device solutions.

Imec says that, as most of the industry is adopting FinFETs as the workhorse transistor for the 16nm and 14nm technology nodes, researchers worldwide are looking into the limits of FinFETs and potential device solutions for the 7nm node and beyond. Two approaches, namely silicon gate-all-around nanowire (GAA NW) FETs (which offer significantly better short-channel electrostatics) and quantum-well FinFETs with silicon germanium (SiGe), germanium (Ge) or III-V channels (which achieve high carrier mobility) are promising options.

Imec says that, for the first time, it has demonstrated integration of these novel device architectures with state-of-the-art technology modules like replacement-metal-gate high-k (RMG-HK) and self (spacer)-aligned double-patterned (SADP)

dense fin structures. By building upon existing advanced FinFET technologies, the work shows how post-FinFET devices can emerge, highlighting both new opportunities as well as complexities to overcome, it adds.

The research into advanced logic scaling is performed in cooperation with Imec's key partners in its core CMOS programs including Global Foundries, Intel, Micron, Panasonic, Samsung, SK Hynix, Sony and TSMC. Imec and its technology research partners demonstrated SiGe-channel devices with RMG-HK integration. Besides SiGe FinFETs, a unique GAA SiGe nanowire channel formation during the gate-replacement process has been demonstrated. The novel CMOS-compatible process converts fin channels to nanowires by sacrificial Si removal during the transistor gate formation, says Imec. The process may even enable future heterogeneous co-integration of fins and nanowires, as well as Si and SiGe channels. The work also demonstrates that such devices and their unique processing can lead to a drastic 2x or more improvement in reliability (NBTI, negative-bias temperature instabil-

ity) with respect to Si FinFETs, it is reckoned.

Imec also demonstrated silicon GAA-NW FETs based on silicon-on-insulator (SOI) with RMG-HK. The work compares junction-based and junction-less approaches and the role of gate work-function for multi- V_t (threshold voltage) implementations. New insights into the improved reliability (PBTI, positive-bias temperature instability) with junction-less nanowire devices have been gained, says Imec.

Extending the heterogeneous channel integration beyond Si and SiGe, Imec has demonstrated for the first time, it is claimed, strained Ge quantum-well FinFETs by a novel Si-fin replacement-fin technique integrated with SADP process. Results show that combining a disruptive approach like fin replacement with advanced modules such as SADP-fin, RMG-HK and direct-contacts can enable superior QW FinFETs, Imec says. The devices set the record for published strained Ge pMOS devices, outperforming by at least 40% in drive current at matched off-currents, it is reckoned.

www.imec.be

www.vlssymposium.org

GlobalFoundries completes IBM Microelectronics deal Foundry gains RFSOI and SiGe technologies

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with more than 160 customers and operations in Singapore, Germany and the USA) has completed its acquisition of IBM's Microelectronics business.

GlobalFoundries says that it gains differentiated technologies to enhance its product offerings in key growth markets, from mobility and Internet of Things (IoT) to Big Data and high-performance computing. The deal also strengthens its workforce, adding expertise in semiconductor development, device expertise, design, and manufacturing. Also, the addition of more than 16,000 patents and applications makes GlobalFoundries the holder of one of the world's largest semiconductor patent portfolios, the firm reckons.

"We have significantly enhanced our technology development capabilities and reinforce our long-term commitment to investing in R&D for technology leadership," says CEO Sanjay Jha. "We have added world-class technologists and differentiated technologies, such as RF and

ASIC, to meet our customers' needs," he adds.

In RF, GlobalFoundries reckons that it now has technology leadership in wireless front-end module solutions. IBM has developed capabilities in both RF silicon-on-insulator (RFSOI) and silicon-germanium (SiGe) technologies, complementing GlobalFoundries' existing mainstream technology. The firm says that it will continue to invest to deliver the next generation of its RFSOI roadmap, aiming to capture opportunities in the automotive and home markets.

In ASICs, GlobalFoundries reckons that it now also has technology leadership in wired communications, enabling it to provide the design capabilities and IP necessary to develop high-performance customized products and solutions. With increased investments, the firm plans to develop additional ASIC solutions in areas of storage, printers and networking. The most recent ASIC family, announced in January and built on GlobalFoundries' 14nm-LPP technology, has said to have been well accepted in the marketplace, with

several design wins.

Through the acquisition, GlobalFoundries increases its manufacturing scale with IBM Microelectronics' fabs in East Fishkill, NY and Essex Junction, VT. These will operate as part of the firm's growing global operations, adding capacity and engineers.

Moreover, the transaction builds on the firm's investments in the burgeoning Northeast Technology Corridor, which includes GlobalFoundries' Fab 8 facility in Saratoga County, NY and joint R&D activities at SUNY Polytechnic Institute's College of Nanoscale Science and Engineering (CNSE) in Albany, NY. The firm's presence in the northeast now exceeds 8000 direct employees.

The acquisition includes an exclusive commitment to supply IBM with advanced semiconductor processor solutions for the next 10 years. GlobalFoundries also gains direct access to IBM's continued investment in semiconductor research, solidifying its path to process geometries at 10nm and beyond.

www.globalfoundries.com

Custom MMIC names Analog Devices' veteran as VP of sales & marketing

Monolithic microwave integrated circuit (MMIC) developer Custom MMIC of Westford, MA, USA says that John Greichen has joined its leadership team as VP of sales & marketing as the firm continues to rapidly grow its standard product and design services offerings.

Greichen has over 30 years of broad technology and business experience. Most recently, he was general manager of the RF & microwave business unit at Analog Devices Inc, where he started a group in 1997 that grew into a substantial, highly profitable business for the firm. Prior roles include director of marketing at Hittite



**John Greichen, Custom MMIC's new
VP of sales & marketing.**

Microwave Corp, senior technology & management consultant at Arthur D. Little Inc, and design engineer at Raytheon Corp and Textron Corp. Greichen also has a BS in Electronics Engineering and an MBA from the University of Rhode Island.

"With his management experience and extensive knowledge of our industry, we believe John will be a tremendous asset for our team," says president & CEO Paul Blount. "John has already taken the lead with our sales and marketing strategies, as we look to expand the market presence of our highly successful standard product lines."

www.CustomMMIC.com

Analog Devices launches 2–50GHz GaAs pHEMT MMIC distributed power amplifiers

Analog Devices Inc has launched the HMC1127 and HMC1126 MMIC distributed power amplifiers, based on a GaAs pHEMT design.

Covering frequencies of 2–50GHz, the HMC1126 and HMC1127 are suitable for instrumentation, microwave radio and VSAT antennas, aerospace and defense systems, telecoms infrastructure, and fiber-optic applications.

The new power amplifier die are said to simplify system design and

improve performance by eliminating the need for RF switches between frequency bands. Each amplifier incorporates I/Os that are internally matched to 50Ω, facilitating integration into multi-chip modules (MCMs). All data is taken with the chips connected via two 0.02mm (1 mil) wire bonds measuring 0.31mm (12 mils) in length.

With a die size of 2.7mm x 1.45mm x 0.1mm and operating from a supply voltage of +5V at 80mA, the

HMC1127 has P1dB output power of 12.5dBm, Psat output power of 17.5dBm, gain of 14.5dB, and output IP3 of 23dBm.

With a die size of 2.3mm x 1.45mm x 0.1mm and operating from a supply voltage of +5V at 65mA, the HMC1126 has P1dB output power of 17.5dBm, Psat output power of 21dBm, gain of 11dB, and output IP3 of 28dBm.

www.analog.com/HMC1126

www.analog.com/HMC1127

Analog Devices announces new Fellows

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides ICs for analog and digital signal processing applications) has named senior engineers Ahmed Ali and Peter Katzin as Analog Devices Fellows, a technical position awarded to engineers who contribute significantly to the firm's business success through exceptional innovation, leadership, entrepreneurship and an ability to bridge organizations and mentor others within the company. In addition to their business impact, Analog Devices Fellows serve as company ambassadors and are recognized as industry leaders in their fields of expertise.

"Ali and Peter exemplify all the qualities of a Fellow, which represents the highest level of achievement for a technical contributor at Analog Devices," says Ray Stata, co-founder & chairman of the

board. "Ali has received 40 patents for his innovations and played an instrumental role in creating a series of industry-leading benchmarks in high-performance and high-speed converters. Peter is overseeing the development of Analog Devices' new silicon germanium product families, and has proven himself to be an exceptional innovator, mentor, and a driving force behind many technological breakthroughs."

Ahmed Ali received his BSEE and MSEE from Ain Shams University in Cairo, Egypt. He completed his PhD at the University of Pennsylvania in 1999. His experience includes high-speed converters and RF synthesizers for cellular applications, as well as serving as an adjunct professor at the University of Pennsylvania. In 2002, Ali joined Analog Devices' High-Speed Converter Group in Greensboro,

NC, where he began working on pipelined analog-to-digital converters that have helped Analog Devices set a series of industry-leading performance benchmarks.

Peter Katzin graduated from Cornell University in 1983 and joined Hittite Microwave Corp in 1987, where his efforts drove growth. After a six-year stint in Analog Devices' Communications Division supporting the first cellular and cordless telephone handset transceivers, Katzin returned to Hittite as director of engineering in 2000, taking responsibility for the development of all RF and microwave IC products. In 2004 Katzin assumed a broader technical role as chief engineer, providing leadership across circuit design, process selection and design methodology. He returned to Analog Devices upon its acquisition of Hittite in June 2014.

Custom MMIC appoints MMS Technical Sales as New England representative

Monolithic microwave integrated circuit (MMIC) developer Custom MMIC of Westford, MA, USA has appointed MMS Technical Sales Inc of Westford, MA and Rochester, NY as its new technical representative covering the New England region.

"Their extensive knowledge of the

RF and microwave customers in the New England region, built up over many years, gives them a unique understanding of the opportunities for Custom MMIC," comments Custom MMIC's president & CEO Paul Blount. "We look forward to growing our business in this region with MMS."

MMS Technical Sales was founded in 1978 and has an experienced team of high-tech professionals offering components and related technologies for the RF/microwave and wireless markets.

www.mmstechnicalsales.com

www.CustomMMIC.com

MACOM divesting Automotive business to Autoliv

Divestiture to enable higher growth rate and accelerate path to target operating model for core business

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has entered into a definitive agreement to sell its Automotive business to Autoliv ASP Inc. The Automotive business represented about 18% of MACOM's consolidated revenue in its fiscal second-quarter 2015 (ended 3 April).

The agreed consideration is \$100m in cash, subject to customary working capital and other adjustments, plus the opportunity to receive up to an additional \$30m in cash based on the achievement of revenue-based earn-out targets through 2019.

"The divestiture of our Automotive business will enable MACOM to realize its full potential as a pure-play high-performance analog company and demonstrates our confidence in achieving high growth rates in our retained core businesses," believes president & CEO John Croteau. "We anticipate our optical and laser businesses will continue to outperform, quickly contributing to consolidated MACOM earnings and cash flow consistent with our pre-divestment expectations for our business as a whole, even without the Automotive business in the portfolio," he adds.

"MACOM's operating margin has expanded to the point that the Automotive business was no longer

accretive to our operating model, and therefore not consistent with our long-term strategic vision from both a growth and profitability perspective," continues Croteau.

"This divestiture will significantly accelerate MACOM's achievement of its target operating model of 60% non-GAAP gross margin and 30% non-GAAP operating margin," he expects.

MACOM's board of directors has approved the transaction, which remains subject to anti-trust approvals and other customary closing conditions. The sale is currently expected to close in MACOM's fiscal fourth-quarter 2015.

www.autoliv.com

www.macomtech.com

Infineon receives Bosch supplier award for SiGe

77GHz automotive radar chips

At its 14th Global Supplier Award ceremony in Stuttgart, Germany, Robert Bosch GmbH has presented Dr Reinhard Ploss, CEO of Munich-based Infineon Technologies AG, with an award in the 'Innovations' category in recognition of the firm's RASIC (radar system IC) product family of silicon germanium (SiGe)-based 77GHz monolithic microwave integrated circuit (MMIC) radar chips. This is the fifth time that Infineon has been awarded as a supplier.

The Bosch Global Supplier Award recognizes outstanding performance (in quality, costs, logistics and innovations) in the manufacture and supply of products or services. In 2015, Bosch honored 58 suppliers from 11 countries, in the five categories of 'Innovations', 'Purchasing of indirect materials', 'Raw materials and components', 'Electronics and electromechanics' and 'Mechanics'.



Infineon's CEO Dr Reinhard Ploss.

and comfort," said Ploss. Radar chips in innovative packaging help to reduce system costs. This is creating new sales opportunities for Bosch and Infineon, since such cost reductions are making radar systems affordable for compact vehicles as well, says Infineon.

"We are proud to have made a key contribution to the development of driver assistance systems that offer extensive benefits in terms of safety

Already a standard feature in many premium and high-end vehicles, radar sensors measure the distance between vehicles in front of, next to and behind the vehicle they are installed in. Bosch's radar system is used for adaptive cruise control (ACC), as well as emergency braking and traffic jam assist systems. Infineon supplies the chips that transmit and receive radar signals in order to measure distances to other vehicles and objects. Infineon has integrated its radar chips in packages without affecting transmission and reception quality. Infineon is the world's second-biggest manufacturer of chips for automotive electronic systems, and the number one manufacturer in Europe. Every new vehicle built in the world currently is equipped with 55 components from Infineon on average.

www.bosch.com

www.infineon.com/rasic

TowerJazz and Anatrix develop RadHard RF ASIC; reaches flight qualification

180nm SiGe BiCMOS used in US fab; development extended to 130nm

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) and privately held Anatrix LLC of Colorado Springs, CO, USA (a provider of custom analog, RF and mixed-signal ICs for consumer electronics, wireless and radiation-tolerant markets) have developed a Radiation Hardened by Design (RHBD) RF front-end ASIC (application-specific integrated circuit) using TowerJazz's SBC18HA 0.18µm silicon germanium (SiGe) BiCMOS process through its US Aerospace & Defense business unit in its Newport Beach, CA facility. The new ASIC has produced what is claimed to be leading-edge RF phase detection with integrated controller functions, and has successfully entered flight qualification status.

Anatrix says that its proprietary RadHard by Design methodology allows its customers to achieve program radiation tolerance specifications without expensive and time-consuming overdesign, creating the optimum trade-off between total ionizing dose, single-event effects tolerance and cost.

"TowerJazz technology was critical to the success of this program; its SiGe BiCMOS process allowed

Anatrix to achieve outstanding RF performance utilizing SiGe HBT [heterojunction bipolar transistor] devices while creating a cost-effective solution for our space customer by incorporating CMOS-based analog and digital control circuitry," comments Anatrix's president Greg Pauls Ph.D.

Anatrix has an extensive silicon-verified RadHard by Design IP portfolio on TowerJazz's 180nm CMOS and SiGe processes in its Newport Beach, CA facility, and is currently extending its development into TowerJazz's 130nm processes.

"The design expertise of Pauls and his team very effectively utilizes and implements the strengths of our SiGe foundry offerings and the breadth of its features," comments Mike Scott, director – Aerospace and Defense business unit at TowerJazz. "We look forward to additional successful IP development at the 180nm node as well as our 130nm platform later in 2015."

Through its Newport Beach facility (Jazz Semiconductor), TowerJazz supplies strategic, on-shore foundry services for critical US aerospace and defense (A&D) applications serving the widest range of technologies that may be used by A&D customers for government, military, and defense requirements, including large-die ROICs (readout integrated circuits),

imagers, MEMS (micro-electro-mechanical systems) and millimetre-wave devices, among others.

TowerJazz's modular 0.18µm SiGe BiCMOS platform incorporates high-speed, standard and high-breakdown SiGe bipolar transistors (NPNs) for low noise, high switching speeds and better linearity than can be achieved with typical 0.18µm CMOS, it is claimed, for applications where those features are required. With capacity expansion and new technologies in areas such as high-speed SiGe, ROICs (7ML and 8ML), imaging and MEMS, TowerJazz says that it continues to demonstrate its ongoing commitment to its A&D customers.

"During engineering model phase testing, our customer achieved electrical performance in their system beyond what had been reached previously when using commercially available parts," says Pauls. "As a fabless company, this kind of customer feedback gives us confidence we can continue to create world-class radiation-tolerant designs through our partnership with TowerJazz," he adds.

TowerJazz exhibited at the 2015 IEEE Nuclear and Space Radiation Effects Conference (NSREC) in Boston, MA, USA (13–17 July).

www.anatrix-ic.com
www.towerjazz.com/aerospace-defense.html

WIN's revenue grows 43% in first-half 2015

WIN Semiconductors Corp (which is the world's largest pure-play gallium arsenide foundry) has reported revenue of NT\$3.1bn (US\$100.2m) for second-quarter 2015, up 10.4% on last quarter and 25.9% year-on-year, according to Taiwan's Digitimes.

Revenue was NT\$1.03bn in June (up 0.9% sequentially and 12.65% year-on-year) and NT\$5.91bn for

the first six months of 2015 (up 43.1% year-on-year). Already this year, WIN has seen its first-quarter revenue grow 3.5% sequentially, bucking seasonal trends.

WIN Semiconductors provides foundry services for GaAs components used mainly in smartphones. The firm's major clients include leading GaAs power amplifier (PA) makers Avago Technologies and

Skyworks Solutions in the USA, as well as China-based RDA Micro-electronics.

As the peak season approaches, rising demand for power amplifiers should buoy the firm's sales performance in second-half 2015, it is reckoned.

www.digitimes.com/news/a20150706PD209.html
www.winfoundry.com

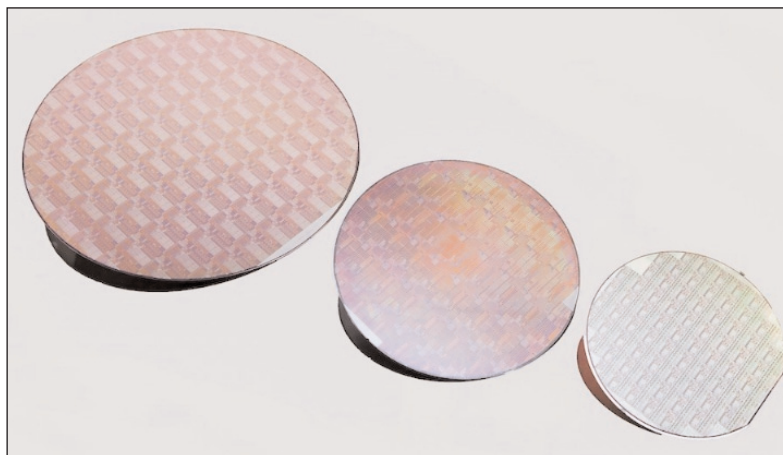
Peregrine launches first 300mm RF SOI platform

UltraCMOS 11 platform uses custom fabrication flow from GlobalFoundries' Fab 7 in Singapore

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has announced the UltraCMOS 11 platform, the first RF SOI technology built on the 130nm 300mm RF technology platform of GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries). Peregrine says that, by moving to a 300mm wafer, it opens the door to new enhancements and advanced features in future generations of its UltraCMOS technology platform, which can leverage GlobalFoundries' 300mm production-proven design enablement and manufacturing expertise and scale.

Peregrine collaborated with tier-one fab GlobalFoundries to develop the next-generation UltraCMOS 11 platform, which uses a custom fabrication flow from GlobalFoundries' Fab 7 facility in Singapore.

"As an industry first, the new RF SOI technology reaffirms our commitment to the RF market, and is



Peregrine's UltraCMOS technology platform now includes 300 mm wafers. Pictured are wafers from the UltraCMOS 11 technology platform (left), UltraCMOS 10 platform and UltraCMOS silicon on sapphire (right).

another example how GlobalFoundries' 300mm fab in Singapore can provide new levels of performance, reliability and scalability for integrated RF front-end solutions," says Brian Harrison, GlobalFoundries' senior VP of Integration and Factory Management. "We will continue to leverage our RF process development expertise and manufacturing scale to maximize the

platform will be the foundation for Peregrine's high-volume mobile products and SOI products for other applications. "By using 300mm wafers, Peregrine ensures our technology roadmap will continue to be on the leading edge of RF SOI," reckons Peregrine's CEO Jim Cable.

www.globalfoundries.com

www.psemi.com

technology's capabilities and drive differentiation," he adds.

Building on the UltraCMOS 10 technology platform (also developed and manufactured by GlobalFoundries), the UltraCMOS 11

Director of RF process technology promoted to vice president

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has promoted Alain Duvallet to vice president of RF process technology. Duvallet has been an integral part of Peregrine since March 2010, previously serving as director of RF process technology.

"In his five years with Peregrine, Alain has demonstrated his leadership abilities and technical expertise by overseeing several successful launches of UltraCMOS technology generations," says Mark Miscione, VP of RF technology solutions & quality assurance.



Alain Duvallet, Peregrine's vice president of RF process technology.

"Alain and his team's most recent accomplishment was this week's introduction of UltraCMOS 11 technology, the industry's first RF SOI 300 mm technology platform."

Duvallet will continue to lead Peregrine's technology development team and will advance the UltraCMOS technology platform to support the firm's two business units — mobile wireless and high-performance analog.

Prior to joining Peregrine, Duvallet spent 28 years with Motorola and Freescale Semiconductor. He holds engineering degrees from Ecole Supérieure d'Electricité and Ecole Polytechnique in Paris, France.

www.psemi.com

X-FAB announces 180nm SOI foundry technology for automotive applications

X-FAB Silicon Foundries AG of Erfurt, Germany — an analog/mixed-signal and micro-electro-mechanical systems (MEMS) foundry for automotive, industrial, consumer, medical and other applications — has announced what it claims is the first cost-efficient 180nm silicon-on-insulator (SOI) technology for automotive and industrial applications that need to operate in harsh environments.

X-FAB says that its new suite of 40V and 60V high-voltage devices for its XT018 180nm SOI platform outperforms bulk complementary metal-oxide semiconductor (CMOS) technologies and provides cost savings of up to 30%. The XT018 technology includes comprehensive design support, resulting in fewer design cycles and the possibility of first-time-right success, offering cost-competitive implementation of next-generation automotive solutions and leading to faster time to market, the firm reckons. The new devices make the XT018 process suitable for advanced automotive applications such as monolithic motor controllers and physical layer transceivers including integrated or stand-alone LIN/CAN (local interconnect network/controller area network) transceivers. "Requirements for automotive designs are becoming ever more challenging to fulfill — for example, the latest CAN standard and the more stringent specifications for EMC and ESD robustness. X-FAB's XT018 technology enables designers to deal with these challenges."

"Until now, SOI technologies were seen as rather exotic and very expensive solutions, but our XT018 SOI technology offsets the added cost of SOI with a smaller chip size, higher performance, and easier design," says product marketing director Volker Herbig. "Therefore it makes first-time-right success achievable."

The XT018 platform is specifically designed for next-generation automotive, industrial and medical applications with up to 200V operating voltage and an operating temperature up to 175°C. The XT018 180nm modular high-voltage SOI CMOS technology combines the benefits of SOI wafers with deep trench isolation (DTI) plus those of a state-of-the-art six-metal-layer 180nm bulk CMOS process. Using SOI wafers as the starting material, in combination with trench isolation instead of the more commonly used junction isolation techniques in CMOS, simplifies the design concept, says X-FAB. The SOI wafers eliminate the parasitic bipolar effects to substrate, reducing latch-up risk. They also enable the development of devices such as truly isolated diodes, allowing reverse supply voltage protection that is difficult to achieve with bulk CMOS or BCD technologies, adds the firm.

The centerpiece of the new offering is a low-Ron 40V NMOS transistor with on-resistance of just 26mΩ-mm². It is complemented by robust 40V and 60V electro-static discharge (ESD) enhanced devices as well as

matching PMOS and depletion transistors.

"Requirements for automotive designs are becoming ever more challenging to fulfill — for example, the latest CAN standard and the more stringent specifications for EMC (electro-magnetic compatibility) and ESD robustness," says Herbig. "XT018 technology enables designers to deal with these challenges."

The new XT018 SOI technology allows for much more compact designs compared with the conventional junction isolation scheme, says X-FAB. For example, it allows area-efficient lateral isolation in-between circuit blocks against cross-coupling for the output driver and sense inputs. The easy integration of isolated devices enables a short design cycle, making first-time-right functionality possible even for complex systems-on-chip with automotive HV (high-voltage) device requirements, the firm adds.

The enhanced XT018 foundry platform is available now, including full PDK (process design kit) support for all major electronic design automation (EDA) vendors, extensive device characterization and modelling, as well as comprehensive analog, digital and memory intellectual property (IP). Additional new devices such as depletion transistors, Zener diodes, high-performance bipolar junction transistor (BJTs) and a 200V insulated-gate bipolar transistor (IGBT) device are also ready to be used.

www.xfab.com/technology/soi/018-um-xt018

Custom MMIC appoints JS Commtech as Korean technical rep

Monolithic microwave integrated circuit (MMIC) developer Custom MMIC of Westford, MA, USA has appointed JS Commtech as its new technical representative covering Korea.

"Their extensive knowledge of the

Korean RF and microwave industry gives them a unique understanding of the opportunities for Custom MMIC," comments president & CEO Paul Blount. "We look forward to growing our business in Korea."

JS Commtech was founded in

2006 and has an established team of technical sales professionals offering components and related technologies for the RF/microwave and wireless markets.

www.jscommtech.com
www.custommmic.com

ORNL makes scalable arrays of heterojunctions within nanometer-thick 2D crystalline monolayer

E-beam lithography and pulsed laser vaporization selectively converts MoSe₂ into MoS₂; other materials and structures to be explored

The US Department of Energy's Oak Ridge National Laboratory (ORNL) has for the first time, it is claimed, combined a novel synthesis process with commercial electron-beam lithography techniques to produce arrays of semiconductor junctions in arbitrary patterns within a single, nanometer-thick semiconductor crystal (Mahjouri-Samani et al, 'Patterned Arrays of Lateral Heterojunctions within Monolayer Two-Dimensional Semiconductors', *Nature Communications* 6, 7749; doi:10.1038/ncomms8749).

The process relies on transforming patterned regions of one existing single-layer crystal into another. The researchers first grew single, nanometer-thick layers of molybdenum diselenide crystals on substrates and then deposited protective patterns of silicon oxide using standard lithography techniques. They then bombarded the exposed regions of the crystals with a laser-generated beam of sulfur atoms. These replaced the selenium atoms in the crystals to form molybdenum disulfide, which has a nearly identical crystal structure. The two semiconductor crystals formed sharp heterojunctions.

"We can literally make any kind of pattern that we want," says Masoud Mahjouri-Samani, who co-led the study with David Geohegan (head of ORNL's Nanomaterials Synthesis and Functional Assembly Group at the Center for Nanophase Materials Sciences, and the principal investigator of a Department of Energy basic science project focusing on the growth mechanisms and controlled synthesis of nanomaterials). Millions of two-dimensional (2D) building blocks with numerous patterns may be made concurrently, Mahjouri-Samani adds. In the future, it might be possible to

produce different patterns on the top and bottom of a sheet. Further complexity could be introduced by layering sheets with different patterns.

"The development of a scalable, easily implemented process to lithographically pattern and easily form lateral semiconducting heterojunctions within two-dimensional crystals fulfills a critical need for 'building blocks' to enable next-generation ultrathin devices for applications ranging from flexible consumer electronics to solar energy," says Geohegan.

Tuning the bandgap

"We chose pulsed laser deposition of sulfur because of the digital control it gives you over the flux of the material that comes to the surface," says Mahjouri-Samani. "You can basically make any kind of intermediate alloy. You can just replace, say, 20% of the selenium with sulfur, or 30%, or 50%," he adds. "Pulsed laser deposition also lets the kinetic energy of the sulfur atoms be tuned, allowing you to explore a wider range of processing conditions," notes Geohegan.

By controlling the ratio of sulfur to selenium within the crystal, the bandgap of the semiconductors can be tuned, determining the electronic and optical properties. To make optoelectronic devices such as electroluminescent displays, microchip fabricators integrate semiconductors with different bandgaps. For example, since molybdenum disulfide's bandgap is greater than molybdenum diselenide's, applying voltage to a crystal containing both causes electrons and holes (the positive charges created when electrons vacate) to move from molybdenum disulfide into molybdenum diselenide and recombine to emit light at the bandgap of molybdenum diselenide.

For that reason, engineering the bandgaps of monolayer systems can allow the generation of light with many different colors, as well as enable other applications such as transistors and sensors, Mahjouri-Samani says.

Next, the researchers will see if their pulsed laser vaporization and conversion method will work with atoms other than sulfur and selenium. "We're trying to make more complex systems in a 2D plane — integrate more ingredients, put in different building blocks — because, at the end of the day, a complete working device needs different semiconductors and metals and insulators," says Mahjouri-Samani.

To understand the process of converting 1nm-thick crystal into another, the researchers used powerful electron microscopy capabilities available at ORNL (notably atomic-resolution Z-contrast scanning transmission electron microscopy, which was developed at the lab and is now available to scientists worldwide using the Center for Nanophase Materials Sciences). Electron microscopists Andrew Lupini and visiting scientist Leonardo Basile imaged hexagonal networks of individual columns of atoms in the nanometer-thick molybdenum diselenide and molybdenum disulfide crystals. "We could directly distinguish between sulfur and selenium atoms by their intensities in the image," Lupini says. "These images and electron energy loss spectroscopy allowed the team to characterize the semiconductor heterojunction with atomic precision."

www.nature.com/ncomms/2015/150722/ncomms8749/full/ncomms8749.html
<http://cnms.ornl.gov>
<http://science.energy.gov>
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Cree acquires SiC power module firm APEI

APEI becomes Cree Fayetteville Inc

Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) and gallium nitride (GaN) power and RF products as well as LEDs, has acquired Arkansas Power Electronics International Inc (APEI) of Fayetteville, AR, USA, a provider of power modules and power electronics applications.

Cree reckons that, by combining two highly complementary firms, the acquisition enables its Power & RF business to help accelerate the market for SiC power modules, as well as strengthening the firm's position in SiC power electronics, infusing the Power & RF business with additional intellectual property and applications expertise at the systems level from APEI.

The companies' shared focus on delivering SiC power products has already led to collaboration on multiple government contracts. In 2014, the co-development of a High-Performance Silicon Carbide-based Plug-In Hybrid Electric Vehicle Battery Charger on an ARPA-E program resulted in an R&D 100 award (recognizing the 100 most innovative technology advancements of the year).

"Extending our R&D capabilities with APEI, a leader in wide-bandgap power R&D, will help us accelerate delivery of a full spectrum of SiC power modules to meet customer requirements for performance and cost," says Frank Plastina, executive VP, Cree Power and RF.

"Joining forces with the market leader in silicon carbide power gives us an opportunity to commercialize our products faster," comments APEI's president & CEO Dr Alex Lostetter. "This ideal combination of chip technology and packaging will give us first-mover advantage, helping us to set the industry standard for power modules," he reckons.

The APEI team (now Cree Fayetteville Inc) will continue to be based in Fayetteville and will operate as part of Cree's Power & RF business. The transaction is not targeted to have a material impact on Cree's fiscal 2016 earnings.

www.apei.net
www.cree.com/power

Mitsubishi Electric installs first 3.3kV, 1500A traction converter/inverter system with all-SiC power modules on high-speed train

Tokyo-based Mitsubishi Electric Corp has completed installation of, and begun testing, railcar traction converter/inverter systems with all-silicon carbide (SiC) power modules on N700 Shinkansen bullet trains for Central Japan Railway Company (JR-Central). These are the first 3.3kV, 1500A traction systems to

be installed on a high-speed train line, reckons the firm.

Mitsubishi Electric has been working to downsize its traction system for Shinkansen bullet trains. The use of SiC power modules reduces the new converter/inverter system's size and weight by about 55% and 35%, respectively, compared to

existing systems. The weight of the traction motor, including this system, is reduced by about 15%.

The power modules were developed with support from Japan's New Energy and Industrial Technology Development Organization (NEDO).

www.MitsubishiElectric.com

Mitsubishi Electric's railcar traction inverter with all-SiC power modules achieves 40% power savings

Mitsubishi Electric Corp says that its traction inverters incorporating all-silicon carbide power modules, installed in a 1000 Series urban commuter train operated by Japan's Odakyu Electric Railway Co Ltd, have been verified to achieve an approximate 40% savings in power consumption compared with a train using conventional circuitry.

The traction inverter, which is rated for 1500VDC catenaries, was

tested over a four-month period. The verification compared a car retrofitted with an all-SiC traction inverter and another car fitted with a conventional gate turn-off thyristor traction inverter, both of which were put into actual commercial service. The test measured the power consumption and electric power regeneration ratio of the two cars' main circuits, which comprise traction inverters, high-efficiency

main motors and filter reactors.

Between 17 January and 8 May, the following results (average values) were recorded: a 17% power saving during powered operation; an increase from 34.1% to 52.1% in the power regeneration ratio (calculated as power from regenerative brakes to catenaries divided by total electric power to drive the rail car); and 40% power savings overall.

Microsemi announces second \$100m stock repurchase

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems for communications, defense & security, aerospace and industrial markets) says its board of directors has authorized a new share buyback plan for the repurchase of up to \$100m of the firm's common stock.

The timing and amount of repurchase transactions will depend on market conditions and corporate and regulatory decisions, as well as completion of the existing \$100m share buyback program announced on 10 September 2014, under which the firm has purchased about \$60.5m in stock through 23 July 2015. The purchases for both programs will be

funded from working capital.

The new authorization permits the firm to repurchase up to \$100m of common stock before 31 July 2017. The program does not obligate the company to acquire any particular amount of common stock, and may be modified or suspended at any time at the company's discretion.

www.microsemi.com

NXP and Freescale shareholders approve merger

At an extraordinary general meeting of shareholders of NXP Semiconductors N.V. of Eindhoven, The Netherlands and a special general meeting of shareholders of Freescale Semiconductor Ltd of Austin, TX, USA, NXP's proposed acquisition of Freescale was approved with over 99% of the votes cast. The NXP special meeting also appointed Gregory L. Summe and Peter Smitham as non-executive directors of NXP, effective as of the closing of the merger.

"The combination of NXP and Freescale creates an industry powerhouse focused on the high-growth opportunities in the Smarter World," says NXP's CEO Rick Clemmer. "We fully expect to continue to significantly out-grow the overall market, drive world-class profitability and generate even more cash."

Completion of the merger remains subject to obtaining anti-trust and other regulatory approvals in certain jurisdictions, and other customary closing conditions. NXP and Freescale continue to expect the merger to close in second-half 2015.

In connection with the merger, NXP has filed with the US Securities and Exchange Commission (SEC) a registration statement on Form F-4 (declared effective on 1 June) that includes a definitive joint proxy statement of NXP and Freescale.

www.freescale.com

www.nxp.com

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GREAT2 GaN transmitter completes second year aboard Proba-V satellite as industrial prototypes complete testing

What is described as the first European-made device based on gallium nitride (GaN) to be sent into space has completed its second year of operations. Hosted by the European Space Agency (ESA) on its Earth-observing Proba-V mini-satellite in 2013 as a test prototype, the transmitter is currently used routinely to return mission imagery to the ground.

"The X-band transmitter in question incorporates an experimental gallium nitride (GaN) amplifier," says Andrew Barnes, overseeing ESA's work in GaN. "It is still working seamlessly today after two years in orbit, showing no drift in performance," he adds.

The GaN-based transmitter is used to downlink data to Proba-V's Kiruna ground station — in the Swedish Arctic — once per orbit for a week at a time, alternating with a second transmitter using a conventional gallium arsenide amplifier.

With its data coming down at a standard rate of 42.22Mb/s during each approximately 12 minute pass, the cubic-metre-sized Proba-V builds up a complete picture of all the Earth's vegetation cover every two days.

Access to the GaN-based transmitter also increases the operational flexibility of the satellite — in principle its data rate can be boosted to 100Mb/s, while its programmable radio-frequency output power can also be increased as needed, while operating at a lower voltage than its conventional equivalent.

GaN has been described as the most promising semiconductor since silicon, capable of operating at

much higher voltages and temperatures than comparable materials. GaN also possesses inherent resistance against the radiation encountered in space.

"In terms of communications for space, GaN offers a five- to ten-fold increase in communications power, while requiring no additional cooling systems," says Barnes. "Its promise is such that back in 2008 ESA launched the 'GaN Reliability Enhancement and Technology Transfer Initiative' (GREAT2), bringing together leading universities, research institutes and industry to develop space-compatible production processes for making GaN microwave power transistors and integrated circuits," he adds.

"With GREAT2, ESA has come in at an early stage of industrialization to ensure that the resulting products meet the demanding requirements of space use, such as resistance to shock and temperature extremes, as well as continuous operations for years at a time," continues Barnes.

The GREAT2 partners include United Monolithic Semiconductors (UMS) based in Germany and France, responsible for the industrial foundry used for manufacturing GaN products.

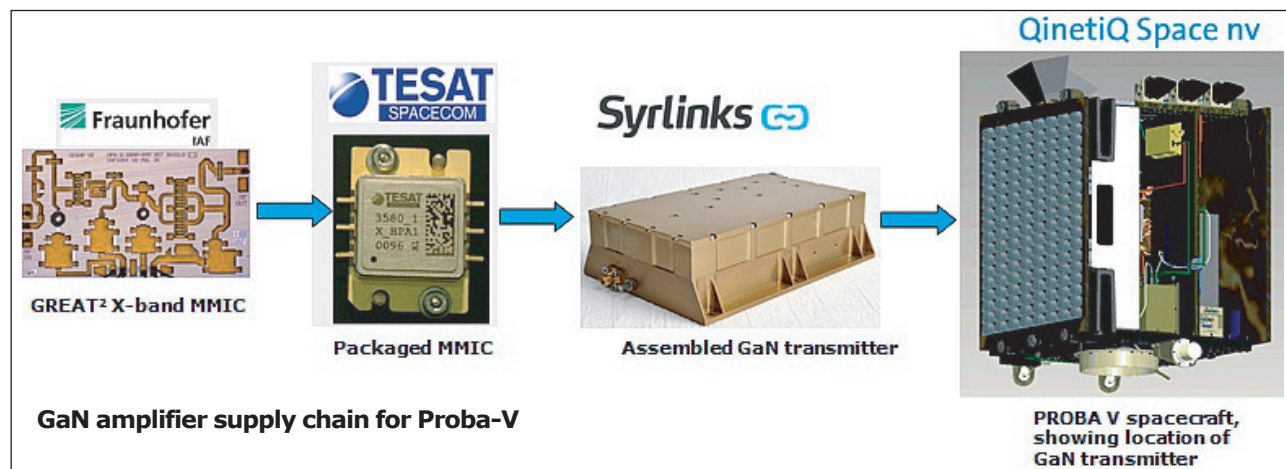
Proba-V's GaN-based X-band transmitter was an early prototype result from GREAT2, seizing a chance to have an early test of the technology in orbit. The GaN amplifier was incorporated into Proba-V's

existing communication system by Syrlinks in France. Since then, while the transmitter has been proving its worth in space, the first industrial prototypes have successfully completed their testing for reliability and robustness.

"As a result of GREAT2 we were able to place the UMS GaN manufacturing process onto the European Preferred Parts List of the European Space Components Coordination — a list of recommended parts for space missions — in 2012," says Barnes. "This was two years earlier than originally planned," he adds. "This was along with obtaining early flight heritage on Proba-V, and the two achievements together have lent confidence to other ESA projects to make use of the technology."

ESA's Biomass mission — an Earth-observing satellite to track global forest biomass — is now planning to use European GaN technology to produce mission-critical solid-state power amplifiers for its P-band synthetic aperture radar. "Work is currently ongoing to qualify high-power GaN power transistors assembled in hermetic packages for the Biomass mission," Barnes reports. "Beyond that, our long-term goal is to make space-qualified hermetically packaged GaN transistors commercially available on the open market, which would be a first for Europe."

<http://great2-project.com>



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GaN Systems appoints Kruvand as sales representative

GaN Systems Inc of Ottawa, Ontario, Canada — a fabless producer of gallium nitride (GaN)-based power switching transistors based on its proprietary Island Technology for power conversion and control applications — has appointed Texas-based engineering sales and sales firm Kruvand Associates as its representative in the US states of Texas, Oklahoma, Arkansas and Louisiana.

Specialist sales engineering and marketing company Kruvand has expertise in power, interconnect, thermal, electromechanical, RF & wireless active and passive components. GaN Systems says that, as sales of GaN power transistors ramp up and replace silicon semiconductors in power applications, Kruvand's Inside Sales and Customer Team will provide pre-sales and design services to GaN Systems'

customers and distributor partners in these important geographical areas.

"We are building a network of the very best distributors and representatives," says Julian Styles, director sales & marketing, Americas at GaN Systems. "Time to market is crucial in today's highly competitive commercial environment, and are focused on helping our customers achieve optimum results within project deadlines. Kruvand Associates is long-established and has an unrivalled reputation as a representative in the West South Central states... We anticipate a long and mutually beneficial association," he adds.

Kruvand's president & CEO Robert Logan describes GaN Systems as having the broadest power switching transistor range available, including the world's highest-current device

and the smallest packaged GaN transistor. "Our customers recognize immediately that this amount of power out of a tiny package, one quarter the size and one quarter the weight per Watt compared to silicon devices is definitely a key differentiator," he says. "We have customers in multiple markets, including power, telecommunications, medical, computing/datacomms/IT, oil and gas, energy, industrial, consumer and transportation, who are either designing in GaN right now, or looking to get on board with GaN in the very near future. Without it, they realize they may get left behind."

Kruvand's Inside Sales & Customer Service team will facilitate all inquiries and transactions from its offices in Dallas, Austin, Houston, Tulsa, Oklahoma, and El Paso.

www.gansystems.com

VisIC claims lowest-resistance 650V gallium nitride power conversion switches

VisIC Technologies Ltd of Rehovot, Israel, a fabless developer of power conversion devices based on GaN metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) founded in 2010, has unveiled what it claims is the lowest-resistance 650V blocking voltage transistor, specifying a specific on-resistance ($R_{ds(on)}$) of just 12m Ω .

Reducing unnecessary losses in electrical energy conversion has been, and continues to be, a

long-term goal for many companies producing energy conversion subsystems such as power supplies, photovoltaic inverters and electrical motor drives. These subsystems are used extensively in industrial, commercial and residential applications (robotics, elevators, washers, air conditioners, etc). Now a step-function reduction in conduction and switching losses for high-speed switching is possible due to VisIC's developments, says the firm.

Used in power conversion switches (the fundamental building block for most energy conversion subsystems), VisIC's 650V, 50A GaN transistors are targeted at the \$12bn power transistor market.

Based on a new design for GaN HEMTs, VisIC reckons that its products can accelerate the push to extend GaN-based technology from communications subsystems into power conversion subsystems.

www.visic-tech.com

VisIC launches 650V normally-off GaN power switches

VisIC has launched its first normally-off GaN power switch (sampling soon to OEMs).

The ALL-Switch (Advanced Low-Loss Switch) is expected to provide the fastest power-switching devices available among low-resistance components. Applications include photovoltaic inverters, UPS,

HEV/EV and high-voltage DC-DC conversion.

"With the combinations of our technology and the cost of GaN-on-silicon, we see ourselves able to meet our goal to deliver GaN performance to OEMs at silicon MOSFET prices," says CEO & co-founder Dr Tamara Baksht. "Deliv-

ering this promise to the very large 650V applications space will rapidly expand the use of GaN-based components, since GaN also provides the efficiency gains, cost reductions and size reductions OEMs want to deliver to their customers in systems currently using silicon IGBTs and MOSFETs."

Advantech Wireless releases second-generation GaN-based 1250W Ku-band SapphireBlu UltraLinear SSPA/SSPB for satellite broadcast teleports

Advantech Wireless Inc of Montreal, Canada (which manufactures satellite, RF equipment and microwave systems) has launched the second-generation gallium nitride (GaN)-based 1250W Ku-band SapphireBlu UltraLinear SSPA/SSPB (solid-state power amplifier/solid-state power block) for satellite broadcast teleports.

The second-generation SapphireBlu Class of UltraLinear GaN-based SSPAs and block up-converters (BUCs) is suitable for high-power, wide-frequency band uplinks. One single GaN-based SSPA offers higher performance in multi-carrier mode than several linearized traveling wave tubes (TWTs) and Klystrons, making them suitable for

large teleports and broadcast industry. The new systems can saturate all transponders of an entire satellite and obtain maximum bandwidth/power efficiency.

"These units are designed as an alternative to legacy TWTs and Klystrons in large teleports," says VP business development Cristi Damian. "By removing the need for expensive indoor filter-combining schemes, UPS [uninterruptible power system], air conditioning systems, and expensive outdoor waveguide runs, a single 1250W Ku-band second-generation GaN unit can easily replace 10 or more Klystrons or indoor TWTs," he adds. "In many cases, this allows consolidation of traffic from multiple

antennas and multiple satellites to a single antenna and a single satellite," Damian continues. "These teleport architecture changes will then result in massive OpEx cost reductions, and will free up the cash for the teleport operator. The initial cost of investment is recovered in most of the cases in just one year of electricity bill savings."

The new UltraLinear GaN-based SSPAs and BUCs are redundant-ready, with power expandable to 3kW by phase combining; high power density in a compact, rugged, weatherproof package with considerable reduction in size, weight, and energy consumption.

www.advantechwireless.com

Advantech launches DVB-S2X-ready second-generation GaN-based 400W C-band SSPA/SSPB for Ultra HD transmission

Advantech Wireless has launched a second-generation SapphireBlu gallium nitride (GaN)-based 400W C-band SSPA/SSPB (solid-state power amplifier/solid-state power block) designed for broadcasting applications. Offering very high linearity (yet no additional increase in size, weight and energy consumption) in a compact single package, the systems are designed for Ultra HD transmission broadcasting and

are DVB-S2X ready.

"We have over 20 years of experience working with broadcasters and providing cutting-edge technologies to deliver audio and visual content clearly and reliably," says VP business development Cristi Damian. "We understand the challenges that broadcasters and service providers face while adopting the new bandwidth-demanding Ultra HD standard," he adds. "The

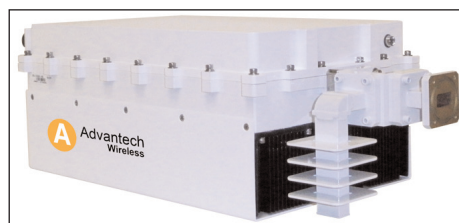
second generation of GaN SSPAs empowers broadcasters to deliver their messages while maximizing efficiency and reducing operational cost." The units are designed for very high linearity, as imposed by the heavy Ultra HD traffic, and at the same time be ready to operate under the high-density modulation schemes that are now part of the DVB-S2X standard.

www.advantechwireless.com

Advantech Wireless launches next-gen 150W Ku-band GaN-based BUC SSPA/SSPB

Advantech Wireless has launched a next-generation GaN-based 150W Ku-band solid-state power amplifier block up-converter (BUC SSPA/SSPB).

Designed in a compact weather-proof package for the next generation of high-throughput satellite constellations, the new 150W Ku-band BUC provides higher linearity with higher efficiency, says the firm.



New 150W Ku-band GaN-based BUC.

"The next generation of GaN SatCom SSPAs continues the development

roadmap introduced by Advantech Wireless back in 2010," says Cristi Damian, VP business development. "These 150W Ku-band GaN units provide an impressive 70% reduction in overall size, and 60% reduction in weight, as compared to the first-generation GaN products. At the same time, the energy efficiency is improved by an additional 25%," he reckons.

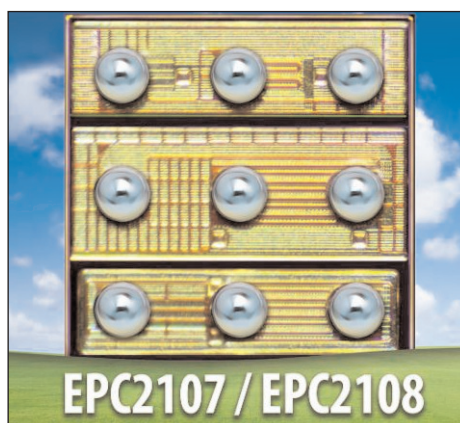
EPC launches eGaN power ICs with integrated bootstrap FET for A4WP Rezence-compliant wireless power transfer

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has launched the EPC2107 (100V) and EPC2108 (60V) eGaN monolithic half-bridge power integrated circuits with an integrated bootstrap FET, eliminating gate-driver-induced reverse recovery losses as well as the need for a high-side clamp. EPC says that this is the first time that a bootstrap FET has been integrated in an eGaN power circuit.

Designed specifically for resonant wireless power transfer applications, the new products enable rapid design of highly efficient end-user systems, setting the stage for mass adoption of wireless power transfer, it is reckoned. In addition, the GaN power integrated circuits come in small chip-scale packages, reducing the size of the overall system. Also, the new line of chips is lower in cost due to reduced overall component count (one GaN device versus three FETs).

Rezence wireless power standard

Although there are several standards for wireless power transfer, the Rezence standard of the Alliance For Wireless Power (A4WP) offers superior features and capabilities to consumer end-users, says EPC. For example, Rezence allows for spatial freedom when charging, eliminating the need for exact positioning of devices when charging. It also has an exceptional charging range, providing true 'drop and go' charging. Additionally, the A4WP standard allows charging of multiple devices with different power requirements simultaneously. Another key feature is that Rezence-compliant wireless power systems will charge devices in the presence of metallic objects such as keys, coins and utensils, making it suitable for automotive,



retail, and household applications.

In short, says EPC, Rezence provides the flexibility and capabilities to bring wireless charging to the masses, a rapidly emerging market that is expected to be a \$15.6bn industry by 2020.

EPC says that, having introduced the first eGaN FET for wireless power transfer in 2012, its gallium nitride devices play a major role in this market. In addition to designing Rezence-compliant power products, EPC has published a 'Wireless Power Handbook' dedicated to addressing wireless power system design issues such as multi-mode operation and EMI compliance.

EPC's new products and benefits

By integrating two eGaN power FETs into an integrated power circuit, the interconnect inductances and the interstitial space needed on the PCB are eliminated. Having this single integrated power component increases both efficiency (especially at higher frequencies) and power density, while reducing assembly costs to the wireless power system designer's end-product, says EPC.

The new devices come in 1.35mm x 1.35mm chip-scale package for reduced size, improved switching speed and thermal performance, leading to increased power density.

Wireless power demonstration systems

In support of the EPC2107 and EPC2108 integrated circuits (which cost \$0.89 and \$0.85 each, respectively, in 1000-unit quantities), EPC

also offers complete demonstration wireless power transfer systems, as well as development boards for the evaluation of the two new eGaN power integrated circuits.

The A4WP Class 3 (EPC9113) or A4WP Class 2 (EPC9114) wireless power demonstration systems have three components:

- ZVS Class-D Source (or amplifier) board (Rezence Class 2: EPC9510 (costing \$418.95) – included in EPC9114 kit and featuring the 100V EPC2107; Rezence Class 3: EPC9509 (costing \$418.95) – included in EPC9113 kit and featuring the 60V EPC2108);
- Class 2 or 3 Rezence-compliant source (or transmit) coil; and
- Category 3 Rezence-compliant device (or receiving) board including coil.

The EPC9113 wireless power demonstration kit is A4WP Class 3-compliant, capable of delivering up to 16W into a DC load while operating at 6.78MHz (which can be modified to operate at 13.56MHz). The EPC9114 wireless power demonstration kit is A4WP Class 2-compliant at 10W. The purpose of the demonstration kits (which both cost \$895 each) is to simplify the evaluation process of using eGaN FETs for highly efficient wireless power transfer. Both kits utilize the high-frequency switching capability of EPC's GaN transistors to facilitate high-efficiency wireless power systems.

For customers with their own coil design, the source (or amplifier) boards are also sold separately as EPC9509 (featuring the 60V EPC2108) and EPC9510 (featuring the 100V EPC2107).

All products are available from Digi-Key.

www.digikey.com/Suppliers/us/Efficient-Power-Conversion.page
<http://epc-co.com/epc/Products/eGaNfets/EPC2107>
<http://epc-co.com/epc/Products/eGaNfets/EPC2108>

EPC publishes 'Wireless Power Handbook' for designing efficient amplifier for wireless power transfer system

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has announced publication of the 'Wireless Power Handbook', designed to provide power system design engineers with experiences and points of reference critical to understanding and designing highly efficient wireless power systems using GaN-based transistors. As a supplement to EPC's 'GaN Transistors for Efficient Power Conversion', the new practical guide provides step-by-step analysis on the use of GaN transistors in wireless power transfer.

Highly resonant wireless power transfer using eGaN FETs has proven to be a viable path to efficient, convenient wireless power. The use of magnetic fields contributes ease of use and robustness, but most importantly it is considered safe. However, the implementation of this technology poses many challenges to power system designers. At the heart of highly resonant wireless power is

the amplifier, which drives the coils that generate the magnetic field. EPC says that eGaN FETs have, in part, driven the wireless power revolution by offering high efficiency and robustness to operating conditions and by being easy to use.

EPC says that the handbook addresses the many design aspects needed for a wireless power transfer system. Topics covered include how to effectively compare component devices, such as eGaN FETs and MOSFETs, when used in an amplifier design. This comparison, complete with experimental verification, illustrates the superiority of eGaN FETs over MOSFETs, EPC claims. Wireless power solutions rely on ease-of-use for consumer convenience and eGaN FET performance ensures that the requisite challenges associated with ease-of-use can be met using the simplest and most cost-effective solutions.

"Magnetic field technology may have caught up with the concept of wireless power, but the implementation poses many challenges to power system designers," says EPC's CEO Alex Lidow. "Based upon experimental results, this hand-

book shows that the ZVS Class D topology, fitted with eGaN FETs, exhibited superior performance as compared to the other amplifiers."

'Wireless Power Handbook: a Supplement to GaN Transistors for Efficient Power Conversion' is available for \$39.95 and can be purchased from EPC's distributor Digi-Key.

The author Michael DeRooij is EPC's executive director of Applications Engineering. Prior to joining EPC, he worked at Windspire Energy and the GE Global Research Center. Dr de Rooij received his Ph.D. from the Rand Afrikaans University and conducted postdoctoral studies on power electronic integration, packaging and a high-frequency MOSFET gate-driver at the Center for Power Electronic Systems (CPES) at Virginia Tech. He is a senior member of the IEEE and has authored over 25 publications, most recently co-authoring 'GaN Transistors for Efficient Power Conversion'. He has been granted 21 US and international patents and 19 US and international pending patent applications.

<http://epc-co.com/epc/Products/Publications/WirelessPowerHandbook>

EPC adds 5mΩ 150V and 7mΩ 260V eGaN FET power transistors

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has launched two eGaN FETs that have a maximum operating temperature of 150°C and maximum pulsed drain currents of 260A for the 150V EPC2033 and 140A for the 200V EPC2034, which have a typical typical on-resistance (RDS(on)) of 5mΩ and 7mΩ, respectively.

Applications include DC-DC converters, synchronous rectification in DC/DC and AC/DC converters,

motor drives, LED lighting, and industrial automation.

The products further expand EPC's family of 'Relaxed Pitch' devices featuring a 1mm ball pitch. The wider pitch allows the placement of additional and larger vias under the device to enable high current-carrying capability despite the extremely small 2.6mm x 4.6mm footprint.

To simplify the evaluation process of the eGaN FETs, the EPC9047 development board is available to support easy 'in circuit' performance evaluation of the EPC2033. In a half-bridge topology measuring 2" x 1.5", the EPC9047 con-

tains two EPC2033 eGaN FETs using the Texas Instruments UCC27611 gate driver, as well as supply and bypass capacitors. The board contains all critical components that can be easily connected into any existing converter, plus layout for optimal switching performance. There are also various probe points to facilitate simple waveform measurement and efficiency calculation.

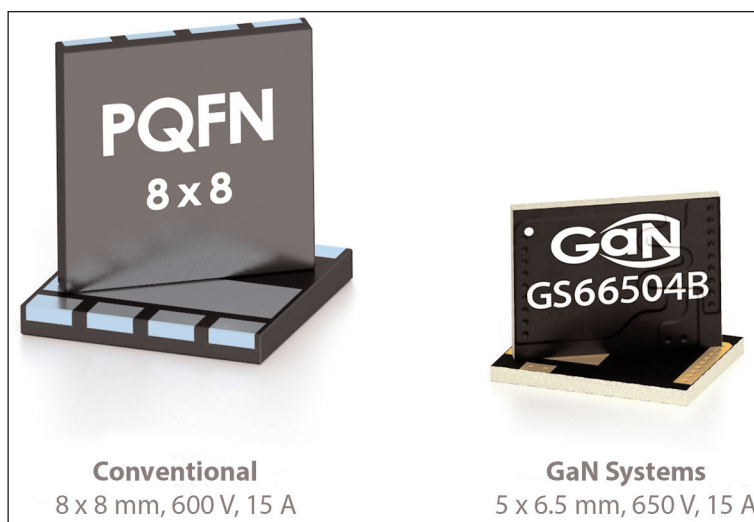
The EPC2033 and EPC2034 are priced at \$4.25 and \$4.37, respectively (in 1000-unit quantities). The EPC9047 development board is \$137.75. All are available now for delivery from Digi-Key.

GaN Systems claims smallest 650V, 15A GaN transistor

Footprint of 5.0mm x 6.5mm 50% smaller than competing devices

GaN Systems Inc in Ottawa, Ontario, Canada — a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications — is claiming that its GS66504B — one of a family of 650V devices spanning currents of 7A to 200A — is the world's smallest 650V, 15A GaN transistor, with a footprint of just 5.0mm x 6.5mm (50% smaller than competing devices). "Our message to designers in applications as diverse as flat-screen TVs, games consoles, washing machines, inverters, electric vehicles, motors and wider is the same: if you are not on-board with GaN, you will be left behind by your competitors."

"We were somewhat surprised to see announcements at last week's PCIM power electronics exhibition and conference that trumpeted gallium nitride 600V, 15A devices in 8mm x 8mm dual-flat no-lead (DFN) packaging as the 'industry's smallest' enhancement-mode devices — our part is clearly much



smaller," states CEO Jim Witham. "But I suppose this is just an indication of how quickly the GaN market is moving, and a positive indication that silicon has reached its limits," he adds.

"Our message to designers in applications as diverse as flat-screen TVs, games consoles, washing machines, inverters, electric vehicles, motors and wider is the same: if you are not on-board with GaN, you will be left behind by your

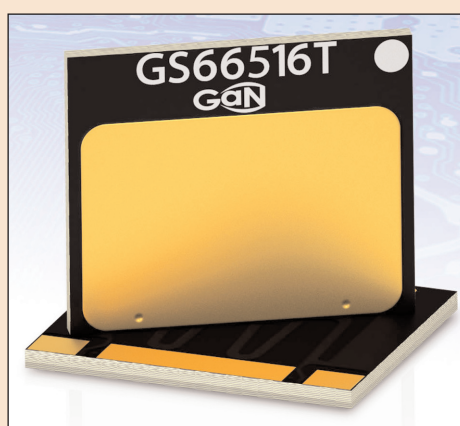
competitors," continues Witham. GaN Systems claims to be the first company to have developed and brought to the global market a comprehensive product range of devices with current ratings from 7A to 250A — its Island Technology die design, combined with its extremely low inductance and thermally efficient GaNPX packaging and Drive Assist technology means the company's GaN transistors offer a 40-fold improvement in switching and conduction performance over traditional silicon MOSFETs and IGBTs. Devices are available now through its worldwide distribution network.

www.gansystems.com

GaN Systems launches highest-current GaN power transistor

GaN Systems has launched the latest addition to its range of enhancement-mode (E-mode) GaN-on-silicon high-power transistors based on its three core proprietary technologies. The new device is claimed to have the highest current capability on the market at 60A, further expanding the firm's range of power switching semiconductors.

The GS65516T 650V E-mode high-electron-mobility transistor (E-HEMT) power switch features GaN Systems' new proprietary topside cooling configuration (announced in March), which allows it to be cooled using familiar and conventional heat-sink or fan cooling techniques. The device is based on the company's ultra-low



GaN Systems' GS65516T E-HEMT.

figure of merit (FOM) Island Technology die design, packaged in low inductance and thermally efficient GaNPX packaging, and measures 9.0mm x 7.6mm x 0.45mm.

Additional features include

reverse current capability, integral source sense and zero reverse recovery loss. Dual-gate pads help design engineers to achieve optimal board layout.

The GS65516T suits high-frequency, high-efficiency power conversion applications such as on-board battery chargers, 400V DC-DC conversion, inverters, uninterruptable power supplies (UPS) and VFD motor drives, AC-DC power supplies (PFC and primary) and VHF small form factor power adapters.

The GS65516T is available to customers packaged on tape & reel or mini-reel, through GaN Systems' worldwide distribution partners.

www.gansystems.com

Qorvo announces second edition of GaN For Dummies

Qorvo Inc of Greensboro, NC and Hillsboro, OR, USA, a provider of RF solutions for mobile, infrastructure and aerospace/defense applications, has announced a second edition of its 'GaN For Dummies' books, including updates to the originals (published in 2014). Written in conjunction with publisher John Wiley and Sons Inc, the two volumes consist of:

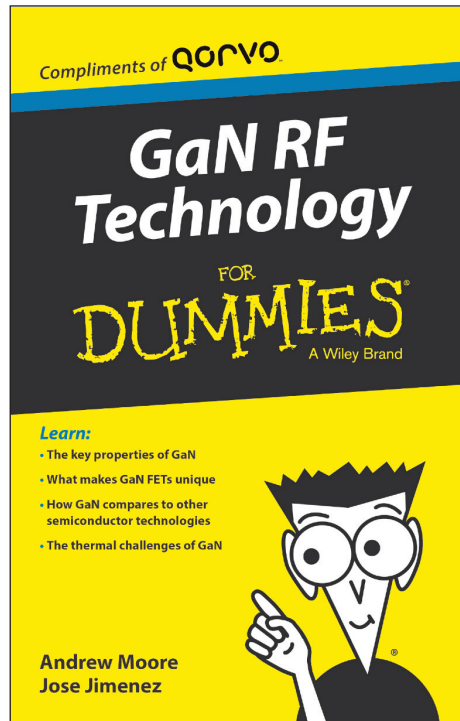
Volume 1, GaN RF Technology For Dummies, covers:

- The key properties of GaN
- What makes GaN FETs unique
- How GaN compares to other semiconductor technologies
- The thermal challenges of GaN
- Ten important facts about GaN technology.

Volume 2, RF Applications of GaN For Dummies, includes:

- How GaN benefits your system applications
- Why and when to use GaN
- Important design factors for GaN
- GaN's utility in multiple applications
- Ten keys to success using GaN.

GaN transistors were first demonstrated in the 1990s and now are



widely available for commercial and defense applications, based on the high power density and high efficiency that can be achieved. The GaN For Dummies books aim to help both technical and non-technical professionals to learn more about the basics of gallium nitride

(GaN) in radio frequency (RF) technology and how they can use GaN in RF product designs.

"GaN technology is rapidly gaining traction for base transceiver stations (BTS), cable TV (CATV) and defense systems because it can meet the exacting performance requirements those applications demand," says Dr Douglas Reep, Qorvo's senior director of research, Infrastructure and Defense Products. "GaN For Dummies provides company leadership, system engineers and designers with a short course introducing the benefits of GaN, illustrating its exceptional reliability and unique performance capabilities."

Market research firm Strategy Analytics forecasts that revenue for GaN RF devices in both military and commercial applications will increase at a compound average annual growth rate (CAAGR) of more than 20% to nearly \$560m in 2019.

Both e-book volumes are free and available for download from the GaN For Dummies web page at the following address.

www.qorvo.com/gan-for-dummies

Pasternack expands line of solid-state high-power amplifiers with GaN, GaAs and LDMOS models covering UHF, VHF, L, S and C bands

Pasternack Enterprises Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has introduced a new portfolio of solid-state high-power amplifiers (SSPAs). The coaxial packaged RF amplifiers cover UHF, VHF, L, S and C frequency bands and are widely employed in applications such as electronic warfare (EW), instrumentation, military communications, radar, SatCom, telecom, data links and medical devices.

The firm's latest release of RF amplifiers includes 22 models with output power levels greater than

10W that cover broadband frequencies from 150kHz to 7500MHz. The solid-state 50Ω hybrid microwave integrated circuit (MIC) designs use gallium nitride (GaN), gallium arsenide (GaAs) or LDMOS silicon transistor technology that offers high dynamic range and allows gain levels ranging from 40dB to 60dB. The typical gain variation of the amplifiers is ±1.5dB. Some models have a P1dB (output power at 1dB compression point) ranging from +10W to +50W, while some devices have a P_{sat} (saturated output power) ranging from +40dBm to +50dBm.

All of the high-power amplifiers in the product family have single voltage supplies that are internally regulated and the circuits are enclosed in environmentally sealed metal packages. The rugged coaxial packages withstand environmental conditions like humidity, altitude, shock and vibration, and each module is designed with stainless-steel SMA female connectors. Each solid-state high-power amplifier is classified as EAR99.

The new high-power solid-state RF amplifiers are available in-stock and ready to ship now.

www.pasternack.com

IQE and Cardiff University establish joint venture to develop and commercialize compound semiconductor technologies in Europe

JV to work with Cardiff's Institute of Compound Semiconductors

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has established a joint venture with Cardiff University to lead the development and commercialization of compound semiconductor technologies in Europe.

IQE says that establishing the JV is a key milestone towards the creation of a European CS cluster centred in Wales, which is increasingly seen as a strategic enabler for the UK and European electronics industries. Compound semiconductors are designated a Key Enabling Technology (KET) for the economic growth drivers identified in the European Commission's 'Horizon 2020' economic growth strategy, aimed at the re-industrialization of the EU.

The JV will work closely with Cardiff University's Institute of Compound Semiconductors (ICS), which itself establishes CS research, development and innovation in Wales, with over £29m of funding from the Welsh and UK governments. The ICS forms part of Cardiff University's £300m investment in new research and innovation centres.

Collectively, the ICS, the JV and IQE's existing operations in Cardiff establish the core elements of a CS ecosystem in Wales to bridge early-stage research, product development, prototyping and pilot production, through to high-volume manufacturing. This clustering also aims to enable the region to continue to attract, develop and retain talent in the CS field, including research posts, industry placements, and graduate employment. Notably, Cardiff University recently announced the appointment of professor Huffaker from University of California, Los Angeles (UCLA) as Chair in Advanced Engineering and Materials. By working closely with the Alacrity Foundation, a unique

entrepreneurs training camp, the National Software University, Cardiff University and other UK and European semiconductor companies, a complete range of KET skills development should be facilitated by the CS cluster.

The JV will be jointly owned and jointly controlled by Cardiff University and IQE. To establish the JV, IQE will contribute equipment with a market value of £12m, which will be matched by a £12m cash contribution from Cardiff University. IQE will also license certain intellectual property (IP) to the JV. The JV will be established effective from 1 August, which will create a non-cash exceptional gain of about £4.7m in IQE's accounts due to the difference between the book value and market value of the equipment contributed by IQE. Also on that date, IQE will receive and recognize revenue of £2m relating to the IP license.

Both partners see significant benefits accruing from the JV. Cardiff University will now have a route to commercialize the R&D to be carried out at the ICS, and aims to attract significant corporate and other R&D funding. IQE will be able to take the technologies developed at ICS and the JV directly into large-scale mass production.

"This JV with Cardiff University is a key step in

creating the world's first compound semiconductor cluster, spanning the complete Technology Readiness Level (TRL) scale from basic research to full-scale production," comments IQE's chief executive Dr Drew Nelson. "Our goal is to build this cluster into one of global significance and scale, leading to widespread economic benefits for the region, and providing a broad range of CS technologies to support the rapid growth of the Key Enabling Technologies agendas, in Europe and throughout the rest of the world," he adds.

"The university's mission is to be consistently among the top 100 universities in the world and the top 20 in the UK," notes professor Colin Riordan, Cardiff University vice-chancellor. "Fundamental research is essential for sustaining academic growth, and for improving the health, wealth and well-being of society. Coupling IQE's infrastructure with Cardiff's existing strengths in expanding areas of semiconductor devices and materials will create cutting-edge opportunities that will put us ahead of our competitors," he adds.

"This new company will help create commercial opportunities from the excellent compound semiconductor research work going on at Cardiff University," comments Edwina Hart, the Welsh Government's Minister for Economy and Science. "Together with the appointment through our Sêr Cymru program of professor Diana Huffaker, a world-renowned expert in the field, Cardiff is now well placed to become a hub for compound semiconductor research and exploitation."

www.cardiff.ac.uk

www.iqep.com

www.ee.ucla.edu/people/faculty/faculty-directory/diana-huffaker

This JV with Cardiff University is a key step in creating the world's first compound semiconductor cluster, spanning the complete Technology Readiness Level (TRL) scale from basic research to full-scale production

IQE's first-half 2015 revenue grows year-on-year Net debt cut further as profits grow year-on-year

In a trading update for first-half 2015, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported results in line with market expectations and ahead of the same period last year, with growth in EPS and a further reduction in borrowings.

Expected revenue is £53.2m, down 11% on £60m in second-half 2014 but up 2% on first-half 2014's £52m. Adjusted operating profit is £6.7m, up 5% on first-half 2014's £6.4m. Adjusted fully diluted earnings per share (EPS) is 0.9p, up 5% on first-half 2014's 0.86p. Net debt has been cut further, from £35.5m a year ago and £31.3m at the end of 2014 to £31.1m at the end of June 2015.

"This was a solid start to the year, in which we delivered continued improvement in our financial results and further reduced our borrowings," notes chief executive Dr Drew Nelson.

In the wireless market, key customers have continued to enjoy strong revenue growth, driven by new flagship smartphone platforms, growth in sales to China, and upgrades to 4G/LTE. This has primarily benefitted their filter businesses, but also provides a stable platform for compound semiconductor components including power amplifiers (PAs), notes IQE.

Strong sequential wireless revenue growth is expected in second-half 2015, primarily reflecting normal seasonal trends. Also, although of less consequence, some temporary production disruption suffered by one customer during second-quarter 2015 has skewed some sales into Q3. This customer-specific issue did not relate to IQE's products, and has since been resolved.

"Our wireless business is proving to be a stable platform to leverage strong and sustainable growth in our photonics business," says Nelson. The photonics business has continued to perform well, enjoying strong and sustainable revenue growth driven by a wide array of end-market drivers including data centres, optical communication, industrial heating, and a range of sensing applications.

In advanced solar, during first-half 2015 IQE began pilot production with its triple-junction technology, which is now being deployed into

Good progress continues to be made in IQE's other markets, including gallium nitride and compound semiconductor on silicon

field installations. The end customer has a pipeline of projects scheduled for deployment in 2016/17, which IQE expects to drive steady growth in demand for epiwafers.

Good progress continues to be made in IQE's other markets, including gallium nitride and compound semiconductor on silicon technologies, which are expected to transition to volume over the next 2–3 years.

"We are making encouraging progress in advanced solar and power switching, both of which we believe will be high-growth markets for IQE in the near future," summarizes Nelson.

On 9 July IQE also announced a new joint venture with Cardiff University to drive the development and commercialization of compound semiconductor technologies in Europe, and to provide an anchor for the development of a compound semiconductor cluster.

"The second half has started well, and we are on track to meet our expectations [for the full year] and deliver continued growth in profits and cash generation," concludes Nelson.

IQE will release its final first-half 2015 results on 15 September.

www.iqep.com

NI AWR software speeds Astra's MMIC component design for phased-array radars

NI (formerly AWR Corp) of El Segundo, CA, USA says that India-based RF/microwave module and sub-system maker Astra Microwave Products Ltd (AMPL) has designed an S-band gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) digital phase shifter as well as a digital attenuator for active phased-array radars using NI AWR Design Environment software.

NI says that its Microwave Office software gave the designers an advantage by speeding up the layout process, as any changes made in the layout were automatically updated in the schematic with updated simulation results, while AXIEM provided the designers with the ability to EM simulate and optimize the entire structure and avoid layout coupling.

"NI AWR software has improved the AMPL MMIC design flow and has reduced simulation times while at the same time providing better accuracy in simulation results," comment assistant manager K. Suman Reddy and engineer M. Laxmi at Astra. "It has given us an incredible advantage by speeding up the entire layout process," they add.

www.ni.com/awr

Riber's first-half revenue up 18% year-on-year to €5.7m Orders boosted by strengthening sales & marketing for research

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported an 18% rise in revenue from €4.8m in first-half 2014 to €5.7m in first-half 2015 (43% from Asia, 40% from Europe, 11% from Africa and 6% from North America).

MBE Systems sales picked up again, doubling from just two research systems in first-half 2014 to four (with total MBE Systems revenue rising by 32% from €2.1m to €2.8m).

Sales of services & accessories (€2.1m) and cells & sources (€0.8m) collectively are up 7% overall compared with first-half 2014. Individually, services & accessories revenue fell by 10% from €2.3m to €2.1m, while cells & sources doubled from €0.4m to €0.8m.

Sales also reflect the first contribution by MBE Control Solutions of Santa Barbara, CA, USA (acquired in March), which provides MBE sys-

tem maintenance and refurbishment services.

Orders have fallen by 15% from €8m in first-half 2014 to €6.3m in first-half 2015. Specifically, MBE Systems orders have fallen by 19%, from €5.5m to €4.5m (comprising four MBE systems, including one production machine for Asia). Orders for services & accessories have fallen by 48% from €2.1m to €1.1m (which includes €0.3m from MBE Control Solutions). However, orders for cells & sources have risen by 83% from €0.4m to €0.7m (including prototype equipment for the OLED market).

Regarding OLED flat-screen markets, in line with its development plan, Riber has delivered part of the linear cells to equip a pilot line in Korea and has launched initial on-site qualification tests.

Despite orders falling from first-quarter 2015 (€4.5m), Riber says that a recovery in its order book from Q2's low is supported by a new research MBE system sold in July to an academic customer in France.

Also, faced with a sluggish industrial market, during second-quarter 2015 Riber further strengthened its sales & marketing operations for the research market.

"Order levels are building back up again, and we are rolling out major sales and marketing efforts to accelerate this momentum, which is reflected in a growing pipeline of potential orders," says Frédéric Goutard, chairman of the executive board. "Alongside this, in the OLED sector, we are continuing to develop our new range of cells, working closely with Korea's leading industrial firms in this business," he adds. "The full benefits of these promising developments are expected to be seen from 2016".

Riber notes that, in the context of order levels improving but belatedly, deliveries will extend into 2016, suggesting a fiscal 2015 in line with last year.

Detailed first-half earnings and the outlook for full-year 2015 will be issued on 25 September.

www.riber.com

Soitec appoints CFO to lead strategic refocusing

Soitec of Bernin, near Grenoble, France, which makes engineered substrates including SOI (silicon-on-insulator) wafers, has appointed Grégoire Duban as chief financial officer, supporting the ongoing strategic refocusing of activities on the firm's core electronics business (announced on 19 January).

Reporting to CEO Paul Boudre, Duban will also oversee the firm's restructuring. In this role, he will work closely with Thierry Tron, who has been made deputy chief financial officer after having led the management control department for four years then joining the team supervising treasury, financial consolidation and subsidiary accounting from 2009.

Duban will focus on executive

management's and the administrative affairs and finance division's plans to restructure the firm, finalize the divestment of the solar systems division's assets, cut costs and boost its financial performance. Duban, a graduate in law (Université d'Assas, Paris) and the holder of a diploma in financial analysis (from the American Institute of Banking in New York), also gained a PMD master's degree in finance from Harvard Business School (Boston). He is also a senior advisor at Grant Thornton Executive. Before joining Soitec, Duban was senior director of finance at Alvarez & Marsal France. Previously, he held CFO/CEO positions at DEKRA Automotive, Diana Ingredients, Gravograph and Sediver, after investment banking roles with

Indosuez and the Crédit Agricole group in the USA.

"Duban possesses over 18 years' experience in leading change under corporate restructuring programs at groups in the energy, digital and automotive sectors," says Boudre. "His expertise is focused on improving operating performance, implementing new business models, restructuring operations and refocusing businesses to increase the profitability of groups in transition, such as ours," he adds. "I would also like to express my gratitude to Olivier Brice, who is leaving his position as chief financial officer to move on to new responsibilities, after supporting Soitec in recent years with tremendous professionalism and outstanding commitment."

www.soitec.com

II-VI Advanced Materials demos first 200mm SiC wafer Development builds on AFRL-funded scale-up of APVT crystal growth

II-VI Inc of Saxonburg, PA, USA says that the Advanced Materials Division of its Performance Products Segment in Pine Brook, NJ, which supplies single-crystal silicon carbide (SiC) substrates and CVD-grown polycrystalline diamond materials, exhibited what is said to be the first 200mm-diameter silicon carbide wafer at the 2015 Compound Semiconductor Manufacturing Technology (CS MANTECH) conference in Scottsdale, AZ, USA (18–21 May) and the International SiC Power Electronics Applications Workshop (ISiCPEAW 2015) in Stockholm, Sweden (27–28 May).

"This achievement is a direct result of our consistent focus on providing the market with leading-edge quality substrates at the diameters required to enable more cost-effective semiconductor device manufacturing," says II-VI Advanced Materials' general man-

ager Dr Thomas Anderson. "The earlier introduction of our 150mm-diameter SiC substrates was extremely well received by our customers, and significant growth in the demand reflects market recognition of the improved economics of SiC device manufacturing at increased diameters," he adds.

"Devices built on these substrates will be or are currently being utilized in a wide range of applications requiring high power density and system efficiency, such as electric vehicles, inverters for PV solar energy and other renewable energy installations."

The development program builds on years of work funded, in part, by the US Air Force Research Laboratory (AFRL), which focused on the manufacturing scale-up of II-VI's Advanced Physical Vapor Transport (APVT) SiC crystal growth technology as well as the development of

fabrication, polishing and cleaning processes. These efforts have resulted in the achievement of quality material while at the same time increasing the diameter from 3" to 100mm, then to 150mm and now to the first 200mm SiC substrates.

"This 200mm SiC wafer demonstrates our market-leading crystal growth and fabrication technologies, as well as our commitment to respond to and work with our customers to ensure a smooth transition to the next generation of substrates," says Dr Andrew Souzis, director of business development. "We are dedicated to pushing the boundaries of SiC substrate technology to ensure that the market has the material it needs to make high-performance SiC-based devices both cost effective and widely utilized," he adds.

www.iiviadvmat.com

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TÜV expands EHS certification services to III-Vs

Focus is on OSHA and EMC testing

At SEMICON West 2015 in San Francisco, CA, USA (13–16 July), independent full-service testing, inspection and certification company TÜV Rheinland announced the expansion of its services to include environmental, health & safety testing and certification of group III-V compounds in semiconductor manufacturing environments.

Assessing hazardous compounds

TÜV says that, because silicon transistor scaling appears to be reaching its limits under current technology, attention is turning to the group III-V compound family of materials including gallium arsenide (GaAs), aluminum arsenide (AlAs), indium arsenide (InAs), and indium gallium arsenide (InGaAs).

When arsenic, phosphide and other group III-V materials are bound or embedded in a solid wafer, they do not pose an inhalation risk. However, if evaporated during processing (such as wafer heating, etch, or laser ablation), arsine gas or arsenic compounds may be driven off the wafer and are more likely to affect people.

Arsenic-containing compounds may deposit on unprotected clothes or cleanroom garments. If they are not properly segregated, then they can migrate within the facility and even be brought home on employees' clothing.

TÜV Rheinland can test to SEMI S2 and S8 standards to assess potential health risks accompanying semiconductor manufacturing, and can certify an OEM in compliance with national standards, or can develop an action plan to help bring a facility up to standard so that there are no certification barriers to market.

In-situ EMC testing

TÜV Rheinland notes that there are situations when heavy equipment cannot be moved to an offsite lab even with its electromagnetic compatibility (EMC) testing facilities located throughout North America. For these clients, TÜV Rheinland maintains a fleet of dedicated mobile labs with specialized equipment to test at a client's location. All test equipment is brought to the customer in climate-controlled box trucks owned by TÜV Rheinland

(never a third-party shipping or trucking firm). In most instances, on-site testing takes no more than three days, from arrival to departure.

North American market

The US and Canadian governments have clearly defined regulations which products — especially electronics equipment — must satisfy before they can be approved for sale. TÜV Rheinland of North America is accredited as a Nationally Recognized Testing Laboratory (NRTL) by the USA's OSHA (The Occupational Safety and Health Administration) and by the SCC (Standards Council of Canada).

The cTUVus certification mark issued by TÜV Rheinland tells both consumers and business partners that an OEM's products have been thoroughly tested and specifically certified to comply with the electrical and fire safety regulations. With a single cTUVus mark, customers can demonstrate compliance for both the US and Canadian markets.

www.TUV.com/us

Microsanj demonstrates thermorefectance thermal imaging system with new software package

Microsanj LLC of Santa Clara, CA, USA — a supplier of high-resolution, thermorefectance imaging analysis (TIA) systems, tools and consulting services — participated in three conferences during the recent Microwave Week event in Phoenix, Arizona.

At the 2015 IEEE MTT-S International Microwave Symposium (IMS) in Phoenix (16–22 May), Microsanj demonstrated the NT220B thermorefectance thermal imaging system with the newly released SanjVIEW 3.0 software package, which offers: enhanced resolution on samples with low reflectivity; full-field and pixel-by-pixel

calibration; improved, more powerful image processing algorithms; and user-friendly applications optimized for devices such as gallium nitride (GaN) high-electron-mobility transistors (HEMTs), active load-pull monolithic microwave integrated circuits (MMICs), and nanowires.

"Continued enhancements to the Microsanj thermal imaging systems is essential for ensuring we are offering systems that meet the growing challenges for thermal analysis of devices with shrinking dimensions and increasing complexity," comments the firm's CEO Dr Mo Shakouri.

At the IEEE Radio Frequency Integrated Circuits Symposium (15–19 May), Microsanj presented the paper 'High Resolution Thermal Characterization of a GaAs MMIC'. Also, on 22 May at the 85th Automatic RF Techniques Group (ARFTG) Microwave Measurement Conference (Measurements and Techniques for 5G Applications), Microsanj presented the paper 'Transient Temperature Measurement of Microwave Devices', providing insight into how thermorefectance imaging can help to ensure optimal performance and long-term reliability for advanced device designs.

www.microsanj.com

AXT appoints former Emcore president & CEO as chief operating officer

AXT Inc of Fremont, CA, USA, which makes gallium arsenide, indium phosphide and germanium substrates and raw materials, has appointed Dr Hong Q. Hou as chief operating officer, responsible for global operations (reporting to CEO Dr Morris Young).

Among his extensive technical and executive-level experience in the compound semiconductor industry, Hou served as director, president & CEO of Emcore Corp from March 2008 to January 2015. He co-founded Emcore's photovoltaics division in 1998, and led the commercialization of high-efficiency multi-junction solar cell technology for space power applications. From 2000 to 2006, he was VP & general manager of its fiber-optics device and broadband business units respectively, growing annual



Dr Hong Q. Hou.

revenue significantly in both divisions and delivering positive financial performance. Hou was promoted to director and chief operating officer in December 2006, and subsequently president & CEO in March 2008, where he managed Emcore any through several major business challenges and adverse market conditions, and formulated and executed the firm's strategic plans. From this January to June, Hou was a venture partner at ARCH Venture Partners.

"Hong brings a wealth of technical and business experience at a time when our market is evolving and

we are increasingly serving a number of new product applications in the fiber-optics, solar and communications markets," says Young. "Hong has a demonstrated record of success in managing through significant transitions and has the vision and skills to help AXT maximize the tremendous opportunity we see in the coming years," he adds.

Hou holds a Ph.D. in Electrical Engineering from the University of California at San Diego (UCSD) and has also completed executive management courses at Stanford Business School. He conducted research at AT&T Bell Laboratories and Sandia National Laboratories early in his career, and has published more than 200 journal articles and holds eight US patents.

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Orbotech's SPTS Technologies sells Thermal Products business for \$28m to Sumitomo's SPP Technologies

50 SPTS staff to become SPP Technologies employees

SPTS Technologies Ltd of Newport, Wales, UK (which is owned by Israeli firm Orbotech) has sold its Thermal Products business to SPP Technologies Co Ltd (SPT), a subsidiary of Sumitomo Precision Products Co Ltd (SPP) that specializes in the production and support of micro-electro-mechanical systems (MEMS)- and semiconductor-related process equipment.

SPTS was formed by Sumitomo Precision Products in October 2009 (as SPP Process Technology Systems Ltd) in order to merge predecessor firm Surface Technology Systems plc (STS) together with assets acquired from Aviza Technology Inc, including Newport-based single-wafer process equipment subsidiary Aviza Technology Ltd and Aviza's Scotts Valley-based Thermal Products business (which provided spare parts, upgrades, and new or remanufactured systems to customers of Watkins Johnson, SVG, and Aviza furnaces and APCVD systems). Also, December 2010 saw completion of the transfer of ownership from SPP to SPTS of Primaxx Inc of Allentown, PA, USA, a provider of residue-free MEMS dry etch release equipment.

Subsequently, in August 2011, backed by European private equity firm Bridgepoint, a management buy-out of SPP Process Technology Systems Ltd from Sumitomo Precision Products formed SPTS Technologies Ltd. Then, in July 2014, SPTS Technologies was acquired for \$370m by Orbotech Ltd of Yavne, Israel (which makes production equipment for manufacturers of printed circuit boards, flat-panel displays and other electronic components).

With manufacturing facilities in Allentown, PA and San Jose, CA, USA, as well as in Newport, SPTS Technologies currently offers plasma etch, physical vapor deposition (PVD), chemical vapor deposition (CVD)

and thermal wafer processing solutions for the advanced packaging, MEMS, LED, high-speed RF on GaAs, and power management device markets.

The latest transaction includes the sale of all thermal product lines and virtually all worldwide assets of SPTS' Thermal Product business, and will involve about 50 SPTS employees worldwide currently engaged in the Thermal Products business (who will become SPT employees).

"Historically, the Thermal Products business has been part of SPTS's growth and success, with a range of production-proven vertical batch furnaces that continue to be the process tools of choice at leading semiconductor fabs around the world," says Kevin Crofton, president of SPTS and corporate VP at Orbotech. "Divestment at this time, however, will benefit SPTS by enabling us to focus resources on our core Advanced Packaging, MEMS, RF and Power devices businesses [served by its etch, PVD and CVD product lines]. We believe this sale will provide new opportunities for the Thermal Products business under the ownership of SPT," he adds.

"This acquisition will allow us to expand the product portfolio that we offer our customers, create a footprint in the global semiconductor capital equipment industry and establish a worldwide presence for our com-

pany," says SPT president Toshihiro Hayami. "We expect the Thermal Products business to contribute to the success of SPT and look forward to new product development activities related to this business in its current and adjacent markets."

SPT acquired the assets of the Thermal Products business based on a valuation of about \$28m, consisting of \$22m in cash plus about \$6m in accounts receivable. Half of the cash was paid on completion and the balance will be paid in 2016, without any performance conditions. Orbotech intends to use the net proceeds to repay a portion of the amount outstanding under its credit facilities. The firm adds that the sale does not materially affect expectations for its financial performance in second-half 2015 or its long-term business model.

In concert with the acquisition, SPT has established the new wholly owned company SPT USA Inc of San Jose, CA. Based in Silicon Valley, the newly acquired Thermal Product business focuses on selling newly manufactured and remanufactured systems, spare parts, service and upgrades, as well as product development. "We have been providing the leading-edge plasma etch and CVD technologies for MEMS and other markets in Japan," says Toshihiro Hayami, president of SPT and director of Sumitomo Precision Products Co Ltd. The formation of SPT USA "allows us to expand the product portfolio that we offer customers, and establishes a global presence for our company," he adds. "Utilizing synergy effects with our existing products and technologies, we are interested in investing in new product development activities related to the business in its current and adjacent markets."

www.spts.com

www.orbotech.com

www.spp.co.jp

Divestment will benefit SPTS by enabling us to focus resources on our core

Advanced Packaging, MEMS, RF and Power devices businesses...

Sale will provide new opportunities for the Thermal Products business

SPTS receives awards from BVCA

SPTS Technologies Ltd of Newport, Wales, UK (an Orbotech company that makes etch, PVD and CVD wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets) has won multiple awards at this year's seventh annual British Private Equity & Venture Capital Association (BVCA) Management Team Awards at a ceremony on 25 June in London. The BVCA Management Team Awards recognize the UK's top private equity and venture capital-backed companies.

SPTS won three Wales regional awards: Large Buyout Private Equity-backed Management Team of the Year, International Impact Management Team of the Year, and CEO of the Year (for Kevin Crofton). SPTS also received the UK National Award for Large Buyout Private Equity-backed Management Team of the Year.



"The entire company's dedication was instrumental in creating a successful and profitable global company that ultimately resulted in the successful sale to Orbotech last year," says Kevin Crofton, president of SPTS Technologies and corporate VP at Orbotech. "That transaction ensures the future success and longevity of the company, and positions us for further growth," he adds. "We are grateful for the support of our previous investors, Bridgepoint, and the BVCA judges for recognizing the growth of our global business."

www.spts.com

Speeding up R&D for GaN-epi on (WS₂, MoS₂) 2D substrates

At LayTec's in-situ Seminar at the 16th European Workshop of Metal Organic Vapour Phase Epitaxy (EWMOVPE 2015) in Lund, Sweden (7–10 June), Dr Arnab Bhattacharya of Tata Institute in Mumbai, India, reported the latest in-situ results for a completely new type of growth process: MOCVD of gallium nitride (GaN) on transition-metal dichalcogenides (WS₂, MoS₂).

The new 2D materials have a graphene-like structure and are suitable as substrates for III-nitride growth. While searching for the best growth parameters, Bhattacharya's team used LayTec's EpiTT in-situ metrology tool for real-time observation of growth rates and growth modes.

www.nano.lu.se/ewmovpe2015

www.laytec.de

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LAYTEC
Knowledge is key

ClassOne launches mid-sized, four-chamber electroplater

ClassOne Technology of Kalispell, MT, USA, which manufactures wet-chemical processing equipment (especially for cost-conscious users of small substrates in emerging markets), has added to its Solstice family of <200mm-wafer electroplaters with the fully automated, cassette-to-cassette Solstice S4, available with up to four chambers and delivering throughput of up to 75wph (wafers per hour).

ClassOne introduced the Solstice family in 2014 to provide high-performance yet cost-efficient electroplating solutions for users of <200mm wafers, in MEMS, LEDs, RF, power, sensors and other emerging markets. In footprint (68" x 82"), capacity and cost, the new S4 is positioned between the 70.25" x 40"-footprint manual-load, development-oriented Solstice LT (with one or two chambers) and the 68" x 114"-footprint fully automated, cassette-to-cassette Solstice S8 electroplater (with up to eight chambers).

"Certain users had been asking for a smaller version of our S8," says chief technology officer Kevin Witt.



ClassOne's Solstice S4 electroplater.

"Others wanted a smaller incremental step up from our LT development tool. The new S4 was a natural answer to both requests. It provides cassette-to-cassette automation but has a 28% smaller footprint than the S8. Also, S4 pricing starts at \$700,000, compared with \$1.5m for the S8," he adds.

"It's about giving customers more options," says president Byron Exarcos. "With the new Solstice S4 we're providing more ways for budget-constrained users to get exactly what they need to improve their processes," he adds.

"For some, the S4 will provide an affordable way to replace wet benches, automate production and gain significant improvements in uniformity, consistency and productivity. For others, the S4 will be a natural replacement for aging Equinox systems."

All Solstice models share the same chambers, software controls, electronics and processing results — enabling users to move easily from process development on the LT, to mid-volume production on the S4, to high-volume production automation on the S8.

All Solstice systems are priced at less than half of what similarly configured plating systems from larger manufacturers would cost, it is claimed. The tools are designed for a broad spectrum of electroplating processes using many different metals and alloys on opaque or transparent substrates. ClassOne also supports plating customers with process development, deployment and service around the globe.

www.classone.com/products
www.semiconwest.org

Thermco launching upgrade for vertical furnace systems

At the Semicon West 2015 event in San Francisco, CA, USA, Thermco Systems (a division of Tetreon Technologies Ltd of Washington, West Sussex, UK that designs and manufactures furnace systems, custom wet benches and chemical handling equipment) is launching the VTR 7000XE as a new technology platform for semiconductor vertical furnaces.

The new product enables production customers using older SVG Thermco 6000/7000 vertical furnaces to replace all of the now obsolete process, communications and automation control systems. The highly successful VTR 7000 Series product range is still used in production semiconductor fabs worldwide.



"We have listened to our production customers who want to extend the life of their existing VTRs but need modern and robust PC-based control systems and user interfaces for older vertical furnace systems," says CEO Gerry Thurgood.

"The introduction of the VTR 7000XE platform not only upgrades the process and automation controls but also provides new features such as SPC [statistical process control] equipment monitoring," he adds.

www.thermcosystems.com

Thermco Systems' new VTR 7000XE, which provides an upgrade for process, communications and automation control systems of VTR 7000 Series vertical furnaces.

Oxford Instruments' PECVD systems ordered by Chinese LED maker Enraytek

Oxford Instruments says that several PlasmaPro 800 Stratum plasma-enhanced chemical vapor deposition (PECVD) systems have been ordered by China's Enraytek Optoelectronics Co for manufacturing high-brightness LEDs. Enraytek's key products are HB-LEDs for TV backlighting and LED lighting, with manufacturing capability covering all aspects from sapphire substrate materials, epitaxial wafers, and chips for packaging and testing.

Oxford Instruments says that its large-capacity, open-loading PlasmaPro 800 PECVD systems are industry proven for HBLED processes, allowing up to 300mm wafers, and are designed to produce the high-quality and uniform dielectric films needed in LED manufacturing. The

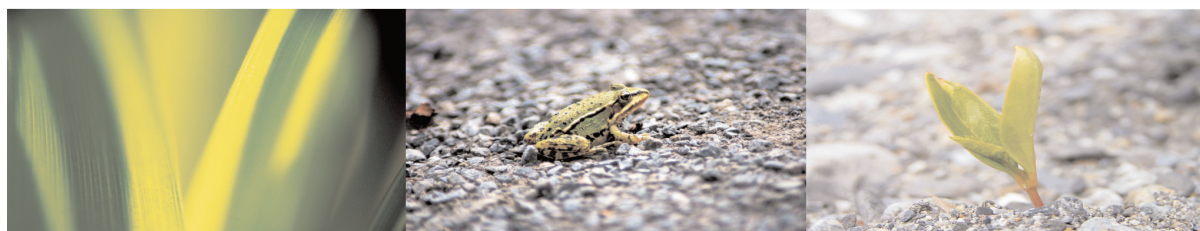


firm adds that the PlasmaPro's small footprint and substrate temperature control allows high-performance processes and precise process control, while the large electrode delivers the cost of ownership demanded by the LED industry.

"As one of China's foremost LED design and manufacturing companies, cost-efficient and state-of-the-art processing equipment is key for Enraytek," says Enraytek's vice president Xu Chunchao. "We chose Oxford Instruments systems following a rigorous selection process, as they could offer us the advanced technology, support and cost of ownership we require," he adds.

"With an already established installed base in Chinese LED companies, we back up our installations with a comprehensive ongoing customer support," notes Dr David Haynes, sales & marketing director at Oxford Instruments Plasma Technology (OIPT).

www.oxford-instruments.com/plasma



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Leti & EVG launch INSPIRE nano-imprint litho program Partnership to demo cost-of-ownership benefits for new applications

Micro/nanotechnology R&D center CEA-Leti of Grenoble, France and EV Group of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) have launched a program in nano-imprint lithography (NIL) called INSPIRE to demonstrate the benefits of versatile nano-patterning technology and spread its use for applications beyond semiconductors.

In addition to creating an industrial partnership to develop NIL process solutions, INSPIRE aims to demonstrate the technology's cost-of-ownership benefits for a wide range of application domains, such as photonics, plasmonics, lighting, photovoltaics, wafer-level optics and bio-technology.

Leti and EVG will jointly support the development of new appli-

cations from the feasibility-study stage to supporting the first manufacturing steps on EVG platforms and transferring integrated process solutions to their industrial partners, thus significantly lowering the entry barrier for adoption of NIL for manufacturing novel products.

In its effort to support high-volume manufacturing applications, in early July EVG launched the HERCULES NIL equipment platform, and the INSPIRE program's activities will complement the firm's efforts within the framework of its NILPhotonics Competence Center (launched in December 2014).

"After more than a decade of R&D activities, EVG has propelled NIL technology to a level of maturity that enables significant advantages for certain applications compared to traditional optical lithography," claims EVG's corporate technology

development & IP director Markus Wimplinger.

After launching its NIL technology-development program more than 10 years ago, Leti oriented the use of the technology mainly for photonics applications. In early 2014, the program was integrated in the Silicon Technologies Division to establish a NIL collaborative program.

"Leti and EVG have a long history of collaborating on ways to bring new technologies to market at reasonable costs for the benefits of our customers," notes Laurent Pain, patterning program manager in Leti's Silicon Technologies Division. "Through INSPIRE, we will develop new ways for them to use this flexible, powerful nano-patterning technology to create new products for a wide range of applications."

www.leti.fr

www.evgroup.com

EVG achieves third consecutive triple win in VLSIresearch customer satisfaction survey

For a third consecutive year, EV Group of St Florian, Austria has earned all three awards from VLSIresearch's annual customer satisfaction survey. EVG has again been ranked as one of the '10 BEST Focused Chip Making Equipment Suppliers', as well as one of the 2015 'BEST Suppliers of Fab Equipment', increasing its ratings in both award segments compared to last year. EVG was also distinguished with a 2015 'RANKED 1st award' in the 'Other Fab Equipment' category.

According to VLSIresearch, EVG received its highest scores in the supplier performance category, including technical leadership, recommended supplier, trust in supplier, and partnering. However, EVG says that it also scored well across the board, including in the customer service and product performance categories, where it received some of its highest marks

in quality of results, usable performance, and field engineering support. This year marks the 13th consecutive year that EVG has been listed among the 'THE BEST' suppliers, as well as the third year claiming the number one spot as the highest-ranked wafer bonder supplier.

"EVG is a master in cost-effectively bringing new technologies into different markets and enabling customers to bring their products to market cost-effectively using emerging technologies," comments VLSIresearch's CEO & chairman G. Dan Hutcheson.

"EVG's focus on exploring and commercializing new technologies, coupled with their strong focus on customer relationships and high-volume manufacturing, embodies their approach to delivering high customer satisfaction," he adds.

"This achievement reflects EVG's ongoing commitment to our

customers' success through our 'Triple I' philosophy of invent-innovate-implement," says EVG's executive sales & customer support director Hermann Waltl.

For this year's survey, VLSIresearch received feedback from more than 96% of the chip market, 82% of the subsystems market, and 32% of the solar market. Participants were asked to rate equipment suppliers among 15 categories based on three key factors: supplier performance, customer service, and product performance. A total of 3842 suppliers were rated, resulting in 57,207 total responses.

A white paper detailing EVG's survey results has been issued by VLSIresearch and is available for download from the web address below.

<https://electronics.wesrch.com/pdfEL1SE1CEETDPT>
www.EVGroup.com

EVG ramps nanoimprint lithography into high-volume manufacturing with HERCULES NIL track system

EV Group of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) has unveiled the HERCULES NIL — a fully integrated track system that combines cleaning, resist coating and baking pre-processing steps with EVG's proprietary SmartNIL large-area nanoimprint lithography (NIL) process in a single platform.

Offering what is claimed to be industry-leading productivity and throughput, the system provides a complete, dedicated UV-NIL solution suited to high-volume manufacturing (HVM) of emerging photonic devices. It does so by imprinting structures in sizes ranging from tens of nanometers up to several microns that alter or improve the optical response of surfaces and devices, such as anti-reflective layers, color and polarizer filters, light-guiding plates, and patterned sapphire substrates (PSS) used in manufacturing light-emitting diodes (LEDs). Other rapidly emerging applications for NIL include MEMS (micro-electro-mechanical systems), NEMS (nano-electro-mechanical systems), biological and nano-electronic applications.

"After more than a decade of research and continuous improvements, EVG has now propelled NIL technology to a level of maturity that enables significant advantages for certain applications compared to traditional optical lithography," says executive technology director Paul Lindner. "In addition, the Hercules NIL allows a wider array of applications, particularly in the fields of photonics and biotechnology, to finally leverage the cost-of-ownership and resolution benefits of NIL in volume production," he adds.

The Hercules NIL combines EVG's expertise in nanoimprint lithography, resist processing and high-volume manufacturing solutions into a



EVG's HERCULES NIL track system provides a complete, dedicated UV-NIL solution that is suited to high-volume manufacturing of emerging photonic devices. It combines cleaning, resist coating and baking pre-processing steps with EVG's proprietary SmartNIL large-area nanoimprint lithography process in a single platform.

single integrated system that offers throughput of 40wph (wafers per hour) for 200mm wafers. The system is built on a highly configurable and modular platform that accommodates a variety of imprint materials and structure sizes — giving users greater flexibility in addressing their manufacturing needs. The fully integrated approach also minimizes the risk of particle contamination.

Key attributes are:

- fully automated UV-NIL imprinting and low-force detachment;

EVG has now propelled NIL technology to a level of maturity that enables significant advantages for certain applications compared to traditional optical lithography

- full-area imprint coverage (avoiding pattern stitching errors associated with step-and-repeat lithography systems due to limited field size);
- volume manufacturing of structures down to 40nm and smaller;
- highest coating uniformity of $\pm 1\%$ (resulting in minimal residual layer thickness and variation for processed structures over the entire wafer);
- supports a wide range of structure sizes and shapes (including 3D);
- ability to be used on high-topography (rough) surfaces; and
- ability to fabricate multiple-use soft stamps to extend the lifetime of master imprint templates.

Available now, HERCULES NIL systems have already been installed and are being used for high-volume manufacturing at production sites of leading photonic device manufacturers, says EVG.

www.evgroup.com/en/products/lithography/nanoimprint_systems

OEM Group expands wafer surface preparation to LED processing for automotive lighting

OEM Group of Phoenix, AZ, USA (which supplies new and re-manufactured semiconductor capital equipment and upgrades focused on emerging markets) has received first-in-fab and repeat tool orders for its Cintillio wet chemical processing system from several ultra-bright (UB) LED makers in the automotive lighting sector.

With these orders, OEM Group has now expanded its production proven and patented ECO-Process wafer surface preparation solutions from the established markets of power device, CMOS IC and MEMS manufacturing into UB-LED fabrication (a new market for Cintillio). The tools will be used for ozone processing of some of the most sensitive layers exposed during LED manufacturing, including exposed silver, which to date has presented LED makers with difficult challenges where surface preparation is involved, says OEM Group.

Along with novel ozone processes optimized for exposed silver, ECO-Processes provide LED makers with significant reductions in chemical waste disposal and deionized (DI) water consumption, greatly

improving cost of ownership for wafer surface preparation, claims OEM Group. By taking the original Semitool wet chemical processing technology in this new direction, OEM Group says that it has demonstrated how it applies its focus to create sustaining solutions for emerging technologies.

Market research firm LEDInside expects continued significant growth in the automotive LED segment, particularly in daytime running lights (DRLs), high/low headlamp beams, and fog light applications, with a compound annual growth rate (CAGR) of 48% forecast from 2014 to 2018.

Also, McKinsey & Company notes in a recent report that LED adoption can be accelerated by applying best practices in manufacturing, including increased automation levels and 'lean' manufacturing methods, as OEM Group now offers with Cintillio. OEM Group says that the repeat and first-in-fab orders from major UB-LED makers in Asia and Europe reflect the confidence that its customers have in these surface preparation processes.

"It is a testament to the development work on ozone processing over sensitive layers, such as Ag, carried out by our process development group based in Coopersburg, PA, that we are seeing traction and growth in the UBLED market," says Paul Inman, business development Chemical Process Technology (CPT) at OEM Group. "This work has enabled us to provide process solutions not only for UB-LED FEOL [front-end-of-line] applications, but also throughout the entire UBLED process flow," he adds.

"The ability to reduce DI water consumption by up to 85%, and the virtual elimination of chemistry and related disposal costs, are factors leading to a marked increase in interest in the ECO-Processes, especially in areas suffering severe water shortages," notes CPT product manager Graham Pye.

Since its introduction in 2009 as a replacement for the Semitool batch processing platform, Cintillio has provided a platform for acid, ozone and solvent processing in power device, CMOS IC, MEMS and now LED applications.

www.oemgroupinc.com/cintillio.php

Monocrystal produces first 300kg Kyropoulous sapphire crystals

Using its proprietary modified Kyropoulos (KY) method, Monocrystal Inc of Stavropol, Russia, which manufactures large-diameter sapphire substrates and cores for LED, optical product and RFIC applications (as well as screen printing metallization pastes for silicon-based solar cells), has produced what is reckoned to be the world's first 300kg KY sapphire crystal.

"We are committed to helping our customers enable large-size sapphire applications in both LED and consumer electronics by growing extra-large sapphire crystals," says



Monocrystal's CEO Oleg Kachalov with 300kg Kyropoulous crystal.

CEO Oleg Kachalov. "At the same time, larger crystals will drive sap-

phire cost down and open new price-sensitive markets to us," he adds. "Our 300kg crystals put Monocrystal production scalability to a revolutionary level and are vital for broader sapphire adoption in smartphones and other handsets, where glass is still the mainstream."

Monocrystal has been developing sapphire crystal growing technology for more than 30 years, and 300kg crystal represents a milestone in expanding its capabilities in both capacity development and cost reduction.

www.monocrystal.com

OEM Group receives repeat AGHeatpulse RTP order for 150mm GaN-on-sapphire LED manufacturing

OEM Group of Phoenix, AZ, USA (which supplies new and re-manufactured semiconductor capital equipment and upgrades focused on emerging markets) says that a leading LED maker has placed a repeat order for an AGHeatpulse RTP (rapid thermal process) system, to be used for annealing gallium nitride (GaN) films deposited on 150mm sapphire substrates. OEM Group says the repeat order again validates the AGHeatpulse RTP system's demonstrated capabilities meeting the exacting thermal requirements of new LED manufacturing technologies, and supports the LED industry's move from batch processing of smaller-diameter sapphire substrates to single-wafer processing of 150mm sapphire substrates.

Currently, over 75% of all LEDs are manufactured using GaN-on-sapphire technology. The deposited GaN layer benefits from a thermal anneal process to improve the crystalline structure of the GaN layer. Traditionally, this has been done in small furnaces or manual-load RTP systems.

"LED manufacturers have begun to leverage the cost efficiencies of large-diameter substrates," comments sapphire substrate maker Rubicon Technologies. "LED manufacturers have been making progress in migrating to 6" wafers," he adds. "During the production process, the use of, say, 2" wafers, means more wasted space between wafers and more edge loss. So 6" enables a more efficient production process, resulting in a lower LED cost."

However, lingering technology challenges have created some limitations for the mass adoption of large-diameter LED substrates.

OEM Group says that, with its emphasis on developing enabling technologies for new markets, it optimized the AGHeatpulse RTP system to meet LED fabrication device performance, reliability, and product yield requirements, and to meet LED manufacturing cost targets. For the GaN anneal process, the firm's development team ported the proven capabilities of automated RTP systems from silicon device

applications to high-volume manufacturing of LEDs on 150mm sapphire substrates. The repeat order from a leading LED customer demonstrates the value of OEM Group's emphasis on development and continuous innovation, the firm adds.

Originally manufactured by AG Associates and now owned and manufactured by OEM Group, the AGHeatpulse RTP system has demonstrated proven ability to meet the technology requirements for the latest LED devices. Specific benefits of the Heatpulse system that are important for the manufacture of LEDs include:

- control and repeatability of the thermal ramp-up and steady-state temperature;
- uniform temperature across the substrate with high run-to-run repeatability;
- fully automated substrate handling using a unique susceptor auto-loader;
- advanced data-log reporting and host control capability.

www.oemgroupinc.com/agheatpulse.php

Plasma-Therm singulator plasma dicing system ordered by high-volume LED maker

An MDS-100 MicroDie Singulator plasma dicing system from Plasma-Therm LLC of St Petersburg, FL, USA has been ordered by a global high-volume LED maker.

The manufacturer produces LEDs for residential, commercial and automotive lighting, and placed the order after extensive testing and qualification, says Jim Pollock, executive VP of sales & service. "We demonstrated that plasma singulation is better, faster and very cost-effective for LED production," he says. "We anticipate more orders from this customer and from other manufacturers in the near future as market forces drive plasma dicing into the mainstream."

Advantages over sawing and laser ablation include speed, minimum street width, chip integrity, elimination of chipping and cracking, and higher die strength, says Pollock. Plasma dicing also enables dies with rounded corners and non-orthogonal shapes.

"Plasma singulation is a revolutionary development that enables greater manufacturing efficiencies," claims Thierry Lazerand, director of business development. Plasma dicing allows streets to be reduced from 90µm wide to under 10µm, which boosts die yield by 15% per wafer.

This is the third MDS-100 ordered for volume production, with a fourth ordered recently by a global sensor and imaging firm. The systems per-

form dicing of wafers up to 200mm on industry-standard tape frames. They hold up to three process modules with cassette-to-cassette material handling. They are also available with manual load-lock modules for R&D and pilot production.

Developed in partnership with On Semiconductor, Plasma-Therm's plasma singulator technology was introduced in November 2013 with the MDS-100. PlasmaTherm and On have a cross-licensing agreement for patented technology used in Singulator systems. Plasma-Therm has secured US patents for several aspects of Singulator technology. Other non-US patents are pending.

www.plasmatherm.com

SemiLEDs' operating efficiency improvements yield positive quarterly cash flow

Cost cutting and design wins to boost margins

For fiscal third-quarter 2015 (ended 31 May), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of \$3.5m, down 23% on \$4.6m both last quarter and a year ago but at the mid-point of the \$3-4m guidance range.

Revenue from LED chips grew by 47% sequentially (rebounding from a low of 11% of total revenue last quarter to 22%). Revenue from LED components fell by 36% sequentially (dropping back from the spike to 69% of total revenue last quarter to 58%) and revenue from lighting products fell by 38% sequentially (dropping back from 19% of revenue to 15%).

Gross margin has fallen back from negative 14% last quarter to nega-

tive 24%, although this is still better than negative 61% a year ago. Selling, general & administrative (SG&A) expenses have fallen by \$255,000 from \$1,876,000 last quarter to \$1,621,000, while R&D expenses have been cut by \$18,000 from \$612,000 to \$594,000. Likewise, operating margin has fallen back from negative 62% to negative 88%, although that is better than negative 138% a year ago.

On a non-GAAP basis, net loss was back up from \$2.5m (\$0.09 per diluted share) last quarter to \$2.8m (\$0.10 per diluted share).

Cash inflow from operating activities was +\$0.1m, versus cash used in operating activities of \$1.36m last quarter. "Our continuing efforts to improve operating efficiency

have resulted in a positive cash inflow from operating activities," says chairman, president & CEO Trung Doan. Capital expenditure has been cut further, from \$423,000 last quarter to \$275,000. Hence, free cash flow was negative \$0.17m, cut from negative \$1.8m last quarter. During the quarter, cash and cash equivalents fell from \$6.7m to \$6m. "As we reduce our cost and expect to secure new design wins, we look forward to further improving our cash position and margin," adds Doan. "Our focus remains on specialty, complete and high-end LED solutions."

For fiscal fourth-quarter 2015 (to end-August), SemiLEDs expects revenue to be steady at \$3.2-3.8m.

www.semileds.com

Soraa launches first 4-degree AR111 LED lamp

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched what it says is the first full-visible-spectrum 4° AR111 LED lamp. Designed to precisely light small objects and spaces, the ANSI-size-standard 6W AR111 4D LED lamp has what is claimed to be outstanding peak intensity; flawless beam definition and edges; exceptional color (a CRI of 95 and R9 of 95) and whiteness rendering; and is customizable with the firm's SNAP System.

"With low power consumption, a unique 4° beam enabled by our GaN-on-GaN LED and Point Source Optics, and VP₃ Vivid Color and VP₃ Natural White technologies, our new AR111 lamp makes precision lighting perfect," claims George Stringer, senior VP of Americas sales & marketing.

Soraa's Point Source Optics technology enables a peak intensity of 12,600Cd for the Vivid series and



Soraa's 4° AR111 LED lamp.

15,900Cd for the Brilliant series.

Soraa says that its Violet-Emission 3-Phosphor (VP₃) LED technology enhances the rendering of colors and whiteness. Utilizing every color in the rainbow, especially deep red emission, VP₃ Vivid Color renders warm tones accurately, and achieves a color rendering index (CRI) of 95 and deep red (R9) rendering of 95.

Also, unlike blue-based white LEDs without any violet emission, the VP₃ Natural White is achieved by engineering the violet emission to properly excite fluorescing brightening agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

Designed for seamless fixture integration, Soraa's AR111 LED lamp is compatible with a wide variety of industry-standard dimmers and transformers, and is suitable for use in enclosed, non-ventilated indoor and outdoor fixtures. The AR111 4D LED lamp is available in 2700K and 3000K color temperatures.

Additionally, the 4° LED lamp works with Soraa's magnetic accessory SNAP System. With a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, increasing design and display possibilities.

www.soraa.com

Plessey wins AMSCI UK grant to support transition to 8" GaN-on-Si production

Project supports work with Aixtron and Bruker to boost yield of GaN-on-silicon process

UK-based Plessey Semiconductors is to lead a £1.3m UK government-funded project in conjunction with Aixtron Ltd (the UK subsidiary of deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany) and Bruker Nano Surfaces Division (which has an office in Coventry, UK). The project will accelerate high-volume manufacturing of Plessey's LEDs created with GaN-on-silicon technology at its manufacturing site in Rotherborough, Devon.

In accordance with an announcement on 26 March from the Department for Business, Innovation and Skills, 20 supply chain projects from across the UK will benefit from a total of £67m of government investment in relation to the Advanced Manufacturing Supply Chain Initiative (AMSCI), a funding



Plessey's GaN-on-silicon wafers.

competition designed to improve the global competitiveness of UK advanced manufacturing supply chains and encourage major new suppliers to locate in the UK. In addition, £109m is being invested

in the same projects by industry. Specifically, Plessey Semiconductors is receiving a grant of £1m as part of the £1.3m project with Aixtron Ltd and Bruker Nano Services. The project should create up to 55 jobs and safeguard 2 jobs.

"This project supports the work we have ongoing with Aixtron and Bruker to further increase the yield of our GaN-on-silicon process," says Plessey's chief technology officer Dr Keith Strickland. "These improvements are required as part of our move to 200mm (8") silicon substrates," he adds. "A 200mm wafer has almost twice the usable area of our existing 150mm (6") wafers and therefore will almost double the number of LEDs produced for the same relative cost."

www.plesseysemiconductors.com/led-plessey-semiconductors.php

Seren Photonics wins UK Royal Society's Emerging Technologies award

As one of 30 finalists at the UK Royal Society of Chemistry's Emerging Technologies Competition 2015 in London on 29 June, Seren Photonics Ltd of Pencoed Technology Park, UK was awarded third place in the 'Materials' category for its innovation in semi-polar gallium nitride (GaN) templates for next-generation LEDs.

Presenters from across Europe went head-to-head to pitch their ideas for the latest healthcare, energy and sustainability, and materials technologies to panels of industry experts. The competition, which is in its third year, included small companies and academic entrepreneurs from nine countries outside the UK for the first time, including Denmark, Germany, Switzerland and The Netherlands.

Seren's technology and business strategy, presented by chief development officer Dr Bedwyr Humphreys, emphasized the benefits of semi-polar GaN in enhancing the performance of existing LEDs, enabling accelerated adoption in automotive and general lighting applications.

Spun off from the University of Sheffield in 2009 with funding from venture capital firm FusionIP plc (now part of IPGroup plc), Seren has commercialized technology developed by professor Tao Wang of the Electronic and Electrical Engineering Department and uses nano-engineered structures to enhance the properties of III-nitride materials.

"We've worked hard to identify our key markets, articulate our USPs [unique selling points] and develop

a compelling value proposition," says Humphreys. "Receiving this second award so close after winning an award at the European Venture Capital Forum in Rome really emphasises the impact this technology could have on the LED industry," he adds.

Now in its third year, the Emerging Technologies Competition aims to accelerate the commercialization of the best and most impactful ideas in healthcare, energy and sustainability, and materials. The competition is backed by multi-national partner companies such as GlaxoSmithKline, Croda, Procter & Gamble, Pfizer, AstraZeneca, GE Healthcare, Schlumberger and Lubrizol.

www.rsc.org/competitions/emerging-tech
www.serenphotonics.co.uk

Bridgelux to be bought by China Electronics Corporation

Bridgelux Inc of Livermore, CA, USA has agreed to be acquired by an investment group led by China Electronics Corporation (CEC) and ChongQing Linkong Development Investment Company.

Established in 1989, CEC is one of China's largest IT firms, controlling 61 second-level subsidiaries including 13 listed holding companies employing over 70,000 staff at manufacturing facilities in Beijing, Shanghai, Wuhan, Shenzhen, Nanjing, Changsha, and Xiamen.

Bridgelux is a manufacturer of solid-state lighting sources with over 145 staff. Last year it announced an expansion of its China operations, raising its investment and capabilities in China by opening an R&D center in Xiamen dedicated to supporting the development and manufacture of new solid-state lighting products — including extensions to its V Series chip-on-board (COB) product line — and opening an applications lab in Shanghai's Hongqiao district to assist China customers with the design and enhancement of lamps and fixtures integrating Bridgelux's LED light source products. Bridgelux's Xiamen R&D facility is co-located with China-based LED and solid-state lighting firm Kaistar Lighting (which was jointly founded by CEC and Epistar), a strategic supply chain partner

that provides outsourced contract manufacturing of LEDs to Bridgelux and invested in the firm in 2012.

In 2013, Bridgelux transferred its gallium nitride-on-silicon technology assets to Toshiba and inaugurated a new phase in their GaN-on-Si LED collaboration (including an expanded licensing and manufacturing supply relationship), while Bridgelux continued to develop and market its GaN-on-sapphire LED products as a fabless solid-state lighting company.

"Advances Bridgelux has made over the last 13 years have been instrumental in driving the adoption of energy-efficient LED technologies worldwide," comments CEC's CEO Mr Liu. "Bridgelux has all of the characteristics we look for in an investment, including leading technology, a broad IP portfolio and a globally recognizable brand and channel," he adds. "This investment is an important step toward further aligning CEC and partner assets into a coordinated supply chain built to serve the unique requirements of the solid-state lighting market."

With its existing investments in lighting fixture and lamp manufacturing as well as other IT and consumer electronics technologies, CEC's captive businesses are expected to offer Bridgelux substantial scale and growth benefits.

Also, CEC and its affiliates have built technology development and manufacturing operations across the LED supply chain. Bridgelux reckons that alignment with these partners should give it a durable, long-term cost advantage, complementing its existing technology, and will allow it to focus on segment- and application-level innovations.

"CEC is the perfect partner to help Bridgelux achieve its next level of growth," believes Bridgelux's CEO Brad Bullington. "Leveraging the momentum of our existing partnerships with CEC affiliates, complemented by a strong supply chain, world-class manufacturing, and chip, packaging and go-to-market capabilities, CEC will help Bridgelux expand its technology footprint and reach more customers globally."

Bridgelux and CEC expect the acquisition to close in September. Bridgelux will operate as a stand-alone firm under its existing management team as a US subsidiary of CEC, proceeding with its existing products and next-generation roadmap. Over time, Bridgelux expects to see the benefits of its enhanced relationship with the CEC supply chain via an expansion of its product portfolio and a greater ability to serve lighting customers with an expanded range of new technologies.

Bridgelux to spin off LED smart-lighting business Xenio

Bridgelux plans to spin off its Xenio-branded smart lighting LED platform business as new company Xenio Corp, based in San Francisco.

Xenio will develop software-enabled LED modules for the Internet of Things (IoT) market, benefitting from partnerships and investments from Bridgelux, Toshiba, DCM Ventures, VantagePoint Capital Partners and others.

The new firm, which will have independent, dedicated engineering and go-to-market teams, will be overseen by Bridgelux's CEO Brad Bullington as executive chairman,

who will leverage the leadership of Bridgelux while seeking additional expertise from the IoT and building management industries.

Having incubated some core technology assets and IP over the past two years within Bridgelux, Xenio will focus on LED module design and manufacturing to address the \$135bn lighting opportunity in the IoT market. At May's Lightfair International (LFI) in New York, Bridgelux launched its Xenio Point, Xenio Link and Xenio Power products (for shipping in volume later this year).

"Establishing Xenio as a stand-alone company is a significant acknowledgment of the unique capabilities required to serve a new set of connected lighting and data infrastructure platforms which we believe will unlock the potential of solid-state lighting technology," says Bullington. "We are creating a new company that has a strong LED heritage," he adds. "This transaction allows us to immediately focus on addressing the rapidly growing opportunity in IoT and connected devices."

www.bridgelux.com

Samsung launches chip-on-board LED packages with small LES and advanced color quality

Samsung Electronics Co Ltd of Seoul, Korea has introduced new chip-on-board (COB) LED package lineups, including small LES (light-emitting surface) COB packages, high CRI (color rendering index) COBs and vivid COBs which, due to their scaled-down light-emitting space, can provide a design alternative for LED lighting makers.

"By expanding our COB package lineup, we are providing greater value to the LED lighting market, while giving our customers much more design flexibility with which to address market needs," says Jacob Tarn, executive VP, LED Lighting business team.

Samsung has introduced three small-LES COB packages (LC010C, LC020C and LC040C) to meet demand for higher light intensity with very small form factors, plus two new lineup options to its existing LC Series (LC006B, LC008B, LC013B, LC019B, LC026B, LC033B and LC040B). The new high-intensity offerings include LC Series COB packages with a CRI over 95, as well as the Vivid COB LC Series.

Small-LES COB LED packages

Samsung LED's new LC010C, LC020C and LC040C small-LES COB packages offer 10W, 20W and 40W

options, respectively, as well as significantly reduced dimensions. In the 40W-class LC040C, the LES diameter has shrunk to 11mm from the 17mm typically specified in conventional 40W COB packages. For the LC010C and LC020C, the LES has been scaled down to 6mm from 11mm and to 8mm from 12.4mm, respectively. The LES packages are about 35% smaller than the LES in most existing COB packages, it is claimed. Moreover, they offer high light intensity and even higher center-beam candle power (CBCP) to provide a narrow-beam solution for spotlights, the firm adds.

In addition, the new small-LES COB packages (sampled in July) are fabricated using flip-chip technology that enables them to deliver high reliability with low droop, under high current and high thermal conditions. The new lineup features high luminous efficacy of 110lm/W at a correlated color temperature (CCT) of 3000K, CRI of 80+ and junction temperature of 85°C.

COB LED packages with CRI>95

Samsung's **Samsung's new COB LED packages offer high CRIs of over 95**

of over 95, adding significantly to the firm's lineup of LC Series COB packages providing CRI levels over 70, 80 and 90.

The high color-rendering packages are said to faithfully reveal the true colors of various objects, and are used mainly for commercial LED lighting, which needs to present the color of goods in their most natural state. The high-color-quality COB packages support CCT specifications of 2700–3500K.

Vivid COB packages

The new Vivid COB packages are claimed to feature much more vivid colors than virtually any commercial LED light, making objects appear as attractive as possible to the human eye. This feature is enabled by the Vivid COB packages' color spectrum tuning and phosphor controlling. The package hence helps to depict the red, blue and green coloration of objects much more clearly, the firm adds.

The ultra-high-CRI lineup is available now; the new Vivid COB packages will be first sampled in July.

Samsung showcased the new LED ranges at Guangzhou International Lighting Exhibition 2015 in China (9–12 June).

www.samsung.com

Phoseon surpasses 50,000 hours of UV LED lamp lifetime

UV LED curing firm Phoseon Technology of Hillsboro, OR, USA says that lifetime testing of its UV LED lamps has now surpassed 50,000 hours of operational on-time, with lamp irradiance being greater than 80% of its original output when the test first began more than five years ago. For perspective, based on a single-shift workweek of 2000 hours per year, 50,000 hours equates to 25 years of UV LED operating on-time.

Phoseon maintains over 50 UV LED curing lamps in various stages of lifetime testing at any given

time. These light sources are stressed with decreased air flow, high temperatures and other parameters that mimic the harsh working conditions of industrial UV LED curing equipment.

"Claims of UV LED longevity have been more than validated with these results," says VP of engineering Scott Igl. "This 50,000 hour air-cooled lamp showcases Phoseon's commitment to supplying high-performance, highly reliable light sources. The technology embedded in today's UV LED lamps is built on this foundation so customers can

be assured of many years of high-quality UV LED curing," he adds.

In addition to lifetime testing, Phoseon's reliability program consists of Highly Accelerated Lifetime Testing (HALT), Failure Modes and Effects Analysis (FMEA), and a manufacturing burn-in process where each product is built, calibrated, burned-in and recalibrated before customer delivery. The reliability and development programs are supported by over 200 world-wide patents exclusively devoted to UV LEDs.

www.phoseon.com

Lumileds boosts LUXEON CoB Core Range efficacy and flux by 10%

Lumileds of San Jose, CA, USA has launched the next-generation LUXEON CoB Core Range as it continues to roll out chip-on-board



(CoB) LEDs with higher efficacy and flux combinations. With the Gen 2 products, the LUXEON CoB Core Range now delivers an average of 10% higher efficacy and 10% higher flux with a lower voltage and the same footprint, targeting lighting designers in particular.

"We are seeing tremendous demand in the retail and hospitality markets, where our award-winning CrispWhite Technology really shines," says LUXEON CoB product family director Eric Senders.

"These applications require not just the best quality of light, but the cost effectiveness that goes with an

LED solution with up to 150lm/W efficacy," he adds.

For example, designers who implemented the LUXEON CoB 1208, which has a light-emitting surface (LES) of 15mm, are upgrading lumen output from 3600 to 4000 lumens with a 10% higher efficiency. Alternatively, if the same output is maintained, efficacy can be boosted from 115lm/W to 140lm/W with the Gen 2 LEDs.

Lumileds is offering the LUXEON CoB Core Range (Gen 2) LEDs in multiple lumen packages from less than 1000 lumens for MR16 and

PAR lamps, up to 7600 lumens for 100W CDM (ceramic discharge metal halide) replacements. Color options include the 2200K for a candlelight ambiance and very efficient 90 CRI (color rendering index) parts for high quality of light.

For ease of upgrade, the LUXEON CoB Core Range (Gen 2) products are fully compatible with Lumileds first generation of CoBs. Also, the firm's ecosystem of compatible drivers, optics and holders helps to speed the time-to-market of all directional lamps.

www.lumileds.com/LUXEONCoBCoreRange

Luminus launches ultra-high-density COBs to replace metal halide in retail spot lights

Luminus Inc of Sunnyvale, CA, USA, which makes LEDs and solid-state light sources, has launched a new family of ultra-high-density chip-on-board (COB) arrays designed to replace ceramic metal halide technology commonly used in spot lights for retail lighting.

The new XH series COBs are available in a variety of standard light-emitting surface (LES) diameters including 6mm, 9mm, 11mm and 14mm, so customers can use their existing ecosystems for optics and connectors while producing new bulbs and fixtures with higher lumen output and increased center-beam candle power (CBCP). The 9mm and 11mm XH series COBs deliver the lumen output and quality of light to replace 39W and 70W metal halide sources, respectively,

says the firm. As well as having a small form factor, the 6mm XH series generates 1500 lumens with a correlated color temperature (CCT) of 3000K and a color rendering index (CRI) of 80. When combined with a 85mm-diameter optic, it throws an 8° beam with a CBCP of over 30,000Cd.

"The high lumen density of our XH series is enabling our customers to replace metal halide by taking advantage of our high quality of light and shaping the beam into narrow spots with high CBCP while still maintaining small form factors in their bulb and luminaire designs," says product marketing director David Davito. "This results in more attractive retail displays where spot lights with more 'punch' will draw the consumers' eyes to

targeted garments and merchandise, while also reducing energy bills," he adds.

The XH series is available in a wide range of popular CCT and CRI combinations, including the 95-CRI minimum AccuWhite and below-black-body Sensus options (launched last year), which have been adopted in premium retail applications worldwide, says the firm. As with all Luminus COB products, the XH series is 100% specified and tested at 85°C to guarantee hot performance in the application.

Luminus exhibited the XH series and other new illumination light sources at the LightFair International 2015 event in New York City (5-7 May).

www.luminus.com

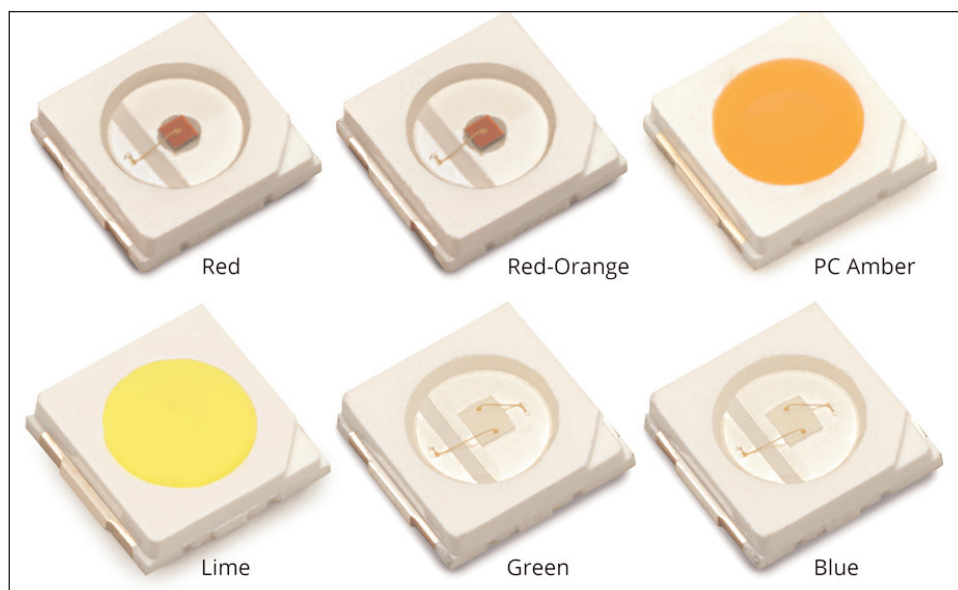
Lumileds launches LUXEON 3535L Color Line of mid-power LEDs

Lumileds has launched the LUXEON 3535L Color Line (joining its existing 3535L White LEDs), giving makers of emergency vehicle lights, signs, color tunable bulbs and architectural lamps access to single-color mid-power LEDs in Red, Red-Orange, Phosphor-Converted (PC) Amber, Lime, Green and Blue.

"The tremendous success our customers have had with our high-power color emitters convinced us that multiple markets could benefit from similar colors in the mid-power performance range," says LUXEON 3535L Color Line product manager David Cosenza.

For example, the LUXEON 3535L PC Amber LED can replace three 2200K LEDs in a warm dimming lamp while also delivering what is claimed to be best-in-class flux and hot/cold factor (flux at 85°C relative to flux at 25°C). The result is higher lumens per Watt and lumens per dollar for makers of warm dimming bulbs.

Also, the LUXEON 3535L Lime LED is said to make color-changing bulbs, such as the Philips hue,



much more affordable. "When mixed with Red, Lime's unique color point enables much warmer white light to be created than off-white plus red combinations," says Cosenza. The 3535L Lime LED features a typical flux of 56lm (100mA, 25°C) and an efficacy of 190lm/W.

Lumileds says that the LUXEON 3535L Color Line demonstrates the increased flexibility of its color fam-

ily through smaller lumen offerings. With the LUXEON 3535L Colors, existing customers aiming to broaden their product line can realize the optimum amount of color every time — even using the same optics as the LUXEON Rebel Color LEDs and LUXEON Z Color emitters to quickly take their new products to market, says the firm.

www.lumileds.com/LUXEON3535LColors

LUXEON 3535L mid-power LED lifetime data released

Lumileds has released LM-80 test results for its LUXEON 3535L mid-power LED line, enabling L90 fixture life of more than a decade.

Completing 10,000 hours of LM-80 testing at 55°C, 85°C and 105°C, Lumileds has exceeded lumen-maintenance requirements of the US Environmental Protection Agency's ENERGY STAR program, qualification by the DesignLights Consortium (DLC), as well as other emerging specifications. Projections based on TM-21-11 show that the devices will maintain 90% of their initial lumen output (L90) for a minimum of 60,000 hours at a 200mA drive current and T_s temperature of 85°C. Exceptional lifetimes were extrapolated at all test conditions, says



Lumileds. This performance means that LUXEON 3535L LEDs can operate in an LED fixture for 13 years (based on 12 hours of usage per day, 365 days a year) while maintaining at least 90% of the initial brightness.

Historically, customers have expressed concerns regarding the

long-term performance of mid-power LEDs says Lumileds. The firm says that, by leveraging its expertise in high-power LEDs, it has developed the LUXEON 3535L line of mid-power emitters that demonstrate what is claimed to be unparalleled lumen maintenance and reliability.

Offered in a range of correlated color temperature (CCT) and color rendering index (CRI) options, the standard-format LEDs are suitable for applications such as troffers, downlights, low-bay and TLEDs. In addition, the LUXEON 3535L packages are offered at three performance and price levels (3535LS, 3535L, 3535L HE) giving fixture designers flexibility.

Cree's new XHP35 family of high-power LEDs boosts output by 50%

Cree Inc of Durham, NC, USA has launched the XLamp XHP35 family of LEDs, which yields 50% more light output than Cree's previous highest-performing single-die LED, setting a new performance standard for the 3.5mm footprint.

Built on Cree's SC5 Technology platform, the XHP35 introduces the firm's high-voltage power die architecture, empowering manufacturers to unleash the full capacity of extreme high-power LEDs using existing drivers. The XHP35 delivers up to 1833 lumens without the optical inefficiencies of a multi-die LED to enable new designs with reduced size and lower system costs, says Cree.

"The XHP35 LED brings the performance of Cree's Extreme High Power LEDs to the XP footprint," comments Jorge Fraile, CEO of Hispaled. "In addition to delivering an impressive amount of light, the XHP35 LED allows us to leverage existing drivers to achieve the full performance of Cree's high-power LEDs at lower drive currents."

Cree says that, unlike other existing high-power LEDs, the XHP35 family uses a new 12V monolithic power die to deliver extreme high-power performance at drive currents at or less than 1A, making the use of high-power LEDs more accessible for lighting designers. This is uniquely enabled by Cree's SC5 Technology Platform, which is built on Cree's silicon carbide technology and features advances in epitaxial structure, chip architecture and a light conversion system optimized for thermal and optical performance.

Built on Cree's SC5 Technology platform, the XHP35 introduces the firm's high-voltage power die architecture, empowering manufacturers to unleash the full capacity of extreme high-power LEDs using existing drivers

The XHP35 LEDs are available in high-density and high-intensity versions that are optimized to deliver the maximum performance for specific applications. The XHP35 High Density LED delivers new levels of light output in the compact XP footprint for high-lumen applications, such as outdoor and high-bay lighting. The XHP35 High Intensity LED is optimized to deliver maximum candela through secondary optics to boost performance and reduce size for applications requiring high light intensity (such as stadium, torch and track lighting).

Samples of both High Density and High Intensity LEDs are available now, and production quantities are available with standard lead times. The XHP35 LEDs are available with a color rendering index (CRI) of 70, 80 and 90 and correlated color temperatures (CCTs) ranging from 2700K to 8300K with 2-step and 3-step EasyWhite options.

www.cree.com/LED-Components-and-Modules/Products/XLamp/Discrete-Directional/XLamp-XHP35

Feit Electric files LED patent infringement lawsuit against Cree

Feit Electric Company Inc of Pico Rivera, CA, USA has filed a complaint in the United States District Court for the Middle District of North Carolina alleging that the 4Flow line of LED light bulbs of LED maker Cree Inc of Durham, NC, USA infringes US Patent Nos. 8,408,748 and 9,016,901.

"Feit Electric Company fully supports competition in the market but competition by patent infringement is not acceptable," states president Aaron Feit. "Our company invests in LED lighting technology and we are building a patent portfolio to protect our position in the market. The action commenced today against Cree is simply that strategy put into action," he adds.

Feit Electric has been "building a patent portfolio organically in conjunction with product development and through opportunistic acquisitions," says executive VP Alan Feit.

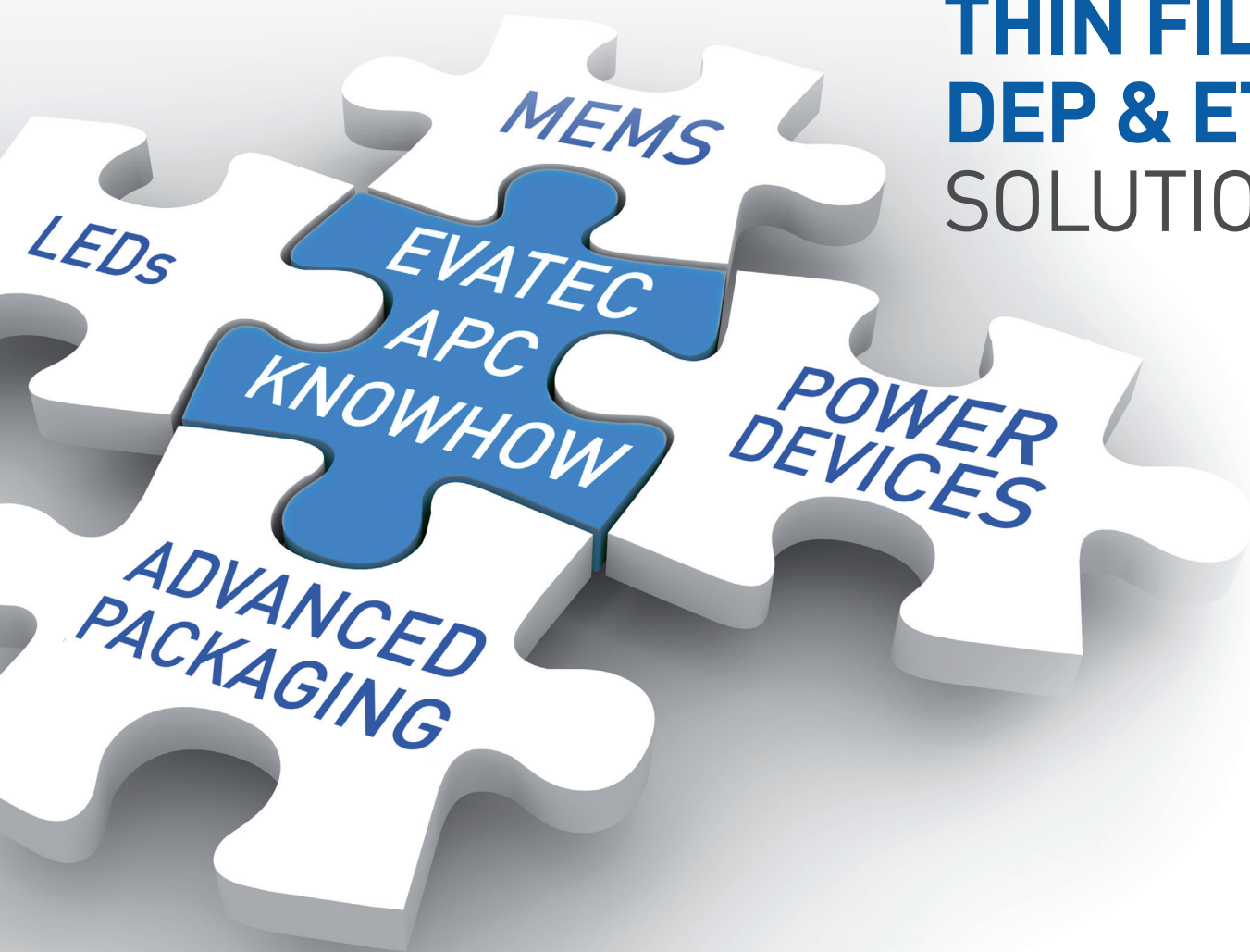
In the action, Feit Electric is seeking an injunction against sales of Cree's 4Flow LED light bulbs as well as damages for past infringing sales.

Previously, in January, Cree filed complaints with the US International Trade Commission (ITC) and the US District Court for the Western District of Wisconsin against Feit Electric and its Asian supplier Unity Opto Technology Co Ltd alleging infringement of 10 patents related to LED lighting and to address what was claimed to be Feit's false and misleading advertising claims that certain of its

products meet ENERGY STAR specifications. Cree requested that the ITC issues an order to exclude infringing and falsely advertised articles from entry into the USA, and a cease and desist order requiring the respondents to cease selling infringing and falsely advertised LED bulbs in the USA. In February, the ITC agreed to open an investigation into unfair trade practices ('Certain Light-Emitting Diode Products and Components Thereof, ITC Inv. No. 337-TA-747') that includes Cree's allegations of infringement of eight of its US patents 6,657,236, 6,885,036, 6,614,056, 7,312,474, 7,976,187, 8,766,298, 8,596,819 and 8,628,214 related to LED lighting.

www.creebulb.com

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First automotive camera with IR & visible capabilities

Osram Opto Semiconductors GmbH of Regensburg, Germany and Michigan-based Advanced Vision Systems LLC (which develops camera technologies for transportation and security markets) have partnered to develop a camera that provides high-quality images at night or in poor lighting conditions.

Driver monitoring can warn a fatigued driver to pull over and rest. It also supports other ADAS (Advanced Driver Assistance Systems) features like lane-departure warning and switching between autonomous and manual driving modes. In extreme cases, such as drunk driving, it can disable the vehicle.

Until now the technology has suffered visibility limitations at 940nm infrared wavelengths. However, Osram and Advanced Vision Systems have developed a new camera system that is now available for original equipment manufacturers. The system combines an Osram emitter with an Advanced Vision Systems camera to create what is said to be the first infrared camera with exceptional image quality in both visible (400–700nm) and near-infrared (940nm) spectrums. Normally this would need two different cameras and alternating filters.

“We developed special automotive-qualified IR emitters that enable Advanced Vision Systems to find the right balance between required illuminations for both camera and eye safety,” says infrared product marketing manager Rajeev Thakur.

Driver monitoring technology uses an IR camera with active illumination. The camera is mounted inside the vehicle and positioned towards the face of the driver in order to monitor their eyes, nose and face. Active illumination from Osram IR 940nm high-power stack emitters, as used in the IR Oslon, provides light that is not perceptible by the human eye. The light is reflected from the driver’s face and captured by the image sensor.

Cameras currently in production do not work well at night or in poor lighting conditions. They do not produce quality images in the IR spectrum and several require an 850nm emitter that has a red glow, which can be distracting to drivers because the human eye is more sensitive to this wavelength. The new camera from Advanced Vision Systems uses Osram’s Oslon 940nm emitters, which eliminate the red glow, use fewer LEDs, and require less power consumption per LED.

In addition to a more efficient and safer driver monitoring camera, the potential use in other automotive applications includes side-view or surround-view cameras for blind spot detection, rear-view cameras for cross-traffic alerts, and self-parking. It is hence a suitable driver monitoring solution that provides cost savings for other applications.

“To achieve optimal camera platform performance, we needed the participation of highly capable development partners,” says Advanced Vision Systems’ president Brian Skocaj. “Osram is a recognized leader in IR and a key partner not only in the development process but the market development as well.”

Driver monitoring is also essential technology for the advancement of autonomous driving. In scenarios where the driver needs to take back control from the car, a monitoring system will need to ‘watch’ the driver in order to give them adequate time to safely do so. Special image sensors for IR are needed because the emitters used must match the sensitivity peak of the image sensor and also provide adequate illumination without causing eye-safety issues.

www.advancedvisionsystems.com

Osram IR LED used to unlock Fujitsu smartphones by iris scanning

Using infrared light-emitting diodes (IREDs) from Osram Opto as the light source, Fujitsu Ltd’s ARROWS NX F-04G (marketed by telecoms firm NTT DOCOMO Inc, currently only in Japan) is said to be the world’s first smartphone capable of being unlocked by scanning the iris of the user. The IREDs are claimed to be the only products capable of the high power needed for iris scanning from a compact package.

Secure methods for unlocking cell phones and tablet computers are gaining importance because these devices are being used increasingly for sensitive applications such as online banking and online shopping.

Not only do these methods provide better security, but they also offer a more convenient way for users to authenticate their phone. Manufacturers are hence increasingly turning to biometric identification as a secure and convenient solution. As well as fingerprint scans, many manufacturers are now considering iris scanning. With biometric unlocking, IR light illuminates the user’s eye, and the camera on the smartphone simultaneously takes a picture of the iris in which characteristic features are then identified.

Osram claims that, at just 2.4mm high and emitting a typical radiant intensity of 2900mW per steradian

(a combination currently available only from this IRED), its Oslux SFH 4780S LED offers the best size-to-performance ratio and, for the first time, opens up compact and reliable iris scanning for mobile devices.

The SFH 4780S’ emission wavelength of 810nm enables the scanner to identify iris patterns for all eye colors — brown, blue, green, grey — with a high degree of reliability, claims Osram. The light source is also very efficient, minimizing drain on mobile device batteries, it adds. In June, the firm received the 2015 Kaiser Friedrich Research Award for developing the SFH 4780S.

www.osram-os.com



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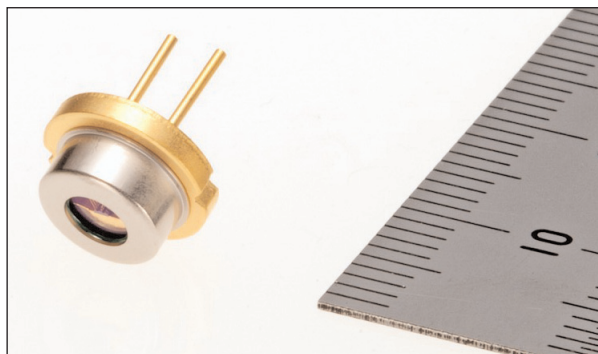
Mitsubishi Electric launching 2.5W 638nm red laser diode for pulse-operation projectors

Tokyo-based Mitsubishi Electric Corp is launching the ML562G84 638nm-wavelength red laser diode (LD), offering what is claimed to be record output power (under pulsed operation) of 2.5W for a 638nm projector light source.

The record output power - despite the small package size - is attributed to an improved laser diode structure (i.e. optimized layer structure and emitting-region size). Also, pulse operation is possible with a pulse duty ratio (proportion of time that laser light is on) of up to 40%.

Light sources for projectors are conventionally mercury and xenon lamps, but these are being replaced with solid-state light sources offering higher energy efficiency, a wider color range and longer life. In particular, laser diodes deliver high output power while consuming low power because of their high power-conversion efficiency, broad color gamut (due to the narrow spectrum), and superior picture quality with a high contrast ratio.

Previously, the output power of red laser diodes with wavelengths shorter than 640nm was insufficient for high-brightness projector applications at high temperature. As a first step toward overcome this limitation, Mitsubishi Electric applied specialized window-mirror



Mitsubishi Electric's ML562G84 638nm-wavelength high-power red laser diode.

structures and epitaxial growth technology to develop a laser diode, packaged in a 5.6mm-diameter transistor-outline can (TO-can), achieving 1.0W power output under pulsed operation. The new laser diode structure has since been applied in a 9.0mm TO-CAN package to achieve what is claimed to be industry-leading output power of 2.5W at the 638nm lasing wavelength. Also, due to lasing at such a short wavelength, the luminosity from a single light source exceeds 120 lumens, meeting the demands for bright projector systems, says the firm.

Mitsubishi Electric also claims that the new 638nm red laser achieves record electrical conversion efficiency of 39% at 2.5W (at 25°C), helping to reduce power consumption. In addition, due to using the large

9.0mm-diameter TO-can package, good heat dissipation allows a wide operational temperature range (operating case temperature, T_c) of 0°C to +45°C.

The 638nm red laser light and highly efficient operation contributes to laser projectors with a wide color range and low power consumption.

There are two types of laser projection system with spatial light modulators (SLMs). One is a single SLM type, which uses red, green and blue (RGB) laser sources under sequential pulse to express RGB pictures to get real color pictures. The other has three SLM devices, which uses the light sources under CW. Projectors using a pulse light source can be brought to the market relatively quickly. The new red laser diode is suitable as a red light source in single SLM projectors.

The product is also compliant with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive 2011/65/EU. Sales will begin in September.

www.mitsubishielectric.com/semiconductors/products/opt/laserdevice

Alfalight completes delivery of 850 weapon-mounted ruggedized lasers

Alfalight Inc of Madison, WI, USA, which designs and manufactures infrared and visible laser and electro-optical systems for defense and security applications, has completed delivery of over 850 ruggedized lasers, which provide multiple capabilities and are used in a wide variety of military applications.

Completion of the development and manufacturing contract has

pushed Alfalight over the 3000-unit mark for military lasers shipped in fiscal-year 2015.

"Our backlog has grown considerably over the last few years, and achieving this new milestone is significant in extending our volume production capabilities for military laser systems," says president & CEO Mohan Warrior. "Alfalight is committed to serve our defense

industry customers with products built with well-controlled manufacturing processes and established readiness to serve our customers' higher-unit volume needs," he adds.

"Feedback from end-users on the performance of the lasers has been very positive," says Rob Williamson, director of product marketing.

www.alfalight.com

Avago unveils industrial fiber-optic products at Power Conversion Intelligent Motion Europe 2015

At PCIM (Power Conversion Intelligent Motion) Europe 2015 in Nuremberg, Germany (19–21 May), Avago Technologies Ltd (a designer and supplier of III-V-based analog interface components for wireless, wireline, storage and industrial applications) unveiled an array of new industrial fiber-optic products targeting renewable energy, industrial motor drive and transportation applications, including the following:

AFBR-59FxZ — compact 650nm POF transceivers with bare fiber locking system

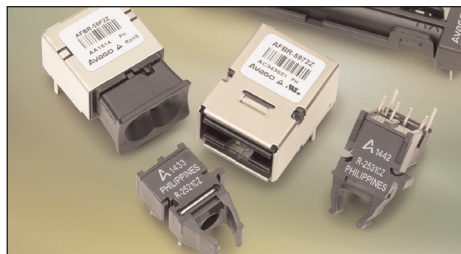
- supports serial data communications from 100Mbps to 1Gbps;
- bare fiber locking mechanism, eliminating the need for connectors;
- footprint comparable to RJ-45 connector.

AFBR-25x1CZ — enhanced 650nm versatile link fiber-optic receivers

- supports data rates from DC to 5MBd with superior EMI performance;
- link distances up to 50m using 1mm 0.5NA plastic optical fiber (POF) and 500m using 200 μ m 0.37NA plastic clad silica (PCS) fiber;
- operates in 3.3V or 5V supply with TTL data output;
- available in horizontal, vertical and 30°-tilted packages.

AFBR-3905xxRZ/3950xxRZ — high-voltage galvanic insulation links

- Suppresses transient peak voltages up to 50kV per IEC 60664-1 specification;
- Available in 1-, 2-, 3- and 4-inch length;
- Supports data rates from DC to 5MBd (AFBR-3905xxRZ);
- Supports data rates from DC to 50MBd (AFBR-3950xxRZ);
- Suitable for high-voltage on-board insulation in applications such as power distribution, smart grid, and industrial inverters and motor drives.

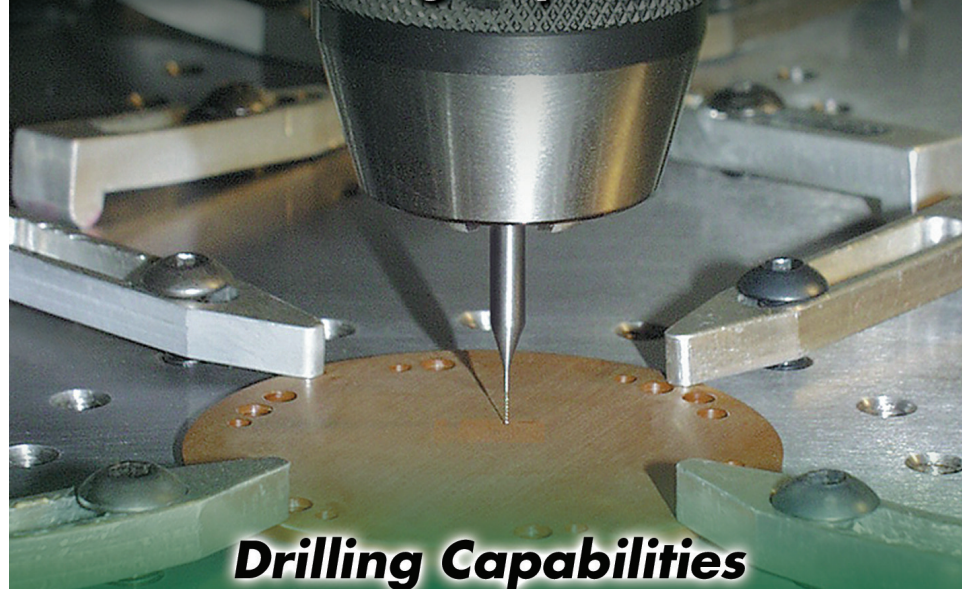


Samples of the AFBR-3905xxRZ, AFBR-3950xxRZ, AFBR-59FxZ, AFBR-25x1CZ and evaluation boards are available now.

www.avagotech.com/fiber

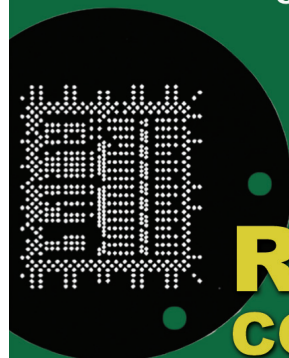
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FBH showcasing dual-wavelength diode laser for Raman spectroscopy

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), FBH (Ferdinand-Braun-Institut, Leibniz-Institut für Hoechstfrequenztechnik) of Berlin, Germany showcased a range of improvements and new developments regarding diode lasers and UV light-emitting diodes.

Separating signals — dual-wavelength diode laser for Raman spectroscopy

FBH exhibited novel dual-wavelength diode lasers suitable for use in miniaturized, portable laser measurement systems for Raman spectroscopy applications. The laser sources alternately emit light from only one chip at two different stabilized wavelengths, defined by gratings implemented into the chip. Wavelength selection is realized by separately addressable sections within the laser.

The diode laser chip is applicable for SERDS (shifted-excitation Raman difference spectroscopy), enabling the measurement of Raman spectra under real-world conditions even in highly fluorescent environments and when exposed to daylight. It is hence possible to separate Raman signals from background interference.

Moreover, SERDS improves the detection limit by one order of magnitude compared with standard Raman spectroscopy.

Using such chip-scale monolithic light sources, a compact SERDS measurement head as small as a laser pointer has been realized for the first time, it is claimed. The device is the basis for a miniaturized and versatile SERDS spectroscopy system, enabling in-situ measurement in various security- and health-related fields including biology, medicine, food control, and pharmacy. Applications in absorption spectroscopy and terahertz radiation generation are also possible.

Higher brilliance and output power for diode lasers and bars
FBH develops high-brightness

diode lasers in a variety of designs and packages, covering wavelengths of 630–1180nm. Single emitters with a stripe width of 90µm, for example, can reach 3.5W/mm-mrad (peak). The same applies to smaller stripes, delivering 4–5W/mm-mrad from a 30µm aperture.

For rapid prototyping applications, FBH has developed distributed Bragg reflector (DBR) ridge waveguide (RW) lasers with 24 individually addressable emitters featuring a wavelength spacing of >0.3nm and a spectral width of <1pm.

Further activities at FBH aim to constantly improve efficiency, reliability and output power. For example, bars emitting at a wavelength of around 940nm at temperatures of –70°C (203K) have yielded a record 2kW peak power per bar at a pulse width of 200µs. To date, such powers could only be achieved by combining the optical beams from at least four single bars, says FBH.

UV-B LED module for plant lighting

FBH is developing LED technology in the UV-B and UV-C spectral ranges, from the chip to the final radiation module. Applications are wide-ranging and include medical diagnostics and fluorescence spectroscopy as well as UV curing and disinfection.

A further application is plant lighting, for which the FBH has developed and manufactured a module enabling irradiation with UV-B light of a specific wavelength. In this particular case, LEDs emitting at a wavelength around 310nm are used to stimulate health-promoting secondary metabolites in plants. The optical power can be flexibly adjusted between 0 and 100%. The concept has been tested in experiments at the Institute of Vegetable and Ornamental Crops (IGZ).

CLEO Europe

At the associated Conference on Lasers and Electro-Optics/Europe (CLEO Europe 2015), FBH gave the

short course 'High Power and High Brightness Semiconductor Laser Diodes and Applications'. It is also presenting several lectures and posters, including the following.

- narrowband gallium nitride (GaN) external-cavity diode laser with 400mW output power at 445nm for deep ultraviolet frequency doubling;
- micro-integrated, narrow-linewidth master oscillator power amplifier designed for quantum sensors in space;
- nanosecond high-current pulsed operation of ridge-waveguide lasers;
- coexistence of multiple stable continuous-wave states in micro-integrated external-cavity diode lasers;
- generation of 0.7W second-harmonic picosecond pulses near 560nm using a DBR diode laser and a ridge-waveguide PPLN crystal;
- GaAs-based phase modulator for laser radiation at 1070nm;
- coherent combining of two high-brightness laser diodes phase-locked by a Michelson-type external cavity;
- high-brightness narrow-stripe broad-area laser with 7W optical output at 910, 935 and 970nm for coarse spectral beam combining;
- timing jitter reduction of a two-section external-cavity semiconductor laser by harmonic mode-locking and optical feedback;
- spectral broadening of mode-locked semiconductor lasers by resonator-internal pulse shaping;
- controllable dual-wavelength-stabilized Y-branch DBR diode lasers at 785nm for SERDS;
- array with 24 DBR lasers for scanning applications (fabrication and characterization); and
- increased slow-axis beam quality in 9xx nm high-power broad-area diode lasers by modifying the lateral current profile at the device edges.

www.world-of-photonics.com

www.cleoconference.org

www.fbh-berlin.com

[/business-areas/diode-lasers](http://business-areas/diode-lasers)

DILAS acquires founding site and headquarters building

Founded in 1994 in a state-owned building, diode laser maker DILAS of Mainz, Germany has now acquired ownership. The owner LLB Rheinland-Pfalz (Landesbetrieb Liegenschafts- und Baubetreuung) agreed to sell the building, which DILAS expanded by adding another floor level and increasing the cleanroom area.

The building includes 4200m² of office space, high-tech research laboratories and production area. The total property is about 5000m².

The official hand-over of ownership took place on 9 July between state government representatives and DILAS' general manager



Official handover of DILAS' building.

Dr Marcel Marchiano. The state of Rheinland Pfalz was represented by

Dr Salvatore Barbaro (Secretary, Ministry of Finance), Dr Petra Wriedt (deputy managing director, LBB), Andreas Nath (portfolio manager, LBB) and Claudia Renner (press spokeswoman, LBB).

"By owning the building, we are now in a position to increase our competitiveness, by introduction of new production technologies," says Marchiano. "In addition, the necessary conversion work will be done under our own responsibility."

DILAS showcases high-brightness fiber-laser-pumping products

At Laser World of Photonics 2015 in Munich, Germany in June, DILAS showcased a series of high-brightness fiber-coupled diode laser pump modules.

Additions and enhancements to its product line include the following:

- High-brightness fiber-coupled pump modules (up to 240W, 200µm, 915nm; up to 250W, 200µm, 976nm; and up to 270W, 225µm, 976nm) are available with optional volume Bragg gratings (VBGs) for wavelength stabilization. The tailored bar-based, fiber-coupled modules target a wide range of high-power fiber-laser pumping

applications in industry and R&D as well as in direct-diode applications.

- COMPACT-EVOLUTION (600W, 200µm, 976nm and 1200W, 300µm, 976nm) is a unique turn-key platform of small physical size (19" rack mountable), ease of use and operational versatility. The systems are equipped with a standard diode laser control unit used for external interfaces such as the common analog/digital interface, BUS interfaces and remote access option for easy analysis and parameter settings.
- Fiber-coupled pump module (25W, 105µm, 915/976nm):

Developed for ytterbium fiber-laser pumping applications requiring high-speed modulation rates in the kHz regime, the module is equipped with a filter to protect against back-propagating light at >1µm. The fiber-coupled module is also suitable for medical or materials processing applications that require a small fiber core diameter and low numerical aperture (NA 0.15) in a small footprint (<65mm x 22mm x 10mm).

DILAS also presented a technical white paper on 'Surface Cladding with Multi-kW Diode Lasers'.

www.dilas.com

ProPhotonix exhibits new fiber-coupled laser diode modules

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer LED illumination systems and laser diode modules for OEMs and medical equipment companies (as well as a distributor of laser diodes for Panasonic, Ushio, Osram, QSI, and Sony), exhibited its new Fiber PRO Laser series of compact (19mm-diameter) fiber-coupled laser diode modules for applications such as DNA sequencing, particle analysis,

flow cytometry, medical imaging, inspection and metrology.

The Fiber Pro Laser provides stable output power from precision alignment of optics and laser diode. The module is available with a single-mode fiber and diffraction-limited output for superior beam quality. Protective jacket options of 3mm or 9mm are available. The output end of the fiber is offered with standard connector (ST, FC, LC) options, or an output collimator with factory-set beam size (colli-

mated or focused).

The Fiber Pro Laser is available in a range of wavelengths including 405, 488, 520, 635, 639, 780 and 830nm. Electronic options include analog and digital modulation.

"With its stability and superior optical performance, the range will allow us to further serve the most demanding technical applications of our customers," says David McGuinness sales director, EMEA.

www.prophotonix.com

www.world-of-photonics.com

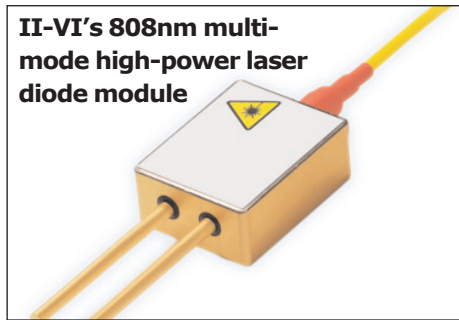
II-VI launching next-generation 808nm laser, boosting chip output above 10W

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA — represented by its subsidiaries II-VI Suwtech of China and II-VI Laser Enterprise GmbH of Zurich, Switzerland — launched its next-generation 808nm multi-mode high-power laser diode single-emitter portfolio.

The new chip has been optimized to deliver output powers above 10W with higher efficiencies at improved reliability, enabling next-generation higher-power fiber-coupled modules for pumping in material processing and medical applications.

The expanded portfolio of 808nm fiber-coupled modules offers output

II-VI's 808nm multi-mode high-power laser diode module



powers from 15W up to 30W with the same mechanical dimension and fiber configuration (200µm fiber core/0.22NA). The new fiber-coupled products are an expansion of the proven high-volume generic 'BMU' single-emitter platform. These high-output-power/brightness BMUs come in an easy-to-mount compact hermetic package, says the firm. Diode-pumped solid-state

(DPSS) laser manufacturers, medical instrument makers and other subsystem developers can upgrade their product performance (by replacing existing low-power modules), simplify their product configuration (by using fewer modules) and improve their product reliability (through less complex fiber management), adds the firm.

II-VI says that, based on its chip design technology and high-volume package manufacturing, the new products offer extended lifetime. Also, the wavelength range and fiber connector types can be tailored to meet specific customer applications. The new-generation laser diode chip is also available with an open heat-sink on an AIN submount or on a C-mount.

II-VI Laser adds high-power multi-bar stack laser diode modules

At Laser World of Photonics 2015, II-VI Laser Enterprise GmbH of Zurich, Switzerland — which produces 980nm single-mode pumps, high-power laser diode and vertical-cavity surface-emitting lasers (VCSELs) — debuted its new expanded portfolio of high-power multi-bar stack laser diode modules. This includes a new series of tap-water-cooled stacks for medical, pumping and defense applications, showcasing what is claimed to be the industry's broadest wavelength range of high-power laser diodes enabling multi-kilowatt direct-diode systems.

The Tap Water Stack is a new QCW-style high-reliability stack platform targeting high peak power and pulsed applications especially for the medical and defense markets. Key advantages are the use of industrial water instead of de-ionized water and the hard solder technology for die bonding. The use of industrial tap water not only reduces complexity of design for the cooling circuit, it



II-VI Laser's multi-bar stack laser diode module

eliminates the de-ionizer cartridge, as well as water resistivity and pH control that is otherwise required. By employing hard-solder die bonding technology, the new product is especially suitable for long-pulse on/off operation modes in the millisecond regime and not only microsecond operation.

II-VI Laser Enterprise is a subsidiary in the active optical products segment of engineering materials and optoelectronic components provider II-VI Inc that was formerly the business unit Oclaro Switzerland GmbH — a gallium arsenide (GaAs) laser diode manufacturing plant in Zurich and

associated product portfolios — acquired in September 2013 from optical communications component maker Oclaro Inc of San Jose, CA, USA.

Now shipping in volume to laser system manufacturers supplying the industrial, semiconductor, automotive and materials processing markets, II-VI Laser Enterprise says that its high-power laser diodes uniquely cover the entire wavelength range of 910–1070nm (in up to seven standard wavelength windows). Output power is 150W and 250W on a micro-channel cooler or up to 120W on what is claimed to be the industry's smallest-footprint passive mini-cooler, enabling scaling of system power up to 40kW and beyond. For pumping applications, more than 100W per bar is available in the 8xx nm wavelength range, and in the eye-safe wavelength band around 1470nm more than 50W has been demonstrated.

www.ii-vi.com/business_units/II-VI-Laser-Enterprise.html

II-VI Suwtech launching high-power low-noise and high-power fiber-coupled green diode lasers

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), II-VI Suwtech of Shanghai, China — a subsidiary of engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA — launched two new product lines: a high-power low-noise (HPLN) laser and a high-power fiber-coupled (HPFC) laser.

Both HPLN and HPFC lasers have been developed from II-VI Suwtech's high-power green diode laser (GDL). HPLN lasers realize less than 0.5% RMS noise at output power higher than 100mW. HPFC lasers achieve high output power up to 300mW with high polarization stability in single-mode (SM), multiple-mode (MM) and polarized-mode (PM) fibers.

In 2014, II-VI Suwtech developed a patented micro-chip design (patent approved) for its green



II-VI Suwtech's high-power green diode laser.

diode laser that successfully lowers noise at high output power. The HPLN — with its high power sta-

The HPFC laser has broad applications in bioscience and analytical instruments, says the firm

bility, high reliability, good beam quality and high PER (polarization extinction ratio) — has wide applications in life science, laser display and machine vision.

II-VI Suwtech developed high-power fiber-coupled (HPFC) lasers from its green laser with high coupling efficiency. The new technology enables laser beam output from fiber with what is claimed to be exceptional polarization stability (PER>17dB), long-term reliability, and high coupling efficiency. Based on this technology, II-VI Suwtech has launched compact, cost-efficient fiber-coupled high-power lasers up to 300mW in various types of fiber: single-mode, multiple-mode and polarization-mode. The HPFC laser has broad applications in bioscience and analytical instruments, says the firm.

www.ii-vi.com/business_units/suwtech.html

II-VI Suwtech showcases high-power fiber-laser pump module at Laser World of Photonics 2015

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), II-VI Suwtech of Shanghai, China — a subsidiary of engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA — showcased its new high-power fiber-coupled diode pump module platform that offers the scalability of output powers up to 300W with different emitter and fiber configurations (105µm fiber core for power levels less than 200W and 200µm for more than 200W). With an integrated design, the single-emitter-based platform delivers increased brightness, says the firm.

The new platform has been designed to address kilowatt-class fiber-laser applications. The novel optical schematic couples the diode beam into the fiber with high efficiency and controlled NA (numerical aperture). A cladding-

mode-stripping feature allows users to reduce optical loss on fiber splicing and increase overall reliability.

The high output power/brightness enables fiber-laser manufacturers to generate higher power levels using fewer pump modules to increase electrical-to-optical conversion efficiency and to design a

High output power/brightness enables fiber-laser manufacturers to generate higher power levels using fewer pump modules to increase electrical-to-optical conversion efficiency and to design a pump configuration with a compact footprint

pump configuration with a compact footprint, says the firm.

The integrated design and fewer components ensure highly efficient volume manufacturing, module performance and extended product lifetime, it adds.

Together with the modules, II-VI Suwtech also offers unique 300W per port Nx1 high-power combiners that can handle 300W per input port. High-power Nx1 multimode combiners enable high-efficiency combining of multiple high-power pump sources into a single output fiber. Up to 31 input ports are available, corresponding to multi-kilowatt power handling capability. II-VI notes that all its photonics combiners conform to stringent environmental and mechanical standards to give high reliability and long lifetime for all field applications.

www.ii-vi.com

JDSU demonstrates high-precision laser technology for macro-materials and micromachining processes

At Laser World of Photonics 2015 in Munich, Germany (22–25 June), JDSU of Milpitas, CA, USA exhibited its latest technology for macro- and micro-machining applications, and showcased its portfolio of lasers for metrology, life sciences and research, including the following:

● **CORELIGHT kiloWatt-class fiber laser and direct-diode laser turn-key systems and engines**

Each CORELIGHT system or engine incorporates one or more high-brightness 2.1kW ytterbium fiber-laser modules or 2.1kW direct-diode laser modules. Building upon high-power modules allows for straightforward power scaling while maintaining the high optical brightness necessary for ultra-fast, precise materials processing. CORELIGHT Series laser products are suited to processing steel, aluminium, copper, brass and other metals.

● **NPRO Lasers**

The NPRO 125/126 diode-pumped lasers produce up to 700mW of continuous-wave (CW), single-frequency output at either 1064nm or 1319nm. Its key features include fiber-optic or free-space output, narrow linewidth, low noise, frequency tunability, and adjustable power. The NPRO 125/126 lasers are used for a variety of applications including fiber-optic sensing, coherent communications, remote antenna links, optical heterodyne, lidar oscillators, and passive sonar.

● **ST Series fiber-laser pump**

The highly integrated and ultra-compact 140W ST Series fiber-laser pump is claimed to be the highest-

brightness diode laser on the market, providing electrical-to-optical power conversion efficiency of 50%, as well as robustness and reliability. This performance enables simpler, lower cost, and more robust fiber-laser design alternatives, says the firm, and has brought the power of kW fiber lasers to a wider range of machine tool customers.

● **Solid-state lasers**

JDSU's continuous-wave and pulsed-diode-pumped solid-state lasers cover a wide range of wavelengths, from visible to near-IR. The lasers have been designed for easy integration. Some products offer an option for fiber coupling into a single-mode fiber. Typical applications include metrology, interferometry, DNA sequencing, and flow cytometry.

● **Ultrafast scientific lasers**

JDSU says its ultrafast scientific lasers offer low-volume, turn-key, customer-friendly operation without compromising reliability. They are suitable for a wide variety of applications, including research to the life sciences and metrology. The portfolio delivers a full range of performance, generating pulses from <50fs to >500ps, wavelengths from 260 to 1550nm, output power up to 50W, energy up to 1mJ, and frequencies from single pulses to >25GHz.

● **PicoBlade**

A precise, fast, full-featured picosecond system that features cold-ablation process, the PicoBlade laser is suited for demanding industrial applications and the requirements of system integrators.

PicoBlade includes pulse-on-demand, FlexBurst pulse control, high average power, and what is claimed to be industry-leading pulse repetition rates. The PicoBlade laser system, which plays a key role for hundreds of existing customers in defect-free manufacturing, has the unique flexibility to combine best-in-class beam quality and pulse flexibility through real-time energy control.

● **Q-Series Lasers**

JDSU's Q306 laser delivered 40W of UV power in the exact same form factor as its Q305 predecessor. The new Q306 provides the same process advantages that the previous Q-Series models in terms of pulse profile, while providing higher average power to enable higher overall throughput with the of up to 1mJ of energy at 355nm with an exceptional beam quality (M2 less than 1.2).

Conference presentations

Also, at the Laser World of Photonics conference, JDSU experts presented three sessions :

Erik Zucker, senior director, Lasers Product & Technology Strategy, presented two sessions:

● 'Laser and Applications in Macro- and Micro-Materials Processing';

● 'Multi kW Fiber Laser Modules and Engines Enabled by High-Brightness Laser Diode Pumps';

Markovic, Andreas Rohrbacher, Peter Hofmann, Wolfgang Pallmann, Simonette Pierrot, Hubert Ammann and Bojan Resan presented:

● '160W 800 fs Laser System without CPA for High Speed Surface Texturing'.

www.jdsu.com

JDSU's CCOP unit wins Fujitsu's Valued Supplier Award

At its annual Supplier Day in Allen, Texas, USA, Japan-based business, information technology and communications solutions provider Fujitsu granted its 2015 Valued Supplier Award to JDSU's Communications and Commercial Optical

Products (CCOP) business unit for demonstrating "exemplary support, flexibility and responsiveness while working on the Fujitsu Network Communications Business' network engineering initiatives, and for providing low-cost technol-

ogy solutions that replace older and more expensive products".

In January, CCOP also received the Distinguished Partner Award from Fujitsu for its long-standing relationship and contribution of next-generation optical solutions.

Lumentum shares being distributed on 3 August

JDSU of Milpitas, CA, USA has announced several key dates in connection with the separation of its Communications and Commercial Optical Products (CCOP) business segment as a separate public company named Lumentum Holdings Inc, and the special dividend distribution of about 80.1% of Lumentum's common stock to JDSU shareholders, subject to the conditions set forth in Lumentum's registration statement on Form 10, as filed with the US Securities and Exchange Commission (SEC) on 26 February.

Lumentum will specialize in optical components and subsystems for the telecoms market, with high-growth opportunities in data communications, driven by the rapid expansion of cloud networking and data-center infrastructure, and in high-performance lasers for both macro and micro materials processing applications. Lumentum will also focus on growing its 3D

sensing and commercial lasers business and expanding into other market segments that can benefit from optical and laser technologies.

JDSU's continuing businesses, namely Network Enablement (NE), Service Enablement (SE) and Optical Security and Performance Products (OSP), will become Viavi Solutions Inc.

"By operating as two independent companies, we believe Lumentum and Viavi Solutions will each be able to leverage a strong history while being more flexible and better positioned to capitalize on new opportunities in their respective markets," says Tom Waechter, president & CEO of JDSU and CEO-designate for Viavi.

For every five shares of JDSU common stock held on 27 July, JDSU shareholders will receive one share of Lumentum common stock (plus cash in lieu of fractional shares).

The special dividend distribution is

expected to be effective on 1 August, and paid on the first trading day afterwards (3 August) to JDSU shareholders of record as of the close of business on 27 July who continue to hold shares until the ex-dividend date.

The distribution of Lumentum common stock completes the formal separation of CCOP from JDSU, with Lumentum becoming an independent, publicly traded company. JDSU will become Viavi Solutions Inc and retain ownership of about 19.9% of Lumentum's outstanding shares. Based on about 235.3 million shares of JDSU common stock outstanding as of 27 June, a total of 47.1 million shares of Lumentum common stock is being distributed to shareholders and 11.7 million shares are being retained by Viavi. Viavi is committed to liquidating these shares within three years from the closing.

www.jdsu.com

JDSU announces board members for Lumentum and Viavi

JDSU has announced the boards of directors for Lumentum Holdings Inc and Viavi Solutions Inc, the two publicly traded companies resulting from the spin-off of its Communications and Commercial Optical Products (CCOP) business.

"Both Lumentum [formerly CCOP] and Viavi Solutions [JDSU's Network Enablement (NE), Service Enablement (SE) and Optical Security and Performance Products (OSP) businesses] will have strong leadership and proven board and management teams, positioning them to deliver on their strategies," says president & CEO Tom Waechter (CEO-designate for Viavi).

Each of the Lumentum directors is to be appointed to the Lumentum board, effective upon completion of the spin-off.

Lumentum is appointing the following directors:

- Harold Covert, former executive VP & chief financial officer of

Lumos Networks Corp;

- Penelope Herscher, president & CEO of FirstRain;

- Martin Kaplan, former executive VP of Pacific Telesis Group Inc;

- Brian Lillie, chief information officer of Equinix Inc;

- Samuel Thomas, director, chairman & CEO of Chart Industries Inc; and

- Alan Lowe, CEO-designate for Lumentum, current president of JDSU's CCOP segment since 2008 and executive VP of JDSU.

"Our company will benefit from the collective institutional knowledge of the business and expertise in key market segments that these individuals bring with them," comments Lowe. Covert will serve as chairperson of the audit committee, Penelope Herscher as chairperson of the compensation committee, and Martin Kaplan as chair of Lumentum's board of directors as well as chairperson of the governance committee. JDSU previously

announced the appointment of Pamela Strayer.

Viavi's board will include the following directors:

- Keith Barnes, ex-chairman & CEO of Verigy and executive with Agilent, Electroglas, IMS and Cadence;

- Richard E. Belluzzo, managing partner of Corso Partners LLC;

- Tim Campos, chief information officer and a member of the senior management team at Facebook;

- Masood Jabbar, former president of the Computer Systems Division and chief financial officer for Sun Microsystems Inc;

- Pamela Strayer, senior VP & chief financial officer at Plantronics; and

- Thomas Waechter, current CEO of JDSU and CEO-designate.

Strayer will serve as chairperson of the audit committee, Keith Barnes as chairperson of the compensation committee, and Richard Belluzzo as chair of Viavi's board as well as chair of the governance committee.

GigOptix achieves first quarter of GAAP profitability

Q3 revenue to be a record \$10.3m, up 21% year-on-year

For second-quarter 2015, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has reported a fifth consecutive quarterly revenue increase, to \$9.8m (up 9% on \$9.1m last quarter and up 22% on \$8m a year ago, and exceeding April's guidance of \$9.3–\$9.5m). Product revenue in particular was up 10% on last quarter and 31% on a year ago.

"We are seeing strong pull in our High-Speed Communications (HSC) business in both Datacom — with our 40Gbps and 100Gbps drivers and TIAs [transimpedance amplifiers] for data-center active optical cables (AOC) and transceivers — and in telecom — with our linear-coherent 100Gbps and 200Gbps devices used for both long-haul and metro

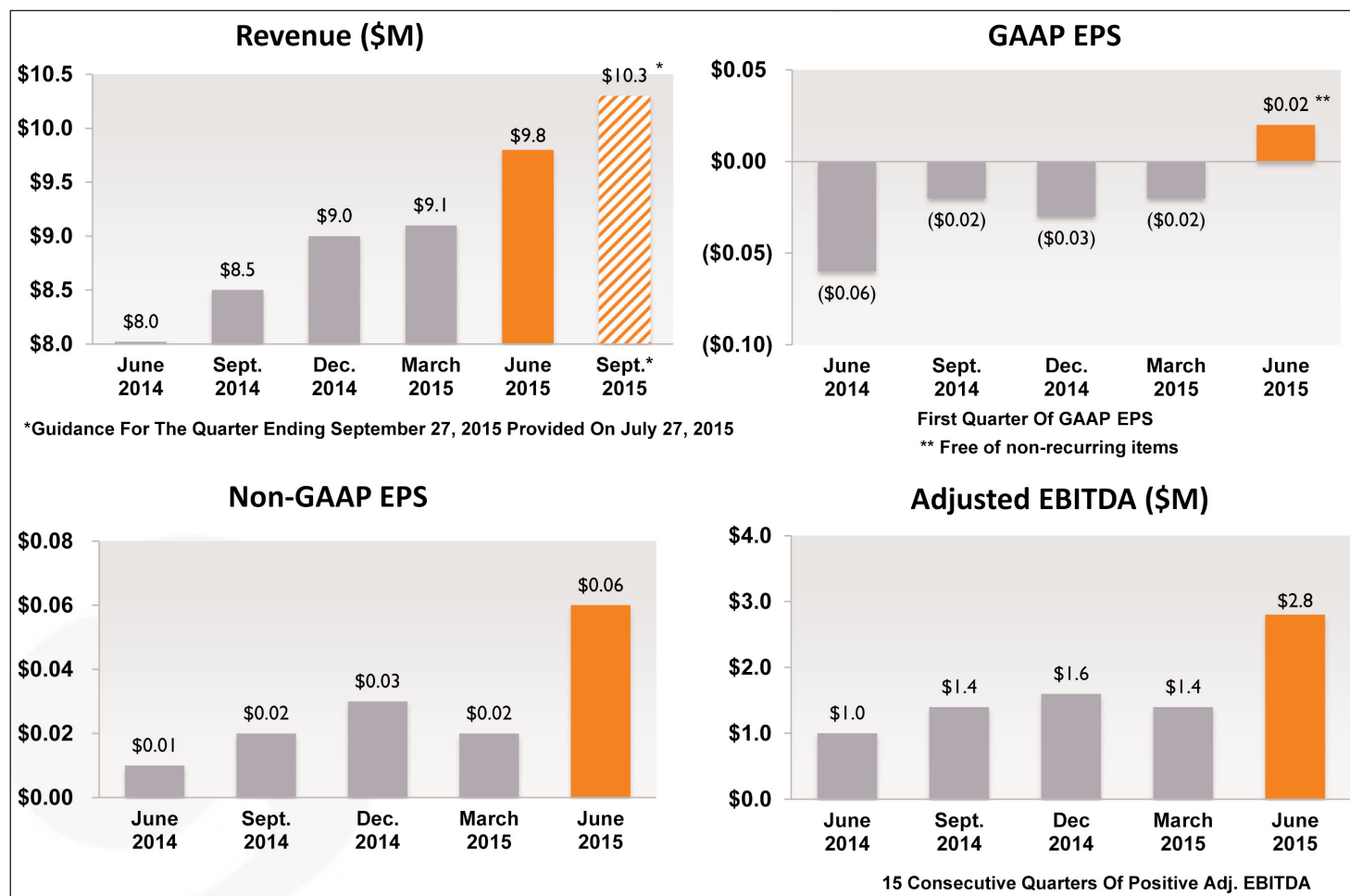
applications," chairman & CEO Dr Avi Katz. "In addition, in our Industrial product line we are experiencing several new business opportunities that are driving continuous revenue growth."

Revenue for the Industrial ASIC (application-specific integrated circuit) product line was \$3.2m (33% of total revenue), up 13% on \$2.9m last quarter and up 33% on \$2.4m a year ago.

The High-Speed Communications business (Datacom and Telecom optical communications products plus wireless RF point-to-point products) has grown further to \$6.6m (67% of total revenue), up 6% on \$6.2m last quarter and up 18% on \$5.6m a year ago. Optical communications remains the fastest-growing segment (expected to continue growing into 2016). In Telecoms, linear coherent 100

and 200Gb/s devices for long-haul and metro applications saw continuous shipment growth (including record 100Gb/s device shipments due to new customers acquired in Q2 plus increasing demand from legacy customers). GigOptix also started qualification shipments of its new-generation 400Gb/s devices for telecom applications (expected to become an increasingly larger revenue opportunity in 2016).

In Datacoms, GigOptix continues to see strong demand for 48Gb/s devices for AOC and transceiver integrator customers. "Furthermore, our latest developed 100Gb/s devices continue to experience strong demand in supporting the next generation of data-center connectivity," says Katz. "Both products are in demand due to the growing number of installed new mega data-centers by the Web 2.0



► OEMs. In fact, our 40Gb/s QSFP+ devices have become the de facto standard for active optical cables and transceiver installations with many of those new data-centers," he adds. In first-half 2015, GigOptix shipped about 2 million devices to support the new Web 2.0 data-center installations (slightly more than the total volume shipped in the whole of 2014).

On a non-GAAP basis, gross margin has risen further, from 59% a year ago and 62% last quarter to a record 66%, due to a richer product mix and enhanced price and expense control programs.

Operating expenses have been cut from \$4.9m last quarter to \$4.4m (back level with \$4.4m a year ago), driven primarily by tight spending controls and the ramp-down of seasonal expenses in Q1.

"The combination of higher revenue, better margins and on-going strict expense controls translated into record profitability," notes Katz. Net income has risen further, from \$0.3m (\$0.01 per diluted share) a year ago and \$0.7m (\$0.02 per diluted share) last quarter to a record \$2.1m (\$0.06 per diluted share), the fifth consecutive quarter of positive net income (and 50% higher than the \$0.04 per diluted share for the whole of 2014). Likewise, adjusted EBITDA has risen from \$1m a year ago and \$1.4m last quarter to a record \$2.8m (the 16th consecutive quarter of positive adjusted EBITDA).

Capital expenditure has been increased from \$0.4m last quarter to \$0.7m to support continuous investments in innovation as well as enhanced revenue growth.

Driven by an inventory build to support new products (primarily in the High-Speed Communications business), inventory has increased from \$6m last quarter to \$6.8m. Overall, free cash flow was hence \$1.1m. During the quarter, cash and cash equivalents correspondingly rose by \$0.7m, from \$17.7m to \$18.4m.

"The all-around record quarterly financial results we achieved in Q2 represent a positive and significant inflection point in the eight-year history of GigOptix, going back to our inception in July 2007," says Katz. "We delivered our first quarter of GAAP profitability, free of non-recurring items, and the highest ever non-GAAP profitability and adjusted EBITDA. This record performance clearly shows the success we continue to achieve with our global growth and scalable strategy," he adds.

For third-quarter 2015, GigOptix expects record revenue of \$10.3m (up 5% on Q2/2015, and up 21% year-on-year), while maintaining the high level of profitability (despite operating expenses rising slightly to support the increasing revenue). Gross margin should remain in the mid-60s.

In addition (as pre-announced on 29 June), GigOptix is raising its initial

Our expanded product base for 100Gb/s and higher speeds put us in a prime position to be a key supplier when the telecom metro build-out commences... no later than the first half of 2016

revenue guidance for full-year 2015 from \$37.5m to at least \$39m (up 20% on 2014's \$32.9m). "Overall, we expect 2015 to yield the highest annual revenue, best profitability and largest cash generation from operations in our history," says Katz.

"Our expanded product base for 100Gb/s and higher speeds put us in a prime position to be a key supplier when the telecom metro build-out commences," believes Katz.

"We continue to hear from our customers that this build is coming with a target date of no later than the first half of 2016. This build-out offers a vast revenue opportunity for us in the next year to come," he adds.

During Q2, GigOptix announced a significant booking of \$7.9m to ship ASIC products a large aerospace & defense contractor through early 2017. "The shipments will occur in roughly equal instalments during this timeline," notes Katz. "We have also added this quarter new designs in the automotive and GPS markets, which we see growing and supporting continuous development of this product line through the balance of 2015 and 2016," he adds.

"By leveraging our value-add ASIC solutions using our portfolio of analog and digital IPs for various applications, as well as RF and optical device knowledge that resides within our High-Speed Communications business, we continue to serve and develop new businesses with our existing customers while at the same time acquiring new accounts and establishing an emerging government and commercial market," concludes Katz.

www.gigoptix.com

NeoPhotonics closes follow-on stock offering with underwriters' over-allotment option exercised in full

NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications networks) says that, after closing its follow-on public

offering of 5,971,034 shares of common stock (at a price to the public of \$7.25 per share) on 27 May, the underwriters 30-day option to purchase up to 895,655 additional shares (to cover over-allotments, at \$7.25 per share minus the

underwriting discount) has also been closed after underwriters exercised their over-allotment option in full.

With this option exercised, NeoPhotonics' follow-on offering totals 6,866,689 shares.

www.neophotonics.com

ESSenTIAL European collaboration accelerates silicon photonics prototyping services

ePIXfab MPW services extended and integrated into Europractice IC

Imec of Leuven, Belgium and its partners have completed a three-year program (2012–2015) to leverage a variety of silicon photonics technologies by making them accessible for industry and academia worldwide.

Within the ESSenTIAL program funded by the European Commission, imec has worked with CEA-LETI of Grenoble, France, Ireland's Tyndall National Institute (based at University College Cork), VTT Technical Research Centre of Finland, IHP (Innovations for High Performance Microelectronics) of Frankfurt (Oder), Germany, TNO (the Netherlands Organization for Applied Scientific Research in Delft) and CMC Microsystems of Ontario Canada to develop advanced multi-project-wafer services as well as packaging services for silicon photonics. The services were made accessible to industrial players — both small- and medium-sized companies — enabling them to test silicon photonics technology.

Silicon photonics is a key enabling technology for a wide range of markets, from optical interconnect networks in data centers to disposable biosensor chips for immunoassays. Silicon photonics builds on the technology portfolio and economy of scale of CMOS fabs to manufacture photonic integrated circuits (PICs) with a combination of passive devices — in particular wavelength- and polarization-selective devices — and active devices such as optical modulators and detectors. The ESSenTIAL program has expanded the services of ePIXfab, an alliance of European entities set up in 2006 to support the emergence of a fabless silicon photonics ecosystem. ePIXfab has provided affordable multi-project wafer (MPW) services to fabless R&D teams worldwide developing photonic circuits. European users received some benefits based on European Union

(EU) funding, but the ePIXfab services were provided globally.

"ePIXfab was founded to provide the silicon photonics research community an access path to advanced CMOS technology with the goal of sharing cost and expertise," says Ghent University professor Roel Baets, one of the founders of ePIXfab and research team leader associated with imec. "ePIXfab has helped to accelerate the field of silicon photonics and to let it move from a research field to a field of critical industrial importance," he adds.

Within the ESSenTIAL project, the portfolio of silicon photonics services offered by ePIXfab has been

extended in many ways. High-speed active devices (up to 25Gb/s) were added to the MPW offering. Furthermore, ePIXfab has started to organize extra MPW runs on two silicon photonics technology platforms with unique features, at IHP and at VTT. In total, over 200 silicon photonics circuit designs were prototyped at imec, LETI, IHP or VTT, including nearly 50 designs from companies. Another major achievement of the project was the creation of silicon photonics packaging services at Tyndall.

"Packaging is often seen as the Achilles heel of photonic component technology," notes Peter O'Brien, head of Tyndall's Photonics Packaging Group. "Tyndall Institute has developed a family of solutions, encompassing optical, electrical and RF packaging," he adds.

"These standardized packaging approaches for silicon photonic chips are available to industry through the ePIXfab alliance."

Given the shortage of skilled engineers in silicon photonics, especially at the design level, ESSenTIAL has spent considerable resources on training activities. Over 110 experts were trained in regular six-monthly training events and several hundreds more were reached through webinars. ESSenTIAL has also conducted 80 feasibility studies with European SMEs, resulting in at least 22 new projects and over 30 project proposals.

During ESSenTIAL the MPW operation for silicon photonics was integrated into the Europractice-IC service, marking a milestone for the further growth of Europe's silicon photonics, it is reckoned. "Through the Europractice service, more than 650 European academia and 300 companies worldwide have now access to Si Photonics technologies," says Europractice service chairman Carl Das. "As we have implemented in electronics, we will offer a complete silicon photonics ecosystem to users in open access, thus accelerating product innovations," he adds. Towards this, Europractice-IC now offers periodic and low-cost access to advanced silicon photonics technologies, standardized photonics packaging and photonics design support. Further, access to Europractice-IC's silicon photonics ecosystem can be financially supported for European small- and medium-sized companies via the EU-funded project ACTPHAST (Access Center for Photonics Innovation Solutions and Technology Support).

www.imec.be
www.epixfab.eu/essential-project
www.actphast.eu
www.europractice-ic.com/SiPhotonics_general.php

IHS names Infinera leader in optical networking and data-center interconnect market

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has been named as a leader among the top optical network hardware vendors in the 2015 Optical Network Hardware Vendor Scorecard of IHS (formerly Infonetics Research).

Infinera is described as the "one plus ultra of the rapidly growing Internet content provider and data-center interconnect market". The report further highlights Infinera as a leader not because of size but because of "outstanding customer perceptions, large market share gains and tight finances".

The 2015 Optical Network Hardware Vendor Scorecard profiles, analyzes and ranks the 10 largest global vendors of optical transport equipment. It evaluates the top optical hardware vendors on criteria using metrics that include direct feedback from buyers, vendor market share, market share momentum, financials, brand recognition, reputation for

innovation and other benchmarks. Infinera emerges as one of the three leading optical transport equipment providers worldwide.

"Infinera has excellent scores across the board," says Andrew Schmitt, research director, Carrier Transport Networking at IHS. "Infinera has market presence with excellent scores from customers for product reliability, service and support. The company also had excellent momentum as a result of big market

Infinera has market presence with excellent scores from customers for product reliability, service and support. The company also had excellent momentum as a result of big market share gains in 2014 and is the top perceived vendor when it comes to technology innovation

share gains in 2014 and is the top perceived vendor when it comes to technology innovation," he adds.

"The IHS Optical Network Hardware Vendor scorecard shows that Infinera's focus on customer satisfaction, quality and market-leading innovation continues to resonate with global network operators," says Infinera's CEO Tom Fallon. "We are honored to receive the highest recognition from IHS for the second year running based on our success deploying Intelligent Transport Networks around the world."

Last year IHS (then Infonetics) ranked Infinera as the top optical vendor in its 2014 scorecard as a result of very high ratings among customers for technology innovation, reliability, and service and support. This year, IHS refined its scoring system and classified the top optical hardware vendors into three categories: leader, established or challenger, depending on their overall score.

www.infonetics.com

www.infinera.com

Applied Optoelectronics launches 25Gb/s directly modulated lasers

Applied Optoelectronics Inc (AOI) of Sugar Land, near Houston, TX, USA, a manufacturer of fiber-optic access network products (including components, modules and equipment) for the internet data-center, cable TV broadband, and fiber-to-the-home (FTTH) markets, has launched laser diodes operating at a data rate of up to 25Gb/s.

The new distributed feedback (DFB) lasers are designed for next-generation data centers, where interconnect speeds of 25Gb/s will enable higher data throughput, reduced power consumption, and reduced size.

AOI's proprietary laser manufac-

turing process, using molecular beam epitaxy (MBE), is conducted in-house at a fab in Sugar Land.

"AOI's 18-year history of innovation as a manufacturer of advanced laser diodes has provided a solid foundation of experience, which we have leveraged in the design of these new 25Gb/s devices," says Dr Alex Anselm, VP & head of AOI's Semiconductor Products Division. "Directly modulating lasers at such high frequencies requires precise control over the epitaxy process as well as many novel design features in the devices themselves," he adds. "By utilizing our in-house fab, we were able to optimize the

design quickly and expect to move rapidly into production."

Key technical highlights of the products include: low threshold current (<8mA); high slope efficiency (>0.25W/A); fast rise/fall time (<20ps); a proprietary high-yield device process; and compliance with the Telcordia GR-468 reliability requirements.

The lasers are expected to be used in 100Gb/s QSFP-28 transceivers and light engines, including CLR4 and PSM4, for data-center applications.

Samples are available now, with production beginning in fourth-quarter 2015.

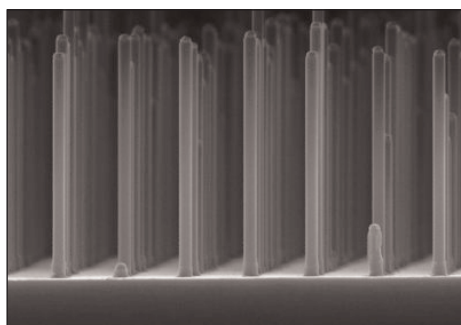
www.ao-inc.com

GaP nanowires boost solar fuel cell efficiency tenfold

Eindhoven University of Technology (TU/e) and FOM Foundation have presented a prototype of a solar cell that produces fuel rather than electricity (Anthony Standing et al., 'Efficient water reduction with gallium phosphide nanowires', Nature Communications (17 July 2015) DOI: 10.1038/nscomms8824).

The electricity produced by a solar cell can be used to set off chemical reactions, which can generate a fuel (a 'solar fuel' – as a promising replacement for polluting fuels). One possibility is to split liquid water using the electricity that is generated (electrolysis). As well as oxygen, the hydrogen gas that is produced can be used as a clean fuel in the chemical industry or combusted in fuel cells (e.g. in cars) to drive engines.

To connect an existing silicon solar cell to a battery that splits water may be an efficient solution now but it is expensive. Many researchers are



Array of GaP nanowires.

hence seeking a material that can both convert sunlight into electrical charge and split the water, all in one. TU/e and FOM see gallium phosphide (GaP) as the ideal candidate.

GaP has good electrical properties but it cannot easily absorb light when it is a large flat surface, as used in GaP solar cells. The researchers overcame this problem by making a grid of very small GaP nanowires (500nm long and 90nm wide). This immediately boosted the yield of hydrogen ten-fold, to 2.9%. This is

a record for GaP cells, but still well below the 15% achieved by silicon cells coupled to a battery.

According to research leader and TU/e professor Erik Bakkers, it is not simply about the yield — where there is still a lot of scope for improvement. "For the nanowires, we needed 10,000 [times] less precious GaP material than in cells with a flat surface. That makes these kinds of cells potentially a great deal cheaper," Bakkers says. "In addition, GaP is also able to extract oxygen from the water — so you then actually have a fuel cell in which you can temporarily store your solar energy," he adds.

The research was performed within the BioSolar Cells program jointly funded by FOM Foundation, NWO (Netherlands Organization for Scientific Research) and the Ministry of Economic Affairs.

www.fom.nl

www.tue.nl

First Solar to power 200MW phase 2 project in Dubai

First Solar Inc of Tempe, AZ, USA is to supply cadmium telluride (CdTe) photovoltaic modules to power the 200MW_{AC} second phase of the Mohammed bin Rashid Al Maktoum Solar Park in Dubai, United Arab Emirates (UAE).

Earlier this year, a consortium led by ACWA Power (a water and power developer, owner and operator based in Saudi Arabia) and Spanish engineering and construction firm TSK was chosen by Dubai Electricity and Water Authority (DEWA) to develop, construct, own and operate the independent power project. The project's tariff of 5.84 cents per kW-hr establishes a global benchmark, it is claimed, reducing the cost of solar electricity by over 20%.

When completed in early 2017, the utility-scale solar plant will be the largest facility of its kind in the Middle East, producing enough energy to power 30,000 average homes in the UAE and displacing

over 469,650 metric tons of CO₂ per year. It will be powered by over 2.36 million modules, compared with the 152,880 that were installed in the 13MW_{AC} first phase of the park. The plant will be built over an area of almost 4.5 million square meters (equivalent to 100 soccer pitches).

"ACWA Power's commitment to deliver reliable and sustainable electricity at the lowest kW-hr tariff is reflected clearly in the win it has secured in the second phase of the Mohammed bin Rashid Al Maktoum Solar Park," says ACWA Power's president & CEO Paddy Padmanathan. "The technology we plan to implement has a proven advantage over conventional solar panels, delivering more annual energy for the same nameplate watts under the specific project conditions of the DEWA project. The organic performance growth program that First Solar is developing with their PV modules sets a benchmark in the PV industry."

"This milestone project will establish a new benchmark for the reliable, affordable and sustainable generation of solar energy in the Middle East and around the world," reckons TSK's procurement managing director & board member Alfonso Targhetta.

"In this competitive environment, the decision to power the project with First Solar technology is testament to the ability of our high-performance modules to reliably deliver energy, even in challenging operating conditions," says Ahmed S. Nada, VP & region executive for the Middle East at First Solar. With this win, First Solar will be the leading PV provider in the Middle East, with installed capacity of 270MW by 2017, he adds. As well as the 13MW_{AC} first phase of the park, its modules are also being installed at the 52.5MW_{AC} Shams Ma'an plant under construction in Jordan (for completion in second-half 2016).

www.firstsolar.com

Final module installed at Australia's largest solar project

First Solar Inc of Tempe, AZ, USA has installed the final cadmium telluride (CdTe) thin-film photovoltaic module at the 102MW_{AC} Nyngan Solar Plant in New South Wales (NSW). Its 1.36 million modules will produce enough electricity annually to power over 33,300 average homes in NSW.

About 25% of generation from block one began in March this year. About half of the plant is now online and delivering energy into the grid. Once complete, the plant will not only be the largest PV plant in the Southern Hemisphere, but also a major milestone for the utility-scale solar industry in Australia.

"First Solar's modules have dramatically improved in efficiency in recent years, and this project demonstrates the increasing commercial competitiveness," claims Jack Curtis, First Solar's regional manager for Asia Pacific. "These 1.36 million modules will have a higher energy yield than traditional crystalline silicon modules, particularly in hot climates, will produce no carbon emissions, and will require no water during operation. Utility-scale solar PV is already cost competitive with conventional gen-

eration in many parts of the world and will increasingly deliver economic stimulus to rural Australia without depleting natural resources."

During the project's planning and construction stages, First Solar worked with the Australian Renewable Energy Agency (ARENA) and Sydney-based integrated energy firm AGL (the largest ASX-listed owner, operator and developer of renewable energy generation) to ensure that the energy industry benefits from their experiences.

"We have published 19 reports covering a range of topics from planning, approvals and logistics to procurement, construction and grid connection," says ARENA's CEO Ivor Frischknecht. "Pooling and sharing this knowledge will make it easier and cheaper to develop large-scale solar plants in Australia by helping reduce financial, regulatory and technical barriers," he adds.

Construction of the Nyngan plant has created over 250 on-site jobs, as well as off-site jobs to supply material as well as roles responsible for the design, management and support of the project.

"First Solar has pursued every opportunity to support local and regional businesses throughout the construction of the Nyngan Solar Plant," says Curtis. "In addition to boosting the local economy through job creation, First Solar supported Australian automotive parts manufacturers who were exploring new business opportunities. They produced vital parts, like mounting structures, transformers and switchgear to the plant."

Local procurement accounted for over 55% of the total procurement spend on the Nyngan Solar Plant.

As well as the Nyngan Solar Project, AGL also engaged First Solar to deliver the 53MW_{AC} Broken Hill Solar Plant, also in NSW (due for completion in November). First Solar has provided engineering, procurement & construction (EPC) services for both projects, and will provide maintenance support for five years once the solar farms are operational. The projects are supported by funding of \$166.7m from ARENA and \$64.9m from the NSW Government.

www.arena.gov.au

www.firstsolar.com

Silicon Ranch selects First Solar for 12MW Aerojet Rocketdyne

First Solar says its CdTe thin-film PV modules and solar tracker racking solution have been chosen by Nashville-based turnkey renewable energy provider Silicon Ranch Corp for installation at its 12MW_{AC} Highland Industrial Park solar field that will provide power to the adjacent 1200-acre manufacturing & test facility of aerospace & defense firm Aerojet Rocketdyne, directly supplementing its daytime operations.

Also, under a unique set of power purchase agreements (PPAs), excess electricity generated by the installation will be released to Arkansas Electric Cooperative Corporation (AECC) of East Camden, AK, and integrated into the cooperative's diverse generation portfolio.

"With its manufacturing facility in Perrysburg, Ohio, First Solar meets Aerojet Rocketdyne's commitment to work with US firms and support domestic development and manufacturing of technology that advances our nation's strategic objectives," says Erik Didriksen, Aerojet's EH&S strategist.

Silicon Ranch's president & CEO Matthew Kisber says the firm's choice was based on First Solar's streamlined Module Plus solution, which is essentially a bundling of First Solar PV modules, wiring and mounting system, pre-engineered to optimize its module technology. The Aerojet project includes a single-axis tracking table mounting system, which allows the modules to follow the sun across its daily arc.

The tracker technology produces up to 25% more energy than fixed mounting systems, and is a configuration preferred by utility-scale solar projects worldwide.

"Silicon Ranch's choice to partner with First Solar shows how this technology contributes to a competitively designed commercial and industrial solar power project," says Dana Diller, First Solar's VP of business development - US. "This market segment includes large-scale business operations seeking ways to save on energy costs while adopting sustainable, environmentally sound purchasing practices. First Solar enables power plant operators and owners to mitigate their risk and maximize their energy return."

www.siliconranchcorp.com

Perovskite PV market to reach \$214m in 2025

Conversion efficiency rises from 2% in 2006 to 20.1% in 2015

In the emerging photovoltaic technology sector, the energy conversion efficiency of perovskite solar cells have improved incredibly quickly, from just 2% in 2006 to over 20.1% in 2015, according to IDTechEx Research's report 'The Rise of Perovskite Solar Cell 2015-2025: Technology, Status and Market', which forecasts that the perovskite PV market will reach \$214m in 2025. Growth will come in the utility (tandem/hybrid cells) and smart window/BIPV (building-integrated PV) applications. However, the take-off will be slower than many anticipate as the technology is not yet production ready and still grapples with issues such as stability and lead toxicity (since alternatives to lead have low efficiency), says the report.

A winner arrives out of the blue?

The dramatic increase in efficiency has also put perovskites on a par with leading thin-film PV technologies such as cadmium telluride (CdTe), copper indium gallium (di)selenide (CIGS) and amorphous silicon (a-Si).

This efficiency improvement also means that perovskites have

already surpassed the likes of organic photovoltaics (OPVs), dye-sensitized solar cells (DSSCs) and amorphous silicon, which have been on the market for some time. Indeed, this has led to the plug being pulled on R&D efforts on OPVs and DSSCs as the community has switched to perovskites en-masse.

Since perovskite materials have a wide bandgap, this creates an opportunity in pairing them up with low-bandgap photovoltaic technology. This can yield several extra efficiency percentage points, which will make a difference in a highly competitive market where system costs depend on efficiencies, says IDTechEx.

In parallel to this, perovskite solar cells offer additional value propositions including: flexibility, semi-transparency, tailored form factors, thin film, light weight, and processing costs. These features are already set to erode much of the uniqueness of its rival technologies, which may make life even harder for applications already pushed to the niche corners of the markets, believes IDTechEx.

Solving technology problems

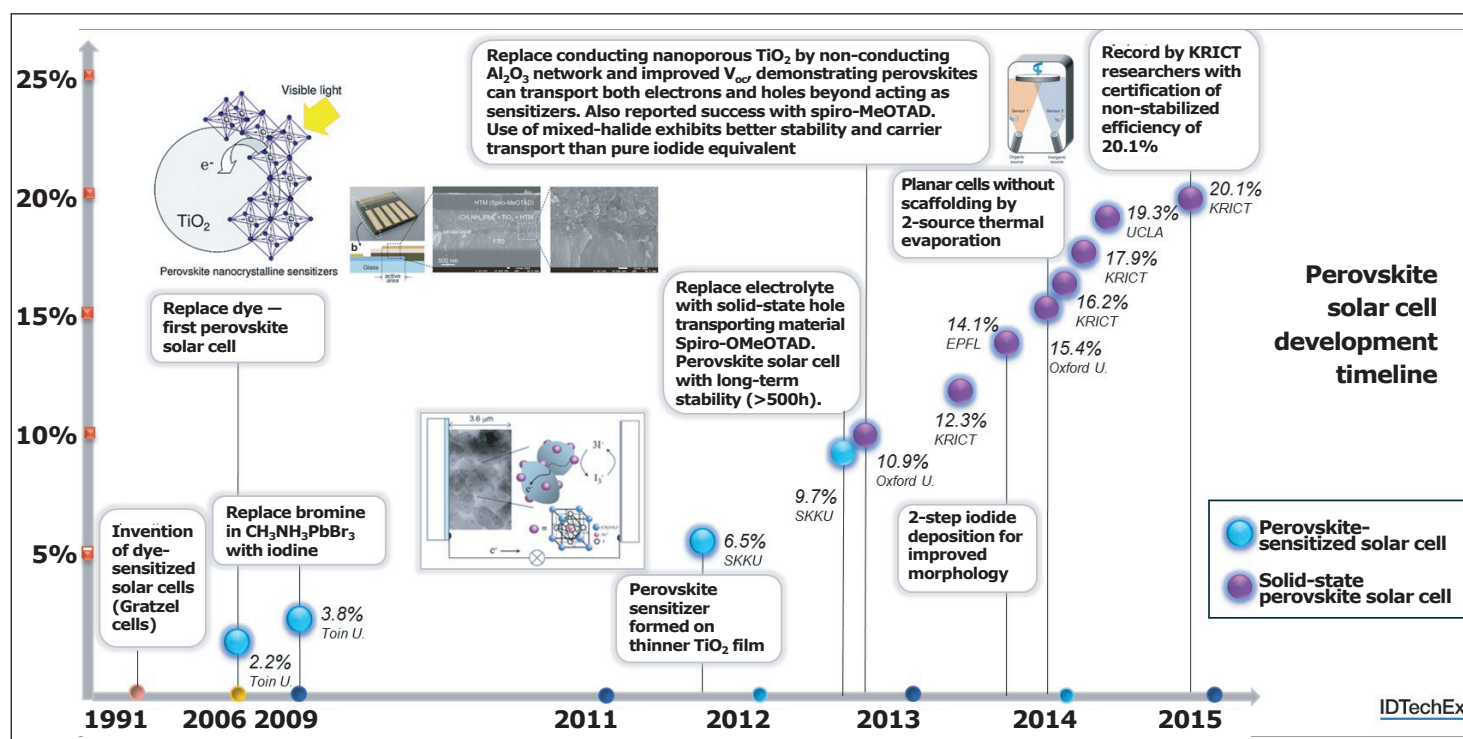
However, the technology is not commercially ready yet. Even the device architecture is in a state of flux. Indeed, the original perovskite started as a simple variant of DSSCs in which a perovskite was just a dye, but the device structure is evolving out of the mould of DSSC into a potential planar architecture system.

The lead toxicity raises the market barrier to entry and adoption risk, particularly in Europe, says IDTechEx. Lead-free versions already exist, but lead substitution incurs a severe penalty in cell efficiency. The trade-off is currently too steep, but research in the pipeline is promising.

Another issue is lifetime, which is a particular challenge because the target applications (such as utility and BIPV) demand long lifetimes.

The instability issues are not yet fully understood. If they are extrinsic, they can be managed by isolating the system using high-performance barriers such as glass or flexible versions being developed for other applications such as OPV and OLEDs. If they are intrinsic, then new material systems must be developed.

www.IDTechEx.com/perov



CIGS and HCPV to be game changers in PV market

The share of global photovoltaic (PV) production capacity taken by conventional crystalline silicon (x-Si) solar technologies is forecasted to decline further, from 84.7% in 2014 to 78.4% by 2019, as they approach their theoretical limit in energy conversion efficiency and as alternative emerging PV technologies increasingly raise the efficiency record, according to the report 'Chasing the Sun: Searching for Game Changers in Disruptive Photovoltaic Technologies' (part of Innova Research's Renewable Energy and Environmental Technologies service).

The report classifies emerging solar technologies into three categories: thin-film PV, including copper indium gallium (di)selenide (CIGS), cadmium telluride (CdTe), thin-film silicon (TF-Si); concentrated PV (CPV), including low-concentrating LCPV and high-concentrating HCPV; and third-generation solar technologies, including organic PV (OPV),

dye-sensitized solar cell (DSSC), copper zinc tin sulfide (CZTS), quantum dot (QD) and perovskite.

"Thin-film and CPV technologies are poised for large commercialization in the near future, while the third-generation PV technologies will still have a long way to go towards that goal," says research director Nancy Wu (lead author of the report).

"Winners among the emerging PV technologies will be CIGS and HCPV," she believes. "Both are benefiting from their outstanding cost-reduction potentials and the feasibility for massive adoption."

CIGS leads thin-film PV expansion, with production capacity growth from an estimated 1.8GW in 2010 to a forecasted 5.6GW in 2019, followed by CdTe growing from 2.5GW to 3.5GW. Meanwhile, production capacities for CPV modules are forecasted to grow from 1.5GW in 2010 to 2.4GW in 2019 (with over 60% of capacity contributed

by HCPV in 2019).

In alternative solar technology, thin-film PV accounts for most merger and acquisition (M&A) activity, followed by CPV, with 24 and 14 deals closed, respectively, from 2010 to 2014. The total values of M&A deals in the thin-film and CPV fields were estimated to be \$1.08bn and \$247m, respectively, in this period.

The USA leads in intellectual property (IP) publication in CdTe, CIGS and CZTS, while Asian countries including China, Japan and South Korea have been catching up in DSSC, QD and perovskite PV technologies over the past five years. The increasing research focus on alternative solar PV technologies, particularly on their efficiency enhancement and stability of the systems, should greatly drive up commercialization in the next few years, reckons Innova Research.

www.innovaresearchinc.com

Imec reports record 11.3% perovskite module efficiency

At its ITF USA 2015 (Imec Technology Forum) in San Francisco in July, nano-electronics research center Imec of Leuven, Belgium reported a record 11.3% aperture-area efficiency and 11.9% active-area efficiency for its perovskite thin-film photovoltaic (TFPV) module. The geometrical fill factor was more than 95%, and the efficiency was measured over an aperture area of 16cm².

Organometal halide perovskites are considered to be excellent material for thin-film solar cells, as they have shown high conversion efficiencies at the cell level. While the power conversion efficiency of this new class of thin-film solar cells has grown rapidly in the last few years, further improvements are still needed to make thin-film photovoltaics an attractive technology for industrial production, says Imec. Larger-area processing and narrow interconnections are prerequisites for processing efficient thin-film modules.

The record devices have been fabricated using a conventional lab-scale spin coating process. Imec also used a linear coating technique (blade coating) for all the solution-based layers, to prove the industrial viability of the fabrication methods. The modules hence achieved a 9% aperture-area efficiency. Imec reckons these achievements are breakthroughs in bringing thin-film PV technology to industrial scalability for applications such as building-integrated photovoltaics (BIPV).

"Imec is steadily improving the conversion efficiencies of its perovskite solar cells and at the same time adjusting the fabrication processes to enable industrial adoption of this promising technology," says Tom Aernouts, R&D manager for thin-film PV. "Leveraging our expertise in organic photovoltaics enables us to make rapid progress in enhancing the conversion efficiencies, ultimately aiming at conversion

efficiencies of more than 20% for this type of thin-film solar cells."

Imec is developing a platform for glass-based perovskite modules and collaborates with the cross-border Dutch-German-Flemish thin-film PV research initiative Solliance, which involves the partners ECN, Imec, TNO, Holst Centre, TU/e, Forschungszentrum Jülich, University Hasselt and Delft University of Technology. Due to its high power conversion efficiency and stand-alone integration in building elements, both glass-based and thin-film perovskite PV technology are widely considered to be key technologies for the BIPV market. Also, Imec is exploring stacking a perovskite cell on top of a silicon solar cell to raise the conversion efficiency of silicon solar cells. The perovskite cell will capture the light that is not absorbed by silicon, enabling conversion efficiencies of over 30%.

www.imec.be

Solar Frontier continues global expansion by opening UK office

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — says its subsidiary Solar Frontier Europe GmbH of Munich, Germany has opened an office in London, enabling it to scale up its residential and commercial rooftop and power plant business in the UK (meeting local demand for solar energy solutions and services). The firm says that the new branch demonstrates its continued commitment to the European market, in particular the UK (one of the fastest-growing solar markets in Europe).

“The UK office is an important step in Solar Frontier’s global expansion strategy to further grow our business in key global markets,” says Solar Frontier Europe’s managing director Wolfgang Lange. “We look forward to developing CIS solar power solutions alongside our partners in the UK with the high level of commitment and service that differentiates Solar Frontier even in its home market of Japan, where demands for quality are formidable.”



The 7.15MW Banwell Project in the UK.

Solar Frontier has been active in the UK market since 2012. Notably, it supported solar engineering, procurement & construction (EPC) provider

Solar Frontier claims that, due to their CIS technology, its modules are well suited to the UK climate due to excellent low-light performance as well as continued output under partial shading. These characteristics mean higher electrical output in real-world conditions

Belectric with delivery of a 16.5MW ground-mounted installation in Turweston in 2014. Also, in May, Solar Frontier entered into an agreement with New Energy for the World (NEW) to develop several solar projects in the UK market. The first of these projects (a 7.15MW CIS solar power plant in Banwell) was recently sold to an alternative asset manager shortly after coming on-stream in March.

Solar Frontier claims that, due to their CIS technology, its modules are well suited to the UK climate due to excellent low-light performance as well as continued output under partial shading. These characteristics mean higher electrical output in real-world conditions, the firm adds.

www.solar-frontier.eu

Solar Frontier’s prototype ultralight, bendable CIS modules installed at PSA Singapore Terminals

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has completed the first installation of its prototype ultralight and bendable CIS thin-film modules. Developed at Solar Frontier’s Atsugi Research Center in Japan, the new modules were installed at the Pasir Panjang Terminal Building 3 of PSA Singapore Terminals (which operates the world’s largest container transshipment hub).

“Alongside our electrically powered automated Rail Mounted Gantry cranes at our new terminals, these solar modules will also help to

reduce PSA’s carbon footprint as we continue to promote environmental sustainability,” comments Tan Chong Meng, group CEO of PSA International.

“These modules are ultralight, thin and bendable, increasing the ways in which solar energy can be used and opening the way for potential new markets,” says Solar Frontier’s CEO Atsuhiko Hirano.

Unlike crystalline silicon technologies, the properties of CIS enable it to be used to create ultralight, thin and bendable products, and Solar Frontier has developed a new production process to achieve

this, says the firm. Compared to standard modules, the glass substrate layer has been replaced with a bendable and thin metal substrate, the cover glass has been replaced with a high-performance resin film cover, and the frames have been removed. These changes enable a thickness of just 1.5mm, and a weight one-third that of standard modules.

Solar Frontier says that the new features of its prototype modules enable them to be used for a wider range of applications, making solar energy more accessible in the future.

www.singaporepsa.com

Solar Frontier surpasses 3GW of CIS module shipments

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has marked the milestone of shipping more than 3GW of its CIS modules worldwide to date. It is 4 years since the first CIS modules were shipped from Solar Frontier's 900MW Kunitomi Plant in Miyazaki Prefecture, Japan, and 8 years since the firm first commercialized its technology in 2007.

Solar Frontier has now shipped CIS modules directly to 47 countries around the world, proving their real-world performance in different environments ranging from Farasan Island in Saudi Arabia (where the temperature reaches 40°C) to Lithuania (where the temperature can be as low as -20°C). Solar Frontier's biggest CIS project (the 82.5MW Catalina Power Plant in the

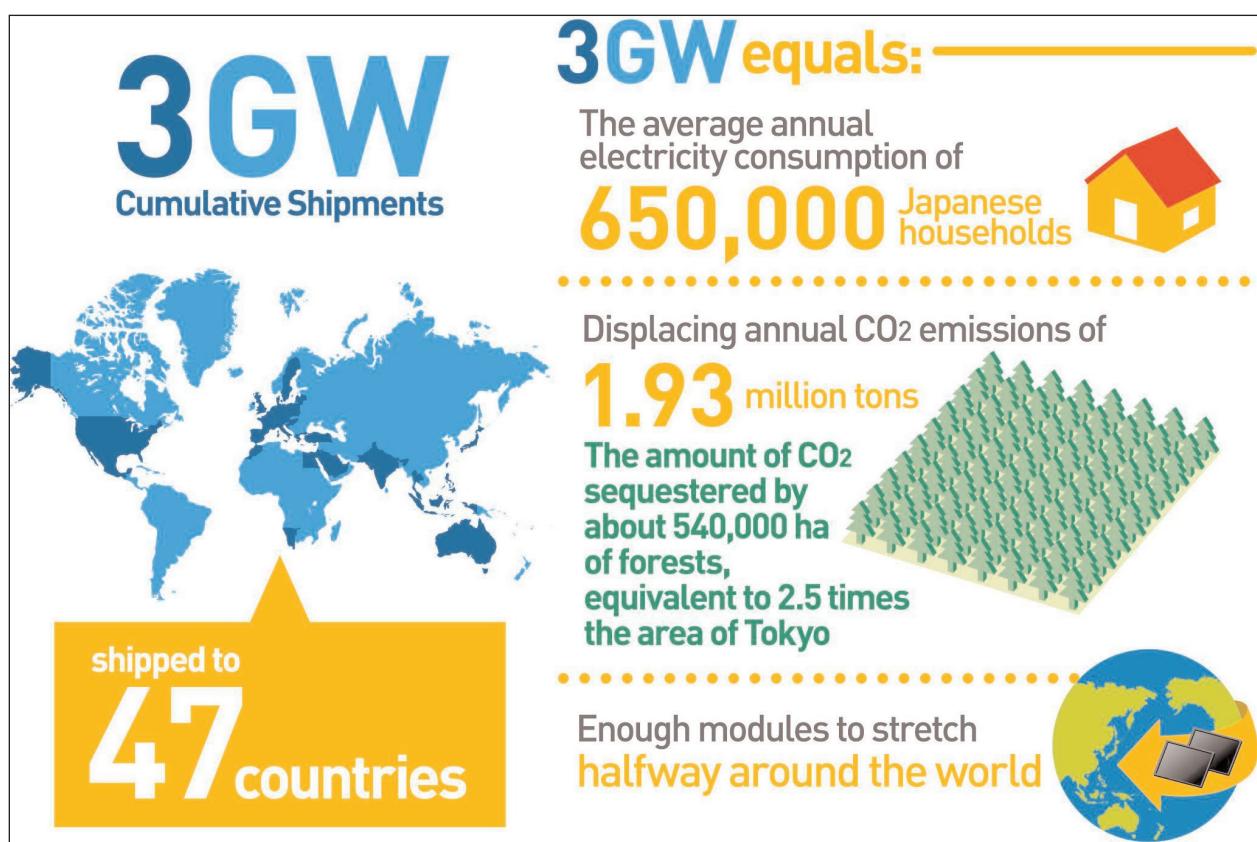
USA) is also the world's largest CIS installation, and has been recognized as the winner of the Intersolar North America Project of the Year Award.

Solar Frontier says that 3GW of CIS modules generates the equivalent of 3679GWh, which could completely power 650,000 households in Japan, Solar Frontier's home market. It is also equivalent to displacing 1.93 million tons of CO₂ emissions per year (the same amount of CO₂ sequestered by about 540,000ha of

forests). Also, since the 3GW of shipments represents about 20 million modules, Solar Frontier's factories have now produced enough modules to reach halfway around the world if laid end-to-end.

"Solar Frontier is now building on its 3GW shipment achievement, supplying CIS modules to more homes and businesses, as well as developing utility-scale power plants around the world," says president & CEO Atsuhiko Hirano.

www.solar-frontier.com



Solar Frontier accepts Intersolar Project Of The Year award

Solar Frontier has accepted the Intersolar North America Project of the Year Award for the 143.2MW Catalina Solar Project (the largest CIS installation in the USA), which includes 82.5MWp of Solar Frontier's CIS modules. The award recognizes landmark projects that exemplify technological innovation, uniqueness, economic feasibility, and benefit to the environment and society.

Developed by EDF Renewable Energy and located in the Mojave Desert in Kern County, Southern California, the Catalina Solar Project employed over 500 workers onsite during construction.

The project was built by Bechtel Power Corp in a rugged desert terrain known for its extreme climatic conditions. Solar Frontier says that its CIS module technology is less impacted by these temperatures

and can deliver higher energy yields than conventional crystalline silicon modules.

"It is another example for investors and project developers to take note of the strength of our technology's performance and our growth in the US market," comments Charles Pimentel, chief operating officer of Solar Frontier Americas.

www.solar-frontier.com

SoloPower to be acquired by London-based Opera Investments for \$220m

Reverse takeover to be finalized by end of Q3

London-based Opera Investments plc (which was formed to acquire businesses or assets in the natural resources sector) has reached a non-binding heads of terms agreement to acquire SoloPower Systems Holdings Inc of Portland, OR, USA for \$220m from New Jersey-based Hudson Clean Energy Partners (a global private equity firm dedicated to investing in renewable power, alternative fuels, energy efficiency and storage) in a reverse takeover transaction that is expected to be finalized in late third-quarter 2015.

SoloPower designs, manufactures and deploys copper indium gallium diselenide (CIGS) thin-film solar photovoltaic (PV) cells and modules on a flexible substrate using a con-

tinuous, roll-to-roll process. The firm targets commercial, industrial and residential rooftop installations through project developers, utilities and/or intermediate distributors. SoloPower claims that its modules can be sold into both established markets (where it achieves lower installation costs by eliminating mounting systems) and new markets (where the lightweight properties allow installation on roofs that cannot otherwise support the weight of a conventional PV system).

The acquisition will involve the issue of new ordinary shares of £0.01 each in Opera to Hudson at a price of £0.28 per Opera share, valuing the existing issued share capital of Opera at £4.8m. In addi-

tion, on completion of the acquisition, an equity financing aims to raise net proceeds of at least \$40m to fund certain future investment and working capital requirements of SoloPower.

"We are delighted to have found such an attractive acquisition target so soon after Opera's formation and listing in April," says Opera's chairman Paul Dudley. "The proposed transaction will give a strong platform from which to grow SoloPower as a pioneer in flexible and lightweight high-performance solar materials and to realise value for its current and future stakeholders," he adds.

www.SoloPower.com

www.operainvestmentsplc.com/company-documents

Singulus launches modular inline sputtering systems for CIGS, CdTe and heterojunction solar cell production

Singulus Technologies AG of Kahl am Main, Germany says that it has taken its product family of vacuum coating systems for solar technology to the next development level and introduced and installed inline sputtering system for copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe) thin-film photovoltaic solar cell production as well as tasks for manufacturing heterojunction cells.

The systems are available with vertical as well as horizontal substrate transport and can be configured for various substrate sizes. They are also suitable for challenging layer stacks and flexible product mixes.

Typical applications include, for example, anti-reflection coatings and barrier coatings, buffer and precursor layers such as copper-gallium, indium, and i-ZnO, but also different metallic layers like Mo, Al, Cu, Ag and NiV, as well as transparent conductive oxide layers

like ITO and AZO, which are necessary for new heterojunction cell technology.

The systems use an inline process in which the substrates are transported on a specially designed conveyor on flat carriers that can be configured flexibly for different substrate formats and materials (e.g. solar wafers). Different automation options for loading and unloading are available.

The Vistar system (with vertical substrate transport) and the Histaris system (with horizontal transport) have been designed to enhance the efficiency of thin-film solar cells while cutting production costs by using state-of-the-art technologies. The machines have the advantage of what is claimed to be outstandingly even coating thicknesses and highly homogeneous coatings. Cell performance is appreciably improved. Due to their modular structure the systems are versatile to use and have a com-

pact design, significantly reducing the production area occupied and therefore cutting investment outlay. High reliability and the easy-to-service design principle boost uptime and slash production costs, claims Singulus.

Through its production systems, Singulus supplies wet-chemical processing, coating machines and selenization systems for second-generation CIGS/CIS cells. Inline sputtering systems add a further production stage to the portfolio, which already spans the key processes of CIGS/CIS cell production.

In light of the anticipated volume of investment in production lines for CIGS/CIS thin-film solar cells, Singulus believes the long-term prospects of the solar segment are bright.

Singulus exhibited at Intersolar North America 2015 in San Francisco (14–16 July).

www.singulus.de

XsunX wins contracts to design and build two large commercial solar projects

XsunX Inc of Aliso Viejo, CA, USA, which is developing hybrid copper indium gallium (di)selenide thin-film (CIGS) photovoltaic (TFPV) cell technologies and 'CIGSolar' manufacturing processes, has signed contracts to design and build two commercial solar systems in Southern California valued at \$650,000.

An executive office facility in Anaheim has contracted XsunX to install a 160kW solar car-port system designed to offset about 80% of its existing energy use. The operating cost savings, and investment benefits, allow the system to provide a 100% return on investment in just over four years, while continuing to provide over \$1m in cost savings through the warranted life of the

system, says the firm.

Following soon after the 160kW agreement, XsunX also signed a contract with a Japanese automation systems manufacturer to implement a 78kW rooftop solar system. This system offsets about 75% of energy use, achieving a 100% return on investment in just over three years while also saving the customer nearly \$600,000 in electrical expenses over the warranted life of the system, adds the firm.

XsunX says that the two deals, in addition to more in the business development pipeline, are indicative of the momentum achieved through its customer service and cost-efficient pricing. Specifically, its recent strategic expansion of

operations to include direct design and construction of solar car-port systems continues to pay dividends, as it has provided the capabilities needed to offer larger, diverse solutions with corresponding investment economics for clients. XsunX says this has yielded interest from a number of organizations, including non-profits, automotive sales dealerships, and niche facilities such as a southern California brewery.

"XsunX continues to leverage its background in construction to achieve the lowest price points," says CEO Tom Djokovich. "As a result, we are quickly establishing ourselves as one of the most cost efficient solar providers for rooftop, as well as car-port, solar systems."

XsunX leverages construction expertise to drive sales

XsunX says that it has seen rapid growth in customer interest resulting from its recent strategic expansion of operations to include direct design and construction of solar carport systems. This has allowed the firm to significantly reduce costs, and offer a more

rapid return on investment (ROI) for customers who purchase its solar power systems.

With over 1.3MW in pending solar carport proposals already under customer review, XsunX secured its first carport design/build agreement for a 160kW system in

Anaheim, CA. The firm is optimistic in its belief that this sale is a strong indicator of customer interest for future agreements, specifically for businesses and organizations seeking to implement cost efficient solar power carports.

www.xsunx.com

Ascent Solar announces preliminary second-quarter revenue of \$2.2m, up 233% on first quarter

For second-quarter 2015, Ascent Solar Technologies Inc of Thornton, CO, USA - which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules integrated into off-grid applications and its EnerPlex series of consumer products - has reported preliminary revenue of \$2.2m, a threefold increase on first-quarter 2015, due to a strong shipment backlog carried over from Q1.

For first-half 2015, revenue is expected to be \$2.9m, reflecting significant growth of about 60% year-on-year.

Second-half 2015 has traditionally been a stronger sales period for the firm, as well as for the consumer electronics sector overall, taking into account the holiday selling season. With shipments already lining up for the rest of the year and a stronger retail presence established, Ascent Solar reiterates its earlier revenue guidance of \$10-12m for full-year 2015, approximately doubling on 2014.

"We remain extremely upbeat for the second half of the year, given the increased visibility of our EnerPlex products in a growing number of reputable retailers," says presi-

dent & CEO Victor Lee. "With launches into several retailers during the first half of the year, we feel confident in confirming our previously issued fiscal-year 2015 revenue guidance," he adds. "We are also seeing increasing traction in the focused high-value photovoltaic [PV] market, as our lightweight flexible PV panels are entering into a mature development stage for some applications such as PV-integrated drones and other high-margin PV applications, which we believe will add to our revenue velocity in second half 2015."

www.AscentSolar.com

Room-temperature wafer bonding for multi-junction III-V solar cells

AlGaAs and InGaAs cells exhibit lowest electrical and optical losses ever reported.

Researchers based in Japan and China have demonstrated a room-temperature wafer bonding technique to make multi-junction III-V solar cells [Masayuki Arimochi et al, Jpn. J. Appl. Phys., vol54, p056601, 2015]. The team from Sony Corp in Japan and the Chinese Academy of Sciences’ Suzhou Institute of Nanotech and Nano-bionics say that this is the first time that such methods have been used for solar cells consisting of aluminium gallium arsenide (AlGaAs) and indium gallium arsenide (InGaAs) absorbing layers.

The researchers comment: “To the best of our knowledge, the obtained GaAs || InGaAs and AlGaAs || InGaAs wafer-bonded solar cells exhibited the lowest electrical and optical losses ever reported.”

The team believes that wafer bonding can overcome the problems of lattice matching that occur when monolithic multi-junction devices are produced. However, wafer bonding techniques often require high-temperature annealing that can lead to wafer bending and void formation, along with dopant diffusion. These factors increase electrical resistance and create optical losses.

Room-temperature bonding has been developed for photovoltaic devices involving a combination of III-V materials with silicon, e.g. AlGaAs || Si, InGaP/GaAs || Si and InGaP || Si. The researchers report: “Nevertheless, there have been no reports on room-temperature wafer-bonded solar cells that consist of only compound semiconductors, to the best of our knowledge.”

The solar cell materials were grown using metal solid-source molecular beam epitaxy under ultra-high

GaAs:Si contact	300 nm	3×10 ¹⁸ cm ⁻³	Bonding interface
AlInP:Si window	20 nm	1×10 ¹⁹ cm ⁻³	
GaAs:Si emitter	200 nm	6×10 ¹⁷ cm ⁻³	
GaAs:Be base	740 nm	7×10 ¹⁶ cm ⁻³	
InGaP:Be BSF	500 nm	2×10 ¹⁸ cm ⁻³	
GaAs:Be bonding	30 nm	2×10 ¹⁹ cm ⁻³	
InP:Si bonding	50 nm	5×10 ¹⁸ cm ⁻³	
InGaAs:Si emitter	200 nm	2×10 ¹⁸ cm ⁻³	
InGaAs:Be base	3000 nm	7×10 ¹⁶ cm ⁻³	
InP:Be BSF	50 nm	3×10 ¹⁸ cm ⁻³	
InGaAs:Be buffer	500 nm	3×10 ¹⁸ cm ⁻³	
p-InP(100) substrate			

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p-InP(100) substrate			

Figure 1. (a) GaAs || InGaAs and (b) AlGaAs || InGaAs room-temperature wafer-bonded solar cell structures. Electrodes and etched contact layers are omitted.

Table 1. Typical electrical properties of GaAs || InGaAs and AlGaAs || InGaAs room-temperature wafer-bonded solar cells along with single-junction solar cell properties under 1 sun AM1.5G spectrum. Shadow losses of bonded samples are 1% and 5%, respectively.

	Short-circuit current	Open-circuit voltage	Fill factor	Efficiency
GaAs single-junction	27.2mA/cm ²	0.99V	79.5%	21.4%
InGaAs single-junction	48.9mA/cm ²	0.31V	65.4%	10.0%
GaAs InGaAs wafer-bonded	20.7mA/cm ²	1.26V	81.0%	21.1%
AlGaAs single-junction	22.7mA/cm ²	1.05V	79.7%	19.0%
AlGaAs InGaAs wafer-bonded	21.4mA/cm ²	1.32V	77.8%	22.1%

vacuum rather than metal-organic chemical vapor deposition (MOCVD) — avoiding residual impurities from organic precursors. The group III metals (Ga, Al, In) were supplied from effusion cells. The arsenic source was a valved cracking cell.

GaAs was used as a substrate for AlGaAs and GaAs solar cells. The $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$ solar cell used a (001) InP substrate. The InGaAs solar cells were grown at 495°C. For the other devices, arsenide and phosphide layers were grown at 580°C and 510°C, respectively, apart from AlGaAs that was deposited at 710°C to improve quality. The lattice mismatch of all the structures was less than 10^{-4} , according to x-ray analysis. Phosphides were used for window and back surface field (BSF) layers.

The InGaAs bottom-cell devices were wafer bonded at room temperature to either GaAs and AlGaAs cells (Figure 1). Before bonding, the back-side of the InGaAs cell was given p-ohmic contacts of gold/zinc/gold/chromium/gold by evaporation and annealing at 400°C for 3.5 minutes. The bonding surfaces were further prepared by planarization with chemical mechanical polishing (CMP).

During room-temperature bonding, the surfaces were irradiated with argon ions to create dangling bonds. The bonding force was 5000N. The n-ohmic contacts were formed after bonding with gold-germanium/nickel/gold fingers. The exposed GaAs surface was etched before RF sputtering of an anti-reflective coat of reflectivity $\sim 3.5\%$. The devices were completed with 10 minutes of 350°C annealing of the n-contacts and dicing into 5mmx5mm chips.

Theoretical estimates of wafer-bonded AlGaAs || InGaAs solar cells suggested a peak efficiency of 33% for a structure with 11% aluminium-content AlGaAs. A GaAs || InGaAs solar cell would have 25% efficiency in the same calculation. The measured efficiencies fell short of these values (Table 1).

In particular, the AlGaAs cell was found to have a lower open-circuit voltage 1.05V rather than the 1.11V expected from the GaAs cell voltage plus 0.12V for the difference in bandgap. The researchers suggest that “the quality of the AlGaAs single-junction solar cell was not sufficient, despite the high-temperature AlGaAs growth”.

The voltage drop across the wafer bond was estimated at 0.04V, suggesting low electrical loss from this factor. The current mismatches between the cells adversely affected the short-circuit currents of the bonded devices, impacting efficiency benefits. The efficiency increased to 27.7% for an AlGaAs || InGaAs structure under 120-sun illumination (Figure 2).

The series resistance also increased under concentrated illumination to $4 \times 10^{-2} \Omega\text{-cm}^2$ at 120 suns. Previous experiments with p^+ -GaAs/n-InP wafer bonding

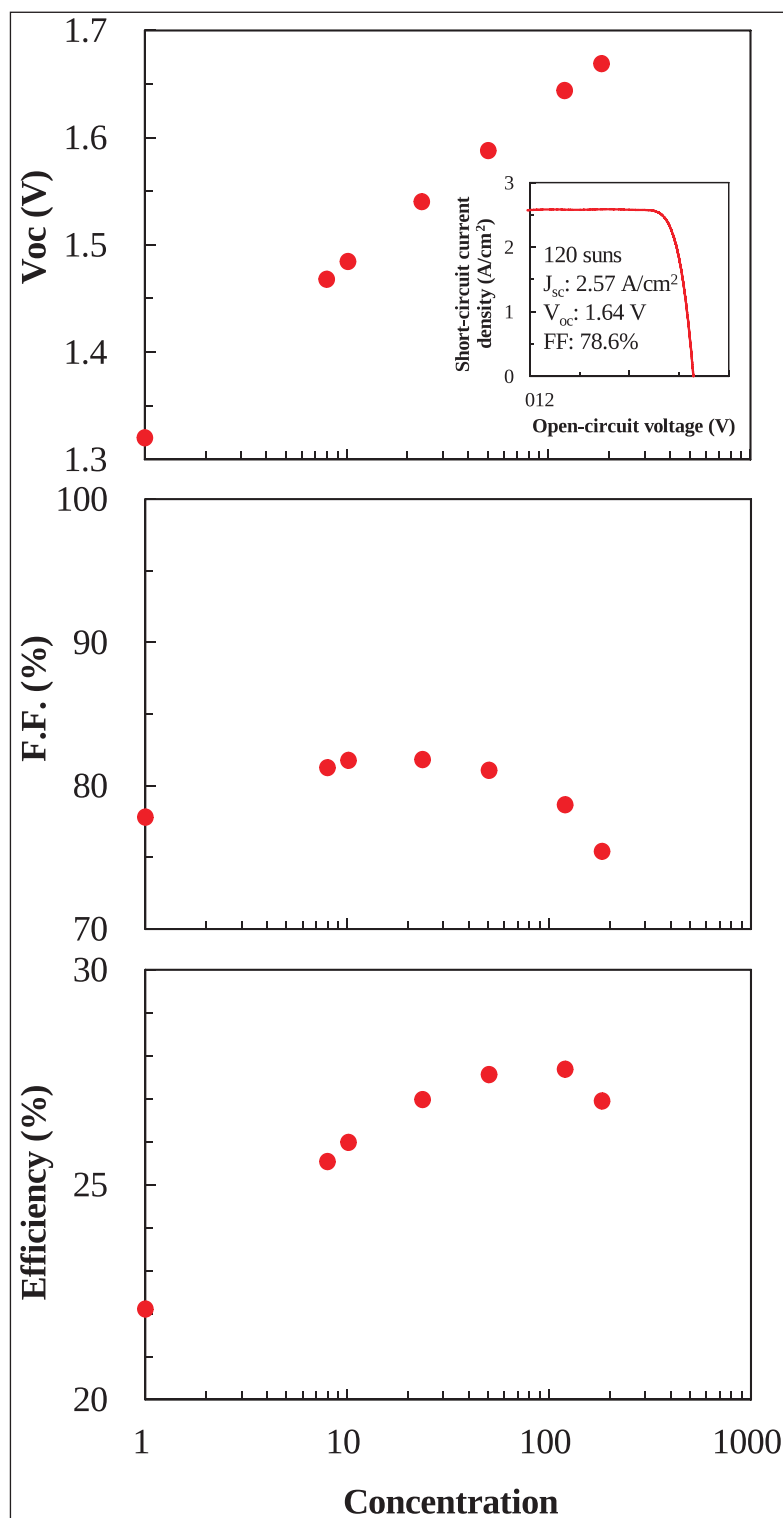


Figure 2. Solar cell properties of AlGaAs || InGaAs wafer-bonded solar cell as function of solar concentration ratio under AM1.5G spectrum. Inset: current-voltage characteristic at 120 suns.

interfaces suggest that the resistance should be as low as $2.5 \times 10^{-5} \Omega\text{-cm}^2$. The researchers believe that some of the problems at high concentration are due to the grid electrode being too thin (400nm) to handle the current generated. ■

<http://dx.doi.org/10.7567/JJAP.54.056601>

Author: Mike Cooke

Laser diodes for mid-IR spectroscopy

Mike Cooke reports on developments of devices around the $3\mu\text{m}$ wavelength carbon-hydrogen bond fingerprint region.

While laser diodes (LDs) are well established for applications in the visible and near-infrared parts of the spectrum, longer-wavelength mid-infrared devices are still in development. In particular, new device structures such as quantum cascade lasers (QCLs) and interband cascade lasers (ICLs) are the subject of much research and companies are keen to drive and commercialize these technologies into new products.

Spectroscopy is an application where laser diodes can be used to create low-cost, compact devices with a wide range of uses such as chemical analysis and medical inspection. Mature laser diode technology in the near infrared ($0.75\text{--}1.4\mu\text{m}$) is already being deployed in this application.

However, wavelengths longer than $2.4\mu\text{m}$ (short-infrared) and up into the mid-infrared ($3\text{--}5\mu\text{m}$) provide more detailed information about many molecules. For example, the $3\mu\text{m}$ region of the mid-infrared spectrum can be used to study stretch vibrations in carbon-hydrogen bonds. Most organic materials have such bonds and the different spectroscopic responses can be used to "fingerprint" particular molecules. For such fingerprinting, one seeks strong absorption cross-sections and high spectral selectivity.

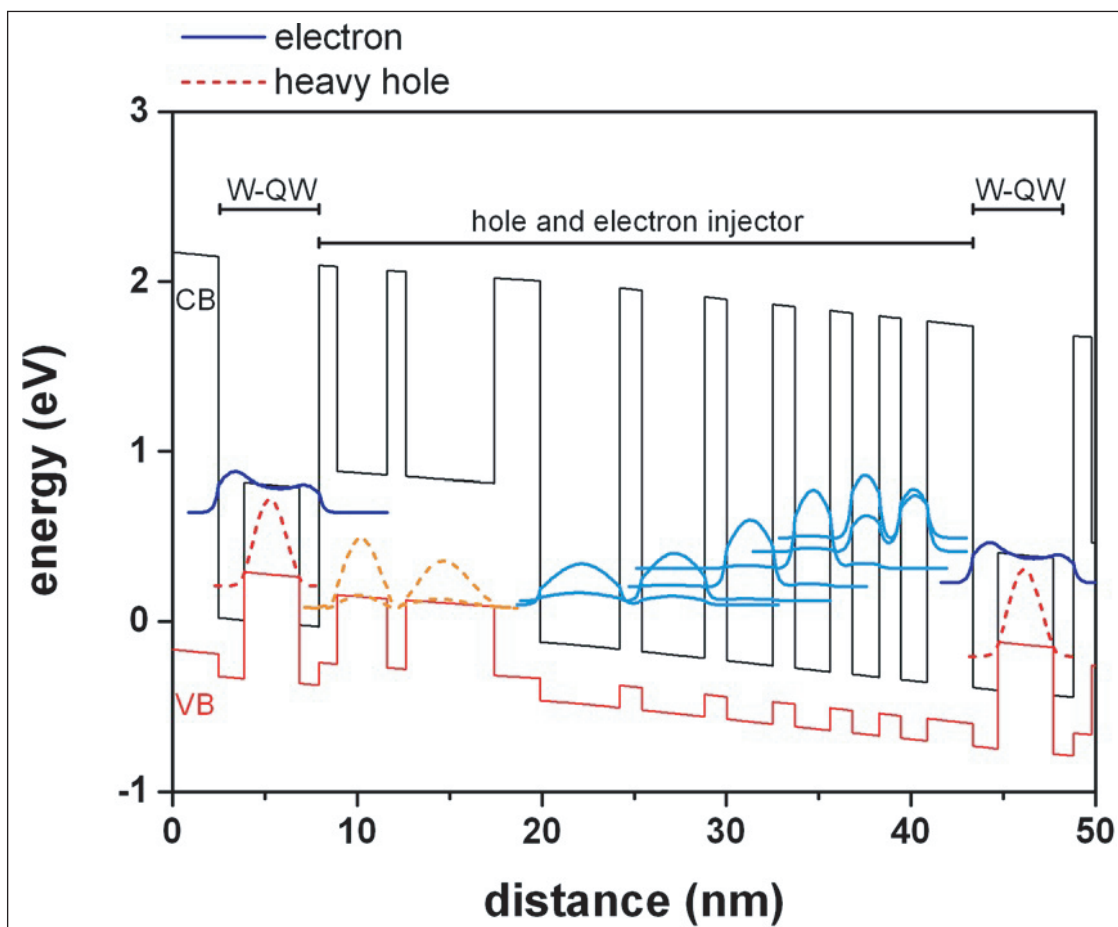


Figure 1. Band structure of conduction and valence bands for one and a half stages, containing two W-QWs and respective hole and electron injectors. Dashed (solid) lines depict absolute moduli square of heavy hole (electron) wave functions at W-QW as well as in injector region.

In addition to QCLs ($3\text{--}10\mu\text{m}$) and ICLs ($2.7\text{--}5.5\mu\text{m}$), some more traditional and mature quantum well laser technologies reach out to these wavelengths. Here, we look at some recent research seeking to provide laser diode technology for $\sim 3\mu\text{m}$ spectroscopy.

Reducing interband cascade wavelengths

Researchers based in Germany and UK claim record short $2.8\mu\text{m}$ wavelength performance for interband cascade lasers [Julian Scheuermann et al, Appl. Phys. Lett., vol106, p161103, 2015].

The team from nanoplus Nanosystems and Technologies GmbH and Universität Würzburg in Germany and University of St Andrews in the UK are interested in tunable laser absorption spectroscopy (TLAS) or other spectroscopic analysis.

nanoplus provides ICL laser diodes with 3–6 μm wavelength with a view to spectroscopy. Their devices have recently been used in an optical feedback cavity-enhanced absorption spectroscopy (OF-CEAS) experiment where the minimum detectable absorption coefficient for a methane (CH_4) wavelength at 3.24 μm , corresponded to 3 parts per billion sensitivity at atmospheric pressure [K. M. Manfred et al, Appl. Phys. Lett., vol106, p221106, 2015].

ICLs are seen as a sort of hybrid of traditional diode and quantum cascade laser technology. The “sweet spot” for emissions is in the range 3.6–3.8 μm . Advantages of ICLs over QCLs are lower threshold currents and power consumption. However, ICLs generally have lower output power.

A 5-stage structure was grown on tellurium-doped gallium antimonide (GaSb) using solid-source molecular beam epitaxy.

The stages (Figure 1) included a W-type quantum well with 2.5nm AlSb/1.4nm InAs/3.0nm $\text{Ga}_{0.65}\text{In}_{0.35}\text{Sb}$ /1.1nm InAs/1.0nm AlSb. The electron injector region consisted of six InAs/AlSb pairs with the five nearest to the W-QW highly silicon doped to encourage carrier rebalancing. Although the paper does not report the structure of the hole injector, it seems likely to consist of GaSb/AlSb layers.

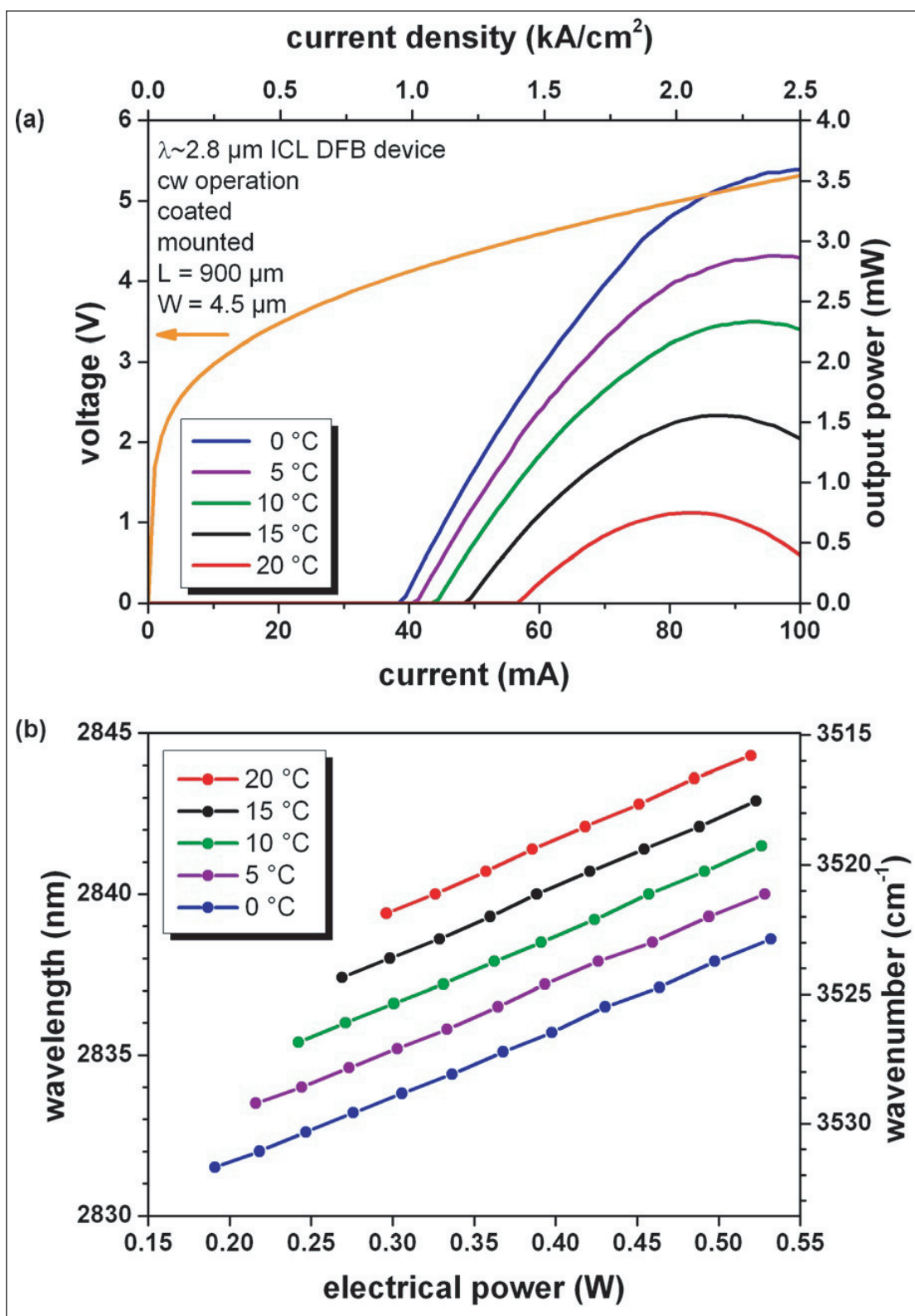


Figure 2. (a) Light output, current and voltage characteristics of ICL DFB device at temperatures ranging from 0°C to 20°C in cw operation. (b) Respective tuning diagram, showing range of single-mode operation.

The ICL region was sandwiched in a waveguide with 200nm GaSb confinement on each side and 1.5 μm /2.5 μm upper/lower cladding with InAs/AlSb superlattice layers. The confinement and cladding were separated by transition layers that smoothed the conduction-band discontinuity.

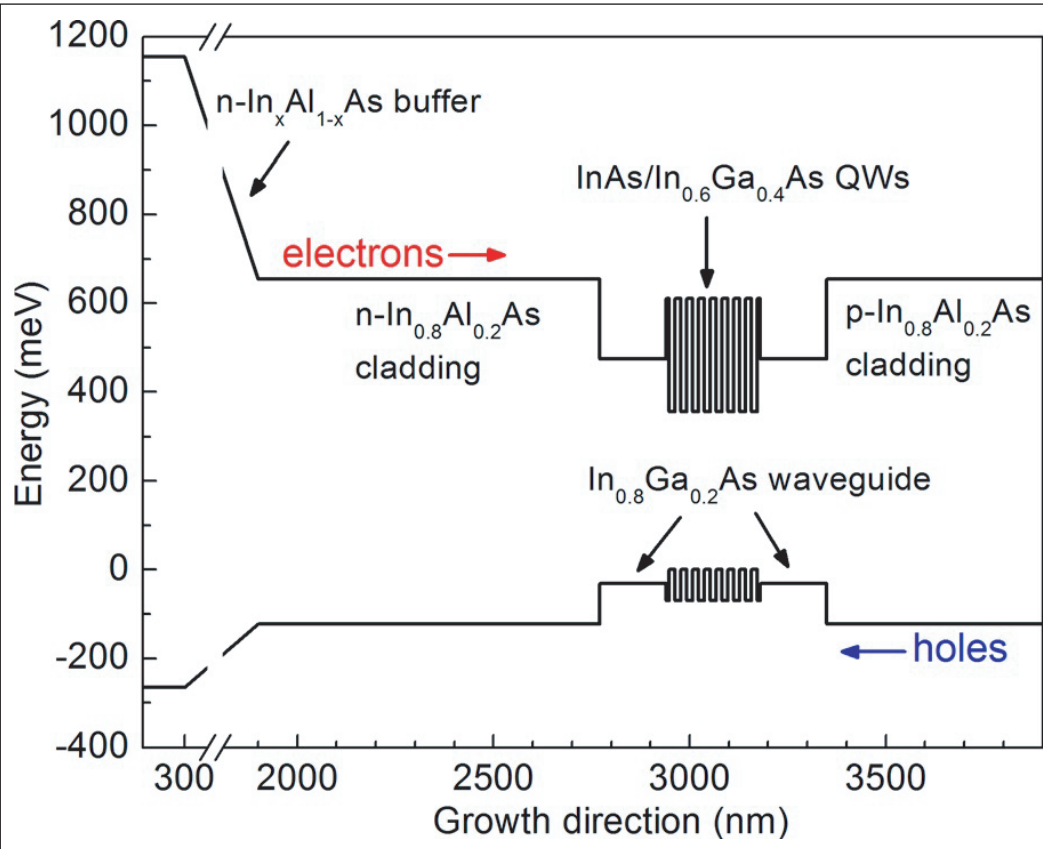


Figure 3. Energy-band structure of InP-based metamorphic type-I QW laser. Injection directions of electrons and holes are indicated.

The characteristic temperature for the threshold (T_0) of the broad-area ICL was 67K, claimed as a record for ICL material by the researchers. The emission wavelength peaked around 2.84 μ m.

Narrow-RWG laser diodes with 3mm long, 7.8 μ m-wide cavity had continuous wave (cw) output power of more than 11mW at 20°C. These diodes emitted laser light up to 50°C. Previous reports of ICLs with emission wavelengths shorter than 3 μ m have been for broad-area devices in pulsed operation.

The DFB output up to a few milliwatts (less than 4mW) in cw operation at room temperature. The threshold was at 1.4kA/cm². The threshold power was 6.2kW/cm² — much lower than the best indium phosphide QCLs reported so far.

Current based tuning (Figure 2) gave a 7nm wavelength range (21nm/W, 0.13nm/mA). Combining current and temperature (0.29nm/K) tuning extended this to 12nm. The researchers say that this is more than sufficient for TLAS. By varying the DFB gratings, wavelengths between 2777.5nm and 2928.8nm, a range of more than 150nm, could be produced.

Antimony-free QW

China’s Shanghai Institute of Microsystem and Information Technology has developed a long-wavelength indium arsenide (InAs) QW laser diode grown on indium phosphide (InP) substrate [Y. Gu et al, Appl. Phys. Lett., vol106, p121102, 2015]. The researchers claim the longest wavelength achieved, 2.9 μ m, as a record for antimony-free (Sb) structures.

Antimony-based semiconductor lasers can achieve 3 μ m cw operation at room temperature, using gallium antimonide substrates. However, GaSb is more expensive than InP and presently is of lower quality. Further, GaSb-based devices suffer thermal management problems due to its low thermal conductivity.

Gas-source molecular beam epitaxy (GS-MBE) was used to grow the laser structure (Figure 3) on sulfur-doped (001) n-InP. An indium aluminium arsenide template/cladding layer of 0.87 μ m metamorphic n-In_{0.8}Al_{0.2}As (485°C) was grown on 1.6 μ m compositionally graded InAlAs buffer (495–455°C) on top of

➤ Broad-area, ridge-waveguide (RWG) and distributed feedback (DFB) devices were produced from the epitaxial material. The RWG and DFB laser diodes were passivated with silicon nitride and silicon dioxide.

For the DFB laser diodes, metal gratings on the sides of the ridges were used for longitudinal mode selection. The top contact metals were sputtered. Electrochemical deposition of 10 μ m of gold provided thermal management. The substrate was thinned to 150 μ m before deposition of the bottom contact.

The structures were cleaved into bars with 900 μ m cavities. The devices were further passivated with aluminium oxide on the front facet. The back facet was coated with a highly reflective metal mirror.

The DFB devices were mounted on aluminium nitride heat spreaders and soldered into TO packaging with thermoelectric cooling. The packaging was hermetically sealed. The windows were anti-reflective.

The broad-area laser diodes had a threshold current density of 383A/cm² at 20°C under pulsed operation. According to the researchers, the threshold is only slightly higher than for devices with wavelengths longer than 3 μ m.

Cascaded type-I QW devices have been reported with thresholds as low as 100A/cm² for quinary diode lasers and around 300 A/cm² for a superlattice design. QCL thresholds tend to be greater than 2kA/cm², depending on materials.

$\text{In}_{0.52}\text{Al}_{0.48}\text{As}$, lattice-matched with the underlying InP substrate. The indium-content grading went from 52% to 84%, overshooting the 80% of the metamorphic template layer. The overshoot was designed to ensure full relaxation of the template layer. The n- and p-type doping for InAlAs layers were provided by silicon and beryllium, respectively.

The active region featured a multiple QW structure with eight 15nm InAs wells in 15nm $\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$ barriers, grown at 435°C. The QW material composition and thicknesses were designed to provide strain compensation with respect to the template. The use of eight wells compensated for the impact on radiative recombination from the relatively large density of threading dislocations (10^6 – $10^7/\text{cm}^2$) in the template layer.

$\text{In}_{0.8}\text{Al}_{0.2}\text{As}$ was chosen for the waveguide material, which has been found to have better performance than $\text{In}_{0.8}\text{Al}_{0.2}\text{As}$ or $\text{In}_{0.8}\text{Al}_y\text{Ga}_{1-y}\text{As}$ alternatives. The upper p-InAlAs cladding was 1.8 μm , followed by 300nm p- $\text{In}_{0.8}\text{Al}_{0.2}\text{As}$ for the contact. The waveguide, cladding and contact were grown at 465°C.

Ridge waveguide laser diodes were produced with 8 μm wide ridges. Isolation was provided by 300nm silicon nitride. Finished devices were mounted epi-side up on copper heat sinks. The measurements were made with the devices in a liquid nitrogen cryostat.

A laser diode with a 0.8mm-long cavity lased around 2.80 μm at 160K under 200ns 100kHz pulsed operation at 1.2x the threshold current. The wavelength red-shifted to 2.91 μm at 230K, "by far the longest wavelength of InP-based type-I QW lasers," according to the research team.

Continuous wave operation was limited to less than 180K due to self-heating effects. The 150K cw output power was 1.2mW/facet at 400mA injection. The cw lasing operation voltage was ~1V at 150K and ~1.2V at 180K.

The pulsed and cw current density thresholds at 120K were 812A/cm² and 797A/cm², respectively (Figure 4). The increase in threshold for pulsed operation had a characteristic temperature (T_0) of around 60K between 120K and 200K. The corresponding figure for cw injection was 53K. Above 200K, T_0 for pulsed operation decreased to 17K. This drop is attributed to increased carrier loss.

Extrapolating the cw threshold current at 120K to infinite cavity length gave a value of 465A/cm². The

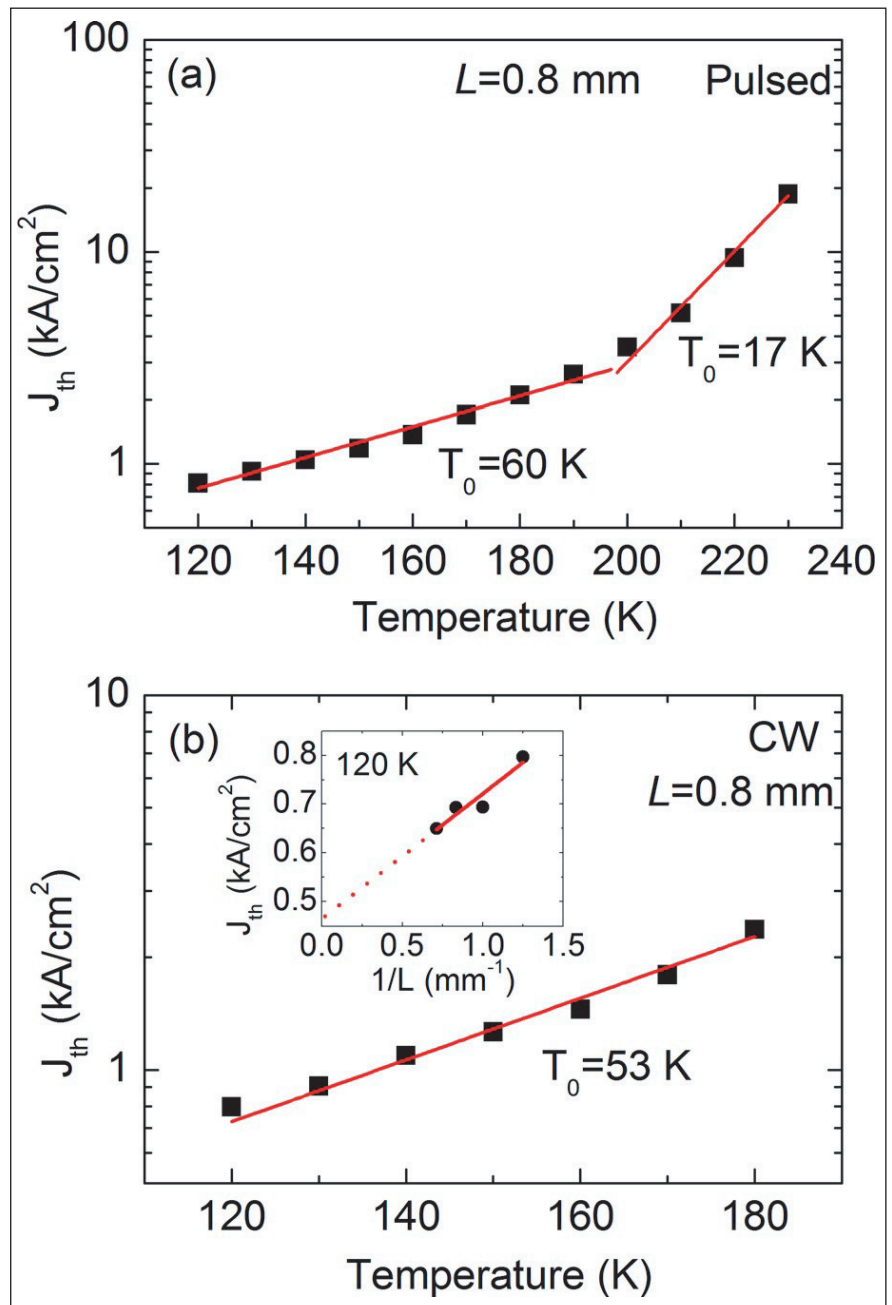


Figure 4. Temperature dependence of threshold current density of laser with 0.8mm cavity length under (a) pulsed and (b) cw operation. Inset of figure (b) cw threshold current density (J_{th}) as a function of reciprocal cavity length ($1/L$) at 120K. Solid and dotted lines are fits to experimental data and extrapolation, respectively.

1.4mm cavity threshold was 650A/cm².

The researchers say that they need to improve carrier confinement to increase operation temperatures. Electron and hole leakage could be reduced with blocking layers on the n- and p-sides of the device. The researchers describe their work as being at an early stage. ■

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

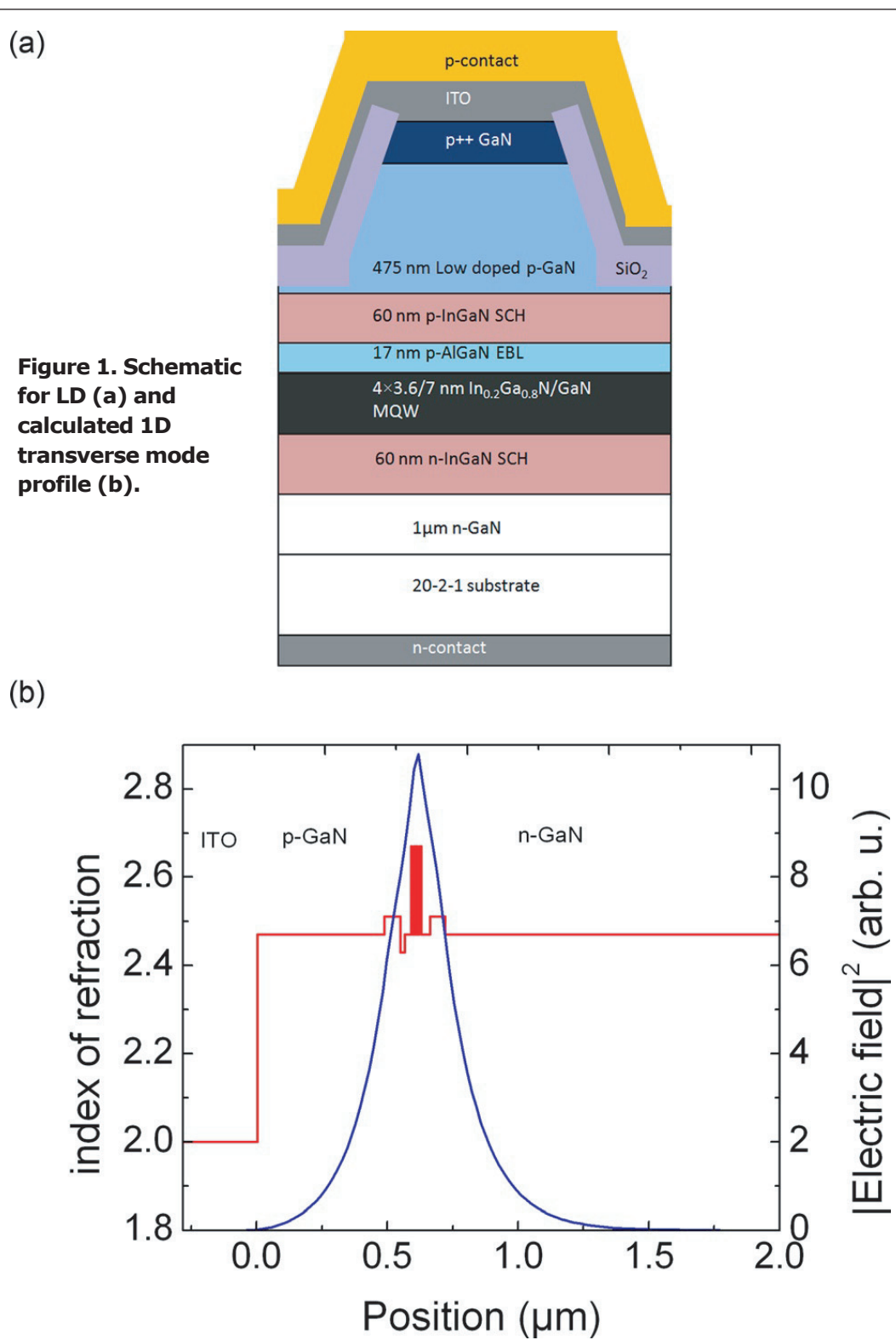
Enhancing optical confinement for III-nitride semiconductor laser diodes

Mike Cooke reports on research attempting to improve waveguide and cladding layers for blue 450nm wavelength devices.

The III-nitride semiconductor light-emitting devices that use various combinations of gallium aluminium indium nitride (GaAlInN) have an ever widening range of wavelength applications from the visible to deep ultraviolet. Laser diodes (LDs) have more complex structures, where optical confinement can be as critical as electrical performance, than light emitting diodes (LEDs). However, the properties of laser light are used widely in projector and data storage systems and could even be employed in general lighting in future.

In particular, researchers see potential applications for InGaN LDs in white lighting, since LDs do not suffer from the same efficiency droop problems at high current as LEDs. This is because carrier concentrations in LDs tend to become clamped at the value at the laser threshold, rather than continuing to increase with increased current.

Here, we look at some recent research that has tried to improve optical confinement techniques in blue InGaN LDs.



Indium tin oxide

University of California Santa Barbara (UCSB) has used indium tin oxide (ITO) as part of the cladding for semipolar indium gallium nitride (InGaN) laser diodes (LDs) [A. Pourhashemi et al, Appl. Phys. Lett., vol106, p111105, 2015].

The semi-polar ($20\bar{2}1$) crystal orientation avoids quantum-confined Stark effects (QCSEs) from the large electric fields in the (0001) c-direction that arise from charge polarization of the III-nitride chemical bond. Devices grown on c-plane material suffer from reduced efficiency because these QCSE fields tend to pull apart electrons and holes, inhibiting recombination into photons.

The ITO cladding was used to reduce the aluminium gallium nitride (AlGaN) content of the device structure. Devices with AlGaN cladding suffer from catastrophic optical mirror damage (COMD) at lower current densities due to the confined optical mode energy density.

Al-free devices grown on gallium arsenide (GaAs) substrates “are less prone to both sudden failure and gradual degradation”, according to the researchers. They add: “Although analogous reliability studies still need to be done for III-nitride LDs, these studies suggest that either reducing or eliminating the Al content in the cladding layers could potentially improve the manufacturability and reliability of high power semipolar and nonpolar III-nitride LDs.”

Another disadvantage of AlGaN cladding is the low hole carrier density in p-AlGaN due to the poor doping capability of even the best acceptor impurity element — magnesium. Increasing Al-content further reduces hole densities. Low hole density makes for high typical resistivity in p-AlGaN: $4\Omega\text{-cm}$, compared with $1 \times 10^{-4}\Omega\text{-cm}$ for ITO. The resistivity in p-GaN is around $1\Omega\text{-cm}$.

UCSB used metal-organic chemical vapor deposition on semipolar ($20\bar{2}1$) GaN substrates to produce the epitaxial material for the LDs (Figure 1). The 60nm upper and lower waveguides consisted of $\text{In}_{0.06}\text{Ga}_{0.94}\text{N}$. The 17nm electron blocking layer (EBL) used magnesium-doped p- $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$. The ohmic p^{++} -GaN contact layer was 12nm thick. The magnesium-doping was reduced as much as possible to avoid phonon-assisted absorption by acceptor-bound holes — a mechanism thought to be the single largest contributor to modal loss in III-nitride LDs.

The material was formed into ridge waveguide devices $8\mu\text{m}$ wide and $1200\mu\text{m}$ long. The 200nm silicon dioxide current aperture was applied with magnetron sputtering onto the sides of the ridges and the non-ridge areas of the device. The 180nm ITO layer

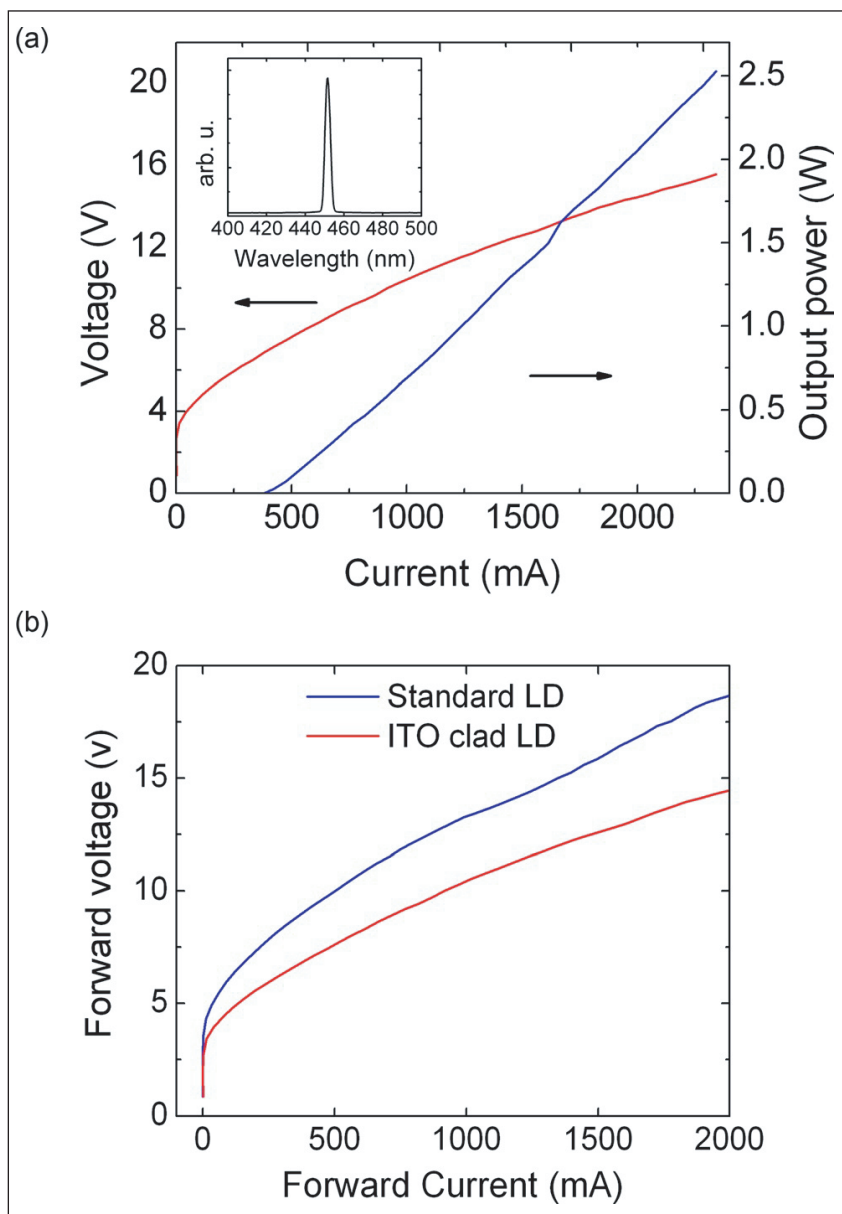


Figure 2. (a) Light output power, current and voltage (L-I-V) characteristics after facet coating for LD. Inset: lasing spectra.

was deposited by electron-beam evaporation at 260°C in an oxygen-rich atmosphere. The contact metals were titanium/gold on the p-side and aluminium/gold on the n-side.

The devices were separated using a dicing saw. The mirror facets were mechanically polished. The back mirror was coated with an 8-period high reflectivity quarter-wavelength silicon dioxide/tantalum pentoxide structure. The front mirror had a 1-period anti-reflective structure of the same materials.

In pulsed operation at room temperature (Figure 2), the threshold current was 509mA ($5.30\text{kA}/\text{cm}^2$). The slope efficiency of $1.36\text{W}/\text{A}$ represented a differential efficiency of 50%. The researchers comment: “This high slope efficiency corresponded to a maximum output power of 2.52W and an external quantum efficiency of 39% for a drive current (current density) of 2.34A ($24.4\text{kA}/\text{cm}^2$).”

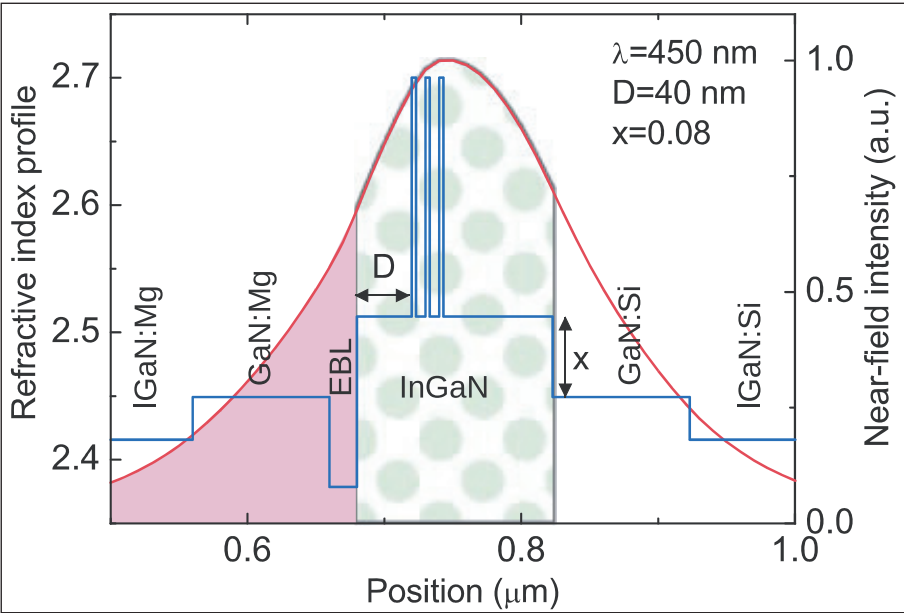


Figure 3. Refractive index profile and corresponding optical mode distribution of blue LD. Solid purple and dotted green regions correspond to optical mode confined within Mg-doped region and InGaN waveguide, respectively.

► The team estimates that optical power density at the front mirror with 2.52W operation was $94.43\text{ MW}/\text{cm}^2$. The COMD power density for c-plane InGaN LDs of $40\text{--}70\text{ MW}/\text{cm}^2$ has been reported, versus $30\text{ MW}/\text{cm}^2$ for GaAs-based devices under single-pulse excitation. The researchers point out that the peak output power of their device was not limited by thermal roll-over or COMD, but rather by power-supply limitations to currents less than 2.34A. In terms of current-voltage performance, the reduction in GaN cladding enabled by use of ITO reduced the forward voltage somewhat, but the peak wall-plug efficiency was still low at 7.3%.

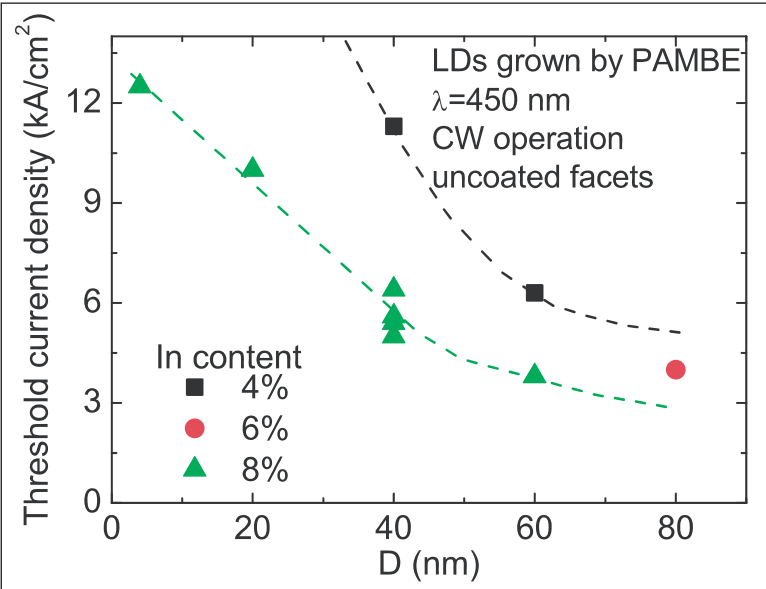


Figure 4. Threshold current density of LDs as function of distance D between MQW and magnesium-doped EBL. Dashed lines are guides to the eye.

Waveguide confinement

Researchers in Poland have been using InGaN waveguides to enhance optical confinement in 450nm wavelength blue LDs, reducing threshold currents [Grzegorz Muziol et al, Appl. Phys. Express vol8, p032103, 2015]. The team from Institute of High Pressure Physics and TopGaN Ltd employed low temperature plasma-assisted molecular beam epitaxy (PAMBE) in order to achieve high material quality with indium contents up to relatively high values of 8%.

The epitaxial material for the laser diodes (Figure 3) was grown on c-plane bulk ammono-GaN substrates with dislocation density of around $10^4/\text{cm}^2$. The layers up to and including the multiple quantum well (MQW) were constant in thickness with 80nm $\text{In}_x\text{Ga}_{1-x}\text{N}$ bottom waveguide, and three 2.6nm $\text{In}_{0.17}\text{Ga}_{0.83}\text{N}$ quantum wells separated by 8nm $\text{In}_x\text{Ga}_{1-x}\text{N}$ barriers.

The emission wavelength of all devices was within 2nm of 450nm. The structure also included 700nm silicon-doped aluminium gallium nitride ($\text{Al}_{0.065}\text{Ga}_{0.935}\text{N}$) bottom cladding, designed to compensate for the tendency to bow caused by strain from the different lattice constants of GaN and InGaN. With the AlGaN bottom cladding the radius of curvature of the 1" substrate was in the range 40–60m.

The thickness D of the upper $\text{In}_x\text{Ga}_{1-x}\text{N}$ waveguide layer was varied up to 80nm. Increasing the indium content x up to 8%, and D to 80nm, reduced the laser threshold current (Figure 4). With D at 5nm and x at 8%, the threshold current was $12.5\text{ kA}/\text{cm}^2$ — increasing D to 80nm reduced this to $3.6\text{ kA}/\text{cm}^2$. Changing x from 4% to 8% reduced the threshold by 50%. Despite the increased distance between the electron blocking layer (EBL) and MQW structure, the researchers found no decrease in injection efficiency.

The researchers believe that the effect of increasing D is to reduce the overlap of the optical mode with the magnesium-doped layers of the device, which have larger optical absorption than undoped regions. However, increased x also increases optical absorption because the band-edge is closer to that of the quantum wells and also as a result of indium fluctuations in higher content material. At the same time, the refraction index contrast of high- x InGaN with the surrounding layers reduces optical leakage, enhances optical confinement and increases differential gain of the light amplification. ■

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

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Improving gallium nitride LED material quality using carbon nanotubes

Output power increased from 194mW to 266mW by using three layers of CNTs on conventional sapphire substrates.

Researchers in China have used carbon nanotube (CNT) layers to improve the material quality and performance of indium gallium nitride (InGaN) light-emitting diodes (LEDs) [Liang Shan et al, Jpn. J. Appl. Phys., vol54, p065102, 2015].

Yantai University, Chinese Academy of Sciences' Institute of Semiconductors, and Tsinghua University used the CNTs to create patterned sapphire substrates (CNPSS) on which to grow III-nitride epitaxial layers. The aim was to improve both crystal quality and light extraction efficiency. Threading dislocations (TDs) reduce the efficiency of light emission from III-nitride devices. Further, a large difference in refractive index between GaN and air causes many of the emitted photons to be reflected back and trapped in LED devices.

The CNT layers were designed to improve crystal quality in a manner similar to epitaxial lateral overgrowth, where a mask restricts the nucleation of the GaN growth to a few small areas. The crystal then grows from these seed areas and coalesces to form material with fewer threading dislocations.

The CNTs were grown on 4-inch sapphire substrates using low-pressure chemical vapor deposition (CVD)

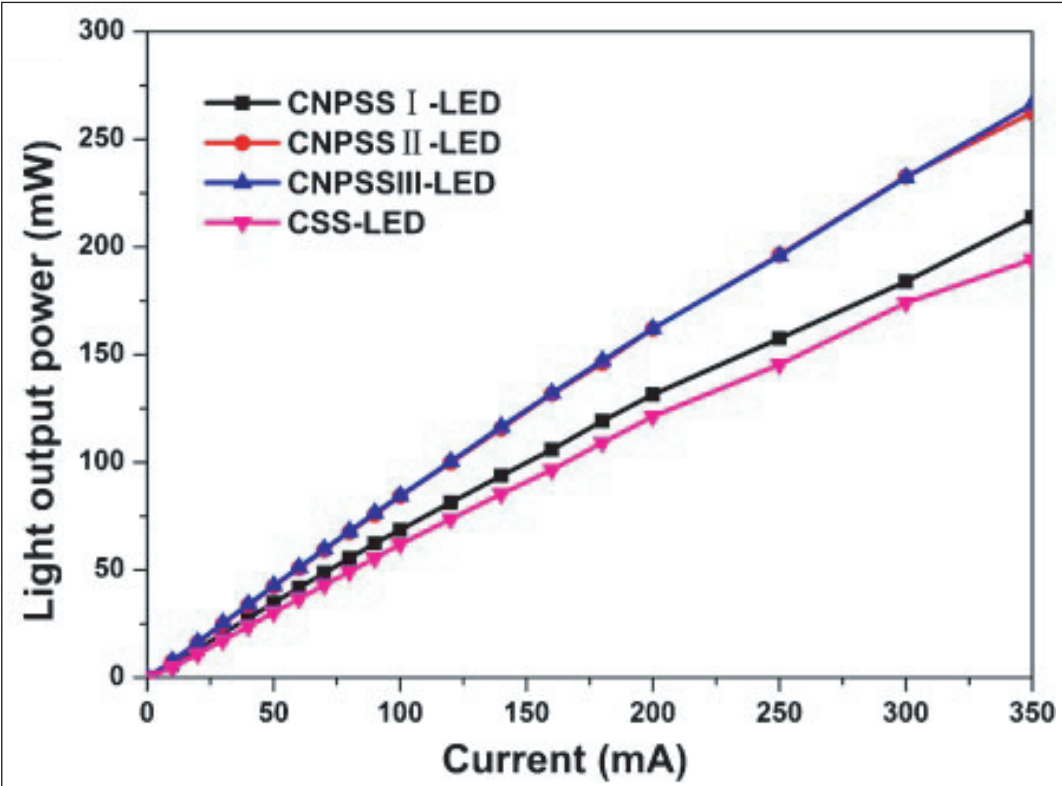


Figure 1. Light output power for LEDs.

Table 1. Full-width at half maximum (FWHM) values for (002) and (102) rocking-curve peaks, estimated dislocation densities. Results for CNPSS structures up to three CNT layers and conventional sapphire substrate (CSS) are compared.

Sample	(002) FWHM	(102) FWHM	Screw-type	Edge-type
CNPSSI-LED	290.6arcsec	405arcsec	1.70x10 ⁸ /cm ²	60.49x10 ⁸ /cm ²
CNPSSII-LED	284.4arcsec	402.8arcsec	1.63x10 ⁸ /cm ²	60.56x10 ⁸ /cm ²
CNPSSIII-LED	261.2arcsec	384.9arcsec	1.37x10 ⁸ /cm ²	56.81x10 ⁸ /cm ²
CSS-LED	275.6arcsec	489.9arcsec	1.52x10 ⁸ /cm ²	101.38x10 ⁸ /cm ²

using a 5nm iron film as catalyst. The precursor was acetylene (C₂H₂). The CNTs were formed in super-aligned arrays with diameters of ~15nm. The aligned film was dry spun from the silicon substrate and transferred to 2-inch c-plane sapphire wafers. A focused

laser beam was used to align the CNTs with particular directions of the subsequent GaN crystal structure. In multi-layer structures, the directions of the CNTs in successive layers were perpendicular.

The wafer was dipped in ethanol and dried. The CNTs bunched together in 2-4 μ m bundles. The gaps between the bundles were 200-500nm.

The LED heterostructure was grown using metal-organic chemical vapor deposition (MOCVD): 30nm GaN buffer, a recovery layer, 3.5 μ m undoped GaN, 2.3 μ m n-GaN, InGaN/GaN multiple quantum well (MQW), p-AlGaIn/p-GaN superlattice, and 80nm p-GaN. The MQW consisted of a 9-period structure with 3nm wells and 10nm n-type barriers.

The LED chips consisted of 45milx45mil (1.14mmx1.14mm) mesas surrounded by an exposed n-GaN contact. The p-GaN was covered in nickel/silver/platinum/gold serving as reflector and contact. The n-contact was chromium/platinum/gold. The resulting chips were bonded to silicon submounts.

X-ray analysis of GaN epitaxial material grown on CNT-patterned sapphire substrates (CNPSS) was used to assess the density of screw- and edge-type dislocations (Table 1). The decreasing density of threading dislocations with number of CNT layers (I-III) was attributed to the narrower windows between CNT bundles in which the GaN can nucleate. "These reduced nanoscale windows can result in faster and more uniform coalescence of neighboring nano-islands, which can further reduce the TD density in the overgrown GaN films because of reduced strain and misorientation between these nano-islands," the researchers comment.

The improved crystal structure results in reduced leakage current at a reverse bias of 10V (Table 2). The forward voltage at 350mA injection current was ~3.62V for all devices, including the conventional sapphire substrate (CSS) version.

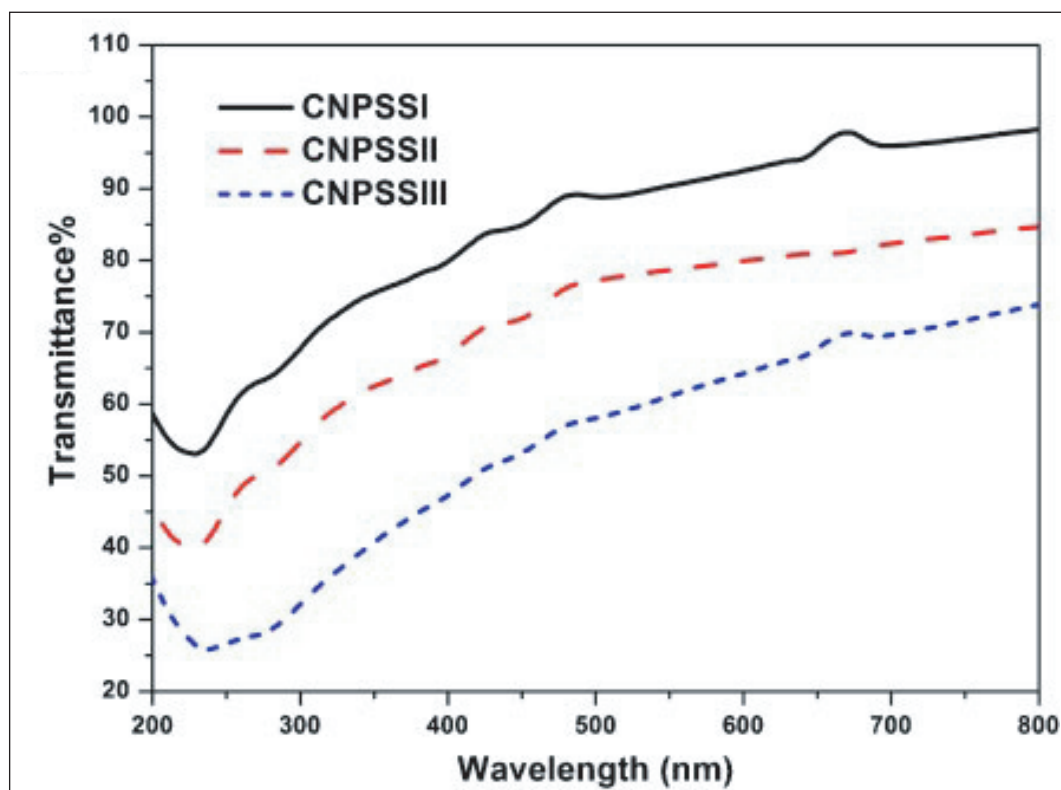


Figure 2. Transmittance of CNPSS based on baseline of transmittance of CSS.

Table 2. Current leakage at 10V reverse bias, light output power at 350mA injection, transmittance of 450nm wavelength light of CNT layers relative to CSS, and divergence angle of output radiation at 350mA.

Sample	Leakage	LOP	Relative transmittance	Half-maximum divergence
CNPSSI-LED	1.21 μ A	213.8mW	75%	145°
CNPSSII-LED	0.77 μ A	262.4mW	70%	144°
CNPSSIII-LED	0.35 μ A	266.3mW	50%	142°
CSS-LED	2.74 μ A	194.2mW	100%	158°

The light output power (LOP) increased with the number of CNT layers (Figure 1, Table 2). The main improvement came from the reduction of dislocation density in the LED epitaxial material. "Additionally, photons had more opportunities to be extracted to the outside, owing to the diffraction of CNTs," the researchers write.

The similarity of the LOP for two and three layers of CNT is attributed to increased absorption as the number of layers increases (Figure 2, Table 2). The angular dispersion of the radiation with CNTs is also directed more into the forward direction, reducing losses of optical power from photon trapping by internal reflection at interfaces of different refractive index. "The CNPSS-LED has suppressed lateral guiding modes and the trapped photons are re-directed into radiated modes," the researchers explain. ■

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Author:

Mike Cooke

Gallium nitride HEMT-LED without metal interconnection

Hong Kong University of Science and Technology shows how a reduction in parasitics decreases leakage current by three orders of magnitude.

Hong Kong University of Science and Technology (HKUST) has produced indium gallium nitride (InGaN) light-emitting diodes directly connected with aluminium gallium nitride (AlGaN) barrier high-electron-mobility transistors (HEMTs) [Chao Liu et al, Appl. Phys. Lett., vol106, p181110, 2015].

The researchers comment: "We believe the demonstrated integration scheme of the HEMT-LED is highly promising for a wide range of applications, such as smart lighting, displays, and optical communications."

The production of HEMT-LEDs without metal interconnections (Figure 1) reduces the influence of parasitic losses in terms of power and time delay. However, combining InGaN and AlGaN processing can be tricky.

The Hong Kong team first grew the layers for the HEMT on sapphire using metal-organic chemical vapor deposition (MOCVD). The sequence was 3.0µm GaN buffer, 100nm GaN channel, 1nm AlN spacer, and 20nm AlGaN barrier. The channel layer was grown at higher pressure and III/V ratio than the buffer to improve the mobility of the two-dimensional electron gas (2DEG) conducting region. The Hall mobility was 1530cm²/V-s with a carrier density of 1.2x10¹³/cm². The sheet resistance was 330Ω/square.

The LED layers were re-grown on the GaN buffer layer selectively exposed with inductively coupled plasma etch using a silicon dioxide mask. The n-GaN contact layer of the LED was 1.6µm. The active region was a 5-period InGaN/GaN multiple quantum well with 3nm wells and 11nm barriers. The p-contact layers

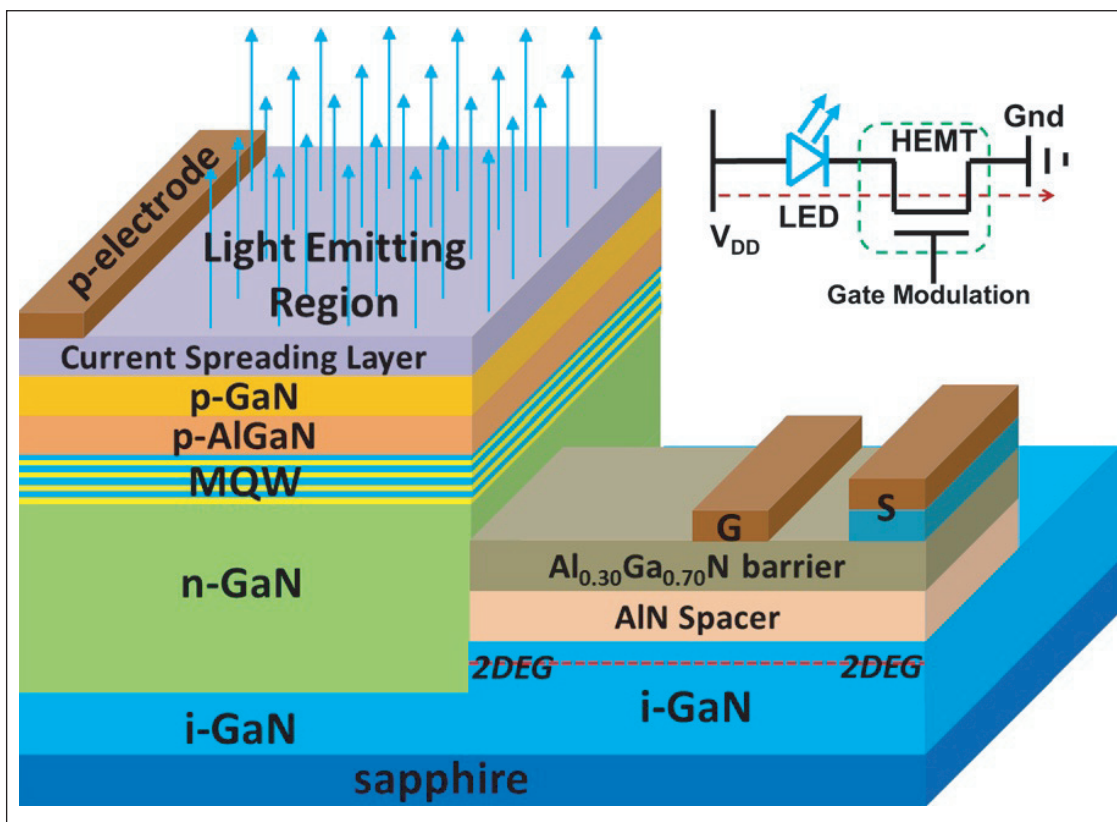


Figure 1. Schematic of finished HEMT-LED device. Inset: equivalent circuit diagram of device.

consisted of 15nm p-Al_{0.15}Ga_{0.85}N for electron blocking, and 170nm p-GaN.

The LED 450µm x 460µm mesa was fabricated using ICP etch with the HEMT region protected by photoresist. The HEMT mesa was similarly produced with the LED region protected. The annealed ohmic source electrode was titanium/aluminium/nickel/gold. The p-contact of the LED consisted of a nickel/gold current spreading layer and titanium/aluminium/titanium/gold electrode. The Schottky gate for the HEMT was nickel/gold.

Scanning electron microscopy (SEM) showed that the channel of the HEMT was in "intimate contact" with the n-type layer of the LED, giving a three-terminal LED-HEMT. The researchers estimate that the interconnection resistance was reduced by an order of magnitude compared with devices connected with wires.

The team comments: "The reduced parasitic resistance accounts for approximately 15% of the total par-

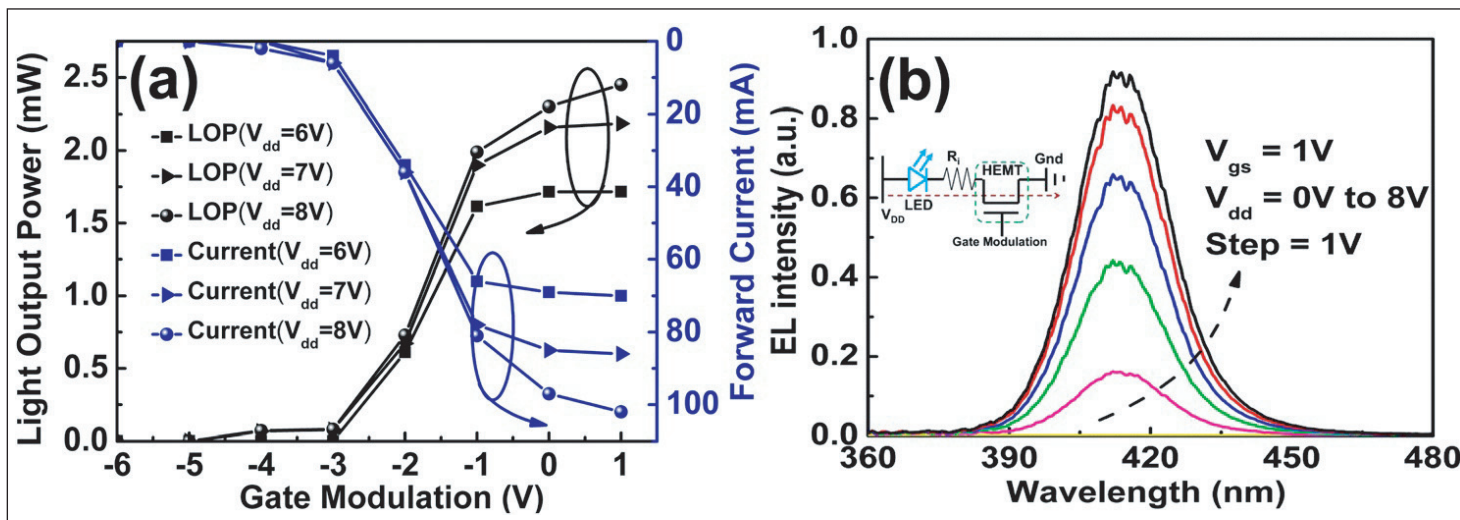


Figure 2. (a) LOP and current-voltage characteristics of fabricated HEMT-LED device modulated by gate biases at different drain voltages and (b) electroluminescence spectrum modulated by drain bias at 1V gate.

asitic resistance of the driving circuit, which can help cut down the delay time (RC) of the driving circuit." Parasitic inductance and resistance also increase power consumption, generating heat and lowering efficiency. Other potential advantages over metal wire interconnection include smaller footprint, reduced fabrication complexity, and enhanced device reliability.

The researchers have previously tried to produce HEMTs after the material for the LED has been grown. This resulted in a 1mA/mm off-state breakdown at 40.5V. By contrast, the HEMT-first approach resulted in a reduction in off-current by three orders of magnitude, with an off-current of 6.3 μ A/mm at 200V. The researchers attribute the difference to the high resistance of the buffer being maintained in the HEMT-first

method, even after the high-temperature selective growth process for the LED layers.

A single HEMT produced on sapphire had a maximum drain current of 420mA/mm and 12.8 Ω -mm on-resistance. The performance of a HEMT-first LED-HEMT had similar performance except for a shift of 3V in potential difference from the drain bias of the HEMT-only device. This was due to the turn-on voltage of the LED. At high bias, the LED resistance of 11 Ω was negligible compared with the on-resistance of the HEMT of 128 Ω .

The light output power (LOP) was controlled by both the gate potential and the bias across the LED-HEMT (Figure 2). ■

<http://dx.doi.org/10.1063/1.4921049>

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Toyoda Gosei achieves specific on-resistance of less than $2\text{m}\Omega\text{-cm}^2$

Reducing on-resistance in vertical gallium nitride MOSFETs.

Toyoda Gosei Co Ltd in Japan has developed a vertical trench metal-oxide-semiconductor field-effect transistor (MOSFET) on free-standing gallium nitride (GaN) combining 1.2kV blocking voltage with low specific on-resistance [Tohru Oka et al, Appl. Phys. Express, vol8, p054101, 2015]. The researchers comment: "To the best of our knowledge, this is the first report on vertical GaN-based MOSFETs with a specific on-resistance of less than $2\text{m}\Omega\text{-cm}^2$."

The threshold voltage was +3.5V, which is high compared with the values usually achieved with lateral structure GaN-based devices. High-power automotive applications need normally-off devices with thresholds above 3–5V to prevent false switching arising from noise and other factors. The advantage of lateral devices is lower specific on-resistance in general. A vertical structure should allow the reduction of chip size and production cost reduction.

Toyoda Gosei mainly supplies plastic and rubber parts to the automotive industry, along with white LEDs and general industrial products. The company's white LEDs

will be manufactured using GaN technologies. Toyoda Gosei says that its main LED applications are tablet computers and liquid-crystal displays, although it also produces various other lighting devices that use LEDs,

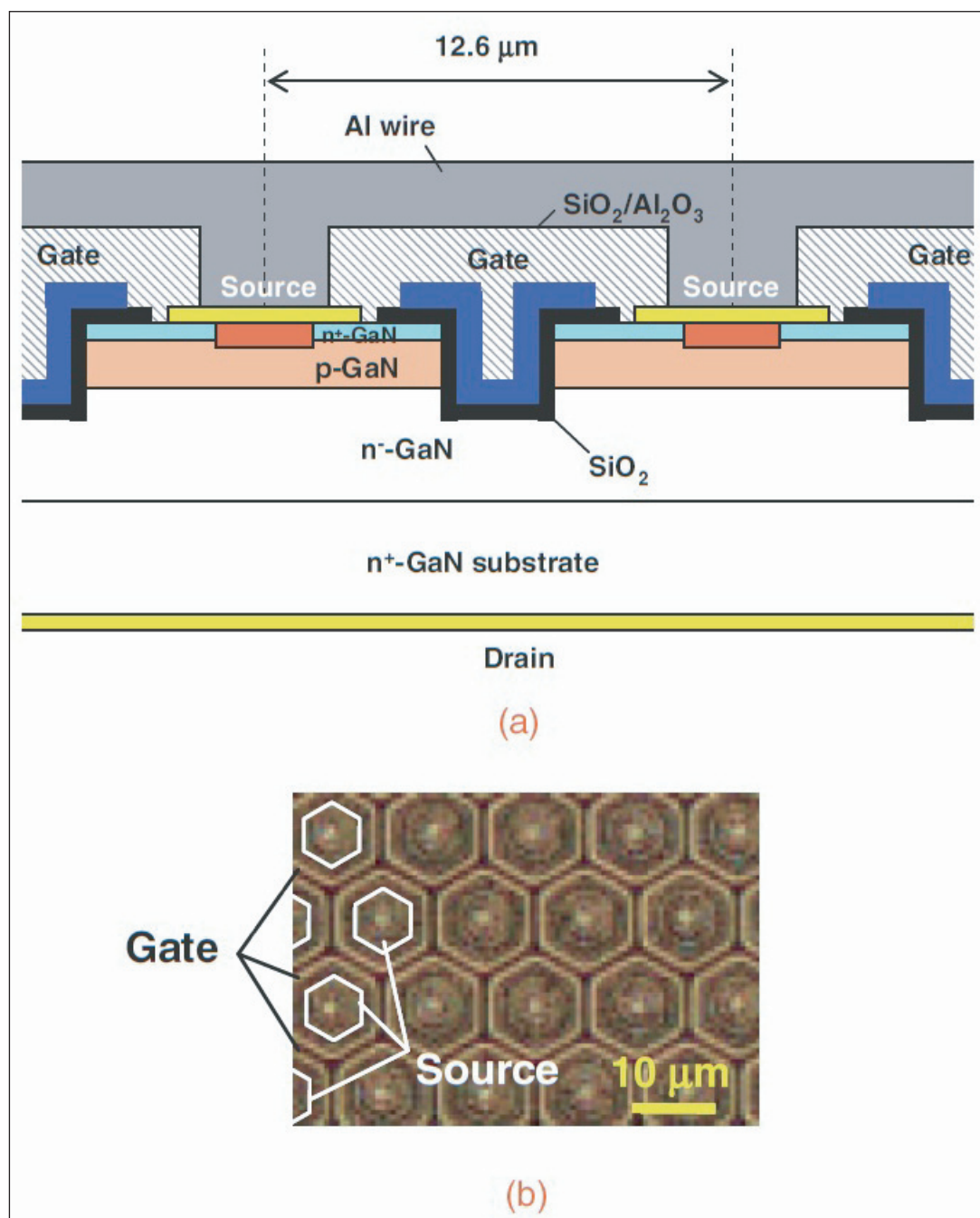


Figure 1. MOSFET schematic (a) and micrograph of hexagonal transistor array.

including fluorescent and security lights.

Metal-organic chemical vapor deposition (MOCVD) was used to create the epitaxial structure for the vertical transistors on free-standing n^+ -GaN substrates with $0.2\mu\text{m}$ n^+ -GaN, $0.7\mu\text{m}$ p-GaN, and $13\mu\text{m}$ n^- -GaN. The $13\mu\text{m}$ drift layer was thinner, but more heavily doped, than the group's previous devices. The thinner layer was designed to reduce resistance, while maintaining 1.2kV-class blocking voltage. The p-GaN channel was also thinned, and the doping concentration reduced. The aim, here, was also to reduce resistance.

Transistor fabrication (Figure 1) involved inductively couple plasma (ICP) etching for mesa isolation, p-body contact recessing, and gate trenching. The gate dielectric was 80nm silicon dioxide, grown using atomic layer deposition (ALD). Interlayer dielectrics of 100nm aluminium oxide and 800nm silicon dioxide were produced by atomic layer deposition and plasma-enhanced chemical vapor deposition (PECVD).

The p-body electrode was palladium; the source/drain electrodes were titanium/aluminium. The source electrode was stacked on top of the p-body electrode to reduce the cell pitch ($12.6\mu\text{m}$). The device was annealed at 550°C for 5 minutes in nitrogen to produce ohmic contacts.

Potential crowding at the pn-junction edge was reduced with field-plate termination around the isolation mesa periphery.

The transistors were produced in an array with a hexagonal trench gate layout. The researchers write that there is a definite advantage of polygonal cells over striped devices in terms of channel density, increasing the ratio of gate width to unit cell area ($0.267/\mu\text{m}$) by a factor of two over a stripe-cell device ($15\mu\text{m}$ pitch). This should reduce specific on-resistance.

The MOSFET achieved 0V off-state blocking up to 1250V. At +40V gate potential the current density was 10.2mA/mm with a 0.5V drain bias. The researchers comment that this is 3.3x the value obtained in their

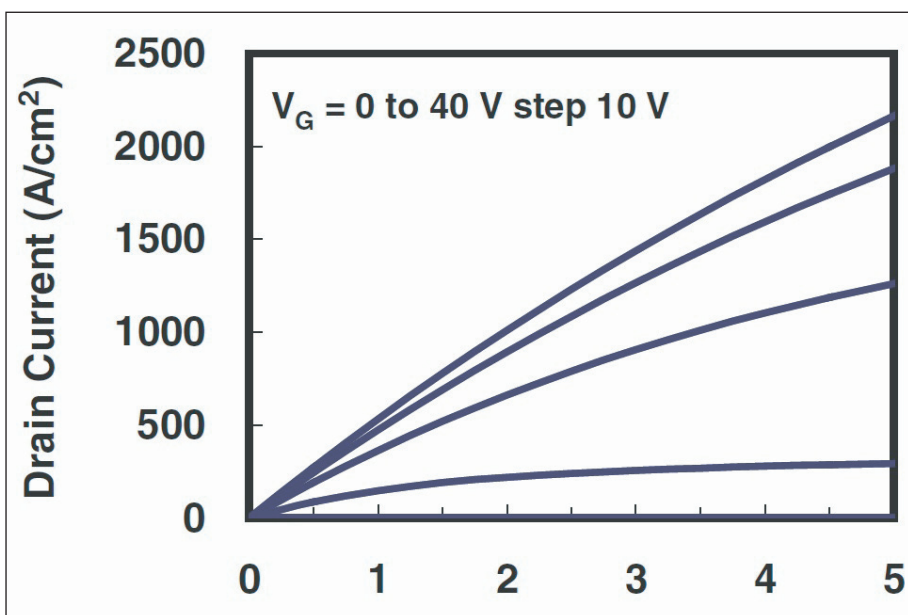


Figure 2. Drain current versus voltage for range of gate potentials.

previous devices with the same gate potential.

The forward-sweep threshold voltage was +3.5V. The team observes that theoretical considerations would lead one to expect a threshold of 33V. The significant difference is attributed tentatively to the presence of fixed charges at the interface between the gate dielectric and trench surface. There was also hysteresis of 0.5V in the backward-sweep threshold.

The linear region with a gate potential of 40V demonstrated a specific on-resistance of $1.8\text{m}\Omega\text{-cm}^2$ (Figure 2), which is a 6.6-fold reduction on the group's previous work. The improvement is attributed to the increased ratio of gate width to unit cell area (2x) and current density per unit gate length (3.3x). These improvements were based on the hexagonal layout and an enhanced epitaxial process.

The researchers comment: "The results demonstrated that the performance of vertical GaN MOSFETs is approaching the best performance of SiC MOSFETs." The team believes that further miniaturization could lead to sub- $1\text{m}\Omega\text{-cm}^2$ specific on-resistance 1.2kV-class devices. ■

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Vertical gallium nitride transistors with buried p-type current blocking

Device developed by UCSB and Arizona State University combines two-dimensional electron gas with vertical design for better electric field distribution.

University of California Santa Barbara (UCSB) and Arizona State University in the USA have developed gallium nitride (GaN) Current Aperture Vertical Electron Transistors (CAVETs) with a buried p-type layer, creating a reverse-biased pn junction [Ramya Yeluri et al, Appl. Phys. Lett., vol106, p183502, 2015].

The CAVET (Figure 1) combines both a two-dimensional electron gas (2DEG) and a vertical structure. The 2DEG near the aluminium gallium nitride/gallium nitride (AlGaN/GaN) interface offers high conductivity, while the vertical structure should allow better electric field distribution with lower peak values.

In lateral GaN transistors such as high-electron-mobility transistors (HEMTs) the electric field peaks near the surface layer. Charging and discharging of surface states in lateral devices causes current collapse and other performance dispersion in pulsed operation. Also, high peak fields near the surface of lateral transistors can cause premature device degradation.

In vertical devices, the peak field is moved away from the surface. The vertical design also allows for denser circuits with breakdown voltage increasing as the thickness of the drift layer. In lateral transistors the breakdown voltage is raised as the lateral source-drain distance is increased.

The epitaxial material for the UCSB/Arizona device was prepared using both metal-organic chemical vapor deposition (MOCVD) and ammonia molecular beam epitaxy (MBE). It has been found that using MOCVD to deposit n-GaN on p-type layers increases resistance. By contrast, ammonia MBE does not impact resistivity for such buried p-GaN layers. Ammonia MBE is also carried out at lower temperature, limiting diffusion of the magnesium doping from the p-GaN.

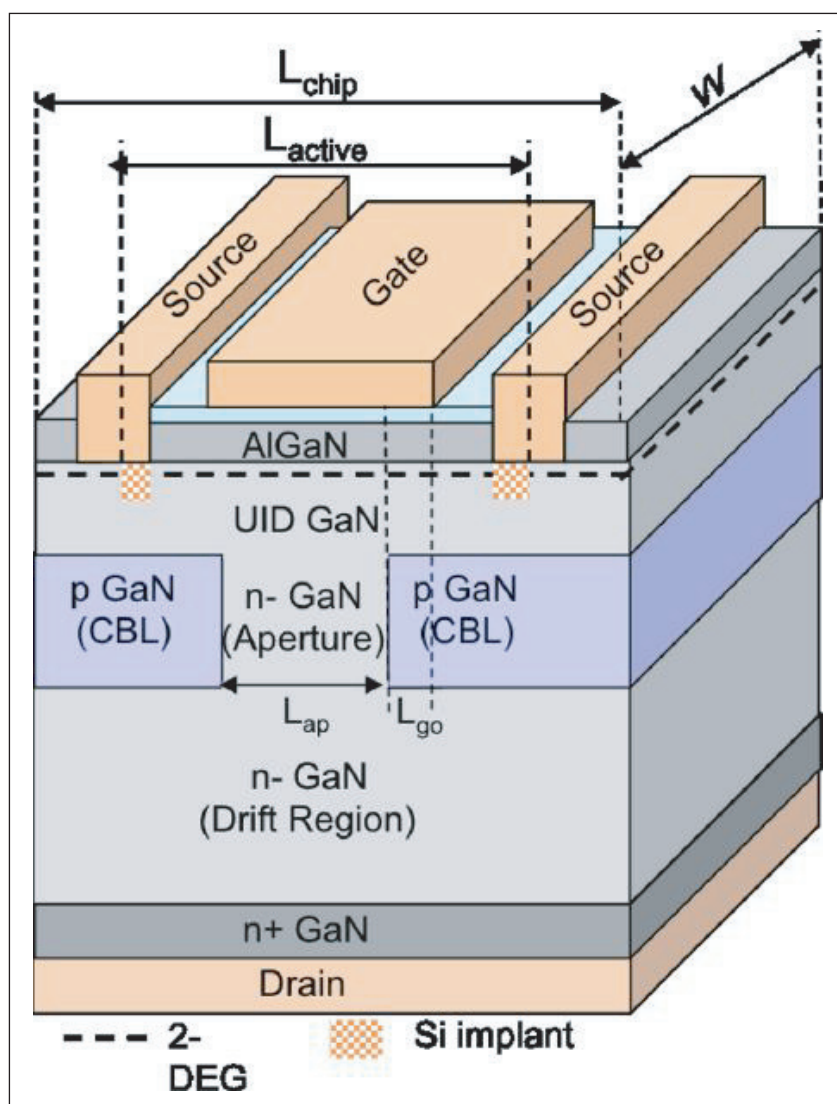


Figure 1. CAVET schematic with AlGaN/GaN heterojunction channel, p-GaN current-blocking layer (CBL) and aperture layer, and n-GaN drift region.

The MOCVD was used for the initial layers on free-standing n⁺-GaN substrate, starting with the 3μm n-GaN drift layer. The p-GaN current-blocking layers (CBLs) were selectively re-grown, also by MOCVD, in etched 100–120nm recessed areas on either side of

the aperture. The magnesium doping for the p-GaN was activated with an anneal at 700°C.

The remaining GaN and AlGaIn layers were re-grown using ammonia MBE, after a surface clean. The electrical path from the source electrodes to the two-dimensional electron gas (2DEG) near the AlGaIn/GaN interface was made n-type conductive with a silicon implant. The doping was activated with annealing at 1280°C for 30 seconds in nitrogen.

The source electrodes of aluminium/gold were deposited on the silicon-doped GaN surface with the overlying AlGaIn etched away. The gate consisted of 15nm MOCVD silicon nitride dielectric and nickel/gold electrode. The aluminium/gold drain contact was applied to the back-side of the substrate.

The devices were isolated with a combination of aluminium implants and mesa etching. The implants isolated the active region of the device. Mesa etching isolated separate devices.

The combination of the two isolation techniques avoided side-wall leakage currents.

Probe pads were created on the aluminium implant region with additional aluminium oxide and silicon nitride insulation.

Devices with 4µm aperture, and gate/CBL overlap of 2µm, demonstrated low on-resistance of 0.4mΩ·cm² and high on-current of 10.9kA/cm². The peak transconductance was 282mS/mm with 4V drain bias. The on-resistance was about half that of a lateral HEMT produced by the researchers with a p-GaN back-barrier. The team suggests that the CAVET was acting like two HEMTs in parallel.

Measurements with pulse widths as short as 200ns showed no current collapse or dispersion. The on/off ratio was more than 10⁸. The subthreshold swing was 'very low' (85.4mV/decade at 1V drain bias).

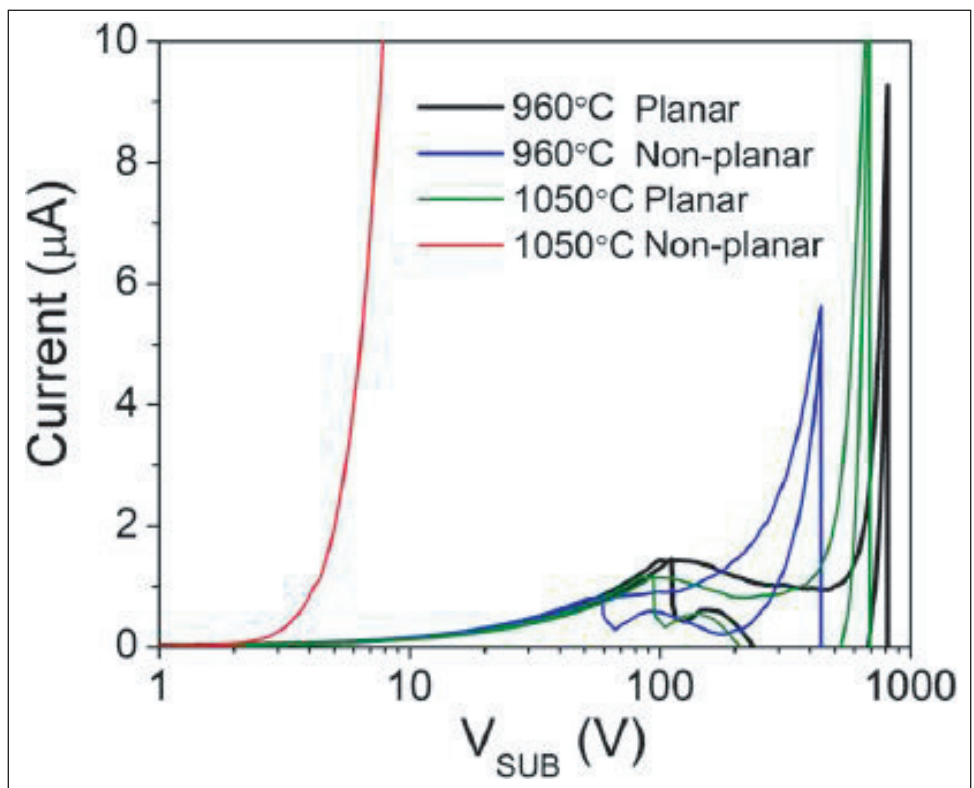


Figure 2. Breakdown voltage for planar and non-planar re-growth at p/n junction in n/p/n structure at two different p-GaN growth temperatures, 960°C and 1050°C.

The three-terminal breakdown was about 20V, caused by source-drain leakage that increased with drain bias. Tests with planar and non-planar pn GaN structures suggested that lowering the p-GaN re-growth temperature could improve breakdown characteristics (see Figure 2).

The researchers comment: "This suggests a path to combine the high breakdown voltages demonstrated in planar n/p/n structures and transistors with low ON-resistance and high ON-current, enabling power transistors with higher power densities and higher average electric fields."

Planar structures with n/p/n layers achieved breakdown fields of 3.1MV/cm — close to the ~5MV/cm critical field value for bulk GaN. ■

<http://dx.doi.org/10.1063/1.4919866>

Author: Mike Cooke

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Current gain in III-nitride hot-electron transistors

UCSB has implemented emitter and collector barriers using AlN/InGaN polarization dipole barriers.

Researchers at UCSB (University of California Santa Barbara) have claimed current gain for the first time in III-nitride hot-electron transistors (HETs) using base current controlled common emitter characteristics [Geetak Gupta et al, IEEE Electron Device Letters, published online 25 March 2015].

HETs are vertical unipolar devices with an emitter that injects high-energy electrons across a base region, at the end of which transit the electrons are filtered and collected. The filtering of high-energy electrons is achieved with quantum barrier regions above and below the base.

The transport across the base region is ballistic — meaning that the mean free path is greater than the base thickness. This is in contrast to bipolar transistors that use diffusion effects in their operation. Potentially, HETs could operate with shorter delays and at higher frequency compared with bipolar transistors. However, to be useful, HETs require gain greater than 1, low base-collector leakage current, and low base resistance.

HETs are often produced using III-arsenide and/or III-antimonide materials. The combination of these semiconductor families allows the creation and use of large band discontinuities for the barriers. The III-nitride family contains a large range of band discontinuities that have recently been used to create HETs. However,

these devices have been limited to current gains of the order of 0.1 (i.e. losses rather than gain) up to now.

The charge polarization of the III-nitride chemical bond was used to set up polarization dipole layers at various positions in the device to induce barriers (Figure 1). In particular, layers of aluminium nitride (AlN) and In_{0.1}Ga_{0.9}N were used to create emitter and collector barriers, respectively. The polarization properties of III-nitrides was also used to increase the conductivity of the base region by inducing a two-dimensional electron gas (2DEG). The 2DEG was also enhanced through modulation doping in the emitter.

The structures were grown using plasma-assisted molecular beam epitaxy (PAMBE) on sapphire substrates. The GaN layer in the base region was either 8nm or 2nm.

The collector GaN layers were grown at 700°C. The temperature was then reduced to 570°C to grow the base-collector InGaN barrier. This was covered with 4nm or 1nm of low-temperature 570°C GaN, before raising the temperature to grow the rest of the device.

The low-temperature GaN layer was designed to protect the InGaN layer from decomposition in the subsequent growth. The need for the protection layer sets a lower limit on the base thickness ($t_B = \text{GaN} + \text{InGaN} = 8\text{nm}/2\text{nm} + 5\text{nm}$).

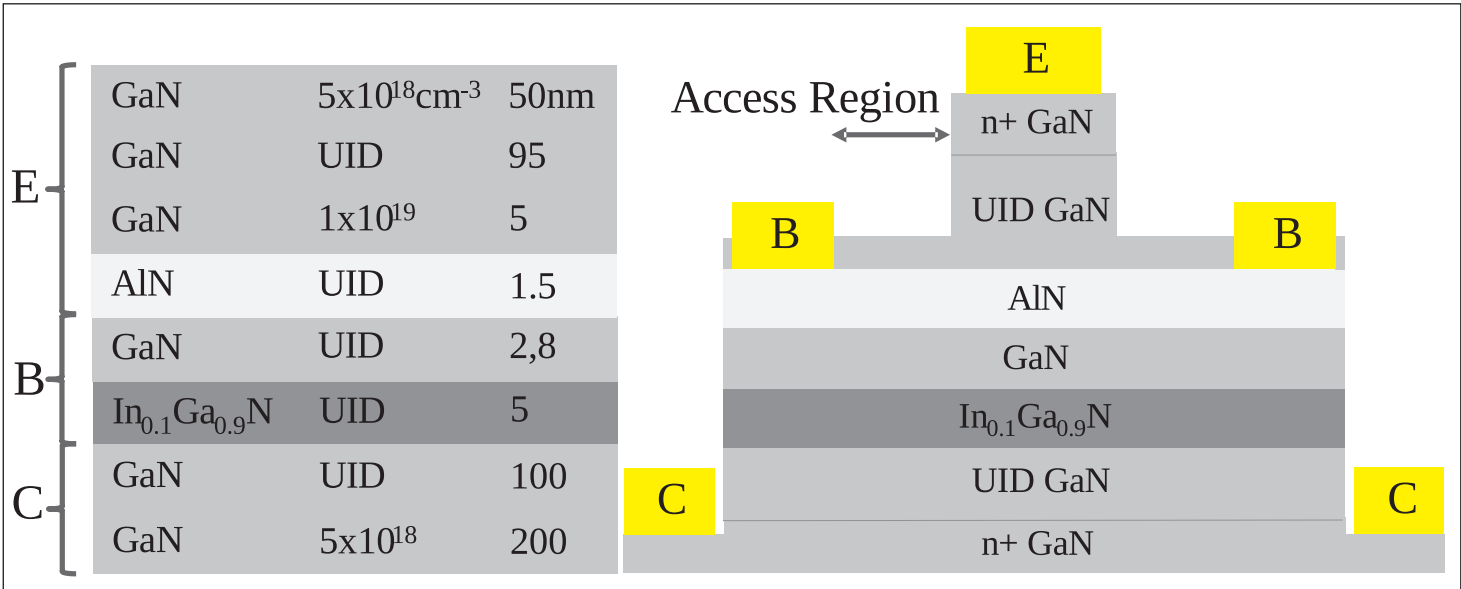


Figure 1. (a) Layer structure of as-grown III-N HETs for samples B1 and B2 (8nm and 2nm GaN, respectively) and (b) structure of fabricated device.

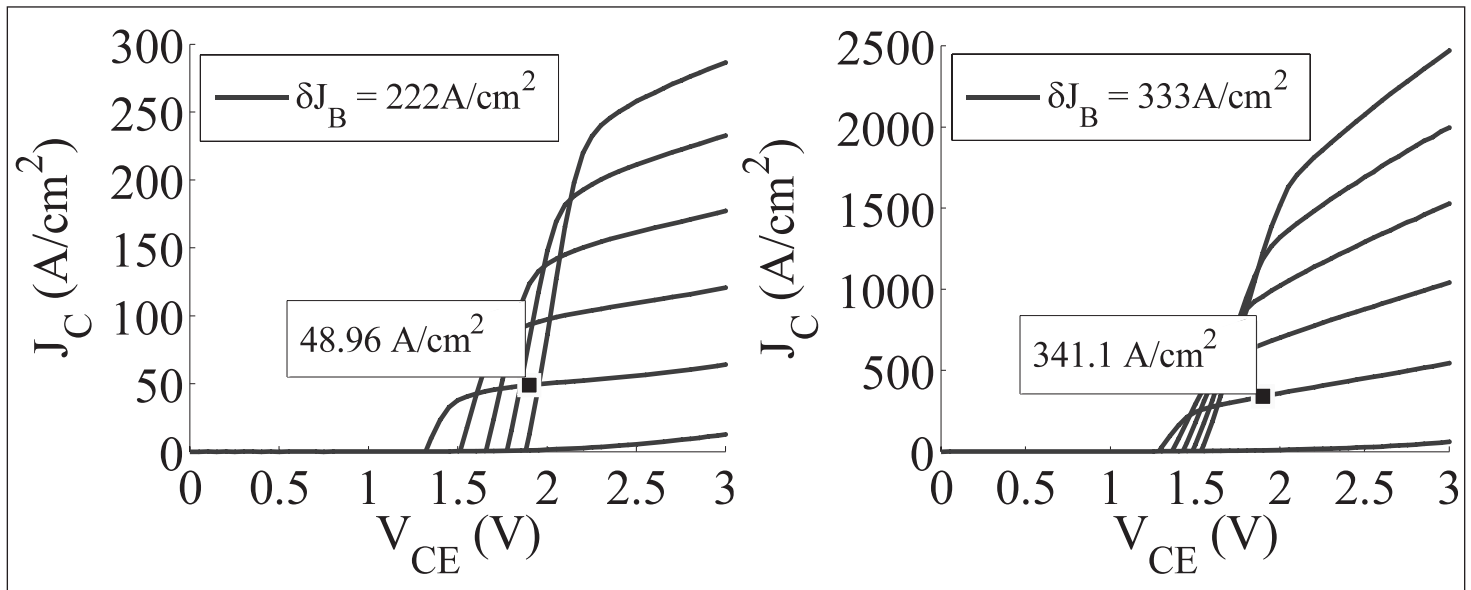


Figure 2. Common-emitter characteristics of HET structures (a) B1 and (b) B2. The collector current density (J_C) curves correspond to six base current (J_B) steps from 0 to $5\delta J_B$.

The etching for the device fabrication used a combination of reactive-ion etching and inductively coupled plasma etching techniques. The AlN layer served as a stop layer for the inductively coupled plasma etch. A post-etch anneal was carried out at 400°C in nitrogen for 10 minutes. The base contact of aluminium/gold was then formed on the AlN, giving a tunnel junction access to the base region 2DEG. Further reactive-ion etching exposed the collector, before deposition of the ohmic emitter/collector contacts.

The thickness of the AlN layer had to be thick enough for the 2DEG to form, but also sufficiently thin to enable the base contact tunnel junction to remain ohmic. The researchers comment: "The multiple purposes served by the AlN layer enable us to aggressively scale the base thickness."

The base contact and sheet resistances of the sample B1 with 8nm GaN layer were 0.49Ω-mm and 1787Ω/square, respectively, lower than the values for

sample B1 (2nm GaN, 1.44Ω-mm, 3550Ω/square). The mobility degradation for B1 is attributed to alloy scattering in the underlying InGaN layer.

Common-emitter measurements gave a current gain of 0.22 for B1 and 1.02 for B2. The researchers comment: "Since the only difference between the two samples is the GaN thickness, the increase in gain can be directly attributed to the decrease in t_b from 13nm to 7nm." The reverse bias base-collector leakage for both B1 and B2 was $\sim 100\text{A}/\text{cm}^2$.

The researchers believe that further progress to higher gain needs thinner bases, while maintaining low base contact and sheet resistances. Better understanding of the quantum mechanical reflections at the base-collector barrier should also lead to better performance. ■

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2-7 August 2015

20th American Conference on Crystal Growth and Epitaxy (ACCGE-20) and 17th US Biennial Workshop on Organometallic Vapor Phase Epitaxy (OMVPE-17) and The Second 2D Electronic Materials Symposium

Big Sky, Montana, USA

E-mail: aacg@comcast.net

www.crystalgrowth.org/ACCGE-20---OMVPE-17-Conference.html

9-13 August 2015

SPIE Optics + Photonics 2015

San Diego Convention Center,
San Diego, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics1>

26-28 August 2015

GFP-2015: IEEE Photonics Society's 12th International Conference on Group IV Photonics

Vancouver, British Columbia, Canada

E-mail: m.figueroa@ieee.org

www.gfp-ieee.org

30 August - 4 September 2015

11th International Conference on Nitride Semiconductors (ICNS-11)

Beijing, China

E-mail: registration-icns11@pku.edu.cn

www.icns-11.cn

2-4 September 2015

SEMICON Taiwan 2015

Taipei World Trade Center (TWTC),
Taiwan

E-mail: staiwan2@semi.org

www.semicontaiwan.org

31 August - 1 September 2015

1st International Forum on Sapphire Market & Technologies

Shenzhen, China

E-mail: veyrier@yole.fr

www.i-micronews.com/yole-events/eventdetail/40/-/1st-int-forum-on-sapphire-market-technology.html

31 August - 3 September 2015

17th China International Optoelectronic Expo (CIOE 2015)

Shenzhen, China

E-mail: cioe@cioe.cn

www.cioe.cn/EN

6-10 September 2015

16th conference on Defects Recognition, Imaging and Physics in Semiconductors (DRIP XVI)

Suzhou, China

E-mail: drip16@163.com

<http://dripxvi.csp.escience.cn>

8-10 September 2015

European Microwave Week (EuMW2015), incorporating:

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**45th European Microwave Conference (EuMC)
10th European Microwave Integrated
Circuits Conference (EuMIC)**

12th European Radar Conference (EuRAD)

Palais des Congrès, Paris, France

E-mail: aubert@laas.fr

www.eumweek.com

13–18 September 2015

**II-VI 2015: 17th International Conference
on II-VI Compounds and Related Materials**

Campus des Cordeliers, Paris, France

http://ii-vi-2015.sciencesconf.org

15–18 September 2015

**Process Certification and Defect Recognition:
Hybrids, Microcircuits and RF/MMIC Modules**

Pasadena, CA, USA

E-mail: tgreen@tjgreenllc.com

www.tjgreenllc.com/course/process-certification

21–24 September 2015

SPIE Remote Sensing 2015

Centre de Congrès Pierre Baudis, Toulouse,
France

E-mail: info@spieeurope.org

http://spie.org/spieremotesensing

27 September – 1 October 2015

**ECOC 2015:
European Conference on Optical
Communication**

Feria Valencia, Spain

E-mail: ecoc2015@viajeseci.es

www.ecoc2015.org

4–8 October 2015

IPC 2015: 28th IEEE Photonics Conference

Reston, VA, USA

E-mail: c.c.scott@ieee.org

www.ipc-ieee.org

4–9 October 2015

**16th International Conference on
Silicon Carbide and Related Materials
(ICSCRM 2015)**

Congress Center Atahotel Naxos Beach, Giardini
Naxos, Sicily, Italy

E-mail: webmaster@icscrm2015.org

http://icscrm2015.imm.cnr.it

6–8 October 2015

SEMICON Europa 2015

Dresden, Germany

E-mail: semiconeuropa@semi.org

www.semiconeuropa.org

12–14 October 2015

**International Semiconductor Conference
(CAS 2015)**

Sinaia, Romania

E-mail: cas@imt.ro

www.imt.ro/cas

12–15 October 2015

SPIE Optifab 2015

Joseph A. Floreano Rochester Convention Center,
Rochester, NY, USA

E-mail: customerservice@spie.org

http://spie.org/spieoptifab

13–16 October 2015

SCTE Cable-Tec Expo 2015

New Orleans Ernest N. Morial Convention Center,
Louisiana, USA

E-mail: expo@scte.org

http://expo.scte.org

26–29 October 2015

**IMAPS 2015: 48th International Symposium
on Microelectronics**

Orlando, FL, USA

E-mail: blamm@imaps.org

www.imaps.org

26–29 October 2015

**2015 IEEE International Topical Meeting on
Microwave Photonics**

Paphos, Cyprus

E-mail: info@cyprusconferences.org

www.mwp2015.org

28–29 October 2015

UV LED 2015

Troy, N.Y., USA

E-mail: mickey@radtech.org

www.uvled2015.com

3–5 November 2015

**Global Summit on Electronics and Electrical
Engineering**

Valencia, Spain

E-mail: electricalengineering@conferenceseries.net

http://electricalengineering.global-summit.com

4–6 November 2015

**Successful Semiconductor Fabless 2015:
Technology & supply chain challenges for
fabless semiconductor companies**

Paris, France

E-mail: veyrier@yole.fr

**www.i-micronews.com/trade-shows-
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