

# semiconductor **TODAY**

COMPOUNDS & ADVANCED SILICON

Vol. 18 • Issue 1 • February 2023

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## Wolfspeed plans new silicon carbide device fab for Germany



MACOM acquiring OMMIC • Veeco buys SiC CVD firm Epiluvac  
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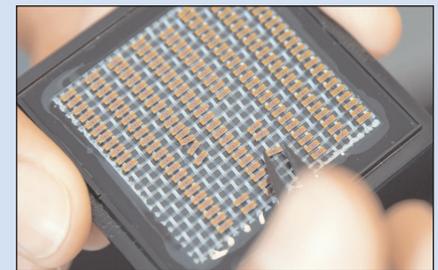
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**p15** Texas-based power semiconductor product maker Diodes Inc has launched its first SiC Schottky barrier diodes.



**p38** Aixtron has launched the AIX G10-AsP system as the first fully automated AsP platform, addressing the growing micro-LED and laser sectors.



**p48** TRUMPF Venture is investing in InP PIC-based quantum technology startup Quside.



Cover image: US-based Wolfspeed plans to build a highly automated 200mm-wafer SiC device fabrication facility — the largest in the world — in Saarland, Germany, with investment from Germany-based ZF Friedrichshafen, one of the world's largest suppliers to the automotive industry. **p18**

## 5G slowdown hits RF sector, while silicon carbide powers ahead

According to IDC, smartphone shipments were down by a record 18.3% year-on-year to 300.3 million units for fourth-quarter 2022 (representing the first ever sequential drop in the holiday quarter), and down by 11.3% for full-year 2022 to 1.21 billion (the least since 2013) — see page 6. This is attributed to macro-economic uncertainties, inflation and dampened consumer demand and hence high inventory, putting the forecasted 2.8% recovery in 2023 in jeopardy.

The impact up the supply chain is shown by the December-quarter revenues of major RF component makers Skyworks and Qorvo in the USA declining year-on-year by 12% and 33.3%, respectively (pages 8–12).

Skyworks notes inventory burn-off by South Korea's Samsung (falling below 10% of its revenue) and Oppo, Vivo and Xiaomi (driving China below 5%). Compared with its Broad Markets sector, the Mobile products sector hence fell to 65% of Skyworks' revenue (from 68% a year ago), with weakness in Android in particular (whereas Apple comprised 68% of total revenue, despite the COVID-related disruption of its production in China).

For the same reasons, Qorvo's Advanced Cellular Group (ACG) revenue fell by 36.6% year-on-year. Likewise, US-based Wolfspeed saw revenue for its gallium nitride (GaN) RF device decline 25% sequentially in the December quarter, citing recession-driven push-outs of 5G orders (page 20).

Further up the supply chain, US-based AXT's indium phosphide substrate revenue in Q4/2022 was down 26% sequentially, due partly to slowing 5G telecom infrastructure installations, particularly in China (see page 30).

Meanwhile, metal-organic chemical vapor deposition (MOCVD) system maker Veeco has reported Compound Semiconductor segment revenue in Q4/2022 down 10.7% sequentially and more than 50% year-on-year (see page 36). "Compound Semi is setting up to be a challenging year in the near term, driven by weakness in 5G RF related to the smartphone weakness," notes CEO Bill Miller. However, longer term, Veeco feels better about the Compound Semiconductor sector because the markets that it is aiming to penetrate, such as power electronics and micro-LEDs, are growing and have enormous potential for the firm.

Correspondingly, on 1 February Veeco said it had acquired Sweden-based silicon carbide (SiC) CVD system maker Epiluvac, targeting power devices (e.g. for electric vehicle applications) - see page 34. It will hence compete with German MOCVD system-making rival Aixtron, which acquired Sweden-based SiC CVD system maker Epigress in 1999, and which launched its high-volume 6x200mm-wafer G10-SiC CVD system last September.

The rapidly growing EV market has also driven Wolfspeed — which is still ramping up production at the world's first 200mm SiC device fab (Mohawk Valley Fab, in Marcy, NY, USA) — to announce plans for a yet larger SiC device fab, this time in Germany, with investment from Germany-based ZF (one of the largest suppliers to the automotive industry) — see page 18.

Meanwhile, other manufacturers of mainly silicon chips are being drawn to further invest in SiC. Most recently, Arizona-based Microchip is expanding its SiC and silicon capacity in Colorado, targeting use in automotive/E-mobility, grid infrastructure, green energy, and aerospace & defense (page 14).

While revenues in the RF sector should rebound in second-half 2023, developments in the SiC power sector are set to continue unabated.

**Mark Telford, Editor**

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

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### Semiconductor Today (ISSN 1752-2935) is published free of subscription charge

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

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# Quarterly smartphone shipments fall a record 18.3% year-on-year to 300.3 million in Q4/2022

## Full-year shipments fall 11.3% to 1.21 billion; 2023's expected 2.8% rebound now in doubt

According to preliminary data from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker, global smartphone shipments fell by 18.3% year-on-year to 300.3 million units in fourth-quarter 2022. This is the largest-ever decline in a single quarter and contributed to a steep 11.3% decline for full-year 2022 to 1.21 billion units — the lowest annual total since 2013 — due to significantly dampened consumer demand, inflation and economic uncertainties. This tough close to the year puts the 2.8% recovery expected for 2023 in serious jeopardy, with heavy downward risk to the forecast, notes IDC.

"We have never seen shipments in the holiday quarter come in lower than the previous quarter. However,

weakened demand and high inventory caused vendors to cut back drastically on shipments," says Nabila Popal, research director with IDC's Worldwide Tracker team.

"Heavy sales and promotions during the quarter helped deplete existing inventory rather than drive shipment growth. Vendors are increasingly cautious in their shipments and planning while realigning their focus on profitability. Even Apple, which thus far was seemingly immune, suffered a setback in its supply chain with unforeseen lockdowns at its key factories in China. What this holiday quarter tells us is that rising inflation and growing macro concerns continue to stunt consumer spending even more than expected and push out any possible recovery to the very end of 2023," she adds.

"We continue to witness consumer demand dwindle as refresh rates climb past 40 months in most major markets," says Anthony Scarsella, research director with IDC's Worldwide Quarterly Mobile Phone Tracker. "With 2022 declining more than 11% for the year, 2023 is set up to be a year of caution as vendors will rethink their portfolio of devices while channels will think twice before taking on excess inventory," he adds. "However, on a positive note, consumers may find even more generous trade-in offers and promotions continuing well into 2023 as the market will think of new methods to drive upgrades and sell more devices, specifically high-end models."

[www.idc.com/getdoc.jsp?containerId=IDC\\_P8397](http://www.idc.com/getdoc.jsp?containerId=IDC_P8397)

### Top 5 companies, worldwide smartphone shipments, market share, and year-on-year growth, Q4/2022 (preliminary results, shipments in millions of units).

Company	Q4/22 shipment volumes	Q4/22 market share	Q4/21 shipment volumes	Q4/21 market share	Year-on-Year change
1. Apple	72.3	24.1%	85.0	23.1%	-14.9%
2. Samsung	58.2	19.4%	69.0	18.8%	-15.6%
3. Xiaomi	33.2	11.0%	45.0	12.2%	-26.3%
4. OPPO	25.3	8.4%	30.1	8.2%	-15.9%
5. vivo	22.9	7.6%	28.3	7.7%	-18.9%
Others	88.3	29.4%	110.2	30.0%	-19.8%
<b>Total</b>	<b>300.3</b>	<b>100%</b>	<b>367.6</b>	<b>100%</b>	<b>-18.3%</b>

Source: IDC Worldwide Quarterly Mobile Phone Tracker, 25 January 2023

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# Skyworks' quarterly revenue falls during Android-related inventory consumption

## Record free cash flow margin of 53% driven by operational efficiencies and tail-off of capital expenditure

For fiscal first-quarter 2023 (to 30 December 2022), Skyworks Solutions Inc of Irvine, CA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$1.329bn, down 5.5% on \$1.407bn last quarter and 12% on \$1.51bn a year ago, but exceeding consensus estimates.

Skyworks' largest customer comprised about 68% of total revenue, despite them being supply constrained due to COVID-related issues in China. In contrast, South Korea's Samsung was less than a 10% customer. "They are going through an inventory burn-off period right now. Proactively, we have reduced our shipments to that customer," notes senior VP & chief financial officer Kris Sennesael. "We stepped back a bit on Android as the inventory levels were building in the channel," adds chairman, CEO & president Liam K. Griffin. Similarly, Oppo, Vivo and Xiaomi are also "going through an inventory cycle now", so China comprised less than 5% of revenue. "That's because the market didn't need more than that, and we didn't want to sell more than that," says Griffin. "We never built the inventory up. We try to meet the demand as it is."

Mobile products comprised 65% of total revenue (down from 68% a year ago), with weakness in Android while customers work down their inventory levels.

Broad Markets products comprised 35% of revenue, down year-on-year due to macroeconomic headwinds, but with a strong contribution from automotive (a sixth consecutive quarter of record revenue), infrastructure, industrial, and the global upgrade to Wi-Fi 6E (which presents a big step-up in content) and some early design wins for Wi-Fi 7 that are now being turned into revenue.

"Skyworks delivered solid first quarter results, leveraging our increasingly diverse portfolio of mobile and IoT solutions," says Griffin. "The rapid expansion of mobile network traffic, advances in cloud and edge computing, IoT, and the electrification of vehicles are major trends that drive complexity and demand for our highly integrated and customized solutions," he adds. "We expanded our design-win pipeline in several emerging high-growth segments":

- In IoT, Skyworks extended its technology portfolio across a growing customer base. The firm partnered with AT&T to launch their first Wi-Fi 6 passive optical network (PON) gateways, unveiled the industry's first Wi-Fi 7 networking system with TP-Link [shipping into their quad-band mesh router systems], and leveraged its advanced connectivity portfolio to support 6GHz fixed-wireless access points at Cambium Networks.

- Across infrastructure and industrial markets, Skyworks integrated Power-over-Ethernet functionality into Cisco's modular switches for enterprise networks, ramped timing platforms to meet high-precision and high-speed requirements for the leading data centers, and delivered frequency-generation and clock distribution technology to a European infrastructure provider for 5G massive MIMO deployments.

- In automotive, Skyworks strengthened its electric vehicle (EV) design-win pipeline with onboard charger content at a Japanese automotive supplier, and secured design wins for digital radio platforms with a top European OEM."

Despite the decline in revenue, on a non-GAAP basis, gross margin has risen further, from 51.2% a year ago and 51.3% last quarter to 51.5%, due to driving operational

efficiencies into the firm's factories with "great execution" despite adjustments made to factory loadings, aided by Skyworks doing "just about everything" in-house. "The ability to do that also includes great supply chain management," says Griffin.

Operating expenses were \$193m (14.5% of revenue), up from \$187m (12.4% of revenue) a year ago but roughly level with \$192m last quarter.

Net income has fallen further, from \$523m (\$3.14 per diluted share) a year ago and \$486m (\$3.02 per diluted share) last quarter to \$415m (\$2.59 per diluted share).

Nevertheless, operating cash flow was a quarterly record of \$773m (up from \$236m last quarter). Capital expenditure has fallen to \$64m (from \$142m last quarter, as the CapEx rate moderates compared with the 10-12% of revenue over the last five years). Free cash flow was hence a record \$709m (a margin of 53% of revenue), up from \$486m a year ago.

During the quarter, Skyworks paid \$99m in dividends and repurchased about 1.8 million shares of common stock for a total of \$166m. On a trailing 12-month basis, the firm has returned \$1.2bn to shareholders through dividends and buy-backs.

Overall, during the quarter cash, cash equivalents and marketable securities rose from \$586.8m to \$992.6m.

Since the end of the quarter, Skyworks' board of directors has declared a cash dividend of \$0.62 per share of common stock, payable on 21 March, to stockholders of record at the close of business on 28 February.

"Additionally, our board of directors has approved a new \$2bn stock repurchase program, demonstrating their confidence in our business

and its ability to continue generating strong free cash flow,” says Sennesael.

For fiscal second-quarter 2023 (to end-March), Skyworks expects revenue to fall to \$1.125–1.175bn, with Broad Markets down slightly sequentially, somewhat in line with normal seasonality. In Mobile, Android-related business will remain low, especially in China, with Vivo and Xiaomi — and, to a certain extent, Samsung as well — still going through the inventory burn-off process.

Gross margin should fall to 50–50.5%. Despite operating expenses being cut to \$189–191m, diluted earnings per share are expected to fall to \$2.02.

“Inventory overhang is starting to abate already... We will start seeing some improvements in the June quarter and then, for sure, in the back half of calendar year 2023,” believes Sennesael.

“As we get through this quarter and starting to see toward the second half of the year a more improving macro-environment, we will be very well-positioned to execute. If things change, we can move faster if we need to. But it’s not a technology issue. It’s not an execution issue,” says Griffin.

“Despite some of those macro-

economic headwinds and challenges and somewhat softer demand and maybe a little bit of inventory correction that is going on, we do believe that we can grow our Broad Markets business this year,” says Sennesael. “We play in some high-growth markets with some really key technologies... We have strong design-win momentum.”

Over the last five years, Skyworks has put a lot of technology-related investments in place (\$500–600m of CapEx annually). “We spent that money over the last four or five years strategically to build up a competency in bulk acoustic wave (BAW) and other filter technology. It’s very, very difficult stuff. It’s not available in the merchant market. So, it was a make versus buy approach. We did the make. So, we developed solutions that are purpose-built for Skyworks and purpose-built for our customers,” says Griffin.

“Now, we have to leverage that capacity. We’re focusing really now on driving operational efficiencies, die shrinks, yield improvements, which gives us a lot more capacity leveraging the installed base of the equipment that we have... without putting more equipment in place,” says Sennesael.

“The vast majority of that CapEx was going into expanding our BAW filter operation where we have — of course, from a small base — doubled and doubled and doubled again the capacity there,” says Sennesael. “Our revenue from devices that have BAW filters in will continue to grow very strongly. We will not hesitate to put more capacity in place if and when needed,” he adds.

“There will be incremental CapEx spend over the next several years, but it won’t be at the level of the last three or four, because now those investments are in-house, at scale, and running,” says Griffin. “It really will help to further improve our strong cash flow that we have already,” notes Sennesael. “We expect further strong cash flow for the remainder of the year, again, based on some moderate CapEx. But we could drive our free cash flow over 30% [of revenue] in this fiscal year,” he adds.

“Skyworks is well positioned to navigate a challenging macro backdrop with its highly profitable business model, leading connectivity technologies and an expanding set of customers across many of the strongest market segments,” concludes Griffin.

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# Qorvo's quarterly revenue falls by a third due to weak end-market demand and elevated channel inventories

## Farmers Branch fab and biotech business to be sold

For fiscal third-quarter 2023 (ended 31 December 2022), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$743.3m, down 35.8% on \$1158.1m last quarter and 33.3% on \$1114m a year ago, but \$18m above the midpoint of the \$700–750m guidance range.

"We enjoyed relatively strong performance in automotive, broadband, defense and silicon carbide (SiC) power devices," says chief financial officer Grant Brown. "However, elevated channel inventories and weak end-market demand pressured revenue and order activity across all three operating segments [High-Performance Analog (HPA), Connectivity & Sensors Group (CSG) and Advanced Cellular Group (ACG)]."

High-Performance Analog (HPA) revenue was \$155m, down 14.8% on \$182m a year ago, as growth in defense and power devices — including robust design activity for silicon carbide (SiC) — was offset by inventory consumption in the 5G base-station infrastructure market and softness in consumer-facing power management integrated circuit (PMIC) markets such as solid-state drives (SSDs) and battery-powered tools.

Connectivity & Sensors Group (CSG) revenue was \$97m, down 38.6% on \$158m a year ago, reflecting lower end-market demand plus channel inventory digestion for Wi-Fi products, partially offset by strength in automotive. However, design activity was strong across customers and products, including ultra-wideband, matter and sensors. Use-cases continue to proliferate their benefit from precision location, indoor navigation, seamless connectivity and enhanced human-machine interfaces.

Advanced Cellular Group (ACG) revenue was \$491m, down 36.6% on \$775m a year ago, reflecting macroenvironment-driven lower smart-phone unit volumes across customers and channel inventory digestion within the Android ecosystem. However, design activity continued to be strong across customers and product categories and supports year-over-year content gains at Qorvo's largest customers (the biggest comprises about two-thirds of ACG revenue).

On a non-GAAP basis, gross margin has fallen further, from 52.6% a year ago and 49.2% last quarter to 40.9% (below the 43–44% guidance), impacted by: 920 basis points due to lower factory utilization and higher inventory-related charges (as net inventory balance rose slightly, from \$841m to \$857m); 30 basis points due to a quality issue at a supplier; and 80 basis points due to inflation across direct costs.

Operating expenses have been cut more than expected, from \$232.5m last quarter to \$205.7m (below the targeted \$225.5–227.5m guidance range) due to OpEx discipline, the timing of product development spend, and lower employee-related expenses including incentive-based compensation.

**We enjoyed relatively strong performance in automotive, broadband, defense and SiC power devices. However, elevated channel inventories and weak end-market demand pressured revenue and order activity across all three operating segments**

Net income has fallen further, from \$330.4m (\$2.98 per diluted share) a year ago and \$276.2m (\$2.66 per diluted share) last quarter to \$76.5m (\$0.75 per diluted share, albeit at the top of the \$0.70–0.75 guidance range).

Net cash provided by operating activities was \$237.4m (up from \$117m a year ago). Capital expenditure amounted to \$34.4m. Free cash flow was hence \$203m. During the quarter, Qorvo repurchased about \$200m worth of shares. Overall, cash and equivalents hence rose from \$914m to \$919m. Qorvo has \$2bn of debt outstanding with no near-term maturities.

"The Qorvo team is operating well in navigating a challenging environment and taking actions to position the company for growth and improved performance," says president & CEO Bob Bruggeworth. "We are introducing best-in-class products and technologies, and our customers are recognizing us with design wins, quality awards, and new and expanded programs," he adds.

Such strategic highlights are listed as follows:

- In High-Performance Analog (HPA), Qorvo began sampling an integrated radar power solution that combines a high-voltage power conversion PMIC with SiC power switches to control a gallium nitride (GaN) RF power amplifier (PA), reducing total solution size by up to 30% in defense & aerospace (D&A) radar power systems while expanding Qorvo's content opportunity.

Qorvo also expanded its SHIP (heterogenous integrated packaging) contract with the US government to develop multi-chip modules that combine digital optical devices with Qorvo's mixed-signal RF.

In aerospace, Qorvo delivered a multi-chip solution that includes its high-frequency bulk acoustic wave (BAW) filter as well as a GaN PA for low Earth orbit (LEO) satellites and

other aerospace applications. The solution supports cellular satellite links, for which Qorvo has secured new design wins. "The opportunity for Qorvo is notable, given the trend in defense & aerospace applications of one to many. That means rather than one jet, there will also be many drones; rather than one geosatellite, there will also be many LEO satellites," notes Bruggeworth. "At the same time, new capabilities are being added to existing platforms that require increased semiconductor content and higher-density and more advanced packaging, all areas where Qorvo is strong and is investing to advance the technology," he adds.

In cellular infrastructure, Qorvo commenced pre-production shipments of its first integrated PA modules (PAMs) to a tier-1 European infrastructure OEM for 5G massive-MIMO base stations. It also began sampling its next-generation PAM, which delivers what is claimed to be market-leading efficiency for 5G massive-MIMO installations to the leading European infrastructure OEMs.

For broadband infrastructure applications, Qorvo sampled a CATV power doubler amplifier that maintains linearity and extends bandwidth to enable higher-throughput DOCSIS 4.0 capabilities with industry-leading power efficiency. Deployments of DOCSIS 4.0 are scheduled to begin this year and Qorvo reckons that it is positioned as the industry leader.

● In the Connectivity & Sensors Group (CSG), Qorvo expanded its Wi-Fi content at a Korea-based smartphone OEM to include Wi-Fi 6E and Wi-Fi 7 designs and ramped Wi-Fi 7 front-end modules (FEMs) for access points and routers for its smart home ecosystem customer.

Qorvo began sampling 5GHz and 6GHz filters that leverage its next-generation BAW process, enabling worldwide Wi-Fi 7 frequency coverage. "There is increasing customer interest related to multi-link operation, which is a key attribute of Wi-Fi 7 and enables higher throughput and lower latency,"

notes Bruggeworth.

Qorvo also began volume shipments of MEMS-based sensors for true wireless stereo earbuds, replacing legacy capacitive touch sensor technology. "Design activity for sensors continues to be strong across markets, including automotive," says Bruggeworth. "We are working with leading automotive tier-1s and have secured automotive smart interior design wins in more than 25 vehicles."

● In the Advanced Cellular Group (ACG), Qorvo began the production ramp of multiple components for a flagship platform of the leading Korea-based smartphone OEM, and secured multiple design wins across Android OEMs in support of 2023 devices. "We have increased our content significantly year-over-year," notes Bruggeworth. "We are broadly serving this customer across our portfolio and continue to support the migration of their mass-market phones to integrated 5G solutions."

Qorvo was also selected by a US-based Android OEM to supply multiple solutions, including ultra-wideband (UWB), antenna tuning and BAW-based antenna-plexing in support of their 2023 smartphone launches. Finally, Qorvo was recognized by multiple customers, including receiving Honor's 2022

**Qorvo's inventory position will decline in March, but remain elevated. In terms of channel inventory, total channel inventory for our components in the Android ecosystem was reduced by over 20% in the December quarter. We expect continued improvement this quarter and anticipate the channel to normalize later this calendar year**

Golden Supplier Award as well as quality awards from Vivo for discrete switches and amplifiers and highly integrated solutions.

"In 2023 and beyond, the secular trends in our businesses remain strong," says Bruggeworth. "Customers increasingly require higher levels of performance, integration and functional density to deliver successive improvements in next-generation products," he adds.

For its fiscal fourth-quarter 2023 (to end-March), Qorvo expects revenue to fall further, to \$600–640m (down from \$1166m a year ago), despite expecting sales to Android smartphone customers to grow sequentially. Revenue from China-based smartphone OEMs will remain roughly flat. The decline reflects ongoing demand weakness across end-markets as well as expectations for further consumption of channel inventory.

"Qorvo's inventory position will decline in March, but remain elevated. In terms of channel inventory, the picture has begun to improve. For example, total channel inventory for our components in the Android ecosystem was reduced by over 20% in the December quarter. We expect continued improvement this quarter and anticipate the channel to normalize later this calendar year," says Brown.

"We expect production levels to remain compressed. This will lead to continuing under-utilization charges related to inventories, which will weigh on gross margin during fiscal Q4 and carry into next fiscal year," he adds. With under-utilization and inventory-related charges having about the same impact as in fiscal Q3, together with continued inflation across direct costs, gross margin should hence be roughly flat at about 41% in fiscal Q4.

Operating expenses should rise about \$20m sequentially due to the timing of product development spend, seasonal payroll effects and other employee-related expenses. Diluted earnings per share are ➤

► hence expected to fall further, to \$0.10–0.15.

“In addition to ongoing alignment of supply and demand, we expect unit volumes across our businesses will recover later this year, and we have secured content gains in large customer programs, all of which will support improved financial performance,” says Brown.

“We would expect June [quarter] to be roughly flattish. I would expect September to see significant sequential growth and then December and the March 2024 quarters to be back to strong annual growth from there,” says Bruggeworth. “At our largest two customers, we are very confident in our ability to grow year-over-year content, and that includes this year,” he adds. “Over the course of fiscal 2024, I could see potentially that 920 basis points of margin [impact from factory under-utilization and inventory-related charges] get cut in half.”

“We continue to make improvements in product development, filter design, process engineering,

factory planning, manufacturing efficiency and many other areas. Today, these gains have significantly increased our effective BAW capacity,” says Brown. “Looking forward, we can double our BAW capacity in the Richardson facility versus our current maximum theoretical thresholds today,” he adds. “We see an expanding market for our BAW technology. We intend to put that to good use as we continue to capture designs and grow our BAW content in flagship phones,” adds Bruggeworth.

“Increasing throughput of an existing asset not only reduces cost, but can reduce complexity within the factory network as production is consolidated. The BAW productivity gains in our Richardson facility [e.g. die-size shrinks, the transition from 6- to 8 inch wafers, and successive generations of BAW filters] allow us to achieve our long-term growth goals across all of our customers, including the most demanding BAW-based placements. As a result, we have decided to sell our Farmers Branch

facility [described as a ‘safety valve’ whose capacity is no longer needed, since the Richardson productivity gains came to fruition]. We’re in the early stages of marketing the site and initial interest has been encouraging. For reference, the site has been incurring approximately \$12m of non-GAAP COGS [cost of goods sold] per year,” Brown notes.

“We are also evaluating strategic alternatives for our biotechnology business to accelerate and maximize its potential value. The Omnia platform, which is based on our BAW sensor technology, has demonstrated significant promise as a diagnostic testing solution,” continues Brown. “The biotechnology unit currently resides in our CSG segment. While the revenue impact from a transaction would be negligible, it would reduce total expenses by about \$32m per year. These actions will sharpen our focus and resources on the many growth drivers across our three operating segments.”

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

## MACOM to acquire OMMIC for €38.5m

### High-frequency MMICs and design capability address telecoms, industrial and aerospace & defense markets

MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies) has entered into a definitive agreement through one of its French subsidiaries to acquire the assets and operations of semiconductor manufacturer OMMIC SAS of Limeil-Brévannes, near Paris, France, which has expertise in wafer fabrication, epitaxial growth and monolithic microwave integrated circuit (MMICs) processing and design.

OMMIC has a 40+ year heritage in material science, semiconductor wafer processing and MMIC design. Its gallium arsenide (GaAs) and gallium nitride (GaN) compound semiconductor manufacturing

capabilities include multiple European Space Agency (ESA)-qualified semiconductor processes and products. OMMIC operates a 3-inch wafer production line and has recently installed, but is not currently utilizing, a 6-inch line.

MACOM reckons that OMMIC’s portfolio of high-frequency MMIC products and its design capability will enable it to better address microwave applications in the telecoms, industrial and aerospace & defense markets.

“We are excited to acquire a new engineering and manufacturing facility located in France,” says president & CEO Stephen G. Daly. “Acquisition of OMMIC is expected to enable us to further increase our focus on the European markets,

expand our wafer production capability and extend our product offerings to higher millimeter-wave frequencies, which are all in line with our long-term strategy,” he adds. “Combining OMMIC’s technology and manufacturing capability with MACOM’s scale and market presence will be a driver of long-term growth and profitability.”

The purchase price of about €38.5m will be funded with cash-on-hand and includes real estate and all associated facilities. The transaction is expected to close during MACOM’s fiscal second-quarter 2023 and is subject to regulatory approvals and customary closing conditions.

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

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# Microchip investing \$880m to expand SiC and silicon capacity in Colorado Springs

## Production ramp-up to meet demand from automotive/E-mobility, grid infrastructure, green energy and aerospace & defense applications

Microchip Technology Inc of Chandler, AZ, USA plans to invest \$880m to expand its silicon carbide (SiC) and silicon (Si) production capacity at its manufacturing facility in Colorado Springs, CO, USA over the next several years.

One significant phase of the expansion is to develop and upgrade its 50-acre, 580,000ft<sup>2</sup> Colorado Springs campus for increased SiC manufacturing for use in automotive/E-mobility, grid infrastructure, green energy, and aerospace & defense applications.

Working in conjunction with the Colorado Springs Chamber & Economic Development Corporation, the City of Colorado Springs and El Paso County also announced that Microchip was approved for state and local incentives of about \$47m for the expansion.

"We estimate this will grow our local economy by approximately \$1.4bn over the next 10 years and create roughly 400 new high-paying jobs for those living in the Pikes Peak Region," commented Colorado Springs Mayor John Suthers. "Ramping up the production of semiconductors is critical to satisfying growing demand across many industries," he added.

"Last year, I helped pass the CHIPS and Science Act to reinvigorate America's semiconductor industry and bring manufacturing jobs back to America," noted US Senator for Colorado Michael Bennet. "In Colorado, we're already seeing the benefits as companies prepare for historic investments from the law. Microchip's planned expansion in Colorado Springs will not only strengthen our national security, but also expand opportunity with another 400 good-paying jobs."

"As concerns mount over foreign dominance of this critical industry, it is increasingly important that the



US achieve domestic production of microchips," believes Doug Lamborn, US Congressman for Colorado's 5th Congressional District.

"Microchip Colorado Springs has a long history of partnering with the city and state," comments Microchip's president & CEO Ganesh Moorthy. "The CHIPS and Science Act

is already making a positive impact on our business through the Investment Tax Credit and we are seeking capacity expansion grants for several of our semiconductor factories, including our Colorado Springs factory."

The Colorado Springs campus

**It is increasingly important that the US achieve domestic production of microchips. The CHIPS and Science Act is already making a positive impact on our business through the Investment Tax Credit and we are seeking capacity expansion grants for several of our semiconductor factories**

currently employs more than 850 people and produces products from 6-inch wafers. The manufacturing technology to be installed will run on 8-inch wafers. The additional 400 jobs at the facility will range from production specialists to technical roles in equipment procurement and management, process control and test engineering.

"With over two-decades of investment in silicon carbide, Microchip's portfolio is designed to provide our customers with innovative power solutions," says Rich Simoncic, senior VP of Microchip's Analog businesses. "This campus is an integral part of producing our SiC technology to assure our customers with supply certainty as they transition to SiC solutions," he adds.

"Microchip's expansion in Colorado Springs and El Paso County puts our region on the map for investment from the CHIPS and Science Act," comments Colorado Springs Chamber & Economic Development Corporation's president & CEO Johnna Reeder Kleymeyer. "We are proud to lead Microchip's expansion project and support the re-shoring of these important manufacturing jobs to the Pikes Peak region."

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

# Diodes Inc launches its first silicon carbide Schottky barrier diodes

Products rated at 650V (4A, 6A, 8A & 10A) and 1200V (2A, 5A & 10A)

Power semiconductor product supplier Diodes Inc of Plano, TX, USA has released its first silicon carbide (SiC) Schottky barrier diodes (SBD). The portfolio includes the DSCxxA065 series comprising eleven products rated at 650V (4A, 6A, 8A and 10A) and the DSCxx120 series comprising eight products rated at 1200V (2A, 5A and 10A).

The wide-bandgap Schottky barrier diodes bring the benefits of significantly improved efficiency and high-temperature reliability, while also responding to market demands for reduced system running costs and low maintenance. The devices are suitable for AC-DC, DC-DC and DC-AC switching converters, photovoltaic inverters, uninterruptible power supplies (UPS), and industrial motor drive applications. They can also be used in a variety of other circuits, such as boost converters for power factor correction (PFC).

The efficient performance of the SiC devices is superior to that of conventional silicon-based products, and provide power supply designers with performance benefits such as:

- Negligible switching losses due to low capacitive charge (QC) that provide high efficiency in fast



switching applications. This is suitable for circuit designs with higher power density and smaller overall solution size.

- Low forward voltage ( $V_F$ ) that further improves efficiency, reducing power losses and operational costs.
- Reduced heat dissipation that helps lower overall system cooling budgets.
- High surge current capability that increases robustness for better

system reliability, while excellent thermal performance reduces build costs, says the firm.

Three package options include surface-mount TO252-2 (Type WX), through-hole TO220AC (Type WX) and ITO220AC (Type WX-NC).

The DSCxxA065 and DSCxx120 series are available for \$1.24–2.33 and \$1.70–6.68, respectively, in 1000-unit quantities.

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

## Alpha and Omega Semiconductor announces silicon carbide license deal and supply agreement

### AOS to provide engineering support for proprietary aSiC technology

Alpha and Omega Semiconductor Ltd (AOS) of Sunnyvale, CA, USA has entered into a license agreement with a "leading power semiconductor automotive supplier" related to AOS's silicon carbide (SiC) MOSFET and diode technology. AOS will license and provide engineering support for its proprietary aSiC technology as well as an accompanying supply agreement.

The new license and supply agreement "further validates the technical leadership of our aSiC technology," says David Sheridan, vice president of SiC products at AOS. "This will provide a great acceleration of our products into the market and have the potential for our customers to secure a geographically diverse supply chain to reduce regional risk."

AOS's automotive aSiC MOSFETs are available from 750V to 1200V, covering the majority of 400V and rapidly expanding 800V electric vehicle (EV) battery systems.

The SiC market is currently one of the fastest-growing segments of the power semiconductor market; the total addressable market (TAM) is forecasted to rise to \$6bn by 2027.

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

# Germany's President visits Infineon's Kulim 3 fab site in Malaysia

## New exhaust-air purification system to improve climate footprint

Infineon Technologies AG of Munich, Germany, says that, as part of his trip to Asia, Germany's President Frank-Walter Steinmeier visited its Infineon Technologies (Kulim) Sdn Bhd site in Kulim Hi-Tech Park (KHTP), Malaysia. The visit focused on Infineon's contribution to enabling the global energy transition with energy-saving semiconductor solutions, as well as by investing in solutions that further reduce the CO<sub>2</sub> footprint in its chip manufacturing.

Infineon is currently spending €2bn on building a third fabrication plant at the Kulim site that will focus on compound semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) that enable further energy-efficiency increases, e.g. in wind turbines, solar power systems, e-vehicles and charging infrastructures. Kulim 3 will be ready for equipment in summer 2024 and will create 900 jobs. Infineon confirmed that construction work is on schedule.

During Steinmeier's visit, Infineon presented its investment in expanding the exhaust-air purification system at the Kulim site. Avoiding CO<sub>2</sub> emissions is a priority for Infineon in implementing its climate strategy. Modern exhaust-air purification systems offer the greatest leverage in this regard. The upgrade in Kulim is expected to result in a reduction of about 8% in global direct site-related emissions (Scope 1) by the end of the 2023 fiscal year compared with the previous year. A planned new exhaust-air purification system in Austin, TX, USA, will lead to further savings.

Infineon has also set the goal of operating 100% of its plants in Malaysia with green electricity in the future and is in close exchange with local suppliers and the government to this end. The initiative aims to further improve Infineon's positive climate contribution.



**German President Frank-Walter Steinmeier autographs a wafer commemorating his visit to Infineon's third fab module in Kulim, currently under construction.**

The firm reckons that its energy-efficient solutions currently help to save 33 times the amount of CO<sub>2</sub> emitted during their production.

"The growing demand for renewable energy, e-vehicles as well as energy-efficient applications will lead to a strong increase in the

demand for power semiconductors," says C.S. Chua, president & managing director of Infineon Asia Pacific. "Our investments in Kulim and beyond are laying the foundation for being able to serve this growing need as well."

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



**Tan Bee Hoon and Malathi Karthigesu of the Infineon Kulim Technology Development team with President Steinmeier during his visit to Kulim 3.**

# onsemi and VW collaborate on SiC for next-gen EVs

## Firms developing complete traction inverter solution for modular car platform

Power semiconductor IC supplier onsemi of Phoenix, AZ, USA has signed a strategic agreement with Germany's Volkswagen AG to provide modules and semiconductors that enable a complete electric vehicle (EV) traction inverter solution for VW's next-generation platform family. The semiconductors are part of an overall system optimization and provide a solution that will support the front and rear traction inverters in the VW models.

As a first step in the agreement, onsemi will deliver its silicon carbide-based EliteSiC 1200V traction inverter power modules. The EliteSiC power modules are pin-to-pin compatible to easily scale the solution to different power levels and types of motors. Teams from the two firms have been collaborating for more than a year on optimization of the power modules for the next-generation platform, with pre-production samples under development and evaluation.

"The superior performance and quality of onsemi's traction inverter

modules, together with our joint efforts to create the best system solution, enable us to deliver the outstanding driving experience and quality customers expect from a VW group vehicle," says Karsten Schnake, head of the operative and strategic semiconductor taskforce COMPASS at Volkswagen.

"onsemi's broad portfolio of intelligent power and sensing solutions further allows us to offer cutting-edge technologies and features in our EVs, from the traction inverter and beyond," he adds. "Besides this milestone, onsemi — with its balanced production facility layout in the USA, Asia and Europe, including the plant in the Czech Republic — is the perfect match to support our strategic markets with all high-voltage solutions and more."

With 19 wafer fabrication and packaging manufacturing sites, onsemi provides VW with more than 500 different devices — including IGBTs, MOSFETs, image sensors and power management integrated circuits (PMICs). In addition,

onsemi has a vertical silicon carbide production chain — which includes volume boule growth, wafering, substrate, epitaxy, device fabrication, best-in-class integrated modules and discrete package solutions — that supports a secured supply chain.

"Our broad manufacturing footprint — including a resilient end-to-end SiC supply chain — empowers onsemi to deliver the supply assurance OEMs demand," says Simon Keeton, executive VP & general manager, Power Solutions Group, onsemi. "Our investments in ramping production globally, especially in silicon carbide, further allow us to support VW's rapidly scaling EV production."

The inverter solution for EVs consists of onsemi's EliteSiC 1200V 3x half-bridge modules, and this system solution supports both axle inverters covering a wide range of power.

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

[www.onsemi.com/products/discrete-power-modules/power-modules/silicon-carbide-sic-modules](http://www.onsemi.com/products/discrete-power-modules/power-modules/silicon-carbide-sic-modules)

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# Wolfspeed chooses Germany for site of largest silicon carbide device fab

Wolfspeed Inc of Durham, NC, USA plans to build a highly automated 200mm-wafer silicon carbide device fabrication facility — the largest in the world — in Ensdorf near Saarbrücken, in the south-western German state of Saarland. The firm's first fab in Europe will be its most advanced, creating an SiC development and production facility in the European Union to support growing demand for a wide variety of automotive, industrial and energy applications.

The fab is planned as part of a collaboration within the IPCEI (Important Project of Common European Interest) for the Microelectronics and Communication Technologies framework, and is dependent on state aid approval from the European Commission. IPCEI funding is intended to support technology development and initial deployment within this project. Germany-based ZF Friedrichshafen AG (one of the world's largest suppliers to the automotive industry) also intends to support the new construction via a sizable financial investment as part of a new strategic partnership.

The European fab is an important part of the Wolfspeed's broader \$6.5bn capacity expansion, which includes opening the 200mm Mohawk Valley Fab in Marcy, NY, USA in April 2022, and the construction in North Carolina of the 445-acre

(180-hectare) John Palmour Manufacturing Center for Silicon Carbide (the world's largest SiC crystal growth facility), which will expand the firm's existing materials capacity by over 10x. The first phase of construction for the materials facility is due to be complete by the end of fiscal 2024.

"This new fab represents a big step forward for both Wolfspeed and our regional customers, as we enhance the ecosystem for semiconductor production and innovation," says president & CEO Gregg Lowe. "Silicon carbide devices offer greater energy efficiency and are essential in the global shift toward sustainable electrification," he adds. "This new facility will be crucial to supporting our expansion in a capacity-constrained industry that is growing very rapidly, especially across the electric vehicle (EV) marketplace. It was important for us to have a facility located in the heart of Europe, near many of our customers and partners, to foster collaboration on the next generation of silicon carbide technologies."

The announcement was made at an event on the 35-acre (14-hectare) site of the planned fab, a former coal-fired power plant in Saarland. To welcome Wolfspeed to the region, German Chancellor Olaf Scholz was in attendance, with Robert Habeck, Vice Chancellor of Germany and

Federal Minister for Economic Affairs and Climate Action, and Saarland's Minister-President Anke Rehlinger. Representing the new partnership were ZF's CEO Holger Klein and board member Stephan von Schuckmann. Wolfspeed also announced a strategic partnership with ZF that includes an investment in Wolfspeed as well as a joint Silicon Carbide R&D facility in Germany, which is part of the same IPCEI framework. Fab construction should begin in first-half 2023, subject to EU Commission approval.

"This project is a great transformation driver and a job engine for a traditionally industrial region," said Saarland's Minister-President Anke Rehlinger. "Furthermore, it bundles important know-how in Europe and contributes to the implementation of the European Green Deal by reducing energy consumption and CO<sub>2</sub> emissions."

The new fab will be designed for manufacturing processes to produce the future generation of silicon carbide devices. It will also employ innovative sustainability measures, including a high proportion of recycled water and a reduced emission footprint, which is intended to serve as a model for more sustainable fabs in the future. The fab should employ more than 600 people when fully operational.

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

## Senior leadership team expanded to support growth

As part of its accelerated growth and capacity expansion plan, Wolfspeed has expanded its senior leadership team (SLT) with the promotion of four global operations leaders to senior VP roles (reporting to president & CEO Gregg Lowe):

- Tom Agron, global expansion operations;
- Lisa Fritz, global quality;
- Adam Milton, global materials operations; and
- Missy Stigall, global fab operations.

"Tom, Lisa, Adam and Missy each made tremendous contributions in shaping the company we are," says Lowe. "These promotions demonstrate our continued commitment to enhancing our culture of innovation, quality and execution."

Also, Wolfspeed has expanded chief financial officer Neill Reynolds' responsibilities (adding procurement, planning and backend operations) and made the following promotions (reporting to Reynolds):

- Jeff Ferraro to senior VP, global procurement & planning;
- Joe Roybal to senior VP, global backend operations; and
- Kevin Speirits to senior VP, finance.

Rex Felton, senior VP of global operations, is leaving Wolfspeed in March. "Rex has done an incredible job of putting the structures, processes and people in place that will allow our global operations to scale efficiently to meet our long-term growth plan," comments Lowe.

# ZF invests in Wolfspeed to support construction of largest SiC device fab

## Joint R&D center in Germany to advance silicon carbide system and device innovation

Wolfspeed Inc of Durham, NC, USA and Germany-based ZF Friedrichshafen AG (one of the world's largest suppliers to the automotive industry) have announced a strategic partnership that includes the creation of a joint innovation lab to drive advances in silicon carbide (SiC) systems and devices for mobility, industrial and energy applications. The partnership also includes a significant investment by ZF to support the planned construction of the world's largest 200mm silicon carbide device fabrication plant in Ensdorf, Germany.

Both the joint innovation lab and the Wolfspeed device fab are planned as part of the Important Project of Common European Interest (IPCEI) for Microelectronics and Communication Technologies framework, and are dependent upon state aid approval from the European Commission.

"These initiatives are a significant step towards a successful industrial transformation," says ZF's CEO Dr Holger Klein. "They strengthen European supply resilience and, at the same time, support the European Green Deal and the strategic goals for Europe's Digital Decade."

### **Wolfspeed and ZF partner on Silicon Carbide R&D Center**

The strategic partnership includes a joint research facility in Germany that will focus on real-world e-mobility and renewable energy system-level challenges. The goal of the collaboration is to develop breakthrough innovations for silicon carbide systems, products and applications, covering the full value chain from chip to complete systems. Additional collaboration partners will be invited to participate in the innovation process, establishing an end-to-end, European silicon carbide innovation network.



The R&D center will focus on innovation for silicon carbide systems and devices to meet specific requirements in all mobility segments including consumer, commercial, agricultural and industrial vehicles as well as in the industrial and renewable energy markets. The collaboration will drive improvements such as higher efficiency, increased power density and higher performances for electrification solutions.

### **ZF to invest in Wolfspeed for next-gen 200mm SiC fab**

Wolfspeed plans to construct a fully automated 200mm wafer fabrication facility in Saarland, Germany. ZF intends to support this new construction by making a sizable financial investment of hundreds of millions of dollars in exchange for Wolfspeed common stock. As a part of this investment, ZF will have a minority ownership stake in the fab. Wolfspeed will maintain all operational and management control rights. Previously, in November 2019, ZF and Wolfspeed (then called Cree) announced a strategic partnership to create highly efficient electric drivelines with a silicon carbide inverter, and these new initiatives represent the next generation of innovation for the partners.

"We have a strong partner by our side in ZF, which brings industry-leading experience in scaling components for electric mobility as well as the aptitude to accelerate innovation in silicon carbide systems and power devices," says Wolfspeed's president & CEO Gregg Lowe. "This partnership will lift silicon carbide semiconductor technology to a new level of global impact, supporting increased sustainability and efficiency efforts across a multitude of industries," he adds.

"Together, Wolfspeed and ZF combine expertise in power electronics and systems with a know-how in applications that is unparalleled in the industry," claims ZF's board member Stephan von Schuckmann. "Wolfspeed brings its more than 35 years in silicon carbide technology, and at ZF we have a unique understanding of the overall systems across all sectors — from passenger cars and commercial vehicles to construction machinery, wind power and industrial applications," he adds. "The close cooperation between fab and R&D center will enable us to develop breakthrough innovations beyond state of the art for the benefit of our customers."

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

# Wolfspeed's quarterly revenue falls 10% due to spare parts supply chain constraints plus weak 5G RF device demand

## New 200mm SiC Mohawk Valley Fab to start meeting burgeoning power device demand in June quarter

For fiscal second-quarter 2023 (to 25 December 2022), Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has reported revenue of \$216.1m, up 25% on \$173.1m a year ago but down 10% on \$241.3m last quarter and at the low end of the \$215–235m guidance range.

“We are continuing to see very, very strong demand across both [silicon carbide] power devices and materials. However, the supply chain issues we discussed last quarter caused variability in our quarterly revenue in the second quarter, with equipment spare part shortages limiting our Durham [power device] fab output, while at the same time we continue to work through the ramp of our taller 150mm [material] boules,” says chief financial officer Neill Reynolds. Wolfspeed recently made a breakthrough in growing taller boules, as it has continued to refine its crystal growth operations. “For both of those areas [SiC materials and power devices] that’s going to be much more of a supply situation rather than it being a demand situation. So bringing on supply is really the critical focus there,” he adds.

“We have made significant progress on both issues and they are currently processing these improvements through our production cycle,” Reynolds notes. “It took a little bit longer in the quarter to get to the cycle times and throughput. So we built a bit of inventory [which rose by 26 days to 161 days of inventory on hand]. So shipping rates at the end of the quarter were a bit slower.

“In terms of our power devices, which grew 48% versus last year, we saw strong performance ahead

of our expectations, mostly resolving the Durham spare parts supply chain issue,” says Reynolds. However, with the Durham fab operating at full capacity [about \$400m per year], power devices revenue is now effectively capped at about \$100m per quarter. So, any significant further power device revenue growth will only come after Wolfspeed starts ramping up production at its new Mohawk Valley Fab in Marcy, NY.

“From a materials perspective, we made very significant progress in improving yields on our taller 150mm boules. These yields are now comparable to our historical yields on shorter boules,” says Reynolds. “However, back-end wafer processing cycle times recovered later in the quarter than anticipated, resulting in lower-than-expected Q2 revenues for our materials products. This past quarter represents the bottom of the revenue trough related to this issue as we exited the quarter at yields, cycle times and shipping rates that will all support future materials revenue growth,” he adds.

“We also saw weaker demand for RF products due to secular headwinds with recession-related pull-back in 5G demand [with some orders pushed out in the quarter],” says Reynolds. RF device revenue was hence down by about 25% (\$15m) from last quarter’s peak.

RF devices continue to be dilutive to consolidated gross margin. “Because of the immense demand for our power devices, we have not been able to optimize the RF manufacturing footprint as we had previously planned,” says Reynolds.

Due to this, plus the lower yields on the taller 150mm boules and lower output of the Durham fab due to the supply chain challenges, gross margin (on a non-GAAP basis)

was 33.6%, down from 35.6% last quarter and 35.4% a year ago. “While we made significant progress on both issues [SiC materials and power devices] in the quarter and expect to see improvement moving forward, they both represented a drag on gross margin,” says Reynolds.

Net loss for fiscal Q2/2023 was \$14.2m (\$0.11 per diluted share), cut from \$18.6m (\$0.16 per diluted share) a year ago but up from \$4.9m (\$0.04 per diluted share) last quarter.

Net cash used in operating activities has doubled from \$32.5m a year ago to \$67m. Total capital expenditure (CapEx) was \$104.1m (down from \$143.9m a year ago). Free cash outflow was therefore \$171.1m (cut slightly from \$176.4m).

For fiscal third-quarter 2023 (to end-March), Wolfspeed targets revenue of \$210–230m, reflecting continued strong demand, as well as supply execution improvement in both the power device and materials product lines, partially offset by continued weak demand for RF devices, for which revenue will remain about \$15m lower than previously expected in both fiscal Q3 and Q4.

Gross margin should be 32–34%, as weakness in RF devices due to the lower volumes is offset by some improvement in both power device and materials products. “The initial challenges in managing taller boules in our back-end processing have been resolved, resulting in significantly higher yields,” says Lowe. “It will take a few months before we return to normal production schedule for these materials as the improved product makes its way through the WIP [work-in-process].”

Operating expenses should be \$98–100m. Net loss are expected to rise slightly to \$15–20m (\$0.12–0.16 per diluted share).

During fiscal Q2/2023, cash, cash equivalents, and short-term investments rose from \$1197.2m to \$2484.4m, due largely to the completion in November of a convertible note offering of \$1.75bn anchored by strategic partner BorgWarner.

"Our power devices continue to penetrate more of the market, with strong customer demand and new partnerships with large multi-national auto manufacturers, such as Jaguar Land Rover and Mercedes, and automotive tier-1s such as BorgWarner and ZF," says Lowe. Quarterly design-ins in fiscal Q2/2023 again exceeded \$1bn, at \$1.5bn (70–75% of which is automotive related).

"We are capitalizing on the immense opportunity in next-generation power devices by expanding our capacity footprint," says Lowe.

"We have made great progress in securing funding for our greenfield facility construction and long-term capacity expansion plan," notes Reynolds, referring to construction of the new materials factory in Siler City, North Carolina and the ramp-up of the Mohawk Valley device fab.

"We continue to successfully run test lots through Mohawk Valley [with yields above expectation], which gives us confidence that we are ready to begin scaling production and recognizing revenue from Mohawk Valley in the fourth quarter of this fiscal year [of the order of single-digit millions of dollars, albeit a quarter later than originally hoped]," says Lowe. "Mohawk Valley is a first-of-its-kind fab, purpose built to produce next-generation SiC power devices. While there may be some variability in our short-term results as we qualify and scale the world's first 200mm silicon carbide device fab while also scaling the first production of 200mm silicon carbide wafers, we are well positioned to capitalize on the explosive growth that we see through the end of this decade," he adds. "Our focus on ramping Mohawk Valley will allow us to better scale our power device production, while our 200mm materials capacity also scales. The learnings from Mohawk Valley have given us a

blueprint on how we will approach the construction and ramp of our next fab [since announced as an SiC device fab to be constructed in Saarland, Germany, with ZF as a minority partner]."

"While customer interest remains strong across both materials and power devices, silicon carbide production and manufacturing can present challenges along the way. Our Durham crystal growth operation, which is the world's largest silicon carbide materials factory, currently supplies our entire device business and a significant share of the merchant market. However, that is still not enough to support the massive accelerating demand for silicon carbide. With the intense growth in demand for both captive and merchant wafers comes challenges of growing our materials output as well," says Lowe.

"The immense demand for both merchant and captive materials gives us further confidence in our decision [back in September] to expand the Durham materials footprint and build The John Palmour Manufacturing Center for Silicon Carbide [in Siler City, named in memory of the firm's late founder & chief technology officer, who passed away on 13 November], dramatically expanding our materials capacity [by more than 10x]," says Lowe. "This factory will be a game changer for our business and will allow us to increase supply at unprecedented levels compared to what is currently in the marketplace," he adds.

"Long-term, The John Palmour Manufacturing Center for Silicon Carbide is critical to addressing the supply-demand disconnect that will support our expanding device footprint [at both Mohawk Valley and the planned fab in Germany], as well as the ever-growing demand for merchant wafers. Construction of The JP is progressing well since groundbreaking in September and things remain on track," says Lowe.

"Despite some macroeconomic pressures on the silicon semiconductor market, we are confident in our long-term outlook and the

strong secular trend for the demand for silicon carbide," says Lowe. "Silicon carbide is on the cusp of mass adoption."

"First, electric vehicles were the bright spot in the auto market in 2022, despite many headlines that auto sales have slowed. Global EV sales grew more than 65% year-over-year," says Lowe. "Our recent partnerships with industry leaders such as Jaguar Land Rover and Mercedes-Benz point to the strength in the demand for EVs and our ability to take share in this space. We remain confident in the industry's strong long-term fundamentals," he adds.

"Second, our \$1.5bn of design-ins in the quarter point to continued robust demand for our power devices. To-date, 46% of our design-ins have converted to design wins, representing more than 1800 projects. We are coming off multiple quarters of record design-ins, with a total of more than \$16bn of design-ins over the last three years. Our design-in number continues to be robust and the opportunity pipeline remains at a staggering \$40bn," remarks Lowe. "We have a strong pipeline of design-ins across a wide range of applications, including automotive, industrial and energy. We are increasingly well positioned to capture a significant share of this opportunity and are committed to investing in the necessary infrastructure to support our growth," he adds.

"Third, we continue our market-leadership position in the materials business, the aspect of our business with the highest barriers to entry. We recently announced an expanded agreement with another leading supplier of silicon carbide materials, which illustrates the intense demand. The industry remains supply constrained, and this will continue to be the case for the foreseeable future."

"The opportunity in silicon carbide technology is generational, given the pace of adoption we have experienced over the last few quarters. I have not seen growth like this in my 30 years in semis," remarks Lowe.

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

# European project PowerizeD kicked off, targeting intelligent power electronics

## Infineon coordinating 62 partners in €72m part-EU funded project

The European research initiative PowerizeD has been kicked-off with a meeting of over 100 representatives from 39 companies and 23 research institutions — comprising 62 research partners from 13 European countries — at the headquarters of the project's initiator and coordinator Infineon Technologies AG in Munich, Germany, which is an active participant via several corporate divisions.

Relying on the digitalization of power applications, PowerizeD aims to take the sustainability and resilience of the European energy chain, from generation to application, to a new level and strengthen Europe's technological sovereignty.

Lasting three years until December 2025, the European Union is funding PowerizeD with about €18m as part of the joint program for digital key technologies (Key Digital Technologies Joint Undertaking, KDT JU) in its Digital Agenda. The amount will be matched by funding from the national governments of the respective countries involved, making total funding of €72m. The subsidies from Germany are being provided by the Federal Ministry of Education and Research (BMBF).

"We have to make highly efficient use of energy if we are to achieve net-zero climate protection goals. Digitalization can help here as a highly decisive lever for more energy efficiency," says Infineon's chief digital transformation officer Constanze Hufenbecher. "We are pleased to be able to combine our strengths with the strengths of so many excellent partners from research and business," she adds.

"Power electronics is key to the energy transformation and is used anywhere and everywhere that electricity is generated, transferred and used efficiently," says Infineon's chief operations officer Dr Rutger Wijburg. "The broad spectrum of power electronics applications makes it very important that we collaborate with partners across the boundaries of corporate entities and organizations to jointly advance Europe as innovation engine."

The project partners are focusing on applications from the fields of energy and mobility. 17 demonstrator paths are concerned with, among other things, the improvement of drives for the rail industry, charging systems for the automotive industry, liquid batteries for the energy industry, and drives for

manufacturing industries. The research partners will take an interdisciplinary approach, with topics including modeling and Digital Twin, Federated Learning, and reliability and sustainability.

The newly developed key technologies are to be realized and demonstrated in concrete form, and are to be evaluated in terms of a large number of universally applicable results. The immediate project objectives include:

- reducing power loss in power conversion by 25%;
- extending the service lives of devices and systems by 30%;
- reducing chip size by at least 10%;
- shortening development times by a challenging 50%.

PowerizeD aims to increase the degree of mechanical and electrical integration of control, driver and switching functionalities in components and to advance the integrated optimization of all power switch functionalities, independent of the semiconductor material used. New switching topologies and advanced control strategies involving the application of artificial intelligence are targeted at improving efficient, robust and reliable operations even further.

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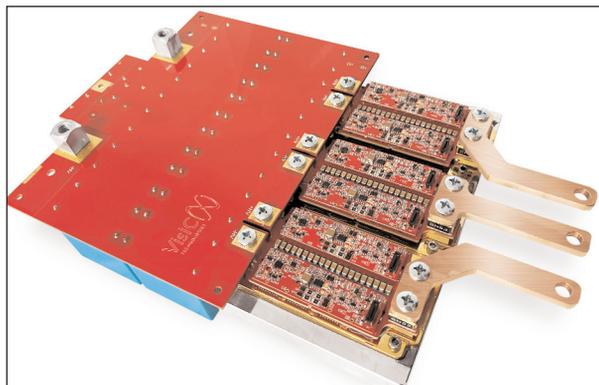
# VisIC demos efficient GaN-based 3-phase traction inverter with automotive-grade PMSM motor

## Paves way to high-power GaN traction inverters, operating a BEV motor

VisIC Technologies Ltd of Ness Ziona, Israel — a fabless supplier of power conversion devices based on gallium nitride (GaN) transistors for high-voltage automotive applications — says that it has successfully tested its 2.2m $\Omega$  650V half-bridge power module, consisting of four parallel 8m $\Omega$  power FET, in a 3-phase configuration on a dyno-test-bench using a permanent magnet synchronous motor (PMSM) motor at a major automotive OEM.

VisIC reckons this has hence proven that its D<sup>3</sup>GaN (Direct Drive D-Mode Gallium-Nitride) technology is well-suited even for the most challenging high-power automotive applications. Concerns about parallelization and oscillations caused by fast-switching transients have been addressed.

The inverter phase current reached 350A<sub>rms</sub> (500A peak) at 400V, although test system set-up limitations prevented higher currents, which the 2.2m $\Omega$  power module is capable of.



**VisIC's 3-phase prototype inverter system.**

Worldwide Harmonized Light Vehicles Test Procedure (WLTP) driving cycle testing was executed and achieved comparable efficiency with commercial silicon carbide-based modules, despite using early non-optimized module prototypes. This means that D<sup>3</sup>GaN will deliver its promise of the highest efficiency, improving car costs through lighter, smaller power systems and a smaller battery size, without compromising the car's driving range. In addition, the D<sup>3</sup>GaN technology,

based on a GaN-on-silicon process, is delivering better than silicon carbide (SiC) performance at the more competitive silicon cost level.

"With this great accomplishment, acknowledged by a leading automotive OEM, VisIC Technologies has provided overwhelming evidence for higher efficiency at lower-cost future electric vehicle (EV)

traction inverters, for the automotive world," reckons CEO & co-founder Dr Tamara Baksht. "The automotive market demands high-power, high-voltage, high-reliability GaN, and our D<sup>3</sup>GaN die and module solutions are the answer."

VisIC's 3-phase prototype inverter system will be available for testing across additional customer sites towards the end of second-quarter 2023.

[www.visic-tech.com](http://www.visic-tech.com)

## GaN Systems named to 2023 Global Cleantech 100

### Firms recognized at Cleantech Forum North America in Palm Springs

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has been named by Cleantech Group to its 2023 Global Cleantech 100 list of firms.

Running since 2009, the Global Cleantech 100 is an annual list of the most innovative and promising companies that will take us from commitments to actions in the effort to reach net-zero. Companies are delivering sustainable solutions in the following six sectors:

- Agriculture & Food;
- Enabling Technologies;
- Energy & Power;
- Materials & Chemicals;

- Resources & Environment; and
- Transportation & Logistics.

The annual report presents a list of companies with the most promising ideas in cleantech — those best positioned to help build a more digitized, de-carbonized, and resource-efficient industrial future.

The total number of nominations from the public, Cleantech Group's expert panel, i3 research portal, awards, and Cleantech Group staff totaled 15,753 from over 93 countries. These companies were weighted and scored to create a shortlist of 330 companies reviewed by the 81 members of an expert panel.

The Global Cleantech 100 Expert Panel comprises leading investors,

corporate and industrial executives active in technology and innovation scouting.

"This Global Cleantech 100 edition is remarkable for the number of businesses in it who represent solutions for some of the hardest of decarbonization challenges and those who are working on some of the critical materials issues coming our way, real soon," comments Cleantech Group's CEO Richard Youngman.

Featured companies were recognized at the Cleantech Forum North America in Palm Springs, CA (23–25 January).

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

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

[the-global-cleantech-100](http://the-global-cleantech-100)

## Gallium Semi opens Philippines manufacturing facility Plant to meet growing demand for RF power transistors and amplifiers

Singapore-based Gallium Semiconductor, which designs and makes RF gallium nitride (GaN) solutions for 5G mobile communication networks as well as aerospace & defense, and industrial, scientific & medical (ISM) applications, has opened its manufacturing facility in Laguna, Philippines. The inauguration was held on 3 February and was led by VP of global operations Henk Thoonen and advisor Kin Tan.

The new production line offers the latest RF power transistor technology, designed to serve customers worldwide. The firm provides RF power amplifier devices in DFN, QFN, ACC and ACP packages.

Gallium Semi says that the technology used in the new facility will help it to meet the growing demand for RF power transistors and amplifiers, and solidify its position as a provider of high-performance



solutions for 5G communications, aerospace & defense, and multi-market applications.

"This investment is a testament to our commitment to providing our customers with the best possible solutions and services," says

Thoonen. "Our new production line, equipped with the latest assembly and test technologies, will allow us to better serve our global clients and continue to provide high-quality products that meet their needs."

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

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## Navitas' GeneSiC MOSFETs used in KATEK's 4.6kW Steca solar inverters

### 1200V, 75mΩ devices used in a two-level converter, with bi-directional boost converters and H4-topology for AC voltage output

Gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA says that the coolcept fleX family of Steca solar inverters made by KATEK GROUP of Memmingen, Germany has adopted its new GeneSiC power semiconductors for improved efficiency, size, weight and cost.

Installed solar power capacity is expected to exceed that of natural gas in 2026, and of coal by 2027, becoming the largest in the world, a 3x increase in installed capacity from 2022–2027. The global levelized cost of electricity from solar is now 40% lower than coal and natural gas. Navitas notes that silicon carbide is rapidly replacing silicon chips in high-power, high-voltage applications such as renewable energy, energy storage and micro-grids, electric vehicles (EVs) and industrial applications.

GeneSiC 'trench-assisted planar-gate' SiC MOSFET technology is said to deliver no-compromise, high-temperature, high-speed performance, resulting in up to 25°C lower case temperature, and

up to 3x longer life than alternative SiC products. With what is claimed to be the highest published 100%-tested avalanche capability, 30% longer short-circuit withstand time, and stable threshold voltage for easy paralleling, GeneSiC MOSFETs are suitable for high-power, fast-time-to-market applications.

Steca — a KATEK brand — develops and produces high-end power electronics for grid inverters and energy storage as well as control technology for photovoltaic systems and fuel-cell systems. The Steca coolcept fleX model solar inverter converts DC power from a string of solar panels into 4.6kW AC power for use in the home, returning to the grid, or being stored locally for later use — to smooth demand and/or support power during an outage.

"Next-generation GeneSiC technology has enabled a major step in system performance without compromising our high engineering standards, especially regarding EMI," says Dr Peter Grabs, KATEK's director of Innovation, Research and Development. "Navitas'

excellent quality — with zero failures — and consistent, short-lead-time delivery are critical success factors as we expand production into new markets."

Each 4.6kW Steca coolcept flex inverter uses 16x GeneSiC G3R75MT12J SiC MOSFETs. The 1200V, 75mΩ-rated devices are used in a two-level converter, with bi-directional boost converters and an H4-topology for AC voltage output. Increased switching frequency shrinks the size and weight of passive components, which optimizes the KATEK unit in size and weight compared with legacy silicon-based inverters.

"Navitas and KATEK are aligned in the mission to 'Electrify Our World' and accelerate the transition from 80% fossil-fuel sources of electricity and uses, to 80% renewable sources and electrical uses," notes Dr Ranbir Singh, Navitas executive VP for the GeneSiC business line. "Both companies also share a focus on sustainability, in line with the UN's Sustainable Development Goals," he adds.

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# Transphorm GaN FET designed into HP's 65W USB-C PD/PPS power adapter

## SuperGaN Gen IV FET technology used in dual-output power adapter

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — says that its GaN technology has been used in a Hewlett Packard USB-C PD/PPS power adapter. The firm reckons that the design win solidifies its GaN FET technology in the 25–350W low- and mid-power adapter space.

The HP power adapter uses Transphorm's SuperGaN Gen IV TP65H300G4LSG 650V GaN FET. The technology is said to offer ease of designability and high reliability with high performance.

Further, Transphorm recently completed over 100 billion hours of field reliability data, with a failure-in-time (FIT) rate of <0.05. These statistics encompass a broad spectrum of power levels including mission-critical applications from 25W through to 3.6kW.

Previously it has been verified that, compared with a larger-die (e.g. 175mΩ) enhancement-mode GaN device, Transphorm's smaller-die (i.e. 240mΩ) SuperGaN FET showed lower on-resistance rise (23%) at 150°C and higher performance at 50% and 100% (full) power, due to the inherent performance benefits of the platform.

"This is an important design win for Transphorm as customers see the benefits of our dedication to quality and reliability with top performance, which is now being embraced by tier-1 customers like HP," says Tushar Dhayagude, VP field applications & technical sales. "Our GaN FETs are agnostic to controllers with integrated and off-the-shelf drivers, resulting in the ease of design and drivability which is now becoming more and more important as we continue to gain adoption in different markets, in both low-power and high-power segments."

[www.transphormusa.com/en/product/tp65h300g4lsg](http://www.transphormusa.com/en/product/tp65h300g4lsg)

# EPC expands GaN ToF laser driver IC family to 80V, 15A for higher-density, lower-cost LiDAR

## Further extension to 100V and 125A due soon

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has introduced the EPC21701, a laser driver that monolithically integrates an 80V, 40A FET with gate driver and 3.3V logic-level input into a single chip for time-of-flight light detection and ranging (LiDAR) systems used in robotics, surveillance systems, and vacuum cleaners. It is tailored to LiDAR systems for gesture recognition, time-of-flight (ToF) measurement, robotic vision, or industrial safety.

The EPC21701 laser driver uses a 5V supply voltage and is controlled using 3.3V logic. It is capable of very high frequencies greater than 50MHz and super short pulses down to 2ns to modulate laser driving currents up to 15A. Voltage switching time is less than 1ns and delay time

from input to output is less than 3.6ns. The EPC21701 is a single-chip driver plus GaN FET using EPC's proprietary GaN IC technology in a chip-scale BGA form factor that measures only 1.7mm x 1.0mm x 0.68mm. The wafer-level packaging is small, low-inductance, and lays out very well with the laser system. With this small form factor and the integration of several functions, the overall solution is 36% smaller on the printed circuit board (PCB) compared with an equivalent multi-chip discrete implementation.

The 80V EPC21701 complements the ToF driver IC family in chip-scale package (CSP) that also includes the 40V, 15A EPC21601 and the 40V, 10A EPC21603 options.

Integrated devices in a single chip are easier to design, easier to layout, easier to assemble, save space on the PCB, increase efficiency, and reduce cost, notes EPC. The new product family should enable faster adoption and increased ubiquity of

ToF solutions across a wider array of end-user applications.

"This new family of GaN integrated circuits dramatically improves the performance while reducing size and cost for time-of-flight LiDAR systems," says CEO & co-founder Alex Lidow. "Integrating a GaN FET with driver on one chip generates an extremely powerful and fast IC and reduces size and cost for wider adoption in consumer and industrial applications," he adds. "With EPC21701 we expand the family to 80V and 15A and will soon extend the family further to 100V and 125A."

The EPC9172 development board features the EPC21701 eToF laser driver IC and is primarily intended to drive laser diodes with short, high current pulses. Capabilities include minimum pulse widths of <2ns, 15A peak currents, and bus voltage rating of 40V.

[www.epc-co.com](http://www.epc-co.com)

## Transphorm's product revenue grows 25% sequentially High-power products grow to over 70% of revenue

For fiscal third-quarter 2023 (to end-December 2022), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — has reported revenue of \$4.5m, down slightly on \$4.6m a year ago but up 22% on last quarter's \$3.67m (exceeding the prior 20% quarterly growth rate). Product revenue was up 25% sequentially and 9% year-on-year, reflecting another strong quarter from ramping shipments of GaN products for a broad range of power conversion applications.

"This quarter saw solid execution and higher-than-expected revenues, with our product revenues being driven by strong traction in the higher-power space," notes chief financial officer Cameron McAulay.

Highlights are listed as:

- increased total design-ins for power adapters and fast chargers to over 80 (with over 25 in production) and total design-ins for higher power (300W–4kW) to over 55 (with over 25 in production);
- a robust five-year pipeline opportunity that now stands at over \$400m;
- shipping production quantities of Transphorm SuperGaN Technology used in the HPi (HP) power adapter (as revealed by a recent product teardown), solidifying Transphorm's GaN-FET technology in the low- and mid-power adapter space;

- secured and shipped a new production order for 100,000 units for another worldwide top-5 laptop manufacturer;
  - new >2kW UPS production win with a global leader in energy, continuing Transphorm's leadership in high-power GaN.
  - the firm's products exceeding 100 billion hours of field operating reliability including in both low-power and high-power applications (believe to be one of the industry's best and only reported broad power spectrum reliability rating for GaN power);
  - availability of a new 240W Power Adapter Reference Design, bringing industry-standard thru-hole packaging delivering power density advantages at low cost to power supplies;
  - completing submission for a \$15m Navy program which, if awarded, will expand metal-organic chemical vapor deposition (MOCVD) manufacturing capacity and capability to increase the firm's RF epiwafer sales (the firm's second business vertical).
- "Our business momentum is exemplified by another strong quarter of design wins as we aggressively pursued and won numerous additional designs-in both high-power and low-power markets, including world-wide tier-1 leaders like HP," says president, COO & co-founder Primit Parikh. "We look forward to building on our success in this segment of the adapter

market, while further growing our leadership in high power, which comprised more than 70% of our revenue in the quarter [up from 65% last quarter]," he adds.

On a non-GAAP basis, operating expenses have risen further, from \$4.4m a year ago and \$5.1m last quarter to \$5.9m.

Net loss has risen from \$4.3m (\$0.09 per share) a year ago and \$5.1m (\$0.09 per share) last quarter to \$9.1m (\$0.16 per share). However, this includes a one-time write-off of \$2.8m (\$0.05 per share) for epiwafer inventory resulting largely from the process of bringing up the firm's Japan epitaxial reactors over the last several quarters.

During the quarter, cash, cash equivalents and restricted cash fell from \$34m to \$23.6m.

"As we enter calendar year 2023, the company is well positioned and remains keenly focused on achieving continued short-term momentum and long-term growth, driven by a robust pipeline," says chief financial officer Cameron McAulay.

"While we still face near term macro-headwinds, we remain well-positioned to translate the above momentum to business growth in fiscal 2024," reckons Parikh. "We also made solid progress on our plans to ramp up additional capacity over the coming year, in order to be prepared and ready to meet the significant demand that lies ahead."

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## AXT's revenue falls 24% in Q4, as InP hit by cooling data-center market and softness in 5G telecoms in China Gross margin recovery to be driven by GaAs-led rebound from Q2

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — says that its full-year revenue rose by 2.7% from \$137.4m in 2021 to \$141.1m for 2022.

However, revenue for fourth-quarter 2022 was \$26.8m, down 23.9% on \$35.2m last quarter and 28.9% on \$37.7m a year ago, and towards the low end of the \$26–29m guidance range.

"The softening of the macro-environment continued as expected," notes CEO Dr Morris Young. "We saw a step back in revenue across our portfolio as customers continue to digest inventory in the channel and evaluate their needs for the coming quarters."

Indium phosphide revenue was \$14m, up 6.9% on \$13.1m a year ago but down 26% on last quarter's record \$17.7m due mainly to continued cooling in the data-center market as well as ongoing softness in 5G telecom infrastructure, particularly in China. "The PON [passive optical networks] market was coming down off its peak, but has been fairly resilient," says Young.

Gallium arsenide revenue has fallen further, more than halving from \$11.3m a year ago and down by a third on \$8.1m last quarter to \$5.5m. "Our gallium arsenide

revenue is down significantly off its mid-2022 highs, with customers in China having slowed significantly," notes Young. "We're seeing a strong impact on applications using wireless devices for IoT and headset markets, as well as industrial lasers, LED lighting and display."

Although it is still down on \$4.2m a year ago, Germanium substrate revenue rebounded slightly from \$1.1m last quarter to \$1.3m, after resolving a payment issue with certain germanium customers.

Total substrate sales were therefore \$20.8m, down 22.7% on \$26.9m last quarter and 27.3% on \$28.6m a year ago.

In addition, revenue was \$6m from AXT's two consolidated raw materials joint venture companies: BoYu (which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic light-emitting diodes) and JinMei (which supplies high-purity materials including gallium and germanium, as well as InP poly and other materials). This was down from \$8.3m last quarter and \$9.1m a year ago, due to pricing pressure and the softer demand environment.

Of total revenue in Q4, the proportion from the Asia-Pacific region was 70% (down on 74.9% a year ago), Europe was 15% (down from 16.7%) and North America was 15% (up from 8.4%). The top five customers again generated about

41% of total revenue, including one customer over 10%.

On a non-GAAP basis, gross margin was 32.5%, roughly level with 32.4% a year ago but down more than expected from 42.2% last quarter. This was due mainly to the significantly lower revenue but also a less favorable product mix than expected as well as a significant drop in the price of raw gallium, which resulted in low margin contribution from JinMei. Nevertheless, full-year gross margin still rose from 34.8% in 2021 to 37.2% for 2022.

Full-year operating expenses rose from \$30.4m in 2021 to \$35.9m for 2022. However, despite still being up on \$8.1m a year ago, quarterly OpEx was cut slightly from \$9.2m last quarter to \$9m.

Net income was \$2.1m (\$0.05 per share) in Q4/2022, down from \$6.8m (\$0.16 per share) last quarter and \$4.1m (\$0.09 per share) a year ago, but at the top of the \$0.03–0.05 per share guidance range. Full-year net income still grew from \$19.1m (\$0.44 per share) in 2021 to \$19.8m (\$0.46 per share) for 2022.

During Q4/2022, cash, cash equivalents and investments rose from \$48.2m to \$52.8m.

"2022 was a productive year in which we grew both our revenue and our profitability, and invested in innovations," says Young.

"As we head into Q1, we're seeing a business slowdown continue as

## STAR Market listing update

In late December 2021, AXT's China-based wafer manufacturing subsidiary Beijing Tongmei Xtal Technology Co Ltd submitted its application to list its shares in an initial public offering on the Shanghai Stock Exchange's Sci-Tech innovation board (STAR Market). In January, the application was formally accepted for consideration.

Subsequently, Tongmei responded to several rounds of questions received from the Shanghai Stock Exchange (SSE). On 12 July 2022, the SSE approved the listing of Tongmei's shares. On 1 August 2022, the China Securities Regulatory Commission (CSRC) accepted Tongmei's IPO application for review.

The STAR Market IPO remains subject to review and approval by the CSRC and other authorities.

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

customers across our portfolio are evaluating and reducing inventory,” says Young. “We continue to perform well in our [InP-related] consumer applications but, because of inventory digestions, we expect it to take a meaningful pause in the first half of 2023 [after only starting to see softness in InP for consumer products in mid-Q1].”

The effect in first-quarter 2023 is exacerbated by the typical business interruption of Chinese New Year as well as the lingering effect of COVID shutdowns in China. AXT hence expects revenue to fall to \$19–21m in Q1/2023.

“This lower revenue is expected to have a significant impact on our manufacturing overhead being spread over fewer units, which will have a negative impact on gross margin,” notes chief financial officer Gary Fischer. “Product mix is also less favorable as a result of lower expected revenue for indium phosphide.” AXT therefore expects gross margin to fall to about 21%, yielding a net loss of \$0.10–0.12 per share.

“In addition to clamping down on inventory, we’re going to put the brakes on CapEx as well, say \$3–5m,” says Fisher. “We’re not buying material. We’re shutting down most of our construction,” adds Young. “Last year, we were going to increase our [InP] capacity by 50%. We are not building that capacity anymore.”

“We are planning for a major reset in Q1, but we do expect that we could see improvement beginning

in Q2 as China re-opens more fully,” says Young. “After such a strong decline, the gallium arsenide market appears to be stabilizing and we could see incremental improvement beginning in Q2.”

“While the germanium substrate market has also been affected by the macro softness, we will be working towards sequential growth in the coming quarters,” he adds.

“With consumer coming back in China, I think the market will start to bounce back in Q3 and Q4 of this year,” says Young. “As business returns, I think we should be looking forward to mid-30% and even high-30% [gross margin],” he adds. “When things rebound, all the stuff that we’ve done for the last two years to improve gross margin is going to blossom again. It’s just taking a pause because of the disruption in the marketplace right now,” adds Fisher.

“Though a softening of the macro-environment has reset our growth trajectory, the trends that have driven our revenue, customer and application expansion remain very much intact,” believes Young.

“We are continuing to see active development for new applications and technology investments using our materials. While the near-term environment is working through a significant inventory correction, the mid-term and longer-term prospect for our markets are vibrant. In addition to the core applications that are driving our revenue today, new uses in automotive sensing,

consumer products, health sensing, displays and more [communications infrastructure, data center] are taking shape in a very real way.”

“We are looking at all possible ways to tighten our budget, but R&D is an area we’re not cutting back yet,” Young notes. “We have made significant progress this year in the development of next-generation large-diameter substrates for gallium arsenide and indium phosphide,” he adds.

“We are making good progress in our 8-inch gallium arsenide wafer development [currently shipping hundreds of wafer to customers]. This product will be a cornerstone for micro-LED adoption in a variety of consumer devices. While a meaningful revenue ramp isn’t expected to begin until sometime next year [albeit now late 2024 rather than early 2024], product qualification at the substrate level are scheduled to begin this year. AXT is well positioned to be a prime player in this market,” Young reckons. “We view micro-LED as a breakthrough display technology for consumers, as it is expected to deliver significant improvement in power efficiency as well as greater brightness and more brilliant colors. Tier-1 companies are advancing its development [for a commercial ramp up in volume production probably late 2024 to 2025], and we believe it has the potential to reshape the gallium arsenide substrate industry.”

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# New customer selects Aehr's FOX system for wafer-level test and burn-in of SiC devices for electric vehicles

## Device qualification initially with OSAT supplier partnered with Aehr

Semiconductor production test and reliability qualification equipment supplier Aehr Test Systems of Fremont, CA, USA says that a new customer, which supplies silicon carbide and gallium nitride semiconductor devices, has selected its FOX-P system for qualification and production wafer-level test and burn-in of its silicon carbide devices for automotive electric vehicles.

Aehr says that the FOX solution was chosen on the basis of its proven ability to cost-effectively implement the customer's target burn-in and stabilization requirements including 100% traceability that every device on the wafer is properly burned in.

The customer will begin its device qualification using an outsourced semiconductor assembly and test (OSAT) supplier that has partnered with Aehr and has FOX-P system capacity installed and capable of doing SiC full-wafer-level test and burn-in of 100% of devices per wafer in a single insertion. The customer will purchase the proprietary FOX WaferPak full-wafer contactors and applications test programs from Aehr, and testing services from the assembly & test supplier for the initial device qualification. Upon qualification of the devices, the customer is expected to purchase new FOX-P system and WaferPak capacity directly from Aehr or through the OSAT.

"Traceability and proof that each device is burned in for the needed test duration, without any chance of a test escape that might allow a device to get through the process and later fail in the field, is critical to the automotive applications these devices will be used in," says Aehr Test Systems' president & CEO Gayn Erickson. In the case of silicon carbide used in the traction inverters that convert the high-voltage DC battery power to AC current that drives the electric

engines, a device failure results in a 'walk home event', where the driver and all passengers get out of the vehicle and walk home.

"Aehr's FOX-P systems and proprietary WaferPak full-wafer Contactors enable our customers to do economical production volume test and reliability burn-in with processes such as high-temperature gate bias (HTGB) and high-temperature reverse bias (HTRB) very cost effectively and ensure extremely high device quality. Our systems provide test cycle duration lasting for 12, 18 or 24 hours or more for pennies or cents per device capital depreciation cost, and in a footprint that is up to 18 times less than a typical test system on a standard semiconductor wafer prober offered by alternative suppliers," he adds.

"Aehr has teamed with this OSAT to provide turnkey support of multiple applications including silicon photonics devices used in data, 5G and future central processing units (CPUs) and chipsets, in addition to silicon carbide and gallium nitride used in electric vehicles, solar, industrial and other infrastructure."

Forecasts from William Blair estimate that the silicon carbide market for devices in electric vehicles alone, such as traction inverters and on-board chargers, will rise at a compound annual growth rate (CAGR) of

**The customer will begin its device qualification using an OSAT supplier that has partnered with Aehr and has FOX-P system capacity installed and capable of doing SiC full-wafer-level test and burn-in of 100% of devices per wafer in a single insertion**

48.4% from 119,000 6-inch-equivalent silicon carbide wafers in 2021 to more than 4.1 million 6-inch-equivalent wafers in 2030, i.e. almost 35 times larger. In addition, 6-inch-equivalent silicon carbide wafers for other markets such as solar, industrial and other electrification infrastructure are expected to grow to another 3 million wafers by 2030.

"The FOX family of compatible systems including the FOX-NP and FOX-XP multi-wafer test and burn-in systems and Aehr's proprietary WaferPak full-wafer contactors provide a uniquely cost-effective solution for burning in multiple wafers of devices at a single time to remove early life failures of silicon carbide devices, which is critical to meeting the initial quality and long-term reliability the automotive, industrial and electrification infrastructure industry needs," says Erickson. "The FOX-XP system can be configured with up to 9 or 18 wafers depending on the customer's specific test requirements and power configuration and is fully compatible with Aehr's FOX-NP system, which is a two-wafer system that is a great fit for new product introduction and qualification."

The FOX-XP and FOX-NP systems, available with multiple WaferPak Contactors (full-wafer test) or multiple DiePak Carriers (singulated die/module test) configurations, are capable of functional test and burn-in/cycling of devices such as silicon carbide and gallium nitride power semiconductors, and silicon photonics as well as other optical devices, 2D and 3D sensors, flash memories, magnetic sensors, microcontrollers, and other leading-edge ICs in either wafer form factor, before they are assembled into single- or multi-die stacked packages, or in singulated die or module form factor.

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

## Rosati retires from Aeher's board

### Co-founding director ends 45 years as board member

Semiconductor production test and reliability qualification equipment supplier Aeher Test Systems of Fremont, CA, USA says that long-time board member Mario M. Rosati has retired from its board. This leaves the firm with six board members.

"As a young attorney (now at Wilson Sonsini Goodrich and Rosati), Mario incorporated the company in 1977 and became our first outside

director," says founder & chairman Rhea Posedel. "His broad business knowledge and invaluable advice was extremely helpful to me during our startup phase, whether it was raising venture capital funding or adding industry leaders to the board. I greatly appreciate Mario's continued contributions and support over his 45 years as a board member."

"Mario was a director of Aeher Test

Systems since its founding in 1977 and instrumental in helping to take the company public in 1997," notes president & CEO Gayn Erickson. "On behalf of the board and the management team, we are very thankful for his leadership and long-standing commitment and contributions over the years that have been a key piece of the company's success."

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## Riber's full-year revenue falls 11% to €27.8m, constrained by electronic component sourcing

### Orders more than double to €29.9m; revenue to grow 35% in 2023

For fourth-quarter 2022, Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems and evaporators — has reported revenue of €15.6m, up by 2% on €15.4m a year ago.

Full-year 2022 revenue was €27.8m (23% from Europe, 72% from Asia, and 5% from North America). This is down 11% on 2021's €31.2m after being strongly impacted by difficulties sourcing electronic components.

MBE systems revenue was €14.8m (comprising six systems delivered, including four production units), down 15% on 2021's €17.4m (comprising eight systems delivered, including four production units). Despite efforts to resolve the supply chain disruption affecting electronic components, the delivery of two research systems (representing an amount of €2.9m) had to be deferred to 2023.

Services & Accessories revenue was €13m, down 6% from 2021's record €13.8m, primarily reflecting the deferral to 2023 of the delivery of a major accessories order due to supply tensions and delays.

#### Orders more than double

The order book more than doubled, rising by 102% from €14.8m at end-2021 to €29.9m at end-2022.

Specifically, orders for MBE systems grew by 212% from just €7.9m to a

record €24.6m (comprising 11 systems). Also, this does not include the option to buy (announced on 8 June 2022) covering four production systems for which firm orders will be confirmed in 2023 when the export license is obtained.

Riber says that orders for Services & Accessories are temporarily down at end-2022, to €5.3m, down by 23% from €6.9m at end-2021.

#### Outlook

Factoring in the deferral of two system deliveries to 2023 and the increase in the order book, Riber is forecasting that full-year revenue will grow by at least 35% to about €40m in 2023.

"With very buoyant market trends and a strong prospect pipeline, the order intake levels are expected to remain robust in 2023," says Riber.

#### Christian Dupont appointed as vice-chairman of Executive Board

Riber's Supervisory Board met on 25 January, chaired by Ms Annie Geoffroy. As proposed by the Appointments and Compensation Committee, it appointed Christian Dupont as a member and vice-chairman of the Executive Board from 6 February.

The appointment is in line with the expansion of the Executive Board to three members. Due to his extensive experience of the micro-electronics industry and its players,

Dupont's mission will be in particular to further strengthen Riber's commercial development and marketing. "His strong people skills and his interest in high-tech entrepreneurial development represent strong assets to support Riber with a new expansion phase," reckons the firm.

After graduating as an engineer from EPFL (École Polytechnique Fédérale de Lausanne), Dupont began his career in 1988 with Texas Instruments, where in 1992 he helped to create its Wireless business unit, which became the wireless semiconductor market leader for 15 years. He was a marketing manager before being appointed to head up the business unit in Dallas and Nice, where he was in charge of the wireless business unit in Europe. From 2007 to 2010, he was CEO of the electro-optics startup Varioptic, which was sold to Parrot, before serving until 2015 as CEO of MEMS auto-focus firm PoLight in Norway, which listed on Oslo's stock market.

From 2015 to 2021, he was chairman & CEO of CEO-CF, the leading collaboration platform for executives from high-growth European technology companies. In 2018, he helped to restructure and refinance semiconductor firm Dolphin Integration as its CEO. From 2019, he was CEO of digital health firm Digitsole.

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## Veeco buys silicon carbide CVD system maker Epiluvac Acquisition to accelerate penetration into SiC epi equipment market

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has acquired Epiluvac AB of Lund, Sweden, which was founded in 2013 and makes silicon carbide (SiC) chemical vapor deposition (CVD) equipment. Epiluvac's technology platform, combined with Veeco's global go-to-market capabilities, is expected to create a significant long-term growth driver for Veeco.

The desire for clean, efficient and reduced fossil-fuel energy is driving tremendous growth in the electric vehicle market, notes Veeco. Applications such as on-board charging, fast charging and power-train inverters are ideally suited for SiC power devices, it adds. The SiC device market is forecasted to grow at a compound annual growth rate (CAGR) of about 30% from 2023 through 2027, according to market research firm Yole Group. Corre-

spondingly, the SiC epitaxy equipment market is expected to grow at a CAGR of about 15%, according to Yole and internal Veeco estimates.

"The Epiluvac team has developed a superior platform and process know-how aligned with markets that are a great strategic fit for Veeco," comments Veeco's CEO Bill Miller. "Their well-designed CVD platform achieves high productivity, is easy to maintain and has superior process control capability that make it uniquely qualified to produce devices that enable lighter, smaller and more efficient power conversion systems. We see this acquisition as a great complement to our metal-organic chemical vapor deposition (MOCVD) epitaxy product line. This acquisition accelerates our penetration into the emerging, high-growth SiC equipment market by reducing our time to market," he adds.

"Our complementary technology platforms, along with Veeco's extensive worldwide sales, service and manufacturing capabilities, will position us well to help our customers enable accelerated SiC adoption," reckons Epiluvac's CEO Per-Anders Eriksson. "The decades of research and development the Epiluvac team has invested in this demanding epitaxial process will be a great asset to Veeco's already impressive process capabilities."

Epiluvac is an early-stage revenue company with 11 employees. The purchase price, all payable in cash, is \$30m, paid at the time of closing, with a potential additional \$35m in performance-based earn-outs. The impact to Veeco's financial results are not expected to be material in 2023, and volume revenue is expected to begin in 2024.

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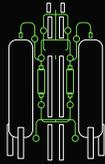
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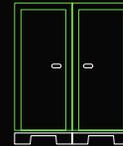
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# Veeco grows revenue 11% in 2022, despite 10.5% dip in Q4 driven by smartphone-related 5G RF weakness

## Semiconductor revenue outperforming wafer fab equipment market; power electronics and micro-LED targeted for Compound Semi recovery

For fourth-quarter 2022, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$153.8m, down 10.5% on \$171.9m last quarter but roughly level with \$153m a year ago.

The Semiconductor segment (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed \$94m (61% of total revenue), down from \$100m last quarter but up sharply on \$65.4m (43% of revenue) a year ago, led by multiple laser spike anneal (LSA) systems for both leading- and trailing-edge nodes, as well as extreme ultraviolet (EUV) and advanced packaging (AP) lithography systems.

The Compound Semiconductor segment (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, Laser Diodes) contributed \$25m (16% of total revenue), down on \$28m last quarter and \$34.7m (23% of total revenue) a year ago.

The Data Storage segment (equipment for thin-film magnetic head manufacturing) contributed \$17m (11% of total revenue), down on \$28m last quarter and \$36.5m (24% of total revenue) a year ago.

The Scientific & Other segment (research institutions and other applications) contributed \$18m (12% of total revenue), up on \$16m last quarter and \$16.3m (10% of total revenue) a year ago.

By region, the Asia-Pacific region (excluding China) comprised 42% of revenue (up on 26% a year ago) driven by Semiconductor system sales; the USA 25% (down on 37%); China 19% (down on 25%) mainly Semiconductor systems for trailing-edge nodes; and Europe,

Middle-East & Africa (EMEA) 14% (up on 12% a year ago); with the rest of the world remaining under 1%.

For full-year 2022, revenue grew by 11% from \$583.3m in 2021 to \$646.1m for 2022.

Semiconductor contributed a record \$369m (57% of total revenue), up 50% on 2021's \$247.1m (43% of revenue), led by increased traction in both leading- and trailing-node laser annealing systems.

Compound Semiconductor contributed \$121m (19% of total revenue), up 13% on 2021's \$107m, driven by systems for photonics applications.

Data Storage contributed just \$88m (13% of total revenue), almost halving from 2021's \$168.8m (29% of total revenue), as hard-disk-drive customers slowed their pace of capacity additions for magnetic head manufacturing.

Scientific & Other (research institutions and other applications) contributed \$68m (11% of total revenue), up 12% on 2021's \$60.5m.

By region, the Asia-Pacific (excluding China) comprised 36% of revenue driven by semiconductor customers; the USA 31% (down from 38%) mainly semiconductor and data-storage customers; EMEA 14% (up from 9%); and China 19%; with the rest of the world remaining less than 1%.

On a non-GAAP basis, full-year gross margin has fallen slightly from 42% in 2021 to 41.9% for 2022. However, despite being down slightly on 42.4% a year ago, Q4/2022 gross margin of 42.3% was up on 42% last quarter, and exceeded guidance due to a more favorable product mix and lower manufacturing and service costs.

Operating expenses were \$41.3m, up from \$40m a year ago but cut from \$43.9m last quarter and lower

than the guidance range due to favorable selling, general & administrative (SG&A) expenses. Full-year operating expenses rose from \$158.5m in 2021 to \$171.2m for 2022, reflecting the R&D investments made in the Semiconductor and Compound Semiconductor segments to execute the firm's growth strategy. However, as a percentage of revenue, OpEx has fallen from 27% to 26.5%, providing operating leverage to the company.

Quarterly net income was \$21.9m (\$0.38 per diluted share), down from \$26m (\$0.45 per diluted share) last quarter and \$22.6m (\$0.43 per diluted share) a year ago. Despite Q4, full-year net income has grown from \$73.6m (\$1.43 per diluted share) in 2021 to \$89.6m (\$1.57 per diluted share) for 2022.

Cash flow from operations was \$33m in Q4 (almost doubling from \$17m a year ago), contributing to \$108m for full-year 2022 (up 60% year-on-year).

CapEx has reduced further, from \$9.2m a year ago (which included \$8m used for the build-out of the new facility in San Jose, CA, adding much needed Semiconductor capacity) and \$6m last quarter to just \$3m, bringing full-year CapEx to \$25m.

During the quarter, cash and short-term investments hence rose further, by \$31m, from \$272m to \$303m (up from \$225m a year ago). As of the end of Q4, Veeco was cash debt positive.

Long-term debt was \$275m, representing the carrying value of the \$278m of convertible notes. Annual cash interest expense was reduced to \$10m in 2022. In January 2023, \$20m of the outstanding 2.7% convertible senior notes matured and were fully settled by payment and cash, reducing total convertible debt to \$258m.

"We entered 2022 with supply chain challenges and strong demand. By the end of the year, the supply chain challenges persisted, while demand became more mixed, due to softness in consumer markets such as smartphones and PCs, and a weakening macro-economic environment in general," notes CEO Bill Miller Ph.D.

"In the current weaker demand environment, customers across certain segments of our business have lowered fab utilization to address elevated levels of inventory," says chief financial officer John Kiernan. "In some cases, they've taken steps to reduce both capital and operating expenses, including spare parts and service.

For first-quarter 2023, Veeco hence expects revenue to fall to \$130–150m. Due to a less favorable product mix and lower volume, gross margin should fall slightly to 39–41%. With operating expenses of \$42–44m, net income is expected to fall to \$6–15m (\$0.12–0.28 per diluted share).

However, aided by record Semiconductor orders in both Q4/2022 and full-year 2022, total orders exceeded revenue throughout 2022, yielding a positive book-to-bill ratio. Specifically, in second-half 2022, Veeco saw an accelerated booking rate for trailing-node semiconductor systems in China. For full-year 2022, China comprised about 27% of total orders, compared with just 19% of revenue (so China revenue is expected to rise as a percentage of total revenue in first-half 2023). Order backlog hence grew by \$60m through 2022, from \$440m to \$500m.

"We enter the year cautiously optimistic given our backlog position, coupled with the mixed demand environment within which we're operating," says Miller. "We expect to outperform the wafer fab equipment market [forecasted to be down 20% or more in 2023] with our Semiconductor products [flat to

slightly up], grow in the data-storage market and maintain profitability during the current macroeconomic challenges."

Based on current visibility supported by order backlog, Veeco's revenue outlook for full-year 2023 remains relatively flat on 2022 at \$630–670m, with revenue in the second half exceeding that of the first half, based on the scheduled shipments of order backlog. The firm continues to target diluted earnings per share of \$1.15–1.35.

"With weakness in consumer end-markets, our Wet Processing business has been experiencing a slowdown. However, the compound semiconductor end-market we're working to penetrate with MOCVD such as GaN power electronics and micro-LED show promising signs of growth over the long-term," says Miller. "We're committed to continuing our R&D investments, demos and evaluations with customers and ultimately realizing growth in these markets," he adds.

On 31 January, to "enhance our long-term growth prospects", Veeco acquired early-stage revenue company Epiluvac AB of Lund, Sweden (whose 11 staff design and manufacture silicon carbide epitaxy systems) for \$30m in cash plus up to \$35m in performance-based earnouts. The acquisition accelerates Veeco's entry into the high-growth silicon carbide epitaxy equipment market which, driven mainly by demand for power electronics in

electric vehicles (EVs), is forecasted to double from \$250m in 2023 to \$500m in 2027 (as the SiC device market triples from \$2bn to \$6bn).

"They had developed silicon carbide previously for 4-inch and 6-inch. This is a new 8-inch single-wafer silicon carbide reactor and main-frame, so it's an automated system that can run independently," says Miller. "They have placed one system into the field, and it's currently under installation. The second tool shipment is actually going to ship to our Somerset New Jersey lab, where we're going to facilitate it and use that as a dedicated demonstration tool to sell equipment. So we're planning a sales kick-off meeting here in the next week or so. With the addition of Veeco worldwide sales footprint, our service footprint and manufacturing operations, we think we have a very good chance to be competitive in this silicon carbide epi market," he adds. "Given the timing of all this, not much revenue in 2023, but hopefully some revenue growth [incremental business] in 2024."

"Compound Semi is setting up to be a challenging year in the near-term, driven by weakness in 5G RF-related to the smartphone weakness. In the longer-term, we do feel better about Compound Semi because these markets we're working in to penetrate, such as power electronics and micro-LED, are growing and have enormous potential for us," concludes Miller.

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# Aixtron launches G10-AsP system at Photonics West

## First fully automated AsP platform targets high-resolution micro-LED displays and lasers

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has launched what it says is the first fully automated AsP (arsenide-phosphide) platform on the market, enabling robust high-volume production linked to very complex requirements. The new system G10-AsP specifically addresses the growing demands in the micro-LED and laser device sectors.

"Micro-LEDs will revolutionize the world of displays as they offer better durability, higher lifetime, a better picture quality and a very low energy consumption. However, this innovative technology challenges the production process as it requires lowest defect levels and highest uniformity rates," says CEO & president Dr Felix Grawert. "The new system enables the highest throughput of its class with uniformity and defect levels never seen before."

For the first time, true mass production of micro-LEDs with the most tightened material requirements and reduced chip sizes of 10µm and lower is becoming a reality, says Aixtron. The G10-AsP also meets the complex requirements to produce indium phosphide (InP) laser and VCSELs (vertical-cavity surface-emitting lasers) in high volume.

The new platform G10-AsP was officially launched on 1 February during the Photonics West 2023 exhibition in San Francisco, CA, USA, where Aixtron presented the new system, explaining the innovations that in the new platform and how it will provide what is claimed to be the highest throughput of its class and maximize cleanroom utilization.

The G10-AsP is reckoned to be the largest 200mm AsP batch reactor on the market and comes with in-situ cleaning and automated cassette-to-cassette (C2C) wafer loading. For the first time, the



**Aixtron's new fully automated AIX G10-AsP system is the largest 200mm AsP Batch reactor on the market and comes with In-Situ Cleaning and an automated cassette-to-cassette wafer loading.**

front-end can be equipped with SMIF (Standard Mechanical Interface) pods to further minimize exposure of the epitaxial wafers to the room environment. With in-situ cleaning built-in, users can reset the chamber conditions on demand — either after each process run for the most demanding requirements or just after a production campaign to benefit from highest throughputs. The platform is based on Planetary Reactor technology, which combines the multi-wafer batch reactor concept with single-wafer rotation for the highest wafer uniformity.

Micro-LEDs will not only be used for the next generation of TV displays but also for future smartwatches, smartphones, augmented reality (AR) projection or automotive displays. Analysts expect this area to be the largest market for LEDs in the next 5–10 years.

The one big challenge to reaching the next level for not only advanced micro-LEDs but also InP and VCSEL applications remains uniformity. Optimized on-wafer uniformity and wafer-to-wafer uniformity must be accomplished in a high-volume production process. The new G10-AsP is said to set a new standard with respect to these values, offering a two-to-threefold

improvement compared with its predecessor. It is hence reckoned that this fully automated platform will initiate a new era for producing micro-LED and photonic devices, overcoming major obstacles that previously have prevented robust mass production.

In telecoms, photonic devices such as infrared lasers and detectors have laid the foundation for managing the ever-growing data volumes

linked to continuously higher bandwidth requirements. Also, they enable 3D sensing (e.g. for facial recognition) and advanced technologies for autonomous driving: With the continuous evolution of this technology, beams must map larger and wider areas. This calls for tighter wavelength tolerances, which translates into very tight requirements for epitaxial layer deposition. Aixtron says that the new G10-AsP can address this need by providing significantly refined control of the epitaxial process with improved material accuracy, reduced defect levels and, as a result, higher yield and better uniformity.

In the production of micro-LEDs, improved uniformity is a prerequisite for economically viable mass production: micro-LED displays rely on a special stamp or matrix transfer process where thousands of LED chips (arrays) of just a few microns in size are picked up and transferred. Because entire arrays of pixels are transferred from the epiwafer substrate, almost perfect uniformity is required — to avoid, for example, a smartwatch or smartphone display having a different color in one corner than the other.

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

# ams OSRAM qualifies Aixtron's G5+ C and G10-AsP systems on 200mm wafers for micro-LEDs

## MOCVD reactors to enable volume production of micro-LEDs for display applications

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that ams OSRAM GmbH of Premstaetten/Graz, Austria and Munich, Germany has qualified its AIX G5+ C and G10-AsP (arsenide-phosphide) metal-organic chemical vapor deposition (MOCVD) systems on 200mm wafers for a micro-LED application.

The AIX G5+ C and the new G10-AsP apply Aixtron's planetary technology for high-resolution micro-LED displays. In spring 2022, ams OSRAM had announced plans to create additional manufacturing capacity in 200mm for the production of LED and micro-LED at its existing location in Malaysia. The MOCVD systems are expected to help enable volume production of micro-LEDs for a new generation of display applications.

"Aixtron and ams OSRAM have a long-standing cooperation, and we are familiar with the performance and quality standards of the equipment. For an ambitious project like the development and production of micro-LED for AsP and GaN devices, we needed exactly such a partner at our side," says Robert Feurle, executive VP & head of ams

OSRAM's Opto Semiconductors business unit.

"The G10-AsP and AIX G5+ C qualification at ams OSRAM is a very important milestone in our company's history," says Aixtron's CEO & president Dr Felix Grawert. "ams OSRAM is a world-class LED manufacturer and perfectly positioned to enable the fundamental new technology that will come to market," he adds. "We are on the verge of a technology shift away from conventional display technologies to a new type of micro-LED displays. Now, Aixtron is entering one of the future's growth markets that has an enormous potential, and we are doing this with a perfect partner at our side."

Micro-LED technology is said to offer significant advantages for display technology such as higher pixel density, longer lifetime, higher brightness, faster switching speed and a wider color spectrum. A key benefit is also the low relative energy consumption, qualifying micro-LEDs for upcoming generations of smaller display-equipped consumer devices that provide a very limited space for batteries.

Micro-LED volume production involves a special transfer process

where many thousands of LED chips (arrays) of just microns in size are picked up and transferred. Any defect can result in dead pixels, which can make an entire array useless. Hence, an almost error-free epitaxy process is necessary, minimizing defects and allowing for high yield and economically viable production of micro-LEDs.

Aixtron says that its new G10-AsP epitaxy tool has been designed to address the specific needs of this application. It is claimed to be the first fully automated AsP reactor offering cassette-to-cassette (C2C) wafer loading as well as a cleaning mechanism based on in-situ etching. Together, these two features are said to have a major impact on yield performance. The system also offers the advantages of batch reactor technology: it comes with what is claimed to be the lowest production cost per wafer currently available in the market and the highest throughput per cleanroom area. At the same time, the new tool comes with precise flow and temperature control, optimizing material uniformities run after run.

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

[www.ams-osram.com](http://www.ams-osram.com)

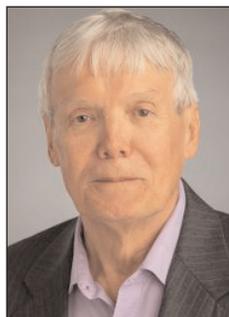
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## k-Space co-founder Roy Clarke named AAAS Fellow American Association for the Advancement of Science recognizes contributions to role of interfaces in thin films and quantum nanostructures

k-Space Associates Inc of Dexter, MI, USA — which was founded in 1992 and produces thin-film metrology instrumentation and software for research and manufacturing of microelectronic, optoelectronic and photovoltaic devices — says that its co-founder and University of Michigan physics professor Roy Clarke has been named an AAAS Fellow by the American Association for the Advancement of Science (AAAS).

Clarke was named an AAAS Fellow for his contributions to the role of interfaces in thin films and quantum nanostructures, and for his entrepreneurship, which has resulted in “several recent inventions and tech transfers”. He joins the ranks of other



**k-Space co-founder Roy Clarke.**

AAAS Fellows including Thomas Edison, W.E.B. DuBois, astronaut Ellen Ochoa, and computing pioneer Grace Hopper.

“This is a well-deserved honor,” comments CEO & co-founder

Darryl Barlett. “Roy has been a leader in scientific entrepreneurship, tech transfer, and in expanding the ranks of applied physics to include more minorities and females.”

Clarke is the Marcellus L. Wiedenbeck Collegiate Professor, University

Diversity and Social Transformation Professor, and professor of physics at the University of Michigan. In 2010, Clarke received the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring from President Obama.

Since 1874, the AAAS has elected Fellows based on their “extraordinary achievements”. At the AAAS Annual Meeting, Fellows are presented with a certificate and a blue and gold rosette. AAAS is the world’s largest general scientific society and the publisher of Science and related journals. A profile of Roy Clarke and his work promoting diversity in applied physics programs was published by Science last year.

[www.k-space.com](http://www.k-space.com)

## Oxford Instruments receives tier-1 orders for InP high-volume manufacturing equipment High-temperature electrostatic clamping in PlasmaPro 100 Cobra ICP etch module aiding automation and scale-up of wafer size

To support demand from high-growth markets such as communications and sensors, indium phosphide (InP) processing capability is becoming more advanced, with a higher degree of automation, while the industry is also looking to migrate to 6”-diameter wafers to increase the number of die per wafer. UK-based Oxford Instruments says that it is enabling this transition by utilizing its high-temperature electrostatic clamping (Hot ESC) for the PlasmaPro 100 Cobra ICP etch module, which is part of its range of ICP InP etch processing solutions. The Hot ESC capability from 75mm wafer size upwards is a full automation-compatible solution, which reduces manual processing for increased reliability and repeatability (critical at larger wafer sizes and with more complex processes).



Oxford Instruments says that its development of leading-edge processes, supported by next-generation hardware, has been recognised by the receipt of orders from tier-1 customers. The solution is in high demand and is ready to enable automated processing and larger wafer sizes. The orders from leading European and Asian optical module and integrated device man-

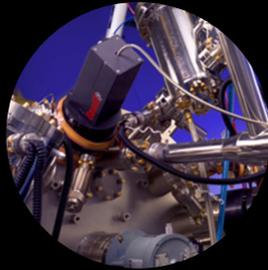
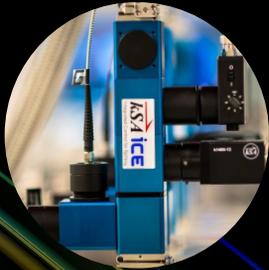
ufacturers (IDMs) are supported by excellent InP market growth projections and the expansion of manufacturing capacity to meet anticipated demand. Datacom and telecom are, and will continue to be, the two biggest segments of the market, but consumer and wearable sensors will also contribute to a compound annual growth rate (CAGR) of 14% in InP photonics market revenue, forecasts market analyst firm Yole.

Oxford Instruments attended the Photonics West 2023 event in San Francisco (28 January–2 February), where its experts shared the latest advances in optoelectronics, photonics, laser and quantum technology.

[www.plasma.oxinst.com](http://www.plasma.oxinst.com)

[www.spie.org/conferences-and-exhibitions/photronics-west](http://www.spie.org/conferences-and-exhibitions/photronics-west)

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# Bridgelux responds to Nichia's Japan patent lawsuit against CoreStaff targeting F90 LEDs

## Bridgelux to employ own patent portfolio to protect rights

On 13 February, Japan-based Nichia Corp filed a patent infringement lawsuit in the Tokyo District Court seeking damages and to enjoin trading company CoreStaff Co Ltd from selling products from the F90 family of LEDs made by Bridgelux Inc of Fremont, CA, USA (a vertically integrated developer and manufacturer of solid-state light sources for lighting applications), which it alleges infringe Japanese patent no. 4974310.

Nichia notes that the Japanese patent — as well as related patents owned in the USA, Germany and China — relates to LEDs incorporating KSF (PFS) phosphors, which enable efficient and reliable LEDs that deliver what is claimed to be excellent light quality with accurate

color rendering. Nichia owns more than 120 patents in over 12 countries covering aspects of this technology, which is important to the LCD backlight and automotive markets, says the firm.

However, the scope of the lawsuit is limited only to such products in Japan and does not cover any jurisdictions outside of Japan. Bridgelux also notes that its F90 products are under Current Lighting Solution and GE Lighting (Savant Company) PSF patent licenses.

Bridgelux believes that Nichia's infringement claims are entirely without merit. The firm notes that, for many years, it has invested significantly in R&D, producing significant intellectual property rights, which currently includes a patent

portfolio of more than 550 worldwide patents spanning LED technologies from chips to luminaires.

Bridgelux says that it respects the intellectual property rights of others and expects others to respect its intellectual property rights. The firm adds that it "will not be intimidated by the misuse of litigation from those seeking an unfair advantage or seeking to limit the advantage Bridgelux has earned from our technology investments".

Because Bridgelux's patent portfolio covers core LED technologies including some key KSF application patents, the firm says that it intends to employ its own patent portfolio to protect its rights.

[www.nichia.com](http://www.nichia.com)  
[www.bridgelux.com](http://www.bridgelux.com)

# Cree LED launches high-brightness SMD LEDs for large-format, high-resolution video screens

## RGB surface-mount LEDs suit stadium signs, airport displays, command center displays, and full-color roadway signs

Cree LED Inc of Durham, NC, USA (a company of SMART Global Holdings of Milpitas, CA) has announced the availability of three surface-mount diode (SMD) LEDs optimized for large-format, high-resolution video screen applications. The new LEDs provide enhanced performance for all types of large-format displays requiring superior image quality and reliability. The SMDs are suitable for stadium signs, airport displays, command center displays, and full-color roadway signs.

First, the CV94A-FGC 3-in-1 red-green-blue (RGB) LED is part of Cree LED's CV94 LED family and features an oval 90°/45° beam angle. CV94 LED SMDs are designed to replace multiple through-hole LEDs in outdoor, larger-pixel-pitch applications,

such as roadway signs and LED billboards. By replacing multiple through-hole LEDs with a single surface-mount LED, signage manufacturers can reduce the complexity and cost of assembling complete displays while also increasing image quality.

Additionally, the CLMWB-FKC, a RGB SMD LED in a small 1.6mm x 1.7mm footprint, has a wide viewing angle and high brightness optimized for high-resolution outdoor LED video screens, such as stadium displays and advertising displays. Both CV94A-FGC and CLMWB-FKC LEDs are IPx8 waterproof rated and feature UV inhibitors to increase reliability in extreme weather conditions.

Finally, the UHD111A-FKA RGB SMD LED features what is claimed to be industry-leading brightness

and reliability in a compact 1.0mm x 1.0mm package that is optimized for high-resolution indoor LED displays that are used in signage at airports, shopping malls and command centers. Unlike other comparable LEDs of this type, the UHD111A-FKA does not contain wire bonds, which results in significant improvement in black levels and contrast ratios.

"These new RGB LEDs deliver higher resolution, better image quality and cost savings for many large-format video screen applications," says David Peoples, VP of marketing.

All three products are available with short lead times, and samples are available through distribution partners.

[www.cree-led.com/products/applications/video-screens](http://www.cree-led.com/products/applications/video-screens)

# MICLEDI highlights micro-LEDs for ultra-compact displays at SPIE AR-VR-MR

## GaN and AlInGaP technology enables full-color micro-LED solutions

In booth #131 at SPIE AR-VR-MR at Photonics West 2023 in San Francisco (31 January – 1 February), MICLEDI Microdisplays B.V. of Leuven, Belgium — a fabless developer of micro-LED display modules for augmented reality (AR) glasses that was spun off from nanoelectronics research center IMEC in 2019 — was on hand to demonstrate its portfolio of red (R), green (G) and blue (B) gallium nitride (GaN)  $\mu$ LEDs. The demonstrations highlight what is claimed to be excellent color performance in blue, green and red across the full range of drive currents for many different types of appliances demanding ultra-compact display modules.

MICLEDI is also displaying red aluminium indium gallium phosphide (AlInGaP) performance results from initial testing and characterization.

As creators of what is claimed to be the first micro-LED arrays for augmented reality built on a 300mm CMOS manufacturing platform, MICLEDI says that it enables more compact, power-efficient devices that address the needs of future ultra-compact displays in terms of display size, resolution, brightness, image quality, power consumption and cost.

The firm's strategy is to enable the optimum full-color ultra-compact display by making the best individual color-performing  $\mu$ LEDs which,

when coupled with its proprietary micro-lenses, can be integrated into the highest-performing full-color 3-panel  $\mu$ LED display module.

As there is no 'one-size-fits-all' solution for ultra-compact displays, different applications (true consumer, industrial, enterprise, medical, automotive and others) require different optimal performance parameters – and MICLEDI says that it is committed to serving customers developing AR glasses from medium to high resolution and medium to high brightness.

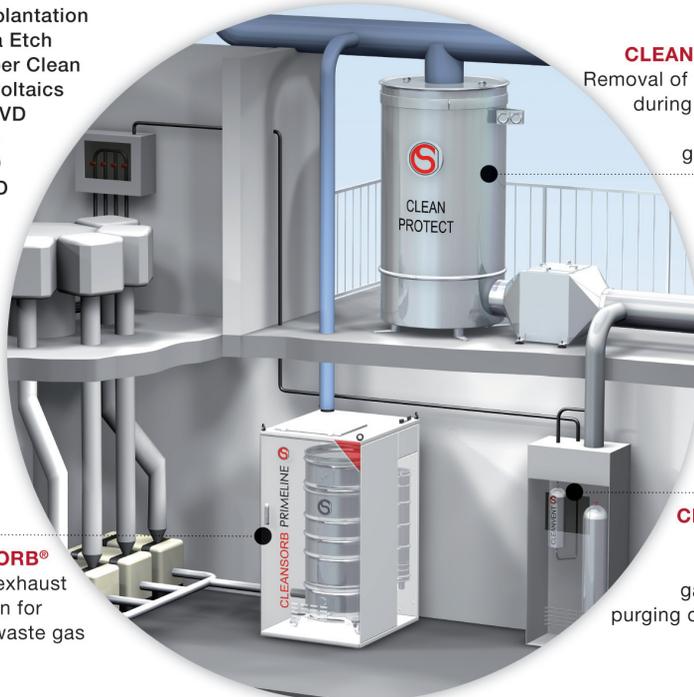
[www.spie.org/conferences-and-exhibitions/photronics-west](http://www.spie.org/conferences-and-exhibitions/photronics-west)  
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# BluGlass secures first customer purchase orders for 405nm and 420nm commercial lasers

## Additional proposals in progress with several customers

BluGlass Ltd of Silverwater, Australia — which has developed proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology — says that it has secured initial purchase orders for its 405nm and 420nm 250mW single-mode gallium nitride (GaN) lasers from two customers.

These commercial purchase orders were received from what are described as industry-leading original equipment manufacturers (OEMs) following BluGlass' product launch at the SPIE Photonics West 2023 conference in San Francisco, CA, USA (28 January to 2 February).

The customers will use these first products to qualify BluGlass' lasers within their own applications, which include quantum and robotic uses. Revenues from these initial low-volume orders are immaterial but, after the lasers are qualified, BluGlass expects to secure recurring larger-volume orders from these customers. Also, additional proposals are progressing with several customers across multiple market segments.

"Our newly launched GaN lasers were incredibly well received at Photonics West, reaffirming the need for a dedicated provider to address unmet market needs

across several verticals," says BluGlass' president Jim Haden. "We are encouraged to have received our first orders so soon after the event. These orders are an important step towards commercial revenues and demonstrate demand for our lasers from key industry players in under-served wavelengths, flexible form factors, and semi-custom designs," Haden adds.

"As a result of this increased interest in our newly released products, we expect additional orders from potential customers and partners to be imminent."

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

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# BluGlass launches suite of 405nm, 420nm & 450nm single- and multi-mode lasers

At SPIE Photonics West 2023 in San Francisco, CA, USA (28 January to 2 February), BluGlass Ltd of Silverwater, Australia – which has developed proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology – has launched its first suite of gallium nitride (GaN) laser products available for customer purchase, spanning 405nm, 420nm and 450nm wavelengths in both single-mode and multi-mode devices, specifically:

- violet 405nm multi-mode 1W laser;
- violet 405nm single-mode 250mW laser;
- violet 420nm multi-mode 1W laser;
- violet 420nm single-mode 250mW laser;
- blue 450nm multi-mode 1W laser;
- blue 450nm single-mode 100mW laser.

Customers can inspect performance data and purchase the products in a range of form factors including TO-cans of different sizes and chip-on-submounts.

The suite of available products has

passed entry-level commercial specifications following significant product development, optimization, and performance and reliability testing.

BluGlass says that it has received interest from customers wanting to deploy its lasers in their product development programs, which span applications including 3D printing, quantum sensing and computing, material sensing, and flow cytometry.

“The release of these laser diodes reflects the significant performance and reliability improvements we have made over the past year,” says president Jim Haden. “The market is telling us there is a growing need for a dedicated GaN laser supplier who can provide greater manufacturing agility and form factor flexibility, to enable manufacturers to expand their product offerings and market applications. We have several potential customers interested in our portfolio, and this significant milestone paves the way for first orders and commercial revenues,” he adds.

“Our product offering will continue to grow and improve – with expanded wavelengths, higher-power

and novel laser architectures also progressing through the supply chain. We expect the execution of our ongoing vertical integration plans to further improve quality and accelerate development timelines for future products and enable us to scale manufacturing capacity to meet demand,” Haden continues.

“The visible laser market is a high-value and high-margin semiconductor segment that is growing rapidly, with ubiquitous use in everything from consumer electronics, advanced manufacturing to medical diagnostics, quantum computing, and defense applications,” he adds. “Within the broader market, GaN lasers offer inherent advantages over traditional infrared laser diodes, including higher energy absorption in key industrial metals, tighter beam focus, and improved efficiency. These competitive advantages are driving significant interest from global customers.”

In addition to the launched products, laser diode designs in other wavelengths and specifications are progressing through BluGlass’ supply chain, including RPCVD-enhanced products.

	Available for Purchase	In Development			Next Generation	
Violet	405nm	MM – 1W	MM – 3W			SM – 500mW
		SM – 250mW	SM – 300mW-400mW			
	420nm	MM – 1W	MM – 3W			SM – 500mW
		SM – 250mW	SM – 300mW-400mW			
Blue	450nm	MM – 1W	MM – 1.6W	MM – 2.2W	MM – 3.5W	MM – 5W
		SM – 100mW	SM – 250mW			
	470nm	MM – 2W			MM – 1.5-2W	
		SM – 100-250mW				
	488nm	SM – 100-200mW				
Green	525nm	MM – 0.5-2W				
		SM – 80-100mW				

MM: Multi Mode SM: Single Mode

## NUBURU showcases new BL-Series blue laser at Photonics West

### 125W BL-125 and 250W BL-250 provide high power and brightness with integrated power monitoring

NUBURU Inc of Centennial, CO, USA showcased its new NUBURU BL-Series at SPIE Photonics West 2023 in San Francisco, CA, USA (28 January to 2 February), where key members of its management team and Advisory Committee were in attendance.

Founded in 2015, NUBURU is a developer and manufacturer of industrial blue lasers that leverage their high-brightness, high-power design to produce fast, high-quality laser materials processing, including laser welding and additive manufac-

turing of copper, gold, aluminium and other industrially important metals. The firm's industrial blue lasers are claimed to produce defect-free welds up to eight times faster than the traditional approaches — all with the flexibility inherent to laser processing.

The BL-Series is a new compact form-factor blue laser enabled by a third-generation light engine design. The lasers are designed as easy-to-service packages that can readily integrate with scanners and beam delivery systems. The 125W BL-125 and 250W BL-250 provide high

power and brightness along with integrated power monitoring, enabling design and fabrication efficiencies across a wide variety of industries.

The BL-Series products showcased at Photonics West are designed to bring the fundamental physical, economic and performance advantages of the blue industrial laser to the manufacturing of products for vehicle electrification, 3C products and additive manufacturing of copper and other reflective materials.

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

## NUBURU and Tailwind finalize business combination High-power, high-brightness industrial blue laser firm trading on NYSE American Stock Exchange

Special-purpose acquisition company (SPAC) Tailwind Acquisition Corp (TWND) and NUBURU Inc of Centennial, CO, USA have completed their business combination (announced on 8 August), resulting in NUBURU becoming a publicly listed company. The combined company will operate under the name Nuburu Inc and its common stock and warrants commenced trading on 1 February on the NYSE American Stock Exchange under the new ticker symbols 'BURU' and 'BURU WS', respectively.

Founded in 2015, NUBURU is a developer and manufacturer of industrial blue lasers that leverage

their high-brightness, high-power design to produce fast, high-quality laser materials processing, including laser welding and additive manufacturing of copper, gold, aluminium and other industrially important metals. The firm's industrial blue lasers are claimed to produce defect-free welds up to eight times faster than the traditional approaches — all with the flexibility inherent to laser processing.

"Becoming a publicly listed company is an important milestone that we expect will provide access to capital and continued momentum for NUBURU," says the firm's

Dr Mark Zediker. "We appreciate the Tailwind team's partnership and look forward to accelerating the development of our high-brightness products to meet the growing demand of our customers globally," he adds.

NUBURU's solutions in metal processing are "critical to growing end-markets in 3D printing, aerospace, consumer electronics and e-mobility," says TWND's CEO Chris Hollod. "We look forward to seeing NUBURU further strengthen its leadership position as it continues to develop best-in-class solutions."

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

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# Kyocera SLD Laser introduces high-power blue laser product line for industrial, biomedical, defense and display applications

## Firm demos innovations in LiFi communication, high-efficiency lasers for AR/VR and optical power transfer

At the SPIE Photonics West 2023 exhibition in San Francisco, CA, USA (31 January – 2 February), Kyocera SLD Laser Inc (KSLD) of Goleta, near Santa Barbara, CA, USA — which is commercializing gallium nitride (GaN)-based laser light sources for automotive, mobility, specialty lighting and consumer applications — introduced high-power 5W blue laser diode products for industrial, biomedical, defense and display applications. The firm is also showcasing its new high-brightness white/IR LaserLight SMD products (winner of the 2021 Prism Award).

Additionally, KSLD is demonstrating its DataLight high-speed LiFi communication system (a 2023 Prism Award finalist) as well as its new innovations in high-efficiency laser diodes for augmented-reality/virtual-reality (AR/VR) applications and efficient optical power transfer technology.

Based on KSLD's proprietary high-gain semi-polar GaN architecture, the new high-power blue laser diode products deliver 5W of optical power at 445nm. The product is available in a TO-can package or chip-on-submount, as well as a fiber-delivered configuration.

The devices are suitable for integration into customer end-systems in industrial marking, engraving for non-metals and organics such as resins, plastics and printed-circuit boards, as well as in 3D printing and welding of metals such as copper for electric vehicle (EV) battery production where absorption is more than 10 times higher than for infrared lasers.

High-power blue lasers also have a broad range of use in biomedical applications including dental, surgical and dermatology (where absorptions in hemoglobin and melanin are more than five times that of

infrared lasers) as well as defense applications including avionics light detection and ranging (LiDAR) and undersea communications.

Additionally, high-power blue laser diodes are used in projection displays to excite RGB phosphors to replace lamps in portable projectors, home theater, boardroom and education projectors, as well as large venues and cinema.

KSLD is also applying its high-gain semi-polar GaN to develop high-efficiency low-power red, green and blue laser diodes to miniaturize, brighten and reduce power consumption of RGB laser beam scanning modules for the emerging AR/VR market.

KSLD is also showcasing its LaserLight SMD devices that deliver high-brightness white and infrared (IR) dual illumination for medical, machine vision, inspection, safety lighting, bioinstrumentation and other applications that require high-intensity spots or high-efficiency fiber-optic delivery of white light. The firm is featuring an expanded IR wavelength range from 850nm to 1000nm, and increased white light output up to 1000 lumens to deliver high-brightness, high-visibility, eye-safe illumination.

Mobility applications include automotive, avionics, drones, railway and marine white light and IR night vision, range finding and flash LiDAR. Specialty lighting applications include portable flashlights and light bars, high-lumen spotlights for avionics, helicopter search & rescue and security applications, as well as entertainment and outdoor lighting. Until now, dual-emission white/IR sources have not been possible because LEDs and legacy lamp-based light sources are unable to deliver high-brightness white and

IR emission from the same point source, and they are incapable of being modulated at the high speeds required for accurate sensing and fast data rates.

To support the future of wireless connectivity, KSLD is displaying DataLight, which is claimed to be the first laser LiFi commercial development kit featuring a high-speed 1Gbps, secure, RF-free, eye-safe bidirectional link. Laser LiFi is being adopted in mobility applications including car-to-x exterior, vehicle interiors, airplane cabins, undersea and space, defense and security, as well as future smart cities, healthcare, and smart factories. KSLD says that it is pioneering LiFi innovations for future products as well, and recently demonstrated record performance of 100Gbps. This product is a finalist for the 2023 Prism awards in the Laser category.

Beyond lighting, sensing and communications, KSLD is demonstrating optical power transmission over fiber using its high-efficiency GaN laser diode and photodiode chip technology. The firm reckons that this advance in the field of power transfer has the potential to replace heavy and sensitive metal wire harnesses in mobility and harsh-environment applications with a lightweight, noise-free optical solution, increasing the efficiency and extending the range of electric vehicles, airplanes or satellites, while making them more secure and safe. This power-over-light solution can be configured to include optical data communications to deliver data and power to sensors in a distributed system in a vehicle or even in space, where radiation-hardened GaN-based semiconductors are ideally suited.

[www.kyocera-sldlaser.com](http://www.kyocera-sldlaser.com)

# TRUMPF industrializing high-volume production of InP-based SWIR VCSELs above 1300nm

## Technology enables new applications such as under-OLED sensors

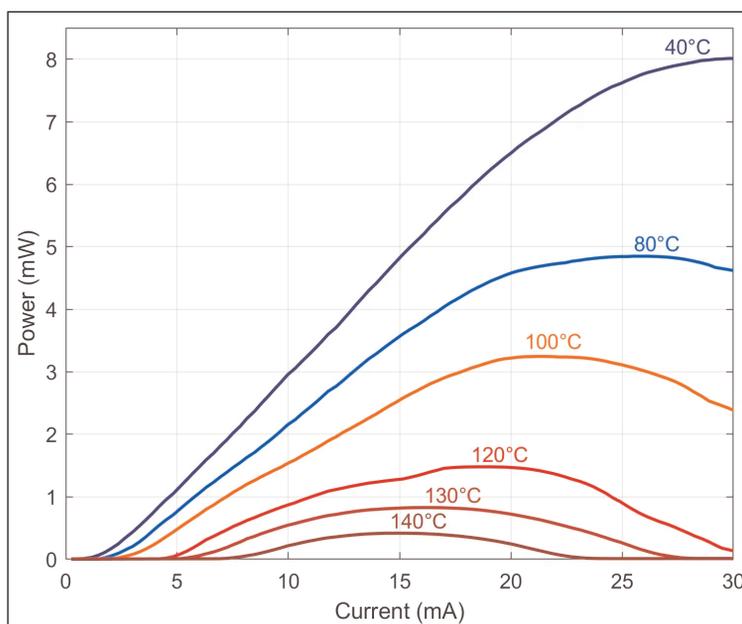
TRUMPF Photonic Components GmbH of Ulm, Germany (part of the TRUMPF Group) — which makes vertical-cavity surface-emitting lasers (VCSELs) and photodiodes for the consumer electronics, data-coms, industrial sensing, heating and automotive markets — is industrializing the production of short-wave infrared (SWIR) VCSELs above 1300nm to support high-volume applications such as in smartphones in under-OLED applications.

The firm says that it has demonstrated outstanding results regarding the efficiency of infrared laser components with long wavelengths beyond 1300nm on an industrial-grade manufacturing level, representing a step further towards mass production of indium phosphide-based (InP) VCSELs in the 1300–2000nm range.

“We are working hard to mature this revolutionary production process and to implement standardization, which would further develop this outstanding technology into a cost-attractive solution. We aim to bring the first products to the high-volume market in 2025,” says CEO Berthold Schmidt.

By developing the new industrial production platform, TRUMPF is expanding its current portfolio of gallium arsenide- (GaAs)-based VCSELs in the 760–1300nm range for NIR [near-infrared] applications. The new platform is more flexible in the longer-wavelength spectrum than are GaAs, but it still provides the same benefits as compact, robust and economical light sources.

“The groundwork for the successful implementation of long-wavelength VCSELs in high volumes has been laid. But we also know that it is still a way to go, and major production equipment investments have to be made before ramping up mass production,” says Schmidt.



**Temperature performance of the light-current measurement of multimode VCSEL at up to 140°C with 1390nm.**



### VCSELs to address new uses

TRUMPF reckons that a broad application field can be revolutionized by the industrialization of long-wavelength VCSELs, as the SWIR VCSELs can be used in applications with higher output power while remaining eye-safe compared with shorter-wavelength VCSELs. The long-wavelength solution is not susceptible to disturbing light such as sunlight in a broader wavelength regime.

One popular example from the mass markets of smartphone and consumer electronics devices is under-OLED applications. The InP-based VCSELs can easily be put below these OLED displays, without disturbing other functionalities and with the benefit of higher eye-safety

standards. OLED displays are a huge application field for long-wavelength sensor solutions.

“In future we expect high-volume projects not only in the fields of consumer sensing, but automotive LiDAR, data communication applications for longer reach, medical appli-

cations such as spectroscopy applications, as well as photonic integrated circuits (PICs), and quantum photonic integrated circuits (QPICs),” says Schmidt. “The related demands enable the SWIR VCSEL technology to make a breakthrough in mass production.”

### Test results up to 140°C at ~1390nm wavelength

TRUMPF is presenting results showing VCSEL laser performance up to 140°C at ~1390nm wavelength. The technology used for fabrication is scalable for mass production and the emission wavelength can be tuned between 1300nm to 2000nm, resulting in a wide range of applications. Recent results show good reproducible behavior and excellent temperature performance. “We are confident that the highly efficient, long-wavelength VCSELs can be produced at high yield to support cost-effective solutions,” Schmidt says.

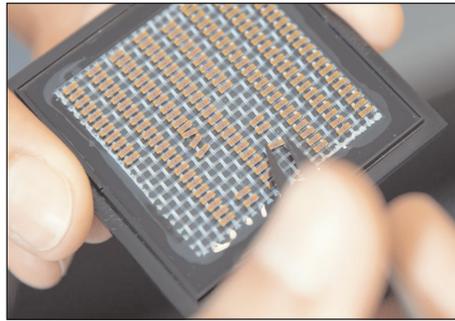
[www.trumpf.com/s/VCSEL-solutions](http://www.trumpf.com/s/VCSEL-solutions)

# TRUMPF Venture invests in InP PIC-based quantum technology startup Quside

TRUMPF Venture of Ditzingen, Germany is making a multi-million euro investment in startup Quside of Castelldefels near Barcelona, Spain.

Founded in 2018 after several years of R&D at the Institute of Photonic Sciences (ICFO) in Barcelona and currently having about 30 staff, Quside's core product is a high-performance random number generator on an indium phosphide (InP) photonic integrated circuit (PIC) chip that is compatible with common semiconductor manufacturing (CMOS) processes, enabling easy mass production.

Using the quantum mechanical properties of light, the chip produces completely random number combinations very quickly (at Gb/s). This makes it possible to improve the encryption of messages



enormously, enabling the encryption of messages that even computationally powerful quantum computers cannot decrypt.

In addition to encryption, Quside's random number generator also enables faster and more energy-efficient calculation of simulations, such as risk analyses in the financial sector or weather forecasts. For example, traffic forecasts can be calculated up to ten times faster,

and energy consumption is up to 20 times lower. Such simulations are also used by the insurance industry, the logistics sector and the pharmaceutical industry.

There is already great demand in industries where security plays a major role. Quside's first customers are from sectors with high-security requirements, such as aerospace. But it is expected that the technology could also play an increasingly important role in private devices. The firm hence plans to expand into the consumer market in the coming years, to use chips to boost the security of smartphones, tablets or even vehicles.

The global market for random number generators is forecasted to grow to €7–10bn in 2026.

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

## Updated 25G & 56G VCSEL technology and portfolio at OFC Firm presenting progress on long-wavelength VCSELs and 100G

In booth 2616 at the Optical Fiber Communication Conference and Exhibition (OFC 2023) in San Diego, CA, USA (7–9 March), TRUMPF Photonic Components GmbH of Ulm, Germany (part of the TRUMPF Group) is showcasing its recently updated VCSEL product portfolio and technology with matching photodiodes.

The firm is introducing the updated product portfolio of its well-established 25G and 56G components with extended temperature range and higher performances.

In addition, TRUMPF is showcasing a live demonstration on the performance of its latest VCSEL and photodiode components.

"At OFC 2023 we are also presenting progress on our 100G as well as our long-wavelength programs to address future demands," says Ralph Gudde, VP marketing & sales.

### VCSELs meeting the demands of data centers

Advanced optical data communication systems benefit from the high-speed data transmission that VCSEL-based technology offers, notes TRUMPF. For interconnect distances below 100m, VCSELs are the best solution in terms of power and cost, the firm adds.

TRUMPF is offering both VCSELs and photodiodes as matching pair solution, in singlets, 1x4 arrays and 1x12 arrays for 14G and 25G for NRZ applications. The same is offered for 56G PAM4 applications.

The VCSELs are specifically designed to meet the demands of data centers, high-performance computing systems, and other bandwidth-intensive applications, as they deliver stable and reliable data transmission at high speeds.

### VCSELs for longer distances

TRUMPF says that it is investing in several technologies to extend the

power, cost and reliability benefits of VCSELs for future applications.

The developments include an extension to long-wavelength VCSELs as well as single-mode VCSELs with polarization gratings.

The long wavelengths span 980–1310nm and even higher wavelengths, addressing longer-range datacom and automotive applications.

Increased bandwidth, lower power consumption, additional multiplexing options and superior noise control are among the expected benefits from the developments of single-mode VCSELs and polarization gratings.

The solutions continue to offer transmission at higher data rates and higher temperature, resulting in improved overall system performance, says TRUMPF.

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

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

[/s/VCSEL-solutions](https://www.trumpf.com/s/VCSEL-solutions)

# Vector Photonics receives over £2.4m of equity investment

## Funding to be used to further commercialize PCSEL technology

Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March 2020, based on research led by professor Richard Hogg) has received over £2.4m of equity investment to further commercialize its unique, all-semiconductor photonic-crystal surface-emitting laser (PCSEL) technology.

The new investment comes from a group of specialist funding companies. Clean Growth Fund is the major investor, followed by the Foresight WAE Technology (FWT) Funds, joined by the UK Innovation & Science Seed Fund (UKI2S), Scottish Enterprise and Equity Gap, which led the round.

Clean Growth Fund and Scottish Enterprise are new investors. Clean Growth Fund is focused on clean tech firms that reduce carbon emissions and support a sustainable future, with Vector Photonics being the first Scottish company in its portfolio. Scottish Enterprise is Scotland's national economic development agency and works to transform the Scottish economy by helping businesses innovate and scale.

The remaining investors have been involved with Vector Photonics



**Vector's executive team: Euan Livingston, Neil Martin and Richard Taylor.**

from the beginning. The FWT Funds invest in high-growth-potential companies with innovative and transformational technologies; UKI2S is a specialist deep-tech seed fund focused on spin outs from the UK's research base; and Equity Gap is an angel investment syndicate, investing at an early stage in new technology businesses throughout Scotland.

PCSELS are claimed to revolutionize semiconductor laser manufacture and performance, reducing power consumption, latency,

physical connection size and costs. Vector Photonics is targeting the datacoms market, where its lasers are said to significantly reduce the power consumption in next-generation data centers and co-located optics applications. In future, PCSEL technology will also enable significant performance improvements in metal and plastic printing, light detection & ranging (LiDAR) and optical sensing — some of the fastest-growing technology markets in the world.

[www.vectorphotonics.co.uk](http://www.vectorphotonics.co.uk)

## Photonis acquiring infrared imaging firm Xenics

In mid-December, Photonis of Mérignac, France (owned by HLD since 2021) — which provides photo-detection and imaging technology for defence and industrial markets — signed a definitive agreement to acquire infrared detector developer and manufacturer Xenics NV of Leuven, Belgium, which was spun off from imec in 2000 and has over 65 staff designing and manufacturing infrared imagers, cores and cameras for line-scan and area-scan products operating in the visible-near-infrared (visNIR),

short-wave infrared (SWIR) and long-wavelength infrared (LWIR) spectral ranges (0.4–14µm). The transaction is financed by Pemberton, CIC and BNP Paribas.

The merged group aims to provide high-end imaging products to business-to-business customers through component manufacturing, a large geographical reach and advanced technological capabilities.

"We are aiming to create a European integrated leader in advanced imaging in high-end markets," says Photonis' CEO Jérôme Cerisier.

"We will together combine our forces to strengthen our position in the infrared imaging market," he adds.

"Xenics will benefit from Photonis expertise and international footprint, which will allow us to accelerate our growth," comments Xenics' CEO Paul Ryckaert. "It is a real opportunity to boost our commercial, product development and manufacturing competences and bring even more added value to our existing and future customers."

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

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

# Lumotive and Lumentum introduce reference design for faster adoption of 3D LiDAR

Lumotive of Redmond, near Seattle, WA, USA, which develops patented Light Control Metasurface (LCM) beam-steering chips enabling next-generation 3D sensors, and Lumentum have jointly announced availability of the M30 Reference Design, a complete software-defined sensor implementation to enable rapid adoption of LCM-based solid-state beam-steering technology.

Integrating Lumotive's LCM beam-steering chip with Lumentum's M52-100 multi-junction vertical-cavity surface-emitting laser (VCSEL) array, the M30 Reference Design is available now for evaluation by select customers. Lumotive showcased the features of LCM beam-steering technology at SPIE Photonics West 2023 in San Francisco, CA, USA (28 January to 2 February).

"Lumentum's high-performance, multi-junction VCSEL arrays have unique and powerful advantages such as increased energy efficiency and scanning accuracy, critical for all-electronic 3D LiDAR sensor solutions," says Rakinder Grover, Lumotive's VP of strategy and partnerships.

"The M30 reference design seamlessly integrates Lumentum's M52-100 VCSEL array technology with Lumotive's transformative beam-steering chips. The result is a software-definable, immediately deployable LiDAR sensor solution that addresses both the low-power and small-footprint requirements of short- to long-range mobility and industrial applications."

Unlike traditional flash illumination solutions, LiDAR sensors based on LCM electronic beam steering are said to have advantages including:

- superior outdoor range performance;
- software-defined scan modes for increased and application-specific performance (range, field of view, frame rate, resolution) only where it matters;
- reduced multipath effects, resulting in better point cloud quality;
- optimization of illumination across the field of view in high ambient light levels and for varying levels of reflectivity;
- significantly improved interference mitigation from other sensors;

- high power density in a small form factor.

"Combined with Lumentum's high-performance, multi-junction VCSEL technology, the LCM beam-steering technology from Lumotive allows customers to implement true solid-state, VCSEL-based LiDAR with software-definable characteristics in a compact package," says Matt Everett, senior director of product line management at Lumentum's Imaging and Sensing business unit. "The M30 Reference Design provides outstanding performance and the ability to dynamically adjust the field-of-view (FoV) and region of interest."

With early versions currently being evaluated by several leading LiDAR systems developers, tier-1 automotive suppliers, and industrial OEMs, the M30 Reference Design with enhanced performance and optimized for volume manufacturing is expected to be available by mid-2023.

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

[www.spie.org/conferences-and-exhibitions/photronics-west](http://www.spie.org/conferences-and-exhibitions/photronics-west)

## Lumentum awarded EcoVadis Platinum Medal

Lumentum has received the EcoVadis Platinum Medal, the highest recognition level at EcoVadis for sustainability performance.

"Being awarded the EcoVadis Platinum Medal affirms our ongoing commitment to driving responsible business practices," says Lumentum's president & CEO Alan Lowe.

"After receiving the EcoVadis Silver Rating in 2019 and Gold Rating in 2022, I am incredibly proud of our employees for their dedication and hard work, which has enabled us to achieve a Platinum Rating in 2023 – placing us among the top 1% of companies assessed by EcoVadis."

Lumentum says that its ongoing mission to uphold the highest standards of social, ethical and

environmental conduct remains a top corporate priority. Its commitments to sustainability include:

- net-zero greenhouse-gas emissions from its global operations (Scope 1 and 2) by 2030;
- emission reductions in line with climate science with the Science Based Targets initiative;
- increase percentage of the firm's electricity from renewable sources to 60% in fiscal 2023;
- divert 90% of non-hazardous waste by fiscal-year 2027.

As a global standard for business sustainability ratings, the EcoVadis assessment evaluates 21 sustainability criteria across four core themes: Environment, Labor & Human Rights, Ethics, and Sus-

tainable Procurement. More than 100,000 companies globally have been rated by EcoVadis.

EcoVadis' business sustainability ratings are based on international sustainability standards such as the Ten Principles of the UN Global Compact, the International Labour Organization (ILO) conventions, the Global Reporting Initiative (GRI) and the ISO 26000 standard.

EcoVadis will be planting a tree on Lumentum's behalf to celebrate the firm's completion of the EcoVadis sustainability assessment, through the EcoVadis partnership with One Tree Planted, a non-profit organization focused on global reforestation.

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

## Lumentum's quarterly revenue up 13.3% year-on-year Growth in Telecoms and Commercial Lasers offset by IC supply constraints and reduced cloud and consumer demand

For its fiscal second-quarter 2023 (ended 31 December 2022), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes optical and photonic products for optical networks and lasers for industrial and consumer markets) has reported revenue of \$506m, roughly level with \$506.8m last quarter but above the midpoint of the guidance range, and up 13.3% on \$446.7m a year ago.

Specifically, sequentially higher revenue from Telecom and Commercial Lasers customers offset the reduction from certain cloud customers due to inventory digestion and from a major consumer customer due to reduced smartphone unit production.

The Commercial Lasers segment contributed a record \$57.2m (11.3% of total revenue), up 7.1% on \$53.4m last quarter and up 16% on \$49.3m a year ago, aided by gaining market share.

The Optical Communications segment contributed \$448.8m (88.7% of total revenue), up 12.9% on \$397.4m a year ago, but down 1% on \$453.4m last quarter. The drop was driven primarily by a decline in Industrial & Consumer — specifically, consumer vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing, due to expected market share normalization relative to Lumentum's main competitor (although this has the advantage of reducing Lumentum's exposure to such a cyclical market). This was mostly offset by 44% year-on-year growth in Telecom & Datacom.

"In addition, due to the escalated data traffic at the edge of the network, customers are deploying our products originally developed for core network applications at the edge or access part of the network. Revenue from edge networking products was up 40% year-on-year in the second quarter, and is now a major component of our Telecom

business," notes president & CEO Alan Lowe.

Growth from Telecom customers was partially offset by the inventory digestion at certain cloud customers. "Revenue growth continues to be limited by supply shortages of ICs from third parties. We have made significant progress over the last year on closing supply gaps, which has enabled our growth to date.

At the end of Q2, remaining IC supply shortages resulted in approximately \$60m of unsatisfied customer demand. This is a modest improvement from the \$80m gap articulated in our last call," says Lowe.

Revenue was especially strong in products which play into the industry's transition to 400G-and-above speeds in next-generation networks, including narrow-linewidth tunable lasers, tunable transceivers for network edge applications, high-speed coherent components and modules, as well as Lumentum's latest ROADMs.

"We achieved a new quarterly revenue record in narrow-linewidth tunable lasers, which are key enablers of all coherent transmission solutions, including 400G ZR and ZR+ modules, and our customers' latest 600G and 800G transmission systems," notes Lowe.

"We also set a quarterly revenue record with our tunable transceivers for network edge applications where a growing set of cable, MSO, and wireless network operator customers use our modules to expand data bandwidth in metro access, fiber deep, and wireless 5G front-haul applications," he adds.

Coherent components serving 400G-and-above applications also achieved record revenue, with about half of that revenue coming from the highest-data-rate applications at 600G and 800G.

Due to continued strong demand and improved access to critical ICs, revenue from ROADMs grew by 45% year-on-year, including 78%

growth for MxN ROADMs and over 70% for high-port-count ROADMs, representing "broader adoption of these next-generation ROADMs with market-leading customers".

As anticipated, inventory digestion at certain cloud customers and their module manufacturers resulted in a sequential decline in Datacom's laser chip revenue.

"Nearly 90% of total revenue is now derived from [telecom] infrastructure markets, which are driven by durable, long-term secular trends in which we serve with highly differentiated products and technologies," says Lowe. "Our technology leadership position is stronger than ever due to successful investments in developing new products and technologies, as well as the two acquisitions we closed this past August [NeoPhotonics Corp, and the IPG Photonics' telecom transmission product lines]," he adds.

On a non-GAAP basis, gross margin has fallen further, from 51% a year ago and 48.2% last quarter to 44.9%, driven primarily by product mix, including lower-margin revenue from the acquisition of NeoPhotonics. Gross margin for the Optical Communication segment was hence 43.9%, down on 50.8% a year ago. Gross margin for the Commercial Lasers segment of 52.4% was roughly flat sequentially but down from 53.1% a year ago.

Operating expenses have risen further, from \$86.4m (19.3% of revenue) a year ago and \$106.7m (21.1% of revenue) last quarter to \$110.3m (21.8% of revenue), due to R&D expense rising from \$47.8m a year ago and \$60.8m last quarter to \$64.4m. Selling, general & administrative (SG&A) expense was \$45.9m, up from \$38.6m a year ago but level with last quarter. OpEx was \$5–7m better than expected, since synergy targets for the first year post-acquisitions have been pulled into the first six months,

	Q2 FY23	Q1 FY23	Q2 FY22
<i>\$ in millions</i>			
<b>Revenue</b>	<b>\$506.0</b>	<b>\$506.8</b>	<b>\$446.7</b>
Optical Communications	448.8	453.4	397.4
Telecom & Datacom	384.2	360.1	267.1
Industrial & Consumer <sup>(1)</sup>	64.6	93.3	130.3
Commercial Lasers	57.2	53.4	49.3
<b>Gross Margin (Non-GAAP)</b>	<b>44.9 %</b>	<b>48.2 %</b>	<b>51.0 %</b>
Optical Communications	43.9 %	47.6 %	50.8 %
Commercial Lasers	52.4 %	52.6 %	53.1 %

(1) Industrial & Consumer contains 3D sensing revenues as well as diode lasers sold into industrial applications.

offsetting some of the impact of NeoPhotonics on margins.

"We are now six months into integrating these acquisitions and tracking ahead of plan in realizing overall cost synergies, which contributed to our profitability and earnings per share results being above our guidance ranges," says Lowe.

Operating income has fallen further, from \$141.6m (operating margin of 31.7%) a year ago and \$137.4m (27.1% margin) last quarter to \$116.7m (23.1% margin), due to product mix including from the recent acquisitions, but above the guidance of 20–22%.

Likewise, net income has fallen further, from \$120.2m (\$1.60 per diluted share) a year ago and \$119.2m (\$1.69 per diluted share) last quarter to \$104.1m (\$1.52 per diluted share, but above the guidance range of \$1.20–1.45, driven partly by the accelerated attainment of acquisition synergies, a cost savings action taken late in Q2, and higher interest income on cash and investments).

During the quarter, Lumentum recorded one-time restructuring and related charges of \$13.9m (due mainly to company-wide integration efforts as it accelerated the attainment of acquisition synergies after the merger with NeoPhotonics, as well as some cost-reduction initiatives, and severance and employee-related benefits related to NeoPhotonics) plus a charge of

\$7.8m related to the settlement of non-ordinary course litigation matters. Lumentum also incurred \$11.7m in extraordinary charges to acquire IC components from brokers to satisfy customer demand.

Overall, during the quarter, total cash, cash equivalents and short-term investments rose by \$55.5m, from \$1624.9m to \$1680.4m.

"These results reflect structural improvement in the long-term operating costs of the company, as we continue to execute on our synergy plan," says Lowe.

When Lumentum acquired NeoPhotonics, it highlighted \$50m in synergy opportunities with \$20m in annual operating expense opportunities within the first fiscal year and then another \$30m cost of sales synergies as it exits the second fiscal year. "We have already exceeded our \$20m cost savings target in annual operating expense synergies over the last six months of integration activity, we have executed well on our operating expense reduction plans, and are confident we will exceed our initial synergy targets," says chief financial officer Wajid Ali. "In December, we took additional actions that will structurally improve the long-term operating costs of the company. The benefits of these actions are reflected in our diluted net income per share guidance for Q3."

For fiscal third-quarter 2023 (to end-March), Lumentum expects

revenue to fall to \$430–460m. This is due to about \$60m of impact primarily in Telecoms from continued supply constraints due to shortages of third-party IC components, in addition to reduced cloud and consumer end-market revenue (with Datacom and 3D sensing lower than prior projections), and a few million dollar sequential decline in Commercial Lasers revenue.

"We expected the hyperscale customers to reduce their inventories of our laser chips during the second quarter. Now, we expect that this will continue throughout most of calendar 2023," says Lowe.

Fiscal Q3 operating margin should fall further to 17–19%. Diluted earnings per share are expected to fall to \$1.00–1.15.

Given the assumption of growth in Telecom and Datacom business offset by seasonally lower consumer revenue, for fiscal Q4 Lumentum expects that Q4 revenue will be roughly flat on Q3, still constrained by IC supply.

Full-year fiscal 2023 revenue will therefore be at the low end of the previously announced outlook of \$1.9–2.05bn. However, due to the substantial structural improvements in operating expenses and tight cost controls, Lumentum now expects that full-year earnings per share will be \$5.15–5.45, above the midpoint of the prior guidance of \$4.65–5.65.

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

## Imec co-integrates SiN waveguide technology with active silicon photonics platform

### Single PIC combining active and SiN passive functions

In an invited talk at Photonics West 2023 in San Francisco, CA, USA (28 January to 2 February), nano-electronics research center imec of Leuven, Belgium said that it has demonstrated co-integration of its silicon nitride waveguide technology with its silicon photonics platform — without any degradation in performance of the high-bandwidth active devices. An important upgrade for imec's silicon photonics platform, the result enables the synthesis of high-quality wavelength-selective devices and other optical passive functions that benefit from accurate optical phase control, meeting market demands for optical transceivers for datacoms, light detection & ranging (LiDAR) and other applications.

Low propagation loss, accurate phase control, low-loss light coupling, lower thermal variation,

and high power handling are some of the reasons why adding high-quality silicon nitride (SiN) boosts silicon photonics integrated circuits (PIC). High-quality SiN layers achieving low optical losses and excellent control over the material properties, such as thickness and refractive index variability, are crucial for improving the energy efficiency of silicon-based optical transceivers. Since such high-quality SiN layers are deposited by low-pressure chemical vapor deposition (LPCVD) at elevated temperatures, it is vital to avoid degrading the performance of the co-integrated baseline silicon and germanium devices.

Imec has tackled those integration challenges within its iSIPP silicon photonics platform, which is available for industrial partners. Due to

various engineering updates and changes in the process flow, imec has, for example, shown a more than four times reduction in the variability of the resonant wavelength of SiN-based micro-rings compared with the same device made with lower-quality PECVD silicon nitride currently used in the imec platform, without degrading the co-integrated active devices.

"The ability to co-integrate high-quality SiN devices with our baseline technology is important to broaden our offering to our partners who can now consider system simplification with single PIC solutions to combine active and SiN passive functions," says Philippe Absil, vice president at imec.

[www.imec.be](http://www.imec.be)

[www.spie.org/conferences-and-exhibitions/photonics-west](http://www.spie.org/conferences-and-exhibitions/photonics-west)

## Pilot Photonics announces availability of nanosecond-switching narrow-linewidth widely tunable laser

Pilot Photonics of Dublin, Ireland — which produces light sources and III-V photonic integrated circuits (PICs) for communications, automotive and space applications — has announced the availability of a new widely tunable laser module. It is claimed to be the only commercially available tunable laser that offers the elusive combination of nanosecond switching and narrow linewidth, solving a long-running challenge in the industry.

Widely tunable semiconductor lasers can typically offer narrow linewidth, or fast tuning, but not both. In optical fiber sensing systems, electronically tunable lasers have traditionally been used for their fast tunability over a wide tuning range, which is achieved using a current-injection tuning mechanism. However, these lasers exhibit linewidths that are unsuitable for

demanding phase-sensitive applications such as coherent optical communications and frequency-modulated continuous wave (FMCW) light detection & ranging (LiDAR). Changing to a thermal tuning mechanism reduces the linewidth, but at the cost of switching speed, which renders the laser unsuitable for some of these applications.

Pilot Photonics' laser is based on a monolithic indium phosphide (InP) chip fabricated on an active-passive platform. Electro-optic tuning with reverse-voltage bias of tuning sections allows milliAmp-order dark currents and facilitates nanosecond switching speeds with low power dissipation. It offers over 30nm of wavelength tuning range in either the C-band or the O-band, and linewidth of 150kHz. Currently available in a 14-pin butterfly package or integrated into an OEM or

laboratory instrument form-factor module, the company is also developing a nano-iTLA (integrated tunable laser assembly) module for high-volume applications.

"We have been working with our partner SMART Photonics on a couple of innovative tunable laser designs made possible with their PIC platform," says Pilot Photonics' founder & chief technology officer Dr Frank Smyth. "These devices target specific challenges that our customers are facing."

At the SPIE Photonics West 2023 exhibition in San Francisco, CA, USA (31 January – 2 February), Pilot Photonics demonstrated the tunable laser and presented a paper 'Widely tunable C-band laser and module with nanosecond tuning and narrow linewidth' detailing its characterization.

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

# Coherent introduces 1300nm high-power DFB lasers for silicon photonics-based transceivers

## 100mW uncooled and 300mW cooled enable 100Gbps and 200Gbps per lane for DR4 and DR8 transceivers

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA has launched its 1300nm high-power continuous wave (CW) distributed feedback (DFB) laser diodes for silicon photonics-based datacom pluggable transceivers.

Cloud and artificial intelligence (AI) service providers are ramping up deployments of 400G and 800G transceivers for their megascale data-center buildouts, with an eye on 1.6T transceivers in the future. Coherent is introducing high-power CW DFB laser diodes that enable 400G to 1.6T silicon photonics-based transceivers, which are among the transceiver technology

platforms deployed in the data-center mid-reach range of 500m to 2km.

“Coherent continues to advance the state of the art in indium phosphide semiconductor laser technology that will enable the cloud to continue to rapidly and sustainably scale capacity,” says Dr Kou-Wei Wang, VP & general manager, Indium Phosphide & Integrated Circuits business unit. “While our new lasers are ideally suited for today’s high-speed silicon photonics-based pluggable transceivers, including our own designs, they are also perfect for future co-packaged optics applications.”

The new lasers achieve 100mW of

output power when uncooled and 300mW of output power when cooled, to enable 100Gbps and 200Gbps per lane, respectively, for DR4 and DR8 transceivers. They are available in four coarse wavelength division multiplexing (CWDM) wavelengths for FR4 transceivers.

Coherent is exhibiting in booth #3815 at the Optical Fiber Communication conference (OFC 2023) in San Diego, CA, USA (7–9 March), showcasing its new products and technology for next-generation optical communications networks and sensing.

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

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

# Optical Internetworking Forum hosts the largest ever multi-vendor interoperability demonstration

## Demo spans 400ZR; Co-Packaging architectures, CEI-112G & CEI-224G and CMIS implementations

At the Optical Fiber Communication Conference (OFC 2023) in San Diego, CA, USA (7–9 March), the Optical Internetworking Forum (OIF) is hosting the largest ever multi-vendor interoperability demonstration.

In demonstrations in OIF’s booth #5101, a record number of participants — more than 30 OIF-member companies — are participating in four critical areas: 400ZR optics, Co-Packaging architectures, Common Electrical I/O (CEI) architectures and Common Management Interface Specification (CMIS) implementations.

“Given the pace of demand for access to broadband and the revolutionary technical advancements needed to support that demand, interoperability is more important than ever,” says OIF Physical & Link

Layer Interoperability Working Group chair Mike Klempa of Alphawave Semi. “This year marks 25 years of industry-changing work bringing together an ecosystem of members to solve some of the network’s greatest challenges, so it’s no surprise that OIF’s demo at OFC will be the largest it’s ever hosted.”

The live and static interoperable optical networking solutions demo at OFC will feature 34 OIF member companies - ADVA; Alphawave Semi; Amphenol; Astera Labs; Cadence Design Systems Inc; Casela Technologies; Ciena; Cisco Systems; Coherent; ColorChip Group; EXFO; InnoLight Technology; Juniper Networks; Keysight Technologies; Lumentum; MACOM Technology Solutions Inc; Marvell; Microchip Technology Inc; Molex; MultiLane Inc; NEC Corp; Nokia;

O-Net Communications; Precision Optical Transceivers Inc; Quantifi Photonics; Samtec; Senko Advanced Components; Sicoya; Source Photonics; Sumitomo Electric Industries; Synopsys; TE Connectivity; US Conec and Wilder Technologies.

To commemorate its 25th anniversary during OFC, at 3pm PT on 8 March (in Theater 3) OIF is hosting a special one-hour session ‘Bringing Order to Chaos – OIF’ feature OIF leadership, Karl Gass, OIF and Nathan Tracy, OIF, TE Connectivity, and special guests Stephen Hardy of Lightwave, Vladimir Kozlov of LightCounting, Sterling Perrin of Heavy Reading/Omdia, and Alan Weckel of 650 Group.

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

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# POET announces availability of 400G & 800G receive optical engines

## POET partners with LuxshareTech as lead customer

POET Technologies Inc of Toronto, Ontario, Canada has started sampling 400G FR4 and 800G 2xFR4 receive optical engines (RXOEs). POET will partner with Luxshare Technology Co Ltd (a subsidiary of Luxshare Precision Industry Co Ltd of Dongguan, China, that designs and manufactures datacom facilities and enterprise-level products) as a lead customer to enable the sale of power-efficient and cost-optimized 400G and 800G transceiver solutions.

"LuxshareTech is focused on expanding its 400G and 800G pluggable transceivers portfolio for the data-center market," says Mike Gao, general manager of LuxshareTech's Opto-electronic business unit. "We are pleased to work with POET Technologies and use their highly integrated chiplet platform to enable us to achieve a solution with superior performance

and ease of compact module assembly," he adds.

"The 400G and 800G FR4 RXOEs are the first of their kind to integrate photonic and electronic components on a single interposer chiplet," says Raju Kankipati, VP of product management at POET. "We expect customers to benefit from the simplified design, superior performance and lower cost offered by POET's wafer-scale integration and passive assembly of components," he adds. "LuxshareTech's experience in designing and manufacturing high-speed optical transceivers and POET's innovative technology can be mutually beneficial in bringing high-volume and low-cost solutions to the data-center market."

Produced by POET's joint venture Super Photonics Xiamen, the 400G FR4 RXOE integrates a quad transimpedance amplifier (TIA), four high-speed photodiodes and an

optical demultiplexer integrated in a single chiplet measuring 12x5mm. The 800G 2xFR4 RXOE consists of an integrated octal TIA, eight high-speed photodiodes and two optical demultiplexers in a single chiplet measuring 15x5mm.

Customers of POET's RXOEs have the option to procure the engines with an integrated fiber array unit (FAU), which provides an even more complete solution for next-generation data-center interconnects. The 400G and 800G RXOEs achieve superior performance through better integration of photodiodes and TIA and exceed the industry-standard specifications for 400GBASE-FR4 interfaces.

POET expects to complete design verification testing and reliability qualification of the RXOEs in first-half 2023 and to start production in second-half 2023.

[www.luxshare-tech.com](http://www.luxshare-tech.com)

## POET to demo 800G optical engines and light source products at OFC

### Technology demos of optical engines for pluggable transceivers, co-packaged optics and AI-ML GPUs

In booth #5311 at the Optical Fiber Communication Conference and Exhibition (OFC 2023) in San Diego, CA, USA (7-9 March), POET Technologies is hosting live demonstrations of its optical engine and light source products.

Specifically, customers and attendees can view mechanical samples and live demonstrations of the following products:

- 800G 2xFR4 receive optical engines with integrated DMUX, photodiodes and trans-impedance amplifier;
- 100G LR4 transmit and receive optical engines for 10km transmission applications;

- O-band LightBar products with high-power continuous-wave (CW) lasers for co-packaged optics and artificial intelligence/machine learning (AI-ML) GPUs;

- mechanical demo of 800G 2xFR4 QSFP-DD transceiver showcasing the simplicity of a transceiver design utilizing POET's optical engines.

"All of POET's integrated optical engines are based on POET's Optical Interposer with hybrid integration of best-of-breed components and monolithic integration of passive elements, resulting in an extremely small chiplet architecture enabling the production of

800G, 1.6T and even 3.2T transceivers in standard pluggable form factors," says Raju Kankipati, senior VP & USA general manager.

"We will also be demonstrating and showing mechanical samples of our innovative LightBar products, an essential component for AI-ML accelerator GPUs, an emerging but potentially huge market," he adds.

"As one of the optoelectronics industry's premier events, OFC is the perfect place to highlight our newly released products and to continue growing our network of potential partners and customers."

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

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

# POET to design optical engines for Beijing FeiYunYi's 100G optical transceiver modules

## \$1m, two-year deal includes initial 10,000-unit purchase order for customer sampling

POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center, telecom and artificial intelligence (AI) markets — has announced an agreement with Beijing FeiYunYi Technology Ltd (BFYY) to design optical engines for deployment in optical modules in the telecom market globally, beginning in China. The agreement, valued at up to \$1m over a two-year period, includes non-recurring engineering (NRE) for POET and an initial purchase order for 10,000 units that will be used to sample customers.

BFYY was formed recently for the purpose of selling modules using POET-designed optical engines sourced from POET's joint venture company Super Photonics Xiamen (SPX). With deep connections to the telecom industry in China, BFYY is investing in assembly facilities to build, market and sell modules for the data-center market, specifically

focused on large telecom service providers.

POET has agreed to design a single-chip optical engine solution that incorporates complete transmit and receive functionalities for implementation in a 100G optical transceiver for BFYY's initial product offering. The unique single-chip solution POET ONE aims to offer significant performance advantages along with minimizing the transceiver design cycle time for BFYY. In addition to the cost benefits of POET's wafer-scale assembly, the single-chip solution will enable BFYY to cost effectively ramp to high-volume production. BFYY has forecasted optical engine purchases from SPX at more than US\$30m over a three-year period.

"The number of 5G and fiber-to-the-home (FTTH) subscribers in China is growing considerably. To keep up with the bandwidth demand, several major service providers are exploring ways to transform their networks," notes

BFYY's CEO Wei Zhang (Wesley Zhang). "Top-tier service providers in China believe that transceivers with POET's Optical Interposer technology can provide a cost-effective and scalable solution to achieve their network automation goals. BFYY plans to utilize its transceiver design and manufacturing capabilities along with the benefits of POET's integration platform to quickly ramp to high-volume production," he adds.

"We are excited to work with BFYY on this initial product and plan to leverage their capabilities and business relationships with service providers to be part of the network transformation journey in China," says Vivek Rajgarhia, president & general manager of POET and vice-chairman of SPX. "We will continue to offer differentiated solutions to our customers for high-speed optical communications in data and tele-communications markets."

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

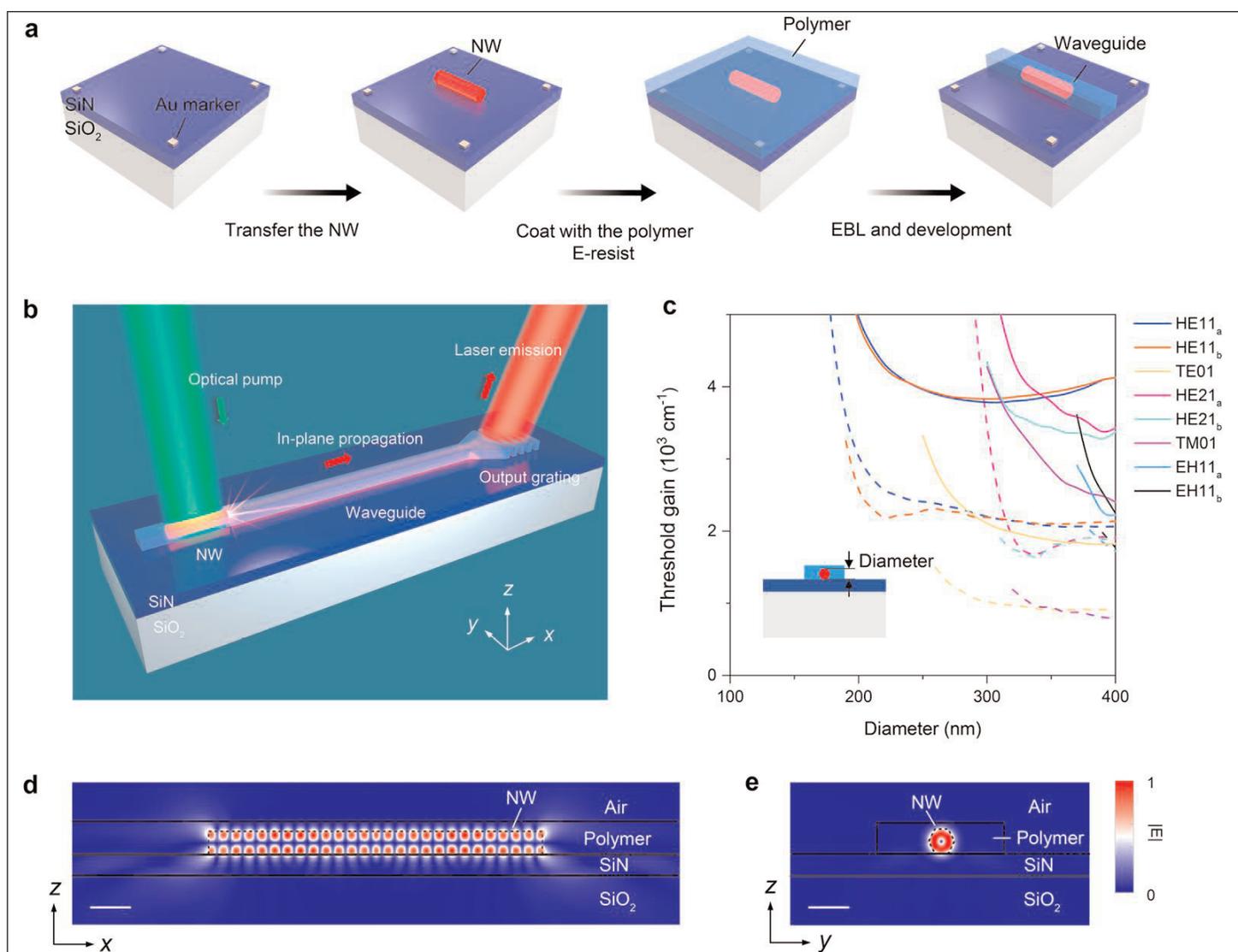
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# Integrating nanowire lasers in hybrid polymer–SiN waveguides

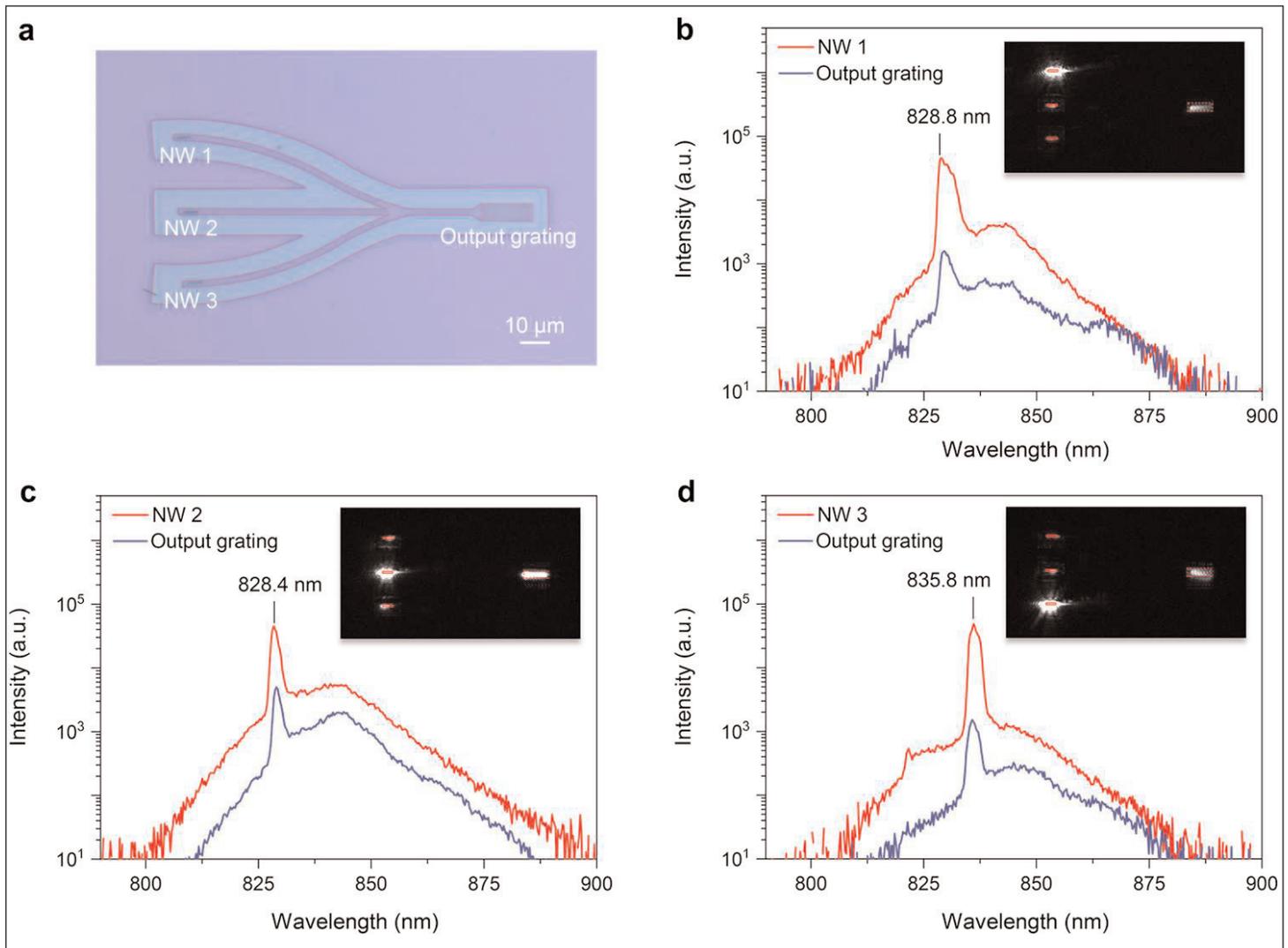
Technique could be applied to wide range of materials and photonic systems.

**N**orthwestern Polytechnical University in China and Australian National University report on progress in integrating on-chip nanowire (NW) laser sources in passive photonic integrated circuits (PICs) [Ruixuan Yi et al, *Nano Letters*, v22, p9920, 2022].

The researchers implemented a straightforward strategy to embed the NWs in a waveguide (Figure 1). First, indium phosphide (InP) nanowires were transferred to a 3 $\mu\text{m}$ -thick silicon dioxide (SiO<sub>2</sub>) substrate with a thin 300nm silicon nitride (SiN) top layer. Gold markers were incorporated into the substrate to



**Figure 1. (a)** Integration process flow for nanowire laser embedded in hybrid polymer-SiN waveguide. **(b)** InP nanowire laser integrated with hybrid polymer-SiN waveguide. **(c)** Threshold gain in air (dashed lines) of different guided modes and embedded in hybrid waveguide (solid lines) versus nanowire diameter with inset cross-section. **(d)** and **(e)** xz and yz plane cross-sections, respectively, of electric field distribution of TE<sub>01</sub> resonant mode supported by nanowire laser (4.47 $\mu\text{m}$  length, 310nm diameter). Scale bars: 500nm.



**Figure 2. (a) Optical microscope image of wavelength multiplexer integrated with three nanowires. (b–d). Spectra collected from nanowires and output grating under excitations on NW 1 (b), NW 2 (c), and NW 3 (d) above lasing threshold, respectively, with inset panchromatic images.**

aid nanowire placement with a tungsten probe. The quantum-confined nanowires themselves can be produced in processes with high quality. The team used nanowires from metal-organic vapor-phase epitaxy on a (111)A InP substrate.

The researchers comment: “This integration strategy of an on-chip laser is applicable to other PIC platforms, such as silicon and lithium niobate, and the top cladding layer could be changed by depositing SiN or SiO<sub>2</sub>, promising its CMOS compatibility.” They add: “Nanowire lasers have the merits of an ultracompact footprint, low threshold, and low energy consumption.”

Although the nanowires were manipulated into position, the team believes that “large-scale integration of multiple nanowire lasers could be achieved once the positions of nanowires were determined, which does not require the manipulation of individual nanowires one by one. In future device development, a nanowire array could be grown directly with controllable positions on the slab or arranged properly through an automated transfer printing technique, promising the large-scale

integration of the waveguide-embedded nanowire lasers.”

After placement, the nanowires were covered with 400nm polymer electron-beam lithography (EBL) resist by spin coating. EBL and development embedded the nanowire in a hybrid polymer–SiN photonic structure, supporting in-plane light propagation. The team suggests that there are standard alignment techniques, which could precisely locate the wires in the waveguide during the EBL.

The nanowires had a high refractive index around 3.45, allowing the use of the end facets as the mirrors of a Fabry–Perot laser cavity.

In a basic PIC setup with an optically pumped nanowire laser at one end and an output grating at the other of a 180μm×1.7μm waveguide, the laser threshold pump fluence was 37.3μJ/cm<sup>2</sup> from a 532nm pulsed laser at 10K. The spectral peak of the laser emission was at 827nm wavelength. By consulting polarization measurements and simulations, the researchers attribute the laser emission to the trans-

verse electric TE01 mode. The team also used similar techniques to determine the coupling efficiency from the nanowire laser TE01 mode to the TE-bound mode of the hybrid waveguide at 2.3%. The researchers subjected the structure to a 3 hour run and found no observable degradation in performance.

The researchers fabricated a range of other PIC structures. In one, the nanowire laser fed in to a Y-splitter that demonstrated roughly 50–50 power splitting. The laser threshold in this case was  $21.7\mu\text{J}/\text{cm}^2$ . The team sees the ability to split power in this way leading to “more complicated structures, such as modulators based on a Mach–Zehnder interferometer, optical phase arrays, etc.”

With a view to wave-division multiplexing, the researchers also fabricated a multiplexer with three nanowire laser feeds (Figure 2). The lasers showed peak wavelengths at 828.8nm, 828.4nm and 835.8nm.

The coupling efficiencies of the demonstrated PICs were limited to less than 5%, due to the mismatch

between the nanowire lasing mode and the hybrid waveguide mode. “Most of the light from the nanowire laser radiates to the free space rather than couples to the waveguide mode,” the team explains. Simulations suggest that, by varying the dimensions of the nanowire and waveguide, coupling efficiencies up to 28% could be reached, coupling the helical HE11a mode of a 150nm-diameter nanowire to the transverse magnetic mode of the waveguide.

At present, the devices only operate stably at the very low temperature of 10K, probably due to “overheating induced by the polymer cladding”. The researchers comment: “By properly designing a heat sink in the waveguide-embedded nanowire, it is expected to increase the lasing operation temperature to 300K: for example, the nanowire could be embedded in a silicon nitride waveguide, which has a much higher thermal conductive coefficient than the polymer.” ■

<https://doi.org/10.1021/acs.nanolett.2c03364>

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# Monolithic GaN optoelectronics on silicon

**Fabricated device includes transmitter, modulator, waveguide, beam splitter, receivers and monitor.**

Researchers in China and Japan have demonstrated a monolithic gallium nitride (GaN) optoelectronic system on silicon (Si) substrate consisting of a transmitter, modulator, waveguide, beam splitter, receivers and monitor [Hao Zhang et al, Appl. Phys. Lett., v121, p181103, 2022].

The team from China's Nanjing University of Posts and Telecommunications and Zhengzhou University and Japan's Nagoya University are seeking to promote optoelectronic systems with low power consumption while using monolithic integration on silicon to reduce material, processing and packaging costs.

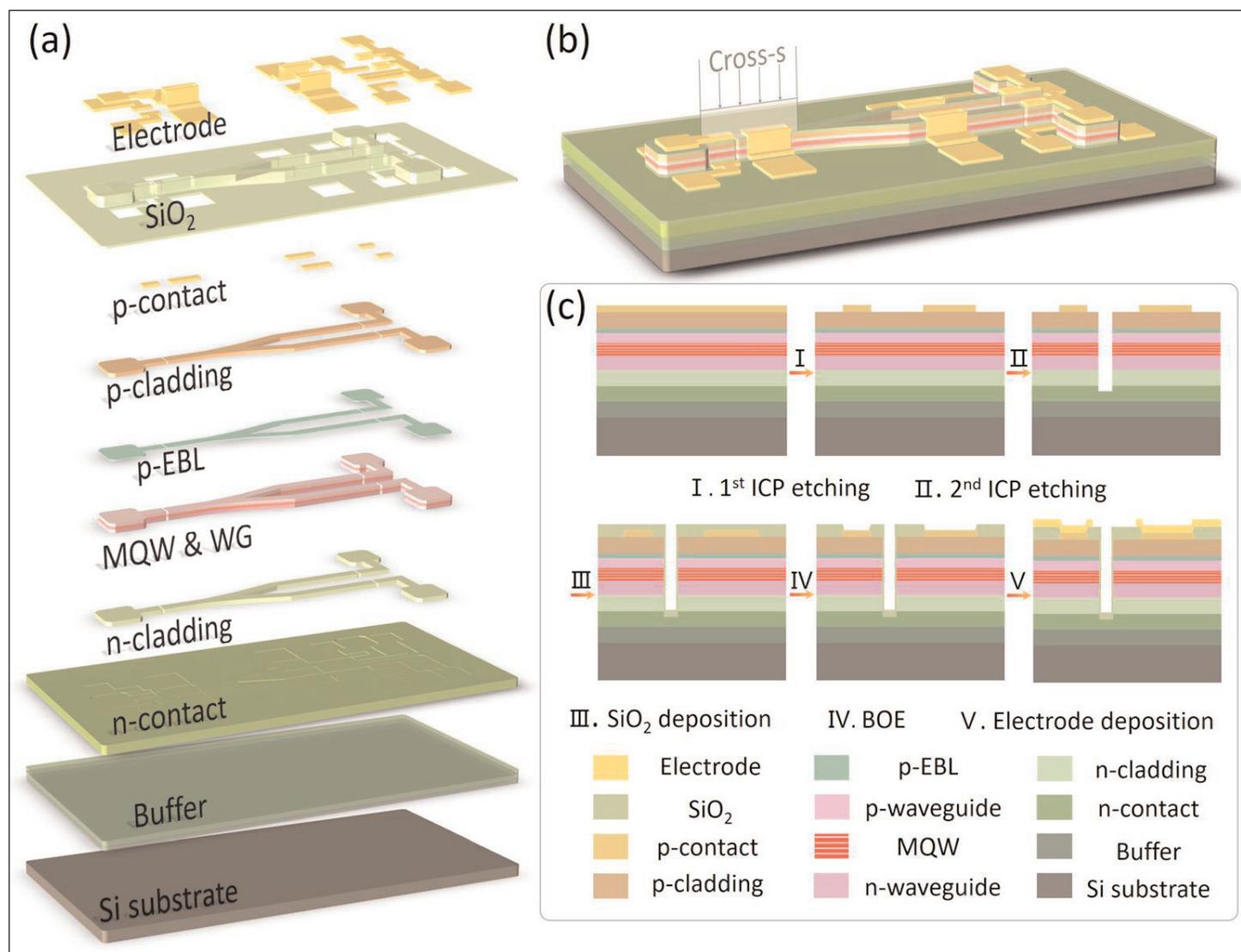
The researchers comment: "We propose monolithic,

top-down approaches to build III-nitride transmitter, modulator, waveguide, beam splitter, receiver and monitor as a single unit onto a conventional GaN-on-silicon wafer without involving regrowth or postgrowth doping."

Apart from visible/ultraviolet light communication, the team sees opportunities in lab-on-chip setups.

The material for the device (Figure 1) was grown on 2-inch Si(111) with a GaN template layer. The buffer consisted of multiple layers of aluminium gallium nitride (850nm AlN/AlGa<sub>N</sub>) and 1030nm undoped GaN.

The n-Al<sub>0.03</sub>Ga<sub>0.97</sub>N contact and n-Al<sub>0.1</sub>Ga<sub>0.9</sub>N/GaN superlattice cladding layers were 2450nm and 750nm,



**Figure 1. (a) Chip device layered structure. (b) Overview. (c) Manufacturing process flow.**

respectively.

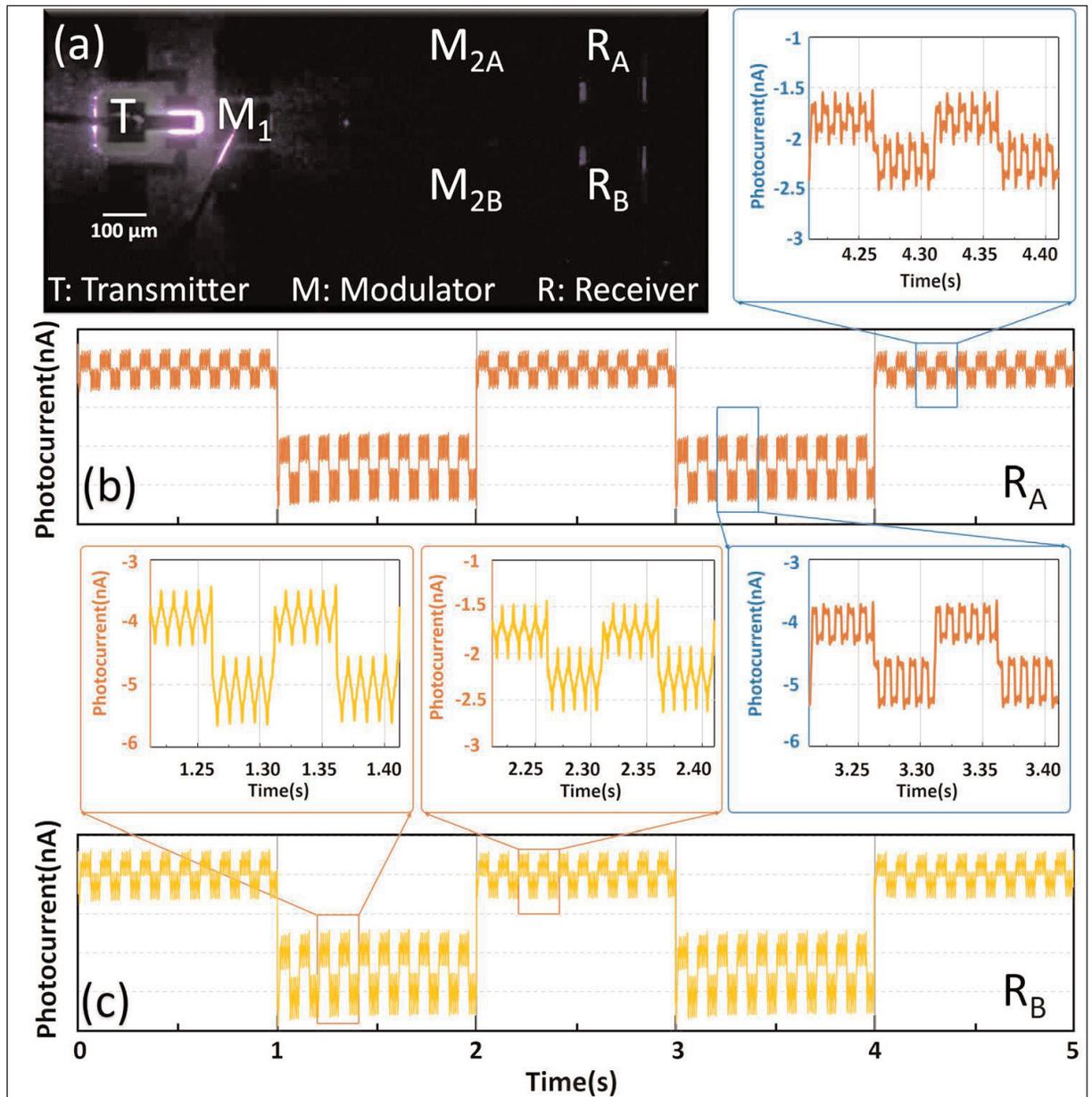
The p-side had a 20nm  $p\text{-Al}_{0.25}\text{Ga}_{0.75}\text{N}$  electron-blocking layer (EBL), 500nm  $p\text{-Al}_{0.1}\text{Ga}_{0.9}\text{N}$  cladding layer, and 25nm p-GaN contact layer.

The inner undoped region had 80nm GaN waveguide, 59nm multiple-quantum well (MQW) active, and 60nm GaN waveguide layers before the EBL. The MQW consisted of 4x 3nm low-indium-content InGaN wells separated by 10nm  $\text{Al}_{0.08}\text{Ga}_{0.92}\text{N}$  barriers. The last barrier before the waveguide was 7nm.

The device fabrication used two inductively coupled plasma mesa etching steps of 200nm (p-contact) and 1.8 $\mu\text{m}$  (down to the n-contact) depths. The waveguide widths were 50 $\mu\text{m}$ . The Y-splitter angle was 30°. The electrodes consisted of titanium/platinum/gold. The electrical insulation was silicon dioxide ( $\text{SiO}_2$ ). The single emitter and two detector diodes were separated from the ends of the transmission waveguides by a gap of more than 6 $\mu\text{m}$  for better electrical insulation among the different devices and to improve weak signal detection.

Electroluminescence (EL) and responsivity spectra showed an approximate 14nm wavelength overlap with the response at shorter wavelength due to the Stokes shift. The EL peak was around 381nm. The response peak shifted noticeably under different reverse biases due to the quantum-confined Stark effect (QCSE) of the structure.

One test (Figure 2) consisted of the transmitter diode



**Figure 2. (a) Configuration of triple modulation on two paths. (b) Signals of receiver A (RA) and enlarged parts. (c) Signals of receiver B synchronized with receiver A.**

(T) being supplied with constant currents in a sequence, while electro-modulation of the light signal was provided by electrodes on the waveguide paths modulating the light absorption characteristic of the semiconductor structure: after the transmitter (M1) and in the two branches of Y-splitter (M2A/B).

The M1 signal was a 10Hz square wave, of 6V peak-to-peak, with a -3V bias. The M2A branch was also square, modulated with 4V, -3V bias, at 100Hz, while the B-branch was modulated a triangular signal with the same peak-to-peak/bias voltages.

On the basis of 'eye-diagram' experiments with 50 megabit per second signals, the researchers believe that such data rates could be achieved with high-speed drive signals and detection circuits. ■

<https://doi.org/10.1063/5.0125324>

Author: Mike Cooke

# Continuous-wave InGaN microdisk laser diodes on (100)-oriented silicon

Thermal resistance was reduced by 32.5% relative to the reference on Si(111).

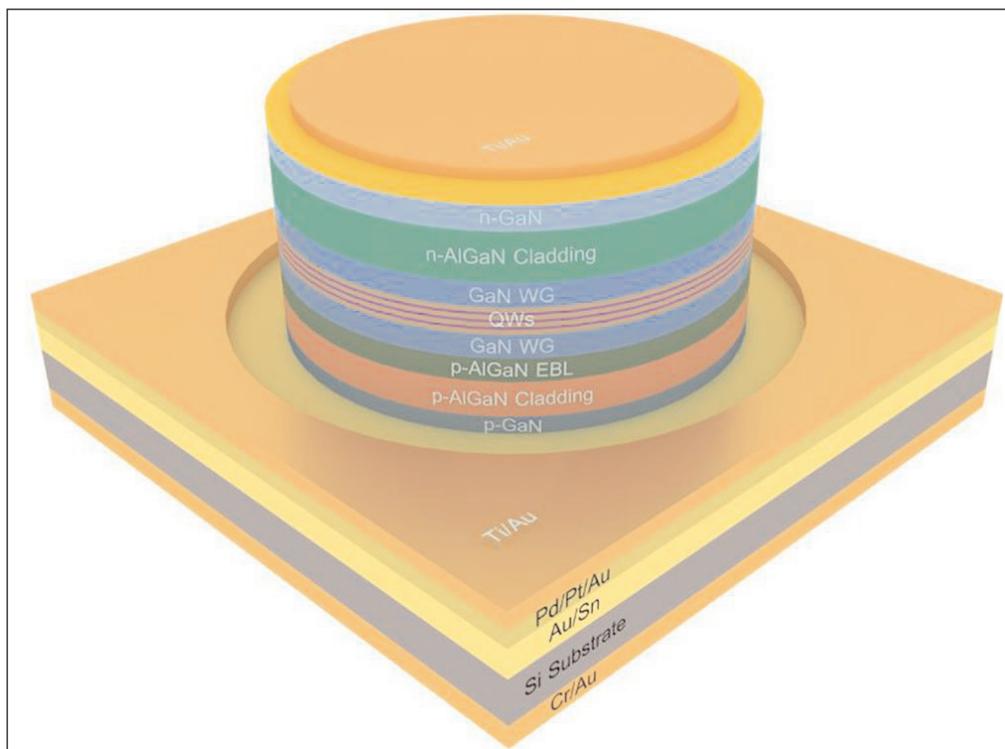
**S**uzhou Institute of Nano-Tech and Nano-Bionics (SINANO) in China has achieved room-temperature continuous-wave (CW) current-injected lasing from an indium gallium nitride (InGaN) microdisk laser on standard (100)-oriented silicon (Si) wafers [Meixin Feng et al, ACS Photonics, published online 28 October 2022.

Si(100) substrates are the mainstream basis for complementary metal-oxide-semiconductor (CMOS) integrated circuits. Unfortunately, GaN-based structures are generally grown on Si(111) due to lattice-matching and thermal-expansion constraints. GaN grown on Si(100) suffers from very high threading dislocation (TD) density such that the internal quantum efficiency is much too low for microdisk lasing.

Indeed, the SINANO material was first grown on Si(111) and then transferred and bonded to Si(100). At the same time, the team worked on designing a structure that improved thermal management to enhance performance and efficiency.

The SINANO team see their work as potentially leading to efficient on-chip laser sources powering photonics based on GaN waveguides on a low-cost silicon platform. The researchers see further opportunities for quantum optics in areas such as parametric down-conversion, single-photon sources, ion trapping, and cavity quantum electrodynamics, along with biosensing and visible light communication.

The laser structure (Figure 1) was first grown p-side up, allowing proper activation of the p-type magnesium-doped layers before wafer bonding. Activation involves thermal annealing to drive out hydrogen from the growth process, which passivates the magnesium acceptors. The laser material was then flip-wafer bonded to the Si(100) substrate, and the

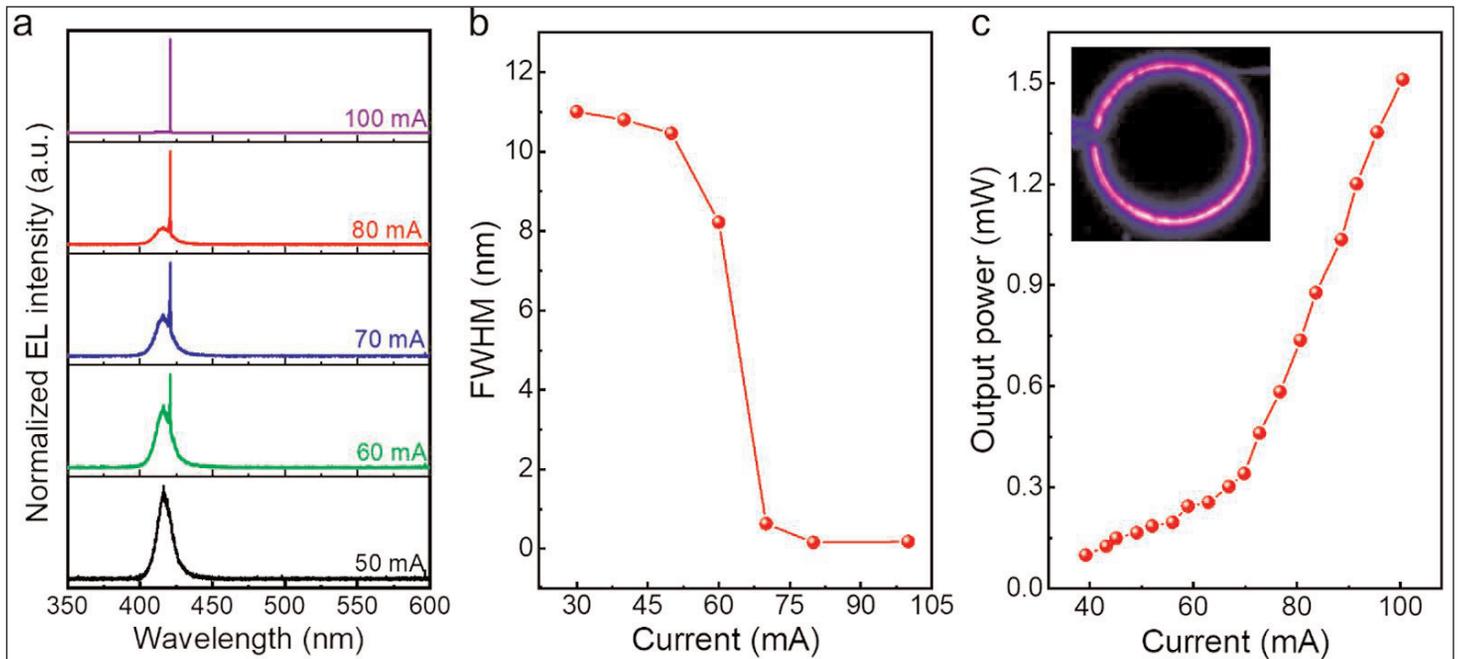


**Figure 1. Schematic diagram of p-side down GaN-on-Si(100) microdisk laser.**

metal-organic chemical vapor deposition (MOCVD) Si(111) growth substrate was removed.

The growth template consisted of aluminium nitride (AlN) seed layer, followed by two AlGaN stress-control and defect (e.g. TD) reduction layers, before application of the 2.6µm n-GaN template layer itself. The laser structure included three 2.5nm indium gallium nitride ( $\text{In}_{0.12}\text{Ga}_{0.88}\text{N}$ ) quantum wells separated by 12.5nm  $\text{In}_{0.02}\text{Ga}_{0.98}\text{N}$  barriers. The waveguide layers were GaN: 90nm on the p-side and 140nm n-side. The cladding consisted of doped AlGaN, 600nm p-side (7% Al) and 500nm n-side (8% Al). An AlGaN electron-blocking layer (EBL) was 20nm thick. In the fabricated device, the n- and p-side contact layers were 30nm and 50nm, respectively.

The Si(100) wafer was bonded to a palladium/platinum/gold (Pd/Pt/Au) p-electrode of the laser structure with gold-tin (AuSn). After bonding the growth substrate and template layers were removed, using wet etch for the Si(111), and plasma for the AlGaN and for



**Figure 2. (a) Normalized electroluminescence (EL) spectra and (b) FWHM of 20 $\mu$ m radius GaN-on-Si(100) microdisk laser measured under CW injection currents. (c) Optical output power versus injection current curve. Inset: top-view EL image at 50mA — part of circular emission pattern obstructed by electrical probe.**

partly thinning the n-GaN. The surface was then subjected to chemical mechanical polishing (CMP), further thinning the n-GaN to the target thickness. The n-electrode consisted of titanium/platinum/gold (Ti/Pt/Au). The microdisks were then sculpted using more plasma etch, before applying the final Ti/Au contact metals.

Since the microdisk etching was critical for reducing surface damage and tilt angle, which affects both non-radiative recombination and reflectivity, the researchers tested six different inductively coupled plasma (ICP) etch recipes. The best used a chlorine/boron trichloride/nitrogen ( $\text{Cl}_2/\text{BCl}_3/\text{N}_2$ ) mix, which gave the most vertical sidewalls ( $\sim 87^\circ$ ).

Under CW operation, the device emitted single-mode laser light with a 402.9nm wavelength (Figure 2). The researchers estimated from the 20 $\mu$ m microdisk radius that this corresponded to about the 776th whispering gallery mode. The spectrum and behavior of the full-width at half-maximum (FWHM) suggest that lasing sets in around 60mA injection. Once lasing dominates, above 70mA current, the output power was about 30% less than that of a reference device on Si(111). The researchers comment that, in their setup, “only a small proportion of the optical output power was gathered from the microdisk sidewall.”

The operating voltage at 70mA was 4.8V, some 29% lower than for the reference on Si(111). This means that the electrical resistance was much less, giving lower power loss and lower Joule heating, which should reduce thermal degradation effects. The researchers attribute these improvements to the reduction in current-crowding effects, an optimized n-type Ohmic contact, and reduced thickness of the n-AlGaN cladding.

“Reduced operation voltages, together with a lower threshold current, contributed to 50% less injected electrical power for the as-fabricated GaN-on-Si(100) microdisk laser,” the team writes.

By studying the temperature dependence of the forward voltage at 70mA pulsed injection, the researchers estimate the thermal resistance of the microdisk at 95K/W, some 32.5% less than for the reference lasers on Si(111). The team attributes the lower resistance to the thinning of the AlGaN layers, which have low thermal conductivity. Also, in the flip-wafer bonding process the AlGaN stress/defect reduction layers are completely removed from the thermal dissipation path, while these block heat flow in the reference device.

The team comments: “The reduced thermal resistance and less injection electrical power contributes to a 66.5% reduced junction temperature, which means that the as-fabricated 20 $\mu$ m radius GaN-on-Si(100) microdisk laser can operate in CW mode while our previous conventional GaN-on-Si(111) microdisk laser cannot.”

The lifetime of the microdisk laser on Si(100) at 77mA is quoted at “several minutes”. “The restricted lifetime is primarily related to the relatively high TD density due to a huge mismatch in the thermal expansion coefficient and lattice constant between GaN and Si(111).”

The lifetime could be increased to the order of 10,000 hours if the TD density could be reduced to the  $10^6/\text{cm}^2$  level. The team are looking to improvements such as using freestanding GaN as the growth substrate with appropriate substrate lift-off with a view to recycling the very expensive material relative to silicon. ■

<https://doi.org/10.1021/acsp Photonics.2c01046>

Author: Mike Cooke

# ams OSRAM to benefit from Apple adopting micro-LEDs

**The Apple Watch is likely to be first of the firm's products to feature micro-LED displays, from 2024, says TrendForce.**

According to market research firm TrendForce, Apple is expected to adopt micro-LEDs for its consumer electronic products in the near future. The Apple Watch will likely be the first of its products to feature a micro-LED display, and adoption is expected to occur in 2024. Then, during 2026–2030, the scope of application of micro-LEDs could expand to encompass artificial reality (AR) headset displays, smartphone displays, automotive displays etc.

The Apple Watch as a product line was launched in 2015 and has been on the market for more than eight years. The latest model (Apple Watch Ultra) was released near the end of 2022 and offers improvements to display specifications. Apple enlarged the display size to 1.93-inches and raised the display brightness level to 2000nits. These upgrades indicate that smartwatch brands continue to seek a larger and sharper display that can show texts clearly in an outdoor setting.

TrendForce believes that Apple will make a breakthrough for its smartwatch in 2024 by incorporating micro-LEDs. With this technology, the Apple Watch's display could exceed 2-inches and achieve an even higher contrast level. Such improvements would satisfy the viewing needs of professionals and enthusiasts of various outdoor sporting activities.

## Apple Watch to facilitate entry of micro-LED displays into mainstream consumer electronics market

TrendForce points out that Apple has always been careful about adopting a new technology, and its process for evaluating a new technology is very lengthy. On the other hand, once Apple has decided to use a particular technology, the company usually tries to apply it across different product lines.

Take organic light-emitting diode (OLED) displays as an example. Besides being incorporated into the Apple Watch and the iPhone, the OLED display is expected to be featured in iPad models for 2024 and the MacBook models for the 2025–2026 period. With the penetration of OLEDs among Apple's products serving as the prime case study, TrendForce believes that Apple will begin the gradual introduction of micro-LEDs, starting in 2024.

Whether micro-LEDs are incorporated into smartwatches, AR headsets or smartphones, two major factors will determine the market competitiveness of this technology, reckons TrendForce.

The first factor involves lowering the costs of micro-LED chips. A notable solution to making the production of micro-LED chips much more economical is to enlarge the wafers that they are made from. Currently, the production lines for mainstream micro-LED chips take 6-inch wafers. Switching to 8-inch wafers will certainly result in a considerable cost reduction.

The second factor is flexibility. The micro-LED has to work with different types of backplanes that contain glass, CMOS, etc. A reliable semiconductor manufacturing process is needed to serve as the basis for scaling up production. Such a process is also critical for the provisioning of a total solution (i.e. from chip production to mass transfer, inspection, and repair).

Among suppliers of LED chips, ams OSRAM has formed the tightest collaborative relationship with Apple in the field of micro-LEDs at this time because it has advantages in addressing the two aforementioned factors. In the future, ams OSRAM will very likely become Apple's key partner in supplying the micro-LED components that are embedded in next-generation displays, reckons TrendForce.

## Micro-LEDs remain Apple's first choice for future display technologies due to considerations of loss of display brightness and impactful product innovations

Looking at the new kinds of display technologies that have emerged lately, micro-OLED and micro-LED are the ones capable of meeting the demand for a high number of pixels per inch (PPI). However, micro-OLEDs cannot reach the higher level of brightness that micro-LED can achieve due to some inherent material-related limitations.

Currently, there is a market rumor saying that Apple will be unveiling a headset device featuring a micro-OLED display this year. Nevertheless, in the development of AR headsets over the medium to long term, TrendForce believes that making a headset with a completely transparent display will require optical

waveguide technology. However, incorporating optical waveguides will reduce the original brightness of a display by as much as 99%. Therefore, micro-LEDs — due to their huge brightness advantage — can provide the sufficient leeway to compensate for this massive loss of brightness. If Apple wants to release an AR headset or a pair of AR glasses that features a completely transparent display in the future, then micro-LEDs are most likely its first choice for the display technology.

Turning to the smartphone market, most brands in the Android camp have made foldable OLED displays a main design feature for their upcoming flagship models. However, as the second largest smartphone brand, Apple has yet to enter the much-discussed market

segment for foldable OLED models. TrendForce believes a possible reason as to why Apple is slow to enter this segment is its focus on micro-LEDs. In addition to rigid backplanes that have glass and CMOS, micro-LED are also highly suitable for flexible backplanes made of PI or other kinds of material with similar attributes. Also, by adopting micro-LEDs, Apple may be able to make iPhone displays foldable, rollable and even 'stretchable' in the future. Hence, micro-LEDs have the potential to be the key technology that Apple will use to realize game-changing product innovations and thereby get further ahead of other brands in the market, reckons TrendForce. ■

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# MIT-led team demonstrates full-color, vertically stacked RGB micro-LEDs

**A 2D materials-based layer transfer enables record array density and the smallest size, reports MIT.**

**M**uch like transistors, LEDs are reaching a limit to how small they can be while also performing effectively. This is especially noticeable in close-range displays such as augmented-reality (AR) and virtual-reality (VR) devices, where limited pixel density results in a 'screen door effect' such that users perceive stripes in the space between pixels.

Now, a team led by Massachusetts Institute of Technology (MIT) has developed a new way to make sharper, defect-free displays ('Vertical full-colour micro-LEDs via 2D materials-based layer transfer', *Nature* volume 614, p81–87 (2023)). Instead of replacing red, green and blue light-emitting diodes side by side in a horizontal patchwork, the team has devised a way to stack the diodes to create vertical, multi-colored pixels.

Each stacked pixel can generate the full commercial range of colors and measures about 4µm wide. The micro-LEDs can be packed to a density of 5000 pixels per inch. "This is the smallest micro-LED pixel, and the highest pixel density reported in the journals," says Jeehwan Kim, associate professor of mechanical engineering at MIT. "We show that vertical pixellation is the way to go for higher-resolution displays in a smaller footprint," he adds.

"For virtual reality, right now there is a limit to how real they can look," says Jiho Shin, a postdoc in Kim's research group. "With our vertical micro-LEDs, you could have a completely immersive experience and wouldn't be able to distinguish virtual from reality," he adds.

Kim and Shin's co-authors include members of Kim's lab, researchers around MIT, and collaborators from Georgia Tech Europe, Sejong University, and multiple universities in the USA, France and Korea.

## Placing pixels

Most existing digital displays are lit through organic light-emitting diodes (OLEDs), but these can degrade over time, resulting in permanent burn-in effects on screens. The technology is also reaching a limit to the size the diodes can be shrunk, limiting their sharpness and resolution.

For next-generation display technology, researchers are exploring inorganic micro-LEDs, which could perform better, require less energy, and last longer than OLEDs.

But micro-LED fabrication requires extreme accuracy, as microscopic pixels of red, green and blue need to first be grown separately on wafers, then precisely placed on a plate, in exact alignment with each other in order to properly reflect and produce various colors and shades. Achieving such microscopic precision is a difficult task, and entire devices need to be scrapped if pixels are found to be out of place.

"This pick-and-place fabrication is very likely to misalign pixels in a very small scale," Kim says. "If you have a misalignment, you have to throw that material away, otherwise it could ruin a display."

## Color stack

The MIT team has devised a potentially less wasteful way to fabricate micro-LEDs that doesn't require precise, pixel-by-pixel alignment. The technique is a vertical LED approach, in contrast to the conventional, horizontal pixel arrangement.

Kim's group specializes in developing techniques to fabricate pure, ultrathin, high-performance membranes, with a view toward engineering smaller, thinner, more flexible and functional electronics. The team previously developed a method for growing and peeling away perfect, two-dimensional, single-crystalline material from wafers of silicon and other surfaces — termed 2D material-based layer transfer (2DLT).

In the current study, the researchers employed this same 2DLT approach to grow membranes of red, green and blue LEDs of near-submicron thickness on two-dimensional material-coated substrates via remote or van der Waals epitaxy. Mechanical release then allowed each LED membrane to be peeled away from their base wafers, before they were stacked together to form layers of red, green and blue membranes. Top-down fabrication then patterned them into vertical pixels, each just 4µm wide.

"In conventional displays, each R, G and B pixel is arranged laterally, which limits how small you can

create each pixel," Shin notes. "Because we are stacking all three pixels vertically, in theory we could reduce the pixel area by a third."

As a demonstration, the team fabricated a vertical LED pixel and showed that, by altering the voltage applied to each of the pixel's red, green and blue membranes, they could produce various colors in a single pixel.

"If you have a higher current to red, and weaker to blue, the pixel would appear pink, and so on," Shin says.

"We're able to create all the mixed colors, and our display can cover close to the commercial color space that's available."

The team plans to improve the operation of the vertical pixels. So far, they have shown that they can stimulate an individual structure to produce the full spectrum of colors. They will work toward making an array of many vertical micro-LED pixels.

"You need a system to control 25 million LEDs sepa-

ately," Shin says. "Here, we've only partially demonstrated that. The active matrix operation is something we'll need to further develop."

"For now, we have shown to the community that we can grow, peel and stack ultrathin LEDs," Kim says. "This is the ultimate solution for small displays like smart watches and virtual-reality devices, where you would want highly densified pixels to make lively, vivid images."

The research was supported, in part, by the US National Science Foundation (NSF), the US Defense Advanced Research Projects Agency (DARPA), the US Air Force Research Laboratory (AFRL), the US Department of Energy, LG Electronics, Rohm Semiconductor, the French National Research Agency, and the National Research Foundation in Korea.

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# Cornell to lead SRC-sponsored SUPREME research center

**The SUPeRior Energy-efficient Materials and dEVICES center will span 2D materials and ultrawide-bandgap semiconductors.**

**C**ornell University in the USA is leading a new \$34m research center that will accelerate the creation of energy-efficient semiconductor materials and technologies, and develop new approaches for microelectronics systems.

The SUPeRior Energy-efficient Materials and dEVICES (SUPREME) Center will bring together researchers from 14 higher-education institutions, in collaboration with the center's sponsor Semiconductor Research Corporation (SRC).

SUPREME is one of seven centers funded by SRC's JUMP 2.0 consortium. It will be funded by SRC and its 14 partner universities; Cornell's investment in the five-year project will be \$7m. Partners include:

- Cornell University;
- Massachusetts Institute of Technology (MIT);
- Boise State University;
- Georgia Institute of Technology;
- North Carolina State University;
- Northwestern University;
- Rensselaer Polytechnic Institute;
- Rochester Institute of Technology;
- Stanford University;
- Yale University;
- University of Colorado, Boulder;
- University of Texas, Austin;
- University of California, Santa Barbara (UCSB); and
- University of Notre Dame.

Huili Grace Xing, the William L. Quackenbush Professor of Engineering in materials science and engineering, and in electrical and computer engineering, at Cornell Engineering, will serve as the center's director. Tomás Palacios, director of Microsystems Technology Laboratories and a professor in electrical engineering and computer science at MIT, will serve as the center's associate director. The center's managing director will be Thomas Dienel, a condensed matter physicist who has been running the user program at Cornell's Platform for the Accelerated Realization, Analysis and Discovery of Interface Materials (PARADIM).

"Our center will focus on the material science, the new device architectures and how they interplay with

each other," says Xing, whose own research has included materials that support unipolar or bipolar transport, such as 2D materials, ultrawide-bandgap semiconductors, and devices with record performance that reveal fundamental limits.

"We're not engineering a particular approach. We're actually going down to the material genome level," says Xing. "If we go down to the building blocks and make a connection, then we can serve a very broad application space in logic, memory, computing, sensing and communication with the desired energy efficiency."

Researchers at the center will explore both fundamental new science and novel engineering technologies, with the aim of driving the semiconductor industry in the next 3–15 years, while also training the next generation of scientists and engineers to work across disciplines.

The center's four primary goals are to:

- assemble interdisciplinary teams of materials scientists, device engineers, chemists and physicists to develop new materials, technologies and devices that can bring at least 10-fold system-level performance improvements to key applications;
- accelerate the pace of discovery and 'lab-to-fab' transition in microelectronics, creating prototype devices at nanofabrication facilities at Cornell and partner institutions;
- maintain a close collaboration with six other centers that are part of the latest iteration of the Joint University Microelectronics Program (JUMP) — a consortium of industry research participants and the US Defense Advanced Research Projects Agency (DARPA), which is administered by SRC — with SUPREME developing and demonstrating new materials and technologies that can be used for prototype chips and systems built by other centers in JUMP 2.0; and
- ensure diverse and broad workforce development.

"We've known for some time that Cornell Engineering faculty are pursuing research at the forefront of semiconductor materials science and engineering," says Lynden Archer, the Joseph Silbert Dean of Engineering. "With this new multi-institutional research center, we

look to the future and to providing leadership that translates to national impact in multiple areas, including autonomous systems and robotics, energy systems, medicine, and space exploration — all fields which require advances in semiconductor materials and new device architectures that consume less energy.”

SUPREME is organized around four interdisciplinary sub-themes: digital and analog; memory and applications; interconnects and metrology; and materials discovery and processing.

The first aims to harness the unique properties of two-dimensional materials, wide- and ultrawide-bandgap semiconductors, advanced ferroelectrics, spin and molecular materials to develop a new generation of digital and analog devices.

The second sub-theme will present new approaches for embedded and neuromorphic memory and storage technologies — such as ferroelectric, spintronic and electrochemical devices — that will support the computational workloads of the future.

The third sub-theme will focus on new physics of electron transport and new materials — such as anisotropic conductors and topological semimetals — to engineer better interconnects from devices to devices, and dies to dies. It will also develop advanced metrology to characterize new materials and accelerate material discovery by high-throughput experimentation.

The fourth sub-theme will develop the new materials and processing technologies required by the first three device-focused thrusts, with an emphasis on several broad classes of materials: 2D and wide-bandgap materials for logic and analog computing; metal-oxide-semiconductors for low-power comple-

mentary architecture; ferroelectrics and electrochemical materials for new memory/computing architectures, and strongly nonlinear optical materials for interconnects.

There are seven Cornell faculty among the center’s 25 principal investigators (PIs), including: Xing; Debdeep Jena, the David E. Burr Professor of Engineering in the School of Electrical and Computer Engineering and in the Department of Materials Science and Engineering; James Hwang, M.S. ’76, Ph.D. ’78, a research professor of materials science and engineering; Dan Ralph Ph.D. ’93, the F.R. Newman Professor of Physics in the College of Arts and Sciences; Farhan Rana, the Joseph P. Ripley Professor of Engineering in electrical and computer engineering; Judy Cha Ph.D. ’09, professor of materials science and engineering; and Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry in materials science and engineering.

The PIs will also work in close collaboration with industry leaders to maximize the impact and relevance of their work, which should not only lead to more energy-efficiency technologies but also ultimately boost equality, according to Xing.

“We want technology that can use as little energy as possible but provide as much function as possible. That is essential if we want to propagate equality,” Xing says. “If we’re able to lower the energy consumption for all of those essential means we want to have in modern life, we can lower the barrier for everybody to have access to information, to have access for education, and to have access to opportunities.” ■

[www.engineering.cornell.edu](http://www.engineering.cornell.edu)

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Fax: +1 408 748 0111  
[www.tecdia.com](http://www.tecdia.com)

## 10 Gas and liquid handling equipment

**Cambridge Fluid Systems**

12 Trafalgar Way, Bar Hill,  
Cambridge CB3 8SQ,  
UK  
Tel: +44 (0)1954 786800  
Fax: +44 (0)1954 786818  
[www.cambridge-fluid.com](http://www.cambridge-fluid.com)

**CS CLEAN SOLUTIONS AG**

Fraunhoferstrasse 4,  
Ismaning, 85737,  
Germany  
Tel: +49 89 96 24000  
Fax: +49 89 96 2400122  
[www.csclean.com](http://www.csclean.com)

**Entegris Inc**

129 Concord Road,  
Billerica, MA 01821, USA  
Tel: +1 978 436 6500  
Fax: +1 978 436 6735  
[www.entegris.com](http://www.entegris.com)

**IEM Technologies Ltd**

Fothergill House, Colley Lane,  
Bridgwater, Somerset TA6 5JJ, UK  
Tel: +44 (0)1278 420555  
Fax: +44 (0)1278 420666  
[www.iemtec.com](http://www.iemtec.com)

**Vacuum Barrier Corporation**

4 Barton Lane,  
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Tel: +1 781 933 3570  
Fax: +1 781 933 9428  
[www.vacuumbarrier.com](http://www.vacuumbarrier.com)  
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Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators

deliver low-pressure LN2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN2 pipe eliminates two-phase flow to all use points.

**Versum Materials**

8555 S. River Parkway,  
Tempe, AZ 85284, USA  
Tel: +1 602 282 1000  
[www.versummaterials.com](http://www.versummaterials.com)

## 11 Process monitoring and control

**Conax Technologies**

2300 Walden Avenue,  
Buffalo, NY 14225,  
USA  
Tel: +1 800 223 2389  
Tel: +1 716 684 4500  
[www.conaxtechnologies.com](http://www.conaxtechnologies.com)

**k-Space Associates Inc**

2182 Bishop Circle  
East, Dexter, MI 48130,  
USA  
Tel: +1 734 426 7977  
Fax: +1 734 426 7955  
[www.k-space.com](http://www.k-space.com)

**KLA-Tencor**

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CA 95035, USA  
Tel: +1 408 875 3000  
Fax: +1 408 875 4144  
[www.kla-tencor.com](http://www.kla-tencor.com)

**LayTec AG**

Seesener Str.  
10-13,  
10709 Berlin,  
Germany  
Tel: +49 30 89 00 55 0  
Fax: +49 30 89 00 180  
[www.laytec.de](http://www.laytec.de)



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**Vacuum Barrier Corporation**

4 Barton Lane, Woburn, MA 01801, USA

Tel: +1 781 933 3570

Fax: +1 781 933 9428

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

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**WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)**

Bregstrasse 90,  
D-78120 Furtwangen im Schwarzwald,  
Germany

Tel: +49 7723 9197 0

Fax: +49 7723 9197 22

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

**12 Inspection equipment****Bruker**

Oestliche Rheinbrueckenstrasse 49,  
Karlsruhe, 76187, Germany

Tel: +49 (0)721 595 2888

Fax: +49 (0)721 595 4587

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

**KLA-Tencor**

160 Rio Robles, Suite 103D,  
San Jose, CA 94538-7306,  
USA

Tel: +1 408 875-3000

Fax: +1 510 456-2498

[www.kla-tencor.com](http://www.kla-tencor.com)

**13 Characterization equipment****J.A. Woollam Co. Inc.**

645 M Street Suite 102,  
Lincoln, NE 68508, USA

Tel: +1 402 477 7501

Fax: +1 402 477 8214

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

**Lake Shore Cryotronics Inc**

575 McCorkle Boulevard,  
Westerville, OH 43082, USA

Tel: +1 614 891 2244

Fax: +1 614 818 1600

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

**14 Chip test equipment****Riff Company Inc**

1484 Highland Avenue, Cheshire,  
CT 06410, USA

Tel: +1 203-272-4899

Fax: +1 203-250-7389

[www.riff-co.com](http://www.riff-co.com)

**Tektronix Inc**

14150 SW Karl Braun Drive,  
P.O.Box 500, OR 97077, USA

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

**15 Assembly/packaging materials****ePAK International Inc**

4926 Spicewood Springs Road,  
Austin, TX 78759, USA

Tel: +1 512 231 8083

Fax: +1 512 231 8183

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

**Gel-Pak**

31398 Huntwood Avenue,  
Hayward, CA 94544, USA

Tel: +1 510 576 2220

Fax: +1 510 576 2282

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

**Wafer World Inc**

(see section 3 for full contact details)

**Materion Advanced Materials Group**

2978 Main Street,  
Buffalo, NY 14214, USA

Tel: +1 716 837 1000

Fax: +1 716 833 2926

[www.williams-adv.com](http://www.williams-adv.com)

**16 Assembly/packaging equipment****CST Global Ltd**

4 Stanley Boulevard,  
Hamilton International  
Technology Park,

Blantyre, Glasgow G72 0BN, UK

Tel: +44 (0) 1698 722072

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

**Kulicke & Soffa Industries**

1005 Virginia Drive,  
Fort Washington,  
PA 19034,  
USA

Tel: +1 215 784 6000

Fax: +1 215 784 6001

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

**Palomar Technologies Inc**

2728 Loker Avenue West,  
Carlsbad, CA 92010,  
USA

Tel: +1 760 931 3600

Fax: +1 760 931 5191

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

**PI (Physik Instrumente) L.P.**

16 Albert St . Auburn ,  
MA 01501, USA

Tel: +1 508-832-3456,

Fax: +1 508-832-0506

[www.pi.ws](http://www.pi.ws)

[www.pi-usa.us](http://www.pi-usa.us)

**TECDIA Inc**

2700 Augustine Drive, Suite 110,  
Santa Clara, CA 95054,  
USA

Tel: +1 408 748 0100

Fax: +1 408 748 0111

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

**17 Assembly/packaging foundry****Quik-Pak**

10987 Via Frontera,  
San Diego, CA 92127, USA

Tel: +1 858 674 4676

Fax: +1 8586 74 4681

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

**18 Chip foundry****CST Global Ltd**

4 Stanley Boulevard, Hamilton  
International Technology Park,  
Blantyre, Glasgow, G72 0BN,  
UK

Tel: +44 (0) 1698 722072

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

**United Monolithic Semiconductors**

Route departementale 128,  
BP46, Orsay, 91401,  
France  
Tel: +33 1 69 33 04 72  
Fax: +33 1 69 33 02 92  
[www.ums-gaas.com](http://www.ums-gaas.com)

**19 Facility equipment****RENA Technologies NA**

3838 Western Way NE,  
Albany, OR 97321, USA  
Tel: +1 541 917 3626  
[www.rena-na.com](http://www.rena-na.com)

**Vacuum Barrier Corporation**

4 Barton Lane, Woburn, MA 01801,  
USA  
Tel: +1 781 933 3570  
Fax: +1 781 933 9428  
[www.vacuumbARRIER.com](http://www.vacuumbARRIER.com)

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**20 Facility consumables****PLANSEE High Performance Materials**

6600 Reutte,  
Austria  
Tel: +43 5672 600 2422  
info@plansee.com  
[www.plansee.com](http://www.plansee.com)

**W.L. Gore & Associates**

401 Airport Rd, Elkton,  
MD 21921-4236,

USA  
Tel: +1 410 392 4440  
Fax: +1 410 506 8749  
[www.gore.com](http://www.gore.com)

**21 Computer hardware & software****Crosslight Software Inc**

121-3989 Henning Dr.,  
Burnaby, BC, V5C 6P8,  
Canada  
Tel: +1 604 320 1704  
Fax: +1 604 320 1734  
[www.crosslight.com](http://www.crosslight.com)

**Semiconductor Technology Research Inc**

10404 Patterson Ave.,  
Suite 108, Richmond,  
VA 23238,  
USA  
Tel: +1 804 740 8314  
Fax: +1 804 740 3814  
[www.semitech.us](http://www.semitech.us)

**22 Used equipment****Brumley South Inc**

422 North Broad Street,  
Mooresville,  
NC 28115,  
USA  
Tel: +1 704 664 9251  
Email: sales@brumleysouth.com  
[www.brumleysouth.com](http://www.brumleysouth.com)

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Fax: +1 770 808 8308  
[www.ClassOneEquipment.com](http://www.ClassOneEquipment.com)

**23 Services****Riff Company Inc**

1484 Highland Avenue,  
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[www.riff-co.com](http://www.riff-co.com)

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USA  
Tel: +1-408-748-0100  
Fax: +1-408-748-0111  
Contact Person: Cathy W. Hung  
[www.tecdia.com](http://www.tecdia.com)

**24 Resources****Al Shultz Advertising Marketing for Advanced Technology Companies**

1346 The Alameda,  
7140 San Jose, CA 95126, USA  
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[www.alshultz.com](http://www.alshultz.com)

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USA  
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**5–9 March 2023**

## Optical Fiber Communication Conference and Exhibition (OFC 2023)

San Diego Convention Center, San Diego, CA, USA

**E-mail:** [custserv@optica.org](mailto:custserv@optica.org)

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

**17–21 March 2023**

## 4th International Congress on Advanced Materials Sciences and Engineering (AMSE-2023)

Hilton Vienna Danube Waterfront, Vienna, Austria

**E-mail:** [eve@istci.org](mailto:eve@istci.org)

[www.istci.org/amse2023](http://www.istci.org/amse2023)

**19–23 March 2023**

## IEEE Applied Power Electronics Conference and Exposition (APEC 2023)

Orange County Convention Center, Orlando, FL, USA

**E-mail:** [apec@apec-conf.org](mailto:apec@apec-conf.org)

[www.apec-conf.org](http://www.apec-conf.org)

**20–21 March 2023**

## China Semiconductor Technology International Conference (CSTIC) 2023

Shanghai, China

**E-mail:** [cstic@semichina.org](mailto:cstic@semichina.org)

[www.semiconchina.org/en/5](http://www.semiconchina.org/en/5)

**20–23 March 2023**

## GOMACTech 2023 (Government Microcircuit Applications & Critical Technology Conference)

Town and Country, San Diego, CA, USA

**E-mail:** [gomactech@pcm411.com](mailto:gomactech@pcm411.com)

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

**22–24 March 2023**

## SEMICON China and FPD China 2023

Shanghai New International Expo Centre,

Shanghai, China

**E-mail:** [semichina@semi.org](mailto:semichina@semi.org)

[www.semiconchina.org/en](http://www.semiconchina.org/en)

**26–30 March 2023**

## 2023 IEEE International Reliability Physics Symposium (IRPS)

Hyatt Regency, Monterey, CA, USA

**E-mail:** [IRPSreg@ieee.org](mailto:IRPSreg@ieee.org)

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

**4–6 April 2023**

## 36th annual Semiconductor and Integrated Opto-Electronic (SIOE 2023)

Cardiff University, Cardiff, UK

**E-mail:** [Future-CSHUB@cardiff.ac.uk](mailto:Future-CSHUB@cardiff.ac.uk)

[www.cardiff.ac.uk/conferences/sioe-conference](http://www.cardiff.ac.uk/conferences/sioe-conference)

**25–27 April 2023**

## 26 Annual CMSE (Components for Military and Space Electronics) Conference and Exhibition (CMSE 2023)

Four Points by Sheraton (LAX), Los Angeles, CA, USA

**E-mail:** [info@tjgreenllc.com](mailto:info@tjgreenllc.com)

[www.tjgreenllc.com/cmse](http://www.tjgreenllc.com/cmse)

**7–12 May 2023**

## 2023 Conference on Lasers & Electro-Optics (CLEO)

San Jose Convention Center, San Jose, CA, USA

**E-mail:** [CLEO@compusystems.com](mailto:CLEO@compusystems.com)

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

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**21–25 May 2023****LightFair 2023**

Javits Center, New York, USA

**E-mail:** michellem@lightfair.com**www.lightfair.com****23–25 May 2023****SEMICON Southeast Asia (SEMICON SEA 2023)**

Setia SPICE Convention Centre &amp; Arena, Penang, Malaysia

**E-mail:** semiconsea@semi.org**www.semiconsea.org****Microwave Week****11–13 June 2023****2023 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2023)**

San Diego Convention Center, San Diego, CA, USA

**E-mail:** support@mtt.org**www.rfic-ieee.org****11–16 June 2023****2023 IEEE/MTT-S International Microwave Symposium (IMS 2023)**

San Diego Convention Center, San Diego, CA, USA

**E-mail:** exhibits@horizonhouse.com**www.ims-ieee.org/ims2023****11–16 June 2023****43rd Symposium on VLSI Technology & Circuits – ‘Rebooting Technology & Circuits for a Sustainable Future’**

Rihga Royal Hotel, Kyoto, Japan

**E-mail:** vlsisymp@jtbcom.co.jp (Asia and Japan) or

vlsi@vlsisymposium.org (North America and Europe)

**www.vlsisymposium.org****25–29 June 2023****World of PHOTONICS CONGRESS – International Congress on Photonics in Europe**

ICM – Internationales Congress Center München, Munich, Germany

**E-mail:** info@photonics-congress.com**www.photonics-congress.com/en****29 June – 1 July 2023****SEMICON China**

Shanghai New International Expo Centre (SNIEC), China

**E-mail:** semichina@semi.org**www.semiconchina.org****11–13 July 2023****SEMICON West 2023**

Moscone Center, San Francisco, CA, USA

**E-mail:** semiconwest@semi.org**www.semiconwest.org****6–8 September 2023****SEMICON Taiwan 2023**

TaiNEX 1&amp;2, Taipei, Taiwan

**E-mail:** semicontaiwan@semi.org**www.semicontaiwan.org****17–22 September 2023****26th European Microwave Week (EuMW 2023)**

Berlin Messe, Germany

**E-mail:** eumwreg@itnint.com**www.eumweek.com****1–5 October 2023****European Conference on Optical Communication (ECOC 2023)**

Glasgow, Scotland, UK

**E-mail:** postmaster@theiet.org**https://ecoc2023.theiet.org****14–18 October 2023****2023 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)**

Monterey, CA, USA

**E-mail:** cs@cshawevent.com**www.bciets.org****14–17 November 2023****SEMICON Europa 2023**

Messe München, Munich, Germany

**E-mail:** semiconeuropa@semi.org**www.semiconeuropa.org****13–15 December 2023****SEMICON Japan 2023**

Tokyo Big Sight, Tokyo, Japan

**E-mail:** semicon@sakurain.co.jp**www.semiconjapan.org****18–22 February 2024****2024 IEEE International Solid-State Circuits Conference (ISSCC 2024)**

San Francisco, CA USA

**E-mail:** Issccinfo@yesevents.com**www.isscc.org****12–23 June 2024****2024 IEEE Symposium on VLSI Technology and Circuits**

Hilton Hawaiian Village Waikiki Beach Resort, Honolulu, HI, USA

**E-mail:** vlsi@vlsisymposium.org**www.vlsisymposium.org**



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