

# semiconductor**TODAY**

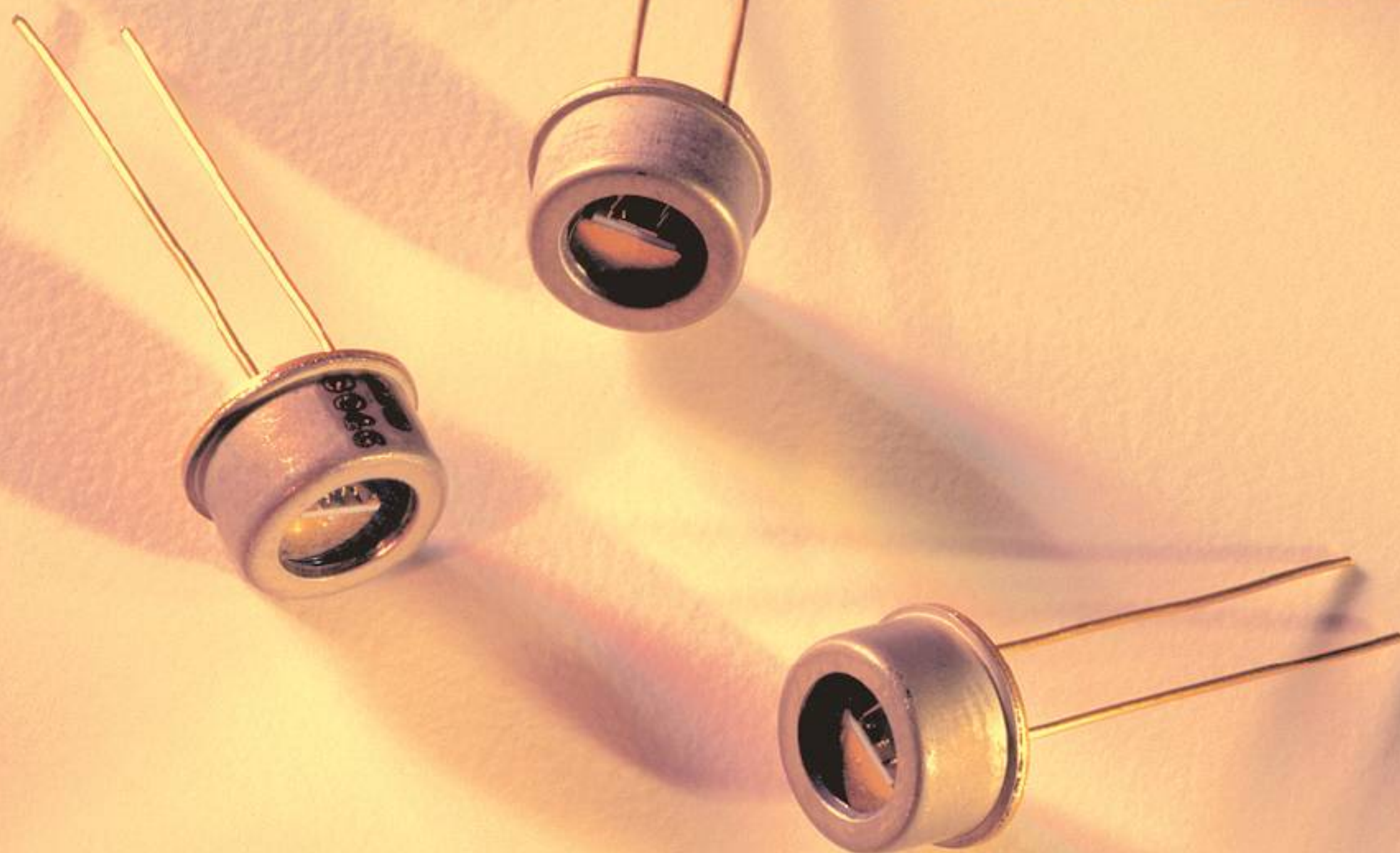
C O M P O U N D S & A D V A N C E D S I L I C O N

Vol. 2 • Issue 8 • October 2007

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## Nonpolar GaN takes the LED and laser spotlight

### Opto developments at ECOC 2007



RFMD building new fab • Anadigics buys Fairchild's RF Group  
ATP grants for deep UV LEDs • ICNS conference report



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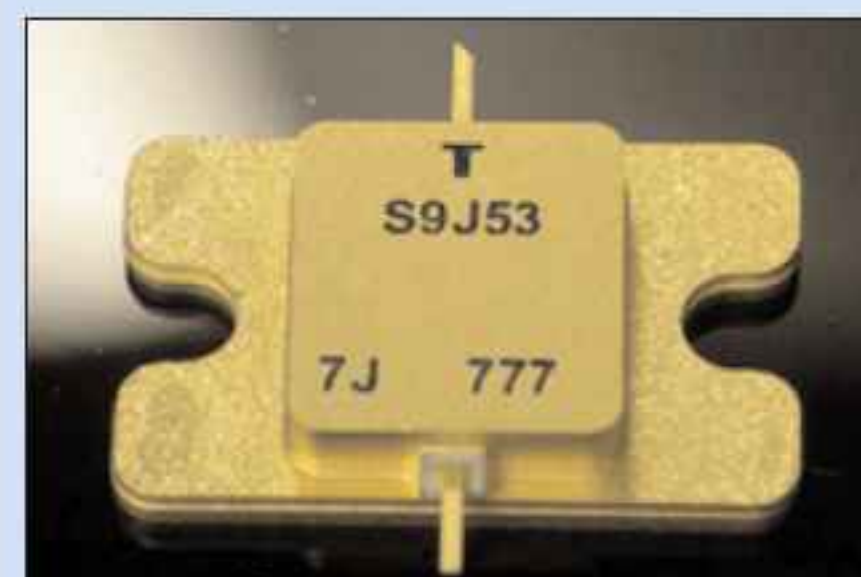
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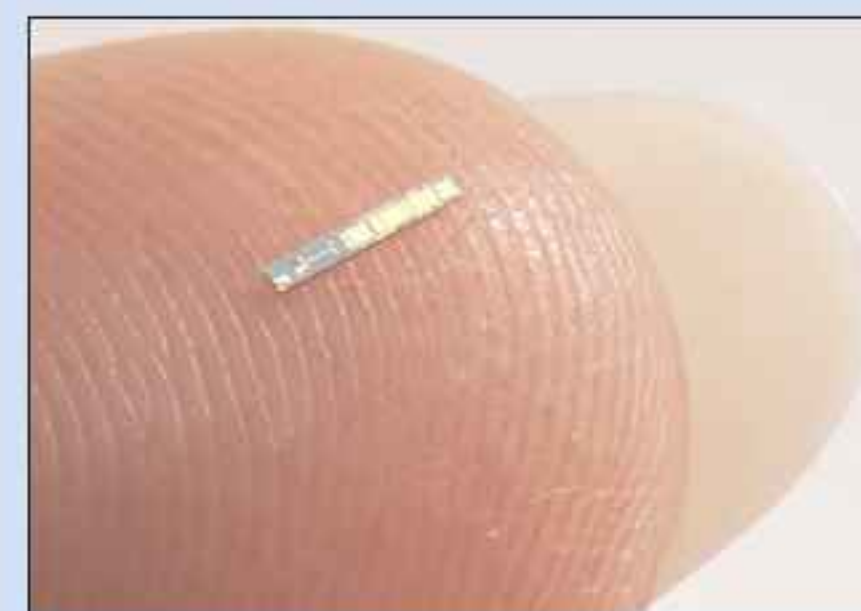
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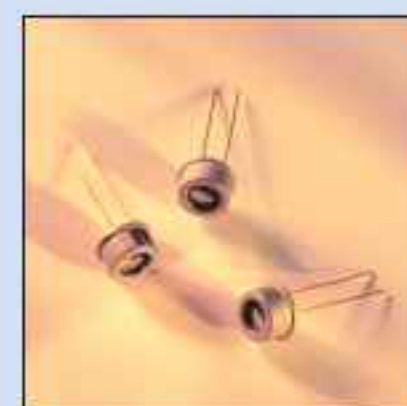
**p16** Nitronex's 28V, 100W-class NPT25100 GaN-on-Si HEMT RF power transistor is now production-qualified.



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**Cover:** Scotland-based laser maker Intense Ltd has launched the Intense-HPD Series 6100 of 980nm high-power single-emitter laser diodes, which uses the firm's quantum-well intermixing technology to deliver up to 200mW of kink-free power while avoiding catastrophic optical damage. **p39**



# GaAs expands, while GaN turns green

Since last issue, when we reported news of RF Micro Devices acquiring Sirenza and TriQuint acquiring Peak Devices, the last month has seen further evidence of the trend towards consolidation in the GaAs RFIC market as the main players make both strategic acquisitions of complementary device technology and manufacturing capacity expansions (as detailed by market research firm Strategy Analytics on page 6).

Most recently, Anadigics has acquired Fairchild Semiconductor's RF Group design center, while RFMD has decided to expand by constructing a second fab at its headquarters in Greensboro, NC (pages 8-9). Meanwhile, as we closed for press, Skyworks announced that it is expanding to meet demand from handset makers by converting its GaAs HBT fab in Newbury Park, CA from 4-inch to 6-inch wafers (see next issue for details).

However, apart from opting for fab conversion rather than construction, in order to meet 'surges' in demand with high flexibility, Skyworks' 'hybrid' expansion model also involves increased use of GaAs foundries in Taiwan. This strengthens another trend in the industry: although TriQuint remains the largest supplier of GaAs foundry services, pure-play GaAs foundry WIN Semiconductor in Taiwan has continued to close the gap, reckons Strategy Analytics, following consolidation in the sector in recent years (with TriQuint and WIN now comprising 60% market share collectively) — see page 13. Not only is WIN rapidly expanding its capacity, but it has also appointed the UK's Plextek as an approved third-party design house as WIN seeks to offer greater GaAs MMIC design capabilities.

Another trend evidenced by a huge attendance of over 930 at September's ICNS 2007 conference is the rapid advance being made in white LEDs and blue-spectrum lasers. Boosted by the advent of low-defect-density free-standing nonpolar (m-plane) GaN substrates, both Japan's Rohm and the University of California Santa Barbara have made significant steps in both increasing the lasing wavelength and reducing the threshold voltage and current density, due to the electronic properties of nonpolar GaN allowing greater optimization of device structure (see feature article, page 55). Reports include: the first nonpolar m-plane blue-violet lasers in February; the first AlGaIn-cladding-free nonpolar m-plane GaN laser, operating first in pulsed mode (in March) and then continuous-wave (in August); and (in September) the first pure blue nonpolar m-plane GaN laser. This emitted in pulsed mode at 430nm using GaN guiding and 452nm using InGaIn guiding. More recent reports (at October's ISCS 2007) extend this to over 460nm, and subsequently to cw mode. Compared to conventional c-plane GaN lasers, apart from suffering less blue shift of the lasing wavelength with increasing current, the rapid lengthening of the lasing wavelength bodes well for the much sought-after aim targeted by both Rohm and UCSB: green semiconductor lasers for applications such as red-green-blue displays.

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**Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

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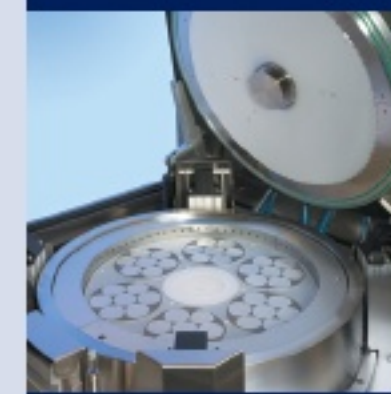


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## Opto-enabled product & component market to grow at 7.7% to 2017

The market for optoelectronic components and optoelectronic-enabled products rose 14.5% from \$494bn in 2005 to a record of \$565bn in 2006, according to the Washington DC-based Optoelectronics Industry Development Association (OIDA) in its 9th annual global optoelectronics market summary and forecast (presented at its forum 'Perspectives on the Optoelectronics Industry' in San Jose, CA, USA in mid-September).

The OIDA defines optoelectronic-enabled products as products and systems that contain optoelectronic components, while optoelectronic components are considered up to the module level.

For optoelectronics-enabled products, annual growth rates ranged from 8% to 43%, led by environment/sensing (43.1%) and medical care/welfare (28.6%). The two biggest segments, consumer display/TV and computing/processing, demonstrated growth of 20.4% and 8.1%, respectively.

The OIDA also forecasts that the market will grow steadily at a compound annual growth rate (CAGR) of 7.7% in the next decade to over \$1.2 trillion by 2017, driven mainly by LCD displays (which will enable consumer-based products ranging from TVs to mobile phones and digital assistants).

For optoelectronics-enabled products, growth drivers will be solar, computing/processing and consumer displays/TVs, with CAGRs of 17.3%, 5.6% and 6.3%, respectively. Their combined total revenue in 2017 should top \$425bn (compared to \$198bn in 2006).

Forecasts for growth from 2006 to 2017 include:

- Flat-panel display (FPD) revenues will grow to nearly \$200bn, driven mainly by a-Si (amorphous silicon) TFT LCDs for consumer products such as TVs.

- White high-brightness LEDs (HB-LEDs) will fuel growth of the LED market to more than \$14bn, driven by solid-state lighting, automotive and signs/displays.

- The laser market should grow steadily from slightly over \$6bn in 2006 to nearly double that. The non-diode market is expected to surpass the diode market in the 2011 timeframe, fueled by materials process, industrial and medical applications.

- The optical communications market should grow at a CAGR of 7% from \$19bn to nearly \$40bn, led by strong growth in optical networking equipment that evolves the network architecture to be more efficient through the use of dynamic optoelectronic components.

- Optoelectronic transceivers are expected to grow rapidly from slightly over \$1bn to more than \$6bn. Key drivers will be Ethernet/Fiber Channel 10Gb/s technology. The emergence of 40Gb/s modules over the next decade will offer new growth opportunities.

- Solid-state lighting devices (mainly HB-LEDs) will grow to more than \$60bn (over 30% of the lighting market), giving competition to incumbent incandescent and fluorescent luminaires. Organic LEDs (OLEDs) will penetrate this market slowly due to their high cost structure.

The 9th annual global optoelectronics market summary and forecast was made available to OIDA members in October.

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

## Firms position for WiMAX

The telecoms industry is on the verge of a major change, as mobile operators make critical decisions about 4G strategies and mobile WiMAX (IEEE 802.16e) moves into real-world deployments of networks operating in the 2.5 and 3.5GHz bands, says ABI Research in its study 'WiMAX Market Analysis and Forecasts'.

"The mobile wireless industry is in a state of major change as mobile operators decide which IP-OFDMA (orthogonal frequency division multiple access) path they will take for their 4G networks," says principal mobile broadband analyst Philip Solis. "The new and unproven (on a large commercial scale) mobile WiMAX has positioned itself against the potential Goliath that LTE (long-term evolution) is expected to become."

The study forecasts substantial numbers of WiMAX users by 2012, with more than 95m using customer premises equipment (CPE) devices, and 200m using mobile devices.

Solis adds that, although while WiMAX equipment interoperability certification timelines have slipped and LTE has benefited from having evolved out of GSM technology, WiMAX is at least two years ahead of LTE in reaching the market.

With the exception of Qualcomm and Ericsson, the study says that the major semiconductor and equipment makers are staking out their positions in the sector, as are mobile operators. Vodafone is looking to WiMAX for its Middle East and Eastern European markets, while BT, Telecom Italia Mobile, and another as yet unnamed "major European mobile operator" are also showing considerable interest in WiMAX. ABI adds that chipset manufacturing firms are also positioning themselves for WiMAX, by supporting a wide variety of emerging device types, such as Ultra-Mobile PCs (UMPCs), mobile Internet devices, and consumer electronics products such as portable game devices, portable media players, and imaging devices.

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## GaAs pHEMT switch market tempered by captive producers and CMOS

Internal production by major users has undermined the traditional merchant market for GaAs pHEMT switches, according to the report 'RF Switch Vendors Face Captive Producers and CMOS' from Strategy Analytics.

The largest user of RFIC switches, RF Micro Devices of Greensboro, NC, USA, now produces its own GaAs switch die for use in power amplifier front-end modules for wireless handsets, notes the market research firm.

RFMD has rapidly emerged as the largest provider of IC-based RF switches (with a market share of 30%), almost all of which it ships in its power amplifier (PA) front-end modules for cellphones. This puts RFMD in a strong position to gain market share in Wi-Fi, as well as strengthening its position as the highest-share, lowest-cost producer of PA modules for cellphones.

According to Asif Anwar, director of the Strategy Analytics GaAs and Compound Semiconductor program, "GaAs switch vendors also face the challenge of silicon RFIC switches, particularly Peregrine Semiconductor's CMOS SoS (silicon-on-sapphire) RF switches, which have made inroads in handsets that require switches, intermediate in complexity between p-i-n diodes and multi-throw GaAs pHEMT switches."

Christopher Taylor, director, RF & Wireless Components for Strategy Analytics and author of the report, adds, "The good news is that multiple niche markets for high-performance RF switches have continued to grow at healthy rates, which has helped specialty RF switch suppliers such as Hittite and Mimix Broadband."

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

## Acquisitions reach \$2bn, driven by IP and product portfolio expansions

Consolidation in the compound semiconductor industry is predicted to continue, reckons market research firm Strategy Analytics. However, the strategies of industry players have matured beyond simply acquiring competing companies in order to gain market share. Instead, companies are now looking for valuable intellectual property and opportunities to expand product portfolios into multiple new markets.

Despite the sub-prime lending crunch, this summer has seen acquisitions with a total value approaching \$2bn, for example by Anadigics Inc of Warren, NJ, USA (of Fairchild Semiconductor Inc's RF Group in Tyngsboro, MA for \$2.3m), by Avago Technologies of San Jose, CA (of Infineon Technologies AG's polymer optical fiber business in Regensburg, Germany for \$27m), by Holland's Philips Electronics (of LED lighting systems maker Color Kinetics in Boston, MA for \$790m), by RF Micro Devices Inc of Greensboro, NC (of fabless RF component firm Sirenza Microdevices Inc in Broomfield, CO for \$900m), and by TriQuint Semiconductor Inc of Hillsboro, OR (of fabless discrete RF transistor firm Peak Devices Inc in Boulder, CO for \$15m).

RFMD and TriQuint's acquisitions, in particular, are driven by the aim to enter new markets by acquiring product portfolios complementary to their own. "The larger players need to expand their horizons beyond cellular handsets if they are to be profitable," Asif Anwar, director of Strategy Analytics' GaAs and compound semiconductor technology service, told Semiconductor Today. "As deals have become more difficult to finance, firms are being forced to scrutinize each deal much more closely and use strategic financing to fund deals," he adds. "The industry has learned to look for affordable gems with unique IP suited to products and strategies."

"I believe we will see further exits,

mergers, acquisitions and divestments," Anwar says. "Companies that have low market share and 'me too' products will find it difficult to survive," Anwar adds. Indeed, in mid-September EiC Corp of Santa Clara, CA announced it was closing down its GaAs RFIC manufacturing operations (following the sale of most of its product line to WJ Communications Inc of San Jose, CA in June 2004).

Another trend driving consolidation is firms selling their fabs, in order to become fabless (following the mainstream silicon sector).

"I believe we will see more GaAs device companies — especially outside the top ten and not tied to military sectors — looking to maximize profitability by going fabless [following the examples of Hittite Microwave Corp of Chelmsford, MA, Mimix Broadband Inc of Houston, TX (since selling its ex-Celeritek fab in Santa Clara, CA to USTI in April 2006) and WJ (since selling its fab in Milpitas, CA in Q2/2007)]. The success of pure-play foundries is a result of these trends," Anwar told Semiconductor Today. "If you're a small player chasing a high-volume market then it doesn't make sense to have a fab, so companies will consider this option. Exceptions are companies that are involved in the defense sector, where high fab utilization is not a critical factor."

"On the other hand, customers for the larger GaAs players such as RFMD and TriQuint expect their suppliers to match their requirements with investments in extra fab capacity," Anwar adds. "Skyworks is an interesting example in that they have chosen a strategy that entails running its own fabs at 100% and then outsourcing extra requirements to a qualified foundry partner, namely AWSIC [Advanced Wireless Semiconductor Company of Tainan Science-Based Industrial Park, Taiwan]," he concludes.

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## Hittite licenses Northrop Grumman's Velocium MMIC product line

Hittite Microwave Corp of Chelmsford, MA, USA, which designs RF, microwave and millimeter-wave ICs, modules and subsystems, has entered into a strategic agreement to license Northrop Grumman's Velocium line of MMIC products and related intellectual property.

Under the agreement, Northrop Grumman's Space Technology sector (NGST) of Redondo Beach, CA, USA will license to Hittite a specified list of standard products and associated technology. Hittite will assume the related customer contracts and become the worldwide supplier for the Velocium products.

Hittite says that the agreement expands its high-frequency product line and enhances its supply chain. The license includes commercial products operating at frequencies through 86GHz that are typically used in millimeter-wave radios and other high-performance electronic systems.

Hittite will use Northrop Grumman as a foundry supplier for GaAs wafers used in the licensed products and, as a strategic partner, the firm will also have preferred access to Northrop Grumman's process technology for new Hittite products.

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

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## WJ's Q3 hit by operational challenges

WJ Communications Inc of San Jose, CA, USA, which designs and supplies RF products for the wireless infrastructure and RFID reader markets, expects Q3/2007 sales of \$9.7–9.9m, down about 23% on Q2's \$12.7m.

"While our scheduled business during the third quarter would have resulted in revenue that was within our previously provided guidance range, we experienced several operational challenges during the quarter that contributed to our lower-than-expected results," says president and CEO Bruce Diamond. "We experienced a shortage of lead frames late in the quarter due to several deliveries being rejected upon inspection by our assembly vendor. This issue has since been

resolved, and we have resumed our shipment schedules."

Q4/2007 revenue is expected to be below analyst estimates and not a material improvement on Q3. According to the financial website RTT News, analysts had expected WJ to report Q4 revenue of \$12.97m.

"Our current revenue outlook is based on initial indications by our customers that overall demand will be lower than previously expected," said Diamond. "Also, it now appears that significant orders related to the TD-SCDMA build-out in China will not materialize until 2008," he adds. "However, we believe it will have a positive impact on our total revenue and financial results next year."

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

## WJ mourns board member Holmstrom

Michael E. Holmstrom (a member of WJ's board since July 2004) died from cancer on 22 September.

Holmstrom was instrumental in guiding WJ's turnaround, said president & CEO Bruce Diamond. "As chairman of our audit committee and member of our executive committee, Mike provided terrific

oversight, council, and guidance."

Holmstrom had over 35 years financial experience in the telecoms industry.

WJ is currently seeking a replacement for Holmstrom on the board. His role on the audit committee and executive committee has been filled by director Cathy Lego.

## Grasen founded for HBTs and HFETs

Fabless firm GraSen Technology LLC of San Jose, CA, USA, has been founded to provide GaAs HBT and HFET products for commercial communications and defense electronics markets (manufactured, tested and packaged in three qualified foundries).

Founders include president and CEO Brad Senge and CTO & COO Stan Gray. Senge has over 33 years experience in RF and microwave component and system design, manufacturing, program management, and business development for wireless communications and defense electronics applications, ranging from RF engineering technician to VP of business development.

Gray has over 30 years experience in the design and manufacturing of RF components for applications in commercial wireless communications and military electronics systems and subsystems. He was the product development manager and chief RFIC design engineer, responsible for the Aeroflex/Metelics HBT and PHEMT amplifier product lines. His experience includes RF ASIC design positions for S5 Wireless, ParkerVision Inc, EiC Corp, and Wireless Access Inc, as well as component design engineering for Stellex Microwave, Voyager Technologies Inc, Mirage Systems, and Lockheed Martin Missiles and Space Company.

As a small business, GraSen is "better positioned to meet quick response to the ever-changing markets we serve," Senge says.

Also, GraSen Engineering provides contract design and transfer services for CMOS RF power amplifier or high-speed logic circuits, RF amplifier assembly, multi-chip modules, MMICs or microwave integrated circuits. Mechanical housing and packaging design services are also available.

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



## Anadigics ships dual-band 802.11n PA to NXP for WLAN module

Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWL6951 wireless LAN (WLAN) power amplifier (PA) module to NXP Semiconductor of Eindhoven, The Netherlands (formerly Philips Semiconductor) for their MRX2000 WLAN module solution in support of the upcoming 802.11n multi-input, multi-output (MIMO) standard.

The MRX2000 enables higher throughput of rich content for quality-critical applications, allowing faster, more powerful wireless connectivity between multimedia devices, it is claimed.

The dual-band AWL6951 is a high-performance indium gallium phosphide (InGaP) HBT power amplifier module designed for transmit applications in the 2.4–2.5GHz and 4.9–5.9GHz bands. Matched to 50Ω at all RF inputs and outputs, it requires no additional RF matching components off-chip, making it the world's simplest dual-band PA module implementation available, Anadigics claims. It also exhibits high linearity and efficiency for IEEE 802.11g, 802.11b and 802.11a WLAN systems under the toughest signal configurations within these standards.

Building on the combination of its patented InGaP-Plus process technology and innovative design concepts, Anadigics claims that its 802.11n PAs and front-end integrated circuits (FEICs) provide high levels of integration, as well as the linearity, efficiency, and output power required to integrate MIMO capability into a broad range of home and office multimedia appliances, such as mobile computing, CATV set-top boxes, HD televisions, and videogame console systems.

## Anadigics acquires Fairchild's RF Group design center in Tyngsboro

Anadigics Inc of Warren, NJ, USA, which manufactures wireless and broadband communications components and modules, has acquired the RF Group of chip maker Fairchild Semiconductor Corp of South Portland, ME, USA for \$2.3m. The divestiture allows Fairchild to focus its resources more on designing and manufacturing its power analog and power discrete semiconductor products (for optimizing system power).

The acquisition includes fixed assets, certain leases, software, licenses to intellectual property, and customer and vendor lists. Anadigics has hired 23 RF design and engineering professionals from the RF Group and will retain the design center based in Tyngsboro, MA.

As a part of the deal, Anadigics has agreed to assist Fairchild transition out of the RF business by providing both business and technical support for a period of time.

"Highly specialized RF talent is rare in the semiconductor industry and is a differentiating factor in our fast-growing markets," says

Dr Bami Bastani, Anadigics' president & CEO. "The establishment of the Massachusetts design center not only fulfills our planned 2008 resource requirements, but further consolidates the industry and provides Anadigics with a knowledgeable and exceptionally experienced RF team." The acquisition should further accelerate Anadigics' design and development of RF devices for the 3G cellular, WiFi and WiMAX markets, Bastani adds.

"While this transaction will increase our anticipated R&D expenses for the fourth quarter of 2007, customer demand forecasts and fourth quarter momentum for our products remain robust, which is expected to partially offset the incremental expenses," says Tom Shields, executive VP & CFO. "For fiscal year 2008, our business model had already planned comparable R&D expenses and, consequently, does not need to be further adjusted for this acquisition," he concludes.

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

## Former Maxim fab manager appointed as Anadigics' senior VP of operations

Anadigics has recruited John Coleman as senior vice president of operations.

Coleman joins from Maxim Integrated Products, where he was managing director of their facility in San Antonio, TX, responsible for bringing online its newest BiCMOS silicon wafer fab in under six months. Previously, he held leadership positions at companies including Atmel Corp and STMicroelectronics.

"John's extensive past experience of working in high-volume analog IC operations will provide valuable insights for Anadigics," says Dr Bami Bastani, president and CEO. "Anadigics has been

experiencing tremendous growth and I look forward to bringing my experiences to Anadigics as we continue to expand our operations in the US and overseas," adds Coleman.

On 9 July Anadigics broke ground on construction of its second 6" GaAs fab (sited in the Kunshan New and Hi-Tech Industrial Development Zone, China), which should start operation by Q1/2009 and ultimately double Anadigics' fab capacity.

Coleman holds a Masters of Science in Physics from the University of North Carolina and a Masters of Business Administration from the University of Phoenix.



# RFMD adds fab to accommodate cellular & multi-market demand

RF Micro Devices Inc of Greensboro, NC, USA, the world's largest manufacturer of GaAs HBTs and pHEMTs, has announced plans to expand its compound semiconductor manufacturing capacity with a new fab in North Carolina to support the expected growth in its Cellular and Multi-Market product groups.

In the cellular handset market, the increasing adoption of highly integrated, multi-chip transmit modules and the migration to 3G multimode devices are expected to drive increased demand for RFMD's GaAs pHEMTs and HBTs (both AlGaAs and InGaP). These market trends require greater quantities of compound semiconductor content and are expected to underpin a five-year compound annual growth rate of greater than 20% from 2007–2012 for cellular front-ends, reckons the firm. RFMD was recently recognized as the leading manufacturer of cellular front-ends.

Also, in markets served by RFMD's Multi-Market products group, it is anticipated that the migration to the IEEE 802.11n wireless local-area network (WLAN) standard (GaAs HBT and pHEMT) and the increasing adoption of WiMAX (GaAs HBT and GaN) will be among the main drivers of increased compound semiconductor content and accelerated market growth. RFMD claims its GaN process technology is quickly being recognized for applications that require high power, linearity and bandwidth compared to existing technologies such as silicon LDMOS. The firm is currently ramping commercial production of its GaN technology.

"RFMD has consistently been the world's largest supplier of GaAs devices for several years... The company continues to move in line with the requirements of the cellular handset market, and this

will continue to drive the volume at RFMD," says Asif Anwar, director of Strategy Analytics GaAs and Compound Semiconductor Technologies service. "RFMD has also developed a coherent multiple-market strategy to target higher-value segments with the rollout of its GaN and GaAs pHEMT technologies as well as the expansion of its IP and product portfolios through the proposed Sirenza acquisition [announced in mid-August]," he adds. "This dual 'high volume-high value' strategy will help the company remain at the forefront of the compound semiconductor industry," Anwar concludes.

"The markets served by RFMD are growing, and RFMD is growing its compound semiconductor content within these markets," says the firm's president and CEO Bob Bruggeworth. "The addition of our third fab will enable us to capture a greater percentage of this growth while also reducing manufacturing costs and driving continued improvement in operating profitability," he adds. "Once complete, our third fab, in conjunction with our second fab, will focus on high-volume cellular and WLAN front-end products that utilize GaAs HBT and GaAs pHEMT." The new fab will also provide capacity for the production of wafer-level packaged surface acoustic wave (SAW) filters and the development of new, next-generation process technologies that provide highly integrated front-end functionality. Meanwhile, the first fab will focus on high-value multi-market products that use specialty GaN, GaAs pHEMT and GaAs HBT technologies.

Meanwhile, in order to satisfy immediate forecasted demand, RFMD is currently increasing its manufacturing levels for both GaAs HBTs and pHEMTs.

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

## State grants for job development

According to The Triad Business Journal, North Carolina state Governor Mike Easley says that RFMD plans to invest \$118m and add 350 jobs over the next four years: \$103m in expanding its existing campus in Greensboro (creating 300 new jobs and raising total staffing in Guilford County to more than 2200) and \$15m in building a smaller facility in Mooresville, Iredell County that will employ 50. This is RFMD's fourth major facility in Guilford County in the 16 years since it opened, Easley said.

After offers of incentives from cities across the south-east USA, RFMD had considered several sites, including expanding its plant in China, but decided to expand in North Carolina. "We are extremely appreciative of the support we received from the Governor, our state representatives, and city officials, who were instrumental in our decision to expand our manufacturing operations here," said Jerry Neal, co-founder and VP of marketing and strategic development.

The expansion is being facilitated by North Carolina state's Economic Investment Committee awarding a Job Development Investment Grant lasting 11 years. For each year that RFMD meets required performance targets, the state will provide a grant equivalent to 70% of the state personal income withholding taxes derived from the creation of the new jobs. If RFMD sustains all of the jobs for 11 years, it could receive up to \$4.25m.

[www.digtriad.com/business/article.aspx?storyid=90248](http://www.digtriad.com/business/article.aspx?storyid=90248)



## Buhaly appointed as new CFO

TriQuint has appointed Steven J. Buhaly as chief financial officer, VP of Finance and secretary. He replaces CFO Stephanie Welty, who is assisting in the transition.

Buhaly has over 20 years of experience in finance and operations. Prior to joining TriQuint, he was CFO at Longview Fibre of Longview, WA from 2006 to 2007. From 2000 to 2005, he was first CFO then chief operating officer at Planar Systems Inc of nearby Beaverton, OR (after joining in 1999 as VP of its Medical Business). Previously, Buhaly had roles in finance and operations at Beaverton-based Tektronix Inc. Buhaly holds a Bachelor of Science and a Masters of Business Administration from the University of Washington.

"Steve's strong operational expertise and solid financial knowledge are valuable assets for our fast growing business," says president and CEO Ralph Quinsey.

● Steve Sharp, chairman of the board of TriQuint Semiconductor, is taking over as chairperson of the Oregon Council of AeA (formerly American Electronics Association) for a two-year term, succeeding Robert DeKoning (CEO of Beaverton-based Routeware). Sharp has served as vice-chair since 2005.

AeA is the USA's largest technology trade association with 2500 member companies representing all high-tech segments. The association has 18 state councils in the leading high-tech states. As chair, Sharp will also serve on AeA's national board. AeA sponsors professional development events for executives, managers, and boards of directors. In Oregon, AeA also advocates for the industry at the State Legislature on issues such as higher education, taxation, and business regulations.

## HV-HBTs launched to halve waste heat in 3G base-station amplifiers

At European Microwave Week (EuMW) in Munich, Germany (9-11 October) TriQuint Semiconductor of Hillsboro, CA, USA launched a new TGH293x family of GaAs high-voltage heterojunction bipolar transistor (HV-HBT) power amplifiers designed to substantially increase the efficiency of 3G cellular base-stations, supporting the development of base-stations that incorporate smaller, less expensive, and more energy-efficient cooling systems.

Tested in a design commonly used by base-station amplifier manufacturers that pairs devices in a 'Doherty' configuration, the devices delivered an efficiency of 57%, surpassing that available using either conventional laterally diffused metal oxide semiconductor (LDMOS) transistors or more expensive gallium nitride devices, the firm claims.

TriQuint reckons the importance of the new-generation HV-HBT in amplifier design will be seen as high-bandwidth wireless markets continue to expand. According to a study by Strategy Analytics, 3G and 4G base transceiver station (BTS) power amplifier shipments should increase at a compound annual growth rate (CAGR) of about 19% through 2010 (not including expansion of the WiMAX market, which could also use the HV-HBTs).

"GSM system amplifiers don't require linear operation, and their efficiencies have traditionally been much higher than amplifiers for 3G systems. Network operators that have deployed 3G systems in the past few years have seen a dramatic increase in OPEX [operating expenditure] costs related to electricity," says Mike Sanna, VP of Network Products. "Those operators have gone back to the base-station OEMs and amplifier companies with aggressive efficiency goals for existing 3G and next-generation 4G systems to get those costs back under control. TriQuint's HV-HBT



TriQuint TGH293x series HV-HBT.

transistors will provide a significant 'step-function' improvement in amplifier efficiencies," he claims. "One of our lead customers reports up to a 10 point increase in amplifier efficiency when using our TGH2932-FL devices."

**LDMOS transistor-based amplifiers used in 3G systems generate as much as 70W of waste heat**

For a 50W average power WCDMA amplifier design, the new transistors create only about 38W of waste heat. LDMOS transistor-based amplifiers used in 3G systems generate as much as 70W of waste heat. So, the new HV-HBT amplifier

reduces waste heat by nearly 50% in comparison, claims TriQuint.

"The immediate opportunity is to realize overall savings in existing style systems, which will generate less waste heat, reduce air-conditioning expense, cut heatsink size, and require fewer cooling fans," says Sanna. "The longer-term opportunity is the potential to eliminate the ground-based amplifier in exchange for a tower-top amplifier. That would result in a much more dramatic reduction in both energy consumption and equipment cost," Sanna adds. "In general, a more efficient amplifier enables radio designs that are far less focused on mitigating the damaging effects of heat, which is a key design consideration today," he concludes.



# TriQuint ships 5 millionth Quantum module to ZTE for Vodafone's ultra-low-cost handsets for emerging markets

RF front-end IC maker TriQuint Semiconductor Inc says that, in the six months since April, it has shipped 5 million integrated Quantum Tx (transmit) modules to ZTE Corp, one of China's leading handset original design manufacturers (ODM), for use in Vodafone's ultra low-cost handsets, a market that is seeing explosive growth.

The TQM6M4028E Quantum Tx module covers both GSM900 and DCS phone bands for the European and Asian markets. It includes two power amplifier ICs, two low-pass filters, a CMOS controller, and a single-pole four-throw RF switch in a 6mm by 6 mm package, making it one of the smallest transmit modules available, TriQuint claims. The integrated CMOS power controller and the high efficiency of the two power amplifier ICs contribute to increased phone talk times. The module also accepts various battery and power supply configurations.

Vodafone models 125 and 225, designed and manufactured by ZTE, are specifically targeted at markets where simple wireless phones can provide an affordable means for citizens to become connected, often for the first time. Vodafone Egypt, Vodafone Romania and Vodacom (South Africa's leading cellular network) were the first countries to launch the models.



**TQM6M4028 Quantum Tx module.**

The global market for such ultra-low-cost handsets should grow to more than 330 million units in 2011 (one in every four mobile handsets shipped worldwide), estimates ABI Research in its report 'Ultra Low-Cost Handsets'.

"The market is evolving in multiple directions and our global handset strategy serves the continuum of needs," says Tim Dunn, TriQuint's VP for Handsets. "We are seeing exceptionally strong growth in Tx module sales across all sectors, including the rapidly growing ultra-low-cost market, where cost-effective integration is vital. These phones offer a new segment of the population the gift of wireless communication."

"Our work with TriQuint as our supply partner represents a big breakthrough in the market. TriQuint's easy-to-use Tx module

has given ZTE an opportunity to demonstrate its capabilities in product design, production and management for Vodafone," says Wang Yong Zhong, ZTE's general manager of GSM Products, Handset BU.

Key to the phones' reduced cost structure is the close harmonization of the Tx module and the integrated transceiver/base-band circuits, says TriQuint. The highly integrated Tx module brings six functions into a single package, minimizing external components in the phone's RF circuit area. By eliminating RF circuit design effort between the power amplifier and the antenna switch, the complete phone design contains less than five key components, enabling faster design-to-market cycle time, TriQuint claims. The combination offers ZTE handset cost and size reductions, while contributing to higher reliability.

"We will continue to develop products that meet the demands of the ultra-low-cost consumer handset sector," says Berry Leonard, TriQuint's product marketing manager of GSM and EDGE products. "Meeting the aggressive requirements of this growing market is a significant milestone, and underscores TriQuint's leadership in enabling the transition to highly integrated transmit modules."

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

## TriQuint celebrates 100 millionth transmit module

On its European Design Center's fifth anniversary (and during European Microwave Week, held just across the street in Munich, Germany), TriQuint Semiconductor celebrated shipping 100 million units of its family of GSM/GPRS and EDGE transmit (Tx) modules.

Pioneered by the engineering staff in Munich, the modules represent an industry first, the firm claims, achieving a 6mm x 6mm footprint and cementing TriQuint's

position as a provider of highly integrated modules for wireless handsets. The modules allow cellular handset makers to replace several discrete parts with one integrated component (the complete front-end modules integrate multiple power amplifiers, filtering, control circuitry, the switch function and ESD protection).

"The establishment of the design center in Munich [in mid-2002, on acquiring Infineon Technologies'

GaAs business] has helped TriQuint assemble a world-class engineering, technical and support team from all across Europe and has bolstered our GSM expertise," says TriQuint Semiconductor GmbH's managing director & sales director Graham Teague. "Today, we have a well-rounded technology portfolio which supports all key air interfaces, from cost-effective GSM/GPRS and CDMA2000, to high-performance EDGE, WEDGE and EV-DO."



## Micromem's MRAM enter prototype production at GCS

GaAs-based magnetoresistive random access memory (MRAM) devices of fabless firm Micromem Technologies Inc of Toronto, Canada have entered prototype production at wafer foundry Global Communication Semiconductors Inc (GCS) of Torrance, CA, USA.

The reticle design from partner Strategic Solutions incorporates a matrix of tests to be performed on the bit structure during processing, giving data on scalability, power consumption, read-write speed and cross-talk separation. Micromem also plans further radiation hardening tests to validate and supplement similar tests last May.

"Once we achieve our predicted target we will begin to execute application-specific development plans for military and other niche application devices," says Steven Van Fleet, project director for the foundry phase. "The modern warfare soldier carries a lot of devices that require heavy batteries. If Micromem's MRAM requires lower power dissipation, meaning lower battery weight, this will be a huge market opportunity."

"We are in discussions with companies that share similar needs in satellites, particularly phased-array satellites," Van Fleet adds. "These require array-based calibration memories that need to be close to the satellite and not housed in metal shielded boxes like silicon-based memory."

Micromem hope to begin a collaboration with development partners in early November, using their specifications to design and build commercial devices from the end of this year.

By early January, Micromem should then transition from the Phase 1 test phase into multiple and parallel product developments.

[www.micromeminc.com](http://www.micromeminc.com)  
[www.gcsincorp.com](http://www.gcsincorp.com)

## Kopin starts shipping 6" HBT wafers produced in IC MOCVD systems

Kopin Corp of Taunton, MA, USA, which makes GaAs-based HBT wafers and liquid-crystal CyberDisplays, claims that its three Aixtron 'integrated concept' (IC) MOCVD systems have been qualified by multiple customers. The firm hails this as a milestone in its plan (announced in April 2006, on completion of the multi-year purchase and supply agreement with Aixtron) to increase its manufacturing capacity for HBT wafers by 50%. This plan combines internal expansion in Taunton and the addition of capacity at KTC, Kopin's licensed original equipment manufacturer of HBT products in Hsinchu, Taiwan.

Kopin claims it is now producing the industry's highest-performing 6" HBT wafers, with exceptionally good uniformity and reproducibility, and is the only company producing technologically demanding HBT structures on these systems in volume.

"We have begun shipment of 6" HBT wafers produced in our IC MOCVD systems, and customer response to the quality of these wafers has been extremely favorable," says Daily Hill, senior VP and general manager of HBT business. "By combining Kopin's proprietary manufacturing

processes with the inherent advantages of these advanced IC MOCVD systems, we have improved our 'on-wafer' uniformity by a factor of at least two, achieved excellent run-to-run reproducibility, and demonstrated reduced maintenance and higher system uptime."

**We have improved our 'on-wafer' uniformity by a factor of at least two.** The IC MOCVD reactors are the highest-throughput systems on the market, capable of growing seven 6" wafers per run, 40% more than

the next largest system, Kopin says. Because of the significant savings in processing costs compared with 4" wafers, the demand for 6" HBT wafers among power amplifier circuit manufacturers is expected to grow rapidly over the next two years.

Most recently, to support the growing demand for HBTs, in mid-August Kopin announced plans for a further expansion of its Taunton production facility (for completion later this year), following receipt of a \$3m development grant from Massachusetts State.

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

## Nasdaq board stays Kopin delisting

In mid-September Kopin said that its common stock will remain listed on Nasdaq pending further consideration by The Nasdaq Stock Market's board of directors.

Under Marketplace Rule 4809, the Nasdaq board decided to call for review the 27 July decision of the Nasdaq Listing and Hearing Review Council that Kopin had until 25 September to file its overdue periodic financial reports and any necessary restatements with the US Securities and Exchange Commission and Nasdaq, otherwise it would be suspended from the Nasdaq Global Market. Nasdaq's

board has therefore also stayed the council's decision to suspend Kopin's securities from trading beyond the 25 September deadline, pending further consideration.

"We continue to work diligently to achieve compliance with all of the Nasdaq's listing requirements," said Dr John C.C. Fan, Kopin's president and CEO. The extra time should allow Kopin's special investigative committee time to complete its investigation into the firm's past stock option granting practices and related accounting and for the firm to prepare and file its audited financial statements.



## WIN closing gap to TriQuint in GaAs foundry market

While TriQuint Semiconductor Inc of Hillsboro, OR, USA remains the world's largest supplier of GaAs foundry services, WIN Semiconductor Corp of Tao Yuan Shien, Taiwan is closing the gap following consolidation in the GaAs foundry sector, reckons market research firm Strategy Analytics in its new report 'WIN Semiconductor Poised to Become Number One?.'

After a slew of companies offering GaAs foundry services emerged in Asia several years ago, in 2002 Strategy Analytics predicted that only a few pure-play GaAs foundry companies would prevail. With the exit of companies such as Taiwan's Suntek early on and, more recently, Global Communication Technology Corp of Hsinchu, Taiwan (acquired by WIN in 2004) and Knowledge\*On of Iksan, Korea, the prediction has come true, the firm says, with just a handful of companies remaining in 2006.

Strategy Analytics estimates that, in 2006, the GaAs foundry market was \$218m, with TriQuint and WIN together accounting for over 60%. TriQuint's market share was estimated to be 40%, nearly double that of its nearest competitor.

While TriQuint is not a pure-play foundry, it has a wide range of processes that can cater to both high-volume and high-value services (as well as being one of the largest suppliers to the military markets), says Strategy Analytics in the report. "The foundry services offered by TriQuint are an integral component of the company's success," said Strategy Analytics' Stephen Entwistle, VP Strategic Technologies Practice, at European Microwave Week 2007 in Munich, Germany. "TriQuint will continue to be the world's largest GaAs foundry in 2007." Asif Anwar, director of Strategy Analytics' GaAs service, adds: "The company is well positioned to defend its number

one position against pure-play foundry competitors, with a strong heritage recognized by both commercial and military customers."

Meanwhile, WIN's investors have allowed it to progressively build up its capabilities as a dedicated pure-play GaAs foundry by expanding both its scale and process mix, says Strategy Analytics. "WIN is the world's largest pure-play GaAs foundry company," noted Anwar at European Microwave Week. "As a privately held company with strong financial backing from its investors, WIN has been able to continually invest in new process technology and resources."

With an expansion roadmap in place that will effectively increase wafer capacity by 200% by 2008, WIN will continue to stretch its lead over the remaining pure-play GaAs foundries still in operation and close the gap on TriQuint, concludes the market research firm.

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

## WIN appoints Plextek as approved third-party design house

Electronics and communications design consultancy Plextek Ltd of Great Chesterford near Cambridge, UK has been appointed as approved third-party design house by GaAs foundry WIN Semiconductor Corp of Tao Yuan Shien, Taiwan.

The move follows Plextek's success with a number of clients using WIN's GaAs IC processes. Plextek is already an approved independent design house for the GaAs foundry Global Communications Semiconductors Inc (GCS) of Torrance, CA, USA since a strategic alliance agreed in 2002.

Founded in October 1999, WIN was the world's first 6" pure-play GaAs foundry and offers processes including 0.15µm gate-length pHEMT and InGaP HBT technology. "We needed an independent design house with extensive experience of GaAs MMIC design on a wide range

of processes, as well as proven capability with using WIN's processes," says WIN's VP of sales & marketing Robert Donahue. "Plextek meet all of these requirements and have impressed us with their professionalism in dealing with WIN foundry customers."

Plextek says that, over the past 10 years, it has designed over 30 full custom GaAs ICs, all of which were first-pass design successes. "The fact that WIN's processes use 6" diameter wafers, combined with the ability to run a four-shift system, allows WIN to offer a truly mass-production capability for GaAs MMICs, which is very attractive to many of our existing and prospective clients," says Plextek's director of RF Integration Liam Devlin.

[www.plextek.com/mmic](http://www.plextek.com/mmic)

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

## WIN orders second Vistec e-beam writer

Taiwanese GaAs RFIC/MMIC foundry WIN Semiconductors has placed an order with Vistec Electron Beam GmbH of Jena, Germany (formerly Leica Microsystems) for a SB250 Variable Shaped Beam system.

The electron-beam lithography system will be delivered and installed in 2008, and used for the production of pHEMT components (mainly for telecoms and satellite transmission applications).

The order represents a follow-on purchase of a Vistec Shaped Beam system by WIN. "This second electron-beam lithography system from Vistec will help us to meet not only current production demands, but also develop products featuring 100nm gate length," said Dr Der-Wei Tu, WIN's senior VP and chief technology advisor.

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



## Velox wins \$2m ATP funding for 1200V, 100A GaN-on-Si

GaN transistor and diode maker Velox Semiconductor Corp of Somerset, NJ, USA (spun off from Emcore's GaN Power Device Group in April 2005) has been granted \$2m for a two-year project (starting in November) to develop high-voltage, high-current electronic components in order to further increase the fuel efficiency of hybrid vehicles. The funding comes as part of the final set of Advanced Technology Program (ATP) awards of the US Commerce Department's National Institute of Science and Technology (NIST). Together with projected industry cost-share of almost \$1.3m, total project funding should be \$3.28m.

Much of the power loss in hybrid electric vehicles is due to the slow operation and high electrical resistance of silicon-based transistors in the inverter that converts DC battery power to AC power for the motor, limiting the power supply's efficiency.

The award will fund development of high-voltage (600V and 1200V), high-current (20A and 100A) power switching transistors, based on

Velox's GaN-on-Si technology, with much faster switching and lower resistance than Si-based transistors. In particular, the program will advance Velox's efforts to develop new enhancement-mode FETs.

Such switching devices could not only significantly increase the fuel efficiency of best-in-class hybrid vehicles, says Velox, but also increase the efficiency and more than halve the size of power supplies used for consumer, laptop computer, industrial and telecom applications.

In Phase I, Velox will develop 600V 20A GaN FETs for improved power supply applications. The following phase will develop 1200V, 100A devices, suited to motor driver applications in the automotive industry.

Cornell University in Ithaca, NY will assist with device development, while Rensselaer Polytechnic Institute (RPI) in Troy, NY will provide modeling expertise. The National Transportation Research Center at Oak Ridge National Labs in Tennessee will help evaluate the devices for vehicular application. A successful product

could provide a positive impact on the \$14.3bn market for power diodes and transistors, says NIST.

"GaN-on-Si technology has attracted significant interest from researchers in the last seven years," says CEO Thomas Hierl. However, major challenges in making GaN-based transistors now need to be addressed in order to produce larger electrical currents and to develop 'enhancement-mode' designs, he adds. Velox has already developed 600V GaN Schottky diodes for consumer and power supply applications that are in the final stages of development before the transition to production.

"The ATP funding will significantly accelerate GaN FETs development at Velox," Hierl adds. "It gives us an opportunity to bring a second GaN-based product to the market following the introduction of GaN-based Schottky diodes, and we look forward to using the GaN growth and fabrication skills mastered on GaN diodes to advance the GaN-based FETs under this NIST-funded program."

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

## SiGe BiCMOS used in first 100Gb/s optical network ICs

Infinera Corp of Sunnyvale, CA, USA, which makes InP-based photonic integrated chips and digital optical communications systems, has used the SBC18QTD 0.18µm SiGe BiCMOS process of wafer foundry Jazz Semiconductor of Newport Beach, CA, USA in the design of the first 100Gb/s ICs for service provider networks.

The SiGe BiCMOS process enables the integration required to develop electronic components for Infinera's InP-based Digital Optical Networks architecture, which is designed to be more flexible, simpler, and quicker to deploy than conventional dense wavelength division multiplexing (DWDM) systems. The system gives service providers greater capacity, scalability, flexibility, reliability and intelligence, Infinera claims. The Digital Optical Network architecture's key building block, the DTN,

has won service provider customers for long-haul and metro networks worldwide since its launch in 2004.

The SBC18QTD process offers next-generation solutions for low-power, integrated wireless and optical products that require high-performance bipolar transistors, high-quality passives and 3.3V CMOS FETs suitable for moderate levels of mixed-signal and logic integration, Jazz claims. The DTN platform is built on Jazz's 0.18µm analog/RF CMOS baseline process and includes two bipolar NPN transistors, 3.3V CMOS, lateral and vertical PNP transistors, 2fF/µm<sup>2</sup> metal-insulator-metal (MIM) capacitors, resistors (poly, Nwell and metal), and high-Q inductors. Options include deep trench isolation, Schottky diode, varactors, triple well, a stacked 4fF/µm<sup>2</sup> MIM capacitor, four metal layers, and thick top metal.

"Jazz process technologies are well-suited for our complex, highly advanced optical systems," says Infinera's chief marketing and strategy officer David Welch.

"Our multi-channel approach requires high levels of integration at high speed and low power, and the 0.18µm SiGe BiCMOS technology has been a good fit," he adds. "Their robust design kits and tools have allowed us to bring this product to market quickly."

"Customers like Infinera can take advantage of our high-performance SBC18 platform to achieve aggressive performance and power consumption specifications as well as fast time-to-market for differentiated, highly integrated products," said Marco Racanelli, Jazz's VP of technology and engineering.

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



## Raytheon awarded \$6.5m DARPA COSMOS contract for integration of compound semiconductor materials on Si

The US Office of Naval Research has awarded Raytheon Company of Waltham, MA, USA a \$6.5m contract to develop affordable, high-performance ICs for electronic-driven military systems.

The US Defense Advanced Research Projects Agency (DARPA) is funding the contract as part of its Compound Semiconductor Materials on Silicon (COSMOS) program, which is managed by Dr Mark Rosker of DARPA's Microsystems Technology Office (MTO) in Arlington, VI.

A Raytheon-led team will integrate high-performance compound semiconductors with low-cost commercial complementary metal oxide semiconductor (CMOS) silicon wafers to improve cost-benefit performance compared with either technology on its own.

COSMOS aims to culminate in the demonstration of a heterogeneously

integrated 16-bit analog-to-digital converter (ADC) through placing compound semiconductor and silicon-based transistors within a 5µm proximity, with  $\leq 5\mu\text{m}$  minimum pitch of the heterogeneous interconnect vias and yield of  $\geq 99.99\%$  of the heterogeneous interconnects.

"The objective is to develop a high-resolution analog-to-digital converter with low power consumption. However, the benefits of the program go significantly beyond the specific objective," says Dr Katherine Herrick, Raytheon Integrated Defense Systems (IDS) program manager. "The processes lead to advanced low-cost analog and digital, microwave and millimeter-wave integrated circuits with applications for next-generation radar, communications and electronic warfare systems."

Teaming with Raytheon IDS on the COSMOS project are Raytheon Systems Ltd in Glenrothes, Scotland, UK; Teledyne Scientific Imaging Company in Thousand Oaks, CA; Massachusetts Institute of Technology in Cambridge, MA; Paradigm Research LLC in Windham, NH; IQE Inc in Bethlehem, PA; engineered substrate manufacturer SOITEC in Grenoble, France; and Silicon Valley Technology Center in San Jose, CA.

"Our team's process of directly growing a compound semiconductor on a uniquely engineered silicon substrate provides a new technical approach that is creating a class of integrated circuits that will enable more affordable systems for the warfighter," says Mark Russell, vice president IDS Engineering.

[www.darpa.mil/MTO/Programs/cosmos](http://www.darpa.mil/MTO/Programs/cosmos)  
[www.raytheon.com](http://www.raytheon.com)

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## Multi-stage LDMOS RFICs for 2.7 & 3.5GHz WiMAX PAs

At WiMAX World USA 2007 in Chicago, Freescale Semiconductor of Austin, TX, USA introduced three high-power LDMOS silicon RFICs that extend its portfolio to the two primary bands used by WiMAX worldwide (2.7GHz and 3.5GHz). As well as reducing cost, form factor and parts count in RF power amplifiers for WiMAX base-stations, the firm claims, the devices are engineered to also increase performance and reliability compared with amplifiers using discrete RF power transistors.

The parts are the first RFICs available in over-molded plastic packages to operate at these frequencies, Freescale claims, enabling them to leverage cost and mechanical stability advantages. They are also the first such devices to integrate multiple gain stages into a single over-molded plastic packaged device, reducing cost, size and complexity.

The MW7IC2725N and MW7IC2750N RFICs (with output powers of 25W and 50W) operate at 2.3–2.7GHz, and the 25W MW7IC3825N operates at 3.4–3.6GHz. Working from a

28–32V<sub>dc</sub> supply, all three use Freescale's seventh-generation high-voltage (HV7) LDMOS process technology, which has been deployed in discrete FETs as well as in RFICs for wireless applications operating at 900MHz and 2GHz.

RF power amplifiers employed in WiMAX base-stations typically require three or four stages of amplification, delivered by discrete RF power transistors to achieve the desired output power. Instead, by integrating two gain stages in a single package, RFICs reduce the number of devices required.

In most cases, the higher RF output power of the RFICs allows elimination of the pre-driver stage in WiMAX. The devices can also be used along with discrete LDMOS FETs to produce even higher RF output power, says Freescale.

The RFICs can further reduce cost since the capacitors, inductors and resistors required on the circuit board are integrated within the device to provide the same inter-stage impedance matching networks,

minimizing board space and cutting design complexity, says Freescale. System cost savings are further compounded when combined with the inherent cost savings of about 25% provided by the over-molded plastic packaging versus current air-cavity packages, the firm adds.

"WiMAX is a very promising technology, but it faces strong competition from existing wireless services, making it essential that WiMAX infrastructure equipment be as cost-effective as possible," says Gavin P. Woods, VP and general manager of Freescale's RF Division. "These RFICs can play a key role in this critical cost reduction."

With the use of over-molded plastic packaging, the RFICs are designed to also achieve tight mechanical tolerances, enabling designers to maintain the high manufacturing yields needed at WiMAX frequencies (difficult to accomplish using traditional discrete devices).

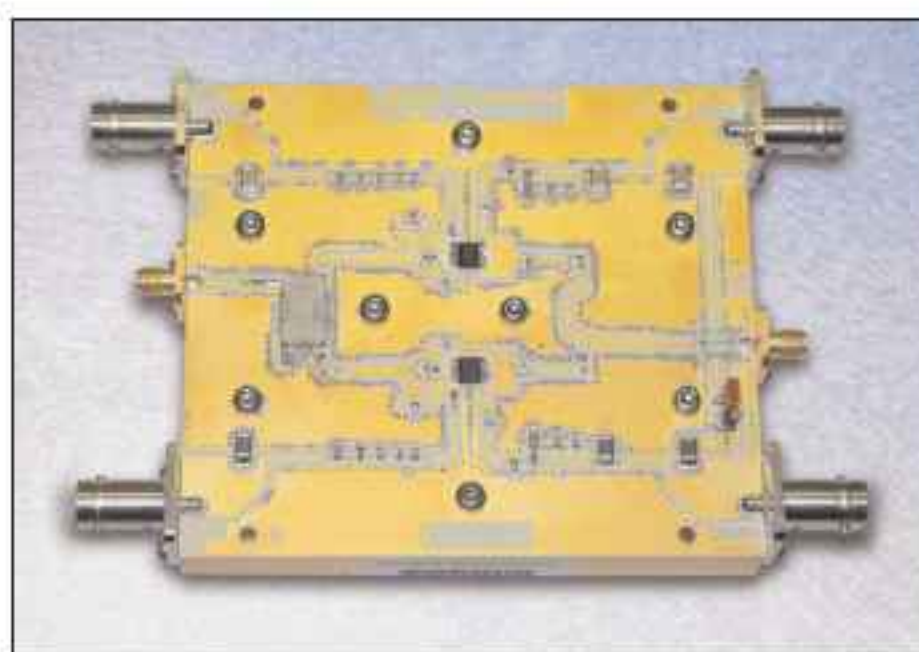
The devices are sampling now, for full production in Q1/2008.

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

## Nitronex unveils broadband Doherty PA for WiMAX

Nitronex of Durham, NC, USA has partnered with Prescient Wireless of Itasca, IL, USA (a supplier of RF products and design services to the wireless and avionics industries) to design a gallium nitride on silicon (GaN-on-Si) broadband Doherty power amplifier for WiMAX applications. Based on Nitronex's existing NPT25015 power transistor, the design provides 6W of linear output power from 2.5GHz to 2.7GHz while achieving greater than 35% efficiency, 10dB gain, and less than 2.0% error vector magnitude (EVM) with digital pre-distortion.

"The inherent low output capacitance and high efficiency of GaN-on-Si are a natural fit for the Doherty architecture," says marketing director Ray Crampton. "Carriers are asking for higher efficiency and broader bandwidth at the same



**Nitronex's HD060 reference design for its NPT25015 power transistor.**

time," he adds. "We are currently collaborating with Prescient Wireless on a reference design based on our 125W NPT25100. Preliminary results show a similar level of performance is achievable at much higher output powers."

Typical performance numbers were taken using a mobile WiMAX waveform defined as a single-carrier

orthogonal frequency-division multiplexing access (OFDMA) 64-QAM 3/4 with a 10MHz channel bandwidth. Output power of 6W is achieved with a 9.5dB peak to average ratio (PAR) @ 0.01% probability on the CCDF (complementary cumulative distribution function) during the transmit portion of a 50% duty cycle true time delay (TTD) signal.

The reference design consists of the schematic, bill of materials, circuit board layout files, detailed performance data, and documentation describing the design. Built and tested Doherty application boards are available.

Both the reference design and a design based on the 125W NPT25100 with preliminary results were displayed at WiMAX World USA 2007 in Chicago, IL (25-27 September).

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



## VT raises \$3.3m for SiGe WiMAX ICs

VT Silicon, a startup based at the Advanced Technology Development Center (ATDC) of Georgia Institute of Technology in Atlanta, GA, has received a \$3.3m Series A round of financing from Silicon Valley-based Menlo Ventures. The funding will help the firm to design and produce prototypes of its new 'intelligent power amplifier' silicon-germanium ICs for mobile WiMAX-enabled devices.

WiMAX is intended to provide much higher bandwidth and broader coverage for mobile devices supporting applications such as streaming video. US telecom network operator Sprint Nextel Corp plans to roll out WiMAX service in large metropolitan areas in 2008, spurring supply of the corresponding chipsets. However, this demands engineering innovation, as the new WiMAX mobile devices will require more power, while being less forgiving of the distortion caused by nonlinear effects that occur at higher power levels, notes VT's CEO Mike Hooper. "They [the new devices] are going up on the complexity curve because they are trying to get more and more information into the same bandwidth."

Meeting the technical demands in potentially high-volume devices will require new levels of optimization, in addition to new techniques for controlling distortion. "What you want to do is build a power amplifier that is more linear for higher power levels," Hooper says. "That can give you more range, better battery life and compensate for other issues that you associate with higher performance," he adds. "Since power amplifiers require a balance of power, linearization, efficiency and other factors, you have to optimize each of these for the specific application where they will be used."

For its chips, VT has developed patent-pending linear enhancement technology (LET) which should permit the higher power levels used by WiMAX devices. The technology is designed to boost power amplifier range, decreasing the distortion in signals while improving battery life.

"This funding will allow us to take the linearization techniques we have already proven in a test chip and apply them to commercial chips within the next 9-12 months," says Hooper. "Our plan is to be shipping samples to customers early next year and to begin ramping to production by the middle of next year."

To justify high-volume consumer applications, the firm is fabricating its amplifiers on lower-cost SiGe instead of GaAs (used in most existing WiMAX PAs). Since SiGe can support both conventional bipolar transistors as well as CMOS, LET can be implemented on the same chip as the PA, providing cost and design simplicity advantages, the firm says.

Hardware costs will be significant for WiMAX (just one of the technologies vying for dominance in next-generation mobile devices). "If chipsets can be produced inexpensively compared to current WiFi devices, WiMAX can supplant WiFi and become the leading technology for mobile broadband applications," Hooper says.

"SiGe affords us the ability to put very sophisticated control and intelligence within the PA because SiGe can combine both CMOS (low-power control circuitry) and bipolar transistors in one fabrication process," Hooper notes. "It gives us the ability to get fairly complex, allowing us to make intelligent power amplifiers."

But designers have to compensate for the relatively low RF power levels produced by most SiGe power ICs. "We have some proprietary technologies to get the power we need," says Hooper. "We can be competitive with GaAs on power levels."

VT initially plans to launch two PAs operating at 2.5 or 3.5GHz for the WiMAX market, made by foundry Jazz Semiconductor Inc in Newport Beach, CA, USA. As a step toward volume production, it will work with customers to create a reference design for each prototype chip.

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

## SiGe demos WiMAX RF front-end modules

At WiMAX World USA 2007 in Chicago on 25-27 September, SiGe Semiconductor of Ottawa, Canada demonstrated technology for a series of RF front-end modules that combine SiGe's WiMAX power amplifier architecture with its expertise in multi-chip module integration, allowing improved battery life and transmission range in WiMAX-enabled consumer electronics.

The series is due to start rolling out in early 2008 with sampling of the SE7261, a front-end module designed for laptop computers. SiGe's roadmap also includes chip-scale front-end modules for small handheld devices including personal digital assistants and cellular handsets, as well as higher-output-power modules for customer premises equipment.

Each module will incorporate all of the circuitry required between the transceiver and antenna (including the power amplifier, power detectors, filters, switches, matching and bias components) and deliver over 20% efficiency at 24dBm output power.

These modules will allow manufacturers to support WiMAX services without compromising battery life, claims senior systems engineer Darcy Poulin. "In addition, providing all of the RF circuitry in a single, fully tested module simplifies design, reduces bill of materials for lower cost and board area, and speeds time-to-market."

"WiMAX is a key step in the convergence of different wireless capabilities into mobile devices for the future," says director of strategy Stefan Fulga. "Our strategy addresses the technical challenges associated with this, including how to support WiMAX, WiFi, GNSS and cellular in portable devices while still meeting expectations for battery life, performance and price."

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



## Nitronex expands Richardson distribution to Americas and Asia

Nitronex of Durham, NC, USA, which makes GaN-on-silicon RF power transistors for the commercial wireless infrastructure, broadband and military markets, has expanded its partnership with Richardson Electronics Ltd of La Fox near Chicago, IL, USA to include distribution in the Americas and all of Asia. The agreement should increase Nitronex's sales and support services for its customers throughout these regions.

Richardson will support all Nitronex RF products, including its family of 2.5 and 3.5GHz WiMAX products (the NPT25015, NPT35015, NPT35050 and the NPT25100), as well as its family of broadband power transistors (the NPTB00025 and NPTB00050).

"We have expanded our partnership with Richardson to provide superior sales support and reduce lead times for our customers in the Americas and throughout Asia," says Nitronex's VP sales & marketing Chris Rauh. "These markets are a critical growth area for Nitronex, and our relationship with Richardson Electronics reflects our commitment to these customers," he adds. "Nitronex is particularly pleased with Richardson's investment in experienced RF power application engineers and lab facilities."

"We have had a very positive response from our early adopters in Japan," says Richardson's VP of wireless and broadband communications Chris Marshall. "We have already seen that the combination of GaN performance, competitive pricing based on Nitronex' silicon substrate technology, and the ability to deliver product now is resulting in immediate demands and rapid sales growth."

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

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

## Toshiba presents GaN power FET with record Ku-band output power

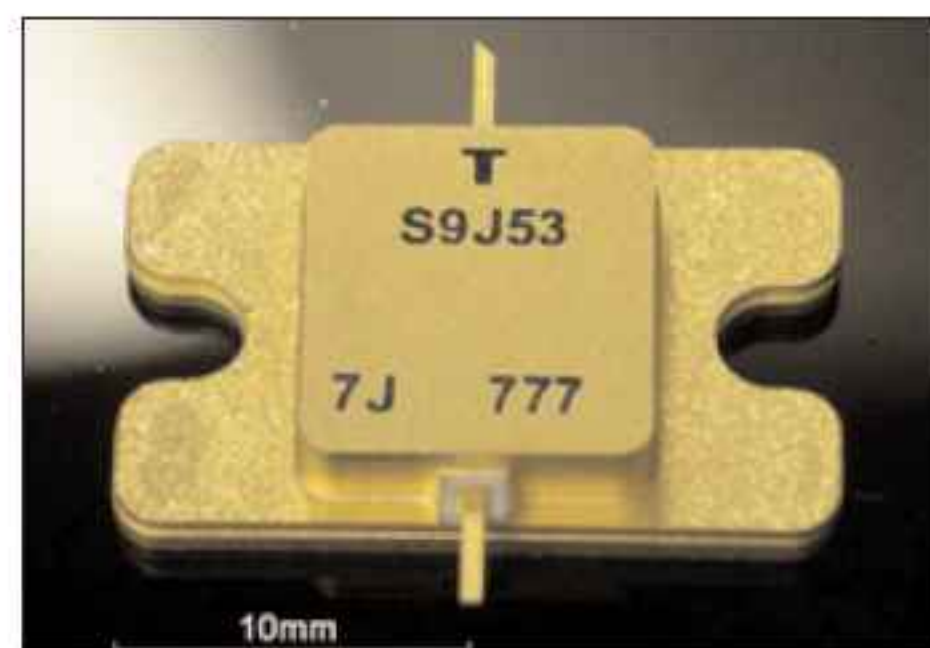
At European Microwave Week 2007 in Munich, Germany, Tokyo's Toshiba Corp presented a new GaN power field-effect transistor with record output power in the Ku-band (12–18GHz) frequency range of 65.4W at 14.5GHz. Key characteristics include linear gain of 8.2dB, a drain voltage of 30V, a chip size of 3.4mm x 0.53mm, and a package size of 21.0mm x 12.9mm.

The main application will be in base-stations for radar and satellite microwave communications, which carry high-capacity signals (including high-definition broadcasts). Ever-increasing communications flows are driving demand for higher output power in signal amplifying devices, as is the development of more powerful radar systems.

Advances in Ku-band microwave amplifiers focus on replacing electron tubes (conventionally used at this bandwidth) with semiconductors. In particular, both for the replacement of electron tubes and for new equipment, Toshiba says demand is growing steadily for GaN power FETs, which offer advantages over established gallium arsenide devices in heat dissipation and high-power performance characteristics at high microwave frequencies.

Toshiba directed its initial efforts in GaN power FETs for microwave frequency applications to developing and marketing devices for the 6GHz band (in 2005) and the 9.5GHz band (in 2006), achieving record output power at those frequencies. The firm has now extended its line-up to 14.5GHz.

The record performance of the new power FET was achieved by optimizing the composition and thickness of the AlGaN and GaN layers in its HEMT structure (formed on a highly heat-conductive SiC substrate). To ensure high performance at Ku-band frequencies, Toshiba applied a shorter gate length of below 0.3 $\mu$ m, and optimized the shape of each electrode and element configuration



**Toshiba's Ku-band GaN power FET.**

to enhance heat dissipation.

However, as gate lengths shorten, suppression of current leakage at the gate electrode is essential to achieve high performance. Toshiba therefore applied a unique overcoat process around each gate electrode, contributing to the suppression of leakage to just a thirtieth of the firm's conventional approaches. To ensure stable processing of gate lengths below 0.3 $\mu$ m, electron-beam exposure is used.

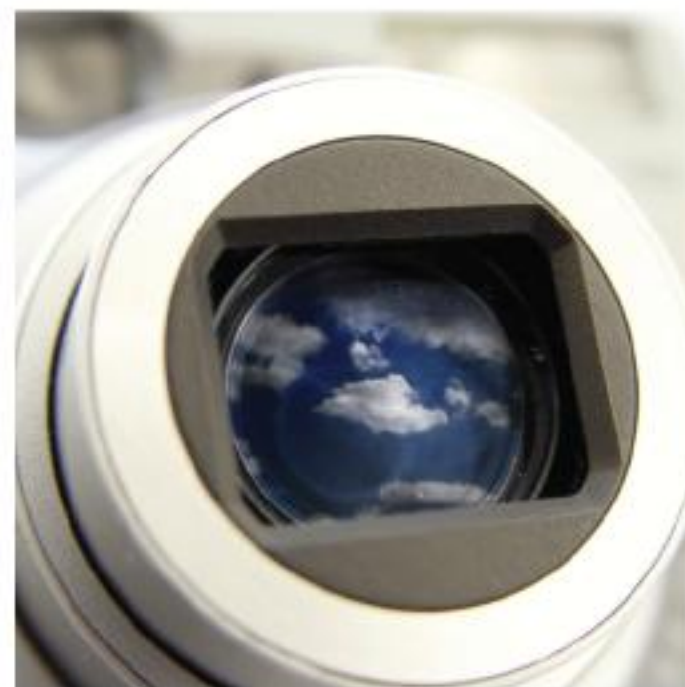
Also, to reduce parasitic inductance and hence improve high-frequency performance, Toshiba replaced source wire bonding by developing a unique technology for via holes, which form a connection through the chip from the front-side surface source electrode to the back-side ground electrode. Forming via holes in SiC substrate, recognized as a highly demanding process, is a breakthrough in development of the new FET, Toshiba claims. The firm also improved the overall design of the matching circuit for practical application at Ku-band frequencies.

Due to the demand for GaN power FETs for radar and satellite microwave communication base-stations, Toshiba is targeting early commercialization of the new Ku-band device. The firm plans to start sample shipment by the end of 2007 and to enter mass production by the end of March 2008.

Toshiba says it is also developing GaN power FETs for the 18–30GHz frequencies (Ka-band) and beyond.

[www.toshiba.co.jp](http://www.toshiba.co.jp)





## Advanced CVD and ALD Precursors

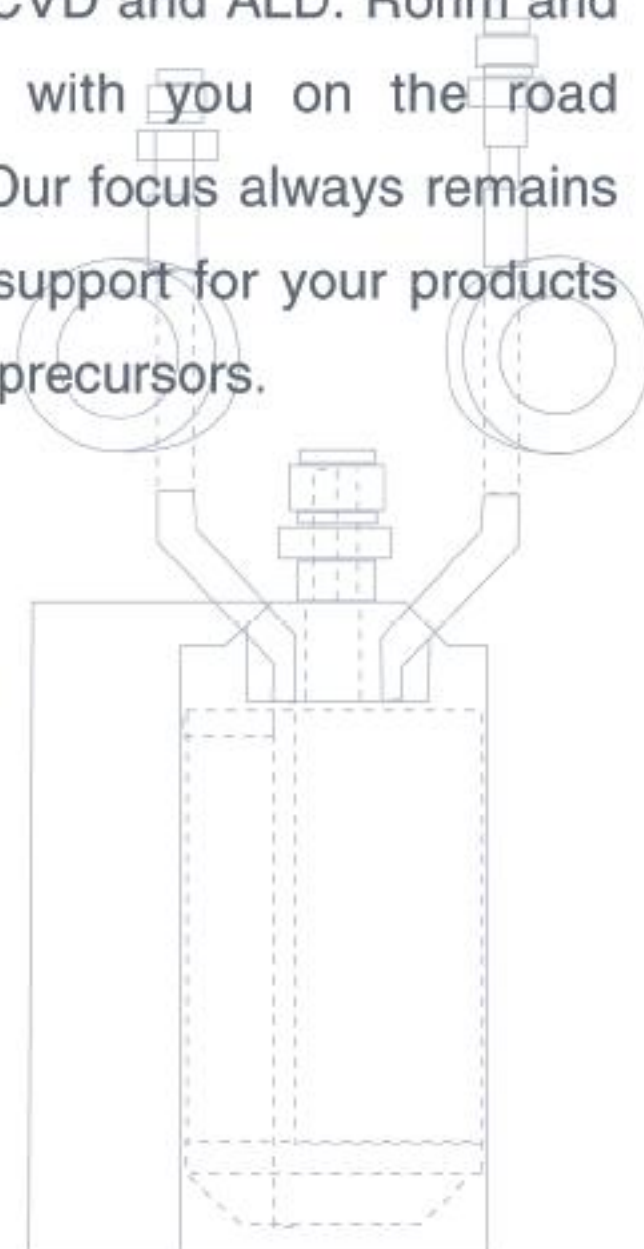
For more than 30 years Rohm and Haas Electronic Materials has delivered industry-leading precursors for CVD used in state-of-the-art compound semiconductor applications around the world. Now silicon semiconductor technology is poised for a leap forward with the promise

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## IN BRIEF

### Epichem formally changes name to SAFC Hitech

As of 1 October, the SAFC Hitech name has formally come into effect, says the business' president Barry Leese (former managing director and co-founder in 1983 of Epichem Group Ltd of Bromborough, UK, which manufactures precursors for metalorganic chemical vapor deposition and atomic layer deposition).

Epichem was acquired by chemical supplier Sigma-Aldrich Corp in February for \$60m to expand the materials science offering of its custom fine-chemical manufacturing and services arm, SAFC of St Louis, MO, USA.

The name change means that Epichem Ltd becomes SAFC Hitech Ltd, Epichem Inc becomes SAFC Hitech Inc, Epichem Asia Co Ltd becomes SAFC Hitech Taiwan Co Ltd, Epichem Shanghai Co Ltd becomes SAFC Hitech Shanghai Co Ltd, and Epichem Korea Ltd becomes SAFC Hitech Korea Ltd.

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

### NTT Photonics Labs orders CCS reactor for InP devices

Japan's NTT Photonics Laboratories ordered a Close Coupled Showerhead (CCS) Flip Top MOCVD system from Aixtron AG of Aachen, Germany in Q2/2007. Delivered in 3x3" wafer configuration, the system will be used to develop InP-based optical and microelectronic devices.

Dr Hiroaki Takeuchi, executive manager of the Advanced Optoelectronics Laboratory at NTT Photonics, said: "We have been very pleased with our previous CCS system which was for GaN electronic device development."

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

## STS centralizing European operations in UK as part of cost cutting

Plasma etch and deposition equipment supplier Surface Technology Systems plc (STS) says that it intends to close its local office in Ulm, Germany. The customer service function will now be coordinated through the firm's headquarters in Newport, Wales, UK.

"Our customers remain our top priority," emphasizes CEO John Saunders. "We have decided to centralize our European operation to ensure a more rapid direct response to customers. The decision will also provide customers access to the entire Customer Support organization's resource," he adds. "Centralising the support offered in Europe gives STS three strategic locations for spare parts and service — Taiwan, USA and the UK. Not only will our customers benefit from this decision, but our agents that play an important role in STS will see the benefits

throughout the world."

"It has become clear that, to improve the overall business efficiency, we had to centralize our spare parts and service functions," Saunders continues. "By concentrating our efforts on three locations, we hope to put STS in a more competitive position worldwide."

● On 27 September, non-executive chairman Nigel Randall stated that STS' financial results for first-half 2007 had been disappointing. Order intake was below expectations, despite a significant recovery in June. Also, the weakness of the US dollar contributed to the poor results.

STS had previously said in April that it was considering the implementation of a cost-reduction programme to reflect the anticipated level of trading.

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

## Sumitomo buying back STS

In late August, to regain control of deposition and etch system maker Surface Technology Systems plc of Newport, Wales, UK, Japan's Sumitomo Precision Products Co Ltd (SPP), which currently own 63% of the firm's shares, made an offer to buy out the other shareholders. The offer of 11.5 pence per share (a premium of about 48.4% as of 23 August) valued STS' total ordinary share capital at about £3.67m.

SPP was previously sole owner from its acquisition of STS in March 1995 until the firm was floated on the London Stock Exchange at the end of 2000. SPP now aims to cancel trading of the shares on the LSE and re-register STS as a private company.

"For a number of years STS has been dependent on the financial support of SPP," says STS' non-executive chairman Nigel Randall.

"The level of financial support has had to increase significantly in the current year. The independent directors now believe the future development of the company's business will be better facilitated as a private company and as a wholly owned subsidiary of SPP," he adds.

STS' independent directors (who own 0.53% of the ordinary share capital) said that they consider the terms of the offer to be fair and reasonable, and recommended that shareholders accept the offer. The acquisition process is now being implemented.

"The SPP directors believe there are considerable benefits to STS, such as enhanced critical mass and financial resources, in it being developed and funded as a wholly owned subsidiary and privately traded business," says SPP's executive VP Hisao Shiotani.

[www.spp.co.jp](http://www.spp.co.jp)



## OIPT launches OpAL ALD system and wins five orders

Oxford Instruments Plasma Technology (OIPT) Ltd of Yatton, UK has launched the OpAL atomic layer deposition (ALD) system for advanced silicon-based semiconductor and other nanotechnology applications.

Complementing the firm's load-locked FlexAL ALD process tool (launched in 2006), the OpAL offers a compact open-loading system based on OIPT's Plasmalab80Plus process tool platform. Capable of processing full 200 mm (8") wafers down to small wafer pieces, the OpAL is suitable for both academic and industry R&D.

The base thermal ALD system can be upgraded with a remote plasma ALD source, which allows for the widest possible choice of precursor chemistry with enhanced film quality and enables low-temperature ALD processes while the remote source maintains low dam-

OIPT's new open-loading OpAL ALD system.



age. Liquid or solid precursors can be heated to 200°C and bubbled with argon, and are housed inside an extracted stainless-steel cabinet (providing safe management of hazardous precursors) within the tool to minimize delivery line length.

OIPT has already received five orders from customers in Europe, Asia and the USA, for both its thermal OpAL-T and combined thermal/plasma OpAL-RPT systems.

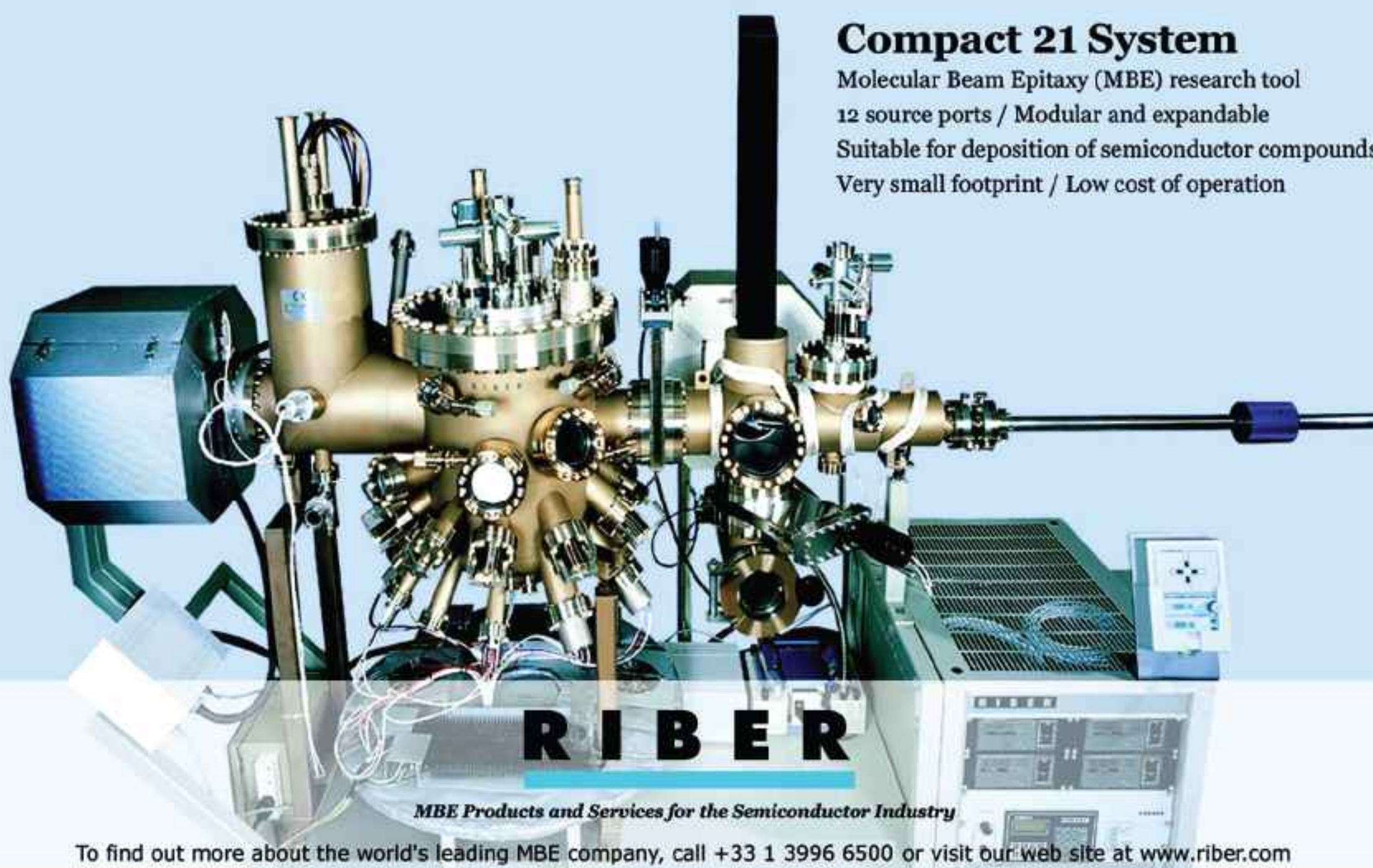
"OpAL offers a high-quality entry route into atomic layer deposition with an excellent range of process capability and uncompromised tool standards," says ALD applications specialist Chris Hodson. "Our intention has always been to offer our customers a family of ALD solutions, and together the OpAL and FlexAL tools give choice with trusted and reliable hardware platforms."

[www.oxford-instruments.com/opal](http://www.oxford-instruments.com/opal)

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## PolyGaN targets expanding product portfolio

Kyma Technologies Inc has added a new, denser form of ultra-high-purity polycrystalline GaN targets to its PolyGaN product line.

Kyma says its PolyGaN products are manufactured using a proprietary process that leverages many of the features of the firm's patented native GaN boule growth process, and claims that these are the highest-purity polycrystalline GaN products available.

Compared to PolyGaN pellets (99.99%), which Kyma has offered since 2005, the new product is a lower-surface-area, denser and higher-purity form of PolyGaN. The PolyGaN targets have purity levels of 99.999% or higher and are available in cylindrical disk form with diameters of 2", 3" and 4" at thicknesses of 2–10mm.

The targets represent a new standard in polycrystalline GaN in terms of purity, density, and low surface area, which provides benefits in terms of greater ease of handling and improved purity and control in their processes, claims chief operating officer Ed Preble.

Applications include:

- targets for plasma sputtering of III-nitride thin films;
- targets for pulsed laser deposition (PLD) of III-nitride device layers;
- feedstock for ammonothermal growth of bulk crystalline GaN;
- source material for sublimation growth of bulk crystalline GaN.

"Our original PolyGaN pellet products have already been successfully demonstrated in multiple processes by multiple customers," says CEO Keith Evans.

"While our primary supply model is to be a direct supplier, we are open to strategic arrangements in which we can help our customers develop their own manufacturing capacity," Evans adds.

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

## Kyma partners with Caracal and EOC to improve nonpolar GaN substrates

In response to growing demand for low-defect-density nonpolar native GaN substrates, Kyma Technologies of Raleigh, NC, USA has partnered with Caracal Inc of Ford City, PA (which develops crystalline SiC technology) and the Penn State Electro-Optics Center (EOC) of Freeport, PA to help it work through a backend process bottleneck.

Kyma was spun out of the Materials Science and Engineering Department of North Carolina State University (NCSU) in 1998. Products include ultralow-defect-density native (free-standing) GaN in customer-defined orientation including polar (c-plane Ga-face or N-face) and non-polar (a-plane and m-plane), GaN and AlN templates grown on sapphire and other substrates, and ultrahigh-purity polycrystalline GaN.

"We joined EOC's Electro-Optics Alliance (EOA) early in 2006 and have enjoyed a number of very positive collaborative interactions with EOC ever since," says Kyma's CEO, Dr Keith Evans. EOC's Dr Bill Everson has experience in single-crystal semiconductor processing across a

broad spectrum of materials, he adds. "Our relationship with Caracal began earlier this year and is already very valuable, due to the energy and experience of Dr Olle Kordina, Caracal's founder and CTO, and Dr Igor Agafonov, Caracal's semiconductor processing expert."

"We are pleased to be able to respond to our customers' growing needs for high-quality nonpolar GaN with improved crystalline orientation control," adds Kyma's chief operating officer Ed Preble. "Our partnerships with both Caracal and EOC have proven to be of great value in terms of increasing our effective manufacturing capability and capacity."

● Dr Drew Hanser, Kyma's CTO and VP of business development, gave an invited talk on the firm's nonpolar GaN substrate manufacturing technology at the 5th International Workshop on Bulk Nitride Semiconductors (IWBNS-V) in Salvador, Bahia, Brazil, 24–28 September.

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

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

[www.electro-optics.org](http://www.electro-optics.org)

<http://iwbns.jp>

## Paskova recruited as chief scientist

Nitride substrate maker Kyma Technologies has recruited Dr Tanya Paskova as chief scientist.

An expert in GaN crystal growth and characterization, Paskova has collaborated with Kyma since early 2006, resulting in several scientific journal articles and conference presentations documenting the structural properties of the firm's native nonpolar GaN substrate products.

Previously, Paskova was assistant professor at Sofia University in Bulgaria and held posts as a visiting lecturer and an associate professor at Linköping University, Sweden and University of Bremen, Germany. In professor Bo Monemar's group at Linköping, Paskova focused on developing GaN epitaxial growth

and studied the basic properties of nitride materials and structures. She has authored over 200 scientific papers, reviews and chapters in journals and books.

"The addition of Tanya to our team represents an exciting opportunity to build upon our ongoing efforts to improve our current products, to develop new products, and to grow our portfolio of strategic partnerships," says Drew Hanser, VP business development and CTO.

"She is not only an expert in crystalline GaN materials, but also a true scientific leader that has developed highly productive collaborative research partnerships around the world," added president and CEO, Keith Evans.



# TDI demonstrates prototype 2-inch nonpolar GaN substrates

Nitride material manufacturer Technologies and Devices International Inc of Silver Spring, MD, USA says that it has demonstrated prototype 2" diameter nonpolar a-plane GaN-on-sapphire substrates.

The new product was featured at the 7th International Conference on Nitride Semiconductors (ICNS 2007) in Las Vegas (16–21 September).

Nonpolar GaN substrates are needed to fabricate GaN light-emitting devices (LEDs and laser diodes) with improved efficiency and output power, especially for devices emitting in the green spectral region. Most commercial GaN-based devices are currently produced on crystalline substrates with polar surface crystallographic orientations parallel to the c-crystallographic plane which, in GaN, is not optimal for optoelectronic applications due to piezoelectric polarization effects. In contrast, GaN devices fabricated on other crystallographic (nonpolar or semipolar) surfaces (such as the a-plane) have previously been demonstrated to show great promise for device improvement.

TDI says that it has developed a process to deposit a-plane GaN



TDI's 2-inch nonpolar a-plane GaN.

layers with improved surface and crystal quality on sapphire to produce commercial nonpolar GaN substrate materials. The product consists of a GaN layer several microns thick with a-plane orientation deposited on r-plane sapphire substrates. GaN deposition is performed using the firm's proprietary hydride vapor phase epitaxial (HVPE) process and equipment.

"Governed by a strong demand from TDI customers for nonpolar GaN substrates, we have introduced a novel HVPE process to fabricate a-plane GaN materials with substantially improved properties while at the same time avoiding expensive technological steps to keep production cost low," says president and

CEO Vladimir Dmitriev. "This allows us to offer c-plane and a-plane GaN products in commercial quantities at similar price levels," he adds.

The product is now available in test quantities in two configurations: (i) with a GaN as-grown surface and (ii) with a GaN epi-ready polished surface. Full-scale production of a-plane GaN template substrates is scheduled for first-quarter 2008.

"Deposition of high-quality GaN materials with nonpolar crystallographic orientations is technically challenging," adds R&D director Alexander Usikov. "Significant process improvements at TDI now allow us to provide our customers with a-plane GaN substrates, which will make development and commercialization work on nonpolar GaN light-emitting devices much easier," he promises.

"We are working on the next generation of nonpolar substrates and device structures, and recently have succeeded in the fabrication of R&D samples of a-plane and m-plane InGaN materials on nonpolar GaN templates and bulk GaN substrates [presented at ICNS]," Usikov adds.

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

## TDI starts production of 100mm GaN and AlN epiwafers

TDI says that its 4-inch (100mm) GaN and AlN epitaxial wafers are now in production and being shipped to customers.

The new wafers are manufactured by TDI's proprietary, patented hydride vapor phase epitaxial (HVPE) process and multi-wafer equipment.

The GaN wafers consist of a 7–12 $\mu$ m thick GaN layer deposited on (0001) c-plane 4-inch sapphire substrates. Target applications are low-defect substrates for blue, green and white GaN-based LEDs.

The AlN wafers consist of a

10–30 $\mu$ m thick electrically insulating AlN layer deposited on (0001) 4-inch SiC substrates. Target applications are low-defect electrically insulating substrates for development and production of high-power AlGaIn-based HEMTs.

"There is a clear trend in the industry to develop and commercialize GaN-based devices on large substrates," says president and CEO Vladimir Dmitriev. "TDI's customers are rapidly moving from the industry-standard 2-inch epitaxial wafers to 3-inch and now to 4-inch

wafers. TDI has successfully expanded its manufacturing facility and deposition equipment to start volume production of 4-inch (100mm) GaN and AlN epitaxial products," he continues.

In addition, TDI is also on track to begin production of 6-inch epitaxial products in 2008, Dmitriev adds. "Volume production of large-area low-cost GaN and AlN substrates will tremendously benefit our customers in terms of device throughput, material yield, and reduced production cost."



# Rubicon files for \$100m IPO

Rubicon Technology Inc of Franklin Park, IL, USA, a vertically integrated manufacturer of monocrystalline sapphire material, wafers, and components for substrates and optical window applications, has filed a registration statement with the US Security and Exchange Commission (SEC) for an initial public offering on NASDAQ, aiming to raise up to \$100m.

Founded in 2000, Rubicon has raised nearly \$44m in venture capital funding since 2001 from firms such as Cross Atlantic Capital Partners, Gazelle TechVentures, KB Partners and River Cities Capital Funds. The firm's main product line is 2-4" sapphire wafers for LEDs and blue laser diodes. Also, it has developed 6" wafers for silicon-on-sapphire (SOS) RFICs, as well as products for military, aerospace, sensor and other applications. Rubicon says that it is also extending its technology to manufacture 8" and larger diameter products to support next-generation LED, RFIC and optical window applications.

Revenue has risen from \$8.95m in

first-half 2006 to \$15.45m in first-half 2007 (about 81% from products for manufacturing LEDs; and about 79% for Asia, 19% for North America, and 2% for Europe). Order backlog has risen from \$4.8m at the end of July 2006 to about \$41.7m at the end of July 2007 (with about 70% to be filled after the end of the year).

Rubicon plans to use the proceeds of the IPO for paying off the outstanding \$8.1m of a \$16m loan and security agreement with Hercules Technology Growth Capital Inc agreed in April, as well as for working capital and other general corporate purposes. Due to 'explosive' growth in the LED market and increasing demand for large-diameter sapphire wafers, in May Rubicon announced plans to expand its manufacturing capacity (by 25% before Q1/2008 and by 40% before the end of 2008) through adding new equipment at its plant in Franklin Park, IL, and opening a new facility in Bensenville, IL (with 30,000ft<sup>2</sup> of new production space complement-

ing its existing operation of more than 80,000ft<sup>2</sup>).

For the rest of 2007, Rubicon plans capital expenditures of about \$7m, mainly to increase manufacturing infrastructure and capacity, then \$12-17m in each of the next two years to support expected sales growth.

● Rubicon Technology has recruited William F. Weissman as chief financial officer, treasurer and secretary.

Previously, Weissman served in various capacities at global IT services firm Kanbay International (including chief financial officer, VP, executive VP and secretary). Responsibilities ranged from general management functions and implementing strategic initiatives to facilitating the firm's international finance and taxation strategy and maintaining capital markets and banking relationships.

Weissman has also held positions with Temstar Inc (a subsidiary of Mark VII Inc), Lockheed Electronics (a subsidiary of Lockheed Corp) and AIRCO BOC (of BOC Group).

[www.rubicon-es2.com](http://www.rubicon-es2.com)

## CrystalQ and Aixtron develop 6-inch GaN-on-sapphire

Deposition reactor maker Aixtron AG of Aachen, Germany and sapphire wafer maker CrystalQ BV of Stadskanaal, The Netherlands have presented initial test results for a 6" (150mm) c-plane GaN-on-sapphire wafer. The development is a result of a joint R&D project started in mid-2005 within the framework of a European Union EUREKA collaboration.

Currently, the industry-standard wafer size is 2", and a limited group of high-end LED makers have switched to processing 3" or 4" wafers. The feasibility of higher throughput requires scale-up of existing technologies to 6" wafers, says CrystalQ, for which fabrication technology for 6" c-plane sapphire wafers needs to be developed that

ensures identical layer deposition results as for standard 2" and 4" diameters (e.g. high yield for LED chip manufacturing). However,

**The feasibility of higher throughput requires scale-up of existing technologies to 6" wafers**

Aixtron has developed a flexible AIX 2800G4 HT mass-production MOCVD deposition system that, as well as handling 2" wafers, can handle 6x6" sapphire wafers while ensuring optimum uniformity of epitaxial layer growth, it is claimed.

For the same purpose, CrystalQ has enhanced its proprietary chemical mechanical polishing

(CMP) process, with its tool design resulting in efficient handling and controllability of the roughness and flatness parameters of 6" c-plane sapphire substrates, the firm says. Effort has been made to reduce the edge-exclusion zone in order to optimize the number of LED chips per wafer. As a result, the standard deviation of the wavelength on the photoluminescence map of the substrate was 2.48nm (0.55%) without edge exclusion.

CrystalQ adds that the joint development project has also resulted in the implementation of a reclaim process for the reuse of 6" sapphire wafers, reducing operational costs for white LED makers.

[www.crystalq.nl](http://www.crystalq.nl)

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



# Sandia demos high-quality GaN on Aonex's A-GaN substrates

The US Sandia National Laboratories has demonstrated the growth of high-quality GaN on the A-GaN substrates of Aonex Technologies Inc, a subsidiary of Arrowhead Research Corp in Pasadena, CA, USA.

Aonex says its A-GaN substrates provide a way to reduce the cost of GaN-based devices while improving performance. According to recent studies by Strategies Unlimited, the market for such advanced substrates for GaN devices is expected to grow to more than \$440m by 2010. This growth will be driven strongly by the blue laser diode market, which Strategy Analytics expects to grow at a compound average annual growth rate of 103% to over \$1bn by 2011. Strategy Analytics also forecasts the LED market to grow from \$5.2bn currently to \$8.9bn by 2011.

The A-GaN substrates are intended to offer a low-cost replacement for bulk GaN substrates in blue laser manufacturing, and could enable improved design flexibility, leading to smaller devices and further cost savings. The firm claims that the substrates could also offer benefits for manufacturing blue LEDs (currently fabricated on sapphire and silicon carbide substrates, which give lower-than-desired device quality and yield). Using bulk GaN substrates instead can produce superior devices, but the substrate cost is prohibitively high. Aonex reckons that its A-GaN substrates could help break this trade-off between cost and performance by enabling the growth of high-performance device structures on reasonably priced substrates while simplifying the manufacture of high-efficiency, vertical devices.

The firm describes its A-GaN wafers as effectively veneers of bulk GaN wafers, offering high material quality at a lower price than bulk GaN. Each substrate consists

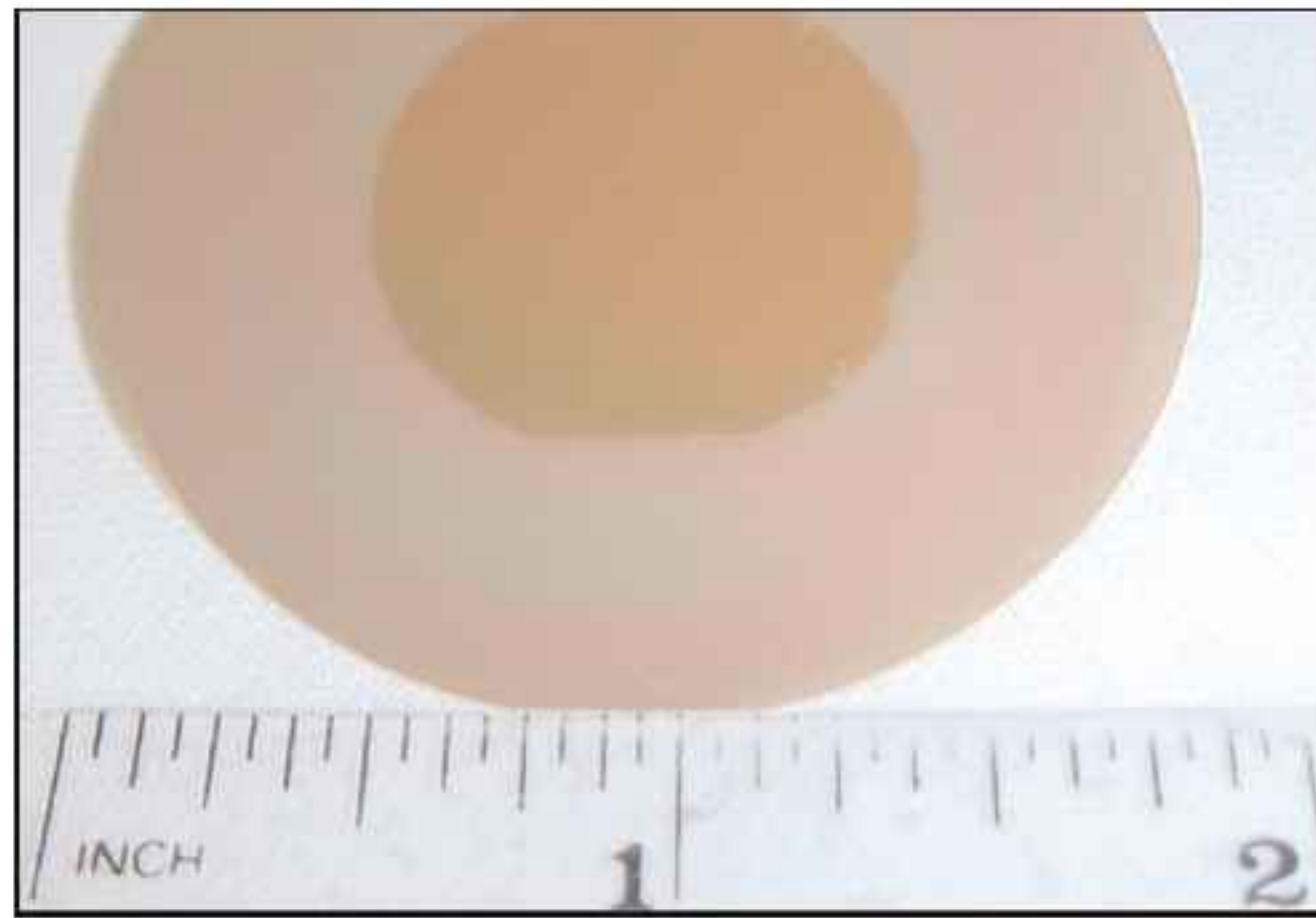


Photo of GaN growth on Aonex's A-GaN substrate.

of a thin, single-crystal layer of GaN (about 500nm thick) bonded to a low-cost polycrystalline AlN support wafer. The thin GaN layer provides the high-quality surface for device fabrication, while the AlN support material is chosen for its low cost, fracture resistance, process compatibility, and ease of removal following device growth.

The substrates are fabricated using a proprietary process to transfer thin layers of GaN directly

from bulk GaN substrates and onto the support material. These layers enable the growth of GaN with quality comparable to that of the original bulk GaN donor, the firm claims. Also, because multiple layers can be transferred from each bulk GaN donor wafer and used to form multiple substrates, the cost of A-GaN wafers could

be substantially lower than that of bulk GaN. Aonex has already demonstrated the transfer of 10 layers from a single substrate and expects to reach 20 layers or more in production.

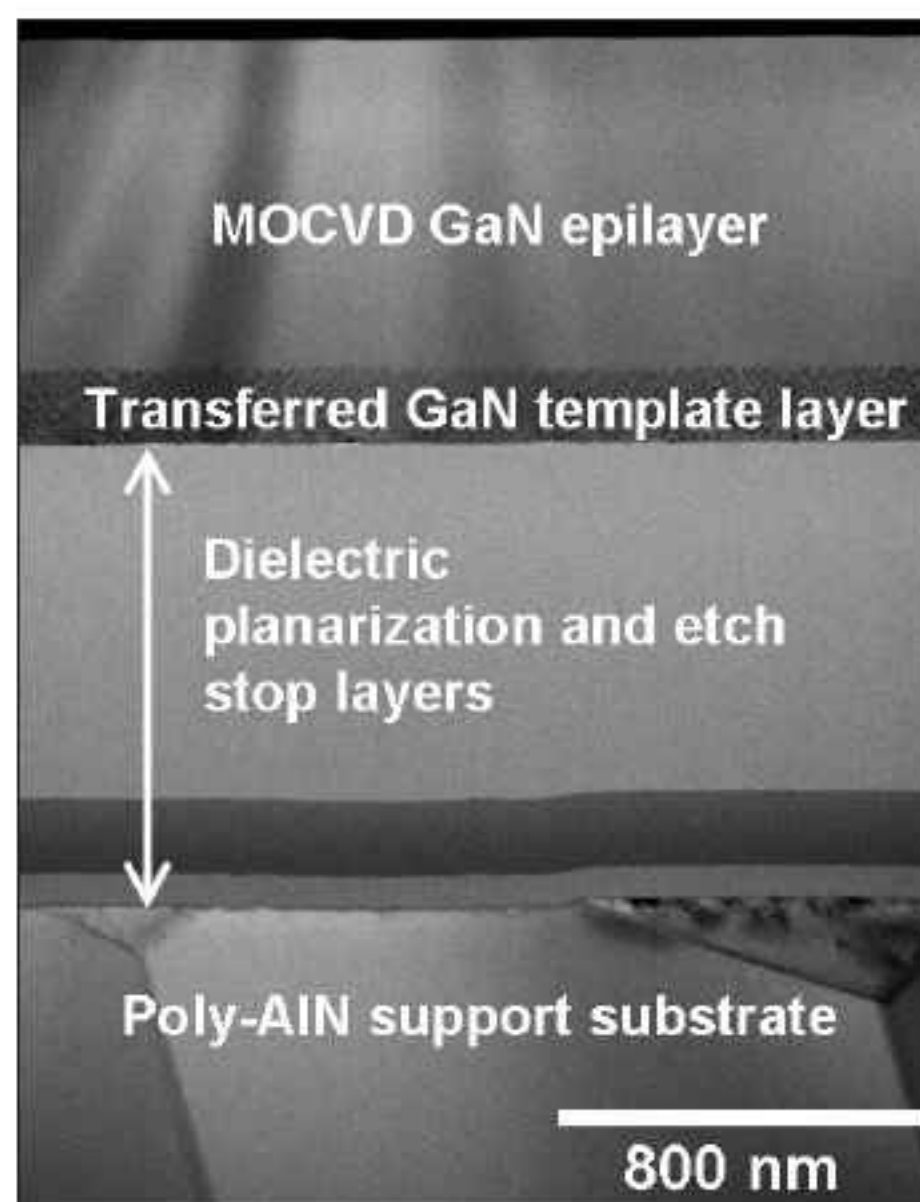
A-GaN also offers a coefficient of thermal expansion that is nearly identical to GaN and increased physical robustness relative to bulk GaN wafers, reducing breakage-related yield loss. In addition, the support material that makes up most of the substrate is readily removable via a simple chemical etch, which could simplify the fabrication of high-performance devices such as vertical LEDs and open up new design possibilities, the firm reckons.

In the collaboration, Sandia grew GaN on A-GaN and sapphire reference substrates. The GaN was then characterized using analytical techniques including TEM to measure the material quality, particularly the density of defects (dislocations). The data indicates that GaN grown on A-GaN was as good as the bulk GaN donor wafer used to fabricate the substrate (about  $4 \times 10^6 \text{ cm}^{-2}$ ).

Aonex says that it is in discussions with device manufacturers to fabricate devices on A-GaN substrates.

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

[www.sandia.gov](http://www.sandia.gov)



Micrograph showing cross-section of the layer structure for GaN epi growth on Aonex's A-GaN substrate.



# Crystal IS wins \$2m DUV LED award & raises \$10.6m for AlN

As part of the final set of Advanced Technology Program (ATP) awards of the US National Institute of Science and Technology (NIST), Crystal IS Inc of Green Island, NY, USA has been awarded \$2m for a three-year contract (starting in November) to develop high-performance deep-ultraviolet LEDs based on its low-defect aluminum nitride substrates. Industry cost-share of \$2.4m raises the sum to \$4.4m.

Crystal IS will investigate the use of its AlN substrates in various crystallographic orientations to develop LEDs emitting at high power at a wavelength of 280nm, with high efficiency and long lifetime.

The funding follows completion in September of a prior ATP contract that started in 2004 which enabled the development of large-diameter, high-quality AlN boules, leading in 2006 to the launch of the world's first 2" bulk AlN substrates. Crystal IS has been supplying substrates

for products including blue and green laser diodes, UV LEDs and lasers, and RF components on AlN.

In July the firm said it was expanding its device development facility (led by Dr Joseph Smart) by installing two MOCVD reactors. The award will allow the firm to explore new paths in the development of UV emitters, says Smart.

UV processing and analytics has opened up applications in recent years in areas spanning homeland security, water and air purification and UV curing of inks and polymers where a small, durable, mercury-free light source offers benefits. However, market growth remains technology-limited, since there are significant challenges to developing cost-effective LEDs operating at deep UV wavelengths less than 320nm. The ATP grant should allow Crystal IS to address these challenges through the use of novel materials, processing techniques and designs.

## \$10.6m second-round funding to ramp 2" AlN substrates

In late August, Crystal IS closed a \$10.6m second round of financing.

"This round of funding will allow Crystal IS to ramp production of the 2" substrates and reduce prices, enabling cost-efficient, high-performance ultraviolet devices and opening new opportunities in current high-volume consumer applications," said CEO Dr Ding Day.

Crystal IS was founded in the Rensselaer Polytechnic Institute (RPI) incubator program to develop growth technology for native AlN crystals and low-defect AlN substrates. In September 2004, it raised \$5.1m to scale its technology. In June 2005 it moved from 6000ft<sup>2</sup> of the incubator in Watervliet, NY to a 10,500ft<sup>2</sup> facility in nearby Green Island. This May, it launched the world's first low-defect-density 2" native AlN substrates. Competing technologies have small areas of less than 2/3" or a high defect density, the firm claims.

Low-defect AlN substrates will enable high-efficiency, high-reliability UV optoelectronic products, with applications in compact explosives detection devices, water purification and medical products. The firm says its manufacturing technique can be scaled further to produce highly affordable substrates, making the process suitable for low-cost applications such as white lighting.

Crystal IS has also developed a GaN-Ready version, where a GaN epilayer is grown on the AlN to address high-volume markets such as 405nm lasers for Blu Ray and HD DVD as well as high-power LEDs.

After recruiting CEO Ding Day in February 2006 and VP, business development, sales & marketing Timothy Bettles in April, Crystal IS is expanding its manufacturing team to manage demand for 2" substrates.

[www.crystal-is.com](http://www.crystal-is.com)

## Crystal IS appoints VP of engineering

Crystal IS has recruited Dr Stephan Mueller as VP of engineering, responsible for further developing its AlN wafers into high-quality, cost-effective substrates both for mainstream external sales and for use in internal development of high-performance UV LEDs.

Most recently, Mueller was principal scientist at Cree, responsible for the management and coordination of many R&D and production projects in wide-bandgap semiconductors.

Mueller has a Masters degree in Physics and PhD in Materials Science from Friedrich-Alexander-University, Erlangen-Nuremberg, Germany via research on the growth of bulk wide-bandgap semiconductor crystals. He is currently adjunct professor in North-Carolina State University's

materials science department.

"Stephan is internationally recognized for his achievements in the field of wide-bandgap semiconductors and has tremendous knowledge of crystal growth at volume production levels that will be key as Crystal IS continues on its path to commercialization," says CEO Ding Day.

Mueller claims Crystal IS is poised for commercial success after demonstrating record technical results. "We plan to build the crystal growth technology from the great foundations that have already been demonstrated to greater levels of consistency and manufacturability to develop substrates meeting the high quality levels at the cost-effective price demanded", he says.



# HexaTech wins \$2m ATP grant for high-efficiency DUV LEDs

HexaTech Inc of Morrisville, NC, USA, which makes single-crystal aluminum nitride substrates, has been granted \$2m for a three-year project (starting in November) to develop high-efficiency deep ultraviolet LEDs that can be used as a high-energy UV light source to kill micro-organisms in drinking and waste water.

Such UV-LEDs could be used by water treatment companies as a replacement for existing mercury-based UV tubes that would be both more environmentally friendly and also last 5–10 times longer. However, although several research groups have demonstrated LEDs with deep UV wavelengths as short as 210nm, so far they convert less than 1% of the applied electrical energy into light.

The funding comes as part of the final set of Advanced Technology Program (ATP) awards of the US Commerce Department's National Institute of Science and Technology (NIST). Together with projected industry cost-share of almost \$1.3m, total project funding should be \$3.28m.

HexaTech was spun off from the Department of Materials Science of North Carolina State University in 2001 with a transfer of technology developed by co-founders Dr Zlatko Sitar (president and chief technology officer) and Dr Raoul Schlessler (VP development). Subsequently, in November 2005, the firm raised \$8.9m in a Series A round of financing led by Intersouth Partners of Durham, NC and joined by H.I.G. Ventures, Sevin Rosen Funds and NC IDEA.

HexaTech says that its proprietary technology combines the benefits of physical vapor transport (PVT)

growth and of seeded growth for the reproducible production of single-crystal AlN boules. Seeded growth enables the fabrication of AlN boules of pre-defined crystallographic orientation. AlN wafers fabricated from the crystals are of well-defined orientation and of high, reproducible crystal quality, the firm says.

Also, more recently HexaTech has demonstrated a polarity-controlled device layer deposition process that

**Deep-UV LEDs can address a \$78m market for the initial replacement of UV tubes at water treatment companies.**

is compatible with industry-standard MOCVD growth equipment. Control over the polarity opens up processing routes that can lead to novel device concepts that have previously been inaccessible, says the firm. It adds that it aims to produce efficient deep-UV LEDs by taking advantage of such processes to grow aluminum gallium nitride (AlGaIn) layers on AlN substrates. HexaTech's CEO Jim LeMunyon told Semiconductor Today that the targeted emission wavelength is 254nm, which is known to interact with DNA in a way that stops water-borne organisms from reproducing.

Regarding commercial prospects for the technology, Hexatech reckons that deep-UV LEDs can address a \$78m market for the initial replacement of UV tubes at water treatment companies, followed by a recurring market of \$15.6m per year (beginning five years after the first UV-LED systems are installed).

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

## IN BRIEF

### Tokuyama starts up Aixtron MOCVD reactor for UV LEDs

Aixtron AG of Aachen, Germany says that Tokyo-based Tokuyama Corp (which manufactures chemical products including ultrapure polysilicon) has started up an Aixtron 200/4 RF-S epitaxy reactor for the development of AlGaIn-based ultraviolet (UV) LEDs at its R&D center in Tsukuba, Japan.

UV-LEDs present significant process challenges, but the AIX 200/4 RF-S can provide high-quality GaN and AlGaIn layers due to its process stability and 1400°C capability, claims Aixtron.

The system had been evaluated and qualified for this application by Tokuyama in collaboration with professor Aoyagi of Tokyo Institute of Technology. The installation of another Aixtron reactor should accelerate Tokuyama's development of UV LED materials and devices.

● Tokuyama also has the world's largest plant for manufacturing aluminum nitride powders (e.g. for AlN ceramic substrates).

In February, Tokuyama and Tokyo-based metal processing firm Dowa Metaltech Co Ltd established the 65:35 joint venture Tokuyama-Dowa Power Material Co Ltd (TD Power) in Yamaguchi, Japan (the site of Tokuyama's factory).

With about 45 staff, the new firm will manufacture and sell not only metal-bonded ceramic substrates but also 'new products based on AlN substrates'.

AlN's high thermal conductivity can be exploited for high-temperature components such as power LEDs and laser diodes for DVD recorders and fiber-optic applications.

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

[www.tokuyama.co.jp](http://www.tokuyama.co.jp)



## CCS reactor orders for blue LEDs

Aixtron of Aachen, Germany says that in Q2/2007 THELEDs Co Ltd of Wonsam-Myun, South Korea ordered two Thomas Swan Close Coupled Showerhead (CCS) MOCVD reactors in 19x2" wafer configuration, for installation alongside its existing CCS reactors for volume production of InGaN blue high-brightness LED chips.

"To react to increased customer demand for high-brightness LED chips, we now have to expand our production capacity [currently 30m chips per month]," says executive VP Dr SangKee Shee.

"Shortly after we had acquired our first Thomas Swan CCS reactors we were able to ramp up to mass production very promptly. We have found it very easy to transfer our processes from one system to another," Shee adds.

Founded in February 2005, the firm began making GaN LED chips in June 2006, and began establishing a new factory this May. In February, Samsung Electronics' wireless division qualified the firm's 0.4t sideview LEDs.

Products are focused on blue (450-470nm) LED chips for uses such as back-light units (BLU) and lighting. Future products include InGaN-based UV and green LED chips and AlGaInP-based red LED chips, as well as epiwafers.

● In Q1/2007 Aixtron received an order for a CCS reactor from China's Sun Yat-Sen University in Guangzhou Region.

Delivered to its optoelectronics research facility in 3x2" wafer configuration, it will be used for R&D of GaN alloys on sapphire and silicon wafers for LEDs.

The reactor will be used to develop heteroepitaxy of nitride-on-silicon for low-cost, next-generation material in display backlighting, says Wang Gang of the university's State Key Lab of Optoelectronic Materials and Technologies.

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

## Veeco launches E475 MOCVD system for R/O/Y HB-LEDs and solar cells

Veeco Instruments Inc of Woodbury, NY, USA has introduced its new TurboDisc E475 As/P MOCVD reactor for mass producing red, orange, yellow (R/O/Y) high-brightness LEDs (HB-LEDs) and multi-junction III-V concentrator solar cells (mainly for space applications).

"Our TurboDisc E450's ability to produce consistently high yields of premium R/O/Y LEDs and multi-junction solar cell devices with the industry's best throughput made it the top-selling MOCVD tool for these applications," claims Dr Piero Sferlazzo, VP and general manager of MOCVD Operations. Now, the next-generation E475 delivers 15% more capacity and improved cost-of-ownership metrics. Users can choose to purchase a new E475 or upgrade their existing E450 tools to the improved specifications, enhancing return on investment.

TurboDisc As/P MOCVD tools are being adopted for cost-of-ownership benefits in high-volume production of multi-junction III-V concentrator



**Veeco's new E475 As/P reactor.**

solar cells, R/O/Y HB-LEDs, laser diodes, pHEMTs and HBTs, says Veeco. "Our systems offer a level of process control and reliability unmatched by competing MOCVD technologies," claims Sferlazzo. The systems feature Veeco's integrated RealTemp 200 technology, enabling superior material quality and process efficiency from direct wafer temperature control, fast gas switching for strict control of interface abruptness, and vacuum load-lock automation for highest productivity, the firm adds.

[www.veeco.com/e475](http://www.veeco.com/e475)

## New executive VP of worldwide sales & service

Veeco has appointed William A. Tomeo as executive VP of worldwide sales & service, which includes global field sales, account management, customer service and field support for all domestic and international Veeco customers. John K. Bulman, executive VP of worldwide sales and foreign operations (and formerly senior VP of North American and sector sales), will retire at the end of 2007.

"Bill will play a key leadership role in further developing Veeco's worldwide sales & service organization to ensure that we maximize growth opportunities in the HB-LED/wireless, data storage, semiconductor and scientific research/industrial markets," says CEO John R. Peeler.

Tomeo joins from JDSU, where he was most recently VP/general

manager of the Service Assurance Solutions Division of the Communications Test business. His 35 years of technology industry sales, marketing and general management experience also include a key marketing role at Agilent Technologies and over 20 years at Hewlett Packard, where he was VP, marketing & worldwide sales for the Communications Test Solutions Group. Tomeo has also been president and CEO of several high-tech start-up companies.

"He brings to Veeco a proven track record of leading global high-tech sales organizations and developing direct and indirect channel strategies to efficiently align with a diverse product portfolio and market exposure similar to Veeco's," Peeler adds.



## JPSA recruits process engineering specialist and director of engineering

J. P. Sercel Associates (JPSA) of Manchester, NH, USA, a designer, supplier, and systems integrator of laser-based materials processing workstations, has recruited Dr Xiangyang Song as an application and process engineering specialist.

Song has more than a decade of experience in applied optics, x-ray and laser technology and research. After a Ph.D. at Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, he worked at Argonne National Laboratory and at the University of Illinois at Chicago, specializing in femtosecond laser research using Ti: sapphire and excimer lasers.

Song will work in JPSA's core competences of UV excimer and DPSS laser materials processing, across a range of applications including wafer singulation and LED lift-off for semiconductor packaging.



**Song (top) and Roberts (bottom)** JPSA has also recruited Larry Roberts as director of engineering. In nearly 40 years in engineering and management roles, Roberts lately spent 14 years as engineering manager/principal engineer at Laurier Inc, a maker of semiconductor die sorters and die from wafer feeders. Roberts has authored papers on fine pitch placement, attachment to PCBs, and automated handling of 300mm wafer frames. He also holds patents on high-speed semiconductor placement equipment and alignment systems.

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

## Sanyo starts up MOCVD reactor

Aixtron AG of Aachen, Germany says that, in Q2/2007, Sanyo subsidiary Tottori Sanyo Electric in Tottori prefecture, Japan started up a new MOCVD reactor, designed for the development and production of optoelectronic devices.

Sanyo, a user of Aixtron MOCVD systems for many years, was the first company to commercialize red 635nm AlGaInP laser diodes, and is one of the world's largest suppliers of AlGaInP red and AlGaAs infrared laser diodes.

Sanyo also has a new generation of GaN-based 405nm laser diodes for optical equipment where stable, accurately controlled output is critical, such as optical mass storage, biomedical instrumentation, medical imaging, fluorescence sensing, spectroscopy and microscopy.

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

# Production solutions for HB LEDs

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Oxford Instruments' process tools offer industry-leading production solutions for HB LEDs; high throughput and high yield with excellent in-wafer, wafer-to-wafer and run-to-run uniformity.

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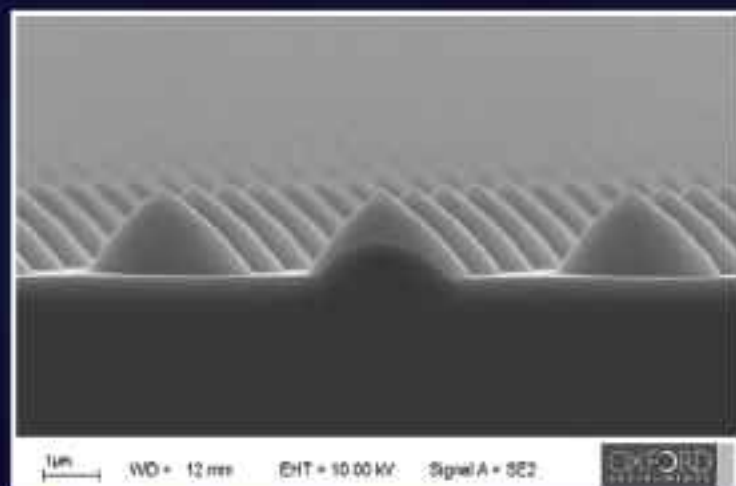
Sapphire, SiC, GaN etching  
20 x 2" up to 4 x 4"

### GaN, AlGaIn, AlGaInP and related materials etching

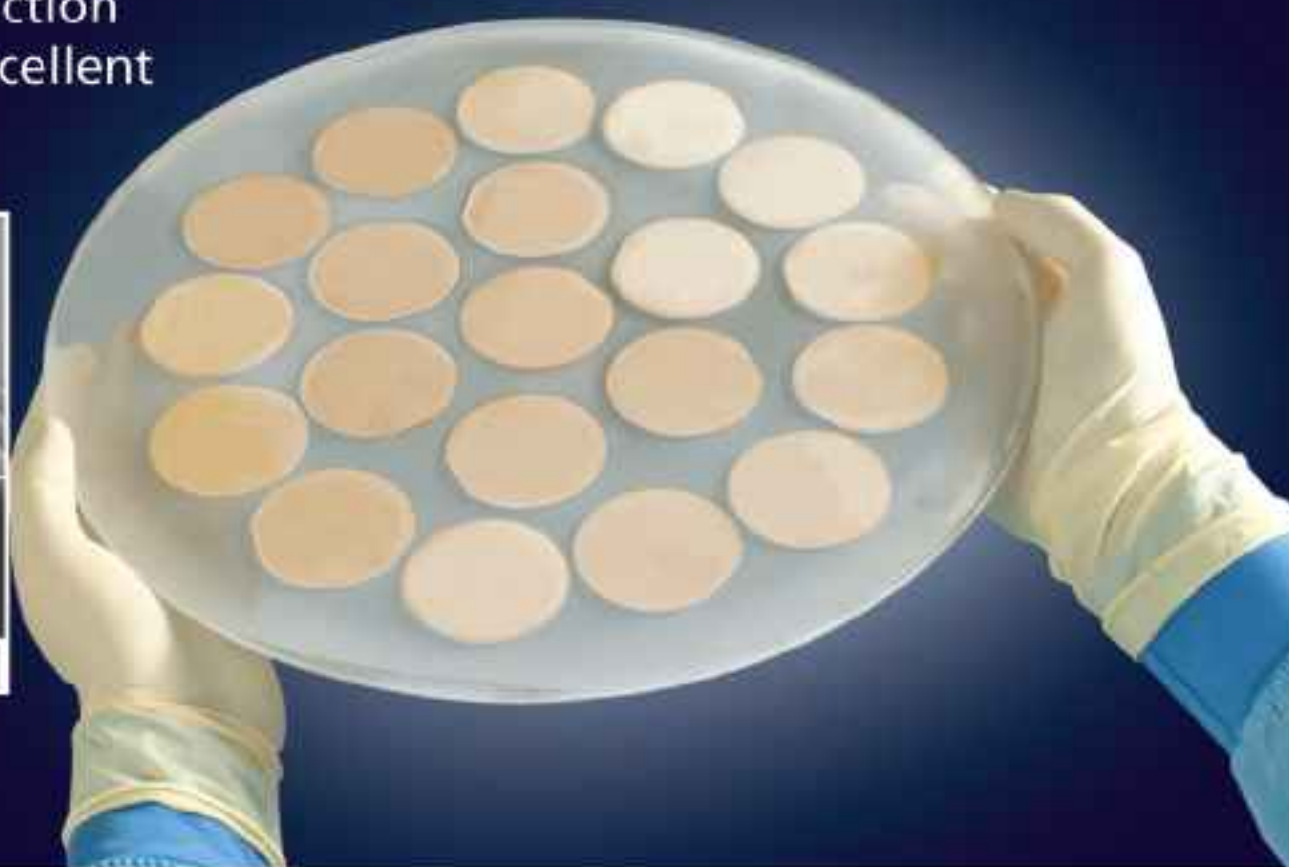
20 x 2" up to 4 x 4" (GaN, AlGaIn)  
10 x 2" up to 3 x 4" (AlGaInP)

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# Luminus expands PhlatLight LED range for microdisplays

Luminus Devices Inc of Billerica, MA, USA has launched the PhlatLight PT54 projection chipset (incorporating separately packaged red, green and blue LEDs, each with a compact 5.4mm<sup>2</sup> (2.7mm x 2.0mm) emitting area capable of sustaining high power under fast pulsing or continuous mode operation), which has been engineered to act as a light source for microdisplays (including high-brightness portable pocket projectors and heads-up projection displays) as well as other general illumination applications. Combined, the three-color chipset produces up to 1400 peak white lumens in pulsed-mode operation.

The photonic-lattice-based PhlatLight PT54 has been optimized for maximum efficiency for 0.4–0.6" 4:3 aspect-ratio microdisplays, and is suitable for 0.55" SVGA digital light processing (DLP), liquid crystal on silicon (LCoS) and high-temperature polysilicon (HTPS) LCD microdisplays.

"Our innovations in packaging, thermal management and optical coupling has led to a truly versatile product line that is enabling appli-



PhlatLight PT54 projection chipset.

cations never thought possible by a solid-state light source," claims Christian Hoepfner, VP of products. "The PT54 is the latest example to benefit from these innovations, which will allow our customers to achieve very efficient light engine designs, while delivering high screen brightness."

**Benefits include 'instant-on' operation with full brightness (since there is no warm-up time, as for mercury lamps).**

Other benefits include 'instant-on' operation with full brightness (since there is no warm-up time, as for the mercury lamps found in traditional projection TVs), a wide color gamut (red 625nm, green 525nm, and blue 462nm typical dominant wavelengths) that exceeds the NTSC standards, and digital power management to optimize battery life and brightness. PhlatLight LEDs also have significantly longer lifetimes (with a median exceeding 120,000 hours, greater than consumer products) compared to arc lamps, eliminating lamp replacements.

Evaluation kits are available to qualified customers.

● The PhlatLight PT39, Luminus' most compact LED projection chipset, is the light source in LG Electronics' recently introduced HS101 pocket projector (which is the brightest LED-based projector on the market, it is claimed). PhlatLight chipsets are also in projection TVs sold in North America by Samsung and NuVision, with screen sizes of up to 61".

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

## Luminus recruits sales director to target solid-state lighting market

Luminus Devices has recruited David Sciabica as director of sales, responsible for targeting its PhlatLight LED products specifically at emerging general lighting applications as the firm plans its entry into the solid-state lighting market.

Luminus currently manufactures LED-based light sources that act as replacements for halogen, arc and florescent lamps in illumination applications including high-definition TVs, video projectors, and avionics displays. Customers include consumer electronics manufacturers such as Samsung Electronics and LG Electronics.

Luminus claims that its PhlatLight (photonic lattice) LEDs are considerably larger and brighter than conventional high-brightness LEDs and are already proven as a

replacement for high-intensity lamps, offering more brilliant color and longer lifetimes in projection TVs and projectors.

"Lighting is a \$100bn industry, and LEDs will continue to displace traditional lamps due to their inherent efficiency, reliability, versatility, and environmental friendliness. Luminus has added and will continue staffing key personnel in applications engineering, product development and R&D to create new solid-state lighting products for early 2008," says John Langevin, VP of sales & marketing. "Dave's experience in the high-brightness LED industry will prove to be a key asset to bring the benefits of proven PhlatLight LED technology to the general lighting market."

Prior to joining Luminus, Sciabica held sales management positions at Philips Lumileds, including VP of sales for North and South America and VP of major accounts. He was part of the initial management team at Hewlett Packard that established Lumileds Lighting in 2000 and contributed to the firm's growth.

During his 18 years with Hewlett Packard, Sciabica managed various sales organizations including global telecom accounts and the strategic accounts group.

Prior to Hewlett Packard, he was technical marketing engineer at Westinghouse Electric Corp.

Sciabica also holds a B.S. in electrical engineering from the University of Pittsburgh.



## Epistar sues Lumileds for breach of settlement after stay of order rejected

On 10 October, LED maker Epistar Corp of Hsinchu Science-based Industrial Park, Taiwan filed a complaint against Philips Lumileds Lighting Co LLC of San Jose, CA, USA to "stop Lumileds competing unfairly and interfering with Epistar's business relations, for breaching the terms of a settlement agreement, and for a declaration of contractual rights".

At the end of September, the US Court of Appeals for the Federal Circuit (CAFC) denied Epistar's request to stay enforcement of the US International Trade Commission's limited exclusion order (which came into effect on 12 July) prohibiting import into the USA of its AlGaInP-based omni-directional mirror adhesion (OMA), metal-bonded (MB) and glue-bonded (GB) LEDs (and next-generation OMA II, MB II and GB II LEDs). The order also bars import of packaged lamps containing the LEDs and boards consisting primarily of arrays of such packaged lamps. Previously, on 19 July, the CAFC had stayed enforcement temporarily.

The limited exclusion order followed the ITC's final determination on 9 May that the LEDs infringe Lumileds' US Patent no. 5,008,718. Companies that use, import, or sell these unlicensed infringing products, even unknowingly, are direct infringers of the patent and are subject to the exclusion order, asserts Philips Lumileds. In denying Epistar's request, the CAFC concluded that Epistar did not meet the key criteria, such as 'likelihood of success on the merits' of its appeal or the demonstration of 'a substantial case on the merits' to obtain a stay, adds Philips Lumileds.

Previously, on 29 August, the ITC denied a similar request by Epistar for a stay of the exclusion order. The CAFC's decision now clears the way for US Customs and Border Protection to enforce the order, says Philips Lumileds.

Epistar's complaint alleges that "Lumileds has been misleading customers and potential customers into believing that many of Epistar's LEDs other than those at issue were also affected by the limited exclusion order entered by the ITC". Furthermore, "Lumileds' statements falsely suggest that Epistar is barred from importing any of its advanced AlGaInP products into the US and that the six products at issue infringe two patents they were expressly found not to infringe," it adds. "Customs and Border Protection earlier indicated that Epistar's new Phoenix and Aquarius lines of LEDs are not within the scope of the order [and can therefore still be imported]". Epistar launched the new AlGaInP LEDs in July, saying that they had been designed without the feature that Lumileds claims is the basis for its patent. In filing the complaint, Epistar says it seeks to stem the flow of misleading information about the scope of the ITC's limited exclusion order.

Also, Epistar says that in July 2004 it settled a dispute with Lumileds over whether certain OMA products infringed the 5,008,718 patent. As part of the settlement, Lumileds agreed not to sue Epistar for infringement based on the OMA products and granted a license to Epistar to make, sell, use, offer to sell and import AlGaInP absorbing-substrate LEDs. But, during the ITC investigation, Lumileds alleged that Epistar's OMA products infringed the patent. Epistar therefore complains that the assertion of the patent against the OMA LED products was a violation of the terms of the settlement agreement.

The complaint also seeks an injunction against Lumileds to "prevent further irreparable harm, as well as compensatory and exemplary damages to redress and deter the ongoing injury to Epistar being caused by Lumileds' alleged illegal practices".

[www.epistar.com.tw](http://www.epistar.com.tw)

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

### IN BRIEF

## Osram Opto appoints manager of Regulations and Emerging Technologies

LED maker Osram Opto Semiconductors GmbH of Regensburg, Germany has appointed Dr Jianzhong Jiao to the newly created position of manager of Regulations and Emerging Technologies. He reports to Tom Shottes, president and CEO of Osram Opto Semiconductors Inc of Santa Clara, CA, USA.

Responsibilities include representing Osram Opto in obtaining, establishing and maintaining regulatory standards for solid-state semiconductor technology, and researching and exploring emerging semiconductors technologies for sensing, illumination and visualization applications.

Previously, Jiao worked for North American Lighting Inc (NAL) for more than 17 years (including as general manager of Engineering Technology for the last nine years), and has been a faculty member at several institutions, including Purdue University and Lawrence Technological University.

Jiao is an expert in automotive and transportation lighting and optical engineering (holding nine US patents on lighting technologies), and has also managed engineering and product development activities, industry standards and government relations.

In addition, Jiao has served the Society of Automotive Engineers (SAE) as the organizer and chairman of the SAE World Congress Lighting Technology Conference, vice chairman of the SAE Lighting Standard Committee, and vice chairman of the SAE Signal & Marketing Devices Sub-Committee.

[www.OSRAM-os.com](http://www.OSRAM-os.com)



## IN BRIEF

### SureFire selects Seoul's LEDs for flashlights

Korean LED maker Seoul Semiconductor Co Ltd says that flashlamp maker SureFire LLC of Fountain Valley, CA, USA has selected its Z-Power LED P4 series to power its SureFire 2.5W model, a compact, high-output lightweight flashlight designed for rugged conditions including camping and military use. Features include a precision reflector, momentary-on, constant-on, and a switch lockout to prevent accidental activation.

"We selected Seoul's Z-power LED P4 series because it offers one of the industry's highest-level of brightness and reliability that also fits all lens designs," says SureFire's VP of engineering Paul Kim. "It can be directly applied to all of our existing SureFire flashlights without the need to design and incorporate new lenses," he adds.

Seoul claims that its Z-power LED P4 series has the industry's highest brightness of 240 lumens at 1A. It also claims the industry's highest luminous efficacy (100lm/W at 350mA maximum) with only a single die, making it a brighter and more cost-effective light source compared to conventional 70lm/W fluorescent and 15lm/W incandescent lighting options.

Seoul also provides LEDs of various white colors segmented by color coordinate temperature 2650-10,000K, which addresses the color deviation problem to render high uniformity of light.

"Seoul Semiconductor's P4 series LEDs are rapidly replacing conventional lighting sources," claims Yang-hee Han, Seoul's VP and general managing director for sales & marketing.

[www.seoulsemicon.com](http://www.seoulsemicon.com)  
[www.surefire.com](http://www.surefire.com)

## Seoul unveils 420lm LED, four times brighter than conventional LEDs

Seoul Semiconductor Co Ltd claims that its R&D team has achieved a record brightness for a single LED of 420lm (maximum) at 600mA (350lm on average). This compares with just 100lm for a conventional single LED of comparable size (e.g. the Z-power P4).

The higher brightness, coupled with ultra-compact size (similar to that of single LED packages emitting 100lm), gives greater design flexibility and much lower cost of application.

"The competition in the LED industry is heating up as customers increasingly demand brighter and smaller products," says Yanghee



Seoul's 420lm LED (left) and a conventional 100lm LED of comparable size (Z-power P4 LED series; right).

Han, VP of sales & marketing. The higher performance, compact architecture and cost advantages of the new technology opens up new markets where conventional LEDs are excluded due to inherent performance limitations, he adds.

Seoul plans to commercialize the new product by Q4/2007.

## Acriche brightness boosted by 50%

Seoul Semiconductor has upgraded its Acriche LED (the first semiconductor lighting source that operates directly from an AC power supply).

"Acriche has a longer lifespan compared to conventional LEDs, and does not require an AC-DC converter, which can add another \$5 per 5W to the cost," says Do Hyung Kim, head of the Acriche unit.

The new version has a luminous flux of 200lm at 3.3W, i.e. an efficacy of almost 60lm/W (50% brighter than the previous version released last November). Also, Seoul has cut the price by 40%, making it more competitively priced to penetrate the conventional lighting market.

The new version is sold as a single emitter without a heat-sink PCB. This enables greater flexibility in designing the PCB type and emitter arrays, the firm says, broadening the range of applications. With upgraded packaging, Acriche is the only semiconductor lighting source capable of withstanding 4W of



Seoul's upgraded, 200lm Acriche LED.

power, the firm claims. Seoul expects this to spur adoption for general lighting applications such as down-lighting and architectural lighting (such as MR16 lamps).

Seoul aims to increase luminous efficacy from 60lm/W to 80lm/W for a 250lm output package by Q4/2007 and to 120lm/w for a 400lm output package by the end of 2008.



## Nichia sues Seoul Semi in Korea

LED maker Nichia Corp of Anan, Tokushima, Japan has filed a new lawsuit in the Seoul Central District Court alleging infringement of its Korean patent no. 491482 by the Z-Power LED P9 Series white LEDs of Korea's Seoul Semiconductor Co Ltd. Nichia is seeking damages for past infringement as well as an injunction against any further infringing activity.

In response Seoul, which is the world's eighth-largest LED maker, has reiterated its announcement of 18 May that only a small amount (\$2000 worth in 2007) of its Z-Power LED P9 was produced and sold in Korea using blue chips made by SemiLEDs Corp of Boise, ID, USA before it started using blue chips supplied by Cree Inc of Durham, NC, USA. SemiLEDs is proceeding with a lawsuit in Japan regarding the P9. Seoul says that it will cooperate with SemiLEDs on that lawsuit.

Nichia is already seeking damages for infringement and an injunction against further infringing activity in:

- a lawsuit against Seoul in the USA based on Nichia's design patents for side-view type white LEDs;
- a lawsuit against Seoul and its Japan distributor Kyoei Sangyo based on Nichia's patents for lighting LEDs;
- a lawsuit against Seoul in Korea based on Nichia's patent for top-view-type white LEDs.

Regarding the latter, Seoul has issued a statement refuting the allegation that the blue chips in its TWH104-HS top-view-type white LED products infringe Nichia's Korean patent no. 406201. Nichia filed its lawsuit in the Seoul Central District Court on 17 September.

Seoul emphasizes that, over the years, it has made significant investments in R&D, and has filed and registered more than 1200 patents. The firm says cross-licensing that it produces and sells products based on its own patent technologies, as well as patent technologies licensed from universities, institutes and companies including the University of California at Santa Barbara and the Solid State Light Display Center in the USA, and Nitride Semiconductor in Japan. Seoul also has cross-licensing and strategic cooperation agreements with LED chip makers including Cree Inc of Durham, NC, USA, Osram GmbH of Regensburg, Germany and Toyoda Gosei in Japan.

Seoul asserts that there is no evidence to support Nichia's claim and attempt to disrupt its business, and adds that, as part of its duty to represent the interest of its shareholders and customers, it will defend itself against what it claims are unsubstantiated attacks from Nichia.

## Nichia and Cree expand cross-licensing

LED makers Cree Inc of Durham, NC, USA and Nichia Corp of Anan, Tokushima, Japan have agreed to expand their patent cross-licensing arrangements announced in 2002 and 2005 to include additional patents relating to white LED technology and certain Cree patents relating to nitride lasers.

The agreement also resolves infringement claims Nichia had asserted against LED products sold by COTCO International Ltd (a subsidiary of Hong Kong-based COTCO Luminant Device Ltd) prior to Cree's acquisition of COTCO

Luminant Device Ltd and its subsidiaries in March.

Also, Cree and Nichia have agreed to resolve any future patent disputes involving products of either company, or any affiliate in which it owns a controlling interest, through a process that eliminates any potential impact on customers. Customers can therefore buy products from one company free of any concern that the other company will make a claim of patent infringement against the customer based on the purchased product.

## IN BRIEF

### Seoul defeats white LED patent actions by AOT and Itswell

On 11 October The Patent Court of Korea turned down appeals by Advanced Optoelectronic Technology Inc (AOT) and Itswell Co Ltd to overturn the Korean Intellectual Property Tribunal's rejection of invalidation actions regarding a white LED patent belonging to Seoul Semiconductor (one of the world's eight largest LED makers in 2006).

In 2005, Seoul won preliminary injunctions for patent infringement filed in the Seoul Central District Court against AOT of Hsinchu Science-based Industrial Park, Taiwan and Itswell of Cheongwon Chungbuk, Korea on the grounds that there had been infringement of Seoul's white LED patent technology.

AOT and Itswell responded by filing invalidation actions against Seoul in the Korean Intellectual Property Tribunal, claiming that the patent lacks novelty. At the end of 2006, the tribunal rejected both AOT and Itswell's invalidation actions.

Both AOT and Itswell subsequently appealed this ruling by filing the latest lawsuits with the Patent Court of Korea.

Previously, on 3 August, the Taiwan Intellectual Property Office rejected AOT's invalidation action against Seoul's white LED patent in Taiwan.

Seoul claims that the legal victories illustrate the novelty and validity of its patent, which was issued in countries such as the USA, Japan, China, and Taiwan and Korea. The firm says that its white LED patent technology can be applied to high-efficiency LEDs for flash, general lighting, automotive and mobile-handset keypads.

[www.seoulsemicon.com](http://www.seoulsemicon.com)  
[www.aot.com.tw](http://www.aot.com.tw)



## XLamp LEDs chosen for MUJI lanterns

Cree says that its XLamp LED has been selected as the light source in a new lantern from the MUJI brand of Tokyo-based Ryohin Keikaku Co Ltd, for use as a table light or portable torch.

MUJI assigned the lantern project to Japanese-based original equipment manufacturer G-Com Co Ltd. G-Com's product design required a bright light source that generates very little heat.

"We first chose Cree XLamp XR-E LEDs for MUJI's high-power bicycle lights, and then again for the new lanterns," says G-COM's VP Tohru Chigusa. "Cree's sales and support people added great value to the product design process."

"G-Com's choice of XLamp LEDs is yet another example of leading portable-lighting manufacturers switching to Cree LEDs," claims Paul Thieken, Cree's director of product marketing for lighting LEDs.

<http://ryohin-keikaku.jp/eng/ryohin>

## Lighting solutions seminars for China

Cree has launched a series of lighting solutions seminars in China with Arrow Asia Pac Ltd of Hong Kong, a business unit of Arrow Electronics Inc, which markets and distributes Cree's LEDs through its sales & marketing network of 51 offices in 11 Asia-Pacific countries and territories.

China is expected to be one of the key LED markets in Asia. To showcase Arrow's lighting solutions, the firm has held a series of seminars in key cities including Shenzhen, Ningbo, Beijing and Xian in China. "The seminars provide designers and manufacturers of lighting products a comprehensive overview of Cree's LED products and Arrow's total lighting solution," says Peng Gun Goh, Arrow Asia Pac's director of lighting business development.

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

# Cree hits 1000lm from single-die LED

Cree Inc of Durham, NC, USA has demonstrated light output from a single-die R&D LED, driven at 4A, of 1050 lumens in cool white (equivalent to the output of a standard household incandescent light bulb) and 760 lumens in a warm-white version.

Luminous efficacies are 72 lumens per watt for the cool-white LED and 52 lumens per watt for the warm-white LED (both substantially higher than those of conventional light bulbs).

Cree says that, historically, its R&D demonstrations have generally been commercialized within 12-24 months. "Cree's XLamp LEDs are the best-performing commercially available LEDs," claims co-founder and director of advanced optoelectronics John Edmond. "But we won't be satisfied until light

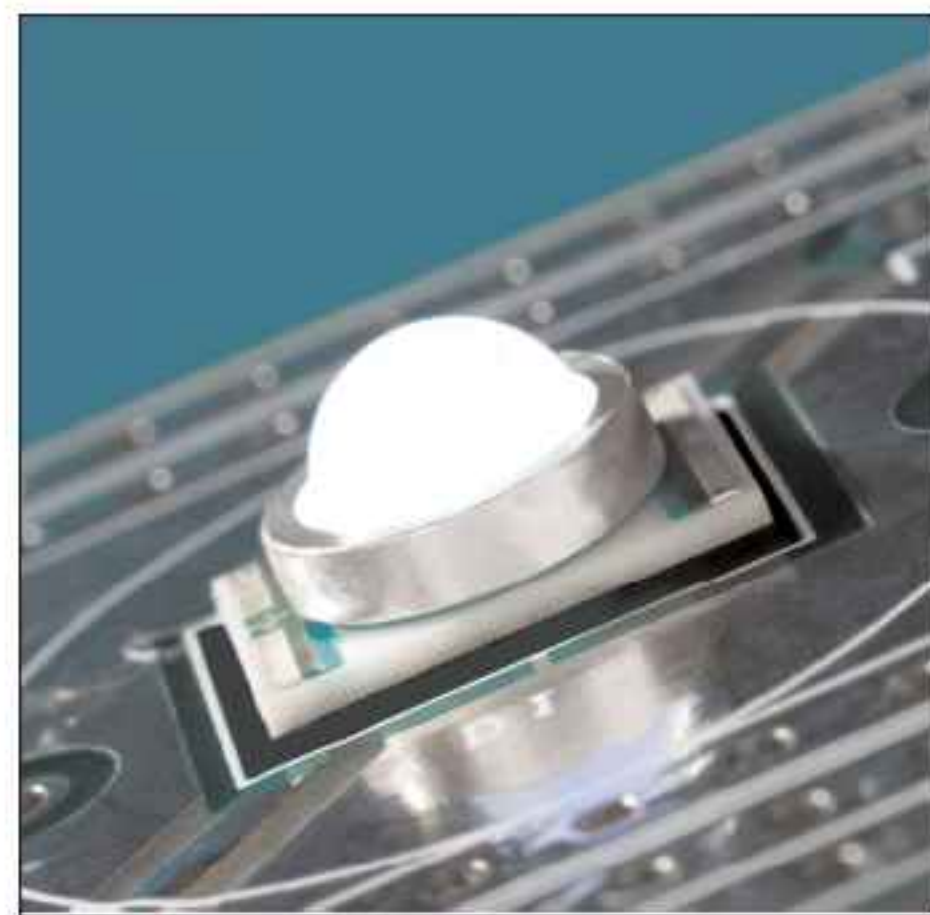


Photo of Cree's XLamp 7090 XR Series LED.

bulbs are obsolete," he adds. "We've worked 20 years to achieve lighting-class LED performance, and we still have plenty of ways to advance the technology further," he adds.

## Record efficacy for power LEDs

Cree Inc of Durham, NC, USA has reported record luminous efficacies for packaged, high-power LEDs operating at a drive current of 350mA in R&D.

The efficacies are 129 lumens per watt for a cool-white LED (with a correlated color temperature of 5813K) and a light output of 135.7 lumens, and 99 lumens per watt for a warm-white (2950K) LED with an output of 104.2lm. These values were measured by the US National Institute of Standards and Technology (NIST) after five minutes of operation (in order to ensure thermal stabilization).

Higher efficiencies have been reported previously in R&D, for example 150lm/W last December by Japan's Nichia, but only from small-area LED chips yielding low output due to a drive current of just 20mA.

The chips used in Cree's latest LEDs are reportedly the same as used in the cool-white LED driven at 4A to demonstrate output of 1050 lumens from a single-die R&D device (albeit with efficacy of just 72lm/W) — see above.

Cree reckons that, in the coming years, its investments in such core LED technology could lead to products that replace traditional light sources in all commercial applications. The technology advances may be seen in commercial products within 12-24 months, the firm adds.

"To replace traditional light sources, LEDs need to provide both high light output and high efficacy," says John Edmond, who is a co-founder of Cree and the firm's director of advanced optoelectronics.

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



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## IN BRIEF

### Firecomms launches transceiver for industrial data links

At September's ECOC 2007 event in Berlin, Germany, Firecomms Ltd, which develops high-speed light sources at visible wavelengths, launched its Industrial Data Link (series IDL300) fiber-optic transceiver (FOT) for fast data communication links over plastic optical fiber (POF) in industrial environments, expanding its range of high-speed POF interfaces.

Based on Firecomms' proprietary technology for resonant-cavity LEDs, the FOT is a 650nm solution that is compatible with low-voltage differential signaling for seamless integration into existing logic bus structures. It's rated for modulation at 250Mbps, and is suitable for use in SMI, IDB and OptoLock connectors.

The IDL FOT has electrical power saving features where the driver IC goes into a sleep state and the RCLED is switched off if no data or toning is present on the input bus to the TX. Similarly at the RX if no optical toning or data signal is present, the RX IC will switch into a sleep mode and power consumption is reduced to approximately 40uA.

The IDL FOT suits the application of high-speed technology in harsher environments, says Hugh Hennessy, VP of global sales & marketing. "Because it's built on a foundation of our automotive technology, this robust transceiver can be used in rugged industrial networks and applications, and fast robotics."

Previously, in June, Firecomms' RCLED-based 650nm Fast Ethernet and IEEE 1394 FOTs were chosen by Molex Inc as light sources for its new plastic optical fiber data link SMI solutions (showcased at NXTcomm 2007).

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

## API moving silicon sensors assembly plant from Dodgeville to Camarillo

Advanced Photonix Inc (API) of Ann Arbor, MI, USA, a vertically integrated designer and optoelectronics manufacturer of photodetectors, subsystems, and terahertz instrumentation, has decided to close its assembly facility in Dodgeville, WI (which produced silicon photodiodes in PIN, large-area APD and FILTRODE configurations) by the end of this year and transfer all operations to its facility in Camarillo, CA. API acquired the Dodgeville operation as part of its acquisition of Silicon Sensors LLC in August 2002.

The decision is based on assessing capacity requirements considering growth within the Optosolutions Product Platform; the recent upgrading and current ongoing consolidation of existing wafer fabrication production to its InGaAs and InP optical receiver manufacturing facility in Ann Arbor; and the general operating requirements at each of the firm's three manufacturing facilities. The firm concluded that it was necessary to adjust production capacity to more appropriately match product demand and customer requirements, while improving the

efficiency of overall manufacturing operations in the Optosolutions Product Platform.

Advanced Photonix says it will take a one time charge for the closure of about \$520,000 in its fiscal second quarter (to end September), and will be laying off the 31 Dodgeville staff by the end of this year. Based on anticipated product demand, the firm will most likely require a modest increase in the direct labor force at the plant in Camarillo over time.

force at the plant in Camarillo over time, but no additional staffing decisions have yet been made.

"The consolidation, while not pleasant, is in the best interest of our shareholders," says chairman and CEO Rick Kurtz. "We will work with our Dodgeville employees to insure a smooth transition."

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

### API's \$1m contract for night vision

Advanced Photonix has received a purchase order worth about \$1m for LED arrays (expected to ship within the next nine months) for night vision displays designed by Night Vision Labs in Virginia and employed by the US military.

As well as general surveillance, the US military's Night Vision Electronic Sensors Directorate (NVESD) has been used successfully in combat (in Abrams tanks, Bradley fighting vehicles, Hummer vehicles and Apache attack helicopters).

"We have been working diligently to secure this business for the

better part of two years," says Adam Tabakian, API's director of sales. "The contract expands our current customer base, and represents our continued growth in the military and defense business segment," he adds.

● Advanced Photonix has completed a private placement with institutional investors and management.

The gross proceeds of \$3.7m (which includes a further \$3m from existing investor Potomac Capital) will be used for debt restructuring, working capital and other general corporate uses.



## LBO raises \$26m to speed laser projection development

Light Blue Optics of Cambridge, UK, which develops miniature holographic laser projection systems, has closed a \$26m Series 'A' funding round, led by Earlybird Venture Capital and Capital-E. Existing investors 3i plc (which led LBO's \$3.5m seed-funding round in mid-2006) and NESTA (the UK's National Endowment for Science, Technology & the Arts) also participated. The funding round follows release of engineering samples to key customers and strategic development partners from July.

"This \$26m investment is one of the most significant European Series 'A' investments in the last five years — testament to the remarkable progress LBO has made with its partners and customers over the past 12 months," says 3i director Stephen Lowery.

Founded in 2004, LBO's projection technology uses laser light sources and patented holographic techniques to deliver large, full-colour, high-quality video images. A diffraction pattern of the desired two-dimensional image, calculated using LBO's holographic algorithms, is displayed on a phase-modulating liquid crystal on silicon (LCOS) microdisplay.

When illuminated by coherent laser light, rather than blocking light, the microdisplay steers the light to exactly where it is needed, making the system highly efficient. Unlike conventional projection systems, LBO's technology does not require a projection lens. Instead, a demagnification lens pair expands the diffracted image from the microdisplay, producing a throw angle of more than 90°. The projected images are in focus at all distances from the projector (even on curved or angled surfaces, without distortion), eliminating the need for a focus control.

As well as easy miniaturization, the technology's benefits include "exceptional levels of brightness and a robust, lightweight optical architecture [without moving parts] that is highly tolerant to a range of microdisplay defects [such as pixel failure]," says Dr Edward Buckley, co-founder and director of business development. As well as low-cost devices for hand-held mobile applications, the technology is also suitable for use in safety critical markets such as aerospace & defence and automotive, he adds.

The new funding will enable LBO to accelerate its product development and commercialization programme towards the high-volume manufacture of projection systems for deployment in markets including automotive, digital signage and consumer electronics, says CEO Dr Chris Harris. In May, LBO also announced a joint development agreement to provide French aerospace & defence firm Thales with engineering samples of its miniature holographic laser projection system for aircraft cockpit displays. "LBO has world-beating technology, excellent customer traction across a wide range of markets, a strong investor syndicate and is ideally placed to become the world's leading supplier of miniature projection systems," Harris claims.

Capital-E partner Rudi Severijns believes that LBO's holographic laser projection technology can take a significant share of the rapidly emerging market for miniature projection systems. LBO estimates that the total addressable market will exceed \$5bn by 2012.

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

## nLight buys fiber maker Liekki to expand to laser modules

nLight Corp of Vancouver, WA, USA, which designs and makes high-power diode lasers emitting at 635–2000nm, has agreed to acquire Liekki Corp of Lohja, Finland, which designs and makes specialty optical fibers and fiber subassemblies (optical engine modules) for fiber amplifiers and lasers used in industrial, aerospace, medical, military and telecom applications. The acquisition should close by the end of 2007.

Founded in 2000, nLight's revenues have grown an average of 70% annually for the past five years (to about \$50m); in September, it was named the fastest-growing technology company in Washington State in Deloitte & Touche USA LLP's Technology Fast 50 program for 2007. It also claims to be the fastest-

growing company in the semiconductor laser market. Including its 60,000ft<sup>2</sup> plant in Vancouver, WA and its 6000ft<sup>2</sup> nLight Laser Shanghai plant in China — and after buying Flextronics Photonics of Hillsboro, OR in August 2006 (which raised manufacturing area to 100,000ft<sup>2</sup>) — the firm has about 270 staff. nLight will retain some, but not all, of Liekki's 30 or so staff.

The acquisition integrates core technology for the rapidly growing markets for semiconductor and fiber lasers, says nLight's president and CEO Scott Keeney. Adding Liekki's technology will enable the firm to make new products by combining its lasers with Liekki's specialty optical fibers to make fiber lasers.

The combination of technology and

teams will provide a complete supply chain from semiconductor lasers and fibers to optical modules, says William Willson, managing director of the Fiber Division. "Liekki will bring its experience in fibers and modules; a unique, patented direct nanoparticle deposition (DND) fiber technology process; and a specialized manufacturing facility, which scales efficiently in this growing market."

nLight plans to make brighter and more intense optical modules, and the flexible fiber will allow it to sell to markets it has previously been unable to supply, including minimally invasive surgery and robotic automotive manufacturing functions such as heating and welding discrete parts.

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

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



## IN BRIEF

### Spire receives \$1m SBIR contract for high-power red diode lasers

Spire Corp of Bedford, MA, USA has received a two-year, \$998,514 Phase II Small Business Innovative Research (SBIR) contract from the US Missile Defense Agency (MDA) to develop highly reliable, high-power cryogenic red diode lasers grown by MOCVD on GaAs.

Spire's subsidiary Bandwidth Semiconductor, which manufactures concentrator solar cells as well as custom LEDs and diode lasers using MOCVD growth facilities in Hudson, NH, will carry out technical tasks related to epitaxial material growth and device processing.

High-power diode laser array technology is of interest to Spire because of its importance to the USA's defense, says Spire's CEO and chairman Roger Little. "It also complements our solar cell product line. Bandwidth Semiconductor can efficiently produce these products."

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

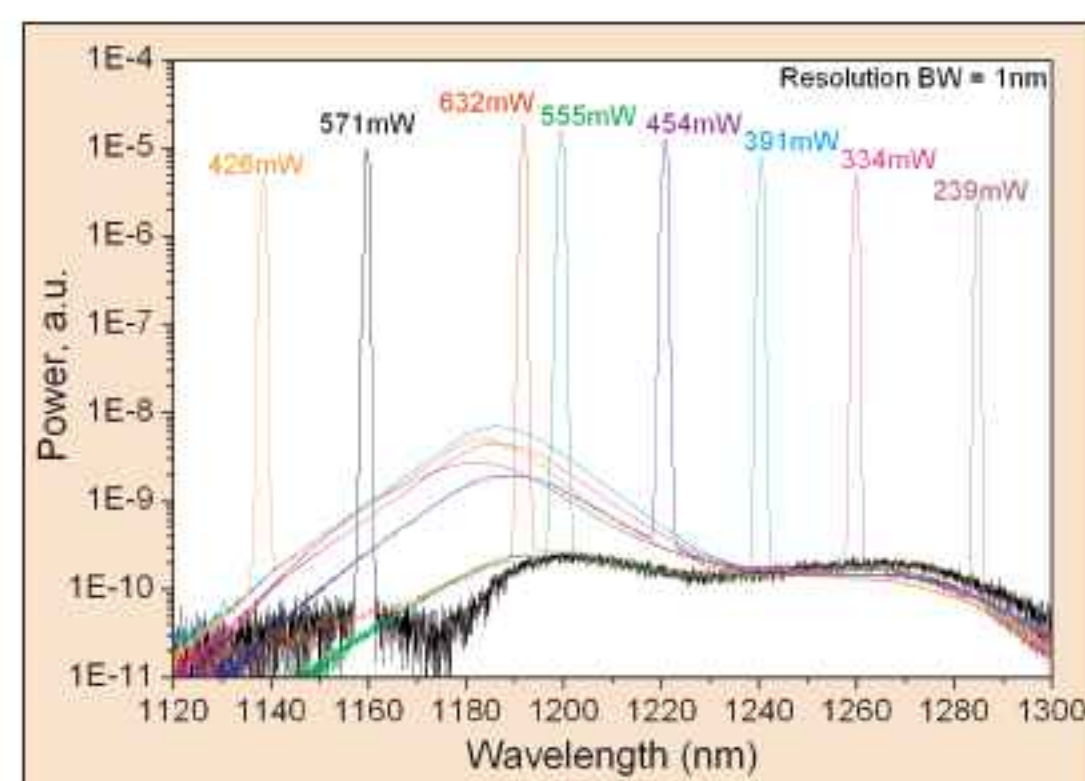
### Innolume launches high-power 1.2μm broadband gain chip

Innolume GmbH of Dortmund, Germany, which manufactures quantum-dot based lasers, gain chips and semiconductor optical amplifiers (SOAs) operating at 1.05–1.32μm, is sampling the GC-1200/160-200mW, a new-generation gain chip providing broad optical gain centered at 1.2μm. The launch represents a further expansion of product lines beyond high-power lasers and SOAs.

Optimized for operation in an external-cavity setup, the GC-1200/160-200mW has typical minimum output power of 200mW over a tuning range of 160nm at wavelengths otherwise not exploitable using conventional semiconductor light sources. The curved waveguide structure supports very low reflectivity of typically less than  $10^{-5}$  for the angled facet. The standard product is delivered in a chip-on-submount configuration.

Initial customer feedback indicates that the new chip exceeds the performance and quality expectations of module and subsystem providers, says business development manager Guido Vogel.

"This chip enables completely new



200mW output vs 160nm tuning range.

applications in instrumentation, industrial and medical systems which previously could not be produced due to the absence of suitable light sources," he claims.

"Tunable lasers and swept lasers for spectroscopy, metrology and optical coherence tomography benefit from the wide tuning range," adds Dr Alexey Kovsh, chief technology officer. "By applying the proper optics and gratings, the new chip may also be used to create fixed-wavelength laser sources with a very narrow line-width well suited for direct frequency conversion to visible light used in, for example, laser projection and flow cytometry."

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

### DILAS launches high-power vertical diode laser stacks

DILAS Diodenlaser GmbH of Mainz, Germany has launched high-power vertical diode laser stack arrays, with wavelengths of 630–1900nm and output power of up to 100W continuous-wave (CW) per bar.

The vertical stacks are designed for applications such as diode-pumped solid-state laser, material processing, defense, reprographics and medical applications requiring kilowatts of continuous-wave (CW) or quasi-CW (QCW) laser power in a compact, easy-to-integrate package.

The water-cooled vertical stack is available in up to 70 stacked bars with collimation for fast-axis as well



DILAS' vertical diode laser stacks.

as slow-axis configurations. The advanced housings, high-precision optic mounting and online sensoric testing give full control and allows all beamlets to be parallel within  $\pm 3\text{mrad}$  for reliable operation.

The standard design includes a dust protective or a hermetically sealed housing with an AR-coated window. Several different models are available, with custom solutions upon request. In addition, the standard models DILAS provides can be customized to fit specific requirements for interfaces, beam propagation, mechanical dimensions, etc.

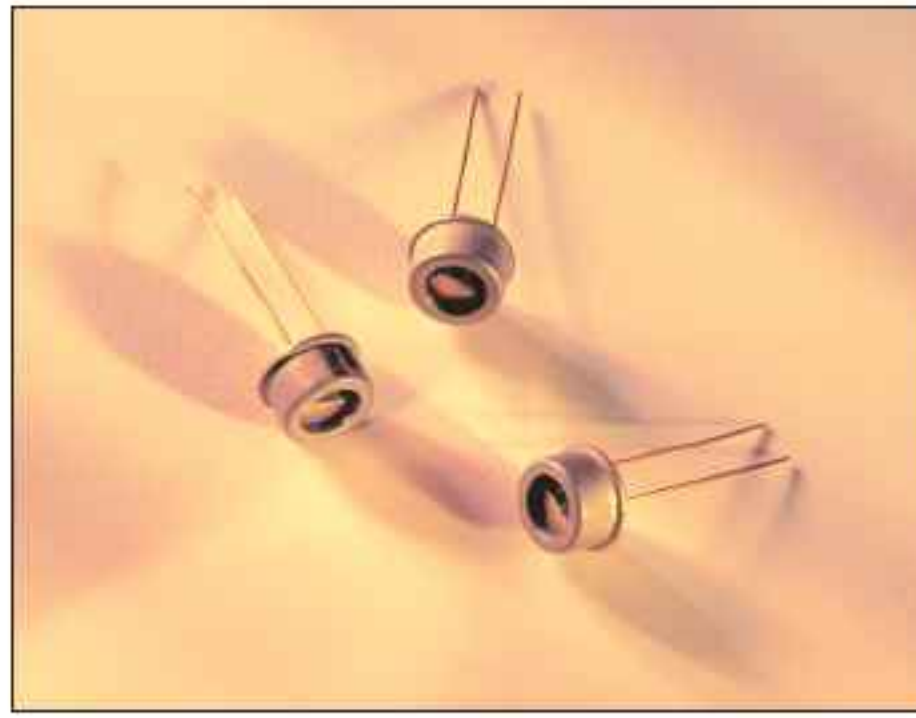
[www.DILAS.com](http://www.DILAS.com)



## Intense launches high-power, single-mode 980nm lasers

Laser manufacturer Intense Ltd of Glasgow, UK has launched the Intense-HPD Series 6100 of 980nm high-power single-emitter laser diodes. The high-brightness, single-mode lasers have up to 200mW of kink-free power available in wavelengths of  $980\text{nm} \pm 5\text{nm}$  and  $980\text{nm} \pm 10\text{nm}$  (or other wavelengths on request for OEM applications).

The Series 6100 is based on Intense's patented quantum well intermixing (QWI) technology, which increases the brightness and reliability of diode lasers while avoiding the usual problems associated with catastrophic optical



**Intense-HPD Series 6100 980nm high-power single-emitter laser.**

mirror damage, the firm claims. Applications include print and imaging, point-to-point communications, medical imaging, optical storage,

sensing and detection, and aerospace and defense.

The lasers are available in standard packages including 5.6mm, 9mm, and C-mount. Monitor photodiodes are optionally available on the 5.6mm and 9mm packages.

The strength of the Series 6100 lies in the combination of Intense's QWI technology and Intense-HPD's high-volume manufacturing processes, says CEO Scott Christie. "The end result is high-performance lasers that can operate at high optical brightness with exceptional reliability, even in the face of constrained power," he adds.

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

## QPC's first Gen III laser ships to US medical customer

QPC Lasers Inc of Los Angeles suburb Sylmar, CA, USA, a vertically integrated manufacturer of high-power semiconductor lasers for industrial, defense, and medical markets, has shipped its first laser in its Generation III product family, a 100W laser, to a medical customer in the US for a surgical application.

The initial shipment of the 100W laser marks the inauguration of the firm's Generation III product line, which uses the firm's proprietary BrightLase semiconductor laser technology and which QPC believes could replace conventional solid-state and gas laser technology with more efficient, rugged, and cost-effective semiconductor-based solutions.

"Gen III lasers provide more than twice the power of Gen I and Gen II products, while offering reduced size, weight and cost compared to traditional laser technology," claims CEO Jeffrey Ungar. "We look forward to continuing the roll out of higher-powered additions to this product line and anticipate growth in the medical, defense, and industrial markets for these Gen III products in 2008."

QPC says the 100W Generation III laser suits surgical laser applications such as urology or cardiology that require high-power laser beams to be delivered with high-brightness in small-diameter optical fiber in order to reach locations inside the body in a minimally invasive fashion.

QPC says that its BrightLase lasers offer a compact, reduced-cost solution with wavelength flexibility, so medical users can accelerate their return on investment while optimizing treatment wavelengths. Traditionally, higher-cost, multi-stage lasers such as lamp-pumped or diode-pumped systems have been used for these applications.

Defense applications of Gen III include laser engines for widely deployable directed-energy weapons based on direct diode or fiber laser technology. Gen III products are also being designed for high-power industrial applications, including materials processing, welding, marking, and engraving.

## QPC expects third-quarter revenues to rise 125% year-on-year

QPC Lasers expects revenue of \$2.1–2.2m for Q3/2007 (up more than 125% year-on-year and 17% on Q2's \$1.8m) and \$5.0–5.1m for the first nine months of 2007 (up more than 180% year-on-year).

"We continue to focus on top-line growth and are pleased with these solid preliminary revenue results," says executive vice chairman and chief financial officer George Lintz.

"We are tracking to our expectations, both in terms of the 2007 total revenue target we stated on our second quarter conference call and the milestones we identified in connection with our recent financings."

During Q3, QPC also shipped its initial BrightLase Seed Lasers to a defense customer and recruited industry veteran Dr Tom Steele as director of market development to

drive expansion for its growing medical business.

Apart from the initial shipment of the first Generation III laser to a medical customer, in Q3 QPC also demonstrated its first visible laser (a green laser for multiple display applications).

QPC plans to announce complete financial results in November.

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

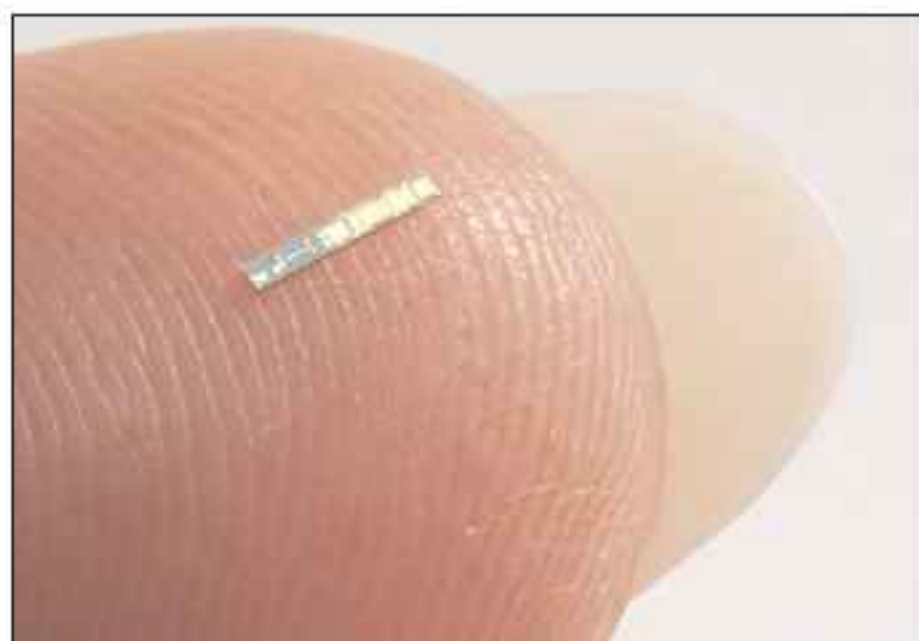


# JDSU demonstrates tunable 'transmitter-on-a-chip' PIC

Using what it calls Integrated Laser Mach Zehnder (ILMZ) technology, JDSU of Milpitas, CA, USA has demonstrated a photonic integrated circuit (PIC) that integrates a widely tunable laser and a Mach-Zehnder optical modulator on a single InP-based die (small enough to fit on the tip of a finger). JDSU says that the new PIC will allow it to develop smaller, higher-performance and more cost-effective tunable solutions that support faster network speeds.

Starting in 2008, the new PIC will be incorporated into full-band tunable transponders and transceivers within compact packages, such as 300-pin small-form-factor (SFF) and pluggable small-form-factor (XFP) modules. The technology also enables JDSU to support transmission speeds of more than 11.3Gb/s as well as being scalable to support 40Gb/s networks.

Recent and dramatic growth in data, voice and video traffic over dense wavelength division multiplexing (DWDM) networks has stimulated service providers to scale up their capacity. However, the use of traditional fixed-wavelength lasers means holding expensive inventory for each wavelength. Also, the



**The Integrated Laser Mach-Zehnder photonic integrated circuit of JDSU.**

unpredictability of wavelength activity often leads to supply shortages for specific wavelengths, compromising network bandwidth capacity.

Instead, fixed-wavelength lasers can be replaced by tunable lasers in transponders and transceivers, creating agile optical networks (AONs) with 'dynamic reconfigurability', whereby network operators can quickly respond to fluctuating traffic by switching between wavelengths on demand. A single tunable laser can cover nearly a hundred 50GHz-spaced channels in a DWDM system, either switched to support different wavelengths on demand or used as a universal source to support a particular wavelength.

As well as simplifying network management and optimizing network activity, this eases the cost of purchasing, storing and managing spare devices for wavelength management. Consequently, market research firm CIR predicts that the tunable laser market will grow at a compound annual growth rate of 37% over the next five years to nearly \$1bn by 2012.

JDSU claims that its new PIC solutions with ILMZ technology will further streamline network management and reduce costs for service providers by providing tunable lasers in smaller form factors. Modules that take up less space in network equipment racks and use less power can reduce data center rental costs and power bills, the firm adds.

"A more compact and integrated approach toward tunable lasers is critical as service providers strive for greater efficiency in their networks," says Alex Schoenfelder, VP and general manager of Integrated Photonics. "Integration at the PIC level will help to lower costs and enable high-volume manufacturing," he adds.

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

## JDSU appoints senior VP of Optical Communications Operations

JDSU, which manufactures broadband and optical communications components, has appointed Keith Lambert as senior VP of Optical Communications Operations. Reporting to David Gudmundson, JDSU's president of Optical Communications, Lambert will focus on driving efforts in the areas of lean manufacturing, cost leadership and operational excellence for the group, aimed at improving gross margins for the company.

JDSU says that Lambert brings direct management experience in

almost every area of operations, including production, lean manufacturing, contract manufacturer management, supply chain

management, planning, materials management, manufacturing engineering and Asia-based operations.

From 2001 to 2007, Lambert was VP of Global Operations at RadiSys Corp, a provider of embedded electronics solutions for telecom



service, medical equipment, test & measurement equipment, and industrial automation. He was also VP and general manager for two business units within RadiSys.

Previously, after starting his career with Digital Equipment Corp (where he held positions in manufacturing and development engineering), Lambert held manufacturing and test engineering positions at 3Com Corp from 1995 to 1999. He was then VP and general manager of Manufacturers' Services Ltd (MSL) from 1999 to 2001.



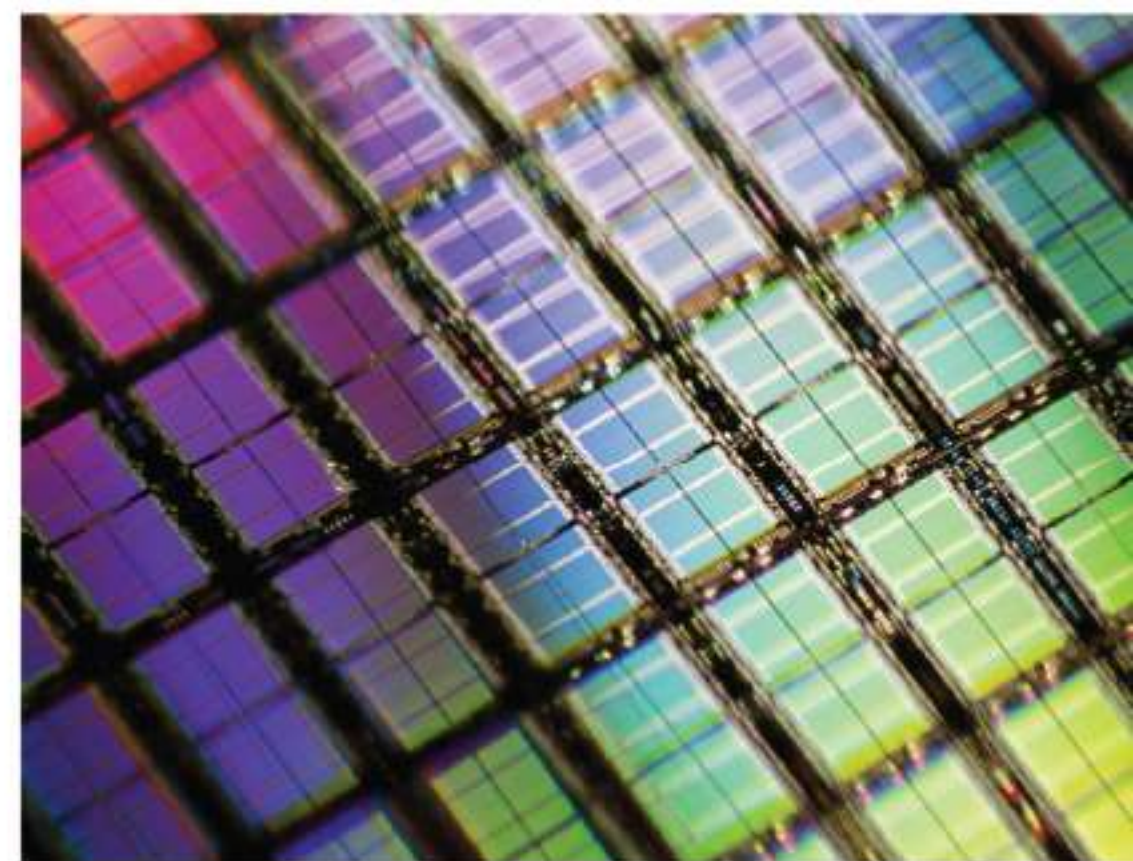


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# Kotura and CyOptics win NIST ATP award for terabit PICs

The US Commerce Department's National Institute of Standards and Technology (NIST) Advanced Technology Program (ATP) has awarded silicon photonics component maker Kotura Inc of Monterey Park, CA and InP-based optical chip maker CyOptics Inc of Lehigh Valley, PA \$5.9m to fund a three-year project for the development of next-generation Terabit photonic integrated circuits (TERAPICS).

Kotura will develop integrated silicon photonics chips for the project, which will serve as the mounting platforms for the laser and receiver

arrays, as well as providing the multiplex and de-multiplex functions. "In network centers and high-performance computing clusters, TERAPICS will reduce the number of transceivers, connectors and fibers by a factor of 100," said VP of sales & marketing Arlon Martin.

Founded in 1999, CyOptics will develop the monolithic arrays of InP-based lasers and detectors, automated assembly processes, and laser and receiver devices. "The TERAPICS development project will leverage CyOptics' broad device portfolio of InP-based lasers,

receivers and integration processes as well as our highly automated assembly and packaging platforms," says VP of marketing and business development Stefan Rochus.

The project will use a combination of monolithic and hybrid integration to reduce hundreds of individual components to less than 10.

The initial phase will provide a platform for 100Gb Ethernet. The end goal is to demonstrate optical laser and receiver components for transmission speeds of up to 1Tb/s.

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

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

## CyOptics launches low-cost 1310nm FP and DFB TOSAs for 10Gb/s enterprise applications

InP-based optical chip and component maker CyOptics Inc of Lehigh Valley, PA, USA has made available sample quantities of its new 1310nm Fabry-Perot (FP) and distributed feedback (DFB) transmit optical sub-assemblies (TOSAs) for 10Gb/s applications. Volume production will begin in December.

The lasers are designed as a ridge waveguide structure and contain InAlGaAs-based multi-quantum well (MQW) active layers for improved static and dynamic performance over temperature. The TOSA products incorporate an integrated InGaAsP monitor photodiode and are packaged in a TO header with receptacle for uncooled use over an operating temperature range of -25°C to 90°C and for transmission rates of up to 10.7Gb/s.

The TX299K (FP) and TX293K (DFB) TOSAs are compatible with the 10Gb/s miniature device (XMD) multi-source agreement (MSA) for high-performance transceivers

addressing the OC-192/STM-64 SONET/SDH, LRM 10 Gigabit Ethernet and 8x Fibre Channel market applications.

The launch of the FP and DFB TOSA's completes CyOptics' 10Gb/s product portfolio, which already includes higher-performance uncooled 1.3µm EML (electro-absorptive laser) TOSAs and 1.5µm EML TOSAs with thermo-electric coolers (TECs) in support of 40km, 80km and DWDM 10Gb/s applications, as well as PIN and APD (avalanche photodiode) ROSAs (receive optical sub-assemblies). The InP laser and detector chips are manufactured in CyOptics' fab in Breinigsville, PA and the cylindrical TO cans and TOSAs are made by CyOptics' packaging partners in Asia.

"With the addition of these low-cost solutions, we have one of the industry's broadest 10Gb/s TOSA product offerings," claims Kou-Wei Wang, VP and general manager of CyOptics' InP OEM business.

## Modulight launches high-power 1550nm TO-can lasers

Modulight Inc of Tampere, Finland, a manufacturer of optical semiconductor components, has launched the ML1470 high-power, single-emitter 1550nm laser chip, housed in a 9-mm TO-can.

Designed mainly for free-space applications requiring powerful laser beams at eye-safe wavelengths, the new device capitalizes on Modulight's decade of expertise in this wavelength range. High power and high efficiency render the product applicable also to battery-operated equipment.

The laser comes in a variety of optical configurations, being capped with a flat window or (on customer demand) with a collimating lens. Heat-sinking and cooling requirements are modest, as the new laser module requires only 3A for full optical output beyond 500mW in continuous wave operation.

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



# Silicon Photonics Alliance launched by OIDA

In conjunction with its forum 'Perspectives on the Optoelectronics Industry: Advances, Challenges and Growth Opportunities' in San Jose, CA, USA in September, the Optoelectronics Industry Development Association (OIDA) of Washington DC has launched the Silicon Photonics Alliance — the association's first formal Community of Interest (COI).

The group is to be headed initially by Tom Palkert, system architect with fabless silicon photonics firm Luxtera Inc of Carlsbad, CA, USA, which in August launched its first product (the industry's first CMOS photonics product). Other firms that have joined the alliance include Corning, Kotura, Molex and US Conec.

"Primary objectives will be to educate the industry about the benefits that silicon photonics brings versus traditional optical solutions," says Palkert. Aims include finding opportunities to participate in forums and working to identify key applications areas. "We will work together to promote silicon photonics in the standards bodies [to assure interoperability among vendors], and accelerate commercial products."

"The establishment of the Silicon Photonics Alliance is a notable development for the optics industry," says Ashok Krishnamoorthy, distinguished engineer and director for SUN Microsystems. "This OIDA Community of Interest brings together

multiple suppliers to create an ecosystem for the industry. I expect that their efforts will accelerate customer adoption of this technology."

"We have grown to unprecedented levels with an extremely diverse membership, and we are excited to be working with Luxtera and the other members to introduce this Community of Interest," says OIDA's VP of business development & marketing David Huff. "We anticipate that this new alliance will help further promote and increase the market adoption of silicon photonics technology."

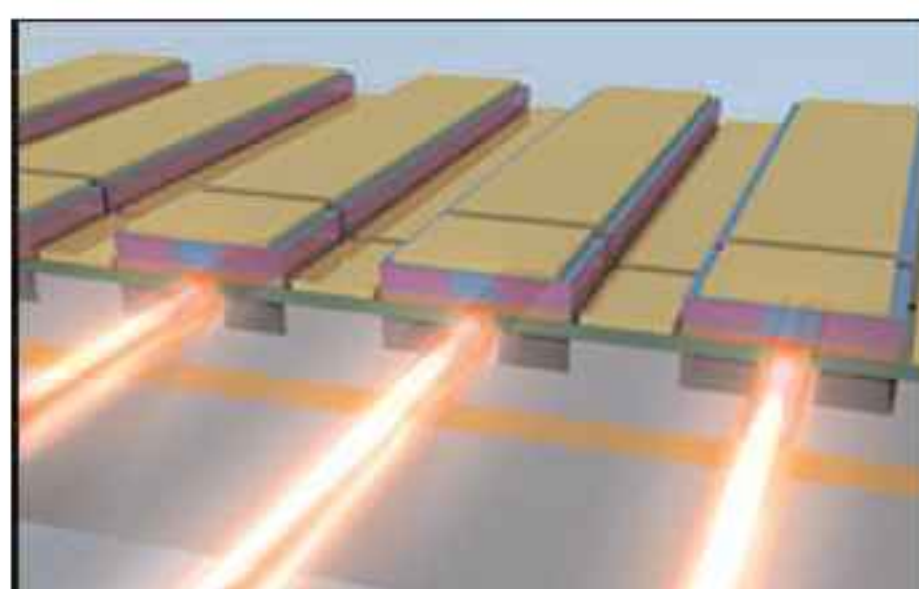
To enquire about joining the alliance, e-mail David Iams at [iams@oida.org](mailto:iams@oida.org).

[www.oida.org/spa](http://www.oida.org/spa)

## Intel demos first 40GHz hybrid InP/silicon laser

A research team led by John Bowers, professor of electrical and computer engineering at the University of California Santa Barbara, working with Intel researcher Oded Cohen in Jerusalem, has demonstrated the first mode-locked silicon evanescent laser: an electrically pumped indium phosphide laser fabricated on silicon that produces pulses at repetition rates of up to 40GHz, even without RF drive (B.R. Koch, Optics Express, Vol. 15, Issue 18 (3 September 2007), p11225). This is the first reported achievement of such a rate on silicon.

Late last year, the team demonstrated the first hybrid silicon laser (operated in continuous-wave mode). The device integrates an InP laser bonded to a silicon waveguide (allowing evanescent coupling of light emitted from the InP active layer into the silicon-based laser cavity). The latest laser adds elements to the laser cavity that allow it to emit highly stable ultra-short (4ps) light pulses with low jitter and



**Integrated mode-locked silicon lasers.**  
(Image: Peter Allen, UCSB.)

high extinction ratios (above 18dB), rivaling those of III-V mode-locked lasers (MLLs), it is claimed.

Intel already produces silicon-based optical modulators for encoding data onto pulses. Now, combination with a stable silicon pulsed laser enables integrated, all-silicon optical communications with multiple channels on the same chip, for applications such as high-speed datacom and telecom transmission, multiple wavelength generation, remote sensing using LIDAR (Light Detection and Ranging), and highly accurate optical clocks.

Future designs incorporating ring structures, distributed Bragg reflector (DBR) mirrors, or deeply etched mirrors should allow for on-chip integration with other optoelectronic components and CMOS electronics. The ability to transition from gain regions to low-loss passive regions should allow new possibilities such as lower-repetition-rate integrated MLLs and single-chip optical time-division multiplexing (OTDM), wavelength division multiplexing (WDM), and optical code division multiple access (OCDMA) on silicon.

"Because our silicon laser is so powerful and its pulses so well timed, we could combine, say, four 40Gb/s lasers into a single 160Gb/s signal," adds first author Koch. "One other thing we hope to do is separate all the wavelengths coming out of each pulse, to create an array of wavelengths that could be separately modulated then recombined for multi-channel communications over a single fiber."

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



## First FP-based optical components for 10GBASE-LRM

Finisar Corp of Sunnyvale, CA, USA has announced availability of what it claims are the industry's first transmitter and receiver optical subassembly pairs (TOSA/ROSA) using Fabry-Perot (FP) laser diodes and PIN detectors for the IEEE 10GBASE-LRM standard (extending performance, conserving power, and expanding control). Demonstrations were held at September's ECOC 2007 show in Berlin, Germany.

To date, LRM (long-reach multi-mode) products have been based on more expensive and power-hungry distributed feedback (DFB) lasers.

The FP lasers in Finisar's TOSA are inherently less expensive but can still meet all performance requirements of the IEEE

10GBASE-LRM standard, and

reduce overall transceiver power consumption substantially, Finisar claims.

In the ROSA, automatic gain control and receive-signal detect capa-



**Finisar's 10Gb/s LRM TOSA/ROSA.**

bilities enable developers to optimize individual link performance and implement intelligent fault detection, says the firm. In the TOSA, a unique impedance matching network reduces power consumption. Also, the TOSA and ROSA are offered in two connector options (SC and LC) and include a flex circuit for simplified electrical connectivity.

"These new 1310nm LRM sub-assemblies are important additions to Finisar's existing portfolio of 850nm short-reach products," says Dr Jim Tatum, director of marketing, Finisar Advanced Optical Components.

## Finisar rebounds from last quarter's inventory adjustments

For its fiscal Q1/2008 (to end July) Finisar reported revenue of \$105.7m. This is down slightly from \$106.2m a year ago, but up 8.7% on last quarter's slump to \$97.3m (from \$107.5m the previous quarter, hit mainly by two customers transitioning to 'just-in-time inventory' arrangements and the utilization by certain customers of excess inventories of products designed for SAN applications).

Revenues for optical products were \$96.4m, up 9% on \$88.4m last quarter. Shipments of 10-40Gb/s products were \$18.2m, up 22.8% on \$14.9m last quarter and more than trebling on \$5.8m a year ago.

Gross margins were down on the previous quarter, due mainly to extra costs from ramping up new products and 'unfavorable manufacturing variances' associated with reducing production levels to better match inventories on hand.

"We were pleased to see revenues bounce back from last quarter as we recovered from a number of customer supply chain and excess inventory issues," says president and CEO Jerry Rawls. "We are heavily focused on the continued penetration of the telecom equipment market for 10Gb/s, 40Gb/s, and WDM [wavelength division multiplexing] products and the

LAN/SAN [local-area and storage-area network] markets for 8Gb/s and 10Gb/s products," he adds.

"We continue to invest in R&D in all these emerging market areas as our customers continue to be optimistic about the end-user demand for more bandwidth."

The latest results are preliminary and do not include figures on profits, pending any adjustments that may be required due to Finisar's ongoing review of its past stock option grants (which have so far prevented it filing its annual report on Form 10-K for fiscal 2007 as well as interim quarterly reports on Form 10-Q).

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

## Ultra-narrow linewidth, low-noise 1310 & 1550nm lasers

Eblana Photonics Ltd of Dublin, Ireland has started shipping single-wavelength 1310nm and 1550nm laser diodes for 10Gb/s analog and other applications demanding ultra-narrow emission linewidth (below 100kHz) and low-phase-noise operation (relative intensity noise (RIN) down to -160dB/Hz), even at emitted powers as low as 500µW.

The latest product series extends Eblana's existing family of laser products targeting high-volume applications such as GPON,

10GBASE-LR/LRM/LW and 10 Gigabit Fibre Channel.

"This new product family increases the affordability of transceivers and transponders in conventional applications that require ultra-narrow linewidth, low-noise sources such as long-reach (LR)/very-long-reach (VR) spans in metro systems and long-haul (LH) and ultra-long-haul (ULH) systems," says Daniel Tine, head of North American sales & business development.

"These lasers also make the superior sensitivity and longer transmission span achieved with coherent communications systems a real commercial alternative to WDM-based access systems," adds Bo Cai, head of Asian sales & business development. "They extend our product offering into the analog, CATV, back-haul and coherent WDM spaces, providing distinct advantages to our customers in those increasingly challenging markets."

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



## Opnext launches XENPAK 10Gb/s LRM modules, enabling upgrade to 10GbE using existing fiber

At ECOC 2007, Opnext Inc of Eatontown, NJ, USA launched a second form-factor to its existing 10G LRM optical pluggable module family. The latest XENPAK form-factor modules offer very low power consumption, superior transmission characteristics and high-temperature performance, claims the firm.

"LRM is an ideal solution for enterprise and campus networks which want to upgrade to a 10 Gigabit Ethernet network without installing new fiber plant," says Rich Zoccolillo, VP of Opnext's Pluggable Business Unit. "The addition of Electronic Dispersion Compensation (EDC) enables these modules to [be] used over existing multi-mode fiber (MMF)."

LRM transceiver volume demand is forecast to grow at a compound annual growth rate (CAGR) of 90%

from 2008 to 2011, according to the report 'Assessment of the 10G Module Market' released in July by market research firm Ovum-RHK.

Opnext provides pluggable optical 10GbE solutions and actively supported the definition of IEEE 10G BASE-LRM standard. The Opnext LRM family of optical transceivers will include four hot-pluggable form factors: XENPAK, X2, XFP and SFP+. Opnext's transceiver design capabilities and native DFB laser diode produce modules which exceed the IEEE 10G BASE - LRM specifications.

● Opnext's full line-up of 300-pin transponder and XENPAK transceiver 10Gb/s modules covers all applications, from legacy multi-mode fiber to long reach (80km and WDM).

The X2 transceiver is a follow on to XENPAK and has been adopted

by major enterprise switch manufacturers. X2 transceiver power consumption is about half that of XENPAK in a smaller footprint that can be used for legacy multimode fiber to long reach single mode fiber (80km and WDM).

The XFP transceiver is a follow on to 300-pin TDM and some DWDM applications, and has been widely adopted by the telecom community.

However, the 300-pin module is still popular for tunable applications with no sign of slowing.

On the horizon is the SFP+ transceiver for 8G storage and 10GbE enterprise applications.

Opnext offers a complete portfolio of 10 Gigabit Ethernet transceivers, including: 10GBASE-CX4, 10GBASE-SR, 10GBASE-LR, 10GBase-ER, 10GBASE-ZR, and 10GBASE-DWDM.

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

## Tunable laser maker Syntune raises \$7.1m in 2nd round

Syntune AB of Stockholm, Sweden has closed a second round of financing of SEK47.8m (\$7.1m, €5.2m), led by InnovationsKapital of Sweden, joined by Teknoinvest, Vision Capital and existing private investors. This follows a SEK42m (\$6.2m, €4.7 m) private equity round in December 2004.

Syntune develops single-chip, widely tunable lasers for applications ranging from fiber-optic communications to sensor systems. As part of the firm's formation in January 2003, Syntune acquired an exclusive license to a patent on a 'modulated grating Y-branch' (MG-Y) tunable laser, jointly owned by IMEC of Leuven and Ghent University in Belgium and UK-based Gayton Photonics Ltd. The technology was developed as part of the EU-funded project NEWTON (New Widely Tunable Lasers for Optical Networks) in which Stockholm-based tunable laser manufacturer Altitun/ADC

(former home to several Syntune executives) was a partner.

"This round of investment enables us to ramp production more quickly, as well as grow our customer base for both our first generation of tunable products as well as our second-generation 10Gb/s tunable transmitter product," says CEO Patrik Evaldsson.

Syntune's product line includes the S3500 widely tunable CW laser, the S3600 MSA-compliant Integrable Tunable Laser Assembly (ITLA) and the S4500 — the world's first truly monolithic, integrated 10Gb/s tunable transmitter, it is claimed.

In communications, Syntune's lasers enable universal dense wavelength division multiplexing (DWDM) transceivers with low power consumption in a small form factor, cutting overhead costs for sparing and maintaining inventories. Tunability also enables flexible networks, which allows operators to

offer innovative services as well as reducing operational expenditures.

"Syntune's approach of using world-class foundries in both chip and packaging fully leverages our investment," says InnovationsKapital's investment director Peder Holm. Syntune uses manufacturing partners, including CyOptics Inc of Lehigh Valley, PA, USA (which specializes in InP optical chip and component technologies), with which Syntune entered into a manufacturing agreement in January.

"We have made great progress in the marketplace and look forward to supporting the volume demands of our customers," says Kevin Green, VP of marketing & sales. According to estimates by market research firm CIR, tunable lasers will be the fastest growing major segment of the components market, reaching almost \$1bn by 2012.

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



# Bookham qualifies submarine pump for volume shipments

Optical component, module and subsystem maker Bookham Inc of San Jose, CA, USA says that its OceanBright submarine 980nm pump laser module has achieved full qualification. The module, which is used in erbium-doped fiber amplifiers (EDFAs), has started volume shipments and is being deployed in undersea cable systems. The product debuted in Europe at September's ECOC 2007 event in Berlin.

To achieve full qualification, the module has demonstrated its ability to meet submarine reliability requirements of less than 50 FITs (failures in time). Bookham has performed extensive qualification testing, including module-level life-test at highly accelerated conditions, analysis of which shows negligible changes in device characteristics (a predicted change in output power of less than 2% over a 27 year lifetime).

"The performance and reliability data for the 980nm pump module confirms its ability to perform to extremely high standards in very demanding conditions. Bookham has long been perceived as a leader in the terrestrial pump market,"



**Bookham's OceanBright submarine 980nm pump laser module.**

claims PLM director Mark Ives. "This product is expanding that expertise into the undersea cable market."

"The OceanBright module is the latest in a line of products built on our proven laser chip technology, which has now been deployed in volume to the submarine market for 10 years."

OceanBright incorporates Bookham's G08 generation-eight laser chip, can exceed an output of 400mW at operating temperatures of 0–45°C and complies with multi-source agreement requirements for use in uncooled applications. Bookham's range of pumps also includes ultra-high-power cooled butterfly and uncooled high-power single-mode and multi-mode pumps.

● Bookham has shipped its 100,000th InP-based Mach-Zehnder (MZ) modulator, which has been in production and co-packaged with lasers for over 10 years and has accumulated billions of field hours (demonstrating reliability of <30FITs).

"InP MZs offer a smaller footprint and lower cost than competing LiNbO<sub>3</sub> and GaAs modulators, and have proven their ability to perform in 10Gb/s metro and long-haul applications," says Jon White, InP MZ and tunable portfolio product line manager. "With increasing bandwidth demanding higher line-card density, the ability to produce ever smaller components and modules is a critical differentiator... InP offers the ideal platform on which to build the next generation of tunable technology and will enable our future 40Gb/s developments and small-form-factor products."

The InP technology now underpins Bookham's new vertically integrated tunable portfolio, including the MSA-compliant integrable tunable laser assembly (iTLA), tunable transmitter assembly (TTA), and tunable small-form-factor transponder (TSFF).

## Discrete optics portfolio expanded with 2.5Gb/s TOSA

At September's ECOC 2007 event in Berlin, Germany, Bookham launched an MSA-compatible 2.5Gb/s transmit optical subassembly (TOSA), expanding its portfolio of discrete optics (which also includes an XMD MSA-compliant ROSA receiver optical subassembly).

Set for commercial availability in November, the next-generation TOSA is designed as an in-feed to the growing TDM, CWDM and DWDM SFP (small form-factor pluggable) markets, and can also replace 14-pin butterfly direct modulated lasers (DML) on card applications.

Incorporating Bookham's buried heterostructure laser (of which over 500,000 have been shipped in the last five years), the firm says that its TOSA technology has proven its reliability in Bookham's DWDM SFP module.

"Our established TOSA technology has underpinned our pluggable optics portfolio for many years," says Graeme Morrison, Product Line Manager – Commodity Optics. "The decision to make a commercially available TOSA follows our strategy of vertical integration:



**Bookham's 2.5Gb/s TOSA.** offering our customers a full range of products, from discrete optics to packaged modules and subsystems."

The TOSA has a transmission capability of 125Mb/s to 5.3Gb/s over 1600–6000ps/nm dispersion, with low penalty and a high extinction ratio of >10dB. At the OC48 data rate it has a reach of up to 360km in the C-band and 200km and the L-band.

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

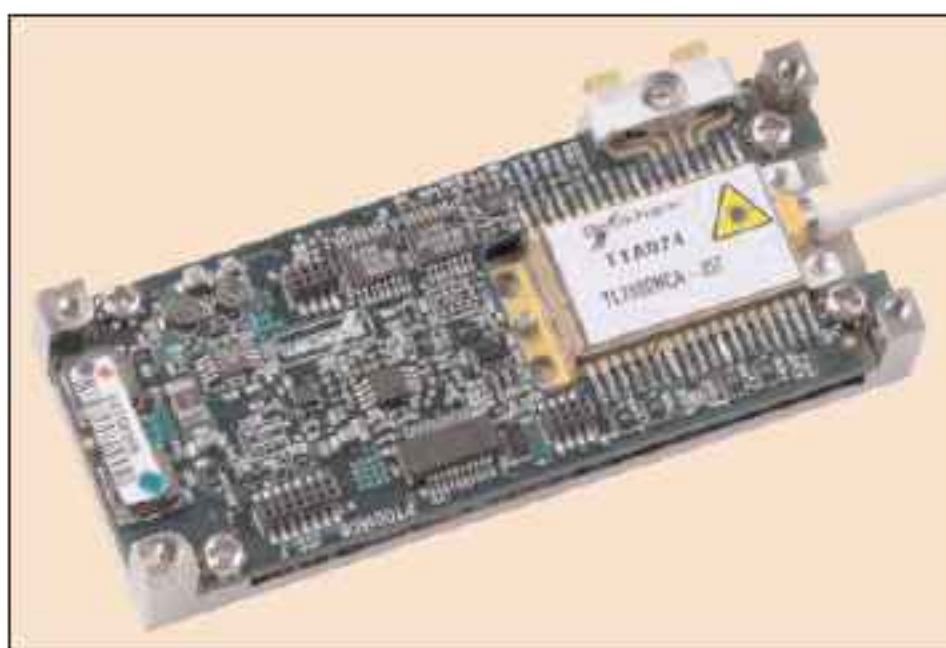


## LambdaFLEX 10Gb/s tunable transmitter assembly reaches full Telcordia qualification

Optical component, module and subsystem maker Bookham Inc of San Jose, CA, USA says that its LambdaFLEX 10Gb/s tunable transmitter assembly (TTA) has reached full Telcordia qualification and is being shipped in volume to customers worldwide.

Together with the firm's tunable small form-factor transponder (TSFF), at September's ECOC 2007 event in Berlin, Germany the TTA was given a live demonstration (the first of its kind in Europe) showing the ability of Bookham's tunable InP Mach-Zehnder (MZ) technology to operate with extremely fast wavelength tuning over the full C-band in a noise-loaded environment (replicating the conditions under which the products perform in long-haul networks).

"Bookham is driving the development of tunable technology, with hundreds of our TTAs being shipped to global tier 1 customers," said Jon White, product line manager for the InP MZ and tunable portfolio. "The market is demanding tunable products of the highest standard: products that can perform in live networks, not just in the lab. With full Telcordia qualification, the TTA



Bookham's TL7000 TTA (left) and TL9000 TSFF (right) modules.

meets the stringent demands that all our telecoms products adhere to."

The TTA integrates Bookham's LambdaFLEX tunable compact MZ onto a module platform which is the size of an iTLA (integrated tunable laser assembly) — a footprint significantly smaller than that offered by the combination of a continuous wave laser and external modulator. The TL7000NCD TTA is a negative-chirped C-band part, designed for uncompensated 80km links, which enables economic full-band tunable deployments in regional metro applications, Bookham claims. The TTA features an industry-standard iTLA interface and command set.

In addition, Bookham's TL9000 TSFF 300-pin transponder combines the tunable compact MZ with an APD

(avalanche photodiode) receiver to create what the firm claims is the world's first MSA-compliant TSFF transponder in a 76mm x 56mm x 11.4mm package. While previous SFF small form-factor transponders focussed on intermediate-reach point-to-point links, the TL9000 expands this capability with a zero-chirp option for multi-span long-haul applications where low-OSNR (optical signal-to-noise ratio) conditions are common, as well as a standard negative-chirp option for regional and metro applications.

Bookham says that, unlike competing technologies, its LambdaFLEX tunable laser portfolio is built on a single indium phosphide optical chip laser platform with no moving parts.

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

## Bookham plans full-band 10Gb/s long-reach tunable pluggable transceiver, for availability in first-half '08

At the ECOC 2007 show, Bookham announced that it is developing a full-band 10Gb/s, long-reach, tunable pluggable transceiver, to be commercially available in first-half 2008.

The new product will combine the firm's InP DS-DBR (digital super-mode-distributed Bragg reflector) tunable laser and Mach-Zehnder (MZ) modulator with an avalanche photodiode (APD) receiver in a pluggable Super X2 format. It will offer the existing benefits of tunability combined with the

'pay as you grow' convenience of a hot pluggable module, says the firm.

"The industry has long recognised the advantages of tunable technology and the flexibility of front-panel pluggable modules; this new product will combine both benefits," says Jon White,

**Industry has long recognised the advantages of tunable technology and the flexibility of front-panel pluggable modules**

product line manager for Bookham's InP MZ and tunable portfolio.

"Our ownership of the core InP chip technology and our heritage in MZ modulators, monolithic tunable lasers and pluggable optics means that we are well positioned to make the tunable pluggable ideal a workable, reliable reality," he claims.

"We are also working towards next-generation tunable TOSA (transmit optical subassembly) components that will enable further size reduction."



# First hot-swappable 10Gb/s tunable DWDM transceiver

At ECOC 2007, Tokyo-based Mitsubishi Electric Corp unveiled what it claims is the world's first hot-swappable 10Gb/s optical transceiver capable of tuning over the whole C-band (1530–1560nm) dense wavelength division multiplexing (DWDM) range.

The new MF-10KWXF series 10Gb/s transceiver allows multi-rate operation at data rates of 9.95–11.1Gb/s for SONET/SDH and 10 Gigabit Ethernet networks, and complies with the XFP-E (extended) 10Gb/s small form-factor pluggable multi-source agreement (MSA).

In October 2006, Mitsubishi Electric commercialized the XFP-E MSA-compliant MF-10KWXB series optical transceiver for DWDM, which used a fixed frequency. But, says the firm, with increased Internet traffic in recent years, service providers are rushing to expand the transmission volume of optical communications networks, so there is increasing demand for a DWDM system that can handle

64 or 128 wavelengths in a single optical fiber. The need for a tunable optical interface to operate this using pluggable transceiver is increasing.

So, in contrast to the MF-10KWXB, the new MF-10KWXF series is the first hot-swappable optical transceiver that can be set to any C-band DWDM grid frequency at the user's discretion by mounting a tunable laser with a low-power-consumption semiconductor modulator (rather than a lithium niobate modulator) in the transceiver module.

Previous tunable DWDM 10Gb/s transceivers were unable to hot swap because they were connected to the substrate with a 300-pin electric connector, so users had to physically remove and insert optical transceiver motherboards, and optical interface maintenance was necessary, which made integrating multiple ports on one board impossible. The MF-10KWXF series is pluggable for multiple ports by

edge connecting using XFI (XFP MSA 4.5 compliant) electric connection conditions.

By complying with the XFP-E MSA and considering maintenance design by using the XFI interface, the transceiver can be used with no changes to the user board even when future XFP frequency tuner DWDM optical communications transceivers are developed.

With a compact size of just 78mm x 48mm x 12.6mm and low power consumption of 7W (maximum), the MF-10KWXF is 50% smaller and uses 40% less energy compared to previous models, the firm claims.

Also, by using XFI edge connecting and receptacle design, the occupied substrate surface area is reduced by 70% compared to models using a 300-pin transponder. Combining this with multiple porting will greatly improve mounting density, reckons Mitsubishi Electric.

<http://global.mitsubishielectric.com>

# Alcatel-Lucent's integrated optoelectronics developments

In three post-deadline papers at ECOC 2007, Alcatel-Lucent announced advances in optical network transmission via new integrated optoelectronics sources as well as a new receiver.

On the receiver side, Alcatel-Lucent researchers in Bell Labs of Crawford Hill, NJ, USA have demonstrated a compact optoelectronic receiver for differential quadrature phase-shift keying (DQPSK) reception that integrates an optical demodulator and four photodiodes on a single 3.2mm x 0.8mm InP-based chip. The firm says this gives a footprint that is more than two orders of magnitude smaller than typical current-generation DQPSK receivers where, in order to support advanced modulation formats, multiple components are connected by precise path lengths. The development could help to cut not only the size

but also the cost of high-data-rate advanced-modulation-format optical transceivers, the firm claims.

On the emitter side, researchers from Alcatel-Thales' III-V lab near Paris, France demonstrated the first integrated version of a laser and an electro-absorption modulator (EML) with a record bandwidth of 60GHz — a step towards a next-generation 100Gb/s source for very short reach (VSR) transmission. Alcatel-Lucent claims that it is also a potential low-cost approach, since it has also demon-

**III-V lab near Paris, France demonstrated the first integrated version of a laser and an EML with a record bandwidth of 60GHz**

strated high operating temperature capability (43Gb/s up to 70°C, as reported at May's International Conference on Indium Phosphide and Related Materials 2007 in Matsue, Japan).

Alcatel-Thales III-V lab has also realized a 42GHz mode-locked laser source with a record wavelength tunability of 16nm, keeping constant both the output power and the narrow pulse width of 2ps. The firm says that this performance has been reached due to a new active layer made of quantum dots. Also, the optical pulses are Fourier-transform limited, which suits propagation in a fiber. These features collectively make such a laser attractive for very high-bit-rate tunable optical transmission, the firm claims.

[www.alcatel-lucent.com](http://www.alcatel-lucent.com)  
[www.3-5lab.fr](http://www.3-5lab.fr)



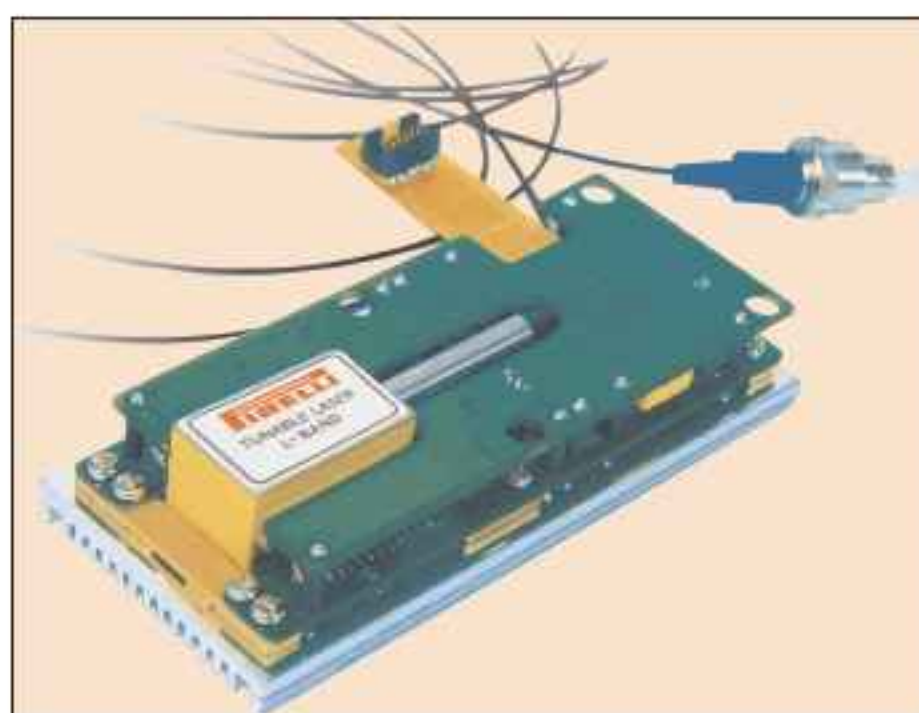
# Pirelli adds full L-band coverage to DWDM tunables and launches 120km XFP transceiver for metro TDM & WDM

At ECOC 2007 in Berlin, Germany, Pirelli Broadband Solutions of Milan, Italy unveiled an expanded range of pluggable and tunable component and module product families that allow operators to optimize cost-performance ratio and to reduce complexity of optical networks, the firm claims.

● Pirelli is adding full L-band coverage (40nm/100 channels) to its DWDM tunable portfolio. This includes its DTL dynamically tunable laser (Telcordia GR-468-CORE qualified and hermetically sealed in a 26-pin butterfly package), its ITLA integrable tunable laser assembly (which allows telecom operators to integrate tunability into networks while reducing development costs and time to market) and its 300-pin MSA transponders, which are available in multiple optical interfaces (NRZ, negative-chirp NRZ and duobinary formats) and extend the reach of metro networks to more than 350km. All L-band solutions deliver the same functionality as their C-band counterparts (built-in reliability, simplified network configurations and reduced systems costs), says Pirelli.

With an enhanced tunable portfolio for next-generation WDM networks, Pirelli says that its solutions are now suitable for metro networks in new markets such as Japan and countries in Latin America like Brazil. "Adding L-band functionality to our tunable product offering is the logical next step in anticipating customer demands," says Daniele Fadini, senior VP of sales for Optical Components & Modules. "Reducing inventory, number of lambdas [wavelengths], providing one interface for all wavelengths, and offering flexibility in the optical layer are now achievable benefits for network operators using the L-band spectrum."

● Pirelli is also expanding its presence in the pluggables market with the launch of a 120km XFP optical transceiver.



The ITLA, now with L-band coverage.

Compliant with the ITU-T G.959.1 recommendation, it is specifically designed to address metro TDM and WDM applications, transmitting signals up to 120km without the need for dispersion compensation units. Like all Pirelli optical transceivers, the 120km XFP supports SONET/SDH, 10 Gigabit Ethernet and FEC (forward error correction).

"The 120km-reach XFP is emerging as a new standard," says Mauro Macchi, senior VP of development and product management. "With this new module, we can target TDM and WDM applications in the metro market, while helping operators to reduce the cost and complexity of the optical network."

Pirelli's XFP product family features high output power and a wide range of dispersion tolerance levels for reach of 80–200km+, allowing optimization of cost-performance ratio across metro and regional networks.

## ● Pirelli begins volume shipments of ITLA to Huawei

Pirelli Broadband Solutions has begun volume shipments of its ITLA (integrable tunable laser assembly) optical solutions to Huawei Technologies Co Ltd.

"After the agreement with Huawei announced last year, we have completed the integration phase of the Pirelli ITLA module," says CEO Mauro Sacchetto. "Now we are beginning to deliver volume shipments of our technology to one of the world's biggest telecommunications equipment manufacturers."

The ITLA enhances equipment vendors' product offerings by providing the option to integrate tunability into next-generation optical networks, Pirelli says.

Designed for DWDM optical network systems, the ITLA is a compact module with built-in control electronics and Pirelli's dynamically tunable laser, which achieves tunability without any moving parts and is Telcordia GR-468-CORE qualified.

Based on multi-source agreement (MSA) standards, the ITLA can be easily integrated into an MSA 300-pin board or a line-card.

The ITLA is now also available for L-band applications.

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

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

## New senior VP of sales for Photonics unit

Pirelli has appointed Daniele Fadini as senior VP of sales for Optical Components & Modules for the firm's growing Photonics business unit, responsible for global sales for the components and modules product families (including dynamically tunable lasers, ITLA modules, DWDM tunable transponders, and 10Gb/s DWDM transceivers).

Fadini brings more than 20 years of international sales & marketing

experience, including at companies such as Avanex and Corning. Most recently, he was senior director of Sales, Europe & Middle East for Avanex Corp, responsible for sales of optical components, modules and subsystems to telecom systems manufacturers, carriers and OEMs, and the management of major global accounts. Previously, he held management positions with Corning Optical Technologies.



## Avanex expands 10G extended-reach tunable transponder portfolio with optical duo-binary modulation

Optical communications component and module maker Avanex Corp of Fremont, CA, USA has expanded its 10G extended-reach tunable transponder product portfolio with the new PowerReach 10Gb/s Optical Duobinary (ODB) transponder (displayed at ECOC 2007). The ODB is available for sample testing with selected customers, and should be in full production in December.

The new device combines Avanex's lithium niobate modulators

with its tunable transponder design to create a high-performance extended-reach tunable transponder with reach of up to 160km without added amplification.

The PowerReach ODB's modulation technology provides higher dispersion tolerance and narrower laser line-width — two key features that allow optical signals to travel longer distance with low transmission bit error. The transponder can typically achieve a bit error rate below  $10^{-3}$

with optical signal-to-noise ratio (OSNR) as low as 12dB through  $\pm 3200$ ps/nm, while maintaining power consumption below 12W (7W at 35°C). The module is also compliant with large form-factor 300-pin MSA standards.

The PowerReach ODB's features allow equipment makers to provide highly reliable, cost-effective extended-reach transmission network solutions, Avanex claims.

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

## First optical transceiver for broad wireless base-stations

At ECOC 2007, Avago Technologies of San Jose, CA, USA announced what it claims is the industry's first optical transceivers for the broad wireless base-station market.

Built specifically to support industrial-level temperature ranges and open standards for the base transceiver station (BTS) market, the AFBR-57J5APZ is part of the industry's first family of optical transceivers for use in next-generation, wireless infrastructure networking equipment.

With high-speed serial links over multi-mode optical fiber at 3.072Gb/s (OBSAI/CPRI standard), the AFBR-57J5APZ operates at the industrial temperature range of -40°C to +85°C with link distances of 500m over OM3 grade fiber. Avago's new product line for the

base transceiver station market will include not only multi-mode but also single-mode optical transceivers that support distances up to 80km: the AFCT-57J5APZ (7km, SM, OBSAI/CPRI, 3.1G) and AFCT-57J5ATPZ (20km, SM, OBSAI/CPRI, 3.1G) will be available in October, and the AFCT-57xxxxxZ (40km/80km, SM, OBSAI/CPRI, 2.47G) by the end of 2007.

The new family of modules targets emerging OBSAI (open base-station architecture initiative) and CPRI (common public radio interface) standards for next-generation wireless base-station systems. "With W-CDMA, GSM, EDGE and WiMAX incorporating data-rich content, base-station system performance must improve," says Dave D'Andrea, director of marketing

for Avago's fiber-optic products division. "OBSAI and CPRI standards address the need for cost-effective, higher-performance wireless base-station systems, and Avago's new product line will provide system designers with the best cabling interconnect solution," he claims.

Compared to the traditional copper cabling used in wireless base-stations, optical fiber supports longer link distances with higher data rates and a lower total cost of ownership, says Avago. Also, at higher data rates, larger copper cables cause more difficulties in installation, maintenance, and upgradeability for base-station implementations compared to a lightweight optical fiber cable, the firm adds.

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

## Avago appoints Bian Ee Tan to new post of chief operating officer

Avago has appointed Bian Ee Tan to the newly created position of chief operating officer from 1 November, reporting to president and CEO Hock E. Tan (no relation).

"Bian Ee brings a wealth of experience to his new role and his appointment reflects his outstanding capabilities at managing successful operations over his long tenure with the company [having

begun his career with Hewlett-Packard in 1973]," says Hock Tan. "Bian Ee will focus on overseeing and driving closer integration of our manufacturing organization with Avago's worldwide sales organization."

Bian Ee Tan has been president of Avago's Asia operations since December 2005. Prior to the closing of Avago's acquisition by KKR and

Silver Lake Partners, Bian Ee was VP and general manager of Agilent's Electronic Components business unit. Other positions held at Hewlett-Packard and Agilent include operations manager for the Singapore Components Operation, managing director of Hewlett-Packard Malaysia, and manufacturing manager for the Semiconductor Products Business segment.

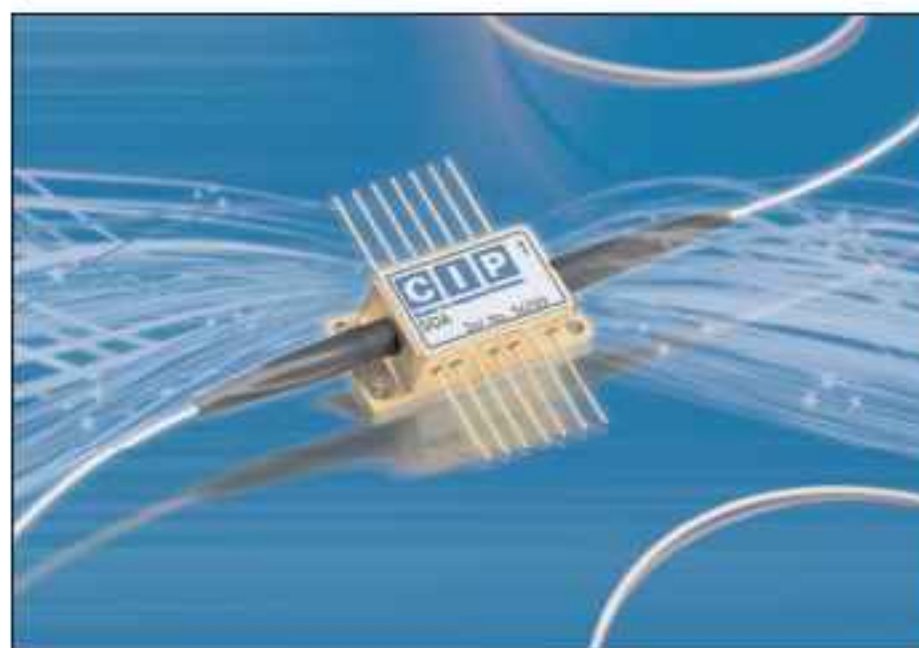


## CIP's record-speed SOA for 100Gb/s all-optical networks

At ECOC 2007, CIP of Martlesham Heath, Ipswich, UK launched a 1550nm InP multi-quantum-well semiconductor optical amplifier (SOA) with highly optimized nonlinear operating characteristics that can be used to implement advanced functions in all-optical networks operating at up to 100Gb/s.

Optimized operating parameters include a saturated gain recovery time ( $1/e$ ) of just 10ps typical, and a 20dB gain with 0.2dB of polarization-dependent saturated gain. To optimize performance in its target applications, the device has an internal active waveguide with a high confinement factor. Together with integration-friendly features that make it easy to be fabricated in arrays and 'push fitted' into hybrid components, the SOA provides a platform for next-generation networks, CIP says.

"We've had a successful 40Gb/s SOA for two years, and employ



CIP's 1550nm InP MQW SOA.

array versions to produce highly integrated 2R regenerators. This much improved device — the fastest commercial SOA ever created — gives the development community a platform to support 100 Gb/s all-optical architectures," reckons chief technology officer David Smith. "Its large-spot ultra-low reflectivity interfaces, when combined with our unique hybrid integration technology, make it possible to build component subsystems using passive alignment."

CIP says that the SOA's tuned characteristics allow it to perform well in a range of advanced optical applications. It can be controlled to exploit four-wave mixing, cross-gain modulation or cross-phase modulation effects to implement all-optical wavelength conversion — providing a dynamic mesh connectivity capability to dramatically enhance the flexibility of point-to-point optical networks. The phase-change characteristics of the nonlinear SOA, and its 20dB gain, can also be used to regenerate optical signals. The device is also suited to implementing all-optical Boolean logic functions.

The device is provided in a butterfly package, and is currently available in small quantities to support R&D applications. Integrated versions of the device, and other packages suitable for high-volume applications, are available on request.

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

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# Emcore grows 12% sequentially but loss more than doubles

For its fiscal Q3/2007 (to end June), Emcore Corp of Albuquerque, NM, USA, which makes components and subsystems for the broadband, fiber-optic and solar power markets, has reported revenue of \$44.5m, up 12% on last quarter's \$39.8m and 23% on \$36.3m a year ago.

Fiber Optics revenue was \$27.6m, up 5% on last quarter's \$26.2m and 6% on \$26.0m a year ago. Despite reduced revenue from the digital fiber-optics sector, Emcore continues to see a significant rise in demand for CATV products, which it expects to continue in fiscal 2008.

Photovoltaics revenue was \$16.9m, up 24% on last quarter's \$13.6m and 63% on \$10.4m a year ago.

However, operating loss was \$13.4m. Operating expenses have risen by \$10.3m from last quarter to \$23.2m. This is mostly due to:

- \$2.2m in development costs incurred in the new terrestrial Solar Power division (as Emcore's second-generation concentrator photovoltaic

system is expected to move from the development stage to production in the December quarter);

- \$3.9m in professional fees from the firm's review of its past stock option grants; and

- \$2.9m in severance- and patent-related expenses (mostly from the closure of the firm's New Jersey facility and relocation of its headquarters to Albuquerque and patent-infringement litigation against optical subsystem maker Optium Corp of Horsham, PA, USA).

Operating expenses also included \$0.2m from Emcore's new optoelectronic device packaging plant in Langfang City, China (which started shipments in May) and \$0.4m from April's \$4m acquisition of fiber-optic communications systems maker Opticomm Corp of San Diego, CA.

Consequently, net loss has risen from \$6.2m a year ago to \$14.5m.

For the firm's fiscal Q4/2007 (to end September), revenue was \$47m (up 6% on Q3 and up 32%

year-on-year), yielding full-year fiscal 2007 revenue of \$170.0m (up 18% on fiscal 2006's \$143.5m).

"As expected, we experienced a much stronger second half for the company, based on increased strength in our CATV and photovoltaics product lines," says CEO Reuben F. Richards Jr. "In our fourth quarter, revenues from our datacom and telecom sectors started to recover and we continue to see sustained growth in our photovoltaics business in both the satellite and terrestrial solar power markets."

"With this increase in revenue levels, we expect corresponding improvement in profitability to reach positive EPS in mid-2008," Richards adds. Emcore's revenue guidance is \$49m for fiscal Q1/2008 (to end-December 2007) and \$210-230m for full-year fiscal 2008 (up 24-35% on fiscal 2007).

- In mid-October the Nasdaq Listing and Hearing Review Council gave Emcore until 4 December to file its overdue Form 10-K for the fiscal year to end-September 2006 and Forms 10-Q for the quarters to end-December 2006, end-March 2007 and end-June 2007 with the Securities and Exchange Commission (SEC), pending suspension from the Nasdaq Global Market.

Since the special committee of Emcore's board completed its investigation into past stock option grant practices, the firm has determined the appropriate measurement dates for all incorrectly dated grants, concluded its accounting review and determined that the additional stock-based compensation charge remains unchanged as reported in November 2006.

Emcore aims to file the reports by the end of October and then, as required, hold an annual meeting of shareholders as soon as possible.

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

## Emcore closes three fiber-optics design centers to save \$7m annually

Emcore is to consolidate its North American fiber-optics engineering and design centers in Virginia (which closed in June) and Illinois and Northern California (closed in September) by relocating production, product support, and key design personnel to the firm's three larger, main operating sites in Albuquerque, NM; Alhambra, CA and Warminster, PA.

"Emcore has acquired several technology companies over the past few years. Each has contributed to the success of Emcore's broadband and fiber-optics businesses through the addition of new technologies, products, and customer portfo-

lios," says president and chief operating officer Hong Hou.

"Consolidation of these design centers into three core sites will provide greater synergy across product lines, better leverage of engineering resources, shorter time to market, and increased customer support," he adds.

"Emcore will reduce operating costs by eliminating duplicate resources and infrastructures," Hou continues.

Emcore expects annual cost saving from the restructuring of about \$7m. However, restructuring, relocation, and other costs related to the closures are expected to total about \$2.0m.



# First Solar adds third CdTe PV plant to Malaysia expansion

First Solar Inc of Phoenix, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride, is investing \$150m in building a third plant in Kulim Hi Tech Park in Kedah, Malaysia with annual capacity of 120MW (to start production in first-half 2009). Two adjacent plants already under construction have a collective capacity of 240MW. The first of the four-line solar module plants was announced in January and broke ground in April (for completion by late 2007 and full volume production by end 2008).

First Solar was formed in 1999 and started commercial production in 2002 at its plant in Perrysburg, near Toledo, OH, USA. By 2005 it had improved the average conversion efficiency of its modules from 6% to 9%. This is still less than the 12% of crystalline silicon PV cells, but its proprietary thin-film process technology cuts raw material and manufacturing costs. Also, in the automated, continuous process, the high-throughput production lines complete all manufacturing steps in just 2.5 hours (from deposition onto glass sheets of a single-junction

polycrystalline thin film less than 3µm thick — with a CdTe absorption layer and CdS window layer — to final assembly and testing of the module). Together, this enabled First Solar in 2006 to achieve the PV industry's lowest cost per manufactured watt at a production scale of just 100MW (less than \$1/W, according to the US National Renewable Energy Laboratory). Under real-world conditions, including variation in the ambient temperature and intensity of sunlight, systems generate more kilowatt hours of electricity per kilowatt of rated power than systems using crystalline silicon solar modules.

In November 2006, First Solar closed a \$459m initial public offering on Nasdaq. The firm has since used 'continuous improvement' methodologies and systematic 'copy smart' practices to replicate production lines with operating metrics comparable to the performance of the base plant. This has enabled it to rapidly expand annual capacity from 25MW in 2005 to 210MW now with the inauguration in July of a new 41,000m<sup>2</sup>, 120MW plant in

Frankfurt an der Oder costing €115m (aided by a German government grant of €45.5m).

Also in July, a secondary offering of shares funded the expansion in Malaysia and associated production start-up and ramp-up costs.

Altogether, annual capacity should rise to 570MW by the end of 2009.

Production from the new plant in Malaysia will meet extra demand of 625MW via contracts worth an extra \$1.1bn in sales over 2007 to 2012 signed in July with existing customers (Germany-based Blitzstrom GmbH, Conergy AG, Gehrlicher Umweltschonende Energiesysteme GmbH, Phoenix Solar AG, and Reinecke + Pohl Sun Energy AG) as well as a new long-term contract with ASSYCE Fotovoltaica (a Spanish renewable energy project developer and system integrator focused on large-scale, grid-connected plants).

"Customers have demonstrated that they are among the best positioned in the industry to develop meaningful project pipelines for large ground and roof-mounted projects across the EU," says CEO Mike Ahearn.

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

## MicroLink receives grant to extend GaAs to solar cells

GaAs-based MicroLink Devices of Niles, near Chicago, IL, USA, is receiving a \$50,000 grant from the Illinois Department of Commerce and Economic Opportunity's Innovation Challenge Matching Grant program. The support comes as a part of Opportunity Returns (the state's economic development strategy for creating jobs and spurring growth in the region) and matches funding received via the federally administered Small Business Innovation and Research (SBIR) program.

MicroLink was established in mid-2000 and shipped its first products

in January 2002. In its 30,000ft<sup>2</sup> MOCVD manufacturing facility the firm produces InGaP epiwafers for HBTs used in WCDMA cell phones sold in Japan (3G NTT DoCoMo), in WLAN modules in PCs and routers, and in RF test equipment.

As part of the Phase I SBIR, MicroLink's GaAs technology will be extended to develop a low-cost manufacturing process for cost-effective, high-efficiency solar cells for terrestrial concentrator photovoltaic systems, in addition to high specific power density for space applications. The project is

expected to create two new jobs and retain three others.

MicroLink is developing high-efficiency multijunction solar cells for use in solar concentrators, using unique processing steps to minimize the amount of GaAs used. This could reduce the cost of the solar cell by 50% while improving heat dissipation, the firm claims. MicroLink has previously been selected to receive a \$3m award to develop solar cell technology as part of the US Department of Energy's Solar America Initiative.

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



# Nonpolar GaN takes the LED and laser spotlight

**The 7th ICNS conference drew a huge attendance to a program focusing on the rapid developments made this year, boosted by the advent of nonpolar GaN materials.**

**T**he 7th International Congress of Nitride Semiconductors (ICNS-7) in Las Vegas, NV, USA on 16–21 September attracted over 930 attendees (a big increase on the 700 at 2005's ICNS-6 in Bremen, Germany). This evidences the high level of interest in nitrides caused by developments in both microelectronic devices (such as GaN high-electron-mobility transistors for high-power amplifiers, e.g. in wireless base-stations) and optoelectronic devices (white LEDs for solid-state lighting and blue-violet lasers for optical data storage, as well as blue and possibly green lasers for red-green-blue applications such as displays).

Apart from the opening plenary talk by Klaus Ploog (director of the Paul Drude Institute for Solid State Electronics in Berlin until retiring in 2006), due to the more than 220 presentations, one of the few sessions not held in parallel was a special LED session 'High Efficiency Solid State Lighting: Solutions for Global Warming'. Speakers were drawn from LED manufacturers Philips Lumileds of San Jose, CA, USA, Cree Inc of Durham, NC, USA, Korea's Seoul Semiconductor Co Ltd and Japan's Stanley Electric Company Ltd, as well as Rensselaer Polytechnic Institute Lighting Research Center of Troy, NY, USA.

Philips Lumileds' executive VP of R&D Frank Steranka reviewed how InGaN-based white LED technology development in 2007 is currently 'on track' according to the US Department of Energy's 2002 Solid-State Lighting LED roadmap. This projects the development of luminous efficacy (in lumens per Watt) from 25 in 2002 to 75 in 2007, 150 in 2012 and 200 in 2020, along with lifetime developing from 20,000 hours in 2002 and 2007 to 100,000 hours in 2012 and 2020.

Steranka highlighted that, in 2007, several companies have products currently on the market at the requisite 75lm/W. A 1000lm source can hence be made without active cooling (indeed, in early September Cree demonstrated 1050lm from a single-die cool-white R&D LED with a luminous efficacy of 72lm/W driven at a current of 4A). However, large heat-sinks are still needed for passive cooling above 75lm/W, Steranka adds.

## US DoE's LED device performance projections.

| Metric                                | 2006 | 2010 | 2012 | 2015 |
|---------------------------------------|------|------|------|------|
| Efficacy-lab (lm/W)                   | 85   | 129  | 151  | 184  |
| Efficacy-commercial cool white (lm/W) | 68   | 113  | 135  | 168  |
| Efficacy-commercial warm white (lm/W) | 38   | 83   | 105  | 138  |
| OEM lamp price -product (\$/klm)      | 35   | 10   | 5    | 2    |
| Lamp life (1000 hours)                | 37   | 50   | 50   | 50   |

This January, Lumileds reported record luminous efficacy of 115lm/W for a single 1mm x 1mm cool-white chip in R&D driven at a current of 350mA, together with 131.5lm/W for a 2mm x 2mm chip, 138.6lm/W for a 3mm x 3mm chip, and up to 142.4lm/W for a 4mm x 4mm chip. Most recently, in mid-September Cree reported 129lm/W for packaged cool-white LEDs in R&D driven at 350mA with a light output of 135.7lm.

For the 2012 target of doubling the efficacy of production LEDs from 75lm/W to 150lm/W, a challenge is the need to boost the drive current from 350mA to 2A (i.e. for a luminous flux of 2000lm). However, Steranka says that it will also be necessary to double the LED's internal quantum efficiency at a current density of 250A/cm<sup>2</sup> from today's 45% to about 90%.

A major problem in white power LEDs is the 'droop' in efficacy by at least 50% as the drive current density is increased from 100mA to 1000mA. However, in February Lumileds claimed that it has overcome the problem, although it did not give details of the enabling epitaxial technology at the time.

But in a 'late news' paper in a separate session at ICNS, Nathan Gardner, section manager III-Nitride Epitaxy at Lumileds, summarized work to be published in the journal Applied Physics Letters on droop-free c-plane GaN LEDs grown by MOCVD.

Gardner attributes the normal droop in external quantum efficiency with increasing drive current in multi-quantum-well (MQW)-based LEDs to be due to non-radiative Auger recombination. This is high in InGaN LEDs, which have carrier densities of over 10<sup>18</sup>cm<sup>-3</sup>, he adds.



A possible solution is to use a larger active region. However, Garner points out that adding quantum wells does not improve the internal quantum efficiency, as holes get stuck at the p-doped side of the QW stack, so only a few quantum wells emit photons.

Lumileds' solution is to instead use a double heterostructure (DH), which can have a thicker InGaN electron-hole recombination region of over 6nm, compared to just 1nm for an MQW-based LED. The result is that, although quantum efficiency is lower, its peak is shifted to higher current density. So, for example for an encapsulated flip-chip LED with a 1mm<sup>2</sup> chip emitting at a wavelength of 444nm, a 9nm DH LED has higher quantum efficiency above a current density of 100A/cm<sup>2</sup> than an MQW LED with two 2.5nm quantum wells.

Following Steranka in the special LED session, Cree's co-founder and director of advanced optoelectronics John Edmond gave an overview of the firm's progress, from its 1mm x 1mm Gen 2 chip (which has a luminous efficacy of 104lm/W at 350mA) to its bigger 2mm x 2mm Gen 3 chip (which has luminous efficacy of 133lm/W for cool-white LEDs at 350mA). Cree's current production LEDs range in luminous flux up to 100–120lm (with a correlated color temperature of 6000K, a forward voltage of 3.25V and a drive current of 350mA). Edmonds added that, to achieve 150lm/W, it would be necessary to reduce the forward voltage to 3V in order to raise external quantum efficiency.

Seoul Semiconductor's president/CEO Chung H Lee outlined the firm's cool-white LED roadmap, including its progress from typical (rather than maximum) efficacy of 20lm/W in 2005 through 40lm/W in 2006 to 48lm/W in Q2/2007, and projections of 80lm/W in Q4/2007, 100lm/W in Q2/2008 and 120lm/W in Q4/2008. He added that, further to its existing product with a luminous flux of 200lm, the firm aims to announce a 240lm product this year. Most recently, in mid-September, the firm achieved a luminous flux of 420lm from a single chip in R&D driven at 600mA.

Also, in an invited talk in a separate session on 'Solid State Lighting and LEDs', Nichia's Yukio Narukawa highlighted the firm's NS6W083A product for lighting applications. Its typical luminous flux at a drive current of 300mA is 80lm. However, Narukawa says that this is 'not enough' for general lighting, and that this must be improved to more than 100lm. Nevertheless, Narukawa adds that, in R&D, the firm's 'HP-White' high-power white LED technology produces a luminous flux of 145lm with an efficacy of 134lm/W at 350mA (or 163lm/W at 50mA) and 361lm with an efficacy of 97lm/W at 1A. So, the production target of 100lm would appear to be within reach.

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

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

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

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## First cw AlGaN-cladding-free blue-violet and first blue nonpolar InGaN/GaN lasers

ICNS also saw reports of the latest progress in nonpolar laser diodes from the likes of University of California Santa Barbara and Japan's Rohm Co Ltd.

Conventional gallium nitride lasers are grown on a substrate such as sapphire oriented along the crystallographic c-plane. However, a GaN heterostructure grown along the c-plane exhibits strong spontaneous and piezoelectric polarization fields. In a laser's quantum-well active light-emitting region, these distort the electronic energy bands, which spatially separates the electron and hole wavefunctions, reducing their radiative recombination efficiency for producing light. The quantum efficiency is reduced more severely as the lasing emission wavelength shifts from blue-violet (about 400nm) through blue (up to about 500nm) towards green (beyond 500nm — much sought-after for combination, e.g., in full-color RGB laser displays). Furthermore, the polarization-related electric fields lead to a significant blue-shift in the peak emission wavelength as the injection current is increased, limiting use in such applications.

In laser diodes, extra carriers are required to screen the polarization-related electric fields and flatten the distorted energy bands before efficient gain can result, increasing the threshold current density for lasing. Also, the polarization-induced electron and hole separation is worse for greater quantum well thickness. The consequent limitation of c-plane quantum-well thickness to less than 4nm requires the use of thick Al-containing waveguide cladding layers (e.g. AlGaN/GaN superlattices) to provide transverse optical mode confinement. However, the thick, strained Al-containing layers can increase the series resistance, operating voltage, operating temperature and lasing threshold current density, as well as leading to shorter device lifetime, cracking of the material due to tensile strain, and reduced manufacturing yield.

In contrast, using a nonpolar GaN substrate whose crystal is oriented instead along the m-plane reduces the polarization-related fields in the laser's active layer, so the energy bands of a quantum well are less distorted (resembling more the rectangular shape for quantum wells grown on GaAs or InP) and the electrons and holes can recombine more efficiently while allowing the use of thicker quantum wells.

Using recently developed low-defect-density free-standing m-plane GaN substrates from Tokyo-based Mitsubishi Chemical Corp, early this year the first nonpolar m-plane blue-violet nitride laser diodes were reported coincidentally by both Rohm Co Ltd of Kyoto, Japan and the group led by Shuji Nakamura, Steven DenBaars and James Speck at University of California Santa Barbara (Jpn J. Appl. Phys. 46 (2007) issue 9 (23 February): Okamoto et al L187; Schmidt et al L190). ▶



Rohm says its InGaN/GaN multi-quantum-well lasers had threshold current densities comparable to that of conventional c-plane lasers:  $3.1\text{kA/cm}^2$  for pulsed operation and  $4.0\text{kA/cm}^2$  for continuous-wave (cw) operation emitting at 401nm (blue-violet).

UCSB's broad-area InGaN/GaN multi-quantum-well devices lased at 405.5nm (blue-violet) with a threshold current density of  $7.5\text{kA/cm}^2$  in pulsed operation.

Subsequently, UCSB demonstrated the first nonpolar m-plane InGaN/GaN laser without any Al-containing waveguide cladding layers (Daniel F. Feezell et al, Jpn J. Appl. Phys. 46 (2007) issue 13 (23 March) L284). Instead, transverse optical mode confinement is achieved by being able to grow an m-plane InGaN multi-quantum-well active region with thick ( $>8\text{nm}$ ) QWs and barriers. Pulsed lasing operation was demonstrated with a threshold voltage of 7.6V and a threshold current density of  $5.6\text{kA/cm}^2$  (compared to  $11.7\text{V}$  and  $7.2\text{kA/cm}^2$  with AlGaIn/GaN superlattice cladding). This was lowered further to 6.7V and  $3.7\text{kA/cm}^2$  for a device with three 13nm-thick QWs by varying the magnesium doping levels in the structure.

The elimination of Al-containing waveguide cladding layers also allows a growth method analogous to that for GaN-based LEDs. The facets of the laser are therefore uncoated and etched. But, by using a focused ion beam to make them smoother and more vertical, the threshold current density was lowered again to  $3.0\text{kA/cm}^2$ .

At ICNS, UCSB's Mathew Schmidt presented the first cw operation of an AlGaIn-cladding-free nonpolar m-plane InGaN/GaN laser, using an index-guided  $1.9\text{mm} \times 800\text{mm}$  ridge design lasing at 413.3nm (Farrell et al, Jpn J. Appl. Phys. 46 (2007) issue 32 (10 August) L761). The threshold current density and voltage have since been reduced from  $6.8\text{kA/cm}^2$  and 5.6V to  $5.4\text{kA/cm}^2$  and 5.6V, with peak output power of more than 25mW.

Meanwhile, Rohm's Kuniyoshi Okamoto presented the first nonpolar m-plane InGaN/GaN laser emitting at longer, pure blue wavelengths: 430nm using GaN guiding and 452nm using InGaIn guiding (Okamoto et al, Jpn J. Appl. Phys. 46 (2007) issue 35 (7 September) L820) — later extended to 456nm (although this has since been extended further to 463nm — see panel). The threshold current density was  $22.3\text{kA/cm}^2$  at 452nm. As well as providing optical waveguides for longer lasing wavelengths, the InGaIn guiding layers prevent macroscopic cracks developing parallel to the c-plane, which is indispensable for fabricating nonpolar lasers at longer wavelengths beyond the blue region, Okamoto says.

Okamoto reckons the latest results suggest that there is a good possibility of achieving the goal of a green laser diode on m-plane GaN. However, he concedes that indium incorporation is an issue for these longer wavelengths. ■

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

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

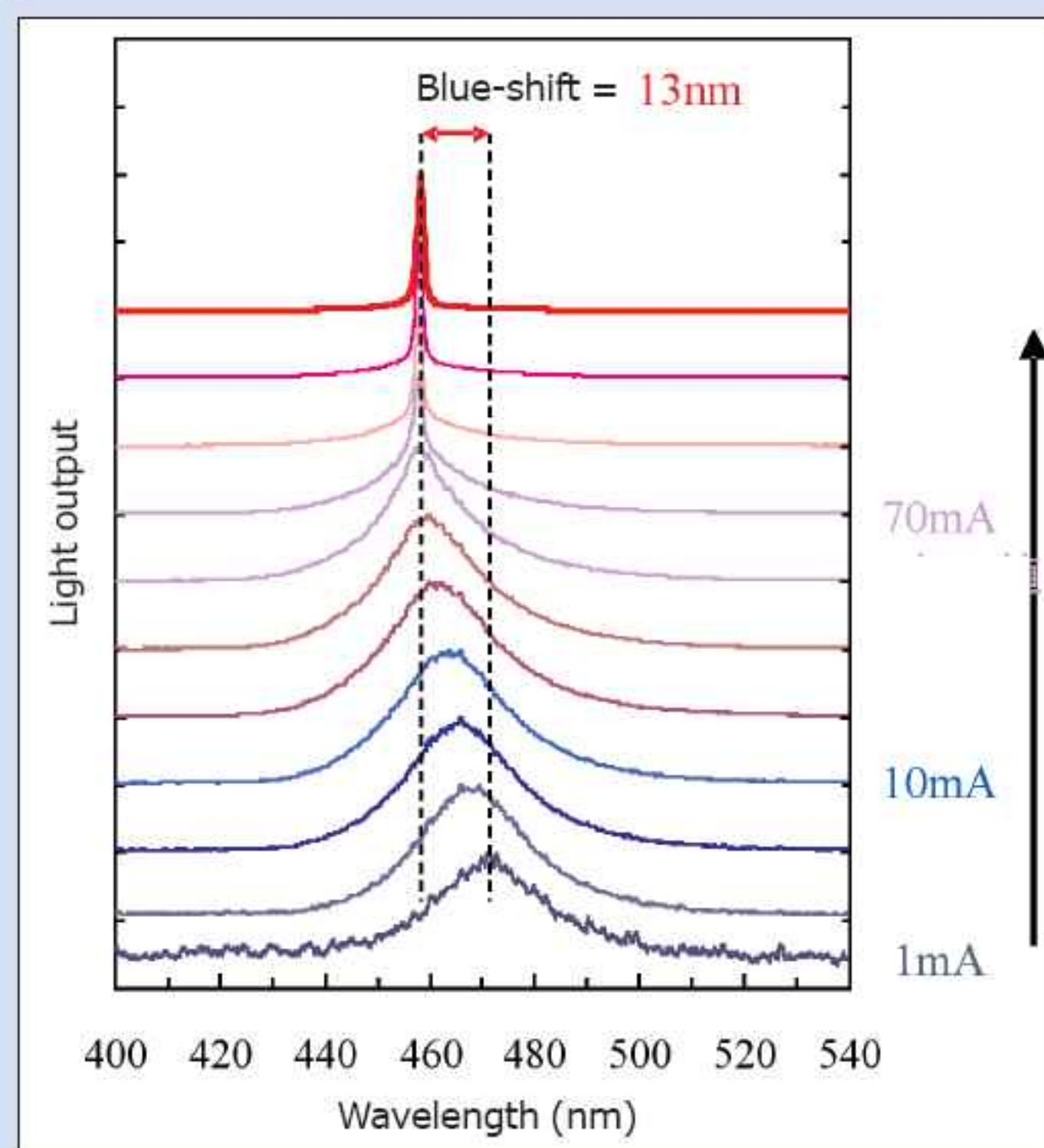
## HR coating enables cw lasing at more than 460nm

At the CEATEC Japan 2007 event in Tokyo (2–6 October) researchers at Rohm led by Kuniyoshi Okamoto demonstrated new m-plane nonpolar GaN-based blue laser diodes with an emission wavelength increased to a record 463nm (measured under pulse oscillation).

Two weeks later, at the 34th International Symposium on Compound Semiconductors (ISCS 2007) at Kyoto University on 15–18 October, Okamoto presented further details. The threshold voltage is 6.7V while, by using high-reflectivity (HR) coating, the threshold current was reduced to 41mA (less than a third of the 452nm laser's 134mA), giving a threshold current density of less than  $5\text{kA/cm}^2$ .

Okamoto concludes that "there is a good possibility of fabricating a green laser diode based on m-plane InGaIn". In February, Rohm stated its aim to develop a 532nm green laser diode by the end of this year.

Since ISCS 2007, on 24 October Rohm said it had achieved continuous-wave operation of a nonpolar GaN blue laser diode emitting at 460nm. Also, as current density is increased from zero up towards  $10\text{kA/cm}^2$ , the blue shift of the peak emission wavelength is just 13.6nm (78meV) compared to 39.8nm (205meV) for a comparable c-plane GaN blue laser emitting at 470nm.



**Light output versus emission wavelength, showing blue shift of just 13nm with increasing current.**



# Electromagnetic alchemy

Antimony compounds have been used for cosmetic and other purposes since 3000BC and were common ingredients in alchemical formulations. Now, applications beckon for high-speed electronics, and for the detection and manipulation of infrared light and magnetic behavior, says **Dr Mike Cooke**.

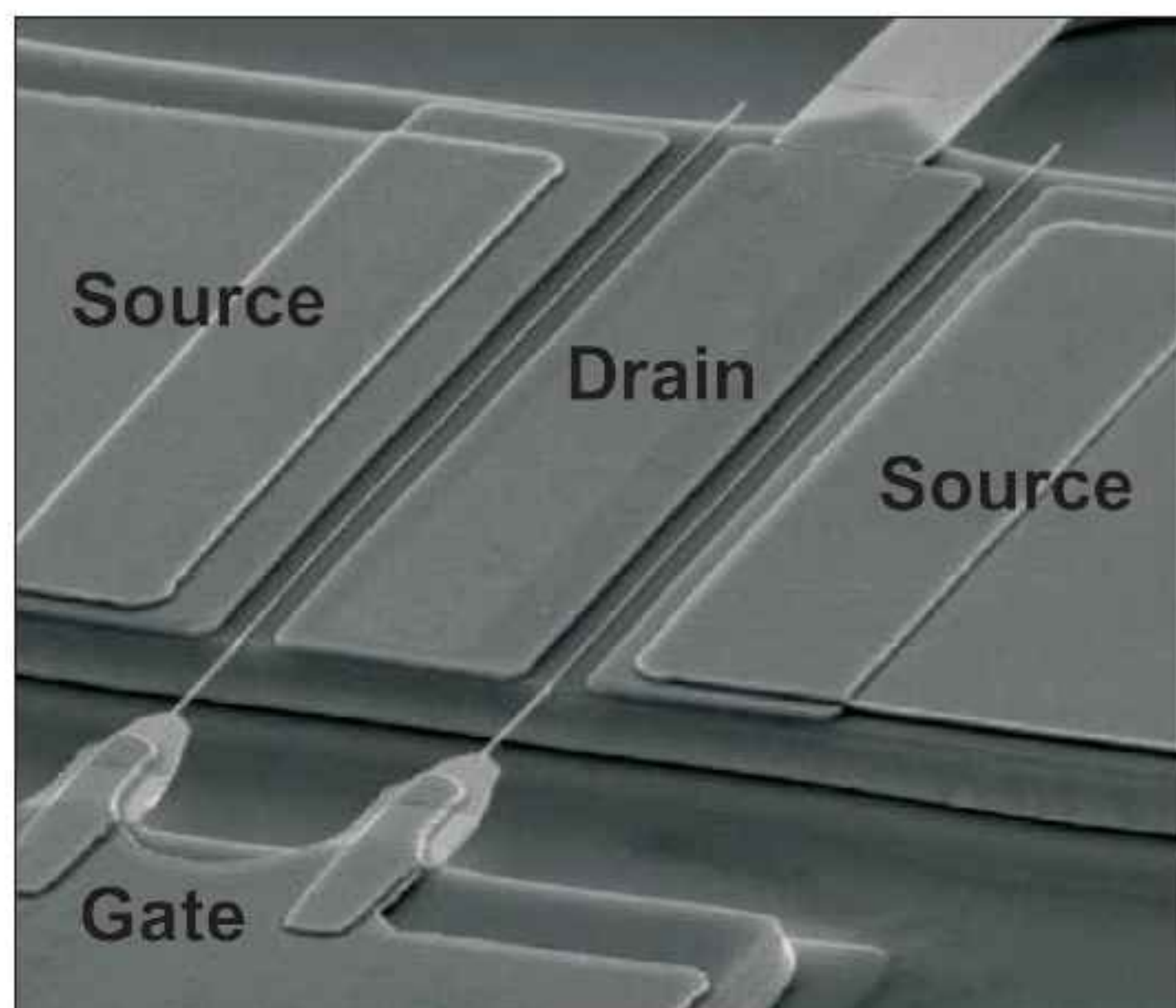
**I**n the last few years, antimonide semiconductor compounds have been of increasing interest for the creation of new high-speed electronics and for accessing infrared wavelengths unavailable to more common compound semiconductors. In addition, InSb's unusually high magnetic electron coupling opens up opportunities for magnetic field detection, electron spin manipulation and even the creation of quantum communications and computing devices.

Key properties of InSb are high mobility and saturation velocity based on the electron's small effective mass ( $\sim 0.014m_0$ ) and an unusually large (negative) electron Landé g-factor representing the electron's magnetic coupling (Table).

## Digital antimony

Qinetiq, a UK firm focused largely on the defense market, is one of the leaders in applying InSb technology. In the electronic application field, Qinetiq has worked extensively with Intel on producing fast field-effect transistors (Figure 1) for use in possible future CMOS production. Impressive results have been achieved in producing n-channel FETs with fast switching speeds and low power drain compared with silicon-based devices in both depletion mode and enhancement mode, based on InSb's high electron mobility and saturation velocity.

The enhancement-mode devices (normally-off, as employed in CMOS) use a recessed gate structure (an



**Figure 1. Image of Intel/Qinetiq two-gate finger InSb quantum well transistor.**

uncooled 85nm device shows a 10-fold reduction in active power dissipation and 1.5-fold increase in speed compared with silicon MOSFETs). A further requirement on which good progress has been made is in producing devices on silicon (Figure 1 of reference [2]) rather than on III-V substrates [3]. Silicon integration is needed not only for integration into existing CMOS infrastructure but also because low-cost devices need to be produced on the largest possible substrate for high volume production — and that means producing on silicon with the largest diameter (currently 300mm, and in future this may reach 450mm). III-V substrates have not yet reached 200mm diameter in volume production, with 150mm GaAs substrates being the largest currently in routine production.

Mike Mayberry, director of Components Research at Intel's Technology & Manufacturing Group, reports that Intel has broken down the problem of integrating III-V materials into CMOS production as five sub-problems:

**Table 1. Comparison of properties of common semiconducting materials and InSb and GaSb.**

|                                    | Units               | Silicon              | GaAs              | In <sub>0.53</sub> Ga <sub>0.47</sub> As | InAs                 | InSb                 | GaSb [1]             |
|------------------------------------|---------------------|----------------------|-------------------|--|----------------------|----------------------|----------------------|
| Energy gap                         | eV                  | 1.12                 | 1.43              | 0.75                                     | 0.356                | 0.175                | 0.726                |
| Electron effective mass            | $m_0$               | 0.19                 | 0.072             | 0.041                                    | 0.027                | 0.013                | 0.041                |
| Electron mobility in pure material | cm <sup>2</sup> /Vs | 1,500                | 8,500             | 14,000                                   | 30,000               | 78,000               | >3000                |
| Electron saturation velocity       | cm/s                | $1.0 \times 10^7$    | $1.2 \times 10^7$ | $8 \times 10^6$                          | $3 \times 10^7$      | $5 \times 10^7$      | $8 \times 10^6$      |
| Intrinsic carrier concentration    | cm <sup>-3</sup>    | $1.6 \times 10^{10}$ | $1.1 \times 10^7$ | $5 \times 10^{11}$                       | $1.3 \times 10^{15}$ | $1.9 \times 10^{16}$ | $1.5 \times 10^{12}$ |
| g-factor                           |                     | 2                    | -0.5              | -5                                       | -15                  | -51                  | $\sim -10$           |



- integration on silicon substrates;
- finding a suitable high-k dielectric;
- making PMOS devices;
- creating enhancement-mode rather than depletion-mode devices;
- miniaturization.

Mayberry believes it is too early to say what a final process would be like for producing III-V channel CMOS devices, although the leading contenders at this time are InSb and InGaAs. InSb has the attraction of high mobility, while InGaAs has been studied more extensively (at MIT, among other places).

While there are promising results in producing PMOS quantum well devices through applying strain to boost p-type mobility, says Mayberry, there is nothing publishable as yet. He agrees that, while it is possible to use different materials for the different transistor channels, integration with the same material would be preferable from a process simplicity perspective. Some groups have studied, for example, the possibility of combining germanium and InGaAs devices, despite the process mismatch.

Along with the Qinetiq work [3], an Intel collaboration with IQE [4] on InGaAs devices resulting from growing III-V layers on silicon substrates has recently been published. The Qinetiq work relates in particular to InSb quantum well channels in a field-effect transistor structure. An 85nm InSb channel device on silicon had a unity current gain cut-off frequency of ( $f_T$ ) of 305GHz at an operating voltage ( $V_{dd}$ ) of 0.5V. The buffer layer system designed to overcome lattice mismatches between the silicon and device levels was 1.8 $\mu$ m thick. A similar In<sub>0.7</sub>Ga<sub>0.3</sub>As device has an  $f_T$  of 260GHz at 0.5V with a 3.2 $\mu$ m buffer between the silicon substrate and device layer.

Presently, molecular beam epitaxy is used to grow the necessary buffer layers and devices, with experiments performed at the 'coupon' level, on fragments of silicon. In terms of scaling up production, Mayberry reports that some other Intel partners are exploring non-MBE techniques for growing III-V layers on silicon. However, this does not rule out the historically slow MBE from being the final process: many processes routinely used in semiconductor mass production started off as low-throughput methods in the lab or small-scale production.

On gate dielectrics, as for PMOS devices, there are some 'promising' but not yet publishable results. Another aspect of the problems concerning the gate dielectric and metal is being dealt with from the theoretical direction of mathematical interface models.

Silicon has been at an advantage, since silicon surfaces consist of a single element, and these surfaces are relatively easy to oxidize to a uniform quality. Compound semiconductors, consisting of a number of different elements, can have very complex surface state structures with different reactivity properties with oxygen and other chemicals that can lead to dielectric layers. Interface states can alter the performance of semiconductor devices — for example, charged interfaces can act like unwanted gate potentials. In addition, one wants a high-k dielectric that is stable on the device surface.

Mayberry believes that these problems are difficult, but not insurmountable [5].

## Photonics

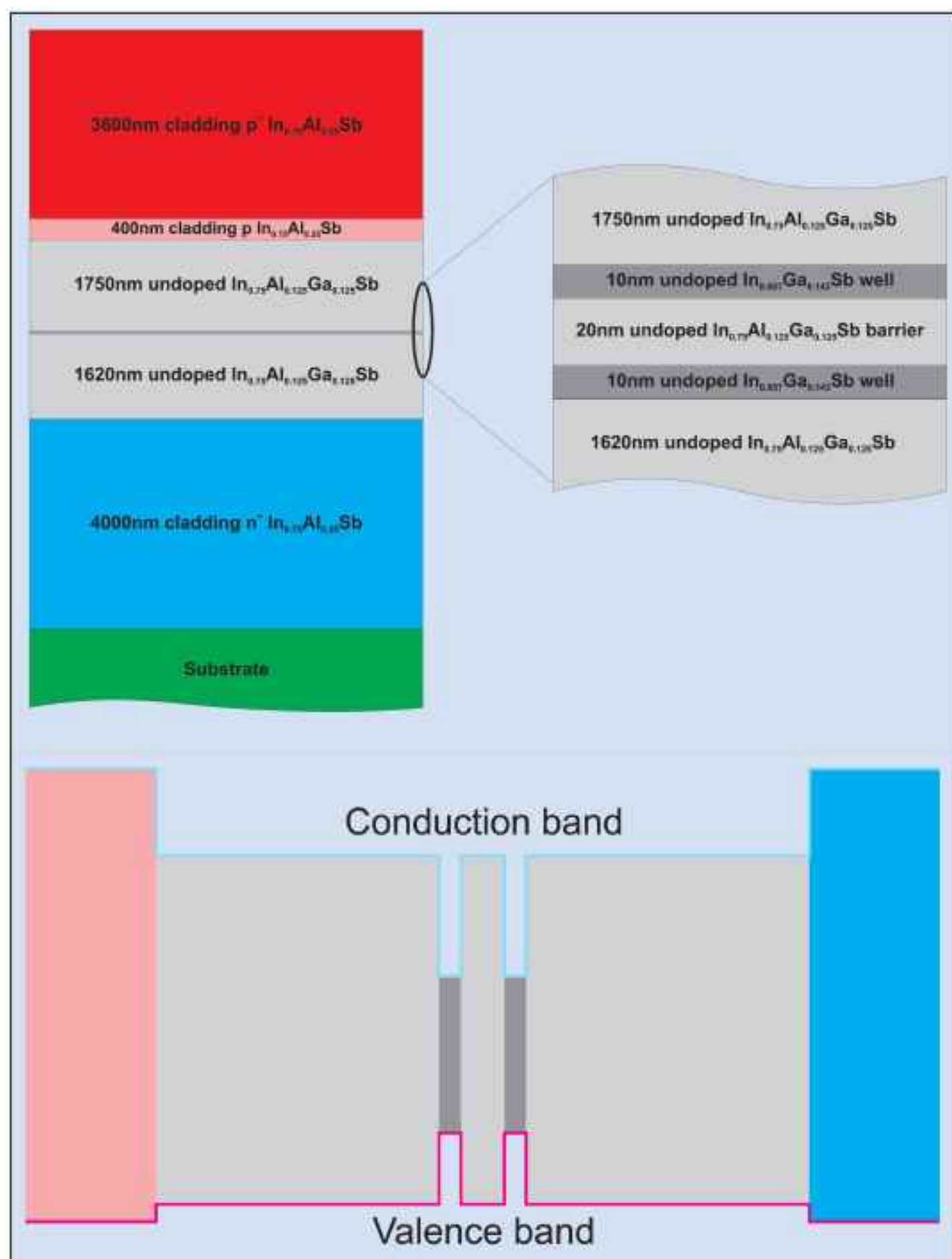
Apart from digital electronics, InSb's properties also have very high-frequency analog and photonic promise [2]. In particular, the narrow bandgap of InSb (0.175eV) and the more complicated alloys are used to detect and create infrared light in the 3–5 $\mu$ m wavelength range. Qinetiq, again, has produced InSb-based two-dimensional 'focal plane arrays' in standard formats (e.g. 1024x768) of infrared photodetectors for thermal imaging camera applications.

For mid-IR (3–5 $\mu$ m) quantum well lasers, Qinetiq has used a particular mélange of Al<sub>x</sub>Ga<sub>y</sub>In<sub>1-x-y</sub>Sb elements. Researchers from Qinetiq and the UK universities of Bristol, Surrey and Lancaster see the material system as offering great promise in terms of making the necessary compromise between the needs of electron and photon confinement and for low series resistance. Theoretical work suggests that the use of compressively strained Type-I wells will lead to the suppression of non-radiative transitions such as Auger recombination (assisted by a third particle) and inter-valence band absorption.

Qinetiq's diode lasers were grown on semi-insulating GaAs substrates using MBE. The choice of a GaAs substrate was due to the aim of eventual compatibility with commercial rather than laboratory production processes. Compressively strained InSb-like wells were deposited between confining layers of Al<sub>0.12</sub>Ga<sub>0.12</sub>In<sub>0.76</sub>Sb with Al<sub>0.25</sub>In<sub>0.75</sub>Sb cladding (Figure 2). Laser mesas with a width of approximately 20 $\mu$ m were wet etched down to the lower cladding layer. Then SiO<sub>2</sub> passivation and insulation covered the devices, except for the top and side contacts. The laser mesas were cleaved to give devices with a length of either 1 or 2mm. The wavelength of the electroluminescence emission peak shifted with changing temperature from 3.4 $\mu$ m at 15K to 3.9 $\mu$ m at 250K. The researchers are targeting operation at even higher temperatures. Possible applications include free-space optical communications, taking advantage of low atmospheric absorption and scattering of wavelengths in the range 3–9 $\mu$ m.

**It is too early to say what a final process would be like for producing III-V channel CMOS devices, although the leading contenders at this time are InSb and InGaAs**





**Figure 2. Layer structure of Qinetiq InSb based quantum well laser (top). Band diagram of quantum well structure of Qinetiq InSb based laser (bottom).**

Yet another aspect for antimonide materials is the possibility of reducing the bandgap even further by using the band bowing effect of nitrogen at dilute concentrations. Warwick University has worked with Qinetiq on the growth and characterization of such materials for longer-wavelength applications. GaNSb and InNSb have been grown on GaSb and GaAs substrates. The GaNSb that was produced shows p-type behavior, with carrier concentrations in the range  $3\text{--}6 \times 10^{18} \text{cm}^{-3}$ . In contrast, InNSb is n-type, with carrier concentrations of  $\sim 2.5 \times 10^{18} \text{cm}^{-3}$ .

While the materials are of 'good' quality with nitrogen content  $< 1.75\%$  for GaNSb and  $< 0.68\%$  for InNSb, the latter material is quite difficult to grow due to a narrow growth temperature window. A band filling effect from the higher carrier concentrations in InNSb creates difficulties in using the narrowed band gap for optical purposes. The absorption edge actually shows an increase in photon energy with increased nitrogen content rather than a decrease. An annealing step can reduce the carrier concentration and thus lower the absorption edge for lower nitrogen concentrations ( $\sim 0.1\%$ ).

Another approach to photonics — InSb nanowires and nanodots — has been explored by Toyo University in



**Figure 3. Schematic of Asahi Kasei's tin-doped antimony-based Hall sensor with improved mobility and temperature dependence.**

Tokyo, Japan. The growth technique involves vapor transport onto a silicon substrate with the aid of a focused ion beam apparatus. Raman spectra, where photons lose and gain energy from vibrational and other state transitions, have been used to characterize performance. The researchers are particularly interested in looking for the size effects on carrier dynamics in nanodot and nanowire structures, allowing energy level and other manipulations for applications.

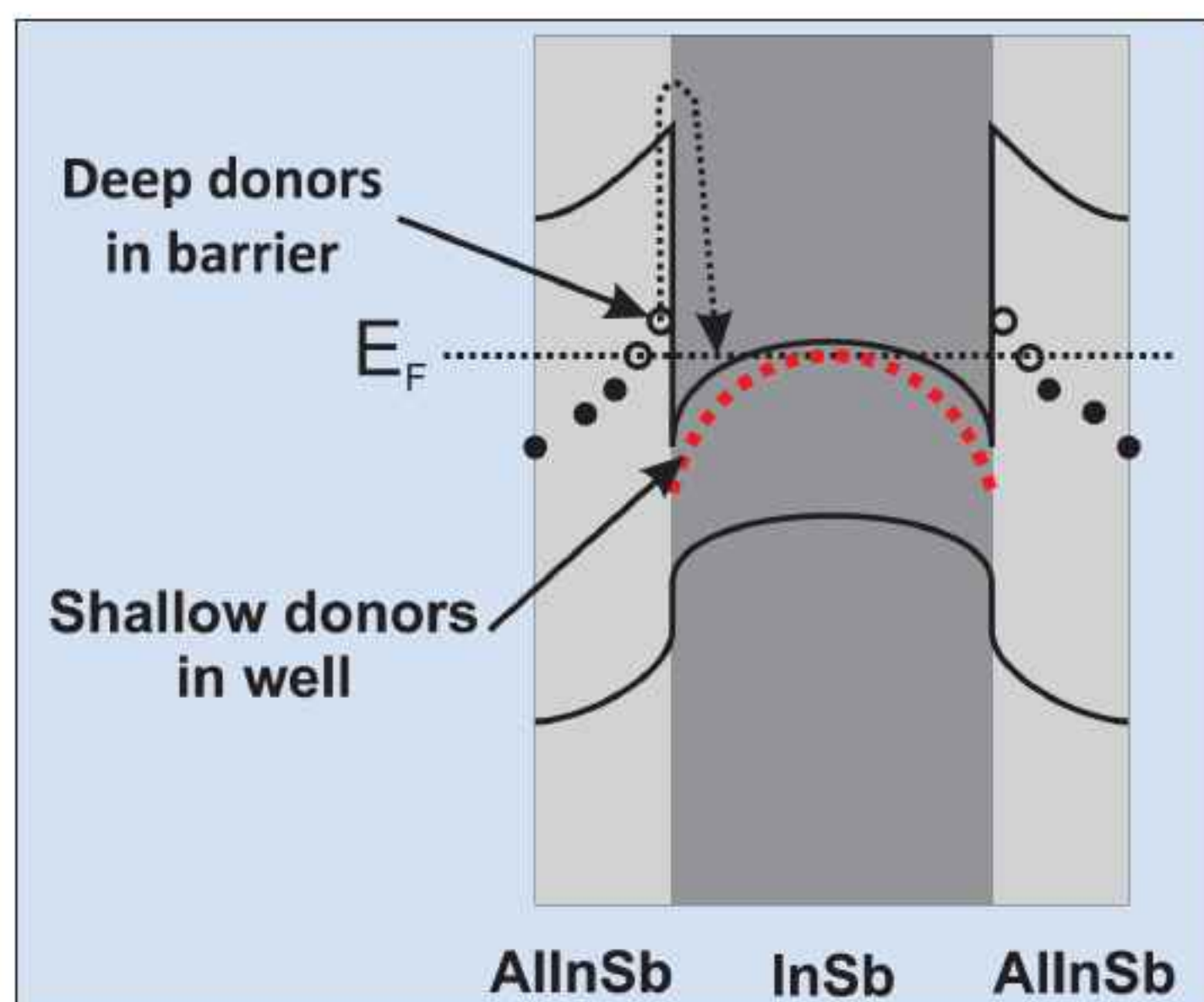
## Magnetics

Two aspects arise in connection with magnetism in antimonide semiconductors: the Hall effect and the electron Landé g-factor. The Hall effect — where a magnetic field applied to a slab of semiconducting material induces a transverse potential difference across the slab — is widely used to probe the charge carrier densities and mobilities in semiconductors. Conversely, where these properties are well established, Hall effect sensors can be used to measure the magnetic field intensity. Hall sensors are widely used in the control of electric motors, washing machines and for hybrid cars.

Asahi Kasei's Ichiro Shibasaki described his company's use of AlInAsSb thin films in Hall effect magnetic sensors at July's Thirteenth International Conference on Narrow Gap Semiconductors (NGS-13) [2]. In addition to the previous applications, Shibasaki sees opportunities in producing mouse-like functionality in advanced mobile phones.

The large mobility of InSb suggests the possibility of making very sensitive magnetic field sensors. For use in motor vehicles and other applications, one also needs a greatly expanded operating temperature range (from  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$  instead of from  $0^\circ\text{C}$  to  $+100^\circ\text{C}$ ). Another attraction of InSb is that it has the





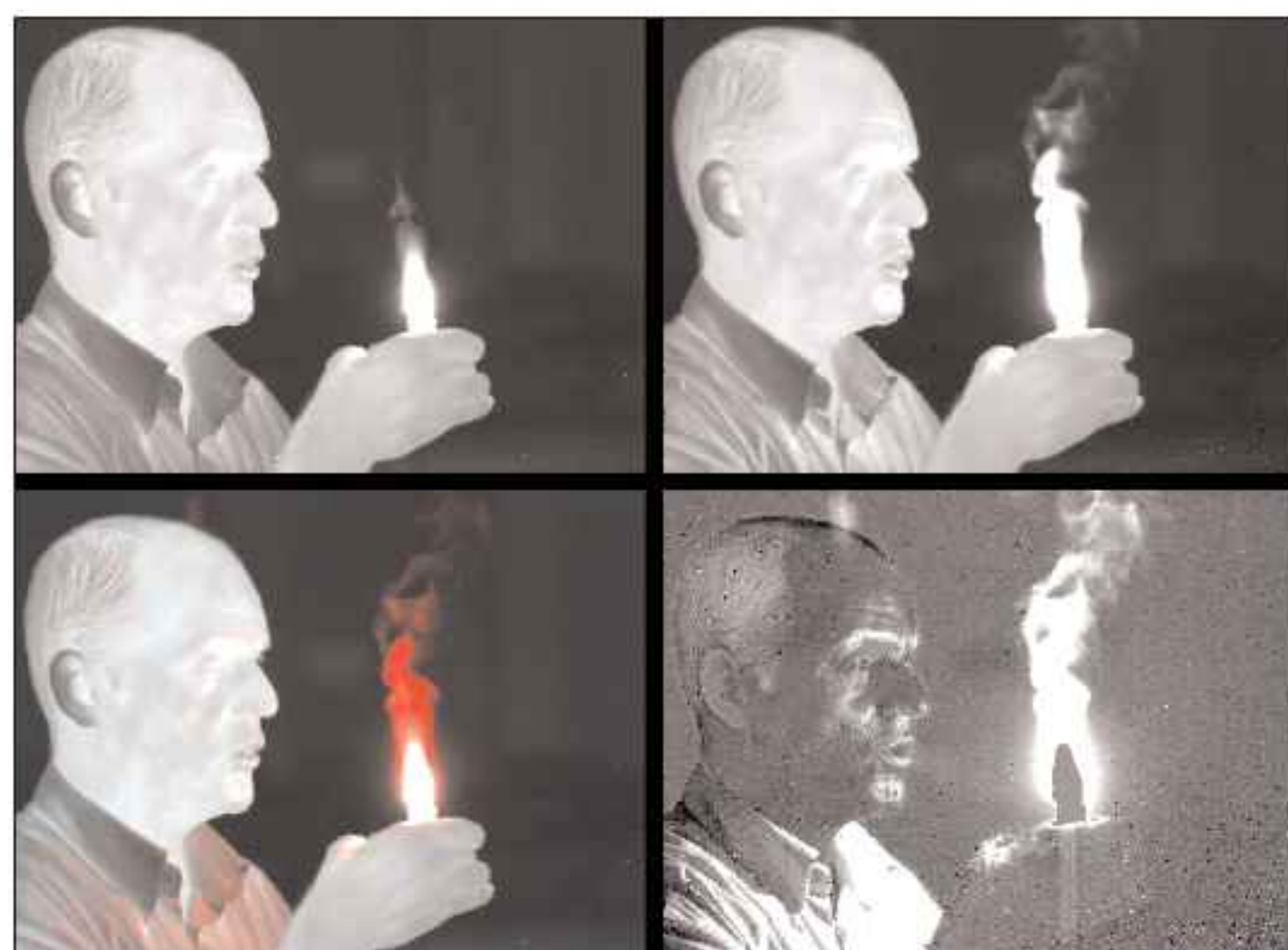
**Figure 4.** InSb quantum wells can suffer from deep donor levels in barriers tossing low-mobility 'extrinsic' electrons into the well.

advantage of a small temperature dependence of its properties.

On its own, InSb has a 14% lattice mismatch with GaAs substrates, which impacts mobilities for films thinner than 500nm (by a reduction of 50% or more). Fabrication processes such as deposition of  $\text{Si}_3\text{N}_4$  or  $\text{SiO}_2$  (e.g. insulation, passivation) can also damage InSb. To overcome these problems, Asahi Kasei has been experimenting with layered structures such as  $\text{GaAs}(6\text{nm})/\text{Al}_{0.1}\text{In}_{0.9}\text{Sb}(50\text{nm})/\text{InAs}_{0.1}\text{Sb}_{0.9}(15\text{--}500\text{nm})/\text{Al}_{0.1}\text{In}_{0.9}\text{Sb}(700\text{nm})$  for creating quantum well Hall effect devices by MBE.  $\text{Al}_{0.1}\text{In}_{0.9}\text{Sb}$  is insulating and lattice matched to  $\text{InAs}_{0.1}\text{Sb}_{0.9}$ . The thin insulating layer of GaAs is a top layer designed to protect the structure from further processing damage. The Asahi Kasei work resulted in great improvements in mobility, Shibasaki reports. Doping with tin can also improve the temperature dependence of devices (see Figure 3).

Although very useful in probing semiconductor properties, the Hall effect does not exhaust the utility of magnetism. With InSb, the electron's g-factor (the effective magnetic moment) has a surprisingly large negative value, opening avenues to even more detailed information regarding the material's properties, with application, for example, to determining hole properties to help with looking for p-channel devices to complement those of n-channel FETs [2].

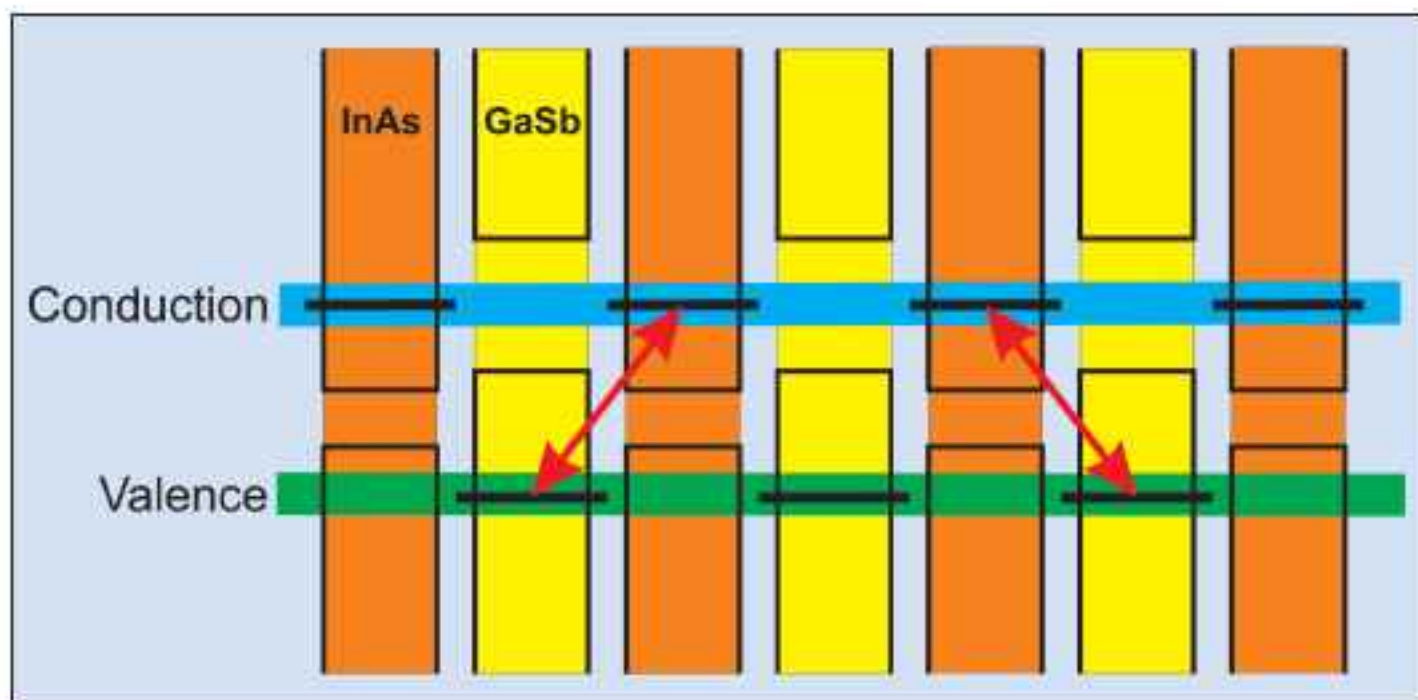
Japanese researchers (Osaka Institute of Technology, Tokyo University of Science, Asahi Chemical, and Chiba University) have also been working on the magnetic properties of non-doped  $\text{Al}_x\text{In}_{1-x}\text{Sb}/\text{InSb}$  quantum well structures. These perpendicular and parallel magneto-resistance investigations were aimed at determining the well-width dependence of extrinsic electrons and carrier accumulation in  $\text{Al}_x\text{In}_{1-x}\text{Sb}/\text{InSb}$  QWs.



**Figure 5.** Thermal image of Dr Martin Walther holding a burning candle from Fraunhofer IAF's two-color IR imager: (top left) with a cut-off wavelength of about  $4.2\mu\text{m}$  — the so-called blue-channel, longer wavelengths are not detected; (top right) detecting the whole spectral range up to  $5\mu\text{m}$  — the so-called red-channel; (bottom left) fusion of both pictures, giving an impression of how to create 'real' color photos in the infrared (the complementary colors red and cyan are used for the two channels: objects emitting infrared radiation in both channels appear 'white', whereas objects emitting only in the long-wavelength channel appear 'red') — the hot  $\text{CO}_2$  created by the burning candle and the reflection on Walther's shirt are clearly seen; (bottom right) differential picture, created by subtraction of blue and red channels — objects emitting IR radiation of comparable intensity in both channels therefore appear dark (looking closely at this picture one can see the  $\text{CO}_2$  in Walther's breath).

'Extrinsic electrons' come from deep donor levels in barriers and can accumulate at heterointerfaces, even when neither the InSb well nor the barrier region ( $\text{Al}_x\text{In}_{1-x}\text{Sb}$ ) are deliberately doped (see Figure 4). These electrons have extraordinarily small mobility — not good when the purpose is to create high-mobility characteristics. To try and probe this problem, the Japanese researchers carried out Hall and magneto-resistance measurements on  $x = 0.1$  QWs grown on GaAs substrates. This value of  $x$  gives a lattice mismatch between the well and barrier as small as 0.5%. The magnetic field dependence of the Hall constant at 77K suggests the presence of two types of electron with different mobilities: one type emanating from the well region and the other from the heterointerfaces. At room temperature, the two-carrier model analysis suggests that the sheet density of the extrinsic carriers from the heterointerface decreases with increasing well widths above 100nm in the shallow wells that were investigated.





**Figure 6.** Superlattice system used in Fraunhofer IAF's thermal imagers.

The large negative electron g-factor in InSb also raises hopes of using spin to create a new dimension in electronic devices (spintronics). Quantum well heterostructures in Datta-Das-type spin-FETs and spin filter formations are the aim of joint work between Imperial College London and Qinetiq. Among the requirements for these applications are a long spin diffusion length, long spin lifetime and high mobility.

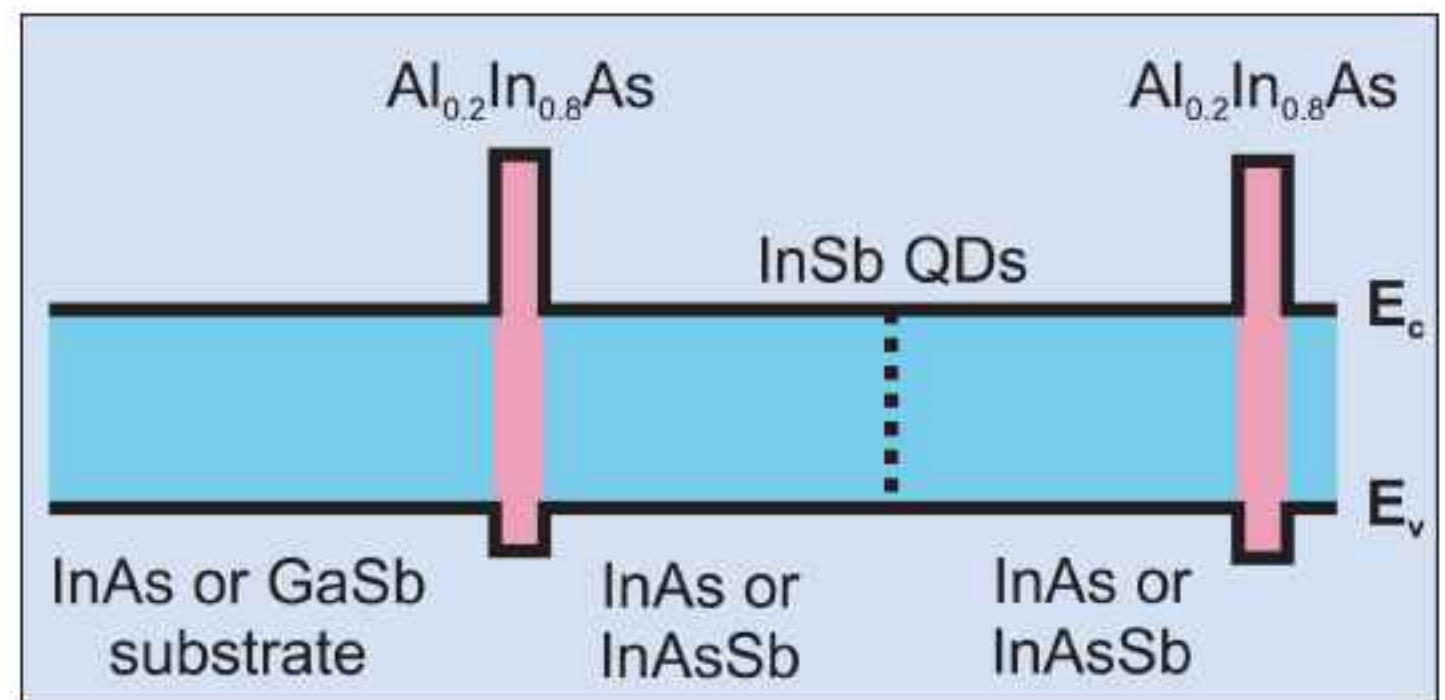
### Sb substrates

Apart from producing epitaxial antimonide semiconductor layers on silicon or GaAs wafers, GaSb and InSb substrates can also be produced. One clear advantage of using such wafers is lattice matching with particular epitaxial layers.

One company producing such substrates is the epitaxial substrate producer IQE, which has production facilities in the UK and the USA. This company has a range of GaSb substrates available from its Wafer Technology division in Milton Keynes, UK. Wafer Technology also has InSb wafers of 50mm and 75mm diameter with a 100mm product 'under development'.

IQE's epitaxy-ready GaSb substrates (50 and 75mm) have been exclusively used in award-winning research and development at Fraunhofer IAF of Freiburg, Germany into InAs/GaSb based two-color thermal (infrared) imaging cameras (Figure 5). This research won Fraunhofer IAF the 2006 Baden-Württemberg research prize (which is worth €100,000).

Fraunhofer IAF used MBE to deposit InAs/GaSb type-II superlattices (SL), creating the bi-spectral infrared imaging system (Figure 6). The 'blue' channel senses radiation with wavelengths in the range 3–4µm, while the 'red' channel detects 4–5µm photons. These wavelengths correspond to black-body temperatures of the order 5000K. The noise equivalent temperature differences of the 'red' and 'blue' pixels are 17mK and 30mK, respectively. By combining the 'red' and 'blue' pixels in a 288x384 array (40µm pitch), the camera overcomes the typical registration problems common to existing multi-spectral cameras that combine different 'color' data from separate sensor arrays. The performance of the new system compares with



**Figure 7.** InSb quantum dot layer is formed by short-time (20s) exposure of heated InAs surface to Sb flux, leaving a monolayer that forms InSb islands with a density of  $\sim 10^{12} \text{cm}^{-2}$ .

that of state-of-the-art mercury cadmium telluride (MCT)-based systems.

The dual-color superlattice detector will be the sensor used in the Multi-Color Infrared Alerting Sensor (MIRAS) system of the new European A400M large military transport aircraft. The MIRAS system is being developed by European Aeronautic Defence and Space (EADS) and Thales.

Fraunhofer IAF researcher Dr Martin Walther comments: "Our new infrared detector is ideally suited for new state-of-the-art early-warning defense systems and, as such, has a big market potential within the civil and military aviation industry."

At the NGS-13 conference, Alexey Semenov described investigations into growing InSb quantum dots on GaSb (and InAs) substrates using MBE at the Ioffe Physico-Technical Institute in Russia (Figure 7). The researchers hope that the greater overlap between the electron and hole wavefunctions compared with QWs could lead to laser devices. InSb QDs show photoluminescence in the wavelength range 3.9–4.4µm.

As reported elsewhere in this issue [2], the US Naval Research Laboratory (NRL), France's Université Montpellier and Germany's Walter Schottky Institute are other developers of devices that use GaSb substrates. Montpellier's devices use the high conduction band offset (2.1eV) offered by AlSb/InAs structures on GaSb substrates to create high-temperature, short-infrared-wavelength (i.e. <5µm) QCLs. The Walter Schottky Institute in Munich uses zinc-doped GaSb substrates in its development of electrically pumped GaSb-based VCSELs. ■

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- [3] Ashley et al, Electronics Letters, 2007, Vol. 43, p.777.
- [4] Datta et al, IEEE Electron Device Letters, Vol. 28, 2007, p.685.
- [5] More details of Mayberry's perspectives can be found at <http://blogs.intel.com/research/2007/08/enforcingmoorelaw.html>



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[www.sicrystal.de](http://www.sicrystal.de)

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## 6 Deposition equipment

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## 24 Consulting

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## 25 Resources

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**9 November 2007**

## LED Korea 2007

Convention and Exhibition Center (COEX), Seoul, South Korea

**E-mail:** [hordon@semicomm.co.kr](mailto:hordon@semicomm.co.kr)

**www.it-conference.net/event/ledk2007**

**20–22 November 2007**

## ILOPE (12th International Lasers Opto-Electronics and Photonics Exhibition)

China International Exhibition Center, Beijing, China

**E-mail:** [heyu@ciec.com.cn](mailto:heyu@ciec.com.cn)

**www.ilope-expo.com**

**26–30 November 2007**

## MRS Fall Meeting, 2007

Boston, MA, USA

**E-mail:** [info@mrs.org](mailto:info@mrs.org)

**www.mrs.org**

**26–30 November 2007**

## First International Conference on White LEDs and Solid State Lighting

Tokyo, Japan

**E-mail:** [wleds07@yamaguchi-u.ac.jp](mailto:wleds07@yamaguchi-u.ac.jp)

**http://w-leds07.eee.yamaguchi-u.ac.jp/index.html**

**3–7 December 2007**

## PVSEC-17:

## 17th International Photovoltaic Science and Engineering Conference

Fukuoka, Japan

**E-mail:** [pvsec17@toyota-ti.ac.jp](mailto:pvsec17@toyota-ti.ac.jp)

**www.pvsec17.jp**

**5–7 December 2007**

## SEMICON Japan 2007

Makuhari Messe, Chiba, Japan

**E-mail:** [jshowsinfo@semi.org](mailto:jshowsinfo@semi.org)

**http://semiconjapan.semi.org**

**10–12 December**

## 53rd annual IEEE International Electron Devices Meeting (IEDM 2007)

Hilton Hotel, Washington DC, USA

**E-mail:** [iedm@his.com](mailto:iedm@his.com)

**www.ieee.org/conference/iedm**

**19–24 January 2008**

## Photonics West, including OPTO 2008

## LASE 2008

San Jose Convention Center, CA, USA

**E-mail:** [CustomerService@SPIE.org](mailto:CustomerService@SPIE.org)

**http://spie.org/photonics-west.xml**

**21–23 January 2008**

## International Conference on Solar Cells (IC-SOLACE 2008)

Cochin, Kerala, India

**E-mail:** [solace2008@gmail.com](mailto:solace2008@gmail.com)

**http://solace2008.org/solace**

**30 January – 1 February 2008**

## SEMICON Korea

Convention and Exhibition Center (COEX), Seoul, Korea

**E-mail:** [hkim@semi.org](mailto:hkim@semi.org)

**www.semiconkorea.org**

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**31 January – 1 February 2008**

**Theory, Modelling & Computational Methods for Semiconductor Materials & Nanostructures**

University of Manchester, UK

**E-mail:** max.migliorato@manchester.ac.uk

**http://eee.dev.ntweb.mcc.ac.uk/research/groups/mandn/events/workshop**

**11–13 February 2008**

**Strategies in Light 2008**

Santa Clara Convention Center, CA, USA

**E-mail:** lubah@pennwell.com

**http://sil08.events.pennnet.com**

**24–28 February 2008**

**OFC/NFOEC 2008**

**(Optical Fiber Communication Conference and Exposition/National Fiber Optic Engineers Conference)**

San Diego, CA, USA

**E-mail:** info@ofcconference.org

**www.ofcnfoec.org**

**28 February 2008**

**Colloquium on RF and Microwave IC Design**

London, UK

**E-mail:** lmd@plextek.co.uk

**www.theiet.org/rficdesign**

**4–6 March 2008**

**2008 China International LED Show (LED CHINA 2008)**

Chinese Import & Export Fair Pazhou Complex, Guangzhou, China

**E-mail:** LED@TrustExhibition.com

**www.LedChina-gz.com**

**18–20 March 2008**

**SEMICON China 2008**

Shanghai New International Expo Centre (SNIEC), China

**E-mail:** semichina@semi.org

**http://semiconchina.semi.org**

**18–20 March 2008**

**2nd annual WiMAX World Asia 2008**

Bangkok, Thailand

**E-mail:** ehealey@trendsmedia.com

**http://asia.wimaxworld.com**

**24–28 March 2008**

**2008 MRS Spring Meeting**

Moscone West and San Francisco Marriott, CA, USA

**E-mail:** info@mrs.org

**www.mrs.org**

**14–17 April 2008**

**CS MANTECH (2008 International Conference on Compound Semiconductor Manufacturing Technology)**

Westin Chicago North Shore, Wheeling, IL, USA

**E-mail:** csmantech@csmantech.org

**www.gaasmantech.org**

**7–8 May 2008**

**Blue 2008 (The 6th International Industry Review)**

Ambassador Hotel, Hsinchu, Taiwan

**E-mail:** Blue-2008@solidstatelighting.net

**www.Blue-2008.com**

**19–21 May 2008**

**3rd annual WiMAX World Europe 2008**

Munich, Germany

**E-mail:** ehealey@trendsmedia.com

**http://europe.wimaxworld.com**

**25–29 May 2008**

**20th International Conference on Indium Phosphide and Related Materials (IPRM '08)**

Versailles, France


**E-mail:** iprm08@see.asso.fr

**http://iprm2008.org**



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