

# 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

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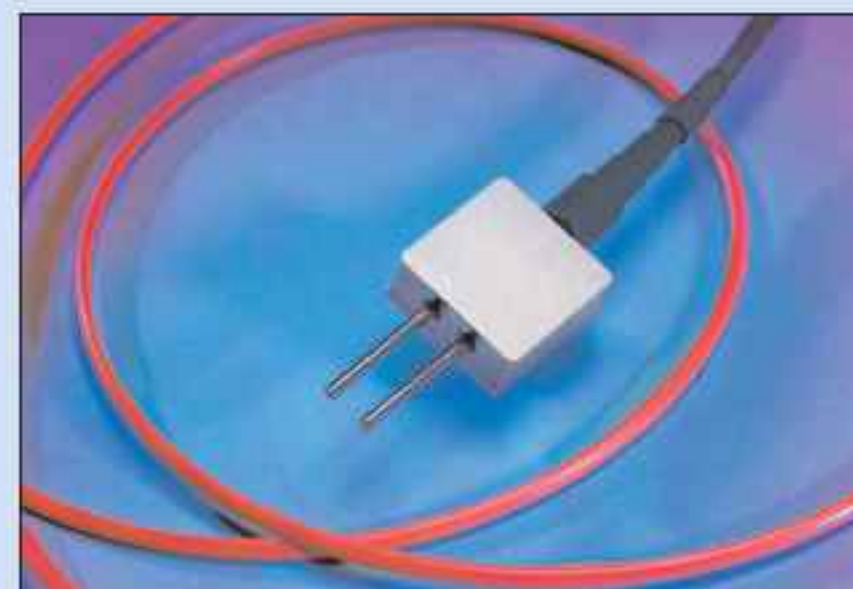
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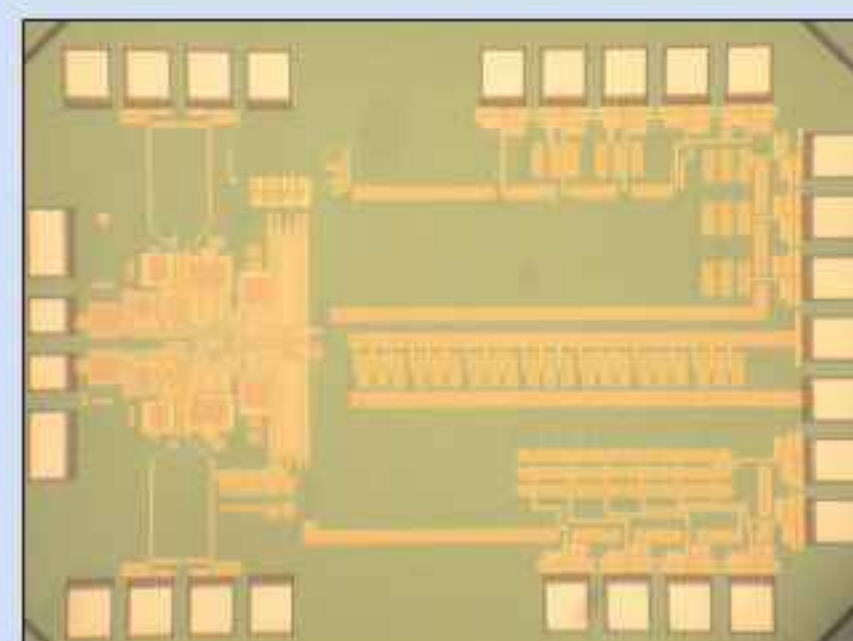
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**p47** The Sintesi concept car, which features strip headlamps based on Osram LEDs. Picture: Pininfarina.



**p55** Intense's Series 8000 793-MFP (mini fiber package) high-power, fiber-coupled diode laser.



**p79** Microphotograph of IMEC's full CMOS multiple antenna receiver for 60GHz (1400µm x 1000µm).



**Cover:** Close-up view of concentrator photovoltaic (CPV) system made by SolFocus, which is working with Arizona State University and Soliant Energy of Pasadena, CA on a \$800,000 DOE-funded project to boost CPV qualification testing throughput. **p70**

# Trends in integration

This issue we focus on developments in silicon technology, including (in the feature on pages 82–85) how it compares with gallium arsenide for various wireless connectivity applications and specifically (in the feature on pages 76–80) how the latest developments in pushing the limits on CMOS silicon's scaling and performance are raising the possibility of its use for 60GHz communications and 77GHz collision avoidance applications. We also report on the EU's DOTFIVE project to boost silicon germanium HBTs from 300GHz to 0.5 Terahertz operating frequencies (page 20), as well as Europe's 'DUALLOGIC' project to integrate Ge pMOS and III-V nMOS on silicon for post-22nm CMOS (page 22).

We also focus on product developments shown at February's GSMA Mobile World Congress in Barcelona, where GaAs-based RF component makers including RFMD, Skyworks, TriQuint, Anadigics and Avago showed their latest progress in improving the levels of integration, functionality, power consumption and performance (see pages 7–16).

Meanwhile, in addition to RFMD's acquisition of Filtronic's GaAs foundry in the UK late last year (which has since made it postpone the planned construction of a second fab at its headquarters in Greensboro, NC, USA — see page 6), TriQuint has now announced the acquisition of WJ which, despite divesting its fab early last year, has continued to make losses on dwindling revenues. However, TriQuint has acquired the fabless firm for its design expertise, as well as for its presence in the wireless infrastructure market (following design wins from Chinese telecom equipment makers for TD-SCDMA multi-chip module chipsets — see page 15).

Consolidation is ongoing among RFIC makers, but the slow (or non-existent) consolidation among optical communications component makers was discussed at February's OFC/NFOEC conference in San Diego (see conference report on pages 73–75). Although generally most firms have made much progress towards breaking even since the optical communications slump post-2001, profitability is still hampered by what is perceived to be an excess of suppliers depressing average selling prices. The consensus is that consolidation is necessary.

Apart from the need for consolidation, the trend for technology integration is another area where optoelectronics can emulate microelectronics. At OFC, Bookham launched its reduced-size (5mm) 40Gb/s InP-based MZ modulator chip, which is being combined with its range of tunable lasers (see OFC/NFOEC news page 57). But most impressive is Infinera's InP-based photonic integrated circuit (PIC) technology, which enables 400Gb/s (i.e. 40Gb/s x 10 channels) capacity per PIC (which could scale to 4Tb/s by 2018). Infinera's roadmap will be covered in more detail next issue.

In the meantime, Semiconductor Today will be attending April's CS MANTECH event in Chicago, so we look forward to seeing you there.

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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).

## Regular issues contain:

- news (funding, personnel, facilities, technology, applications and markets);
- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
- suppliers' directory.

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## Wide-bandgap electronics could grow at 30% to \$300m by 2012 as substrate properties improve

After years of development, the market for electronic devices based on wide-bandgap semiconductors — e.g. gallium nitride (for microwave applications), silicon carbide (for power supplies and motor controls) and less mature materials such as aluminum nitride — is set to grow at 30% or more per year through 2012, according to the report 'Wide-bandgap Electronics—2008' by the market research firm Strategies Unlimited.

The devices will have to compete against established semiconductor-based devices and vacuum tubes in segments that will have a combined value of about \$1bn in revenues by 2012. But, with rapid breakthroughs, the market could reach as much as \$300m, as manufacturing costs fall and the products can compete against silicon devices in power supply applications.

Compared to silicon technology, wide-bandgap materials have superior properties for high-frequency, high-temperature or high-power electronics but have been slower to develop, and are much more difficult and expensive to manufacture (due, among other reasons, to high melting points of more than 2000°C). Wide-bandgap electronic devices are hence targeted at competing in niches where silicon and other solutions are inferior.

Early growth is dominated by products for microwave power amplifiers, such as for communications, radar, and military uses. Growth in products for power management will take longer, while low-power products for high-temperature environments will not see a significant opportunity through the forecast period.

Strategies Unlimited says that there are more than 150 firms in 16 countries researching wide-bandgap materials and devices. Leading suppliers of wide-bandgap electronics are currently Cree Inc of Durham, NC, USA and Japan's Eudyna, with two-thirds of the revenues. The market is split among several types of player. Cree is leveraging its internal manufacturing of SiC substrates and LEDs to be competitive in wide-bandgap electronics, while Durham-based Nitronex is focusing on low-cost manufacturing by growing wide-bandgap material on silicon substrates. Meanwhile,

**There are more than 150 firms in 16 countries researching wide-bandgap materials and devices**

established GaAs suppliers like Eudyna, RFMD, Triquint, and others also aim to leverage their expertise in microwave electronics, while STMicroelectronics and

Infineon aim to leverage expertise in power management components.

However, the projected market growth depends strongly on many factors, particularly on continuing improvements in substrate quality, price, and availability; new device and package designs; and the ability of system designers to take advantage of the new technology.

The ultimate goal is to make the devices on native substrates with diameters of at least 4-inches, and defect levels of  $10^4/\text{cm}^2$ , or less. Such improvements would increase manufacturing yields and lower costs, and ultimately expand the market for the electronic devices, the report says.

[www.strategies-u.com](http://www.strategies-u.com)

## LED growth up to 12% in 2008 then \$11bn in 2012

After growth of just 6% in 2005 and 2006, then 9.5% in 2007 (to \$4.6bn), the market for packaged high-brightness LEDs should grow by 12% in 2008, according to a market update presented by Bob Steele of market research firm Strategies Unlimited at its 2008 Strategies in Light conference in Santa Clara, CA, USA last week.

In 2007 the largest segment was mobile appliances, with 44% market share. However, the largest growth was seen in the solid-state illumination and the signs & displays markets. Solid-state illumination accounted for 7% of the market (\$320m),

With growth accelerating as applications outside the mobile phone market come to the fore, Steele predicts a compound annual growth rate (CAGR) of 20% in the next five years, to a total market of \$11.4bn in 2012.

The largest application in 2012, with 44% of the market, will be signs & displays, including back-lighting for large LCD screens (computer monitors and TVs). The solid-state illumination market is expected to grow from \$320m in 2007 to nearly \$1.37bn by 2012. Energy-efficiency is a major driver for moving LEDs into the general (white) lighting market, but products must deliver value on a cost-of-ownership basis, and must have proven LED fixture efficiency and lifetime to win customer acceptance, says Steele.

Between 2004 and 2007, unit shipments have increased by 26% per year to about 39 billion, while ASPs (average selling prices) have fallen by about 16%. Overall, the product mix has shifted quite dramatically, with high-power packages now accounting for 10% of the market.

<http://su.pennnet.com>

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

## Compound semiconductor substrate market to top \$1bn by 2009–2010

The compound semiconductor substrate material market grew from \$600m in 2006 to almost \$800m in 2007, and should grow to \$1bn by 2009–2010 and then \$1.4bn in 2012, forecasts market analyst firm Yole Développement in its new report 'Compound Semiconductor Materials '08'.

Silicon still dominates the semiconductor industry as the standard substrate. However, optoelectronics and RF and power electronics applications that require material properties not provided by silicon are driving demand for compounds, due to enabling device performance not achievable with silicon (in terms of operating frequency, power output, thermal conductivity, robustness, junction temperature and voltage breakdown).

Driven by demand for wireless technology, gallium arsenide has been the most used compound semiconductor material by volume. Also, sapphire and silicon carbide have been benefiting from the booming LED market, while bulk gallium nitride has become the 'winning choice' for blue laser diode makers, says the report's author

Philippe Roussel. Finally, Yole expects a strong rebound in demand for InP for fiber-optic communications applications.

Nevertheless, in 2007, GaN, GaAs, InP, SiC and sapphire substrates represented just 0.62% of the 8630m square inches of total semiconductor material (including silicon) processed annually in fabs, due partly to the merchant price of compound semiconductor materials being much higher than silicon.

However, all of the above materials are now available in wafers of 4-inch in diameter (except for bulk GaN, which has just been launched in 3-inch form in Japan). The increase in the diameter of wafers is helping to lower the cost of manufacturing devices and make mass-market products affordable, boosting the market for compound semiconductor substrates, says Yole.

The proportion of compound semiconductor substrates used (compared to silicon) is hence forecast to continue its growth (from 0.56% in 2006 to 0.62% in 2007) with consistent growth to 0.84% by 2012, concludes Yole.

[www.yole.fr/pagesAn/products/csmat.asp](http://www.yole.fr/pagesAn/products/csmat.asp)

## Base-station chips to dwindle in next 5 years

Revenues for base-station chip-makers will slowly decrease over the next five years, says market research firm In-Stat in its report 'Worldwide Cellular Base Station Components Forecast'.

Providers are upgrading to the fastest cellular technology as quickly as they can, but doing it while keeping price pressure on infrastructure equipment makers, says In-Stat. Further adding to price pressures are Chinese and other low-cost Asian semiconductor makers that have recently become more prominent in the global market.

"Semiconductor revenue from base-stations is forecast to drop

over the next few years," says analyst Allen Nogee. "In these next five years, WiMAX infrastructure semiconductors will make up a small part of this shortfall, as will other infrastructures, such as mobile TV networks, but these networks likely won't be able to totally fill the gap," he adds.

In-Stat also finds that GSM semiconductor revenue remains strong, driven by capacity expansion in developing countries. However, overall, the number of power amplifiers shipped is forecast to fall from 5 million in 2007 to 3 million by 2011.

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

## Mitsubishi Electric terminating mobile handset business

Tokyo-based Mitsubishi Electric Corp has decided to terminate its mobile handset business in Japan in order to strategically shift its resources to businesses which it plans to strengthen (mainly the Communication Systems Group and other groups involving communication-related business that are expected to show further development and expansion). The 600 or so staff in the mobile handset business' R&D, manufacturing and sales divisions will correspondingly be reallocated.

Mitsubishi Electric started supplying car phones in 1983 to Nippon Telegraph and Telephone Public Corp and, since then, has sold mobile handsets in Japan, with recent products supplied to NTT DoCoMo Inc. It expected to ship about 2.1 million handsets in fiscal 2008 (to end-March).

However, the firm says that it has become difficult to grow demand in the already mature domestic mobile phone market, with the increasingly diverse preferences of consumers leading to severe business conditions. Consequently, Mitsubishi Electric's mobile handset business has recently suffered reductions in shipments.

Mitsubishi Electric is hence terminating launches of newly developed models after the current models supplied to and sold by NTT DoCoMo. However, it will continue after-sales service after the restructuring. Meanwhile, mobile phone dealer Diamondtelecom Inc (a subsidiary of Mitsubishi Electric) will continue and work to further expand its business.

Mitsubishi Electric says that it will also work to maintain and further strengthen the partnership with NTT DoCoMo through the communication-related business that it aims to expand.

<http://global.mitsubishielectric.com>

# RFMD delays Greensboro Fab 2 as it closes Filtronic acquisition

The world's biggest GaAs RFIC maker, RF Micro Devices Inc of Greensboro, NC, USA, has completed its £12.5m acquisition (announced on 20 December) of Filtronic plc's subsidiary Filtronic Compound Semiconductors Ltd. The purchase includes its 6" GaAs wafer fab in Newton Aycliffe, UK (Europe's largest GaAs fab) and its microwave and millimeter-wave RF semiconductor business.

RFMD expects the addition of the high-volume fab to significantly reduce its GaAs pHEMT manufacturing costs and provide incremental manufacturing capacity sufficient to support anticipated near-term growth. The firm also expects the addition of Filtronic Compound Semiconductors' microwave and millimeter-wave component business to strengthen the product portfolio of its Multi-Market Products Group (MPG) and be accretive to its target margin profile for its multi-market business.

"With the acquisition of Filtronic Compound Semiconductors, RFMD significantly benefits in three ways," reckons RFMD's president and CEO Bob Bruggeworth.

"First, the acquisition significantly lowers our overall GaAs cost structure, which we believe will result in improved margins as calendar year 2008 progresses. Second, RFMD's GaAs capacity is increased by approximately 30%, giving us the flexibility to capture near-term demand upside and defer future fab-related capital outlays. Finally, we acquire a strong microwave and millimeter-wave business that adds profitable, high-margin revenue to MPG," Bruggeworth adds.

"We look forward to the growth and cost-reduction opportunities this acquisition makes possible," he concludes.

Indeed, according to a report in The Triad Business Journal, RFMD is postponing its \$103m construction of a second 6" GaAs wafer fabrication plant in Greensboro (which would employ 300 new staff) and shifting the planned production and jobs to the Newton Aycliffe fab.

The plan to build the second fab was initially announced at the end of last September, to support expected growth in the firm's Cellular and Multi-Market product groups (focusing on high-volume HBT- and pHEMT-based cellular and WLAN front-end devices).

At that time, chief financial officer Dean Priddy said RFMD planned to reduce its reliance on outsourced GaAs pHEMT switch manufacturing as Fab 2's capacity came online (having already decided to terminate outsourcing to Filtronic).

But, since the acquisition, the Filtronic fab presents both the capacity and trained staff available immediately to meet RFMD's near-term production demands, making the Greensboro fab investment unnecessary for now.

Jerry Neal, RFMD's executive VP for marketing and strategic development, says that the planned Greensboro plant and its jobs (paying \$42,000 on average) are not being scrapped. However, the plant will not open this year as planned. Product demand will dictate when the facility is completed, he says.

[www.bizjournals.com/triad/stories/2008/03/03/tidbits1.html](http://www.bizjournals.com/triad/stories/2008/03/03/tidbits1.html)

**The Filtronic fab presents both the capacity and trained staff available immediately to meet RFMD's near-term production demands**

## Motorola split: impact on RFMD

Regarding talk by Motorola (RFMD's second biggest customer, after Nokia) of possibly selling its handset business, RFMD's president and CEO Bob Bruggeworth stressed that Motorola's handset business is not as big as it used to be.

Motorola has lost market share in high-end phones (EDGE) to Nokia, but RFMD has high dollar content there too. Also, in low-end phones, RFMD is starting to ramp into other, mid-tier customers as well as Nokia, and starting to regain market share with Korean handset makers that it lost in 2007 (with several design wins in second-half 2007 expected to ramp in second-half 2008). So, the impact of Motorola putting its handset business up for sale "may not be so bad" for RFMD, Bruggeworth reckons.

Subsequently, in late March, Motorola's board said that it had started a process to split the firm into two independent, publicly traded companies, focusing separately on Broadband & Mobility Solutions (includes its Enterprise Mobility, Government and Public Safety, and Home and Networks businesses) and Mobile Devices.

● By the end of February, RFMD had repurchased about 30 million shares at an average price \$3.27 per share (costing about \$100m). This reduces by about 10% the number of outstanding shares of its stock.

This follows RFMD's announcement on 31 January that its board of directors had authorized the firm's first ever share repurchase program: of up to \$150m of its common stock over the next 24 months.

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

# RFMD launches new products at Mobile World Congress

At February's 2008 GSMA Mobile World Congress in Barcelona, Spain, RFMD launched the RF4180 Power-Star dual-band GSM/GPRS transmit module, which is designed to reduce front-end complexity and address the price and performance requirements of emerging-market handsets.

The RF4180 leverages RFMD's power control capabilities to reduce size, simplify transmitter design and ease implementation. The module has two symmetrical receive ports, 50Ω matched input and output ports and GSM/GPRS Class 12 compliance. Designed for use as the final part of transmit sections in GSM900/DCS1800 handsets, it minimizes the requirement for PA-to-antenna matching. When mated with cellular baseband system-on-chip solutions, the module delivers a highly integrated radio solution capable of accelerating time to market cost-effectively, RFMD says.

The RF4180 provides high efficiency and improved performance in a cost-competitive, reduced size transmit module architecture, says RFMD, resulting in improved battery life and talk time as well as reduced thermal dissipation (all key to developing emerging-market handsets).

Also, RFMD is sampling its RF6280 3G transmit system, a flexible solution designed to simplify and accelerate implementation of multi-band and multi-mode 3G handsets and mobile device platforms.

RF6280 supports all major WCDMA frequency bands and consists of a front-end power management IC optimized for use with either one or both of two available PA options: the RF6281 and/or the RF6285. RF6281 is a dedicated single-band PA module (supporting Band I), and RF6285 is a flexible dual-path, multi-band PA module (supporting Bands I, II, III, IV, V, VI, VIII, IX). The centerpiece RF6280 front-end power management IC combines a low-noise, high-efficiency DC-to-DC converter with embedded hardware control algorithms.

Analog bias control and DC-to-DC conversion intelligently and dynamically control PA operating conditions. Enabling mode-optimized PA efficiency and linearity performance, the RF6280 also ensures maximum efficiency across all power levels, data rates (voice-only to HSPA) and non-ideal load conditions (antenna mismatch). This helps to extend

battery life and reduces average thermal dissipation.

By using the broadband characteristics of the dual-band RF6285, the 3G transmit system simplifies the implementation of multi-mode, multi-region 3G handset platforms, RFMD claims. Also, by leveraging a balanced (quadrature) PA architecture, it also provides improved total radiated power (TRP) and specific absorption rate (SAR) performance, eliminating the need for costly RF isolators and simplifying multi-band platform implementation.

The system provides the flexibility to design a single platform that can support multiple WCDMA bands just by changing filter components, says RFMD. No change to the RF layout of the phone board is necessary.

The compact design enables a significant reduction in the space requirements of a tri-band WCDMA solution, including filtering and front-end power management. When combined with improved TRP and SAR and best-in-class efficiency, the system facilitates highly efficient, cost-effective and flexible WCDMA platforms.

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

## RFMD now supplying to all top-five handset makers

RFMD has begun volume shipments to a tier-one handset OEM of its RF3159 high-linearity quad-band GSM/GPRS/EDGE power amplifier module (designed to support EDGE transceivers using linear transmit architectures, including transceivers from Infineon, MediaTek and NXP Semiconductors).

The shipments support a platform resulting in multiple feature-rich handsets, so this represents the start of a possible high-volume ramp to this OEM in 2008. "We expect the ramp of the RF3159 will enable this OEM to quickly and cost-effectively develop additional phones while strengthening its growing portfolio," says Eric Creviston, president of the Cellular Handset Products Group.

The RF3159 is fully matched for easy implementation and is housed in a small 6mm x 6mm package. Its gain and linearity line-ups enable handset makers to optimize the transmit chain to meet various requirements of linearity, efficiency and output power. It is designed to be the final amplification stage in a dual-mode GSM/GPRS/EDGE mobile transmit line-up operating in the 824-915 and 1710-1910MHz bands.

RFMD (which shipped more than 210m EDGE front-ends in 2007) says it is now supplying production volumes to all five of the cellular handset industry's largest OEMs.

RFMD has also started pre-production shipments of its RF3266 WCDMA PA to an unnamed tier-one

handset maker, representing the start of a high-volume ramp to this OEM. The PA will power a feature-rich 3G platform, and is expected to support multiple handsets.

The RF3266 is a Band I, HSDPA-compliant WCDMA PA with integrated power detection circuitry. Housed in a 3mm x 3mm x 0.9mm package, it provides the lowest-profile WCDMA PA in the industry, RFMD claims.

The RF3266 is designed to be the final WCDMA amplification stage in a 3G multi-mode mobile transmit line-up operating in the 1920-1980MHz band.

RFMD says it expects sales growth of more than 40% in the 3G handset market in 2008.

# Anadigics implements Syntricity enterprise yield management

GaAs-based wireless and broadband communications component maker Anadigics Inc of Warren, NJ, USA has implemented an end-to-end enterprise yield management (EYM) system using the dataConductor software suite from Syntricity Inc of San Diego, CA, USA.

The Anadigics system incorporates Syntricity's Advanced Monitoring for Production (AMP) application and Power User Suite to create an integrated environment for new product introduction and production monitoring. Using AMP, Anadigics' can generate web-based reports to determine status, identify and resolve potential production issues. For new device characterization and rapid root cause problem identification, engineers can navigate from AMP to the extensive Power User analytics suite.

Using Syntricity's dataConductor.com Software as a Service (SaaS) delivery model, Anadigics can directly upload data from its global

supply chain, including epiwafer manufacturers, wafer fabrication facilities and assembly, and test suppliers.

Several gigabytes of engineering and manufacturing execution system (MES) data can be

uploaded every day and automatically inserted into a centralized data warehouse, making more than half a terabyte of information immediately available to management and engineers.

Syntricity says that, accessed through a web browser, dataConductor.com can provide

**Several gigabytes of engineering and manufacturing execution system (MES) data can be uploaded every day and automatically inserted into a centralized data warehouse**

companies of all sizes access to a manageable, reliable and secure enterprise yield management system scalable to tens of gigabytes per day of uploaded data and multiple terabytes directly accessible on-line.

"Anadigics is a data intensive company. With our rapid growth we anticipated the need to substantially enhance our engineering information systems," says Greg Guth, Anadigics' senior director of manufacturing engineering operations. "Working with Syntricity, we have been able to quickly implement an EYM system that gives us visibility from wafer supply to final test and substantially improve our yields." Guth adds.

"We believe this deployment provides them with a top-tier capability that will scale smoothly as they grow," says Syntricity's chairman & chief executive officer A.C. D'Augustine.

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

## Anadigics launches RF amplifier for fiber-to-the-home

Anadigics Inc of Warren, NJ, USA has launched the ACA2604 RF amplifier for fiber-to-the-home (FTTH) applications. Based on the ACA2601, the new amplifier features improved frequency flatness over temperature, as required for domestic US telco Gigabit passive optical network (GPON) deployments.

Like the ACA2601, the pin-compatible ACA2604 contains an integrated automated gain control (AGC) circuit (with 22dB gain adjust) in its 5mm x 5mm x 1mm surface mount package rather than an additional external circuit (lowering bill-of-material costs by eliminating many discrete

components). However, it features a higher overall gain than the ACA2601 (24dB versus 21dB), reducing the need for post-amplification in the ONT/ONU or similar subscriber-end equipment, says Anadigics.

"Anadigics specifically designed the ACA2604 amplifier to meet the ITU's stringent requirements for the higher electrical signaling demands of the emerging GPON [Gigabit passive optical network] market," says Ron Michels, senior VP and general manager, Broadband Business. "The amplifier's exceptional linearity and output power ensure optimal video performance for next-generation

digital TV content delivery systems. Many of our customers are already specifying the exact capabilities of the ACA2604 in their reference designs for optical assemblies," Michels adds.

Key features of the ACA2604 are:

- 50–870MHz operating frequency;
- high linearity — 65dBc CTB/CSO (79 channels);
- low equivalent input noise — 4.5pA/rHz;
- 400Ω differential input impedance (no transformer required for photodiode interface);
- a single +5V supply.

General availability was scheduled for Q1/2008.

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

# Anadigics launches new PAs

At the 2008 GSMA Mobile World Congress in Barcelona, Spain, Anadigics launched several new power amplifier (PA) products, (based on its proprietary InGaP-Plus technology) for mobile handsets.

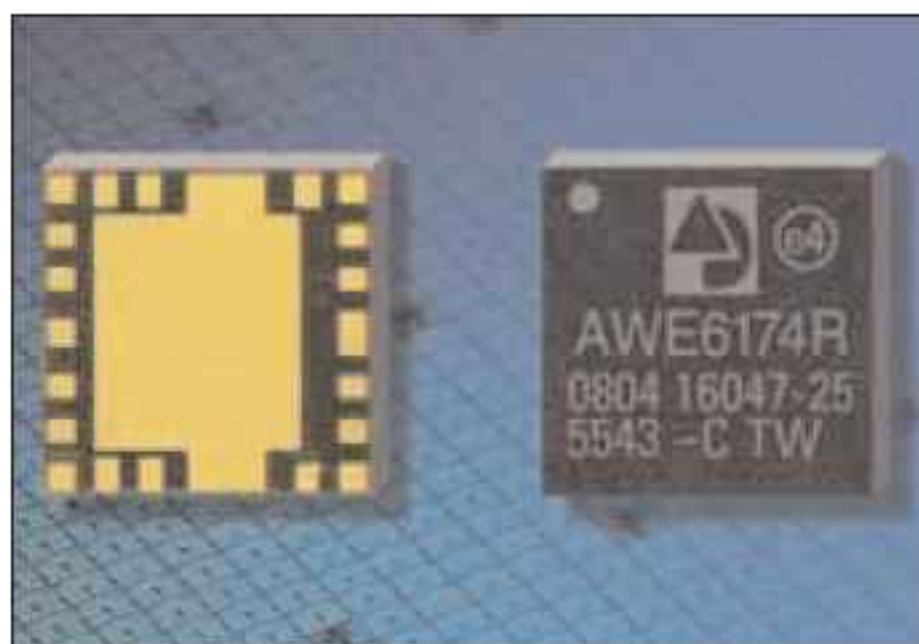
## **3G quad-band Polar EDGE PA for Qualcomm chipset platforms**

Designed to meet requirements for GSM and EDGE mode operation with Qualcomm's WCDMA and HSPA chipsets, the new AWT6155 quad-band polar EDGE PA module for 3G wireless handsets and equipment is housed in a 5mm x 5mm package.

"The AWT6155 is half the size of current generation 7mm x 7mm EDGE PA modules," said EDGE product line manager Joe DeMoura. "That reduces RF board area in dual-, tri- and quad-band designs based on the latest generation of Qualcomm transceivers. The smaller package includes features that our customers expect in a high-performance EDGE PA - separate amplifier chains for GSM850/900 and for DCS/PCS bands and optimized performance in both GMSK and 8PSK modes. The AWT6155 also has an internal reference voltage and integrated power control scheme for simplified GMSK operation, which makes production calibration faster and easier and reduces the number of external components required."

Ali Khatibzadeh, senior VP and general manager of wireless products, added: "...we designed the AWT6155 to deliver the highest quality power output, linearity and overall performance in the smallest form factor that is available and to enable our customers to pack more features into smaller, slimmer handsets based on Qualcomm's industry-leading 3G smart phones and embedded modules."

Sampling of the AWT6155 quad-band polar EDGE PA module was due to begin by the end of Q1/2008.



**AWE6174 quad-band Polar EDGE PA.**

## **Quad-band polar EDGE PA module for 3G handsets: external DC-DC converter halves current consumption**

Anadigics also launched the AWE6174 quad-band Polar EDGE PA module for 3G wireless handsets and equipment.

The new Polar EDGE PA is designed to meet requirements for GSM/GPRS and EDGE operations in dual-, tri- or quad-band handsets based on Qualcomm's WCDMA, HSPA chipsets and their latest-generation transceivers.

The AWE6174 includes separate amplifiers for GSM850/900 and for DCS/PCS bands, optimized for high performance in both GMSK and 8PSK modes, in a 6mm x 6mm package that is 25% smaller than current-generation EDGE PA modules.

An internal reference voltage and integrated power control scheme for simplified GMSK operation make production calibration faster and easier and reduce the number of external components required.

The unique device architecture gives handset designers the option of using an external DC-DC converter to

**Using a third-party DC-DC converter in this way can reduce current consumption by half at medium output power and greatly increase battery life and talk time**

modulate the amplifier bias voltage and reduce current consumption at backed-off output power, says EDGE product line manager Joe DeMoura. "Using a third-party DC-DC converter in this way can reduce current consumption by half at medium output power and greatly increase battery life and talk time," he adds.

Sampling of the AWE6174 was due to begin by the end of Q1/2008.

## **Anadigics expands WiMAX/WiBro portfolio with 2.3-2.4GHz AWM6422 PA**

Anadigics has also expanded its portfolio of products for WiMAX and WiBro (Korea) systems by launching the AWM6422 PA, which operates in the 2.3-2.4GHz frequency band allocated for broadband mobile wireless services and supports the IEEE 802.16e-2005 wireless standard as well as the IEEE 802.16d-2004 and ETSI EN301-021 standards.

A variation of the AWM6423 (launched last year), the AWM6422 is a high-performance device with exceptional linearity and efficiency at high levels of output power, says Anadigics. It requires a nominal +3.3V supply, but also provides enhanced RF performance when used with supply voltages as high as +4.2V. The EVM contribution is low at high output power levels: -2.5% EVM at +22dBm and -4% EVM at +23.5dBm (+3.3V) and -2.5% EVM at +23.5dBm and -4% EVM at +25dBm (+4.2V). RF gain is more than 30dB.

The AWM6422's 4.5mm x 4.5mm x 1.4mm surface-mount package includes: an integrated 25dB attenuator and output power detector; and 50Ω matched RF ports for reduced external component count.

With volume production expected by the end of Q1/2008, the AWM6422 has already been integrated into USB adaptors manufactured for a major Korean telecom company, Anadigics says.

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

## IN BRIEF

### Berkeley's Analog FastSPICE used for multi-mode 3G transceiver simulation

Berkeley Design Automation Inc of Santa Clara, CA, USA, which provides precision circuit analysis technology for analog and RF ICs, says that Skyworks has chosen its Analog FastSPICE circuit simulator for full-circuit functional simulation and complex-block characterization of its multi-mode multi-band analog and RF transceivers.

"Verifying our high-performance analog/RF designs for mobile connectivity requires transistor-level simulation of very complex circuits with true SPICE accuracy," said Kenneth Weller, Skyworks' director of design automation. "Analog FastSPICE provides a 5-7x turnaround time advantage, and a 10x capacity advantage over traditional SPICE, with true SPICE accuracy," he reckons.

Berkeley's tools include Analog FastSPICE circuit simulation, RF FastSPICE periodic analyzer, and PLL noise analyzer. The firm guarantees identical waveforms to the leading 'golden' SPICE simulators down to noise floor (typically 0.1% or less) while delivering 5x-10x higher performance and 5x-10x higher capacity. It achieves this by using advanced algorithms and numerical analysis techniques to rapidly solve the full-circuit matrix and the original device equations without any shortcuts that could compromise accuracy.

"Full-circuit functional simulation and complex-block characterization are key requirements for verification of multi-mode, multi-band radios," adds Berkeley's president and CEO Ravi Subramanian.

[www.berkeley-da.com](http://www.berkeley-da.com)

# First front-end module for 3.9G

At the 2008 GSMA Mobile World Congress in Barcelona, Spain (11-14 February), Skyworks Solutions Inc of Woburn, MA, USA demonstrated what it claims is the industry's first front-end module (FEM) for 3.9G wireless applications. The SKY77445 FEM is designed for long-term evolution (LTE) and evolved universal mobile telecommunication systems (UMTS) terrestrial radio access network (EUTRAN) applications. Samples are available, with volume production scheduled to begin in first-quarter 2009.

"Skyworks' new wireless solution provides outstanding linear power performance and a high level of integration in a very compact size," claims Dr Gene A Tkachenko, senior director of engineering responsible for LTE development. With ease-of-use and low-current dissipation, the 3.9G FEM still provides an attractive cost for handsets and

mobile connectivity, he adds. The new solution uses technology including bulk acoustic wave (BAW) filters, HBTs and advanced packaging, all developed internally and optimally integrated in the new module, Tkachenko says.

The SKY77445 Band VII (2.6GHz) LTE FEM is a fully matched, 16-pin surface-mount module that integrates the power amplifier (PA), inter-stage filter, input and output matching, power detection, and duplexer in a single 4mm x 7mm x 1.1mm package.

It also provides good TX attenuation in the RX band, and operates at a low voltage of 3.3V with high linearity and efficiency, the firm claims. In addition, the FEM meets stringent adjacent channel power ratio (ACPR) and error vector magnitude (EVM) requirements, as demanded by the LTE/EUTRAN standards.

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

## High-efficiency linear power amplifiers for WCDMA handsets

Building on its shipment of more than 50 million WCDMA PAs (up to last December), Skyworks is sampling the new SKY77185 high-efficiency linear power amplifier (PA) for WCDMA handsets. Designed to address the European market for the UMTS radio access network, volume production of the new PA is due to begin in July.

The SKY77185 3mm x 3mm x 1mm band 1 PA with integrated coupler is a fully matched, 10-pad surface mount module, offering full coverage of the 1920-1980MHz bandwidth. The single GaAs MMIC contains all active circuitry in the module. It also contains on-board bias circuitry, as well as input and interstage matching circuits. The SKY77185 is manu-

factured using Skyworks' InGaP GaAs HBT BiFET process, which provides for all positive voltage DC supply operation. Digital bias control can be used to optimize efficiency at high, mid and low power.

Including the integrated coupler for power control (typically a discrete component on the reference design) drastically reduced bill-of-materials, says Skyworks. Also, the PA produces high power added efficiency (PAE) at mid power, which significantly increases talk time.

"Our high level of integration significantly reduces part size and bill-of-materials, while at the same time improving battery life," says Skyworks' director of marketing Thomas J. Richter.

## Skyworks' power amplifiers gaining traction with LG

Skyworks says that it is gaining traction at LG Electronics due to strong demand for its front-end solutions for several recent models:

- The LG-KF700, supported by the SKY77329 power amplifier (PA), is the world's first multimedia phone that combines three input methods: a three-inch touchscreen display; slide-out alpha-numeric keypad, and shortcut dial at the back.
- Powered by the SKY77340 PA, the LG-KF600 is a slider phone.
- Also supported by the SKY77340 PA is the LG-KF510 (a 10.9 mm thick tri-band slider phone).
- Equipped with the SKY77519 FEM, the LG-KT610 offers multimedia features and applications based on Symbian OS, HSDPA connectivity at 3.6Mb/s, GPS navigation, and a PC-like QWERTY keypad with push-email functionality.

"We expect LG to be a catalyst for accelerating growth for Skyworks throughout 2008," said Liam K. Griffin, senior VP sales & marketing. "We believe our highly integrated GSM and EDGE front-end modules complemented by our WCDMA solutions are well aligned to meet LG's increasing 3G needs... Our success at LG and at others



LG's latest generation of multimedia handsets, powered by Skyworks' SKY77329, SKY77340 and SKY77519 power amplifiers.

reflects our unique ability to provide customized architectures which incorporate all critical WCDMA bands working in concert with our selection of 2.5G or 2G FEMs. As the market transitions to multi-mode and multi-band 3G implementations, Skyworks is well positioned to lead in both performance and integration," he reckons.

- Skyworks has won LG's 2007 Best Supplier Award, based on its technology, quality, product reliability and on-time delivery. It was also graded Class A for its work with LG in 2007. LG uses Skyworks' front-ends for handsets spanning all key air interfaces, including CDMA, GSM and EDGE and WCDMA for 3G multimode applications.

## Skyworks ramps low-power RF solutions for ISM bands

Skyworks has announced key design wins and production ramps for its growing line of power amplifiers (PAs), synthesizers, switches, and silicon voltage controlled oscillators (VCOs) which, the firm claims, enhance the performance of analog solutions available on the market.

Skyworks says its design wins in the industrial, scientific and medical (ISM) bands are supporting applications including professional special mobile radio (SMR), radio frequency identification (RFID), automatic meter reading (AMR), and industrial control.

According to The Scott Report on AMR Deployments, only 34% of the

300 million existing electric, gas and water meters in North America employ a wireless application, which helps utility companies to reduce meter-reading costs and to increase revenue, load balance, and improve customer service significantly. Outside North America, just 6% of the 2.5 billion meters use automatic meter reading solutions. As a result, there is pent-up demand for an economical RF

**Outside North America, just 6% of the 2.5 billion meters use automatic meter reading solutions**

solution to more efficiently collect, report and monitor utility usage by both service providers and consumers, says Skyworks.

"Our Linear Products business continues to address new markets by providing highly integrated and innovative semiconductor solutions to solve real-world problems," said Stan Swearingen Jr, VP and general manager of Linear Products. "With our comprehensive RF solution set, Skyworks is setting the bar for performance and footprint, while at the same time reducing the need for extra components," he claims.

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

## TriQuint halves size of quad-band EDGE PA modules

At February's GSMA Mobile World Congress in Barcelona, Spain, TriQuint launched the first two members of its Hadron II power amplifier (PA) module family; the TQM7M5012 and TQM7M5005.

The second-generation EDGE PAs were designed using TriQuint's CuFlip copper bump technology, improving RF performance while reducing current consumption to provide longer device battery life. Debuting with a 5x5mm footprint, the modules are 50% smaller than the previous generation, providing handset makers with extra board space to add other rich features.

The new products build on TriQuint's first-generation Hadron PA module family, found in mobile devices including Samsung's Black-Jack, LG's Shine and Chocolate 3G, Palm's Treo and HTC's Advantage. TriQuint says its EDGE PA module shipments for 3G phones grew 178% in 2007 as it gained market share, and as WCDMA networks

grew to provide 70% of the world's commercially launched 3G services, according to a January update from the Global mobile Suppliers Association (GSA) which stated that most WCDMA-HSPA networks combine with EDGE for service continuity.

"With WiFi and Bluetooth connectivity, FM radios, MP3 players, cameras, and other rich features appearing in more and more 3G phones, design time increases and board space is at a premium," says Tim Dunn, VP for Handsets. "Our CuFlip copper bump technology enables us to shrink the module footprint to 5mm x 5mm while extracting heat from the PA more efficiently and reducing current. The result is improvement in size, performance, cost, and reliability."

Available in EDGE-Polar and EDGE-Linear versions, both products are optimized for best-in-class current consumption in the critical GMSK mode, which significantly improves handset battery life.

The TQM7M5012 for EDGE-Polar is aligned with Qualcomm's newest 3G multimode transceivers.

Compared to the previous generation, it offers lower Rx band noise power level to help eliminate external components in the radio. The TQM7M5005 is designed to work with some of the world's leading 2.5G and 3G transceivers that require a linear power amplifier. TriQuint has developed RF radio application and evaluation boards for both modules, enabling handset development time to be shortened.

"Our silicon partner cooperation enables seamless alignment of the Hadron II PA module family with the transceiver chips, offering a streamlined process for radio design and assembly," says Paul Cooper, strategic marketing manager for Handsets.

TriQuint is sampling the TQM7M5005 and the TQM7M5012 to lead customers, and production is planned for first-half 2008.

## Front-end modules for GSM and CDMA in emerging markets

TriQuint Semiconductor has launched its latest generation of highly integrated front-end module solutions for ultra-low-cost GSM and CDMA handsets in emerging markets.

According to Strategy Analytics, at the end of 2007 there were 3.18bn mobile subscribers worldwide, and by 2010 there will be 4.1bn. The next billion will be drawn from emerging markets, representing an opportunity for significant growth.

The launch includes the TQM6M4028U dual-band GSM Tx module for use in the Americas and the TQM613027 high-efficiency PA-duplexer module for CDMA cellular-band applications (currently shipping in volume for phones in the Americas market, and displayed at February's GSMA Mobile World Congress in Barcelona, Spain).

Using its in-house technology portfolio, the highly integrated modules offer a reduced bill-of-materials, smaller size, longer battery life and

proven interoperability with leading single-chip silicon radios, TriQuint says.

The TQM6M4028U, a member of the Quantum Tx module family, is tested and pre-qualified for use with three leading single-chip base-band/transceiver manufacturers, TriQuint says. At 6mm x 6mm, it has the world's smallest form factor, claims the firm, and is modeled after the TQM6M4028E, which also supports the GSM900 and DCS1800 bands and is used in ultra-low-cost handsets in Europe and Asia.

TriQuint says it has seen tremendous growth in the ultra-low-cost GSM handset market, with shipments of its dual-band Tx modules more than tripling from 2006 to 2007.

The TQM613027 is the third member of the 7mm x 4mm Tritium II PA-duplexer module family and builds on its predecessor, the TQM613025, which was the first high-efficiency PA-duplexer module used in low-cost CDMA cellular-band

handsets for emerging markets, TriQuint claims, offering improved RF performance and minimizing battery consumption (a critical need in countries where access to power outlets is limited). The TQM613027 is a drop-in replacement that has been optimized for manufacturing cost efficiencies.

"Early-on, TriQuint recognized the many benefits of using front-end modules instead of a myriad of discrete RF components," says Tim Dunn, VP for Handsets.

"Our broad technology portfolio enables us to serve the handset market as it grows in multiple directions, from high-end smart phones to ultra-low-cost handsets for emerging markets. No other vendor has the breadth of in-house technology and engineering expertise to realize cost efficiencies while achieving such compact, high-performance designs," he claims.

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

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## TriQuint launches range of LDMOS RF power transistors

At the 13th annual International IC-China event (held in Chengdu, Shenzhen, Beijing and Shanghai), TriQuint launched its portfolio of LDMOS silicon RF power transistors, available worldwide through its Shenzhen and Shanghai offices as well as Avnet Asia Pacific.

The range includes products marketed previously by Peak Devices of Boulder, CO (acquired last August). LDMOS power transistors remain among the most popular for signal amplification in RF systems due to their high linearity, gain and efficiency, combined with cost-effectiveness based on multiple developmental generations in the commercial market, says TriQuint.

The LDMOS devices cover frequencies from 865MHz to 2.7GHz with RF output power from 30W up to 180W. The new range can be used for wireless telecom base-station and MMDS applications, offering a local source for manufacturers supporting China's continued telecoms expansion.

The LDMOS line complements TriQuint's range of GaAs transistors, amplifiers and switches as well as surface acoustic and bulk acoustic wave (SAW/BAW) filters for wireless handsets and networked RF communications applications already marketed in China. "Customers now have more choices: the cost-effective, high-performance of LDMOS as well as the advantages of highly efficient, highly linear GaAs devices that enable the RF engineer to simplify product decisions around customer needs," says Asia sales director Richard Lin.

Boosted by governmental decisions to encourage market entry by foreign vendors, China's 3G value-added services market was forecasted by iSuppli last July to grow to \$19.5bn in 2011.

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

# TriQuint buys WJ

WJ Communications Inc of San Jose, CA has agreed to be acquired by RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA for \$1 per share (totaling about \$72m).

"We have spent the last several months evaluating strategic alternatives for the company in order to maximize shareholder value and accelerate the success of our products and technologies in the global market place," says WJ's president and CEO Bruce Diamond. The agreement represents an 18% cash premium over the 7 March closing price of WJ's common stock on the Nasdaq Global Market and a 50% premium over the average closing price for the prior 30 days. "We believe the combination will drive increased scale and efficiencies that will lead to a level of success commensurate with our innovation and product leadership," he adds.

TriQuint says the acquisition will: combine its advanced technologies with WJ's design expertise; expand its presence in the wireless infrastructure market (cellular base-stations and wireless and cable broadband infrastructure); provide it with a Silicon Valley based design center; and accelerate the evolution to multi-function modules for infrastructure applications.

TriQuint adds that it has focused on applying its technical innovation and cost savings from the handset market to the evolving requirements of the communications infrastructure market. WJ likewise aims to combine RF power, switching and filtering in cost-effective module solutions for base-station and other infrastructure applications.

"We see great synergy with TriQuint in the areas of technology, customer relationships and manufacturing efficiencies," says Diamond. "There is very little product overlap and a good cultural fit between our two organizations," he adds. "We bring a broad product line of RF building blocks and modules as well as a talented Silicon Valley based design team to an established leader in the RF market space."

"WJ's solid reputation in these market areas [cellular base-stations and wireless and cable broadband infrastructure]

is a wonderful complement to TriQuint's strengths in design, manufacturing and customer support," says TriQuint's CEO Ralph Quinsey. "WJ's technical expertise combined with the financial

strength and stability of TriQuint will provide both innovative products and security of supply to the networks infrastructure customer base."

WJ's board of directors has unanimously approved the agreement and recommends that its stockholders approve and adopt it. The transaction has also been approved by TriQuint's board and is expected to close within 90 days, subject to approval by WJ's stockholders and other customary closing conditions.

Upon closing, it is expected that Diamond will continue with the organization, leading the business and assisting in integration. Excluding one-time charges, TriQuint expects the deal to be neutral to earnings during fiscal 2008 and accretive thereafter.

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

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

**"We see great synergy with TriQuint," says Diamond**

**"There is very little product overlap and a good cultural fit between our two organizations"**

**TriQuint says the acquisition will combine its advanced technologies with WJ's design expertise**

## WJ returns to quarterly revenue growth ... but gross margins dip while final test moved to Philippines

For 2007, WJ Communications Inc of San Jose, CA, USA, which designs and supplies RF products for wireless infrastructure, RFID and WiMAX markets, has reported revenue of \$43.9m (down on 2006's \$48.8m). Gross margin fell from 51.4% to 48.5%. However, operating expenses were cut from \$35.9m to \$29m (aided by completing closure of the firm's 4" GaAs wafer fab in Milpitas, CA in March 2007). This contributed to net loss being cut from \$8.4m to \$7m.

For Q4/2007, revenue was \$10.6m, above the updated \$10.2–10.5m estimate given on 8 January (which itself was up on November's guidance of \$9.3–10.3m, due to strength in the distribution side of the business). This also represents a recovery of 7.7% from Q3's \$9.8m, following a drop from \$12.7m in Q2/2007.

"Focused execution on our cost-saving initiatives throughout the past year has resulted in a much lower-cost business model that will provide substantial upside on incremental revenue improvements," says president and CEO Bruce Diamond.

In the interim, gross margin was 47.5%, down on 48.9% in Q3/2007, due mainly to the operational overlap associated with WJ's transition of its final test and support operations to the Philippines (with some doubling up of costs such as staffing). Operating expenses have been cut from \$8.2m a year ago and \$6.3m in Q3/2007 to \$5.9m in Q4.

Earnings before interest, taxes, depreciation and amortization (EBITDA) has risen from –\$939,000

a year ago to +\$366,000 in Q3/2007 and then +\$620,000 in Q4/2007. Net loss has been cut from \$2.9m a year ago and \$1.3m in Q3/2007 to \$802,000. During Q4, cash, cash equivalents and short-term investments grew from \$13.2m to \$16.7m.

"During the fourth quarter we continued to benefit from our strategic initiatives and delivered our third consecutive quarter of EBITDA positive results and improved cash by \$3.5m [up from the initial estimate of \$3.3m]," says Diamond.

"Throughout 2008, we expect to continue to execute on our strategic initiatives and further improve our cost structure," says Diamond. WJ's move of final test and support operations to the Philippines is on track for completion in Q1/2008 and should provide cost savings of \$400,000 per quarter starting in Q2. Together with the closure of the GaAs wafer fab, these two initiatives should reduce WJ's annual cost structure by \$8.8m.

Meanwhile, WJ is driving additional opportunities through the continued introduction of new products to the market, Diamond adds. During second-half 2007, WJ released 18 new products (exceeding the goal of 15), making 35 in total for full-year 2007 (compared to 21 in 2006 and only five in 2005). Diamond says that WJ will continue to make strategic investment in R&D, with a goal of introducing at least 15 new products during first-half 2008 (about 40% power amplifiers, 40% small-signal products, 20% multi-chip modules).

Looking forward, the pending TD-SCDMA roll-out in China should have a significant impact on WJ's business in 2008, Diamond reckons. In January, WJ received its first production order for a TD-SCDMA MCM chipset (delivered in March to a Chinese telecom equipment and network provider, contributing about \$0.5m in revenue). WJ has design wins with the key suppliers in the market, including for MCMs, HBT power products, and other small-signal products, which it expects to total about \$100 per base-station. Current projections account for the roll-out of 50,000 base-stations in 2008, and a program total of 110,000–140,000. Diamond believes that Chinese operators will make scheduling and volume ordering decisions in the near future.

Also in January, WJ re-engaged with a key customer that had delayed qualification of several cost-reduced parts over the last two quarters of 2007 but has now awarded WJ a substantial portion of its next procurement. Shipments are expected to begin in Q2/2008 at the rate of about \$400,000 per quarter.

For Q1/2008, WJ expects revenue to fall slightly to \$9.6–10.6m. However, this is consistent with seasonality trends as well as those currently prevalent in the global economic environment, says Diamond. Nevertheless, gross margin should rebound to 49–51%, mainly due to savings from the transition to the Philippines.

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

## WJ receives second production order for TD-SCDMA MCM chipset

In March, WJ received its second production order for a TD-SCDMA MCM chipset. Worth slightly more than \$1m, WJ expects to deliver products early in Q2/2008.

The order follows the initial production order of \$0.5m (shipped

earlier in Q1/2008 — see above). Additional deliveries are anticipated later in 2008 in support of China's rollout of TD-SCDMA (time division-synchronous code division multiple access: China's 3G mobile telecoms standard).

"This order for our TD-SCDMA multi-chip module, combined with the initial production order received in January, represents the beginning of what we believe will be a significant opportunity in 2008," says CEO Bruce Diamond.

## WJ expands family of InGaP/GaAs HBT gain block amplifiers

Responding to market needs for gain block amplifiers with high linearity and low current, WJ Communications Inc of San Jose, CA, USA has added the WJA1001 to its WJA series of +5V active-bias general-purpose gain block amplifiers.

The WJA1001 is a low-cost, cascadable, broadband gain-block amplifier, based on InGaP/GaAs HBT process technology. It has been optimized internally to offer high-linearity performance for the 1GHz cellular band frequency. The MMIC is internally matched to 50Ω, and minimizes the use of external components thus simplifying system integration: it only requires DC-blocking capacitors and a bias inductor for operation. It features high-cascadable gain with 19dB gain at 900MHz, a +20dBm 1dB compression point and a high linearity of 45dBm OIP3 at 900MHz, while drawing a low current of 100mA, with operation directly from a +5V supply voltage.

The WJA1001 is designed as a Darlington-pair amplifier configuration for diverse, general-purpose pre-driver applications within the 50–3000MHz frequency range. Available in a low-cost surface-mount SOT-89 package, the amplifier is suitable for wireless applications such as GSM, PCS, CDMA, W-CDMA, WiBro and WiMAX, repeaters, BTS transceivers, and RFID.

"Over the past year, the WJA series has given our customers a wide variety of high-performance and low-cost RF and IF amplifiers empowering engineers to meet and exceed product specifications as never before. The WJA1001 is another step in this direction," said Rufino Olay, director of worldwide marketing.

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

# Active-bypass PAs for improved low-power efficiency

At February's GSMA Mobile World Congress in Barcelona, Spain, Avago Technologies Inc of San Jose, CA, USA launched a new family of power amplifiers (PAs) based on the fifth generation of its CoolPAM technology.

The ACPM-7353 supports three power modes: high, mid and active-bypass mode, and offers what are claimed to be the lowest quiescent current levels in the industry. These features can lower the average current of CDMA transmitter usage and conserve power consumption. The power-efficient and highly integrated ACPM-7353 also supports dual-band frequencies (cellular and USPCS) and offers a simplified PA design with a single RF input port for each band.

"Continuous mobile handset usage time is heavily dependant on the power consumption of the power amplifier.

Handsets tend to transmit at lower power levels as cellular network coverage matures, so efficiency at this power level is critical to optimizing performance," says Philip Gadd, senior marketing director of Avago's

Wireless Semiconductor division. "Power amplifiers in mobile handsets do not need to operate continuously at high output power levels."

In active-bypass mode, ACPM-7353 consumes very low quiescent current levels (down to 3mA) with

10dB gain and power levels up to 11dBm output power to improve the low power efficiency of a transmitter. The unique switchless architecture of CoolPAM technology is the foundation for providing the high power efficiency in the power amplifier, resulting in an increase in battery life of up to 10% over previous generations.

"Active-bypass mode in power amplifiers provides tremendous benefit to

extending handset battery life in today's CDMA and UMTS/GSM networks," adds Gadd. "Avago's design team has successfully engineered the next generation of its CoolPAM-based power amplifiers to

enable mobile handsets that run cooler and significantly reduce the amount of required current."

Avago also introduced three more PAs with active-bypass mode: ACPM-7351 (with dual-band IMT2000 and cellular support); ACPM-7822 (J-CDMA support); and ACPM-7824 (CDMA cellular support).

The new PAs are available in two form factors:

- a compact 4mm x 5mm module for the dual-band ACPM-7353 and ACPM-7351;
- a miniaturized 4mm x 4mm module for the ACPM-7822 and ACPM-7824.

The simplified and integrated design of each new CoolPAM-based PA takes up less space than two discrete PAs combined, Avago claims.

[www.avagotech.com/mobile](http://www.avagotech.com/mobile)

**Active-bypass mode in power amplifiers provides tremendous benefit to extending handset battery life**

**Handsets tend to transmit at lower power levels as cellular network coverage matures, so efficiency at this power level is critical to optimizing performance**

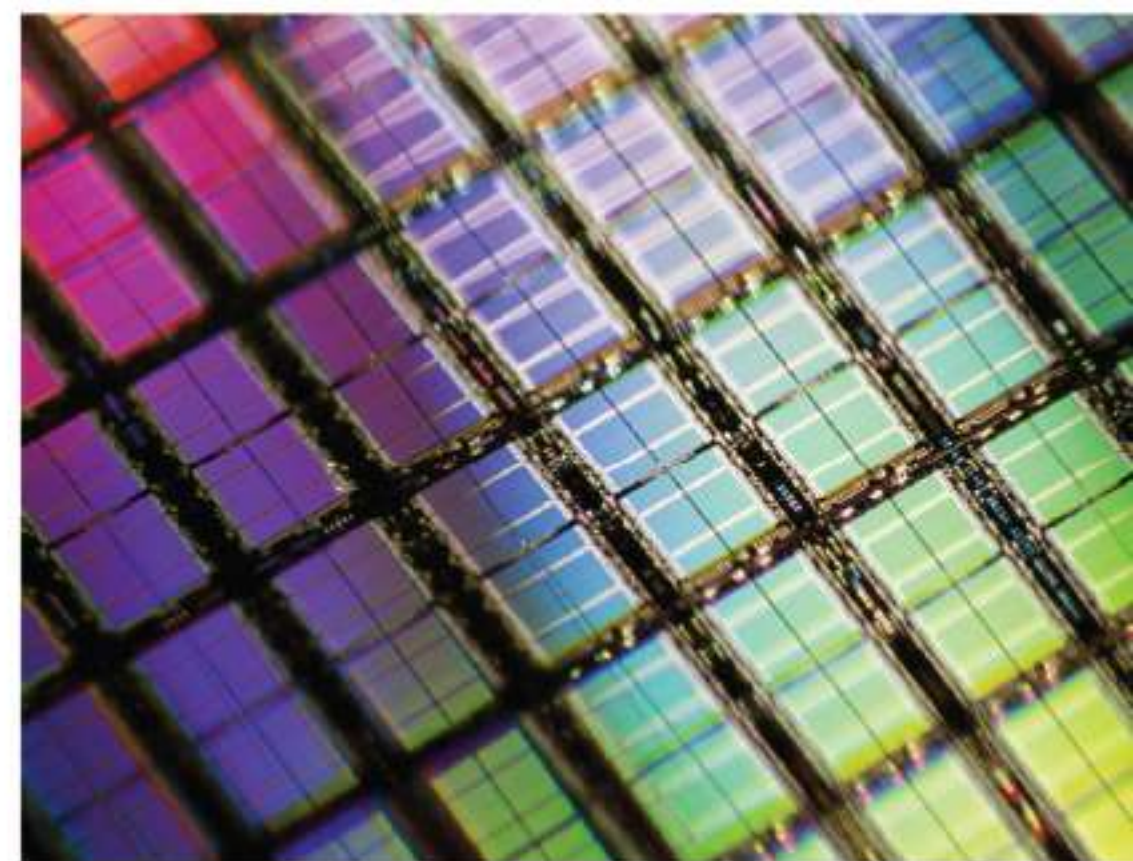


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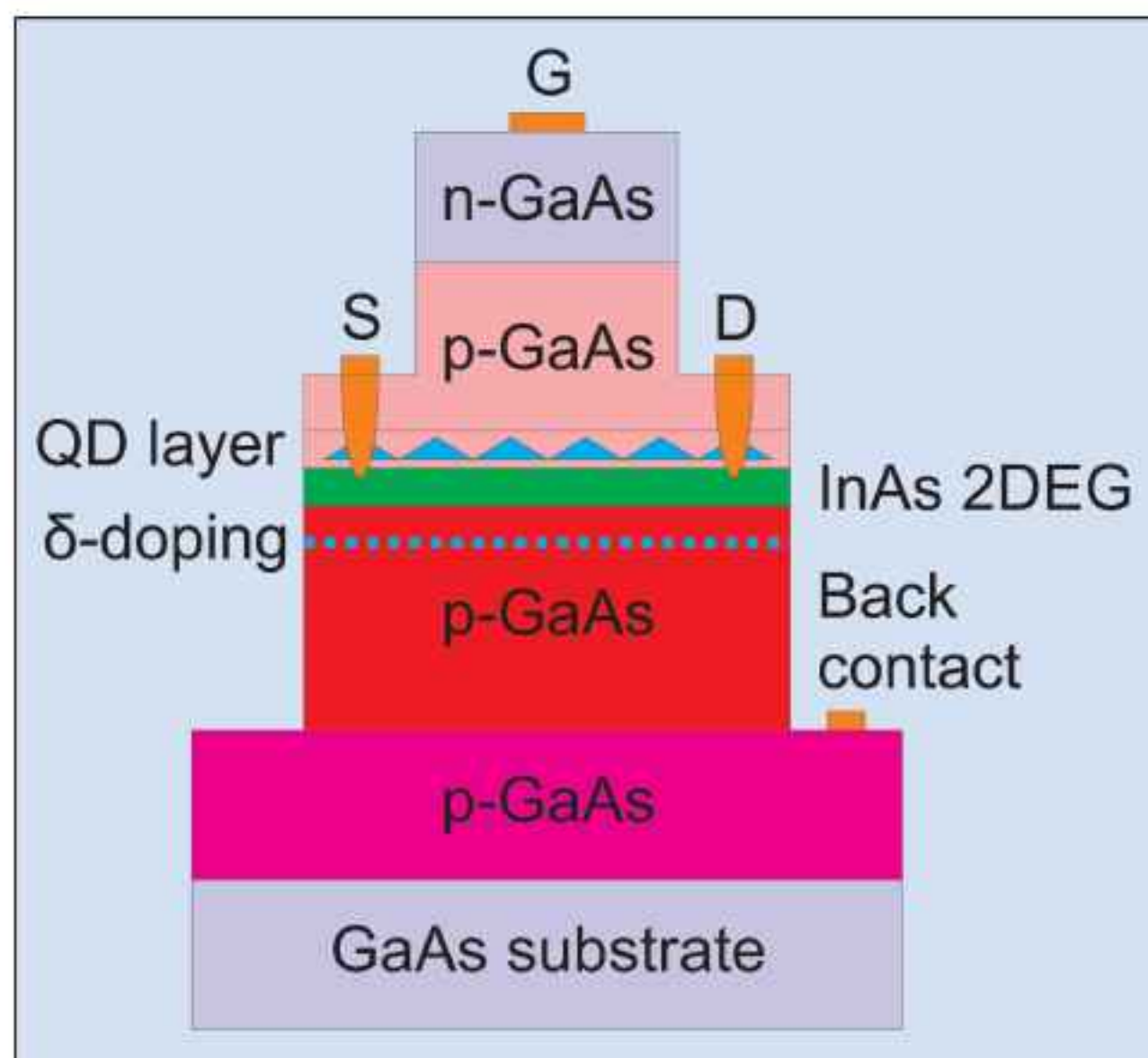
SURFACE TECHNOLOGY SYSTEMS

# Quantum dot memory fast on draw in non-volatile shoot-out

Researchers from Technische Universität Berlin in Germany and Istanbul University in Turkey have developed quantum dot (QD) memory structures with writing times of the order of 10ns (Geller et al, Appl. Phys. Lett. 92, 092108, 2008). One QD structure had a write time as low as 6ns while another arrangement was somewhat slower at 14ns. Presently the devices are limited by the experimental setup and by the parasitic RC cut-off frequencies of the devices. The researchers hope to be able to use the concept to achieve even faster write times, based on the charge carrier relaxation time being of the order of picoseconds.

These QD memory write speeds compare extremely favorably with those of Flash memories, which take of the order of tens of milliseconds. While DRAM writes in nanoseconds, it needs to be constantly reminded of the information it contains, since its retention is of the order of milliseconds. For non-volatile memory, one needs retentions of the order of 10–20 years or better to beat Flash and meet industry requirements.

The fastest memory device was constructed from indium arsenide (InAs) QDs embedded in a p-doped gallium arsenide (GaAs) layer, while the other was based on gallium antimonide (GaSb) embedded in GaAs. An n-doped GaAs layer is then deposited on top of the QDs. Changing the voltage across the device allows the dots to become charged or to be discharged, giving the different memory states. The capacitance of the device depends on the charge level on the QDs, giving the read mechanism. These mechanisms are similar to those of



**Cross-sectional structure of the quantum dot memory device.**

Flash memory, but there is hope that QD-based memory will be more robust in terms of memory retention and long-term reliability.

The quantum dot measure about 15nm across. The estimated possible storage density of such devices is about 1 TeraByte (1000GB)/inch<sup>2</sup> (~160Gbit/cm<sup>2</sup>). The International Technology Roadmap for Semiconductors (ITRS 2007) puts the expected density for this year of DRAM 'at production' at 3Gbits/cm<sup>2</sup>, while in 2015 it is expected to reach 15Gbit/cm<sup>2</sup>. Flash memory densities in 2008 are expected to be of the order of 8Gbit/cm<sup>2</sup> for single memory level cell devices and 17Gbit/cm<sup>2</sup> for two-level cells. The 2015 figures are 40Gbit/cm<sup>2</sup> and 90Gbit/cm<sup>2</sup>, respectively.

**QD memory would compete with developing ferroelectric, magnetic and phase-change memory technologies**

A commercial QD memory would compete with developing ferroelectric, magnetic and phase-change memory technologies, in addition to established Flash devices.

Phase-change memories have perhaps been the most popular alternative to develop in recent years, with possible commercial devices expected soon. They use similar technology to that used in rewritable optical disks (CD, DVD), but using electrical rather than optical writing and reading mechanisms. Its write speed (the time needed to create the phase-change) is around 10ns.

This February, Intel and STMicroelectronics announced that they were sampling prototype 128Mbit phase-change memory devices produced on a 90nm silicon process. These companies expect a rapid scaling to be possible to higher densities compared with traditional Flash devices, which are due to run into some physical limitations to further progress in the next few years. Phase-change memory cell sizes are presently given in the ITRS as 13,000 or 50,000nm<sup>2</sup>, depending on structure, translating to densities of the order 7Gbit/cm<sup>2</sup> or 2Gbit/cm<sup>2</sup>, respectively. By 2015, densities could reach 200Gbit/cm<sup>2</sup>.

Apart from the development competition, there is also the struggle to create a commercial product from a laboratory proof-of-concept. To fend off the alternatives, this needs financial resources, development of a low-cost, high-yield, extendible, manufacturable process, industry partners and luck.

Author: Mike Cooke

<http://link.aip.org/link/?APPLAB/92/092108/1>

<http://sol.physik.tu-berlin.de>

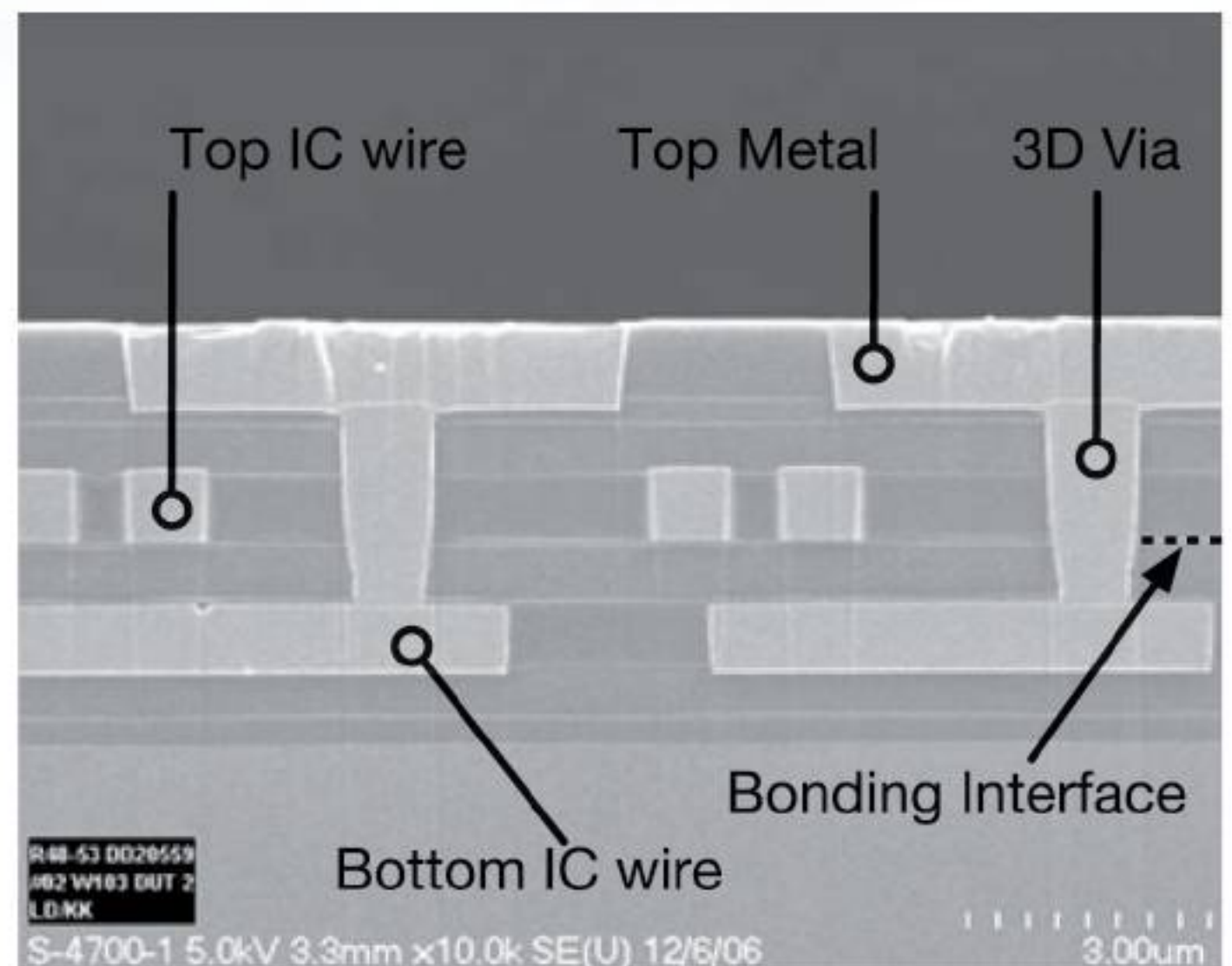
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## First 77GHz CMOS power amplifier

At the International Solid-State Circuits Conference (ISSCC) 2008 in San Francisco, CA, USA in February, Fujitsu Laboratories Ltd of Tokyo, Japan presented what it claimed is the world's first CMOS-based power amplifier (PA) that operates at 77GHz (also see page 80 of the feature article on CMOS in this issue).

The millimeter-wave PA uses standard 90nm CMOS process technology, with standard CMOS modeling technology and design techniques developed to minimize high-frequency signal loss. The technology enables the realization of CMOS RF front-end circuitry that includes a PA, allowing integration with base-band circuitry on a single chip.

Such millimeter-wave circuitry is suited to measuring the distance between two points with high resolution and accuracy (e.g. for automotive radar systems) and is being used for high-capacity data transmission in wireless systems.

For CMOS technology, which allows high levels of integration and functionality, ongoing miniaturization has enabled silicon-based millimeter-wave circuits with operating speeds comparable to circuitry based on compound semiconductors, claims Fujitsu.

Fujitsu has demonstrated the first PA operating at 77GHz to achieve 8.5dB gain and 6.3dBm saturated output power.

Also, a separate PA operating at 60GHz has been developed that achieved gain of 8.3dB and saturated output power of 10.6dBm.

Fujitsu Labs now plans to use standard CMOS technologies to further develop amplifier circuits with higher output power, as well as integrated RF front-end circuits.

<http://jp.fujitsu.com/labs/en>

## EU's DOTFIVE project to boost SiGe HBTs from 300GHz to 0.5THz

The kick-off meeting of the three-year project DOTFIVE ('Towards 0.5 TeraHertz Silicon/Germanium Heterojunction Bipolar technology') has been held by a 15-partner, five-country European consortium led by STMicroelectronics.

The €14.75m project includes funding of €9.7m from the European Commission, making it the largest 'More than Moore' nanoelectronics project under the European Union's Framework Programme 7.

By developing silicon-based HBTs with a maximum operating frequency of 0.5THz, the DOTFIVE consortium aims to establish a leadership position for Europe's semiconductor industry in the area of SiGe HBTs for millimeter-wave applications (where firms like STMicroelectronics and Infineon Technologies are already strong contributors), as well as for future terahertz communications, radar, imaging and sensing applications.

"With this ambitious project, Europe is getting ahead of the RF roadmap defined in ITRS [the International Technology Roadmap for Semiconductors], strengthening its position in an area where the whole ecosystem is already strong," says project coordinator Gilles Thomas, STMicroelectronics R&D cooperative programs manager.

Emerging high-volume millimeter-wave applications encompass, for example, 77GHz automotive radar applications and 60GHz wireless local-area network (WLAN) communication systems. According to market research firm Strategy Analysts, the market for long-range anti-collision warning systems in cars could grow by more than 65% annually until 2011. In addition to these already evolving markets, DOTFIVE aims to be a key technology enabler for silicon-based millimeter-wave circuits penetrating the terahertz gap, enabling enhanced imaging systems with applications in the security, medical and scientific area.

Currently, SiGe HBTs achieve a maximum operating frequency of about 300GHz at room temperature. DOTFIVE has set its goal at 500GHz, conventionally thought possible only by using III-V technologies, it is said. A higher operating speed can either open up new application areas at very high frequencies, be traded for lower power dissipation, or help to reduce the impact of process, voltage and temperature variations at lower frequencies for better circuit reliability. Compared to III-V devices, SiGe HBTs enable high-density and low-cost integration for high-frequency low-power applications, making them suitable for consumer applications.

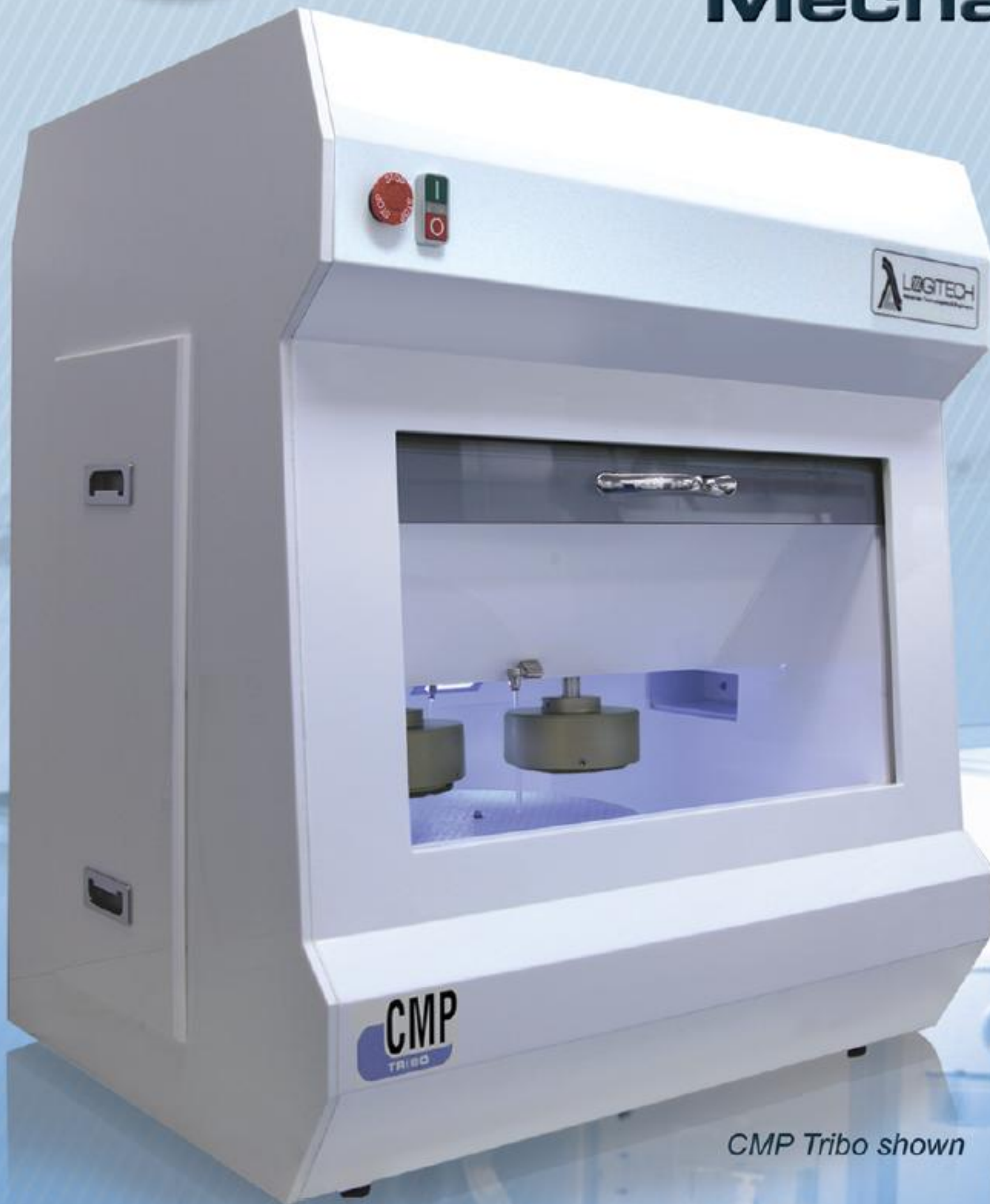
To achieve their goals, DOTFIVE partners will team on R&D of silicon-based transistor architectures, device modeling, and circuit design. The project's 15 partners (from industry and academia) include:

- Infineon Technologies (Germany) and STMicroelectronics (France), which can produce 250GHz HBTs on silicon and are willing to push up to 500GHz by working on structural and technological improvements;
- IMEC (Belgium) and IHP (Germany), research institutes working on innovative HBT concepts, new process modules and transistor structures on silicon wafers;
- XMOD Technologies (France) and GWT-TUD (Germany), which are capable of providing the necessary parameter extraction and RF device modeling expertise; and
- seven academic partners — the Johannes Kepler University of Linz (Austria), ENSEIRB, Paris-Sud University (France), Technical University of Dresden, Bundeswehr University in Munich, the University of Siegen (Germany), and the University of Naples (Italy) — with knowledge of nano-transistors, simulation, modeling and characterization of devices, and design of RF functional blocks. ALMA (France) is in charge of administration and finances.

[www.dotfive.eu](http://www.dotfive.eu)



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# EC project investigating non-Si channels for post-22nm CMOS

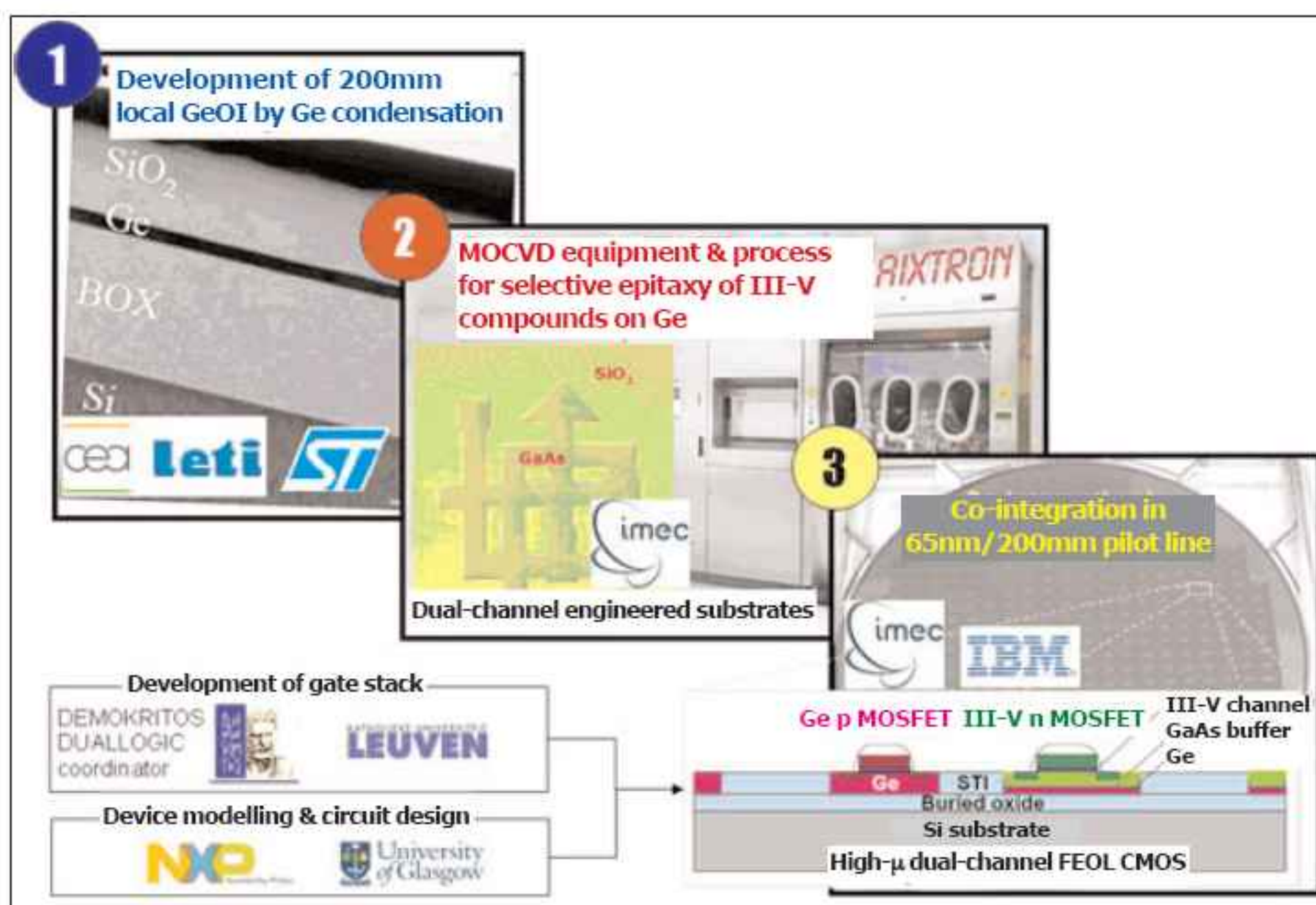
Co-funded by a grant of €5.8m from the European Commission as the 'flagship' for CMOS R&D in its 7th Framework program (FP7) in Information and Communication Technologies, the €9.1m, 36 month project 'Dual channel CMOS for (sub)-22nm high performance logic' (DUALLOGIC) was launched in December by a consortium of: the National Center for Scientific Research (NCSR) Demokritos in Athens, Greece; research institute IMEC and Katholieke Universiteit Leuven in Belgium; IBM-Zurich in Switzerland; CEA-LETI and chip maker ST Microelectronics-Crolles in France; chip maker NXP Semiconductors of The Netherlands; epitaxial deposition reactor maker Aixtron of Germany; and the University of Glasgow, UK.

Led by Dr Athanasios Dimoulas of NCSR Demokritos, the DUALLOGIC project aims to shape CMOS generations beyond 22nm with innovations in nano-electronic materials, equipment, processing and device integration on silicon.

Late 2007 was marked by what was described by Intel's Gordon Moore as the "biggest change in transistor technology in 40 years": the replacement of the polySi/SiO<sub>2</sub> gate stack by a metal/high-k dielectric combination in the 45nm generation of CMOS (now in production).

To break the performance barrier beyond the 22nm node, the next element of the MOS transistor to be replaced may be the active channel.

Replacing silicon in the channel by germanium (in which charge carriers have higher mobility) can enhance transistor performance. But, after five years of research, Ge has been found to outperform Si only for the p-type doped pMOS transistor (not the n-type doped nMOS transistor). So, CMOS technology made entirely of Ge-channel MOS transistors does not seem to be feasible at present.



Backbone of the DUALLOGIC project's collaborative network.

In contrast, III-V materials such as GaAs and InGaAs are effective for nMOS but seem unsuitable for pMOS.

So, DUALLOGIC's objectives are to:

- demonstrate the co-integration of functional high-mobility Ge pMOS and III-V nMOS side-by-side on the same complex engineered substrate on silicon by using a silicon-compatible process in a 65nm/200mm pilot line, showing for the first time that dual-channel front-end-of-line (FEOL) CMOS is scalable and manufacturable;

- investigate short-channel, leakage and transport effects and fundamental materials problems in aggressively scaled high-channel-mobility devices;

- prepare the take-up of project results by the end of 2009 in a broader 22nm or sub-22nm platform by integrating dual-channel FEOL technology with back-end and device architecture modules that could be implemented within a future, larger FP7 R&D project.

Development work includes a full set of FEOL modules: 200mm local

germanium-on-insulator (GeOI) by Ge condensation (CEA-LETI and ST); MOCVD equipment and processes for selective epitaxy of III-Vs on Ge (Aixtron); dual-channel engineered substrates (IMEC); co-integration of short-channel functional transistors using a 65nm/200mm pilot line (IMEC and IBM); gate stacks (NCSR-Demokritos and KU Leuven); and device modelling and circuit design (NXP and Glasgow University).

Besides high mobility, the channel materials being investigated have other properties that make them attractive beyond device scaling for logic, e.g. applications where lower supply voltages are needed to combine low power with high performance. DUALLOGIC could hence create a generic material and technology platform allowing significant diversification in on-chip functionality. It could also be a catalyst for the convergence of 2020 nanoelectronic technologies, as foreseen in the research agenda of Europe's ENIAC technology platform.

[www.ims.demokritos.gr/DUALLOGIC](http://www.ims.demokritos.gr/DUALLOGIC)



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# National Academy Of Engineering elects new members

In January, the US National Academy of Engineering (NAE) elected 65 new US members and nine foreign associates for 2008 (to be formally inducted in October), bringing total US membership to 2227 and the number of foreign associates to 194.

Alexis C. Livanos, president of Northrop Grumman's Space Technology sector (NGST), was elected for "contributions to the development and insertion of advanced semiconductor technology for commercial and government space systems".

Livanos joins 12 current or former Northrop Grumman executives who are NAE members, including Tom Romesser, VP and general manager of the Technology and Emerging Systems Division, and Dwight Streit, VP of Microelectronics Technology and Technical Development, both of NGST.

At NGST, Livanos is responsible for sector operations, where a broad range of space, defense and electronics systems are developed. Previously, Livanos was sector VP and general manager for two divisions, Systems Development & Technology and Space Sensors, within the firm's Electronic Systems sector. He was also deputy general manager for the former TRW Electronic Systems and Technology Division and later executive VP of operations for Space Systems/Loral.

Livanos has more than 30 years' experience in research and applications in microelectronics, solid-state physics, electro-optics and signal processing. He introduced III-V semiconductors to space, including GaAs MESFETs, HEMTs, and HBTs, for national security spacecraft systems. He has also led research programs in GaAs and InP devices, fiber-optics and electro-optic subsystems.

Livanos is a member of the National Board of Directors, National Defense Industries Association; chair of the Intelligence Committee within the C4ISR Division, National Defense Industries Association; serves on the Space Foundation



**NGST's Livanos.**

At the California Institute of Technology, Livanos is a member of the Visiting Committee for the Division of Engineering and Applied Science. In 2008, Caltech is also honoring Livanos with the International von Karman Wings Award and the Distinguished Alumni Award.

Also elected as NAE members were three faculty members of the UCLA Henry Samueli School of Engineering and Applied Science, including professor of electrical engineering M.C. Frank Chang. UCLA Engineering now has 22 affiliated faculty members in the NAE.

UCLA says that Chang, who directs its high-speed electronics laboratory, made seminal contributions to the discovery, development and commercialization of III-V-based HBTs and FETs for RF wireless communications, including work in realizing mass-produced GaAs HBT ICs and power amplifiers. "I had the opportunity to participate in its development phase with a group of distinguished researchers and to carry this through all the way to its production and commercialization," Chang says.

While at Rockwell, Chang led the transfer of HBT technology from the science center to the product division and oversaw efforts to establish a worldwide commercial supply of low-cost MOCVD HBT epi materials with high reliability. He has also made several pioneering contributions to high-speed IC development.

In the early 1990s, Chang's team mass-produced GaAs HBT power amplifiers, enabling the deployment of the first commercial CDMA handsets (in Hong Kong and South Korea).

board of directors; and is a member of the Institute of Electrical and Electronics Engineers (IEEE), and a senior member of the American Institute of Aeronautics and Astronautics.

Chang received a bachelor's degree in physics from National Taiwan University, a master's in materials science from National Tsing Hua University and a doctorate in electrical engineering from National Chiao-Tung University, Taiwan. He joined the UCLA materials science and engineering department in 1979 as a postdoctoral fellow under professor Alfred S. Yue. In 1997, following a career in industry, he returned to UCLA Engineering.

Another new NAE member is Pallab K. Bhattacharya, the Charles M. Vest Distinguished University Professor of Electrical Engineering and Computer Science and the James R. Mellor Professor of Engineering at the University of Michigan, Ann Arbor, who is recognized for contributions to quantum dot optoelectronic devices (including lasers and detectors) and integrated optoelectronics, including demonstrating conditions under which quantum dots form.

He joins 22 other University of Michigan College of Engineering professors as NAE members.

Also elected as a foreign associate is professor Isamu Akasaki of Meijo University in Nagoya, Japan, for "contributions to the development of nitride-based semiconductor materials and optoelectronic devices".

He has conducted research on blue LEDs since the late 1960s, including at Matsushita and, from 1981, at Nagoya University where, in 1985, his group grew high-quality single-crystal GaN on sapphire substrate using low-temperature buffer layer technology (enabling p-type GaN doping with magnesium by MOVPE, the control of n-type conductivity by silicon doping, and the realization of p-n junction blue LEDs in 1989).

His group also achieved stimulated emission in the UV with optical excitation from GaN at room-temperature in 1990 and stimulated emission by current injection from a nitride-based quantum-well diode at room temperature in 1995.

[www.nae.edu](http://www.nae.edu)

## MIT's Palacios awarded Deshpande Innovation Grant

In its spring 2008 round of research grants, the Deshpande Center for Technological Innovation at Massachusetts Institute of Technology has awarded a total of \$500,000 to seven MIT research teams working on early-stage discoveries.

Each spring and fall, the Deshpande Center awards \$50,000 Ignition Grants, which fund proof-of-concept explorations, and \$50,000–250,000 Innovation Grants to help recipients assess and reduce the technical and market risks associated with their innovations. Since 2002, it has provided about \$8.8m in such grants to 75 MIT research projects, and 14 start-ups have spun out of the center.

In a renewal of a spring 2007 Ignition Grant, recipients of spring 2008 Innovation Grants include Tomás Palacios, assistant professor in MIT's Department of Electrical Engineering and Computer Science since September 2006 and a mem-

ber of the Microsystems Technology Laboratory, for work on a new approach to fabrication technology for GaN HEMTs

using low-cost silicon wafers (rather than silicon carbide). The aim is to reduce the cost and improve the performance of electronic devices (which is currently limited by the high electrical conductivity and poor thermal conductivity of silicon substrates).

Palacios has been working on wide-bandgap semiconductors for more than eight years regarding: power amplification at frequencies above 100GHz; digital electronics beyond silicon; new concepts for biosensors and devices; and high-temperature electronics, power generation and conversion.



Palacios joined the Polytechnic University of Madrid's Institute for Systems based on Optoelectronics and Microtechnology (ISOM) in Spain in 1997, where he worked as a research assistant on ultraviolet photodetectors, surface acoustic wave filters and HEMTs. In 2002, he joined professor Mishra's group at the University of California - Santa Barbara, where he developed nitride-based transistors for millimeter-wave applications, obtaining MS and PhD degrees in electrical engineering in 2004 and 2006, respectively.

Other awards received by Palacios in the last few years include the Young Researcher Award at the 6th International Conference on Nitride Semiconductors (ICNS) and the Best Student Paper Award at the 63rd IEEE Device Research Conference (DRC) in 2005.

[http://web.mit.edu/deshpandecenter/proj\\_palacios\\_renew\\_s08.htm](http://web.mit.edu/deshpandecenter/proj_palacios_renew_s08.htm)

## NGST staff receive Asian American Engineer of the Year awards

At the 2008 Asian American Engineer of the Year (AAEOY) awards in Richardson, TX, USA in late February, two employees of defense and technology company Northrop Grumman Corp received awards for their contributions to science, engineering, and their communities:

- Clayton K.S. Kau (VP and general manager of Space and Defense Products Division); and
- Aaron K. Oki (a technical fellow and deputy director of microelectronics).

Both work in Northrop Grumman's Space Technology sector in Redondo Beach, CA.

"Both have made major contributions to the company's stature as a technology and industry leader," said Alexis C. Livanos, corporate VP & president of Northrop Grumman's Space Technology sector (NGST).

Oki leads a 300-member team in the development and production of compound semiconductor tech-



Oki (left) and Kau (right).

nologies. He was named a fellow by the IEEE Board of Directors for his work on compound semiconductor technologies and has also been recognized by the firm's chairman's/president's Award for Innovation in GaAs and InP HBT technologies.

Oki earned a bachelor's degree in electrical engineering from University of Hawaii and a master's degree in electrical engineering from University of California, Berkeley.

Kau is responsible for all NGST's design and manufacturing activities and processes as well as all micro-

electronics process development and fabrication. Previously, he was the VP and program manager of the Advanced Extremely High Frequency (EHF) program (the USA's next-generation, military strategic and tactical relay system, which aims to deliver survivable protected communications to US forces and selected allies worldwide).

Kau earned a bachelor's degree in electrical engineering from the University of Pennsylvania, and a master's degree in electrical engineering and his engineer's degree from the Massachusetts Institute of Technology.

AAEOY awards are presented by the Chinese Institute of Engineers-USA to Asian American professionals in academia, public service and corporate entities for their personal achievements and significant contributions to their associated institution, communities and nation.

[www.st.northropgrumman.com](http://www.st.northropgrumman.com)

# Fujitsu launches GaN-based mobile WiMAX base-stations

At February's GSMA Mobile World Congress 2008 in Barcelona, Spain, Fujitsu Microelectronics Europe launched Tokyo-based Fujitsu Ltd's new BroadOne WX series of base-stations for the IEEE802.16e-2005-compliant mobile WiMAX wireless standard.

The WX series is the first part of Fujitsu's new BroadOne brand, which covers an integrated series of forthcoming base-stations and other products for long-term evolution (LTE), in which next-generation mobile phone systems will be developed for the rapidly emerging wireless broadband market.

The WX series base-stations consume low levels of power, deliver superior performance and, as the smallest base-stations available, are easy to install, claims Fujitsu.

Fujitsu plans to provide three new base-station models, designed for the 2.3 and 2.5GHz frequency bands, providing mobile broadband solutions for all types of environments and needs. The WX300 outdoor macro-cell base-station will be the first model in the series on sale, with global delivery in second-quarter 2008. Configured as a single, light-weight unit, it is designed for wide-area transmission over a radius of several kilometers. The second model, a compact outdoor microcell



**BroadOne WX series base-station.**

base-station, is designed for transmission over a several-hundred-meter radius to fill in areas with a lower concentration of users and remote areas with poor coverage. The third model is an ultra-compact picocell base-station for indoor networks.

The WX300's high-output transmitter uses a gallium nitride HEMT. This device is coupled with Fujitsu's digital pre-distortion (DPD) technology (which adds an input signal with the opposite characteristics to the distortion generated in an amplifier — correcting distortion in advance — and has a proven track record in 3G systems). This creates two high-output (10W) transceivers

(2 x 2 MIMO compliant) packaged in a single unit. Bandwidth is 5, 10 or 20MHz (2 x 5MHz, 2 x 10MHz).

As well as being light (about 20kg) and energy-efficient (with power consumption of 200W or less), the firm claims that the WX300 is the world's smallest all-in-one outdoor macrocell base-station (with a volume of 20 liters, incorporating the wireless transceiver, wireless signal processor, media converter, GPS receiver, and power supply in a single enclosure).

By combining high energy efficiency with a small enclosure, Fujitsu reckons it significantly reduces the cost associated with installing and operating mobile WiMAX base-stations, contributing to the global deployment of mobile WiMAX infrastructure and enabling service providers to offer end-users service at more viable rates, says the firm.

Fujitsu has also agreed a four-year alliance with Airspan Networks Inc of Boca Raton, FL, USA, which makes radio access equipment, to share technology and resell each others' products, enabling the firms to offer a complete product line to WiMAX providers. Airspan will sell the WX300 under the name MacroMAXe.

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

## UQ chooses base-station for Japan mobile WiMAX roll-out in 2009

In early March, Fujitsu said that its BroadOne WX300 had been selected as a critical part of the development of nationwide WiMAX services infrastructure by UQ Communications Inc, a mobile WiMAX operator in Japan that is jointly owned by KDDI Corp, Intel Corp, East Japan Railway Company, Kyocera Corp, Daiwa Securities Group Inc, and the

Bank of Tokyo-Mitsubishi UFJ Ltd. UQ aims to start offering commercial WiMAX service in Japan in 2009.

**The WX300 should accelerate the spread of wireless broadband access throughout Japan, reckons Fujitsu**

Fujitsu says that it is positioning its mobile WiMAX base-station equipment as a solution for the rapidly emerging wireless broadband market as it expands the business both inside and outside of Japan.

The WX300 should accelerate the spread of wireless broadband access throughout Japan, reckons Fujitsu.

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## Digi-Key stocks Cree's SiC RF power MESFETs

Cree Inc of Durham, NC, USA says that its SiC MESFETs are now in stock and ready for shipment from electronic component distributor Digi-Key Corp of Thief River Falls, MN.

Cree's 10W CRF24010 and 60W CRF24060 are uninternally matched SiC RF transistors, capable of supporting wide operational bandwidths. The firm adds that SiC MESFETs are optimized for applications such as wideband military communications, secure homeland defense communications, Class A and A/B amplifiers, TDMA, EDGE, CDMA, W-CDMA broadband amplifiers, and WiMAX.

Also available through Digi-Key's print and online catalogs are the CRF24010-TB and CRF24060-TB Demonstration Test Fixtures.

"The power density and efficiency advantages of Cree's MESFETs will enable scores of engineers to enhance the performance of their new designs," says Digi-Key's president & chief operating officer Mark Larson.

"Cree's 48V products have proven to be extremely useful in applications requiring high power and efficiency over wide operational bandwidths, especially for those operating in high thermal environments," says Cree's director of RF and Microwave products Jim Milligan.

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

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

## INPROX to develop silicon carbide digital position sensor with NASA

INPROX Technology Corp (ITC) of Boston, MA, USA, which is a sensor technology development company providing a platform level and proprietary time-based digital sensor technology, has entered into a space act agreement (SAA) with NASA Glenn Research Center to develop SiC-based position sensors targeting potential uses in future space flight, turbine engine controls and automotive engine applications.

INPROX aims to be a key supplier of SiC-based sensor technology; position, speed and vibration sensors to the aerospace and automotive communities. Under the SAA, high-temperature SiC electronics from NASA will be prototyped into ITC's proprietary linear position sensor technology platform. If proven successful, INPROX intends to continue development for uses in the aerospace, automotive, energy and industrial markets.

"The marriage of SiC electronics, which can remain operational in high-temperature, high-power, and high-radiation environments, enabled with our proprietary digital sensor technology, is of great significance to us, our customers and the aerospace and automotive communities at large," reckons INPROX president Derek Weber.

"The capability to embed electronics in a device without the need to provide cooling provides a substantial technological advantage for many applications in sensing and control," says Phil Neudeck, electronics engineer and team leader for the SiC work sponsored by the Aeronautics Research Mission Directorate at NASA Glenn Research Center.

The rising costs of fuel, both in automotive and aerospace markets, and the drive for greater reliability at lower costs has the sensors and electronics market anticipating the capabilities of these next generation SiC electronics and sensors. Future space missions and satellites will have high-temperature and radiation-hardened requirements. The reduction or elimination of thermal management systems and extended cable runs will help to reduce weight and costs even in the more traditional commercial aviation markets.

In automotive applications, SiC integrated sensors and electronics are being studied for engine controls that display improved combustion measurement and control (capabilities leading directly to lower emissions and more fuel-efficient vehicles).

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

## SemiSouth appoints chief operating officer to aid manufacturing

SemiSouth Laboratories Inc, which makes SiC-based discrete electronic power devices and epi materials, has appointed Kenney Roberts as chief operating officer, using his 34 years of experience to lead manufacturing operations (which remain in Starkville, MS, despite the firm opening a new headquarters in Austin, TX in January).

Prior to joining SemiSouth, Roberts was founder and managing director of Eyzon Consulting and CEO of RF switching firm Teravicta Technologies. Previously, he was COO of

Layer-N Networks and Colorado Microdisplay. He was also senior VP of worldwide operations at mixed-signal analog component and embedded processor supplier Cirrus Logic, VP of operations for mixed-signal IC maker Crystal Semiconductor (acquired by Cirrus Logic), and director of engineering for microprocessor maker Advanced Micro Devices.



"Kenney brings a unique combination of startup experience and extensive manufacturing expertise," says president & CEO Vess Johnson. "Kenney will help us drive our manufacturing operations to the next level," adds co-founder and chief technical officer Dr Jeffrey B. Casady. "We have produced the world's most advanced SiC JFETs and epitaxy in our fab," he claims, "and we are working aggressively to grow the business and increase our presence in the market."

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

# SiC Systems funded for 6" production

Silicon carbide substrate maker SiC Systems Inc of Golden, CO, USA has completed its Series-A round of fundraising, following sales of its initial wafers.

Privately held early-stage development company SiC Systems was founded last year by chairman and chief technology officer Dr Joshua Robbins, VP of R&D Dr Mike Seman; and CEO Ken Whelan, and in July closed angel funding for the initial manufacturing prototype system and to initiate business development.

Talking about the latest funding, Whelan told Semiconductor Today: "We have raised sufficient capital to fund construction and operation of our initial facility and manufacturing systems." The investment will fund volume production and delivery of 150mm (6") 3C-SiC by the end of 2008.

According to the firm, its patent-pending manufacturing process, in development for nearly two years, overcomes design challenges present in current manufacturers' methods. "Our process provides superior control, as compared to traditional methods, of the numer-

ous parameters necessary to produce high-quality SiC. Additionally, the process invention scales to virtually any diameter," claims Whelan.

SiC Systems' initial product offering is 3C-SiC material, which is typically used for silicon- or SiC-based power devices, rather than optoelectronic devices based on GaN epi (for which 4H- or 6H-SiC is typically used). However, although Whelan says that 3C-SiC does have benefits for 'a myriad' of power devices, he adds that "3C is advantageous in particular for LED manufacturers".

R&D quantity samples of the wafers are now available. "We are excited about bringing silicon carbide to mainstream semiconductor manufacturers several years ahead of industry expectation," says Whelan.

The proprietary system should also allow SiC Systems to produce even larger-diameter wafers in the future, featuring none of the scaling or quality problems that plague the nascent industry currently, the firm says.

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

## IN BRIEF

### Norstel attracts €15m in financing for plant expansion

Norstel AB of Norrköping, Sweden, which span off from Finnish silicon wafer manufacturer Okmetic in February 2005, has raised €15m from a consortium including Nordic venture capital firms Northzone Ventures, Eqvitec and Creandum of Sweden together with the Sixth AP Fund (Sixth Swedish National Pension Fund) and other international investors. "We received excellent support from our current investors, but also attracted a lot of new interest," said CEO Iain Jackson.

Norstel says that the financing round is a significant event for it as the firm evolves to become a supplier of silicon carbide (SiC) substrates and epiwafers.

In particular, Norstel plans to supply wafers for use in power electronics, where devices implemented with SiC can reduce energy loss by up to 50% compared to the same device manufactured with conventional silicon technology. Jackson hailed the new investment as "a very positive reaction from the investment community for the potential of silicon carbide as an energy-saving material".

"In addition to continuing to fund our strong R&D progress, it provides us with additional needed capital to expand our capacity in our Händelo facility," said Jackson. Sited 4km from the center of Norrköping, the plant was opened in August 2006 and has floor space of 2000m<sup>2</sup>.

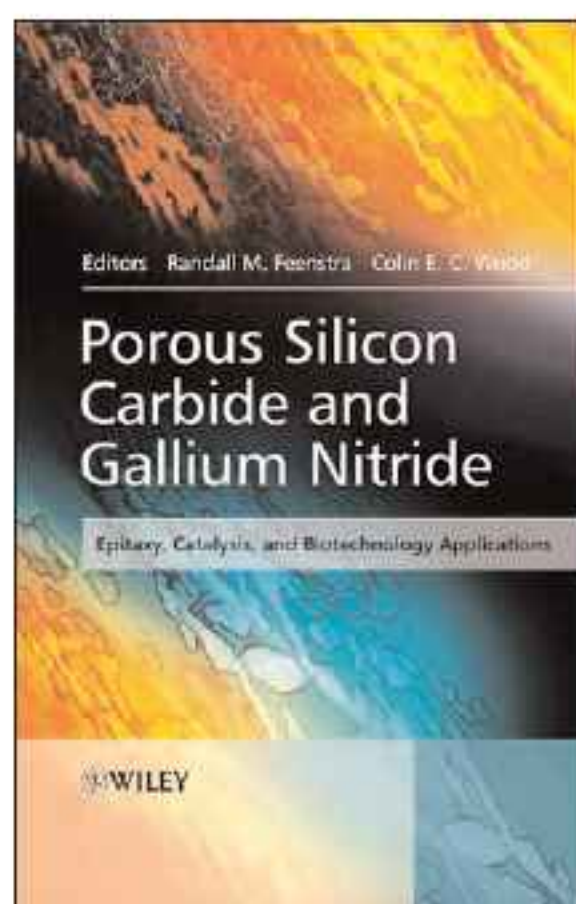
"Norstel have a pivotal role to play in the future of power electronics," added chairman Hasse Johansson. "The automotive industry is extremely receptive to energy-saving solutions for power electronics, especially in all classes of hybrid vehicles."

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

## Filling holes in the knowledge gap

The new 336-page reference book 'Porous Silicon Carbide and Gallium Nitride: Epitaxy, Catalysis, and Biotechnology Applications' by Randall M. Feenstra and Dr Colin E.C. Wood (published in March by WileyBlackwell and available for £95/€133) presents the state-of-the-art in knowledge and applications of porous semiconductor materials with a wide bandgap.

The book begins with an overview of porous wide-bandgap technology, and describes the underlying scientific basis for each application area.



Other chapters cover preparation, characterization, and topography; processing porous SiC; growth of porous SiC and GaN; and GaN growth on porous SiC.

<http://eu.wiley.com/WileyCDA>

# IQE's 54% growth in '07 drives return to operating profit

Substrate and epiwafer supplier IQE plc of Cardiff, UK has reported 2007 revenue of £50.1m, up 54% on 2006's £32.4m (or up 69% at constant exchange rates), boosted by the qualification of various customers and new tools during Q4 (leading to record monthly revenue). This is the third consecutive year of strong revenue growth (averaging about 50% annually).

The firm ascribes its growth to a continued focus on high-growth global markets, particularly high-speed wireless communications. Also, acquisitions made during 2006 (the epiwafer foundries MBE Technology Pte Ltd of Singapore and IQE RF LLC of Somerset, NJ, USA, formerly Emcore's Electronic Materials & Device division) have been integrated into the group and have contributed strongly.

Consequently, wireless revenue has almost doubled from £20.3m to £38.1m, while electronics revenue has risen from £2.1m to £2.8m and optoelectronics has fallen slightly from £10.1m to £9.2m.

Gross profit has risen 250% from £2.3m to £8.2m. Excluding exceptional items, operating results have improved from a loss of £4m to a profit of £0.6m (driven by the wireless segment improving from a loss of £166,000 to a profit of £3.6m, counteracting the loss in optoelectronics rising from £2.4m to £2.8m). The return to operating profitability demonstrates the benefits of a highly leveraged business model and improved efficiencies, IQE says.

Selling, general and administrative expenses grew by £1.4m due to the two businesses acquired in 2006. In addition, £0.44m of one-off exceptional costs arose from the relocation of the Singapore operation to a new facility providing considerable room for expansion (to be completed during 2008).

Capital expenditure grew from £1.4m to £7.8m, including £2.7m to buy property and £3.6m to invest in extra capacity to address growing demand at certain clients (funded by £5.5m of loans). Investment in development expenditure also grew from £0.2m to £1.4m. Net debt is up from £5.9m to £14.2m.

"Now that we are generating profits and cash from operations we have also put in place significantly enhanced banking facilities to support our continued growth," says chief executive Dr Drew Nelson. Soon after year end, IQE appointed Lloyds TSB Corporate Markets as its principal banker and agreed new, increased banking facilities of up to £15.5m for financing growth and working capital. "In the current economic climate, this new facility signals a resounding vote of confidence in IQE's strategy, its business model and management team," he claims.

IQE says that market conditions continue to show robust demand for GaAs-based products, driven mainly by 3G and other high-speed wireless applications. The strong forward demand for GaAs wafers is a consequence of the rapidly increasing number of GaAs components in each high-speed mobile communication device, resulting in growth in demand for GaAs components that is significantly outstripping growth in the overall handset and wireless communication markets.

"Our major markets have continued to be driven by the increasing demand for GaAs based components for high-speed, feature-rich mobile devices that demand the high levels of performance and functionality that our products deliver," says Nelson. "Our strategy of focusing on rapidly growing technologies has given us a solid base from which we can deliver continued and sustainable growth."

"We have maintained our strong growth throughout the first quarter of 2008, and continue to see robust forward demand from our customers, particularly in the high-speed wireless communications sector," Nelson says. Q1 revenues are running 30-40% ahead of 2007.

"Whilst we remain highly focussed on the wireless mobile communications markets, there are also a number of other key high-growth and high-volume opportunities being rapidly developed across the group, he adds. IQE says it is also developing solar cell technology, highly efficient LEDs and ultra-high-speed microprocessor and memory chip materials technology. "As a result, we look forward to another year of high growth and sustained profitability," Nelson concludes.

\* Following its acquisitions in 2006, IQE says it has completed key operational initiatives to enhance productive efficiency, and leverage the inherent large manufacturing capacity in order to offer multi-site, multi-platform manufacturing solutions. These include:

- the integration of both acquisitions, with the subsidiaries contributing strongly in 2007;
- securing a new manufacturing facility in Singapore on attractive terms, with the installation of equipment and initial manufacturing already commenced;
- the alignment of key switch technologies across IQE for dual-site manufacture for several customers;
- the transfer from New Jersey to Cardiff of advanced HBT (power amplifier) technology and its subsequent product qualification;
- ramping production to satisfy rapid growth in customer demand;
- the completion of several R&D projects, leading to significant follow-on awards.

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

# IQE wins its largest GaN epiwafer order

TriQuint Semiconductor Inc of Hillsboro, OR, USA has placed the largest commercial gallium nitride (GaN) wafer order in the history of IQE plc of Cardiff, UK.

Scheduled for delivery throughout 2008, the GaN HEMT epiwafers will support both TriQuint's ongoing R&D efforts as well as its roll-out of commercial and military communications power amplifier products later this year. TriQuint's R&D manager Anthony Balistreri said that, because GaN's performance is superior to existing technologies at higher frequencies, TriQuint's initial product and process releases will target the 2–20GHz range (covering most commercial and military applications viable in today's markets).

"IQE's established track record in providing TriQuint with reliable, high-quality products was a key factor in selecting them to produce and deliver a range of advanced GaN epitaxial materials," says Balistreri. "We've developed a close working relationship with IQE throughout the development phase of our GaN program," he adds.

"This is a key order for us, particularly as our broad product portfolio, which ranges from high volume HEMTs, HBTs and BiFETs to emerging technologies such as GaN epitaxial wafers, provides our customers with a one-stop shop for all their advanced materials needs," says Alex Ceruzzi, VP and general manager at the IQE RF plant in Somerset, NJ, USA, where the wafers will be made. IQE RF is also the leading GaN HEMT foundry for Microsystems Technology (MTO) programs at the US Defense Advanced Research Projects Agency (DARPA).

The announcement was made at the GOMACTech 2008 (Government Microcircuit Applications & Critical Technology) conference in Las Vegas, NV (17–20 March), which

brings together microcircuit industry leaders engaged in development work for the US military and other government agencies. Since being awarded a multi-year GaN research development contract of more than \$30m by DARPA in 2005, TriQuint says it has made significant discoveries relating to new GaN-based amplifiers.

Specifically, in the presentation 'Gallium Nitride HEMT Development for Decade-Wide Amplifier Applications' Balistreri detailed continuing material, device, process and fabrication advances made by TriQuint and partner organizations working on Phase II of the DARPA contract.

Other presentations included:

- 'Long Term Degradation Mechanisms for AlGaIn/GaN HFETs' by Dr Michael Shur of Rensselaer Polytechnic Institute, with TriQuint co-authors J. Jimenez and Anthony Balistreri, on how modeling techniques have pointed to reasons behind GaN device defects and ways to improve designs to avoid premature failure.
- 'High Voltage GaAs pHEMT Technology Provides the Next Step in Power Evolution' by Grant Wilcox, TriQuint's military standard products manager, on the benefits of high-voltage GaAs devices that increase power density by 60–100% compared to processes typically in use today.
- 'Commercial MMIC Packaging Options for High Performance Military Products' by John M. Beal, TriQuint's Texas operations packaging manager, on trends in packaging high-performance GaAs monolithic microwave integrated circuits (MMICs) for commercial applications that can offer practical alternatives to military systems.

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

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

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

## IN BRIEF

### Kopin files delayed reports with SEC

Kopin Corp of Taunton, MA, USA, which makes HBT epiwafers and liquid-crystal CyberDisplays, has filed all its delinquent financial reports with the US Securities and Exchange Commission, including its Q3/2006 Form 10-Q, 2006 Form 10-K, and Q1, Q2 and Q3/2007 Form 10-Q reports. The filings fulfill the requirement for continued listing on the NASDAQ Stock Market.

NASDAQ had previously extended the filing deadline from 25 September to 17 December, then 11 February, and then 17 March.

The delays were due to an investigation into the firm's past stock option granting practices by a special investigative committee (appointed by Kopin's board). Last May, the committee issued preliminary findings and recommendations that financial statements for 1995 through 2006 should be restated. So, the 2006 10-K form contains restated financial statements reflecting accounting adjustments resulting from the stock option review.

For 2006, Kopin recorded \$37.5m of non-cash stock-based compensation expense and associated tax charges of \$80,000 relating to stock option grants made from 1995 through 2006. The firm also recorded previously immaterial audit differences of \$69,000 for all years through 2006.

As previously reported, revenue for 2006 was \$71.1m (down from \$90.3m in 2005), including \$43.9m from III-V products (up from \$42.7m) and \$27.2m from CyberDisplays (down from \$47.6m). Now, Kopin can report a net loss of \$2.1m (compared with net income of \$10.5m for 2005), and that cash and marketable securities fell from \$119.8m to \$105.4m during 2006.

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

# AXT grows 31% as SI GaAs market share passes 20%

Substrate and raw material supplier AXT Inc of Fremont, CA, USA has reported full-year 2007 revenue of \$58.2m (up 31% on 2006's \$44.4m), with gross margin of 34.8% (up from 28.7%) and net income of \$5.3m up from \$944,000.

For Q4/2007, revenue was \$17.6m, up 21% on Q3's \$14.5m and 34% on \$13.1m a year ago. Of total revenue, 17% came from North America (down from 19%), 67% from Asia-Pacific (up from 64%) and 16% from Europe (versus 17%).

Gallium arsenide substrate revenue was \$12.2m, up 23% on Q3's \$9.9m and 10% on \$11.1m a year ago. In particular, revenue for 6" semi-insulating (SI) wafers was \$4.3m, almost double Q3's \$2.2m.

According to market research firm Strategy Analytics, this took AXT's market share in SI GaAs to 20% at the end of 2007 (up from just 3% in 2005), as the firm added 10 new customers during 2007. AXT says that, since it designs and builds its own furnaces and has space for expansion, it was able to increase capacity for 6" SI GaAs quickly while supply was constrained, whereas competitors were unable to do so.

Revenue for semiconducting GaAs grew 37% year-on-year, driven by growing demand for LEDs. But, despite making market share gains, AXT is being selective in the business it accepts, says chairman and CEO Phil Yin, in order to preserve gross margins. However, it has "many opportunities" to supply tier-1 customers (making progress during 2007 in qualifying a major north American supplier that has not been a customer for many years). Initial qualification has indicated positive device results. With additional testing, AXT expects to obtain official vendor approval, followed by production releases in late Q2 or early Q3/2008, says Yin.

Indium phosphide (InP) substrate revenue was \$330,000, down 19% from Q3's \$408,000 and down 28% from \$456,000 a year ago.

Germanium (Ge) substrate revenue was \$747,000, up 39% on Q3's \$536,000 and 135% on \$318,000 a year ago. Ge substrate sales are being boosted by growing adoption of concentrator photovoltaics (CPVs), which Strategy Analytics' estimates at currently just 1% of the solar market, but forecasts to grow at a compound average annual growth rate of about 350% through 2012.

For full-year 2007, Ge substrate revenues grew 145% from 2006's \$909,000 to \$2.2m (with just one customer). Yin says that AXT now has three customers going into volume production (including two in the very early stages of ramp-up). Regarding European customers, one has completed qualification, and finished auditing AXT's facility just in late February. Another three are currently in qualification. AXT should therefore see a ramp-up in second-half 2008 and expects that, long term, Ge should be a big contributor to revenue (Ge capacity utilization is currently just 30–40%, so production could be expanded greatly without much expense). Yin adds that the solar business is so hot that AXT wouldn't be surprised if, in 3–5 years, its Ge substrate revenue surpassed that for GaAs.

Yin reckons that AXT's Ge materials supply joint venture will become an important competitive advantage, as it gives it volume and price guarantees for raw materials, ensuring that AXT can cost-effectively meet the demands of the market as it matures.

Raw materials revenues (mainly 99.999% pure gallium) were \$4.3m, up 19% on Q3's \$3.6m and 258% on \$1.2m a year ago due to additional sales to Asian customers.

During 2007, AXT doubled the output of all five of its raw materials joint ventures (in three of which AXT has majority ownership), allowing AXT to provide all its own raw materials needs (providing considerable cost benefits).

Throughout 2007, the industry experienced shortages in both GaAs and Ge. The joint ventures allowed AXT to maximize its revenue opportunity, says Yin, by supplying to customers that could not get substrates from AXT's competitors, raising the firm's market share. The joint ventures also generated sales of excess raw materials on the open market. Yin says that AXT is continuing to look at using some cash to increase its stake in its joint ventures, as well as perhaps merger and acquisition opportunities.

AXT's gross margin, however, fell to 30.1% in Q4/2007, from 31.3% in Q3 and 38.2% a year ago. Net profit was \$1.9m, up from Q3's \$858,000 but down on \$3.4m a year ago. Capital expenditure was \$1.3m.

"Our strong fourth quarter results concluded what was another solid year for AXT," says Yin. "In addition to posting very meaningful gains in revenue, gross profit, operating income, net income and positive cash flow from operations, we have continued to grow our customer base, significantly increase our market share and make strategic investments into the technologies and products that will expand our addressable market." As positive long-term trends, Yin cites the growth of the handset market, the increasing prevalence of LEDs in a wide variety of lighting applications, and global adoption of solar energy.

**AXT wouldn't be surprised if, in 3–5 years, its Ge substrate revenue surpassed that for GaAs**

Strategy Analytics forecasts that AXT's market share in 6" SI GaAs will grow further to 29% in 2008, making it number-one supplier again. Such growth is likely to come from new customers that will begin contributing to revenue in 2008, as well as from expanded opportunities with current customers, says Yin.

During Q4, AXT agreed a deal with IQE to provide 6" substrates for their 2008 worldwide requirements (beginning shipments in Q1). The deal is worth \$15.1m, with an option to buy a further \$3.5m worth.

Due to the rise in 6" SI GaAs sales and forecasts of increased demand from existing customers, Yin has authorized another expansion of VGF growth operations, by 27% (to be completed in Q3/2008). CapEx should be "a little less than \$6m".

However, regarding raw materials, chief financial officer Wilson Cheung says that, with suppliers increasing capacity, gallium supply and demand are back in balance and there is now no constraint. Average selling prices are stabilizing (currently about

\$510–516/kg for four-nines gallium) and may trend down slightly in 2008. Although there is still constraint in germanium (costing \$1325–1350/kg), AXT expects its raw materials revenue to return to \$3.5–4m in Q1/2008.

So, for Q1/2008, AXT expects overall revenue of \$17.6–18m (flat to slightly up on Q4, with most growth coming from 6" SI GaAs). Growth will come from market share gains as well as new customer agreements from 2007 that will contribute revenue in 2008, says Yin. Also, customers are starting the year with relatively low levels of inventory.

In Q1/2008, gross margins should be in the low-30% range, reckons Cheung. Operating expenses should be stable, because AXT's infrastructure is able to support a quarterly revenue of \$20m. Also, AXT has over 80 cost reduction programs in place, he adds. However, to protect overall gross margin, AXT is looking at product mix carefully, and is even thinking of weeding out customers that present negative margins.

Also, during Q4/2007, AXT announced that it had retained the services of scientist Grant Elliott to augment R&D efforts under chief technology officer Chia-Li Wei. Elliott is focusing on VGF technology enhancements (for SI GaAs) and Czochralski and liquid-encapsulated Czochralski (LEC) crystal growth (of small-diameter substrates, which should open up new markets and further improve AXT's cost structure). AXT's current use of the slow, short-ingot VGF growth technique yields low margins for the low-cost semiconducting LED application (which can also tolerate the lower constraints on etch pit density defects resulting from LEC). LEC should be in production as early as Q1/2009, says Yin. Also, Cz growth will be an important part of the firm's Ge revenue growth strategy, as it will provide flexibility in terms of price and performance, and allow AXT to explore the viability of new substrates, such as gallium phosphide, he concludes.

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

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## IN BRIEF

### OIPT aims to double turnover by 2010

Oxford Instruments Plasma Technology (OIPT) of Yatton, UK received orders for 20 systems in February, the most in one month in the firm's 25-year history.

Spread across Asia, Europe and North America, the orders include:

- five plasma etch and deposition systems for a high-brightness LED manufacturing plant in Malaysia;
- a 'significant' order for an MBE upgrade in North America; and
- a FlexAL atomic layer deposition (ALD) tool for a US government research laboratory.
- an ion beam cluster system valued at over £1m.

"This is in line with our target to double the company's turnover by 2010," says sales & customer support director Mark Vosloo.

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

### Tegal signs WESI for China and Taiwan

Tegal Corp of Petaluma, CA, USA has signed up Shanghai-based WESI Technology (China) for sales distribution and service and technical support for plasma etch and PVD products in China and Taiwan.

WESI is a joint venture between WKK, which distributes capital equipment and services in greater China, and ECI Technology Inc, which supplies online chemical monitoring systems.

"We will now be providing local support again to our customers in China and Taiwan. We will be servicing our large installed base of etch and PVD systems in this region using the more than 200 experienced sales and service team members WESI and WKK bring to our new China and Taiwan organization," says Tegal's VP of global sales and field operations Vahan Tchakerian.

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

## OIPT names applications team leader

Oxford Instruments Plasma Technology (OIPT) has appointed Bob Gunn to the position of applications team leader, with responsibilities for sales support and process development.

Gunn will support OIPT's business growth and contribute to moving the team forward with new developments in plasma and ion beam technology. He has 20 years experience in process, development, customer and technology support management roles.

Mike Cooke, new product introduction manager at OIPT, said: "We are delighted to welcome Bob to the OIPT Applications Team, as his wealth of experience and breadth



**Applications team leader Bob Gunn.** of skills in the plasma technology field will ensure that our systems will continue to develop."

OIPT provides flexible process tools and processes for the engineering of nano-scale structures and devices, based on core technologies in plasma-enhanced deposition and etch, ion-beam deposition and etch, atomic layer deposition (ALD) and molecular beam epitaxy (MBE).

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

## IIT Bombay orders EVG systems

In February, EV Group of St Florian, Austria received an order from the Indian Institute of Technology (IIT) in Bombay for two systems (an EVG620TB bond and mask aligner and an EVG501 wafer bonder) for a new Indian government-supported automotive MEMS-focused Nanoelectronics Centre R&D project being pursued in close cooperation with the Indian Institute of Science, Bangalore (which previously purchased the same EVG equipment).

According to estimates by market research firm Semiconductor Partners, the MEMS market will reach

\$10bn by 2011. After IT peripherals, automotive MEMS represent the second largest segment, with the number of MEMS devices per vehicle expected to increase by about a third during that period.

"We selected the EVG equipment for the Nanoelectronics Centre facility based on the strong recommendation of our partner organization in Bangalore," said professor V. Ramgopal Rao, chief investigator for the Nanoelectronics Centre project, IIT Bombay. "This synergy between the two institutes will facilitate our R&D activities."

Late last year, in their ongoing joint development work, EVG and Brewer Science of Rolla, MO, USA demonstrated temporary wafer bonding for backside processes — including through-silicon vias (TSVs) and backside metallization — optimized for high-temperature packaging applications.

Brewer Science's WaferBOND HT coating materials have been combined with EVG's EVG850TB/DB temporary wafer bonding/debonding platform to create the first high-

yield, high-performance solution for simultaneously debonding and cleaning sub-100µm thinned wafers up to 300mm in diameter.

The solution resulted from a multi-year partnership formed to address demand for flexible, yet reliable, processes and equipment that can accommodate increasingly thin and fragile product wafers particularly for advanced 3D and wafer-level packaging.

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

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

## Edwards launches iXH series of vacuum pumps for compound semiconductor and ALD processes

Vacuum and abatement equipment maker Edwards of Crawley, UK has launched the iXH series, its next-generation family of harsh process vacuum pump products for the semiconductor industry.

Designed for emerging manufacturing processes at 60nm design rules and below, the iXH offers lower cost-of-ownership (CoO) and a smaller footprint than previous generations. It also features a modular design that enables a quicker response to emerging process requirements.

"Along with the drive for higher productivity, new semiconductor manufacturing processes, such as atomic layer deposition (ALD), and compound semiconductor processes, such as gallium nitride, are creating new challenges for vacuum pump technology in terms of powder handling, hydrogen flow, fluorine plasma cleans, ammonia flows and



Edwards' iXH pumps.

pre cursor reactions," says CEO Nigel Hunton. "The iXH has been specifically designed to meet these challenges with enhanced purge flow, temperature-controlled operating range, light gas performance and corrosive gas resistance. Its extended capabilities also offer improved CoO by lengthening pump life and helping to deliver lower utility costs."

ALD processes (such as high-k dielectrics) typically deposit less than 10% of the precursor on the wafer, increasing the potential for deposi-

tion in the pump, says Edwards. To manage such challenging conditions, the iXH offers improved thermal control and increased torque. The iXH's larger exhaust stages and Gas Buster inlet purge can also deal with the process byproducts of extreme powder processes with TEOS flows above 5g/min.

For compound semiconductors such as those based on GaN, where large flows of hydrogen and ammonia are needed, the iXH pump mechanism has been optimized to handle the small size of the hydrogen molecule and to better withstand the corrosive effects of ammonia (extending the maintenance interval).

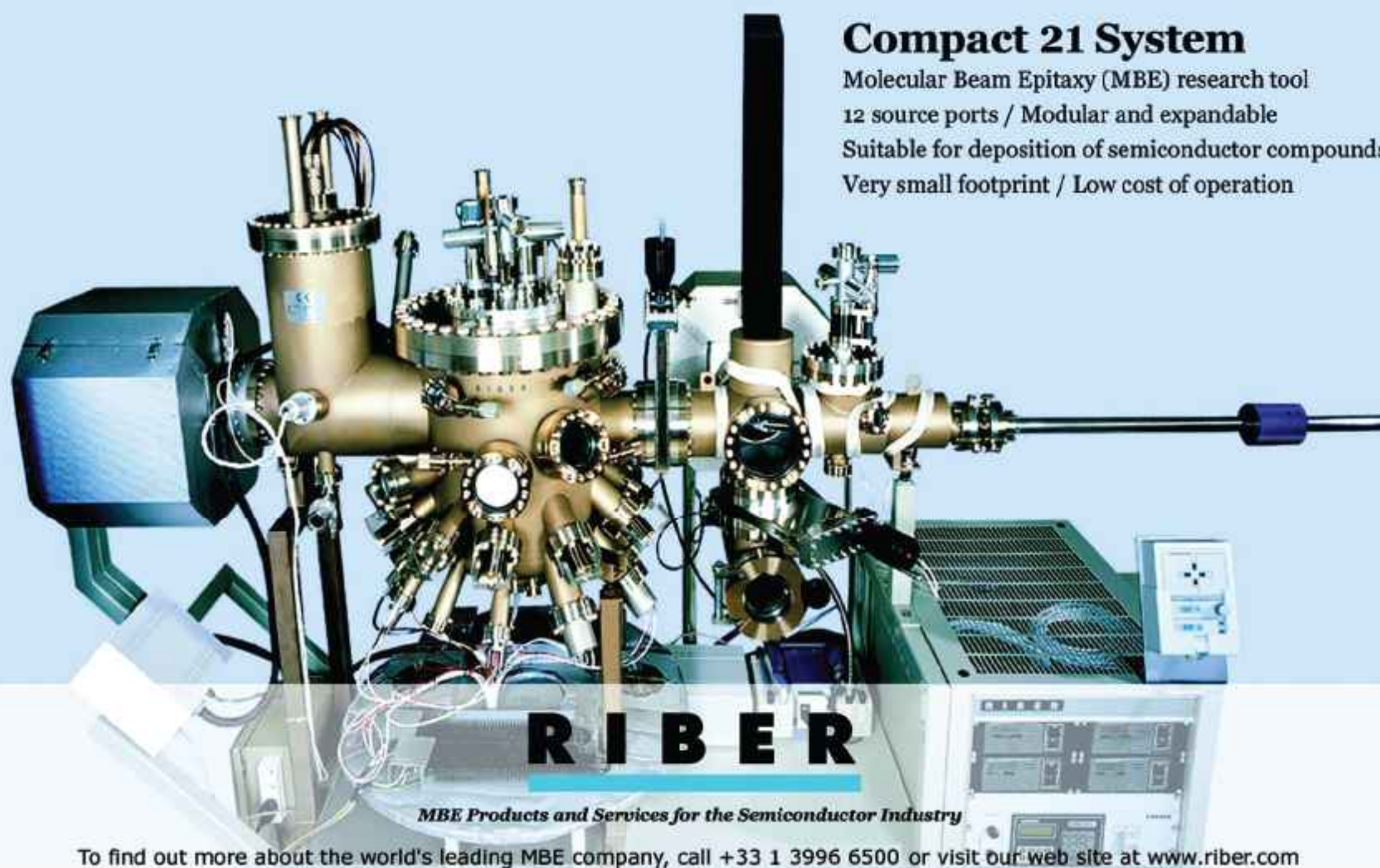
Also, an Active Utility Control (AUC) includes an idle mode for when the pump is not in use, reducing utility costs by more than 10% compared to Edwards' previous generation of harsh process pumps.

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

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# Aixtron grows 25% in 2007

For Q4/2007, deposition equipment maker Aixtron AG of Aachen, Germany has reported revenue of €54.1m, up 5% on Q3's €51.7m.

This took full-year 2007 revenue to €214.8m, up 25% on 2006's €171.7m (and up 7.5% on initial guidance). This is also the first year above €200m since 2001.

The rise was due mainly to equipment revenue for compound semiconductor (including organics) rising 50% to €145.2m (68% of total revenue, compared to just 56% in 2006). This was driven by:

- demand for platform-based systems (with 'Integrated Concept' Crius and G4 systems accounting for 48% of sales, and 72% of orders);
- LED applications (61% of total revenue), particularly for back-light units (BLUs) for LCD displays in laptops, monitors and TVs. Correspondingly, 81% of total revenue came from Asia (versus 10% from the USA and 9% from Europe).

In contrast, silicon equipment revenue fell 9% to €41.7m (19% of total revenue, down from 27% in 2006), due to volatility in the memory chip market.

Reflecting the increasing percentage of new common platform system revenues, together with a favorable product mix, gross margin improved from 37% to 40%.

"Despite the continuing weakness and volatility of the US dollar, we were able to hold the gross margin improvements made earlier in the year and finish the year with a gross margin performance close to our target of 40%," says president and CEO Paul Hyland.

Net profit almost tripled from 2006's €5.9m to €17.3m in 2007. Cash reserves rose 34% from €53.7m at the end of Q3 to €71.9m at the end of 2007.

In Q4/2007, equipment order intake rose again, by 24%, from Q3's record of €70m to a new record of €86.9m (almost doubling on a year ago). This boosted full-year 2007 order intake to €247.7m

(up 39% on 2006's €178m): with compounds up 52% to €208.6m (84% of order intake, compared to 77% in 2006) and silicon down 5% to €39.1m (just 16% of intake).

Consequently, order backlog is €132m (up 55% from just €85.1m at the end of 2006, and the highest level since 2002). Demand for deposition equipment for compounds is particularly strong: 96% of backlog versus just 4% for silicon (compared to 87%:13% in 2006).

However, Hyland cautions that quotation levels are dropping slightly, so the current high level of orders may slow within the next two quarters during a second phase of customers digesting recent purchases (following the last phase in 2006). However, Hyland does not doubt that there will be a further investment cycle, starting "some point between Q4/2008 to Q2/2009".

"When considering our 2008 full-year guidance, we have taken into account the potential risks in the current economic environment," says Hyland. "Despite these climatic considerations, I remain very confident that 2008 will be another year of growth."

On this basis, for full-year 2008 Aixtron forecasts revenue of €270-300m (up 26-40%). The target gross margin is 42% (continuing the figure achieved in Q4/2007).

"When viewed over the next five years, the outlook looks very positive for the market applications we serve and the technology we deliver with our equipment," concludes Hyland.

**Quotation levels are dropping slightly, so the current high level of orders may slow within the next two quarters during a second phase of customers digesting recent purchases**

Aixtron lists short-term market opportunities as: LED backlighting for next-generation LCD screens; increased adoption of LEDs in automotive applications; and emerging LED-based external/street-lighting applications.

Mid-term opportunities include: emerging solid-state lighting device applications; silicon carbide (SiC) hybrid automotive and solar applications; III-V-based concentrator photovoltaic (CPV) solar cells; CVD/ALD for next-generation NAND/DRAM memory; and the development of plastic electronics/flexible TFT back-planes.

Long-term opportunities include: longer-term development of technologies for organic LEDs; the convergence of III-Vs and silicon materials; and the development of new applications using carbon nanotubes.

Correspondingly, although Aixtron's total staffing has risen only 8% year-on-year (from 566 to 609), R&D staffing rose 15%

(from 181 to 210), with R&D expenditure rising from €23.9m to €26.5m.

In particular, despite the current downturn in silicon-related sales, Aixtron is continuing its investment in next-generation memory systems as well as in its joint development programs for ALD and AVD technologies.

"We remain confident we will create additional revenue opportunities in 2009 and beyond," Hyland asserts.

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

**Despite the current downturn in silicon-related sales, Aixtron is continuing its investment in next-generation memory systems as well as in its joint development programs for ALD and AVD**

# MOCVD systems ordered for solar cell developments

Both the main MOCVD reactor makers have recently announced orders for systems to be used in producing III-V-based solar cells: one for concentrator photovoltaic (CPV) cells in Korea and one for space applications in Russia.

## First GaAs MOCVD system for solar cells in Korea

Aixtron of Aachen, Germany has received an order for an AIX 2600G3 Planetary Reactor system from the Korea Advanced Nano Fab Center (KANC), a non-profit organization supported by Korea's Ministry of Science & Technology. KANC will use the 12x4"-configured system, with 'Integrated Concept' (IC) design, to develop III-V concentrator photovoltaic (CPV) cells for terrestrial applications. It will be installed in first-half 2008 at KANC's 3500m<sup>2</sup> 'FAB Building' facility in Gwanggyo Techno Valley near Seoul.

Aixtron says the order makes it the first supplier to Korea of a GaAs MOCVD tool dedicated to the development of III-V-based solar cells (after being the first to deliver a GaAs MOCVD system for solar cells to Taiwan's WIN Semiconductor).

KANC has previously achieved good results with its existing GaAs-based AIX 200/4 horizontal reactor and AIX 2400G3 HT Planetary Reactor for GaN-based applications, so it is hoping for rapid success with the new AIX 2600G3 IC system.

Aixtron and KANC will also establish a co-operation program focused on solar cell manufacturing.

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

## Kvant buys Veeco As/P MOCVD tool for multi-junction solar cells production

Veeco Instruments of Woodbury, NY, USA has sold a TurboDisc E450 As/P MOCVD system to Research-Production Enterprise 'Kvant' of

Moscow, Russia for the production of multi-junction solar cells for commercial space applications.

"Our decision to add Veeco's MOCVD As/P E450 system to our fab was based on the tool's ability to produce exceptionally high-quality films, and the throughput advantage of this system, which is key as we continue to increase output of our photovoltaic cells," says Kvant's director Valery Semenov.

Also capable of producing multi-junction solar cells for terrestrial applications, Veeco's TurboDisc E450 (and its recently launched successor, the E475) As/P tools are engineered for high-volume production. The systems include integrated RealTemp 200 technology for direct closed-loop in-situ wafer temperature control, and fast gas switching for strict control of interface abruptness.

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

## Asian HB-LED makers expanding with Veeco's K465

In February, Veeco Instruments of Woodbury, NY, USA said that an unnamed Japanese high-brightness LED maker has process accepted one of its TurboDisc K465 GaN MOCVD systems. Delivered last December and installed at the end of January, the system is being used to support a capacity expansion of blue HB-LEDs.

Veeco subsequently said in March that a further four of its TurboDisc K465 GaN MOCVD systems have been accepted by high-brightness LED makers throughout Asia.

"K465 systems were qualified for production in a relatively short period of time, enabling our customers to ramp quickly," says Sam DiRenzo, VP & general manager of Veeco's MOCVD operations.

"The speed of installing and qualify-

ing an MOCVD system into production is critical, as our customers continue to increase capacity of HB-LEDs for growing applications such as lighting, displays, automotive and backlighting for laptops."

"Demand for GaN-based blue LEDs is expected to grow at the annual rate of nearly 20% over the next five years, mainly due to market drivers such as signs and displays, automotive, general illumination and LCD backlighting," adds DiRenzo.



**Veeco's TurboDisc K465 GaN MOCVD system.**

Featuring Veeco's most advanced TurboDisc reactor technology, the K-Series MOCVD GaN platform (which includes the K300 and K465 models) has what is claimed to be the industry's highest throughput for high-volume production of GaN-based blue and green LEDs.

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

# Rubicon grows 58% and opens new crystal growth facility

For fourth-quarter 2007, Rubicon Technology Inc of Franklin Park, IL, USA, a vertically integrated manufacturer of sapphire material, wafers and components, has reported revenue of \$9.5m. This is up 58% on \$6m a year ago and up 5% sequentially — despite being capacity constrained — due to a shift in mix to larger-diameter products, i.e. 3" and 4" wafers for LED manufacturing and particularly 6" wafers for silicon-on-sapphire (SOS) RFIC applications. SOS sales rose 15% sequentially to 20% of total revenue (up from 18% in Q3). Revenues for LED applications grew 2% sequentially.

Gross margin grew for the eighth consecutive quarter, from 18% to 39%, due to improved efficiencies, higher factory utilization and the continued shift in revenue to larger-diameter products (with 55% of substrate revenue coming from 3" or greater diameter products, compared to 47% in Q3 and just 23% a year ago). Net income on a non-GAAP basis was \$1.8m, compared to a net loss of \$200,000 a year ago. However, net loss (including non-recurring charges, mainly related to November's initial public offering on NASDAQ) was \$16.6m (albeit down on \$21m a year ago).

For full-year 2007, revenue was a record \$34.1m, up 64% on 2006's \$20.8m. Gross margin rose from 9% to 35%. Gross margin has increased every quarter over the last two years through increased operating efficiencies.

The non-GAAP net profit was \$5m, compared to a net loss of \$4.5m in 2006. Also, GAAP net loss has been cut from \$7.6m to \$2.8m. Cash reserves are \$75m.

Rubicon has also announced the opening of its new crystal growth manufacturing facility three miles

away in Bensenville, IL (after determining its location only last July). Once it is completely built out, it will more than double the firm's existing crystal growth capacity and has the infrastructure to handle the firm's expansion plans at least through 2009.

With the infrastructure in place, the installation of crystal growth equipment has now begun. The first set of furnaces has already started producing high-quality material, according to CEO Raja Parvez.

"Rubicon is ideally positioned in 2008 to meet customer demand in the dynamic and high-growth LED, semiconductor and optical markets we serve," says Parvez. "Demand remains strong in both the LED and silicon-on-sapphire (SOS) markets,"

**Demand for 3" and 4" wafers is a bit weaker for Q1, but Rubicon expects it to be stronger in second-half 2008**

he adds. In Q4/2007, orders worth \$13m for 2008 boosted the backlog to \$45m. "Based on our projected production ramp for 2008, we are very close to being sold out for the year," Parvez reckons, adding that the sales team has already begun focusing on sales for 2009.

"We anticipate revenue in the first quarter of 2008 of \$10m." The proportion of sales from 6" wafers should rise due to increased sales to the SOS market and sales for wafer carriers. Demand for 3" and 4" wafers is a bit weaker for Q1, but Rubicon expects it to be stronger in second-half 2008.

For full-year 2008, Rubicon expects revenue of \$46–49m. Gross margins should be lower by three to four percentage points due to the factory expansion and consequent lower utilization.

Also this year, Rubicon should begin production of 8" sapphire wafers for RF applications (for qualification by silicon-on-sapphire users in 2009).

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

## Rubicon opens NASDAQ market

Executives from Rubicon opened the NASDAQ market on 13 March, celebrating the firm's performance since its initial public offering last November. Rubicon's stock opened at \$14 per share, but closed on 13 March at \$27.87.

Chief financial officer William Weissman attributes the firm's success to its crystal growth technology, efficient production, and growing market demand.

Rubicon applies its proprietary crystal growth technology to make high-quality monocrystalline sapphire for LEDs, RFICs and blue lasers in a form that allows volume production of various sizes and orientations of substrates.

Also, Rubicon is vertically integrated, with capabilities in crystal growth, high-precision core drilling, wafer slicing, surface lapping, large-diameter polishing and wafer cleaning processes, which it uses to convert bulk crystal into products with customer-specified quality and precision.



## EMF announces multiple MOCVD system orders

EMF Semiconductor Systems Ltd of Mitchelstown, Ireland says that it sold multiple MOCVD systems in fourth-quarter 2007.

Last November, co-funded by both South Africa's National Research Foundation, Nelson Mandela Metropolitan University bought a Mercury single-wafer MOCVD system for the development of nanostructures for photonic applications. The university's Physics department, which has been involved in MOCVD growth since the mid-1980s, already has two MOCVD reactors dedicated to R&D of both III-V and II-VI materials. However, this latest reactor, scheduled for delivery in Q3/2008, is a significant upgrade to the current tools and will allow far greater flexibility and control over the growth process.

"The Mercury tool will profoundly change the productivity of their department and even allow them to begin commercializing their

process," says EMF's technical sales manager, Dr Matthew Branch.

"Whereas reproducibility was limited for them in the past, the Mercury tool offers a complete package with a state-of-the-art control console and proven system performance".

Also, in December, a telecom firm in Islamabad, Pakistan ordered a Titan multi-wafer MOCVD tool, to be delivered in December 2008 and fully configured for both narrow- and wide-bandgap materials including GaN. The Titan is one of EMF's 'next-generation' tools, incorporating the patented Vectored-Flow Epitaxy (VFE) process, which involves separate injection of each of the process reagents into the growth chamber and — more importantly — maintaining their separation in the gas phase. The quasi-atomic layer deposition process prevents harmful pre-reactions between incompatible reagents, improving crystal quality and

reducing expensive reagent consumption, claims EMF. The tool has also generated significant interest in recent months for ZnO-type applications, the firm adds.

Finally, following the recent success in jointly developing a commercial-scale remote-plasma chemical vapor deposition (RPCVD) process with Australia's BluGlass Ltd for the manufacture of GaN-based blue LEDs, a second tool, for R&D purposes, is being manufactured, and is on track for delivery in 2008. The patented RPCVD process for growing nitride materials at low temperatures also shows promise for applications such as oxide-nitride mixed structures, photovoltaics and silicon. Combined with EMF technology, the R&D tool offers a complete package that has received considerable interest from universities, research institutes and companies worldwide, says EMF.

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

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# DOE awards fourth-round funding for SSL development

Following last May's fourth-round Solid-State Lighting (SSL) Core Technology Research and Product Development Funding Opportunity Announcement (FOA), on behalf of the US Department of Energy (DOE) the National Energy Technology Laboratory (NETL) has now awarded a total of up to \$20.6m (\$27.8m when combined with industry cost share) for 13 projects.

Five projects have been selected in response to the Core Technology part of the FOA plus two in response to the National Laboratory Call for Core Technology Research, to a total value of \$10.8m (with participants in cooperative agreements providing 20% as cost-share). The selections are expected to fill key technology gaps, provide enabling knowledge or data, and represent a significant advancement in the SSL technology base. Excluding organic LED projects, recipients include:

- AlN substrate maker Crystal IS Inc of Green Island, NY (with LED maker Philips Lumileds Lighting of San Jose, CA as a team member), for the \$1.3m, two-year project 'GaN-ready aluminum nitride substrates for cost-effective, very low dislocation density III-nitride LEDs'. The substrate (with targeted defect densities below  $10^5/\text{cm}^2$ ) will then be tested by growing high-efficiency blue LEDs.

- Georgia Institute of Technology (with team member Luminus Devices), for the \$2.2m, three-year project 'Fundamental Studies of Higher Efficiency III-N LEDs for High-Efficiency High-Power Solid-State Lighting', which seeks to understand the impact of strain, defects, polarization, and Stokes loss upon the internal quantum efficiency of LEDs.

- Lehigh University, for the \$0.6m, three-year project 'Enhancements of Radiative Efficiency with Staggered InGaN Quantum Well Light Emitting Diodes', which seeks to solve the problem of low efficiency in green LEDs (caused by a reduced wavefunction overlap due to the polarization field inside the quantum well).

- Sandia National Laboratories in Albuquerque, NM, for the \$1.3m, three-year project 'Novel Defect Spectroscopy of InGaN Materials for Improved Green LEDs' seeks to develop a platform centered around deep-level optical spectroscopy capable of interrogating deep levels throughout the InGaN band gap.

Six projects have been selected in response to the Product Development part of the FOA, to a total value of \$17.1m (including an average of 32% in cost-share from industry), focused on the improvement of commercially viable materials, devices, or systems.

Recipients include:

- Cree Inc of Durham, NC, for the \$2.6m, two-year project 'Efficient White SSL Component for General Illumination', which aims to develop a low-cost LED capable of replacing standard, halogen, fluorescent and metal halide lamps.

- Philips Lumileds Lighting, for the \$2.7m, three-year project '135lm/W 1050lm Warm White LED for illumination', which aims to develop pre-production prototypes with a correlated color temperature of 2800–3500K and a color rendering index (CRI) greater than 90.

- General Electric of Niskayuna, NY (with team members GE Lumination and the University of Maryland), for the \$2.2m, two-year project 'Affordable High-Efficiency Solid-State Replacement Down-Light Luminaires with Novel Cooling', based on LED cooling using synthetic jets combined with optimized system packaging and electronics.

- Osram Sylvania Development Inc of Danvers, MA, for the \$0.9m, two-year project 'High Quality Down Lighting Luminaire with 73% Overall System Efficiency', which aims to minimize thermal, optical and electronic losses and achieve a luminous steady-state output of 1300lm.

The SSL program is a product system efficiency of 50% by 2025.

## DOE releases updated multi-year plan for solid-state lighting R&D

The US Department of Energy (DOE) has released the March 2008 edition of its 'Multi-Year Program Plan FY'09-FY'14: Solid-State Lighting Research and Development'.

The report describes the activities that the DOE plans to undertake in the period fiscal 2009 through fiscal 2014 to implement its solid-state lighting objectives.

Updates to the March 2007 edition have been made mainly in Chapter 4.0 ('Technology Research and Development Plan') and include higher near-term efficacy targets for LEDs, new emphasis on luminaire performance, new milestones for LEDs, and some re-direction of resources to reflect updated task priorities. For organic LEDs, Multi-

Year Program Plan updates include extra focus on cost and reliability.

The DOE says it will continue to update the Multi-Year Program Plan on a regular basis to incorporate new analyses, progress and research priorities as science evolves.

[www.netl.doe.gov/ssl/PDFs/SSLMYPP2008\\_web.pdf](http://www.netl.doe.gov/ssl/PDFs/SSLMYPP2008_web.pdf)

## Emerging Standardization for Sapphire Substrate Inspection

By Frank Burkeen

Senior Product Marketing Director at KLA-Tencor  
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The HBLED industry continues to thrive driven by market demand from mobile devices, automobiles, computer screens, and niche exterior and interior lighting applications. As HBLED device technology evolves and fabrication techniques become more advanced, defect detection and process control are critical to improving device yields. Sapphire substrate contaminants such as particles, scratches, pits, bumps, stains and residues from CMP processing are known to impact subsequent epi deposition processes and substantially degrade device performance and yield. As such, the need for higher quality sapphire substrates is of critical concern for HBLED device manufacturers.

The adoption of optical surface analyzer (OSA) technology is gaining momentum for use in HBLED manufacturing, specifically sapphire substrate inspection.

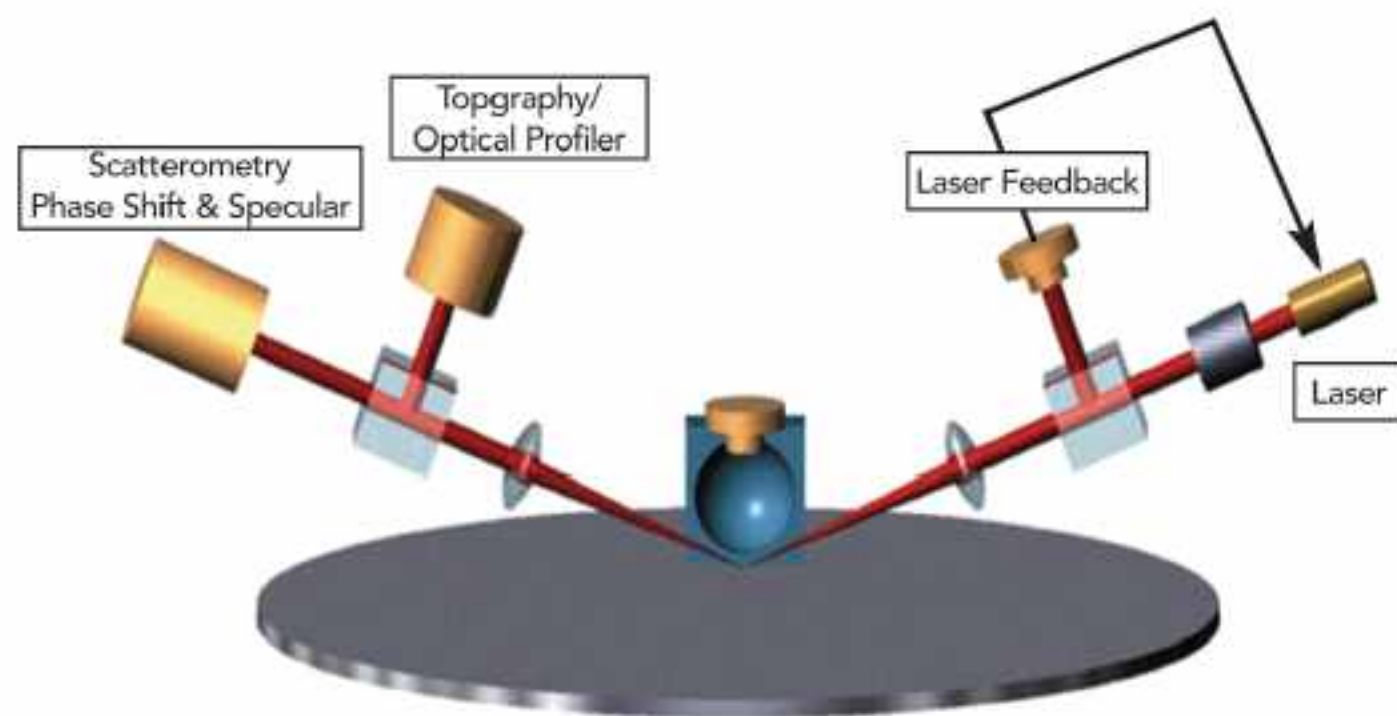


Figure 1: OSA technology combines four signal detection channels, enabling a wide range of inspection applications.

The design of OSA technology combines reflectometry, optical profilometry, scatterometry, and phase shift to measure topographic variations and detect a wide variety of surface defects. The inspection method achieves full surface coverage in minutes to produce high-resolution imaging, wafers maps, and automated defect classification.

At a throughput exceeding 40wph, an OSA system is the only wafer inspection method amenable to volume production and capable of advanced inspection of transparent sapphire substrates. Other inspection tools based solely on scatterometry cannot effectively measure transparent materials due to scattered light interference from the backside of the substrate. An OSA system is designed specifically for defect detection and classification of transparent materials including sapphire, GaN, SiC, and glass.

Figure 2 illustrates a sapphire substrate defect map after OSA inspection. Particles, scratches, pits, and stains are detected and classified in user-defined bins. The defect traceback images show a scratch as detected in the topography channel and two different types of stains as detected in the phase channel.



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Scratches are known to transfer to the subsequent epi layer thereby degrading or killing device performance. Substrate stains have been reported to cause poor epi layer adhesion or result in rough epi morphology.

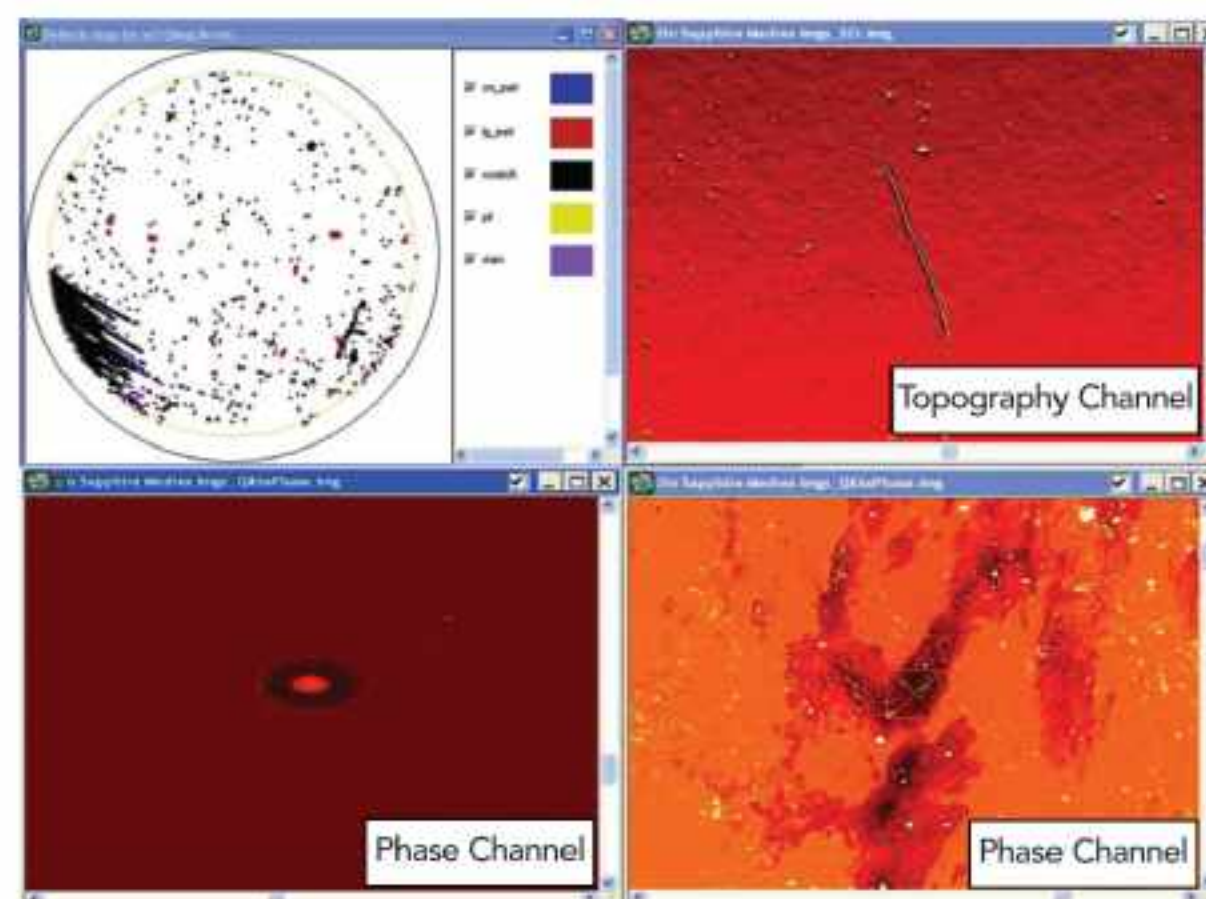


Figure 2: KLA-Tencor's Candela™ OSA defect map and traceback images of scratches and stains as detected in topography and phase channels, respectively.

As HBLED competition tightens and margins are squeezed, manufacturers are relying more on automated OSA inspection technology for process control and yield improvement. The emergence of sapphire substrate reclaim is also driving the need for advanced automated inspection. As supply is strained and material costs rise, the sapphire reclaim business is becoming more prevalent — whether for captive consumption or merchant supply. The reclaim business is even more dependant on OSA inspection as reworked material is highly susceptible to yield impacting defects.

Optical surface analyzer technology is setting the benchmark for automated inspection of sapphire substrates, and is emerging as the industry standard for overall sapphire quality control. HBLED device manufacturers and sapphire substrate suppliers are together converging on OSA inspection specs for quality assurance. Moreover, manufacturer's utilizing OSA technology are the beneficiaries of higher quality sapphire substrates passing distinct inspection specs.

Optical surface analysis technology enables manufacturers and suppliers to automate defect inspection and define objective-controlled process control limits. OSA technology can be employed at incoming substrate inspection, post-clean inspection, and after epi and film deposition processes.

To learn more, go to:  
[www.kla-tencor.com/candela](http://www.kla-tencor.com/candela)

# RPI develops polarized LED

Rensselaer Polytechnic Institute in Troy, NY, USA says that Martin Schubert, a doctoral student in electrical, computer, and systems engineering, has developed the first polarized LED, which could enable their widespread use as more efficient light sources for liquid-crystal displays (LCDs, which require polarized light) in TVs, computers, cell phones and cameras.

Schubert's innovation has made him the second recipient of the \$30,000 Lemelson-Rensselaer Student Prize. First given in 2007 and funded through a partnership with the Lemelson-MIT Program, the prize is awarded to a Rensselaer senior or graduate student who has created or improved a product or process, applied a technology in a new way, or otherwise demonstrated remarkable inventiveness.

"The Lemelson-Rensselaer Student Prize recognizes our most inspired and dedicated students for their ingenuity and deep understanding of the greater global implications of their innovations," said Rensselaer president Shirley Ann Jackson. "Schubert is both a talented engineer and inspired entrepreneur."



**Rensselaer's Martin Schubert.**  
(Photo credit: Rensselaer/Kris Qua.)

Schubert's polarized LED enables better control of the direction and polarization of the light being emitted. Less energy is wasted producing scattered light, allowing more light to reach the desired location. The polarized LED is hence suited to backlighting LCDs without the polarizers needed with conventional LEDs (which reduce the screen's light output). Its focused light can

produce images on the display that are more colorful, vibrant, and life-like, with no motion artifacts.

Schubert first discovered that traditional LEDs actually produce polarized light, but existing LEDs did not capitalize on the light's polarization. He then devised an optics setup around the LED chip to enhance the polarization.

RPI reckons that the invention could advance efforts to combine the power and environmental soundness of LEDs with the clarity of LCDs. Polarized LEDs could replace fluorescent lights (which are less efficient and contain mercury) in TVs and monitors. They could also be used for street lighting, high-contrast imaging, sensing, and free-space optics.

Schubert is the son of lighting research expert and senior chair of the Rensselaer Future Chips Constellation, professor E. Fred Schubert (although received his bachelor's and master's degrees from Cornell University in electrical engineering). He has published three peer-reviewed, archival papers and filed for several patent applications on the polarized LEDs, and should complete his doctorate in electrical engineering this fall.

[www.rpi.edu/lemelson](http://www.rpi.edu/lemelson)

## Forepi boosting LED capacity

Formosa Epitaxy (Forepi) plans to expand its LED monthly capacity to 400m units by the end of 2008.

Forepi expanded from 18 to 20 MOVCD reactors in Q3/2007, for volume production in Q1/2008. The firm is also looking to buy four more MOVCD units by the end of 2008 and increase monthly capacity from 22,000 to 30,000 wafers.

About 70% of revenue comes from backlight applications, mostly with a brightness of 1500-1600mcd for handset panel backlighting.

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

## Epistar to volume produce 110lm/W high-power blue LEDs this year

LED chip and epiwafer maker Epistar Corp of Hsinchu, Taiwan says that its 110lm/W high-power blue LEDs will enter volume production later this year after achieving better yield rates and improved technology, according to a report by Digitimes.

The brightness of the new high-power blue LEDs should reach 1800-2000 millicandelas (mcd), based on new packaging and testing technology.

The firm is currently the only Taiwanese LED maker that is

capable of offering blue LEDs with a brightness of 1700mcd, according to industry sources.

The new high-power blue LEDs are suitable for high-end notebook backlighting and outdoor LED display applications.

Epistar said last July that it had succeeded in developing blue LEDs with a luminous efficacy of 110lm/W, but it had been unable to start volume production until now due to yield issues and customer validation.

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



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# Tianjin: China's first LED City

The Tianjin Economic Development Area (TEDA) in China has become the first city area in China to join the LED City program, an international community of government and industry parties initiated by LED maker Cree Inc of Durham, NC, USA to evaluate, deploy and promote LED lighting for municipal infrastructure.

Tianjin is the fifth city to join the program following Raleigh, NC (last February), Toronto, Canada (July), Ann Arbor, MI (October) and then Austin, TX this January.

About 137km southeast of Beijing, Tianjin is China's third largest city (with a population of 9.5 million), a major commercial and industrial center, and the biggest port in north China. Tianjin is also known for its street-scapes of colonial-era buildings (a remnant of its status as a Treaty Port after 1858). The new satellite city of TEDA is now a

center for multinational businesses and has an extensive modern infrastructure.

Over the past two years, TEDA partnered with Tianjin Polytechnic University in a large, student-produced LED street-lighting project. Twenty graduate students, directed by Pingjuan Niu (professor at the solid-state lighting R&D center), designed, produced and installed about 1500 LED street-lighting fixtures more than a year ago to illuminate 15km of the university's streets.

"LED lighting not only reduces significantly the amount of energy we use for illumination, it also does not contain toxic materials such as mercury or lead," says TEDA's vice chairman Ai Yaming. "In addition to the energy and cost benefits, TEDA and the Tianjin Polytechnic University support the development and manufacturing

of high-quality LED fixtures in our region."

"Our university, its students and TEDA are developing expertise in making the best quality LED lighting with the intent to help accelerate the adoption of LED lighting in China and to increase the economic opportunity for our region," says Niu.

"The LED street-lighting project at Tianjin Polytechnic University is impressive in scale and in the level of quality achieved by Dr Niu and her students," says Cree's VP of marketing, Chris James. "We encourage other Chinese cities and universities to join with these innovators to help us work to significantly reduce the amount of energy used for lighting throughout the world and to accelerate the adoption of this new technology through innovative design and manufacturing here in China."

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

## IN BRIEF

### Cree expands board with Tekelec chief

In January, Cree appointed Frank Plastina, president, CEO & director of publicly traded telecoms network systems and software provider Tekelec of Morrisville, NC, to its board of directors, as well as to the board's Audit Committee and its Governance and Nominations Committee.

"Frank's experience and insight as CEO of a company accelerating the transition to high-performance, efficient, converged networks will expand the breadth and strength of our board," says chairman and CEO Chuck Swoboda. "This transformational insight should be very helpful to Cree as we pursue our strategy to replace traditional lighting solutions with energy-efficient, environmentally friendly LED lighting."

## Cree completes LLF acquisition

Cree Inc of Durham, NC, USA, which manufactures LED solid-state lighting components, has completed its acquisition of privately held luminaire manufacturer LED Lighting Fixtures Inc (LLF) of Morrisville, near Research Triangle Park, NC, USA (announced on 8 February) in exchange for about \$16.45m and issuing 1,852,335 shares of Cree's common stock. Additional cash consideration of up to \$26.4m may be payable over the next three years (tied to new product milestones and key employee retention).

LLF was co-founded in September 2005 by chairman and CEO Neal Hunter, who was also a co-founder of Cree in 1987 and its chairman and CEO until leaving in April 2005. Hunter rejoins Cree as president of the renamed Cree LED Lighting Solutions. The rest of LLF's management team continue in their roles.

Cree reckons that the acquisition expands its market opportunity by providing direct access to the lighting market. Its business hence now

**Cree reckons that the acquisition expands its market opportunity by providing direct access to the lighting market**

encompasses LED chips, components and lighting systems. It further enables Cree to drive retrofit solutions to convert existing lighting

infrastructure to energy-efficient lighting and to accelerate the adoption of LED lighting.

Cree will provide further information about the acquisition when it announces financial results for its fiscal third quarter (to end March) on 22 April.

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

## Seoul launches single LED package giving 900lm at 10W

Korean LED maker Seoul Semiconductor has announced the commercial release of its ultra-bright Z-Power P7 Series LED, which has entered volume production. Seoul claims that the new LED, which incorporates four chips in a single package, delivers record brightness of 900 lumens at 10 watts.

In comparison with a 60W incandescent lamp producing 660lm with an efficacy of 11lm/W, the 10W P7 single LED package produces a luminous flux of 900lm with eight-fold higher efficacy of 90lm/W. This is also nearly one-and-a-half times higher than for compact fluorescent lamps (CFLs), which typically consume 15W and emit 924lm (an efficacy of 61lm/W).

Also, compared with general light sources such as fluorescent and incandescent lamps, which emit in all directions so that only 60-70% of the light produced actually illuminates an object, the P7 can focus light in



a specific direction, based on the users' need. So, there is little loss of light, resulting in an actual luminous efficacy nearly two-and-a-half times greater, reckons Seoul.

Seoul says that the P7 can be applied in fields such as general residential lighting, streetlights, a variety of task lights, high-end flashlights for military, police or rugged use, and landscape lighting requiring extremely bright light.

Seoul launched the first 240lm single-die Z-Power LED P4 Series in December 2006, followed by other products including a 420lm super-bright single-package LED and the world's thinnest LED chip, at 0.17mm and 80lm/W, which runs directly from AC outlets. "We will develop new ultra-high-power products emitting over 1000lm during the third quarter of this year," says Hyuk Won Kwon, general director of the power LED business department.

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

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INSTRUMENTS

# ITC investigating blue LED/laser patent infringement complaint

The US International Trade Commission (ITC) has agreed to institute an investigation based on a complaint filed on 20 February by Gertrude Neumark Rothschild, professor emeritus of Materials Science and Engineering at Columbia University.

The complaint ('In the matter of Short-Wave Light Emitting Diodes') alleges infringement by 34 firms of her 1993 US patent 5,252,499 'Wide band-gap semiconductors having low bipolar resistivity and method of formation' (covering the production of GaN-based semiconductors for LEDs and laser diodes emitting in the blue and ultraviolet). It also seeks to bar importation into the USA of products incorporating infringing devices. These include DVD players using Sony's Blu-ray format, Motorola Razr phones and Hitachi camcorders, as well as instrument panels, billboards, traffic lights and data storage devices. Other firms cited include Blu-ray DVD player makers Matsushita Electric (Panasonic), LG Electronics Inc and Samsung and HD DVD

player maker Toshiba, as well as Nokia, Sony Ericsson, Pioneer, Sanyo Electric, and Sharp.

In the complaint, lawyer Albert Jacobs of Dreier LLP claims that Rothschild made a 'seminal breakthrough' in the production of blue and ultraviolet LEDs. "We'd like her to receive both the scientific recognition and the commercial recognition she so richly deserves," he said.

Rothschild began her research career in private industry, working with Sylvania Research Laboratories in Bayside, NY in the 1950s, and later at Philips Laboratories in Briarcliff Manor, NY. She joined Columbia as professor of materials science in 1985.

She conducted research in the 1980s and '90s into the electrical and optical properties of wide-bandgap semiconductors that is claimed to have been pivotal in the development of short-wavelength emitting (blue and violet) diodes now used in consumer electronics.

Recognized by the American Physical Society as a Notable Woman Physicist in 1998, Rothschild was

chosen as a Fellow of the American Physical Society in 1982, and a recipient of Barnard College's Distinguished Alumna Award this year.

After previous patent complaints filed elsewhere starting in 2002, LED makers including Toyoda Gosei, Osram Opto Semiconductors, and Nichia have already settled with Rothschild over alleged infringement of the patents. Most recently, on 11 March, Philips Lumileds settled in an action that had been brought before the US District Court for the Southern District of New York. A case against Cree Inc is still pending.

The latest case will be referred to ITC administrative law judge Paul Luckern, who will make an initial determination whether it will be subject to ITC review.

Within 45 days after institution of the investigation, the ITC will set a target date for its completion. Any remedial order is effective when issued and made final 60 days later, unless disapproved for policy reasons by the US Trade Representative.

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

## Avago expands 0.5W PLCC-4 LEDs to full range of colors

Avago Technologies of San Jose, CA, USA has supplemented its ASMT-QxBE series of super half-watt (0.5W) power PLCC-4 surface-mount (SMT) LEDs for use in automotive and electronic sign applications with four new colors: a brighter cool white, and warm white, blue and green colors (making a full range of colors, together with the existing white ASMT-QWB2, amber ASMT-QAB2, red-orange ASMT-QHB2 and red ASMT-QRB2 LEDs).

The LEDs have what is claimed to be the industry's smallest package size and a wide 120° viewing angle. Optimized for long operating life under severe environmental condi-

tions, the ASMT-QxBE series has been designed to dissipate heat more efficiently in order to provide better thermal management and consistent light output. Typical luminous flux is 9.8–17lm at 150mA drive current. The junction temperature is a high 125°C, the thermal resistance a low 60°C/W junction to pin, and the operating temperature range is –40°C to 110°C.

The high-efficiency 40lm/W cool white (ASMT-QWBE), 33lm/W warm white (ASMT-QYBE), 10lm/W blue (ASMT-QBBE) and 35lm/W green (ASMT-QGBE) SMT LEDs can be used in automotive applications for backlighting dashboards, dome and

map lighting, puddle lamps, rear reverse lamp indicator lighting, and license plate illumination. The LEDs can also be used for decorative lighting in general lighting applications, channel lettering in electronic sign and signals (ESS) applications, and for backlighting instrument panels and displays in industrial equipment, office automation and home appliance applications. Also, the high-brightness output per LED and small package footprint (3.2mm x 2.8mm x 1.9mm) provide greater flexibility in designing the size, shape and appearance of lighting assemblies, the firm claims.

[www.avagotech.com/led](http://www.avagotech.com/led)

# Osram's Golden DRAGON Plus boosts brightness by 15%

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new Golden DRAGON Plus is 15% brighter than its standard Golden DRAGON.

Together with the high-performance thin-film chip, thermal coupling between the chip and the package, the heat removal properties of its SMT package, and optimized silicon encapsulation, an integrated silicon lens increases the light extraction efficiency considerably. With an operating current of only 350mA and power consumption of 1W, the new generation of single-chip Golden DRAGON Plus LEDs typically achieves 85lm in cold white,



**Osram's Golden DRAGON Plus LED.**

75lm in neutral white and 55lm in warm white versions, says the firm.

The high-intensity single-chip LED can handle currents up to 1A in continuous operation and will last up to 50,000 hours. Its solder pad is the same as that for the other

members of the DRAGON family. The LED is also suitable for standard solder processes. The maximum barrier junction temperature is 125°C, and the thermal resistance is typically 9K/W (maximum 11K/W).

Osram Opto says that the Golden DRAGON Plus' beam characteristics suit secondary optics, broadening its range of applications in general lighting (street lighting, tunnel lighting, all indoor lighting from reading lights to recessed ceiling light, display lighting, furniture lighting, decorative lighting and designer luminaires).

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

## Pininfarina uses LEDs in headlamps

High-brightness LEDs from Osram Opto Semiconductors of Regensburg, Germany have been used in the headlights of Pininfarina's Sintesi concept car, which appeared at the 2008 Geneva Motor Show (6–16 March).

Instead of two separate headlights there is a continuous narrow strip containing 16 Osram Ostar Power LEDs. Pininfarina also chose Osram LEDs for all other lighting, including daytime running lights, turn lights and tail-light clusters as well as the interior lighting (using linearlight flex LED modules).

Osram has a comprehensive product portfolio of LED lighting for the automotive sector that includes the appropriate drivers and controllers, claims Peter Knittl, head of automotive LED marketing. The Sintesi is an example of how LEDs can offer flexibility in vehicle design. "Our high-power Ostar Headlamp LED technology platform opens up so many options for automotive lighting design in addition to traditional headlights and LED strips", adds



**The Sintesi concept car, which features LED-based strip headlamps. Picture: Pininfarina.**

Osram Opto's CEO Rüdiger Müller. The firm says that, by the end of 2008, it will have launched a number of different chip configurations in addition to the current five-chip platform.

[www.sintesi.pininfarina.com](http://www.sintesi.pininfarina.com)

### IN BRIEF

#### Abacus forms LED distribution division

UK-based distributor Abacus has formed the AbacusLED distribution business division, focused on the solid-state lighting market, to sell Osram's discrete LEDs and LED lighting systems together with electronic driver and thermal management technologies.

AbacusLED will also distribute LED light sources from Everlight, as well as drivers from Texas Instruments, National Semiconductor and ST Microelectronics, and thermal management solutions from 3M and Aavid Thermalloy.

Many users need support not only in selecting the right lighting product, but also implementing the right driver and thermal management solutions around it to get the longest operating life and the highest efficiency, says Mike Hall, Abacus Group LED business development specialist.

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

# Luminus closes \$72m VC round

Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (Photonic Lattice) LED products for display and illumination applications, has closed a \$72m round of financing, led by Boston-based Braemar Energy Ventures and joined by San Francisco-based CMEA Ventures and Washington, DC-based Paladin Capital Group in addition to all previous investors.

The latest financing highlights a significant strategic juncture for Luminus, which had been traditionally focused on light sources for the TV and display industry but is now targeting a broader array of applications for its PhlatLight LED technology. The opportunities for solid-state lighting range from general commercial and consumer lighting to specialty applications such as medical, entertainment and

homeland security. Luminus plans to use the capital to accelerate development of new products and expand into new lighting markets. The firm continues to strengthen its team in sales support, applications engineering and product development, and is recruiting staff in the greater Boston area.

CEO Udi Meirav calls the new funding a big vote of confidence in the future of solid-state lighting. "This investment enables a new phase in the growth of our company, and it will provide us with the resources to expand our product line, serve new markets and deliver the full value of our technology to our growing roster of customers."

PhlatLight technology has enabled display applications previously out of reach for conventional LEDs. The LEDs are replacing traditional

lamps in projection TVs and digital projectors from top-tier brands, and are now replacing mercury-based fluorescent backlights in flat-screen LCD TVs (the PhlatLight BLU back-light unit was demonstrated at January's International Consumer Electronics Show in Las Vegas and will be in production later this year). But now Luminus is also targeting the general lighting market.

"We are very bullish on LEDs and solid-state lighting, and we are excited to invest in one of the most promising companies in this space, with ground-breaking technology and outstanding execution," says Braemar's managing director Dennis Costello. Luminus has a growing network of world-class partners, he adds, enabling it to grow significantly in the next few years.

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

## Distributors appointed in Americas and Asia

Luminus Devices has agreed for Toyota Tsusho America Inc (TAI), a subsidiary of Toyota Tsusho Corp, to distribute its PhlatLight LED products and provide technical support for its TV and projector customers in China, Taiwan, Korea, and Mexico.

"Toyota Tsusho has a strong sales and technical support team and they are highly regarded by our display customers," says Luminus' CEO Udi Meirav. "Most importantly, through their logistics excellence and infrastructure, TAI will allow us to better serve our display customers and respond quickly to their needs."

Luminus claims that its patented PhlatLight LEDs are larger and brighter than conventional high-brightness LEDs and are proven as a replacement for high-intensity lamps, offering more brilliant color and longer lifetimes in projection TVs and projectors. PhlatLight technology is currently used in products from consumer electronics manufacturers including Samsung Electronics and LG Electronics.

"PhlatLight products are the brightest LEDs in the world and are uniquely suitable as a light source for large-screen TV and digital projection systems," says Michael Handerman, general manager of TAI's Electronics Materials, Chemical and Plastics Division.

"There are a number of companies in Asia that are interested in Luminus' edge-lit backlighting approach."

This latest agreement follows an agreement in February for Avnet Electronics Marketing, an operating group of Avnet Inc of Phoenix, AZ (one of the world's largest distributors of electronic components and computer systems), to distribute PhlatLight LED products to general illumination customers throughout North and South America.

"There is a tremendous need for higher-brightness, energy-efficient LEDs in a variety of lighting applications," says Cary Eskow, director of Avnet LightSpeed. "PhlatLight LEDs produce thousands of

lumens from a single large chip and are uniquely suited to replace halogen, arc and fluorescent lamps in many applications such as entertainment, architectural and medical lighting."

Avnet will provide comprehensive distribution, design-chain services and supply-chain optimization to help Luminus' customers accelerate product development. Luminus will be supported through LightSpeed, Avnet's specialized solid-state lighting and high-brightness LED unit. LightSpeed has a team of dedicated illumination-focused 'Illumineers' (engineers with experience in high-brightness LED technology, thermal management, power driver stage and secondary optics) that can provide additional engineering and system-level design assistance.

"The demand for our PhlatLight LEDs in new applications is growing exponentially," claims Meirav.

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

[www.em.avnet.com/lightspeed](http://www.em.avnet.com/lightspeed)

# Arasor acquires Novalux to control laser TV supply chain

Australian-listed telecom and consumer optoelectronic device maker Arasor International Ltd of Mountain View, CA has acquired the assets of Novalux Inc of Sunnyvale, CA, USA through the issue of \$7m in Arasor stock and the assumption of debt (bringing the total cost to \$20m).

Novalux was founded in 1998 to manufacture its patented NECSEL (Novalux extended-cavity surface-emitting laser) devices, firstly for telecoms and then, more recently, display applications (e.g. laser TV, pocket projectors and cinema projectors). The firm raised more than \$150m in venture capital from investors including Morgan Stanley Ventures, Crescendo Ventures, and Oerlikon Optics (an Arasor customer and light-engine manufacturer for some of the largest TV brands).

Last November, Novalux sold its GaAs wafer fabrication facility to an undisclosed Silicon Valley company, and has outsourced wafer processing from its low-volume, quick-turn prototype fab to larger-capacity contract manufacturers in Taiwan

(a key step in meeting customer demand for high-volume consumer electronics applications in early 2008, according to Novalux's chief operating officer William Mackenzie).

With the acquisition of Novalux, Arasor says that it can now provide end-to-end manufacturing of light sources for laser displays, realizing the full potential of the joint venture that it formed last November with ZTE Corp (China's largest listed telecoms equipment maker) for manufacturing light sources and light engines in China.

"Arasor has control of the value chain, path to market and significant external capacity to finance the growth of the laser display market well into the next decade," says chief executive Dr Simon Cao.

Arasor reckons that the acquisition of Novalux enables it to:

- Double revenue from the display market (as light engines can contain up to three Novalux laser chips and three Arasor optical chips).
- Secure Seiko Epson, Young Optics, Oerlikon and other customers via

exclusive licenses (as Arasor now owns the complete light source solution for laser TV).

- Stimulate the display market with critical manufacturing infrastructure (funded by capital from the ZTE joint venture) for the \$110bn display market.

- Quickly secure a team of staff with vast experience in laser display and related technologies.

"We have experienced unprecedented growth in telecommunications products, and 2008 will see the scale-up of our consumer division to satisfy demand," says Cao. With the release of laser TVs, Arasor says it can provide a complete light-source solution for both the major brands and the ZTE joint venture. "This significantly increases our earnings potential and our ability to negotiate with large global customers," reckons Cao. "Most importantly, no other company will be able to provide this unified solution," he claims.

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

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

## Arasor and ZTE's \$300m laser display joint venture

In November, Arasor International Ltd and China's largest listed telecoms equipment maker, ZTE Corp, formed a 51:49 joint venture that is claimed to be the world's first entity dedicated to the global deployment of applications based on laser-based display technology.

The aim is to develop commercial products for TVs, projectors and mobile displays (including cellular phones, PDAs and notebooks). Manufacturing will take place at Arasor, ZTE and joint facilities in China. Each laser source will use a set of three Arasor optoelectronic chips (for the primary colors red, green and blue.

Arasor's CEO Simon Cao believes that the joint venture will accelerate the deployment of laser-based display applications, starting with TVs and projectors and eventually all forms of cell phones.

Arasor says that the joint venture provides it with large-scale external funding for laser development and production, a channel to market with one of the world's largest handset providers, and extensive, scalable manufacturing capacity.

In phase 1 (from 2008 to 2010), the China Development Bank is providing financing of up to \$300m. Production is expected to start in second-half 2008, then ramp up to

6m laser sources and 2.4m light engines for cell phones per annum.

Planning for Phase 2 (from 2011 to 2012) has started, and will be based on key benchmarks achieved during Phase 1.

"Partnering with ZTE and the China Development Bank will provide all of the necessary commercial and financial support required to complete the supply chain and ensure the accelerated penetration of laser displays into the global markets," says Cao. "As the largest provider of mobile handsets in China, ZTE makes the perfect cornerstone customer for the JV."

[www.zte.com.cn](http://www.zte.com.cn)

# QPC halves losses as displays boost growth to 158% in 2007

QPC Lasers Inc of Los Angeles suburb Sylmar, CA, USA, a vertically integrated manufacturer of high-power lasers for the consumer electronics, industrial, defense and medical markets, has reported Q4/2007 revenue of \$2.85m, up 32% on Q3's \$2.15m and 119% on \$1.3m a year ago due to increases in both government and product revenue. This included \$1m from a new sector (displays for consumer electronics, following QPC's demonstration of a green laser last September).

Full-year 2007 revenue was \$7.9m, at the top end of October's guidance of \$7-8m (and well above August's guidance of \$6-7.5m). This was up 158% on 2006's \$3.1m (QPC's third sequential year of triple-digit revenue growth), boosted by shipments of initial Generation III products in second-half 2007.

"Production revenue was a significant contributor to our overall revenue growth, increasing 242% over last year," said Dr Jeffrey Ungar, chairman & CEO. "More specifically, we saw notable growth in the medical and consumer electronics markets, a growth trend we expect to see continue into 2008."

Demand for QPC's core Gen I and Gen II product families continues to accelerate, particularly for medical laser products. "We have now shipped nearly 3500 varicose vein removal lasers," said Ungar.

Gen III technology offers up to a ten-fold improvement in efficiency, cost, size, weight and ruggedness on conventional laser technology, it is claimed. "Generation III technology will have the capacity to revolutionize the existing multi-billion-dollar solid-state and gas laser market," believes Ungar. "Our recent entrance into the consumer electronics market is indicative of the potential impact this new advanced technology may have on our business."

Operating expenses in Q4 were \$3.2m, up from \$2.8m a year ago. However, due to one-time non-recurring engineering development revenues and the growth in sales of Gen II and Gen III products (with higher unit prices), gross margin was 63%, up more than usual (from 36% a year ago). So, net loss has been cut from \$2.7m a year ago to \$1m in Q4, contributing to full-year net loss being halved, from 2006's \$18.7m to \$9.7m. Cash reserves rose from \$1.4m to \$6.4m during 2007.

As highlights of 2007, QPC says it: (in December) launched the Ultra-500 high-power laser, offering up to 425W in output power; (in November) won a \$12m laser TV development and production order (with a potential value up to \$230m over 10 years); (in October) won a further \$750,000 contract from a US defense customer for fiber-laser engines designed for specialized airborne weapons (raising the total order to \$1.75m since April); (in July) shipped initial units of its BrightLase Seed Laser to a defense customer; (in September) demonstrated a green laser for multiple display applications; (in February) shipped laser engines at eye-safe wavelengths to US defense contractors (demonstrating a critical technology milestone for a US Army contract); and (in January) announced a partnership for joint production work with defense contractor Northrop Grumman. QPC also recruited a VP of manufacturing to prepare for its ramp-up of production.

"We have added consumer electronics to our target markets, which represents a multi-billion dollar and growing market, ramped our sales and marketing efforts around the world and rolled out a number of higher-powered additions to our product line," says co-founder and chief financial officer George Lintz.

● QPC has expanded its sales teams, and its in-house marketing team, by appointing eight new executives.

To boost international sales, QPC has established region-based sales managers in Europe and Japan, responsible for direct sales as well as managing the 12 representatives and distributors worldwide.

To support domestic growth, QPC has also expanded its direct sales team by adding region-based sales managers for the Northeastern and Southeastern regions of the US, plus an inside sales manager in Sylmar.

QPC's expanded marketing team in Sylmar includes a consumer electronics business development leader, a technical product manager, and an investor relations director.

● In Q4/2007 QPC shipped initial lasers in its laser TV contract, fulfilling the first \$1m of the \$12m three-year development phase.

QPC's green laser for displays is based on frequency doubling of its proprietary BrightLase single-mode laser (which produces single-frequency output powers exceeding 9W continuous wave and peak conversion efficiencies exceeding 50%).

Consumer electronics applications include miniature mobile projectors for mobile phones, PDAs and laptops, plus displays for cars and cockpits.

● QPC has been granted US Patent 7269195 'Laser Diode With an Amplification Section That has a Varying Index of Refraction'. The patent protects a concept unique to QPC for combating self-focusing, which causes conventional laser diodes to produce poor-quality beams when operated at high power.

"This new patent further expands the protection of our intellectual property portfolio to cover new technologies in areas relevant to important new product developments," says Ungar.

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

# Alfalight launches new series of diode laser pump sources

At January's Photonics West show in San Jose, CA, USA, high-power diode laser maker Alfalight Inc of Madison, WI, USA announced the availability of engineering samples of three new series of laser pump sources.

## **10W 940nm pump diodes in uncooled compact form-factor package for industrial lasers and amplifiers**

The AM6-940B series of laser pump diodes provide 10W of 940nm light output with a high-brightness 105µm 0.15 NA fiber.

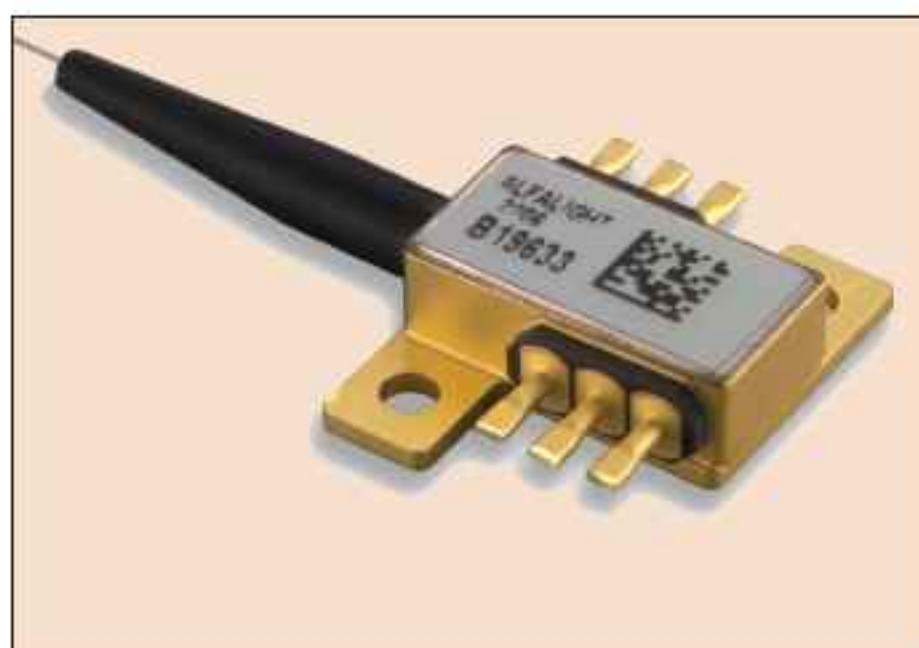
To simplify PCB mounting, the single-emitter laser diode is available in an uncooled, compact 6-pin telecom-grade package that includes a temperature-monitoring thermistor. Target industrial markets include pumping fiber lasers, diode-pumped solid-state lasers, uncooled fiber amplifiers, and direct material processing.

Alfalight is leveraging its experience with high-reliability telecom devices to deliver what is claimed to be exceptional uncooled lifetime in a small form factor, says Bechtold. "This is the first of a family of 9XXnm 10W devices that we will introduce in 2008, as we continue to drive down the \$/W ratio."

## **Wavelength-stabilized 5W 808nm pump diodes**

The AM6-808B and AM6-808BW laser pump diodes provide 5W of 808nm light output with a 200µm 0.15NA fiber, extending recent advances achieved in the DARPA-sponsored Super High Efficiency Diode Sources (SHEDS) development program.

The single-emitter laser diodes are available in both standard 808±3nm and integrated wavelength-stabilization technology (WST) 808±1.5nm versions (AM6-808B-60-503 and AM6-808BW-60-501, respectively),



**Alfalight's 6-pin uncooled compact form-factor laser package.**

and in a 6-pin industrial-grade package that includes a temperature-monitoring thermistor.

Alfalight's proprietary WST integrates a holographically defined semiconductor grating at the wafer level to control wavelength drift to just 0.07nm/°C (versus 0.3nm/°C for the standard version). The stable 'wavelength locking window' is typically 30–40°C wide and spans the operating power range of the device, allowing uncooled operation in a tighter bandwidth and narrow spectrum over a wide temperature range. Due to the highly optimized monolithic design, the efficiency and reliability are on a par with non-stabilized devices without the added cost or complexity of external-grating approaches.

Target markets for the small-footprint device include: microlasers for projection and display systems; small, high-reliability diode-pumped solid-state (DPSS) lasers; and small-form-factor green lasers.

"The rapid extension of our successful SHEDS and WST programs enables us to broaden our offering of innovative, high-efficiency, high-power commercial devices," said VP of sales & marketing Ron Bechtold.

## **Wavelength-stabilized 30W 808nm laser modules for air-cooled DPSS lasers**

The AC3-808B and AC3-808BW series of fiber-laser pump sources,

packaged in third-generation CPM III combined power modules, combine seven single-emitter laser diodes to deliver 30W of 808nm light output.

The modules are available in both a standard BAL 808±3nm (AC3-808B-68-303) version and an integrated WST 808±1.5nm (AC3-808BW-68-301) version, which allows air-cooled operation.

Packaged in a 3.35" x 2.73" x 0.67" lightweight aluminum case (with an attached 1m armored cable with SMA905 optical output connector), the compact modules include a thermistor for temperature monitoring.

The stabilized performance of the 808nm WST diodes enables greatly extended reliability, says Bechtold. The CPM III modules provide over 20,000 hours mean-time-to-failure (MTTF) and do not suffer the catastrophic failure mode inherent in conventional bar-based emitters, says the firm. The new modules enable the upgrade of existing fiber-coupled bar-based DPSS laser systems or a move to new lower-cost air-cooled designs, Bechtold adds. Use of a 685µm fiber bundle with 0.15 NA gives higher brightness and easy incorporation into existing fiber-coupled bar-based 0.22 NA systems.

Target markets include industrial end-pumped DPSS lasers for Nd:YAG or Nd:YVO<sub>4</sub> systems for end uses such as material cutting and processing, light welding, marking and printing.

Production volumes of all laser pump diodes will ship in March.

● At the Photonics West conference, VP of R&D Manoj Kanskar gave a presentation on "Wavelength-Stabilized and Spectrally Narrowed, High-Power, High-Efficiency 808nm and 975nm Diode Laser Pumps".

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

# Raising the bar for high-power fiber-coupled diode laser modules

High-power laser component, module and system maker DILAS of Mainz, Germany launched several new products at Photonics West.

## **First 1940nm high-power diode laser arrays with 10% WPE**

DILAS introduced what it claims are the first commercially available high-power diode laser arrays operating at 1940nm with a wall plug efficiency (WPE) of >10%. Using proprietary epitaxy, they can be integrated into all DILAS packages, from single-bar configurations up to large-scale stack modules that can include hundreds of bars.

Based on a single diode laser array, the new-generation 1940nm conduction-cooled, fiber-coupled diode laser modules generate output power of 6W, 12W, and 18W, using a standard 600 $\mu$ m fiber bundle with a numerical aperture (NA) of <0.22 and an SMA-905 fiber connector.

The new modules target mainly the medical (therapeutic dermatology and surgery) and industrial markets (material processing applications).

## **1550nm conduction-cooled, fiber-coupled modules**

DILAS launched conduction-cooled, fiber-coupled diode laser modules for pumping, medical treatment, material processing, and defense applications that demand high-power stable sources and high beam quality.

The 1550nm modules are based on the firm's single-bar and multi-bar configurations (depending on customer requirements) and are shipped with 400 $\mu$ m, 0.22 NA, SMA fibers that deliver 5–30W output powers in the 1550nm range (depending on the number of diode bars integrated into the module).

## **Expanding to 639 and 650nm visible fiber-coupled modules**

The firm has also broadened its wavelength spectrum by adding a series of high-power, conduction-cooled, fiber-coupled diode laser bars emitting at 639 and 650nm.



**DILAS' 1940nm diode laser arrays.**

Suited to medical and display applications, the modules can deliver up to 5W CW output power from a 400 $\mu$ m fiber with an NA of <0.22, making it the highest-performing visible diode laser bar commercially available, claims the firm.

The modules feature sealed, shock- and vibration-tested packaging.

## **Single-bar-based fiber-coupled diode laser module delivers 50W**

Another new fiber-coupled diode laser module is based on a single laser diode array and delivers up to 50W of CW power at 808 and 976nm through a 400 $\mu$ m SMA-fiber with an NA of <0.22, (the highest-performing diode laser available, it is claimed).

The single-bar-based module is intended mainly for medical applications and end-pumping of solid-state laser materials for fiber lasers.

Measuring just 100mm x 31mm x 20mm, the industry-standard package has a WPE of >35% and a typical spectral width of <4nm (FWHM). Laser power is delivered via a detachable single-core fiber terminated with an SMA 905 connector.



**Single-bar-based fiber-coupled diode laser delivering 50W of CW power.**

## **Fiber-coupled, multi-bar module power boosted to 200W**

DILAS' latest fiber-coupled multi-bar modules emitting at wavelengths of 808, 915, 940 and 980nm allow clad-free light coupling, delivering 130W and 200W through a 200 $\mu$ m fiber with an NA of <0.22. The 4-bar and 6-bar designs are based on industry-standard single conduction-cooled bars, which are optically stacked and polarization coupled.

Standard industrial-grade water chillers can cool the module and its fiber connector, keeping costs low.

For flexible system integration, all DILAS fiber-coupled products have options including an integrated pilot beam, power monitor, fiber detection sensor, fiber interlock, and user-exchangeable protection window (all in a space less than 30mm high).

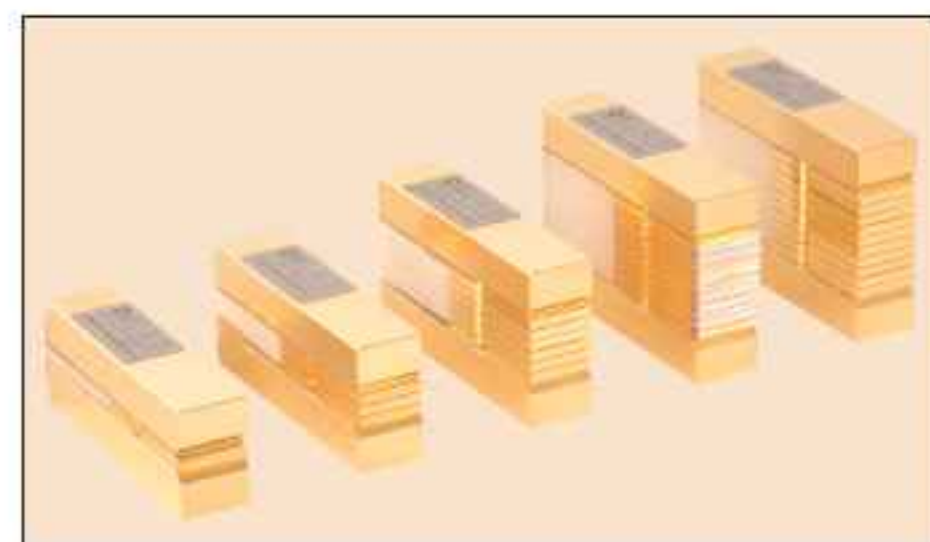
## **High-power 808, 940 and 980nm water-cooled diode laser arrays**

A new series of high-power, water-cooled diode laser arrays in scalable stack designs delivers up to 80W CW per bar at standard wavelengths of 808nm, 940nm and 980nm.

The stack designs are available up to 12 bars side-by-side horizontally or up to 70 bars stacked vertically.

DILAS' water-cooled diode laser arrays suit use as a line source for side-pumping of diode-pump solid-state lasers, direct materials processing, hair removal and line-beam applications as well as two-dimensional arrays for heat treatment and fusion laser applications.

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



**808, 940 and 980nm water-cooled diode laser arrays giving up to 80W.**

## Bookham launches 40W and 60W 808nm laser diode bars

At Photonics West, Bookham launched its portfolio of next-generation 808nm multi-mode high-power laser diode bars, with fully qualified products delivering more than 60W in continuous-wave operation for pumping and fiber-coupled applications.

This first launch is the start of a portfolio of high-power 8xx products, joining the firm's high-power, high-brightness and high-reliability 9xx and 10xx products.

The new range should enable higher efficiency and power, resulting in reduced energy consumption and thermal loads, says the firm. The 40W 30% fill-factor and 60W 50% fill-factor 808nm laser diode bars, available on passive cooler and micro-channel cooler, are designed to deliver higher power, improved efficiencies and extended lifetimes to users' laser systems. To achieve full qualification, the gold-tin hard-soldered laser diode bars passed

rigorous intermittent lifetests, including accelerated long-term operation at 100W for the 50% fill-factor device.

"This new generation of 808nm product is built on a proven semiconductor material structure that will allow us to grow this portfolio of products, increasing output and offering customers a scalable solution to deliver greater power and reliability in their laser systems," says senior product line manager Christian Naumer. "In the Bookham facility, we have demonstrated up to 130W CW at 50% fill factor."

The new bars offer low divergence in the fast and slow axes, which enables cost-effective side-pumping and fiber coupling, reducing losses and improving coupling efficiencies. The 808nm products are available in highly customized configurations, including multi-bar arrays.



Bar on passive cooler.



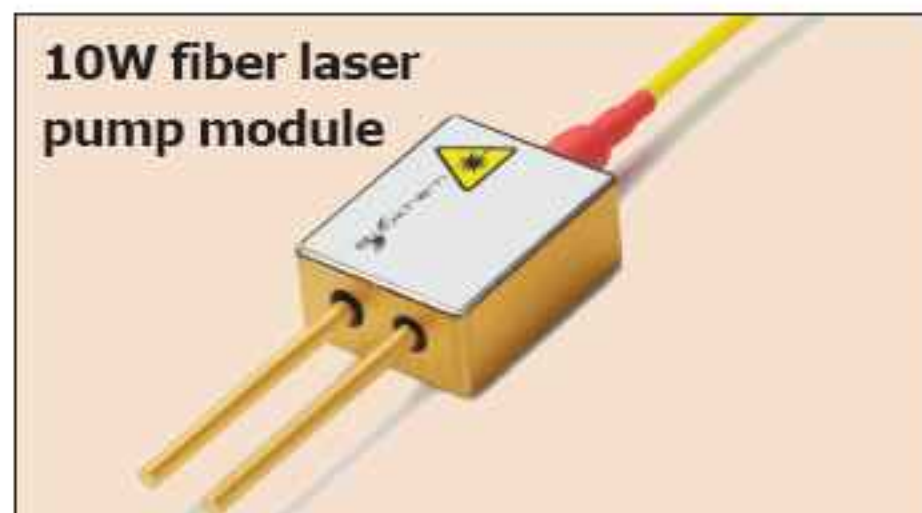
Bar on micro-channel cooler.

## High-power laser diode portfolio expanded for fiber lasers and printing

Bookham also debuted products from its expanding high-power laser diode portfolio, targeting high-growth industrial markets:

- a 10W fiber-laser pump module with 105µm fiber core diameter operating at injection currents up to 12A;
- a 1060nm seed laser module with short-distance fiber Bragg grating to control spectral properties for pulsed fiber lasers;
- low core-fiber-diameter multimode modules (with 40µm or 50µm fiber) delivering up to 2W at 830nm and up to 3W at 940nm, aimed at the computer-to-print (CTP) pre-press printing market.

10W fiber laser pump module



"The number of applications that require reliable, high-power and high-brightness laser diodes is growing all the time, and we are continuing to drive investments and developments of next-generation products to meet the needs of our customers in these areas," said Berthold Schmidt, director of product marketing.

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

### IN BRIEF

#### Laserline using VHB bar for industrial direct diode systems

Laserline of Mülheim-Kärlich near Frankfurt, Germany has selected Bookham's Very High Brightness bar to support its high-brightness direct diode laser systems for industrial material processing.

"Based on our experience of working with Bookham with 120W bars, we chose to work with the company again on this demanding product because of their fast innovation cycles and responsiveness," said Laserline's managing director and co-founder Volker Krause.

"The VHB bar, with its unique form factor, is the perfect match for our high-brightness direct diode systems as it features the Bookham hard-solder technology to support the typical intermittent operation mode we find in industrial and automotive applications," added Krause.

Bookham's announcement of volume shipments of the VHB bar came just 6 months after its launch at June's LASER 2007 show in Munich. The VHB bar, shown for the first time in North America at Photonics West, has a power output of 80W — up to four times the brightness of a typical 10mm bar, it is claimed — and measures just 3.2mm in width. The device supports direct industrial laser systems and enables fiber coupling without beam transformation optics by delivering high output power in a narrow emitting area.

"The key to the speed of this deployment is the way that we have worked in close cooperation with the customer, and designed a product that exactly meets the needs of this cutting-edge systems manufacturer," said senior product line manager Christian Naumer.

[www.laserline-inc.com](http://www.laserline-inc.com)

# Intense launches high-power lasers

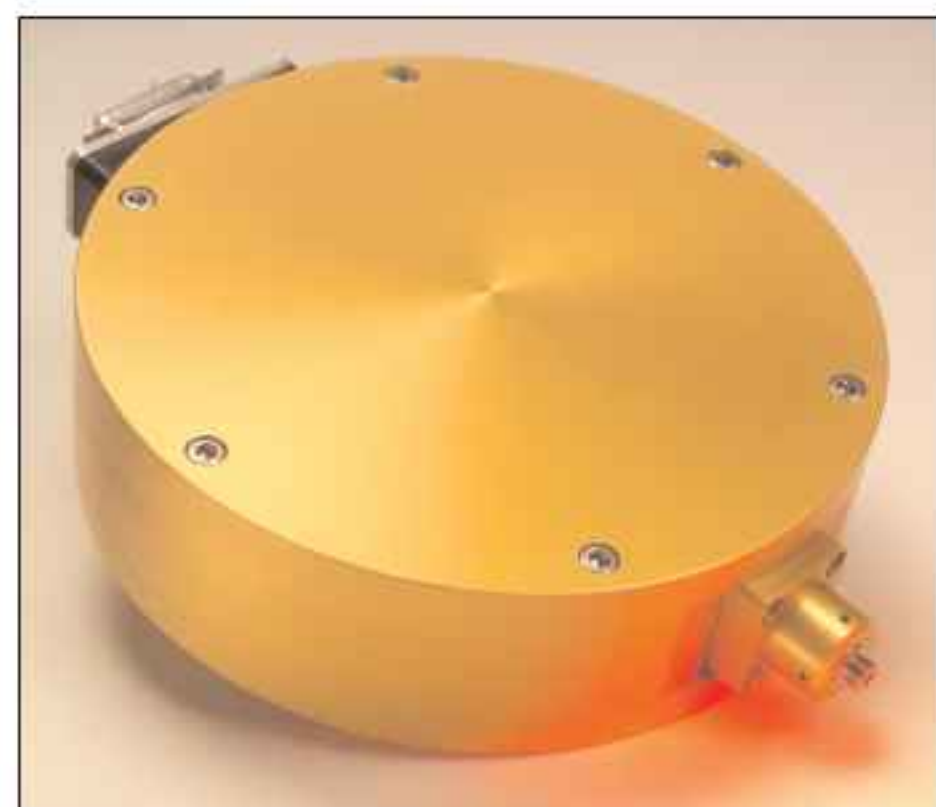
## Power Pack 630 laser modules

At January's Photonics West 2008 show in San Jose, CA, USA, laser maker Intense Ltd of Glasgow, UK launched the Power Pack 630 visible CW high-power, fiber-coupled laser module, which delivers up to 2.5W of 630nm light from a 600µm fiber with 0.22 numerical aperture (NA) while operating at low current levels.

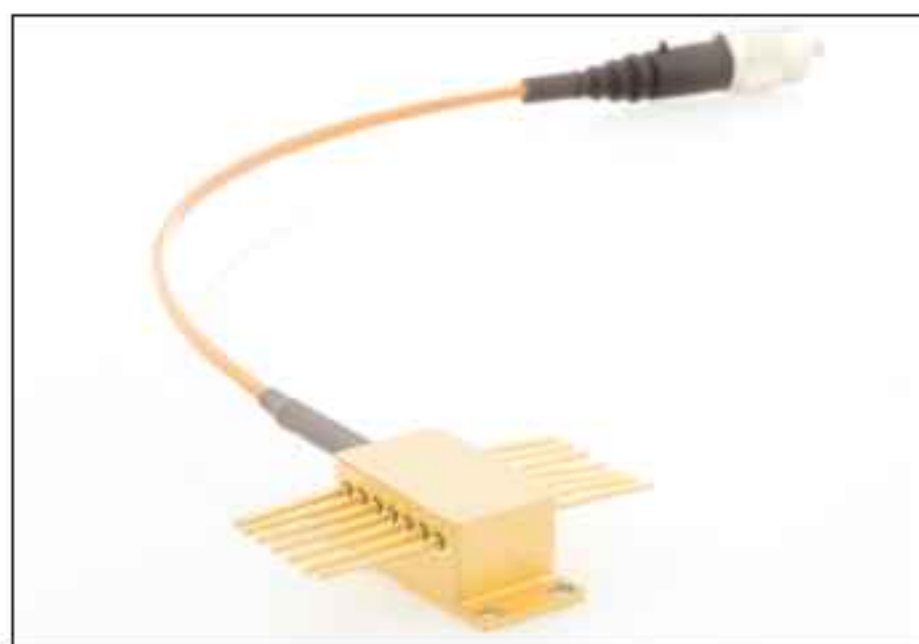
The Power Pack is designed for medical and display applications such as photodynamic therapy, medical imaging, illumination, and entertainment. "Medical and display system developers are focused on smaller size, higher brightness, and lower operating power requirements," says Chris Baker, VP sales & marketing.

The module employs a new integrated turnkey system architecture that combines a forced-air heat-sink and cooling fan, monitor photodiode, thermoelectric cooler and thermistor. For maximum flexibility, the Power Pack is configured as a stand-alone module that easily interfaces with commercial laser current drivers and smoothly integrates into OEM systems. Each module can be configured to interface to a variety of standard fiber output connectors. "All this reduces overall system costs and makes new product development quick and easy," says Baker.

Each module includes an internal visible aiming beam for verifying the alignment of laser output to the target. A 15-pin D connector provides easy integration of I/O signals.



Intense's Power Pack 630 module.



Power Core 808 mini fiber package.

## Power Core 808 laser engine chip

The Power Core 808 is a new family of single-emitter laser engine chips that deliver up to 4W of output power at 808nm and can be customized for a variety of optics applications.

The compact design combines a small emitting aperture (100µm) with low beam divergence to produce very high brightness in a small, simple-to-integrate, chip-level device that is easily packaged into a variety of enclosures, including C-mount, fiber-coupled MFP (mini fiber package) and HHL (high heat load). The Power Core 808 is designed for use in demanding industrial and coding applications, such as pumping and sensor-based instrumentation.

"Laser-based system designers are creating an astonishingly wide range of innovative products, but they frequently face the challenge of how to get the right laser for their particular needs," says Baker. "Our Power Core line of laser engine chips provides high brightness, power, and reliability in a smaller, more efficient package," he adds. "Power Core provides the flexibility designers need so they can pack more lasers in a smaller area or create smaller optics products."

## Expanded Hermes family

Intense has expanded its Hermes family of high-power QCW (quasi-continuous wave) stacked laser arrays. The new lasers, now qualified to military standards, combine high reliability and longer lifetime with robust, modular packaging in a standard wavelength of 808nm with power levels of up to 900W.



Hermes quasi-QCW stacked laser array.

The stacks degrade by less than 5% over  $2 \times 10^8$  shots (compared to competing products that degrade by 20% or more, claims Intense), so Hermes products provide much longer lifetimes, ultimately reducing costs for OEM developers.

The stacked arrays are 'QWI-enabled', developed using Intense's patented quantum well intermixing (QWI) technology (developed by chief technology officer professor John Marsh), which produces superior power, unrivalled brightness, and high reliability for a wide range of demanding applications, such as rangefinding, target designation, and pumping, says the firm.

"Hermes high-power lasers are based on a compact, modular architecture that delivers high brightness and high efficiency," says Marsh. "This improves overall performance of the OEM system, reduces energy consumption, and allows for development of innovative optical products."

The arrays are available as vertically or horizontally stacked assemblies of up to 10 bars, with lensed and unlensed options. Standard configurations include 4-, 6-, 8- and 10-bar stacked arrays, with minimum peak output powers of 360W, 540W, 720W and 900W, respectively. Developed using a highly robust hard solder process for stack assembly, Hermes 900W has been qualified to military standard MIL-STD-810F, Methods 501.4, 503.4, 514.5, and 516.5.

Other wavelengths are available on request for all new products.

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

## Intense launches 793nm diode laser for thulium fiber pumps

Intense Ltd of Glasgow, UK has launched the Series 8000 793-MFP (mini fiber package) high-power, fiber-coupled diode lasers, which deliver up to 3W of continuous-wave (CW) output power from a fiber with a core of 100 $\mu$ m in diameter and a numerical aperture (NA) of 0.22 at a wavelength of 793nm. The diode lasers are also available in a free-space package with 4W ex-facet.

The lasers are designed using the firm's patented epitaxial growth and wafer processing technologies, including asymmetric waveguides, which increase the laser's brightness and reliability. This makes them suitable for use in next-generation, eye-safe thulium-doped fiber-pumping applications, where enhanced power and beam quality are required.

Thulium fiber lasers are used in defense and aerospace applications such as LIDAR and direct infrared countermeasures. They can also be used as replacements for existing diode-pumped solid-state (DPSS) technology in medical applications. In addition to their eye-safe characteristics, thulium fiber lasers offer the added benefits of smaller size, more efficient operation, and the ability to make more precise surgical incisions.

"Our goal is to deliver the highest levels of power and reliability to the next-generation of fiber lasers," says Kevin Laughlin, VP HPL global



**Intense's Series 8000 793-MFP high-power, fiber-coupled diode laser.**

business development. "Series 8000 lasers provide high power and reliability, and a compact design, making them a superior pump alternative to expensive, fiber-coupled bar packages," he claims. "In addition to the eye-safe aspects, thulium fiber lasers also provide a variety of unique processing benefits for medical and industrial applications in comparison to DPSS and Yb [ytterbium] fiber sources."

The Series 8000 793-MFP lasers are also available in custom packaging to match OEM system requirements.

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

### IN BRIEF

#### Intense enters China market with distributor A&P

In January, Intense Ltd signed a distribution agreement with A&P Instruments Co Ltd, an OEM distributor of lasers and instrumentation in the Far East.

The agreement enables A&P to distribute Intense's entire line of high-power, QWI-enabled laser diode products (including visible and IR laser diodes, bars and stacked arrays, fiber lasers, and individually addressable arrays) to manufacturers in China.

"China's rapid manufacturing expansion and quest for innovation present significant opportunities for Intense," says Chris Baker, VP sales & marketing.

"A&P is a highly experienced and successful laser distributor in China...our combined efforts will accelerate the delivery of new products throughout China."

"We have been doing business in China successfully for 24 years and have an unrivaled understanding of what our customers need," said Sammy Woo, A&P's China sales & marketing manager. "Our clients are demanding higher power, reliability, and brightness, and Intense's product line enables us to meet our clients' most stringent requirements."

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

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

## IPG acquires British Telecom's photonics patent portfolio

High-power fiber-laser and amplifier maker IPG Photonics Corp of Oxford, MA, USA has acquired a photonics patent portfolio comprising more than 100 US patents and more than 340 foreign counterparts from British Telecom.

These include patents relevant to components and systems as well as devices and techniques that are

commonly used throughout the photonics industry.

The patents concern pioneering photonics research by British Telecom dating from the 1990s in the fields of optical fiber lasers and amplifiers, semiconductor devices, integrated optics, fiber gratings, high-speed systems and optical networking.

"These patents complement our strong IP portfolio, including the growing number of pending patent applications that we already have," says IPG Photonics' CEO Dr Valentin P. Gapontsev.

Of particular note are early patents covering single-mode lasers, says IPG.

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

# Full-band tunable pluggable transceiver

Bookham showcased its first full-band tunable pluggable transceiver at February's Optical Fiber Communication conference in San Diego, as well as outlining its roadmap of tunable pluggable products, to include the XFP-E format.

Bookham's 10Gb/s high-end LambdaFLEX TL8000 module for long-haul and metro applications is the first in a series of tunable transceivers that achieve the long sought-after goal of combining the benefits of full-band tunability with front-face plate pluggability. The

module exhibited demonstrates the capabilities and technology upon which Bookham is building its tunable pluggable product range.

The TL8000 delivers high-end performance suitable for long-haul links and metro/regional environments at rates up to 11.3Gb/s. It includes Bookham's fully Telcordia qualified InP Mach-Zehnder modulator and DSDBR (digital supermode distributed Bragg reflector) laser transmitter — which underpin the TL7000 tunable transmitter assembly (TTA) and TL9000 tunable small form fac-

tor transponder (TSFF). The TL8000 also includes Bookham's 10Gb/s avalanche photodiode (APD) receiver combined with electronic dispersion compensation (EDC) to provide enhanced performance in low optical signal-to-noise ratio (OSNR) environments.

"This is the first in our new series of tunable pluggable modules that demonstrates our capability to deliver high-end tunable performance in a pluggable format," says product line manager Jon White.

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

## Bookham demos zero-chirp fully qualified tunable SFF transponder

At OFC 2008, Bookham also demonstrated a new zero-chirp variant of its LambdaFLEX TL9000 300-pin transponder, which it reckons is the industry's first fully Telcordia-qualified tunable small-form-factor transponder (TSFF). Bookham claims to have been first to market with TSFFs (in early 2007).

The TSFF has passed more than 2000 hours of testing (necessary for full qualification in accordance with Telcordia GR-468-CORE for integrated modules used in CO environments), proving its reliability and performance in a footprint 58% smaller than previous-generation tunable LFF (large form factor) transponders. The 2.2" x 3" footprint enables network equipment manufacturers to increase port density, placing two SFF transponders on a card where only one LFF would fit. The TL9000 is a direct drop-in replacement for the LFF devices, so customers can also leverage Bookham's already competitive pricing on existing cards using LFF, the firm says.

Now released to volume production, the TL9000 is being field-deployed by a tier-1 North American network provider, and Bookham expects to ship several hundreds of the devices during first-quarter 2008.



The TL9000 tunable SFF transponder.

"Our fully qualified optics, including receivers and transmitters, support products throughout our high-performance tunable portfolio," says executive VP and telecoms general manager Adrian Meldrum. "This vertical integration model, combined with key facilities in the UK and China, enables us to scale manufacturing and control production costs."

The universal nature of the product allows customization to individual specifications, whilst a standard but flexible platform design is used across all applications. This can reduce lead-time, decrease inventory costs, and allow production flexibility and cost optimization, says Bookham. The product can be configured with either a negatively chirped or zero-chirp transmitter for both regional metro and long-haul DWDM applications.

Responding to customer requirements, Bookham is also introducing new features to the configurable product platform. A variable optical attenuator (VOA) can be integrated into the co-planar receiver package within the transponder, extending the operating dynamic range of the Rx chain to powers greater than 8dBm and easing network design constraints. An extended-band transmitter with 100 50GHz-spaced ITU channels is also available, enabled by Bookham's DSDBR (digital supermode distributed Bragg reflector) tunable laser chip.

Bookham says that its ultra-compact InP Mach-Zehnder (MZ) transmitter is the key enabler for the SFF platform, and offers high performance for noise-loaded environments, equal to larger-sized rival technologies. Requiring a smaller voltage drive than other MZ modulator types it is claimed, the technology also enables typical module power dissipation of just 7W. The TL9000 operates at data rates of up to 11.3Gb/s, is fully compliant with the 300-pin transponder multi-source agreement (MSA), and is just 0.45" high, allowing room for airflow and heat-sinking to enable improved thermal management.

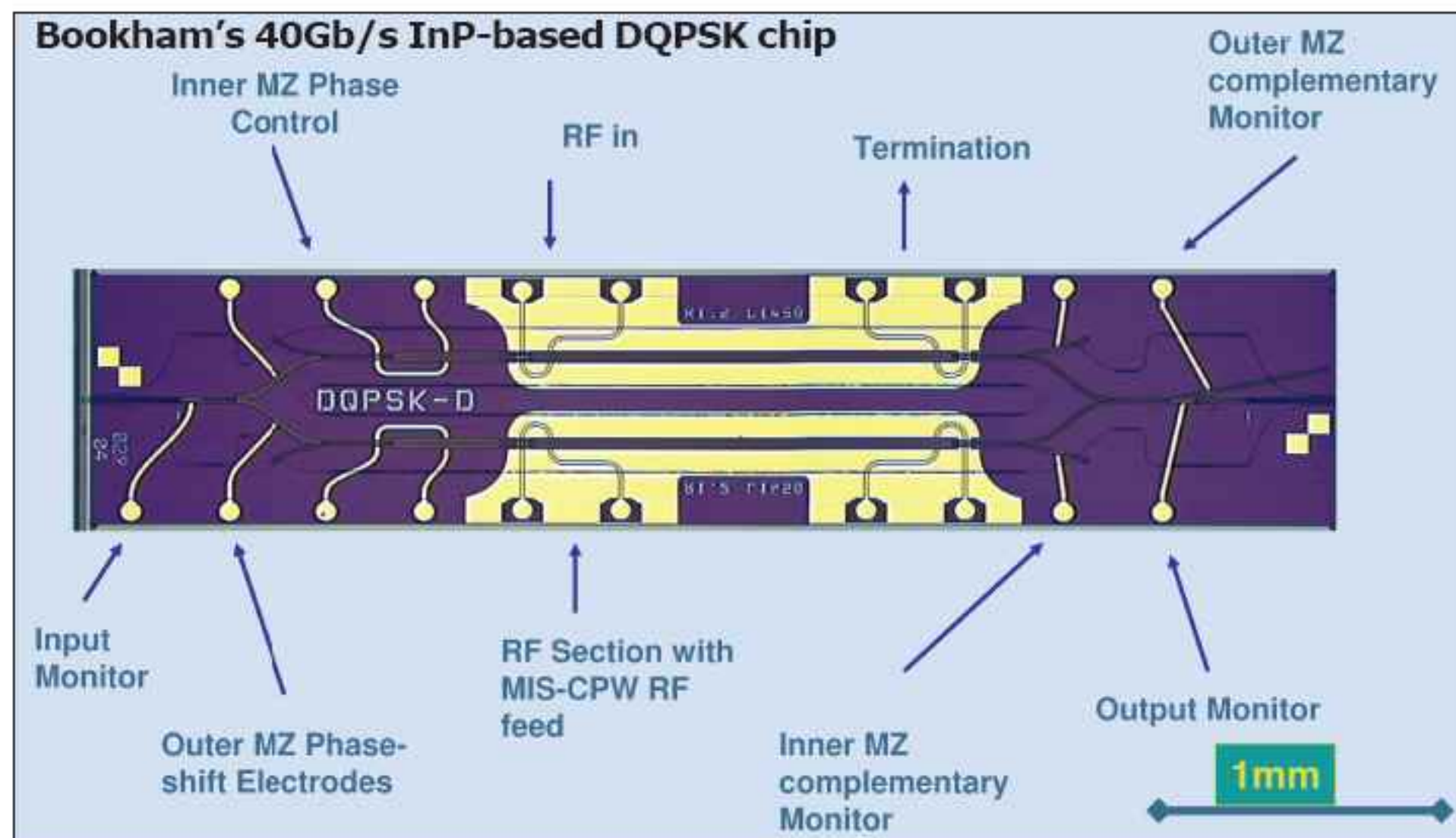
## Bookham launches 5mm 40Gb/s MZ modulator chip

At the Optical Fiber Communication conference (OFC 2008), Bookham demonstrated an ultra-small (5mm) 40Gb/s optical differential quadrature phase shift keying (ODQPSK) modulator chip, implemented via proprietary InP Mach-Zehnder (MZ) technology. The firm will combine this functionality with its tunable laser in new products for the 40Gb/s market.

The reduced-size InP MZ platform will allow Bookham to offer 40Gb/s products in smaller footprints compared to existing 40Gb/s offerings employing larger optics.

Bookham says it is now combining the 40Gb/s MZ modulator chips from its 3" wafer fab in Caswell, UK with its tunable lasers, such as the InP TL5000 Wideband Tunable iTLA, which has been proven for use in both 10 and 40Gb/s systems.

"The capability to offer high-bit-rate performance with our fully qualified, proven tunable laser and InP MZ modulator is crucial as vendors continue to evolve towards 40Gb/s networks," said PLM director, Adam Price. "40Gb/s roll out is still hampered by prohibitive pricing as we see 40Gb/s systems costing in excess of 10 times a 10Gb/s system. With our vertically integrated



InP core technology and strength in the 10Gb/s market, we are able to drive significant disruption in order to enable 40Gb/s systems to be adopted at a cost point that allows widespread adoption," he added.

"The InP MZ platform has the flexibility to implement a range of modulation schemes at 40Gb/s, but it is our vision that ODQPSK, in which we have significant Intellectual Property, is the modulation format to allow the correct price positioning at 40Gb/s, and the scalability to 100Gb/s. ODQPSK also allows 40Gb/s to be deployed onto

a 50GHz grid, and demonstrates higher resilience to polarisation mode dispersion," added Price.

"We have a proven InP capability to allow parallel modulator chip architectures to be implemented for the 40Gb/s approach and have produced an InP ODQPSK chip structure that is only 5mm long," Price concludes. "Traditional LiNbO<sub>3</sub> technology, which uses discrete modulators coupled together to form parallel structures, cannot compete with production simplicity and footprint size," he claims.

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

## Fully qualified 6W telecom-grade multimode pump module

Bookham also launched a fully qualified high-power multimode pump module offering up to 6W power.

Designed to provide the power and reliability required for pumping next-generation amplifiers in cable and FTTx networks, it offers a 50% power increase from the previous generation, and is thought to be the industry's highest-power telecom-grade multimode pump module.

Bookham says that the Telcordia GR-468-CORE qualified 6W uncooled fiber-coupled multimode laser diode allows service providers to extend triple-play service delivery to fiber users located further away from the central office or the cable head-end. The high-power product

supports various pumping applications and enables network providers to deliver a new class of optical amplifier based on erbium-doped air-clad fiber technology, the firm claims, allowing providers to replace DSL running on coax/copper with GPONs (Gigabit passive optical networks) running on fiber to deliver higher capacity and improved quality of service.

The 6W module is built on chips from Bookham's Zurich facility incorporating the firm's proprietary passivation technology, which suppresses catastrophic optical damage (COD) to the laser diode facet, even at very high power levels, says product line manager Simon Loten.

"The module offers vastly improved thermal impedance of the design, and an extremely efficient chip enables improved end-to-end power conversion, offering customers lower power consumption and reduced temperature dependency."

The pump module offers up to 6W in a 105µm multimode fiber with a numerical aperture (NA) of 0.22, and comes in a hermetically sealed two-pin package with a floating anode/cathode.

● The module is built on field-proven technologies used within Bookham's 980nm single-mode pump laser module series, which has now shipped 500,000 units since its introduction in 1995.

# Common specifications released for XLMD 40Gb/s pigtail devices

In conjunction with February's Optical Fiber Communication and National Fiber Optic Engineers Conference (OFC/NFOEC 2008) in San Diego, CA, USA, common specifications have been announced for pigtail-type optical devices based on the 40Gb/s miniature device multi-source agreement (XLMD-MSA), introduced in March 2007 by Eudyna Devices Inc, Mitsubishi Electric Corp, NEC Electronics Corp, Oki Electric Industry Co Ltd, Opnext Inc and Sumitomo Electric Industries Ltd.

The specifications detail the external-modulation laser transmitter devices with built-in driver ICs and the PIN photodiode with transimpedance amplifier (PIN-TIA) receiver devices that comply with the interface standard for SONET OC-768

synchronous optical networking at a transmission rate of 40Gb/s.

The XLMD-MSA specifications include:

- mechanical dimensions and pin assignments of pigtail-type optical devices;
- a high-speed electrical interface using dual SMPM connectors (small-sized coaxial connectors specified in MIL-STD-348A, such as GPPO);
- optical and electrical characteristics.

The metropolitan area networks (MAN), local area networks (LAN) and storage area networks (SAN) that form the backbone of broadband infrastructure currently use predominantly 10Gb/s optical transmission interfaces. The XLMD-MSA aims to establish compatible sources of 40Gb/s optical transmitter and receiver devices embedded

into corresponding 40Gb/s optical transceiver modules. The agreement should speed the growth of the 40Gb/s transceiver module

**The agreement should speed the growth of the 40Gb/s transceiver module market**

market, say the member firms. All members aim to promote MSA-compliant products in order to achieve consistent customer delivery and market growth.

The XLMD-MSA committee says that, in accordance with the future standardization of 40Gb/s pluggable optical transceivers, it will continue to discuss corresponding optical device specifications.

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

## Pirelli spins off PGT Photonics

At OFC/NFOEC 2008 in San Diego, Pirelli of Milan, Italy unveiled the name of its new company PGT Photonics, which had been incorporated at the beginning of February to specialize in second-generation photonics based on nanotechnologies.

PGT integrates the Photonics business unit of Pirelli Broadband Solutions and the Optical Innovation division of Pirelli Labs.

Pirelli describes the move as a strategic initiative to generate greater synergies between R&D activities and the commercialization of its growing product portfolio of optical components and modules.

"The OFC/NFOEC exhibition and conference is the ideal platform to announce to the industry the name of our new company PGT Photonics," said Claudio De Conto, general manager for the Pirelli Group and chairman of PGT Photonics. "With a

more flexible structure suited for the optical communications sector, we will be more closely focusing on our core business while simultaneously leveraging our expertise in order to meet the needs of the marketplace in a timely manner," he adds.

The establishment of the new firm coincides with the conclusion of the first phase of Pirelli Labs' research activity in optical technologies, which in the last 18 months has achieved validation of its initial products and rolled them out onto the market. The firm is focusing on innovative optical components, optical modules, and transportation systems, and has a growing product portfolio due to its laboratories in Milan-Bicocca and a network of international partnerships.

At the same time, Pirelli Broadband Solutions is concentrating its activity on broadband access business, which is increasingly characterized

by market and technology dynamics that are different from those of photonics, Pirelli says.

Having two companies with a presence in photonics and in broadband access, respectively, will allow Pirelli Group to consolidate its position further in both sectors, and to take advantage of opportunities that may arise, including through international alliances, the firm reckons. Both the new photonics company and Pirelli Broadband Solutions will continue to collaborate with researchers at Pirelli Labs Materials Innovation.

At OFC/NFOEC, Pirelli also displayed its product portfolio, which includes its DTL dynamically tunable laser, ITLA integrable tunable laser assembly, 300-pin MSA transponders (including tunable transponders with full C- and L-band coverage), and DWDM XFP pluggable transceivers.

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

# Hitachi and Opnext launch laser for 100Gb/s interface

In a post-deadline paper at OFC/NFOEC 2008 in San Diego, CA, Tokyo-based Hitachi Ltd and optical module and component manufacturing spin-off Opnext Inc of Eatontown, NJ, USA announced the first wide temperature range operation of a 1310nm 25Gb/s EA-DFB (electro-absorption modulator with integrated distributed feedback laser) for 100 Gigabit Ethernet (100GbE) 10km single-mode fiber (SMF) applications.

A study by the IEEE HSSG (High Speed Study Group) showed that, by 2010, the bandwidth required in core networking will be best satisfied by 100Gb/s interfaces. Also, bandwidth needs are expected to double every 18 months, resulting in demand for multi-port 100Gb/s systems. A 10km single-mode fiber 100Gb/s Ethernet specification is being discussed by the IEEE 802.3ba taskforce. For this application, 1310nm four-channel x 25Gb/s WDM (wavelength division multiplexing) transmission is the most attractive technology, say the firms.

One of the technology challenges is to achieve 1310nm 25Gbit/s WDM optical devices. CWDM (course wavelength division multiplexing) technology is expected to be the most cost-effective solution due to the wide wavelength pitch, which enables 100% wavelength yield and either less strict or no temperature control.

Using high-speed device technology that has already been proven in 1550nm

40Gb/s EA-DFB lasers used commercially in 40Gb/s transceivers, Hitachi and Opnext have demonstrated EA-DFB lasers operating at 25Gb/s with wavelengths of 1290, 1310, 1330 and 1350nm.

Also, a wide operating temperature range of 0–85°C was achieved by the use in the electro-absorption

**Uncooled operation is the key to achieving small and low-cost 100GbE transceivers for LANs**

(EA) modulator section of aluminum-based material which has a temperature-tolerant band-gap structure that decreases the temperature-dependent performance of the modulator.

The firms say that the EA-DFB lasers demonstrate the technical feasibility of the CWDM grid, which achieves low-cost 100Gb/s optical transceiver modules with low power consumption and compact size. This is expected to speed adoption of 100Gb/s interfaces in the network.

The 25Gb/s 1310nm CWDM EA-DFB lasers are based on Hitachi's uncooled high-speed laser technology, which has already been demonstrated in previous uncooled 10Gb/s and cooled 40Gb/s EA-DFB lasers, says Masahiko Aoki of Hitachi's Central Research Laboratories. "We believe that uncooled operation is the key to achieving small and low-cost 100GbE transceivers for local-area network (LAN) application," he adds.

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

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

## Opnext gives 100Gb/s and 43Gb/s live demonstrations

At OFC/NFOEC 2008, Opnext gave several live demonstrations, including the following:

- Opnext's first live demonstration of 100Gb/s client-side technology, showing how 100 Gigabit Ethernet (100GbE) transmission can allow increased bandwidth of connections in the core networking area using a simple system configuration with less fiber and fewer optical modules per interface, while maintaining low power consumption and meeting cost constraints. This market is expected to grow strongly, supported by increased numbers of end users (as committed to by a number of ISPs), increased access

rates and methods, and increased services targeted for end-users.

- A 43Gb/s tunable 5x7" 300-pin transponder module (the TRV7BA0) using phase-shift keying and incorporating the SFI-5 interface for long-haul dense wavelength division multiplexing (DWDM) applications, enabling a transition from discrete components to an integrated solution for up to 43Gb/s line-side applications.

- Opnext's portfolio of SFP+ transceiver modules have compact size and low power consumption, enabling increased density of high-speed networking systems, and include: a full range of 8 Gigabit

Fiber Channel modules for storage area networks, plus 10GbE SFP+ modules ranging from long-reach single-mode-fiber applications to short-reach multi-mode-fiber transmission as well as long-reach multi-mode (LRM) and a cost-effective ultra-short-reach option.

"These are exciting times for 100G and 40G advancements," said Opnext's president and CEO Harry Bosco. Technologies demonstrated at OFC/NFOEC are key elements to enabling these markets, he reckons. "Opnext continues to invest in photonic device research and development that allow the integration of such offerings."

# Avanex launches platforms for long-haul, metro and access

At OFC/NFOEC 2008 in San Diego, optical communications component and module maker Avanex Corp of Fremont, CA, USA unveiled several new platform solutions that address critical needs for next-generation optical networking, including small-form-factor tunable transponders, tunable dispersion compensation for terminal equipment, X-cut and Z-cut lithium niobate modulators, tunable WSS/ROADMs, and lower-cost, intelligent Oasis optical amplifiers.

"Our platform discipline focuses on common aspects of design that enable cost reduction — wherever possible, we are rationalizing our product development around standard architectures," says senior VP and general manager Pat Edsell.

"We are now meeting the customer demands for performance required for 40Gb/s and 100Gb/s applications, while continuing to drive cost out of our products and dramatically reduce our time-to-market for development," he adds. "The approach also greatly simplifies our manufacturing world, decreasing lead times dramatically at the same time that we lower inventory costs."

"The common aspects of design in these platforms include characteristics and features to enable efficiency, tunability, flexibility, and scalability," adds senior VP and chief technology officer Giovanni Barbarossa. "These include digital control blocks, programmable functions, real-time monitoring

capabilities, increased capacity through smaller form factors, and value-added synergies with other Avanex products, such as transmission plus tunable dispersion compensation for enhanced reach."

CEO Jo Major added, "After a period in which component and subsystem suppliers have focused diligently on cost reduction in their product lines, we are now moving aggressively to address carriers' intensive focus on systems capable of meeting growing capacity requirements in a cost-effective and elegant way... The new emphasis for Avanex is to produce platform solutions that can play a decisive role in reducing dollars spent per bit transmitted."

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

## SFF 10Gb/s tunable transponder

Avanex has broadened its tunable transponder portfolio by unveiling its PowerReach 2280 line of SFF small-form-factor tunable transponders with a live demonstration at OFC/NFOEC. Applications include dispersion-compensated long-haul DWDM and metro links up to 80km.

The SFF products offer the performance of the large-form-factor (LFF) PowerReach 1280 but in a much smaller footprint, allowing a doubling of line-card port density to help meet demand in metropolitan markets.

The 2280 operates over all data rates from 9.9–11.3Gb/s and is housed in a 300-pin multi-source agreement (MSA) SFF package (3" x 2.2") with standard electrical interfaces. The module integrates Avanex's XS-10 lithium niobate modulator to deliver best-in-class reach, extinction rate, eye quality, thermal dissipation, OSNR system performance, and EOL Rx sensitivity, is available with zero or negative chirp for transmission

flexibility, and can be ordered with either APD (avalanche photodiode) or PIN receiver functionality.

"The PowerReach 2280 transponder delivers the benefits of a reduced form factor and best-in-class performance at reduced cost," says Jeff Zack, general manager of Transmission products. Also, it comes with design features that provide highly reliable, long-reach transmission network solutions, he adds. These include programmable I2C functions compatible with the 300-pin MSA I2C specification edition 4.2, multi-rate jitter filtering, and transmit and receive options such as analog monitoring, adjustable performance parameters, and digital controls.

The 2280 represents an example of Avanex's aim to create highly cost-sensitive, smart and flexible products that enable the system provider to manage their operational expenses while scaling their application quickly, adds senior VP of sales Scott Parker.

## XFP transceivers for long-reach DWDM and TDM

Avanex also launched new 10G XFP transceivers for 40km and 80km transmission in access and metro networks. The PowerPort 2080, for TDM applications, and the PowerPort 2180 for DWDM applications, are 10Gb/s EML-based transceivers that provide a high-performance and lower-power-dissipation reach capability up to 80km.

The improved thermal performance of the PowerPort XFP products enables extended reach in any standard XFP enclosure, it is claimed. This allows higher port density on the system board, cutting overall cost to system providers and providing opportunities for system expansion. The PowerPort XFP platforms also support multiple rates up to 11.3Gb/s and are fully compliant with all ITU-T and XFP MSA standards.

Both PowerPort models are in production and available for sampling.

# Vitesse & Finisar demo uncompensated 10Gb/s 300km link for metro regional networks

At OFC/NFOEC 2008, fiber-optic component and subsystem maker Finisar Corp of Sunnyvale, CA, USA and Vitesse Semiconductor Corp, which designs and sells ICs for carrier and enterprise networks, demonstrated technology for a 300km optical link operating at 10Gb/s using standard non-return to zero (NRZ) modulation that does not require dispersion compensating fiber (DCF). This is thanks to using Finisar's tunable DM200 chirp-managed laser (CML) transmitter and Vitesse's new VSC8240 clock & data recovery (CDR) IC with integrated electronic dispersion compensation (EDC). The combination provides a low power solution (< 2.5W) that eliminates the need for expensive dispersion compensation modules in 10Gb/s metro DWDM networks.

"The result of this collaboration enables our telecom OEM customers

to design transmission equipment that will achieve a 300km reach using Finisar's DM200 butterfly package and Vitesse's EDC chip," says Finisar's marketing director Frank Fan.

Based on Finisar's proprietary CML technology, the DM200 transmitter is available in a transmitter optical sub assembly (TOSA) format or butterfly package and is capable of 4 x 100GHz or 8 x 50GHz narrow tunability across C-band and L-band wavelengths. The CML uses a directly modulated standard DFB laser and a passive optical spectrum reshaping (OSR) filter to achieve extended reach.

The VSC8240 is a low-power, CMOS-based CDR with integrated EDC functionality derived from Vitesse's complete line of EDC and physical layer products covering 10 GbE and SONET/SDH applications for carrier Ethernet and optical

transport networks. It is suited to single receive path applications, such as single-mode fiber (SMF) reach extension applications, in 300-pin modules. The production-ready VSC8240 compensates for both SMF chromatic dispersion and polarization-mode dispersion in a poor optical signal-to-noise ratio (OSNR) environment. Using a decision-feedback equalizer and feed-forward equalizer (DFE/FFE) EDC architecture, it implements an integrated, self-adaptive algorithm that eliminates costly system adjustments.

The collaboration with Finisar illustrates Vitesse's commitment to working with optical module providers to speed and simplify the creation of next-generation fiber applications, said Tony Conoscenti, Vitesse's VP product marketing.

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

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

## Finisar demos 17Gb/s VCSELs for 16G Fiber Channel

Finisar also gave the first public demonstrations of three products:

- an 850nm VCSEL for the emerging 16G Fiber Channel standard;
- a 200km 10Gb/s DWDM XFP transceiver module based on the firm's CML (chirp-managed directly modulated laser) technology; and
- a 40km SFP+ transceiver module.

Finisar demonstrated a complete optical link using a 17Gb/s directly modulated VCSEL, establishing the viability of the 16G Fiber Channel standard with multimode optical fiber. The 17Gb/s VCSEL line rate is required to support the 16G Fiber Channel payload, and should enable the next generation of Fiber Channel optical transceivers.

In 1996, Finisar developed the first commercially available 1Gb/s VCSEL. Finisar has since become the largest datacom VCSEL supplier, with over 70 million deployed.

"There is a significant difference between achieving 17G under controlled laboratory conditions and demonstrating a reliable implementation in a public environment such as OFC," said Joe Young, Finisar's general manager of optics. "This particular demonstration proves the viability of the optical components required to develop the 16G Fiber Channel standard."

Finisar also demonstrated advances in other technologies, including:

- The first public demonstration of a fully MSA-compliant 10Gb/s DWDM XFP transceiver module (based on its CML technology) for OC-192/STM-64 and 10 Gigabit Ethernet (10GbE). The transceiver transmits error-free over 200km of single-mode fiber with power consumption of less than 3.5W, and enables 50GHz channel spacing for increased traffic-carrying capacity.

- An SFP+ transceiver module enabling error-free 10GbE transmission over 40km of single-mode fiber. With power consumption well below MSA requirements of 1.5W, Finisar claims that the technology enables the highest 10G port densities for system vendors that have invested in next-generation SFP+ platforms and want to extend Ethernet into metro networks.

Finisar also exhibited a wide range of networking solutions, including Laserwire, the first 10Gb/s serial active optical cable for low-cost, high-speed serial connectivity (an alternative to copper cabling that consumes nearly 95% less power than 10GBase-T solutions). Finisar also demonstrated advanced bit error rate testing (BERT) technology for 40G/43G SONET/SDH/OTU3 applications built on its Xgig test and analysis platform.

# Finisar's quarterly revenue grows 12% to a record \$112.7m

For its fiscal third-quarter 2008 (ended 27 January), Finisar Corp of Sunnyvale, CA, USA reported record revenue of \$112.7m (exceeding November's forecast of \$104–108m).

Network test & monitoring systems yielded \$9.8m (flat on last quarter). Optical subsystems and components yielded \$103m (up 13%), including: \$55.3m for LAN/SAN (up 9%); \$18.7m for metro (up 19%); and \$24.9m for telecoms (up 21%).

Total revenue was up 12% on last quarter's \$100.7m, due to: revenue from 8Gb/s Fibre Channel storage-area network (SAN) transceivers exceeding \$2m; 10–40Gb/s product revenue rising 60% from \$18.2m to a record \$29.1m (up \$8m due to shipments of SFP+, XFP and X2 transceivers for 10Gb/s Ethernet and SONET applications; up \$2m from shipments of 40Gb/s 300-pin transponders delayed from last quarter after firmware problems).

Excluding charges of \$17.6m (with \$7.4m related to completion of the stock option investigation), gross margin rose from 37% to 38.2% (reflecting the richer product mix due to greater 10Gb/s revenues). Net income rose from \$2.5m to \$6.7m.

Cash reserves grew from \$114.9m to \$122.4m. However, this is down from \$135.9m a year ago due to the \$13.9m acquisition in fiscal Q4/2007 (last March–April) of photonic component and subsystem manufacturer AZNA LLC of Wilmington, MA and transponder manufacturer Kodeos Communications Inc of South Plainfield, NJ (with the aim of developing products for long-haul telecoms, a market not addressed previously).

R&D expenses were up \$1m on the prior quarter (related mainly to developing ICs for the firm's transceivers) and up \$2m year-on-year (due mostly to the AZNA and Kodeos acquisitions).

"It was gratifying to see our revenues reach record levels after spending the last few quarters working our way through several customer-specific issues," says president and CEO Jerry Rawls. "Demand for our products for 10–40Gb/s was particularly robust this past quarter, and we expect that demand will remain healthy for the foreseeable future," he adds. "We will continue to innovate and introduce new products for both the data center and telecom markets."

In datacoms (i.e. products for 1 and 10 Gigabit Ethernet LAN and 2, 4 and 8 Gigabit SAN applications), fiscal Q3/2008 revenue was \$78m, up from \$70m the prior quarter (driven by enterprise spending).

Following the higher-than-expected 1Gb/s LAN/SAN revenue in fiscal Q3/2008, combined with revenue from test equipment for 8Gb/s applications nearly doubling, SAN business may be surprisingly strong in calendar 2008, adds Rawls.

In addition, the growing adoption of virtualization and data centers should increase demand for high-speed optics in the SAN market. However, datacom sales have been constrained by Finisar's lack of 10 Gigabit Ethernet products, says Rawls. The datacom market for 10Gb/s applications alone is estimated to be \$320m in calendar

**Datacom sales have been constrained by Finisar's lack of 10 Gigabit Ethernet products... The datacom market for 10Gb/s applications alone is estimated to be \$320m in calendar 2008 (up from \$250m in 2007)**

2008 (up from \$250m in 2007), but Finisar's revenue was just \$30m in 2007 (including \$13m coming in the last quarter). Despite historically focusing on the XFP form factor, about \$10m of the revenue in that last quarter came from products just introduced and qualified in the previous few quarters (X2-SR, XFP-SR and, more recently, SFP+, all for short-distance 10Gb/s data-center applications). SFP+ is developing faster than I expected, says Rawls. "Revenues have grown very nicely with a number of customers both for 10 Gigabit Ethernet and for 8 Gigabit Fiber Channel. So, we expect that it's going to be a mainstream product, because it offers really excellent density and low power."

"There are several products we will qualify to gain a competitive exposure to this portion of datacom market," says Rawls. These include X2 LRM, for the transmission of 10Gb/s signals up to 220m over multi-mode fiber (typically found in buildings) and X2LR and ZR for longer-distance metro applications. "We will be working hard to qualify our products in the next couple of quarters," he adds.

Short-wavelength SAN business should therefore be strong, with additional 10Gb/s revenues: "We can continue to grow [SAN] revenues in each quarter beyond Q1/2009, especially when we consider some of the trends at work in this industry in 2008 and 2009," reckons Rawls.

In telecoms, however, Finisar's opportunity for growth has been limited by its lack of long-haul products, says Rawls. Long-haul sales are currently very small, as much of its revenue is in LAN/SAN (over distances of less than 500m) and metro (up to 120km — this includes SONET/SDH, although

telecoms is an emerging market for Finisar, acknowledges Rawls). For example, of the \$29.1m revenue from 10–40Gb/s products, revenue for short-reach LAN applications (including X2 SR, XFP SR and SFP+) was \$9.9m (almost double the \$5.2m last quarter), and revenue for 10Gb/s metro applications (mostly XFP transceivers) was \$3.1m (also almost doubling from \$1.7m), while 10Gb/s telecom revenue (also mostly XFP transceivers) was \$16.1m (up 'just' 43%, from \$11.3m).

While the smaller XFP form factor is increasingly being adopted by telecom equipment suppliers, the 10Gb/s 300-pin tunable transponder market remains strong. Finisar estimates that, out of a \$500m market for 10Gb/s telecom products in 2008, XFP represents only about 25% of the market.

The strategy is therefore to launch products that have higher levels of performance. "We are working hard to increase our exposure to this market opportunity through the introduction of a small-form-factor 300-pin transponder for 10Gb/s tunable applications that is based on reliable CML [chirp managed laser] technology from AZNA," says Rawls. CML competes with lithium niobate external modulators by reducing the size and cost of components needed for longer-

distance transmission [up to several hundred kilometers] while reducing power consumption, he adds.

At the Optical Fiber Conference in San Diego, Finisar demonstrated this technology in two new products: the first narrowly tunable 200km 10Gb/s DWDM XFP transceiver for OC-192 and 10 Gigabit Ethernet applications; and a 10Gb/s SFP+ transceiver, which operated over 50km of fiber while using less than 1.5W of power.

The AZNA and Kodeos acquisitions have yet to generate a significant amount of incremental revenue. However, Finisar expects to launch several new products towards late 2008 and in 2009, which should start to boost long-haul revenue.

In fiber-to-the-home (FTTH), Finisar has not yet had any exposure to the market for transceivers.

**The 10Gb/s 300-pin tunable transponder market remains strong... out of a \$500m market for 10Gb/s telecom products in 2008, XFP represents only about 25%**

However, last year it introduced a Gigabit passive optical network (GPON) transceiver for FTTH. It is now engaged with several customers in qualifying the product.

According to consulting firm Light Counting, the FTTH transceiver market was over \$300m in 2007 and is expected to grow

to \$350m in 2008. The GPON portion was just \$27m in 2007, but is expected to grow to over \$60m in 2008 and over \$100m in 2009. Despite being a very competitive

**Finisar expects to launch several new products towards late 2008 and in 2009, which should start to boost long-haul revenue**

part of the telecom sector, Finisar believes it can achieve reasonable gross margins (comparable to its 1–8Gb/s LAN/SAN margins). Offering these products is in line with its objective to

become a strategic supplier to telecom equipment manufacturers by offering them a broader product line, Rawls says. "We are very excited about the prospects for growth in the telecom portion of our business, both near-term and longer-term," he adds.

Overall, for fiscal Q4/2008, taking into account that fiscal Q3 benefited from \$2m of 40Gb/s product shipments delayed from Q2, Finisar expects revenue of \$110–115m (\$10m from network tools, plus \$100–105m from optics, with 10–40Gb/s applications rising from \$29.1m to \$30–35m, comprising most of the revenue growth).

For Q1/2009 (ending in July), revenue should rise to \$113–120m. Overall, customer demand remains strong, says Rawls. "We think fiscal 2009 will be a better year than 2007 and our fiscal 2008."

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

## NASDAQ gives Avanex 6 months to regain \$1 share price

Optical communications component and module maker Avanex Corp of Fremont, CA, USA has received a letter from NASDAQ's Listing Qualifications Department confirming that, for the previous 30 consecutive trading days, the bid price of the firm's common stock closed below the minimum \$1 per share requirement for continued listing.

Avanex will therefore be given 180 days (until 2 September) to regain compliance with the minimum \$1 per share bid price requirement.

However, if (at any time before 2 September) the bid price closes at or above \$1 per share for at least 10 consecutive trading days (or a longer period of time as may

be required by NASDAQ, at its discretion), then Avanex expects written notification that it has complied with rule 4450(a)(5).

Avanex says that it will consider the implementation of various options available to it if its common stock does not trade at a level that is likely to regain compliance.

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

# Optium's record revenues driven by 40Gb/s and ROADMs

For its fiscal second-quarter 2008 (ended 2 February), optical sub-system maker Optium Corp of Horsham, PA, USA has reported record revenue of \$40.3m (up on December's guidance of \$38–39m). This is also up 11.6% on \$36.1m the prior quarter and up 18% on \$34.1m a year ago, driven by sequential growth in reconfigurable optical add/drop multiplexers (ROADMs), analog and cable TV and 40Gb/s products.

In particular, revenue from 40Gb/s products more than doubled and revenue from ROADM products grew by 90% on the prior quarter, as Optium continues to ramp their production capacity aggressively. About 18% of revenues came from from these new product areas, compared to less than 1% a year ago.

"We are continuing to manage through volatility in demand for 10Gb/s products from one of our larger customers by making great

progress in growing revenues through each of our targeted growth platforms," says chairman and CEO Eitan Gertel. "We introduced new high-performance product technologies, expanded capacity for our new product lines and continued to develop relationships with new customers worldwide, particularly in Asia," he adds.

Compared with net income a year ago of \$3.9m, net loss was \$0.8m for the latest quarter, due mainly to operational expenditure made to diversify the product portfolio (ramping capacity for the 40Gb/s and ROADM products in fiscal 2008), as well as litigation expenses (from defending patent infringement lawsuits related to cable TV products). However, this is an improvement from a net loss of \$1.1m the prior quarter.

Cash reserves have almost doubled from \$25.4m to \$47.8m over the last two quarters.

"Our execution in the first half of the fiscal year gives us added confidence that we will meet our objective for annual growth of at least 30% for fiscal 2008," says Gertel.

For fiscal third-quarter 2008, Optium expects revenue to grow to \$42–44m.

"We are growing our company by expanding our product portfolio and production capacity to address high-growth segments of the optical communications market while building a stronger presence with new customers around the world," Gertel says. "Continued momentum in each of these product areas [40Gb/s and ROADMs] is expected to result in growing operating leverage over time. In the near term, we are focused on satisfying the strong customer acceptance of our new product introductions, which has required additional operational investments," he concludes.

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

## Santur launches low-profile version of 10Gb/s tunable transmitter engine for SFF and XFP-E formats

Santur Corp of Fremont, CA, USA, a vertically integrated manufacturer of parallel photonic-array devices for the telecoms industry, has announced the development of the TLMZ-LP low-profile version of its 10Gb/s Tunable Transmitter Engine.

The TLMZ-LP integrates Santur's tunable laser with an InP-based Mach-Zehnder modulator, engineered for the requirements of transmission in either long-haul or metropolitan optical networks (for data, voice and cable TV traffic). Both zero-chirp or chirped versions are available. Their low profile and compact footprint suit use in SFF (small form factor) transponders

and XFP-E pluggable transceivers, says the firm. Santur says that the

**By integrating the tunable laser with the MZ modulator in a low-profile compact footprint package, this allows tunable transceivers to be used in the pluggable XFP-E format**

device brings tunability into metropolitan access networks and doubles the port density in the metro core networks.

"By integrating the tunable laser with the Mach-Zehnder modulator in a low-profile compact foot-

print package, this allows tunable transceivers to be used in the pluggable XFP-E format," says chief technical officer Bardia Pezeshki.

It also eliminates the need to source a separate tunable laser and modulator, as well as the need for polarization-maintaining fiber and a splice or connector between the laser and modulator.

Santur says that it is currently sampling the TLMZ-LP to customers. "Our customer partnerships are making rapid adoption of this new technology possible," says CEO Paul Meissner.

Volume production is scheduled for Q3/2008.

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

# Opnext's profits fall due to parts supply problems

For its fiscal third-quarter (to end December 2007), optical module and component manufacturer Opnext Inc of Eatontown, NJ, USA has reported revenue of \$66.4m, down on its original guidance of \$77–80m and down 13.3% from \$76.6m the prior quarter.

The firm says that this drop is due to lower demand for 300-pin fixed-wavelength products, vendor quality and production delays that limited shipment of 40Gb/s products, plus lower X2 and SFP product revenues, partially offset by increasing demand for XFP products.

Compared to the prior quarter, revenue included \$53.9m for 10Gb/s and above products (down 15.1% from \$63.5m) and \$7.5m for less than 10Gb/s products (down 8.2% from \$8.2m), but \$4.9m for industrial and commercial products (up 1.8% on \$4.8m).

Cisco and Alcatel-Lucent fell from 40.9% and 23% of sales to 37.6% and 19.9%, respectively.

Net income fell from \$5.8m to \$4.3m. Cash and cash equivalents rose by just \$1m to \$203.4m, as \$2.5m of cash from operations was partially offset by additional investments to expand manufacturing capacity and fund the payment of capital equipment lease obligations.

"Following this tough December quarter, we expect to resume our path of sequential revenue growth as we continue our course of profitability," says president and CEO Harry Bosco. "While there will continue to be uncertainty in any given quarter due to our customers' limited near-term visibility, we believe that growth in broadband applications will continue to drive the demand fundamentals of our business," he adds.

"We have accelerated key initiatives, such as additional sourcing of critical parts and increased levels of buffer stocks, which should serve to make us more resilient to the supply issues that plagued us in the December quarter," Bosco continues.

"In addition, our demand forecasting procedures, supported by our automated systems, continue to be refined for shorter intervals to ensure that manufacturing is better aligned with our customer needs."

**The 10Gb/s and above market segment should continue to grow more rapidly than the overall optical market**

Although Opnext believes that the 10Gb/s and above market segment should continue to grow more rapidly than the overall optical market, lack of short-term visibility on the part of some customers, coupled with broader economic uncertainty, has caused it to take a cautiously optimistic view of guidance for next quarter, says Bosco.

For its fiscal fourth quarter (to end March), Opnext expects revenue to recover slightly to \$67–70m.

## ● Back in NASDAQ compliance

Opnext received a NASDAQ Staff Determination Letter on 20 February indicating that, due to its expected restatement of certain financial statements and its resulting inability to timely file its report on Form 10-Q for the quarter to end-December 2007, it was not in compliance with the filing requirements for continued listing of its common stock on the NASDAQ Global Select Market set forth in Nasdaq Marketplace Rule 4310(c)(14).

However, now that Opnext has filed the quarterly report, it has since been notified by the NASDAQ Listing Qualifications Department that it is back in compliance and that the matter is now closed.

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

## Opnext promotes NA sales VP to SVP global sales

Opnext says it has promoted James (Atsushi) Horiuchi, VP of North America sales, to senior VP global sales (including North America, Europe and Asia Pacific). He replaces Christopher Lin, who has resigned to pursue other opportunities. The promotion expands Horiuchi's responsibilities to bring additional focus on strategic initiatives relating to

market growth and serving the global customer base.

"He was and continues to be a driving force behind our domestic and international expansion efforts," says president and CEO Harry Bosco. "He will continue to further our sales initiatives in this new position."

Horiuchi has been with Opnext since 2001, and has been

instrumental in building the North America sales division. He has more than 23 years experience in sales, R&D, manufacturing, and senior management in both Japan and the USA, including more than 10 years in the fiber-optics industry. Prior to joining Opnext, Horiuchi was at Infineon Technologies and Hitachi Semiconductor America.

# Euro roadmap for photonics and nanotechnologies

After a two-year process involving workshops, symposia and interviews with experts, the project Merging Optics and Nanotechnologies (MONA), which was launched in June 2005 and is funded by the European Commission within its 6th Framework Program (FP6), has released the 'European Roadmap for Photonics and Nanotechnologies'. This identifies potential synergies between photonics/nanophotonics and nanomaterials/nanotechnologies.

The roadmap's main component is identification of the highest-priority economic growth areas, taking into account market size, market growth, and the positioning of European industry and research in these areas.

The three principal objectives of the roadmap are to:

- create a consensus viewpoint on the development of research, technologies and innovation;
- promote the timely worldwide exchange of scientific results, market development perspectives, and technology trends;
- contribute to the intelligent deployment of developmental resources at the regional, national, and European levels.

Key nanomaterials that are identified as having the strongest impact for nanophotonics include: quantum dots and wires in silicon, III-V and II-VI materials; and high-index-contrast silicon and III-V nanostructures.

The roadmap also identifies key devices for major applications, and makes corresponding recommendations, including:

- for photovoltaics, develop III-V quantum dot (QD) technology with better control of QD formation, allowing improved efficiency;
- for imaging, maintain R&D on III-V QD infrared sensors (which can improve responsivity, boosting performance and potentially simplifying fabrication), with key players such as France's Sofradir interested as an alternative to mercury cadmium telluride (MCT) and conventional quantum-well infrared photodetectors (QWIPs);
- for lighting (involving major players Osram in Germany and Philips in The Netherlands), intensify R&D on ZnO nanowire-based LEDs (to improve p-type doping, carrier injection and manufacturability) and LEDs using III-V photonic crystal (to develop a low-cost process, with optimized light extraction);

- for datacoms/telecoms (involving major players Bookham in the UK and 3S Photonics in France), maintain R&D on further chip-level electronic/photonics integration (including developing low-cost, wafer-scale approaches to incorporating III-V devices on Si, for low-cost, high-performance optical links and low-cost optical transceivers);

- for sensors, maintain R&D on II-VI QD-based fluorescent markers (to achieve accurate control of the size distribution, for enhanced sensitivity in biosensors);

- for optical interconnects, maintain R&D on III-V QD laser sources (to improve manufacturability, CMOS compatibility and temperature stability, for compact, high-data-rate devices that are manufacturable using microelectronics equipment).

MONA says its roadmap has been developed in the context of worldwide contributions and competition, with strategic cooperation with roadmap-ping activities in Japan, Korea, Taiwan and the USA ensuring overall relevance. It is intended to serve as an input to funding decisions for future EC FP7 work programs.

In particular, results can be used to build upcoming strategic research agendas for both nanomaterials and photonics.

Interested parties are encouraged to distribute the document, which is available at the web address below. The roadmap will be updated regularly, allowing the nanophotonics community to stay informed on the research and industrial evolution of nanophotonics.

[www.ist-mona.org](http://www.ist-mona.org)

**It is intended to serve as an informed input to research funding decisions for future EC FP7 work programs**

## MONA project members

More than 300 professionals in industry and academia contributed to the content of the MONA Roadmap, including the following project members:

- project leader CEA LETI of France;
- Alcatel-Thales III-V Lab;
- market research firm Yole Développement;
- Paris-based network Optics Valley;
- the European Photonics Industry Consortium (EPIC);
- epitaxial deposition equipment maker Aixtron AG of Aachen, Germany;
- glass-maker Schott AG and research organization VDI Technologiezentrum GmbH (VDI TZ) of Germany;
- process equipment maker ASM International of The Netherlands;
- independent research institute IMEC of Belgium; and
- contract R&D firm Acreo AB of Sweden.

## Emcore launches uncooled 1310nm coaxial lasers

Emcore Corp of Albuquerque, NM, USA, which makes components and subsystems for the broadband, fiber-optic and solar power markets, has launched the 1933 DFB family of uncooled coaxial distributed feedback lasers, offering a low-cost solution for 1310nm linear fiber-optic links.

Due to its design, the 1933 series requires no additional cooling, since it can maintain performance even with case temperatures ranging from  $-40^{\circ}\text{C}$  to  $+80^{\circ}\text{C}$ , says Emcore. The 1933 also features high slope efficiency and linearity, even with optical output powers up to 12dBm, the firm claims.

The lasers are packaged in a compact hermetic assembly

together with a monitor photodiode and isolator, for flexible integration into various transmitter configurations. Combining the lower cost of a coaxial package with Emcore's linear optical devices creates an advantage in cost and performance over cooled laser solutions by minimizing the amount of stability control circuitry required to maintain performance over wide temperature ranges, the firm says.

"The 1933 family of DFB lasers expands Emcore's discrete laser product offering. By leveraging our vertical integration and technical heritage in linear fiber optics, we can now offer a low-cost solution," says Gyo Shinozaki, director of marketing for Emcore Broadband.

The 1933F and 1933R models feature forward and return path laser solutions for hybrid fiber-coaxial (HFC) plants, and the 1933W provides a competitive solution for wireless networks. These market segments are expected to grow as operators continue to add more interactive services, reckons the firm. Emcore sees applications throughout North America, Asia Pacific and Europe in both segments.

All variants of the 1933 family are currently sampling, and high-volume production is being readied at Emcore's Langfang manufacturing facility in China, which is expected to come on line in May.

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

## Emcore enhances 1550nm transmitters and fiber amplifiers

Emcore has announced new features for its 1550nm broadband transmitter and optical amplifier product lines. To support the requirements for extended bandwidth CATV systems and RF overlay for PON networks, the new products offer 1GHz RF performance, dual hot-swappable power supplies and SNMP management capabilities.

Emcore's new Medallion 5000 series of externally modulated transmitters offer a 45–1003MHz RF passband with user-adjustable SBS (stimulated Brillouin scattering) suppression capabilities and transmitter output power of +11dBm. Available with wavelength-select lasers that operate on the ITU grid and capable of supporting optical launch powers of up to +22dBm directly into the fiber when used with an Emcore optical amplifier, the Medallion 5000 series delivers high-quality analog and digital data over distances of up to 100km, the firm says. Also, the extension of operational bandwidth to 1GHz allows network operators to future-proof their network to support expanding choices

of standard digital and high-definition video content.

The new PONA 2200 and PONA 3200 series optical amplifiers provide optical output power of +14–35dBm over the entire C-band.

PONA 2200 amplifiers are 1 RU (rack unit), and are available with optical outputs of +14–27dBm.

PONA 3200 amplifiers are 2 RU and have +27–35dBm optical output. Multiple optical output configurations are available, with up to 32 output ports for the PONA 3200 high-power amplifier allowing highly flexible and customizable network designs, with significant cost per watt savings for fiber-to-the-home (FTTH) 'blast and split' architectures.

**In North America alone, an estimated 10 million homes are now passed with fiber, and global FTTH connections will grow from 20 million homes in 2007 to as many as 90 million homes by 2012**

"These new transmitters and optical amplifiers are ideal for extending traditional CATV systems such as head-end consolidation and broadcast transport," says Christopher Larocca, VP and general manager of Emcore Broadband. "Additionally, new FTTH projects in countries around the world are representing a significant and growing market opportunity. In North America alone, an estimated 10 million homes are now passed with fiber, and global FTTH connections will grow from 20 million homes in 2007 to as many as 90 million homes by 2012," he adds. "Network providers are demanding high-quality and economical delivery of video to their customers, while extending capacity and improving network management intelligence. The enhanced features, and cost-effective designs leveraged from Emcore's long-established experience in 1550nm transmitter and EDFA technology exceeds the demanding needs of today's networks," he claims.

Demonstration units will be available in second-quarter 2008.

# GGE places \$39m follow-on order for Emcore concentrator photovoltaic receiver assemblies

In late February, Emcore Corp of Albuquerque, NM, USA was awarded a follow-on production order of \$39m for additional concentrator triple-junction (CTJ) solar cell receiver assemblies, to be deployed in the SunCube terrestrial concentrator photovoltaics (CPV) systems of Green & Gold Energy Pty Ltd (GGE) of Glynde, Australia through its worldwide licensees.

GGE previously placed an initial 5MW order for concentrator triple-junction (CTJ) solar cells in early 2007 and then a \$24m, 105MW follow-on production order in late August for 3 million cells (at that point the industry's largest CPV cell order, for shipment by this December), designed and optimized for GGE's CPV system.

The conversion of these previous solar cell orders to receiver assemblies means that GGE's cumulative order is now for over 6 million CPV receiver assemblies (totaling about 215MW) worth \$78m.

This demonstrates the realization that the cell receiver assembly provides the shortest time to market for their system, says David Danzilio, VP and general manager of Emcore's Photovoltaics Division.

Emcore recently introduced a line of integrated CPV receiver assemblies optimized for operation at 500–1000x concentration which can easily be integrated into existing CPV systems, the firm says. "This product fits seamlessly into GGE's existing optical design and eliminates the cost and time required to internally develop this critical element of the system," says Danzilio. By choosing its complete receiver solution, CPV system developers can focus effort fully on developing their optical design and optimizing the balance of the system, reducing time to market, claims Emcore.

Emcore has already received orders for CPV receiver assemblies from several other terrestrial sys-

tem integrators. "This highly differentiated product has gained broad industry acceptance and we see increasing demand from multiple customers around the world," says Danzilio.

The order backlog for the product line has increased to about \$86m; production has now started at Emcore's high-volume manufacturing line in Albuquerque. This has contributed to a record firm order backlog exceeding 300MW on entering 2008. The firm is currently expanding its production capacity for both solar cells and cell receiver assemblies. Emcore plans to bring online four CPV receiver lines (three in Albuquerque and one in China). "Emcore's continued investment will continue to provide our CPV customers assured supply of the critical engine driving the deployment of economically viable terrestrial CPV systems," says Danzilio.

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

## GGE building 1000MW SunCube plant and 60MW of solar farms

On 17 February at the Green City Festival in Elder Park, Adelaide, Green & Gold Energy launched its SunCube terrestrial concentrator photovoltaics (CPV) system.

"The patent pending SunCube, together with its supporting technologies and the Emcore cell, are receiving worldwide recognition as the CPV system capable of delivering truly fossil-fuel-competitive energy," claims CEO Greg Watson. The SunCube is being launched into the EU market at the CPV Summit 08 in Madrid, Spain on 1–2 April.

GGE has contracts with commercial partners in South Korea, Spain, India, Israel, USA, and Australia to supply about 400MW of SunCubes per year within three years. GGE's high-efficiency two-axis tracking SunCube CPV technology is



**Computer-generated graphic of GGE's SunCube CPV plant.**

supplying renewable energy to Australia's electricity grid.

GGE is at an early stage of working with financial, government and industry partners to build a highly automated SunCube manufacturing plant in Adelaide. Initial availability will be 60MW/200,000 units through 2009, but the targeted annual capacity is 3.3 million SunCubes

(1000MW; 1% of the world renewable energy generation market) within two years (following a 2–3 year construction phase). At full capacity, the plant will cost upwards of AUS\$70m and should employ up to 1000 staff.

The firm has also signed an exclusive Australian, New Zealand and South Pacific Islands distribution license with Zolar Distributors Pty Ltd for domestic, industrial and commercial customers.

GGE is also at an early stage of working with financial, government and industry partners to initially build four 15MW SunCube Energy Farms (SEFs) in South Australia, Queensland, New South Wales, and Victoria that will supply wholesale electricity directly into the Australian national grid.

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

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# DOE investing \$13.7m in 11 university PV projects

In response to last June's 'University Photovoltaic Process and Product Development Support' Funding Opportunity Announcement, the US Department of Energy (DOE) is investing up to \$13.7m over three years in 11 university-led projects focused on developing solar PV technology manufacturing processes and products (making \$17.4m, combined with a minimum university and industry cost share of 20%). The projects have the potential to significantly reduce the cost of electricity produced by PVs from existing levels of \$0.18–0.23 per kiloWatt hour to \$0.05–0.10 per kWh by 2015 (competitive in markets nationwide). The funding is part of President Bush's Solar America Initiative (which aims to make solar energy cost-competitive with conventional forms of electricity by 2015).

The DOE says that universities selected for the projects will leverage fundamental understanding of materials and PV devices to help industry partners advance manufacturing processes and products. Each university will work closely with an industry partner to ensure that the projects retain a commercialization focus and that results are quickly transitioned into market ready-products and manufacturing processes. Also, students will be exposed to diverse PV-related commercialization efforts, enhancing workforce development in an effort to increase competitiveness and retain qualified scientists in the growing domestic PV research and development industry.

Apart from projects focused on silicon and organic semiconductors, projects selected that involve compound semiconductors include:

- Arizona State University with SolFocus of Mountain View, CA and Soliant Energy of Pasadena, CA: 'Reliability Evaluation of Concentrator

Photovoltaics per IEC Qualification Specifications' will focus on reducing bottlenecks in the qualification test (such as environmental chamber testing) while enhancing scheduling and coordination with industry to increase testing throughput and efficiency (to overcome the backlog of products waiting to undergo IEC product testing caused by the recent boom in concentrating PVs). The DOE will provide up to \$625,304 for the \$800,000 project.

- California Institute of Technology with Spectrolab of Sylmar, CA: '100mm Engineered InP on Si Laminate Substrates for InP based Multijunction Solar Cells', aims to reduce the InP layer thickness by a factor of ten by bonding a thin layer to an inexpensive silicon laminate substrate, enabling a cost-effective, scaleable InP-based multijunction solar cell process (and opening up a new design space for high-efficiency multijunction solar cells). The DOE will provide up to \$837,000 for the \$1m project.

- North Carolina State University with Spectrolab: 'Tunable Narrow Bandgap Absorbers for Ultra High Efficiency Multijunction Solar Cells', aims to increase conversion efficiency (by balancing each layer's responsiveness to the sun's broad spectrum and by matching the current produced by each layer) through developing and optimizing a 1–1.5eV graded-strain subcell layer and integrating it into Spectrolab's triple-junction stack to produce a four-junction solar cell (targeting record efficiency of 45%). The DOE will provide up to \$1.15m for the \$1.4m project.

- University of Delaware Institute of Energy Conversion with Dow Corning: 'Development of a Low-Cost Insulated Foil Substrate for CIGS Photovoltaics' will address limitations in the formation of flexible

copper indium gallium diselenide (CIGS) modules (due to the lack of an inexpensive substrate capable of withstanding the necessary high processing temperatures) by targeting the development of a low-cost stainless-steel flexible substrate coated with silicone-based resin dielectric and module processes applicable across a variety of roll-to-roll CIGS manufacturing techniques (targeting efficiencies greater than 12%). The DOE will provide up to \$1.5m for the \$1.85m project.

- University of Florida with Global Solar Energy Inc of Tucson, AZ, International Solar Electric Technology Inc of Chatsworth, CA, Nanosolar Inc of San Jose, CA and Solyndra Inc of Fremont, CA: 'Routes for Rapid Synthesis of CIGS Absorbers' will develop predictive models that quantitatively describe the formation of CIGS films under different processing conditions, for use in developing optimal processing recipes that reduce processing time and identify scaling issues for commercial manufacturing (targeting a CIGS synthesis time of less than two minutes). The DOE will provide up to \$599,556 for the \$800,000 project.

- University of Toledo with Solar Fields LLC of Perrysburg, OH: 'Improved Atmospheric Vapor Pressure Deposition to Produce Thin CdTe Absorber Layers' will reduce cadmium telluride (CdTe) layer thickness to about 1µm (compared to 8µm in existing record CdTe thin-film devices, which increases material costs and deposition time in commercial manufacturing) while targeting a 10% module efficiency. Improvements to contacts, uniformity, and monolithic integration will also be achieved. The DOE will provide up to \$1.16m for the \$1.7m project.

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

# IMEC claims record 24.7% for GaAs-on-Ge PV cell efficiency

As part of the ESA-IMAGER project, independent research center IMEC of Leuven, Belgium says that it fabricated a single-junction GaAs solar cell on a Ge substrate with what it claims is a record conversion efficiency of 24.7%, with an open-circuit voltage ( $V_{oc}$ ) of 999mV, a short-circuit current ( $J_{sc}$ ) of 29.7mA/cm<sup>2</sup>, and a fill factor of 83.2%, as measured and confirmed by the US National Renewable Energy Laboratory (NREL).

IMEC achieved the efficiency on a single-junction GaAs cell measuring 0.25cm<sup>2</sup> grown epitaxially on a Ge

substrate with an improved micro-defect distribution. Materials technology group Umicore produced the Ge substrate through an optimized manufacturing technology, aimed at improving the intrinsic germanium crystal quality.

IMEC says that improving the efficiency of this single-junction GaAs cell is a further step in the development of a hybrid monolithic/mechanically stacked triple-junction solar cell (consisting of stacks of solar cells of different semiconductor materials, chosen to absorb different wavelengths of the

solar spectrum as efficiently as possible.

Among the many possible combinations, IMEC focuses on stacked cells consisting of top cells with III-V materials and bottom cells made from Ge. With this combination, it is targeting a conversion efficiency of 35% and above.

The resulting stacks can be used in both satellite-based photovoltaic cells and terrestrial concentrator photovoltaic cells (CPVs), where high-efficiency energy conversion is paramount.

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

## RoseStreet opens full-spectrum PV development center

RoseStreet Labs Energy Inc of Phoenix, AZ, USA has formally opened its new solar cell development center, which includes a full-spectrum photovoltaic pilot line as well as a laboratory for solar cell packaging and interconnection.

The firm is a 50:50 joint venture formed in October 2006 between RoseStreet Labs LLC and Sumitomo Chemical Co Ltd of Tokyo, Japan with start-up capital of \$6.6m to develop both thin-film and multi-junction high-efficiency solar cells for both the concentrated photovoltaic (CPV) and flat-panel markets. After R&D and product development during 2007, last August the firm announced plans to install the pilot line, which should enable the firm to field test prototypes this year in terrestrial CPV distributed energy, flat panel, space and architectural applications.

RoseStreet Labs Energy collaborates locally on packaging with FlipChip International LLC (a subsidiary of RoseStreet Labs LLC that supplies products and services for wafer bumping and wafer-scale packaging). In addition, Sumika Electronic Materials Inc (a subsidiary

of Sumitomo Chemical that is also based in Phoenix and specializes in epitaxial processes and services) will continue to provide support for manufacturing and development.

"The innovative RoseStreet Energy approach to utilization of solar energy is based on recent research breakthroughs at major scientific institutions," says chief technical officer Dr Wladek Walukiewicz.

"The research advances allowed for realization of new concepts of high-efficiency solar cells," he claims.

In 2005 RoseStreet Labs agreed exclusive patent licenses with both the US Department of Energy's Lawrence Berkeley National Laboratory (LBNL) as well as Cornell University for devices that use a significantly larger fraction of the solar spectrum compared to existing products.

Consequently, the firm is commercializing LBNL's multi-band technology (developed by Walukiewicz and Kin Man Yu at LBNL), which uses oxygen impurities to split the conduction band of zinc manganese tellurium (ZnMnTe). This enables devices to achieve the efficiencies of a triple-junction device with the

manufacturing cost and simplicity of a single-junction device, it is claimed (more than 50% for triple-band material, in theory).

RoseStreet Energy is also commercializing the InGaN multi-junction technology of LBNL and Cornell, which should provide the thermal and radiation properties necessary for next-generation CPVs used in distributed energy power generation. Practical efficiencies of more than 48% in both single-junction and multi-junction devices are potentially achievable, it is claimed.

"Our objective is to develop the high-performance solar cells at prices competitive with current commercial technologies," says Walukiewicz. "Our progress during our first year has been substantial and our momentum is building for the launch of both our thin-film multi-band and multi-junction high-efficiency solar cells," adds RoseStreet Labs Energy's chairman Bob Forcier. "Customer interest has been exceptionally strong for our future product lines on an international basis," he adds.

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

# Teledyne completes acquisition of IR detector maker Judson

Teledyne Technologies' subsidiary Teledyne Scientific & Imaging LLC of Thousand Oaks, CA, USA has completed its acquisition of Judson Technologies LLC of Montgomeryville, PA, USA. The business now operates as Teledyne Judson Technologies.

Judson designs and manufactures infrared detectors using a variety of II-VI or III-V materials including mercury cadmium telluride (HgCdTe), indium antimonide (InSb), and indium gallium arsenide (InGaAs) for military, space, industrial and

scientific applications. Annual sales in 2006 were \$13.8m.

Teledyne Scientific & Imaging consists of two business units: Teledyne Scientific Company and Teledyne Imaging Sensors, which designs and produces infrared and visible sensor subsystems used in space missions, long-range terrestrial surveillance and targeting and astronomy applications. Two of its largest customers are NASA and the US Army.

"With the acquisition of Judson, Teledyne will be able to provide a

substantially wider range of visible and infrared detectors, integrated subsystems and camera products," says Teledyne's chairman, president & CEO Robert Mehrabian. "Judson's capabilities in detector packaging and the production of dewar and cooler assemblies are highly complementary to Teledyne Scientific & Imaging's strength in advanced detector materials and the design of large-format focal plane arrays and imaging electronics," he adds.

[www.teledyne-si.com](http://www.teledyne-si.com)

## PLI awarded \$3.5m for single-photon focal plane arrays

In January, optical component and sub-system maker Princeton Lightwave Inc (PLI) of Cranbury, NJ, USA was awarded a two-year \$3.5m contract by the US Defense Advanced Research Projects Agency (DARPA) to develop focal plane arrays (FPAs) with single-photon sensitivity for use in 3D imaging systems operating at a wavelength of 1.06µm.

The FPA modules will use InP-based Geiger-mode avalanche photodiodes (GmAPDs) to achieve single-photon sensitivity and perform time-of-flight ranging measurements on a per-pixel basis. The modules are intended for use as the optical engines at the core of 3D imaging flash LADAR systems (such as those demonstrated in DARPA's Jigsaw program).

The key component in the 3D imaging FPA is an InGaAsP/InP GmAPD photodiode array (PDA) optimized for detection of single photons at 1.06µm. PLI's commercially deployed single-element GmAPD detector is based on a highly reliable planar-passivated, diffused-junction photodiode structure. This has demonstrated the highest performance to date using this structure for critical single-photon detection parameters such as dark count rate, photon

detection efficiency, and timing jitter, PLI claims.

The GmAPD single-photon avalanche diode (SPAD), when operated above its breakdown voltage, can generate a macroscopic current pulse in response to the absorption of just a single photon. Its operation and readout requires a specialized readout IC (ROIC) designed for 3D imaging applications. On a per-pixel basis, this ROIC senses the GmAPD output current pulse corresponding to the absorption of a single photon and assigns a time stamp indicating the time-of-flight between the launching of a short-duration ranging laser pulse and the photon detection event. The per-pixel time-of-flight information is translated to distance, as in conventional LADAR measurements, and provides the third spatial dimension to complement the 2D image provided by pixel location in the detector array. PLI says that it will hybridize the GmAPD PDAs and ROICs using flip-chip bonding, and a high optical fill factor will be achieved using an array of microlenses mated to the back-illuminated PDA chip.

"We've been developing single-photon counting technology for several years, and 3D imaging is an

excellent application for it since we can leverage our expertise in both semiconductor device design and module packaging," says CTO Mark Itzler (principal investigator for the program). "By the time we complete this two-year development program, we expect to see product-scale demand for these sensors to provide 3D imaging capability in a variety of defense systems."

Since single-photon detection in a GmAPD provides a macroscopic current pulse that can be sensed using digital thresholding circuitry, GmAPD FPA technology (which was initially demonstrated by MIT Lincoln Laboratory under DARPA sponsorship of Jigsaw) provides a direct and (noiseless) 'photons-to-bits' conversion process. Among the benefits of single-photon sensitivity is the ability to obtain 3D image data using low-power pulsed sources and the collection of 3D images even in situations involving very large source attenuation. In particular, the Jigsaw program demonstrated the feasibility of using GmAPD FPA technology to create 3D images of objects obscured by forest canopy and camouflage netting.

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

# 100Gb/s or bust...

**This year's OFC/NFOEC event in San Diego drew 13,000 attendees and showed a strong focus on increasing data transmission rates to satisfy bandwidth demand, reports Bill Ring of WSR Optical Device Solutions.**

**F**or 2008 the Optical Fiber Communications/National Fiber Optic Engineers Conference (OFC/NFOEC) moved to San Diego, CA, where the sunny weather reflected the more upbeat optical communications market. The announcements in the last 18 months of network upgrades to 40Gb/s technology, new submarine system builds by major network operators, and the question of how soon we can have 100 Gigabit Ethernet were hot topics at the event. In addition, several new themes in technology and products were highlighted. A definite transition in the industry is underway, as was apparent in the trade show and in several of the many technical sessions.

## Market forces

The Optical Society of America (OSA) held a one-day executive forum 'Positioning for the Future' on the Monday to discuss the future of communications. In his keynote presentation 'Non-linear Optics: The Roller Coaster Nature of Investor Sentiment on Optical Networking', Bob Flanagan of Oppenheimer discussed the outlook for firms in the optical communication space from an investor perspective. The sector remains troubled compared to other sectors in terms of investment dollars and profitability. In particular, the optical communications components sector represents a small percentage of the money invested by managers of mutual funds compared to other sectors.

One of Flanagan's key points was whether the valuations of optical communications companies is a good reflection of their current performance, and whether investors are starting to favor the sector again. It was stated that there is no correlation of operating income or profit/loss to share holder value. In fact, the highest-valued optical component company has a solar cell business! But compared to the solar market sector (which is currently going through a bubble-type phase of investment), the dynamics appear different. When looking at the climate for deals or exit strategies for optical communications component companies, it is thought that an initial public offering (IPO) is still a good option. This has been demonstrated recently by several companies (e.g. Optium, Opnext and Infinera). So, when is a good time for optical communications component companies to go for an IPO? Probably late in 2008, judges Flanagan, as this appears to be when trends suggest it will be most favorable.

The next two panel sessions in the executive forum involved a mix of market research firms, system vendors, switch makers and wireless providers. The outlook from systems vendors such as Cisco, Alcatel-Lucent, Nortel and Nokia-Siemens was very upbeat. Social networking and video-on-demand are seen as key drivers of bandwidth growth. From a transport and delivery perspective, several companies expressed concern that bandwidth growth requires a 100Gb/s solution now, not in 2010. The way people communicate and the convergence of handheld devices for video,

**Several companies expressed concern that bandwidth growth requires a 100Gb/s solution now, not in 2010**

music, text, GPS and voice are pushing more information across the networks. Will it saturate? Not yet, is the consensus. The younger generation is very connected and network-aware. They behave differently to the previous generation.

Several new applications (such as Facebook, Skype, YouTube and other social networking sites) have changed how people interact. This new social networking paradigm is making the optical transport companies more aware that they need new business models. However, the outlook is positive, with all the companies present believing that a more connectivity-orientated world is already here. Chairing one of the panel sessions ('Position for the Future: Systems Companies Perspective'), Michael Lebbby, president of the Optoelectronics Industry Development Association (OIDA) questioned when 1 Terabit Ethernet will be required. Although no one in the panel could answer this question, nobody doubted that it was coming and would be needed.

In the afternoon section of the executive forum, the component vendors took the stage in two separate panel sessions to discuss the telecom and datacom environments, respectively. All firms participating expressed concerns regarding profitability and competition.

There are still a large number of component vendors. All have made tremendous progress in moving back to break-even and profitability, while gross margins have improved and new manufacturing models have been implemented. In the case of Optium Corp of Horsham, PA, its vertical integration and in-house manufacturing of transponders (rather than outsourcing or moving production to Asia) are the key factors that have

enabled it to win customers and develop a good business model at 10Gb/s (while moving to 40Gb/s). But in the same panel session ('View from the Top: Telecom Component/Subsystem Trends'), Jo Major, chairman, president & CEO of Avanex Corp of Fremont, CA, discussed the excess of suppliers and how this continues to depress average selling prices. This concern was also reflected by Joe Liu, president & CEO of Oplink of Fremont, CA. The topic of mergers was raised as a way to consolidate the market and supply chain. The consensus was that consolidation is necessary, but it is happening very slowly (if at all).

**The consensus in the panel session was that consolidation is necessary, but it is happening very slowly (if at all).**

## Network developments

The OFC/NFOEC plenary session involved three key speakers. The first, from US service provider Qwest, discussed changes in bandwidth demand, and that there is a need for 40Gb/s data-rate transmission now, and for 100Gb/s systems by 2009. Bandwidth consumption is increasing dramatically, although how much it is changing depends on which company you talked to. Ethernet is perceived as moving more into the carrier space, while provider backbone transport (PBT) is perceived as becoming very relevant for metropolitan-area networks. We need high-speed transport, and bigger pipes seemed to be the message.

Next on stage, Ethernet co-inventor Bob Metcalfe spoke on 'Towards a Terabit Ethernet'. Naturally, over the years Ethernet has evolved and is no longer the same as the original system developed at Xerox in 1979 (in fact, commercial deployment took 10 years). He challenged the audience to continue to create new forms of Ethernet: 'Build it and they will come' was his message. Metcalfe also commented on 'Bubblephobia' regarding the current climate of increasing bandwidth demand and the fear of another bubble in optical communications.

Finally, Herwig Kogelnik discussed the current state of the art in communications networks, the 20th anniversary of the first submarine fiber-optic cable system entering operation in 1988, and how it is now obsolete in terms of data rate and capacity. The system has been decommissioned since the traffic load is now too heavy and newer systems have superseded it. He discussed advances in recent years and the new modulation formats for enabling higher speeds, as well as the ongoing work at Bell Labs to remain at the forefront in telecom technology development. The future is bright for optical communications, Kogelnik believes.

**There is a need for 40Gb/s data-rate transmission now and for 100Gb/s systems by 2009**

## OFC shows the path to 100Gb/s

The mood on the OFC/NFOEC exhibition floor was upbeat, with many firms looking towards the next wave of components. Of over 600 firms exhibiting, several component suppliers demonstrated their new device developments, with the themes of high-speed transmission and new modulation formats for achieving the next generation in system performance very prevalent.

An interesting example was the 100Gb/s transponder demonstration by equipment maker Yokogawa. The transponder measures 12" x 6" x 1" (about the size of a large brick) with two fiber pigtails coming out of it. However, the next-generation transponder looks like it is 8" x 4" x 1" (although it was not yet ready). The 100Gb/s eye diagrams at the demonstration looked great. The firm was also selling phase measurement devices.

Datacoms optical component maker Finisar Corp of Sunnyvale, CA was exhibiting its new active cable assemblies. This new approach is intended for data centers where, instead of requiring complex optical testing, the cable looks like a copper cable terminated by two transceivers. The whole approach makes life simpler for the installer. No more heavy copper cable, just a lighter 'green' cable with two modules on either end. The concept sounds excellent, but now raises the issue of developing standard cable lengths. With data centers burdened by the weight of copper cable assemblies, the idea is naturally more elegant.

Bookham Technologies of San Jose, CA was keen to show off its integrated tunable Mach-Zehnder device. The design's compactness is a definite advantage for next-generation dense wavelength division multiplexing (DWDM) systems. With more complex modulation schemes proposed as a route to 100Gb/s transmission and beyond, this device naturally has a role to play.

Another eye-catcher was the booth of Opnext Inc of Eatontown, NJ. A major supplier of 10Gb/s transceivers and transponders, the firm's live demo concerned the coarse wavelength division multiplexing (CWDM) approach for 100 Gigabit Ethernet. Four 25Gb/s uncooled electro-absorption distributed feedback (EA-DFB) lasers with narrow wavelength spacing show the ability of CWDM to produce 100Gb/s devices. The transmitter optical sub-assembly (TOSA) was demonstrated as the 'correct' approach for next-generation Ethernet modules.

Not actually on the show floor but in a room adjacent to the OIDA's Silicon Photonics Alliance meeting, a new firm came out of stealth mode with the launch of its 'Silicon Photonics' LRM transceiver module. Formerly known as SiOptical Inc, Lightwire Inc is headed by Vijay Albuquerque, former general manager of Avago's fiber-optics business unit. Based on silicon CMOS Mach-Zehnder technology, the module is an alternative approach to InP photonic integration. In a similar vein to Luxtera (the other key pioneer of silicon photonics), the emphasis is on power, size and cost.

## OIDA kicks off Silicon Photonics Alliance

The OIDA held three key meetings. The first was a kick-off meeting for the Silicon Photonics Alliance (with the aim of recruiting new members). This was well attended by representatives of over 60 firms.

To help understand the idea behind the alliance, several contributors (including Ashok Krishnarmoothy of Sun Microsystems) discussed the need for optical interconnect technology with a price point of less than \$1 per gigabit. Existing technology, which is based on the parallel optics approach (i.e. SNAP-12 and POP-4) is still above this. Firms such as Luxtera Inc of Carlsbad, CA (leader of the alliance) feel that, by using silicon photonics, the target could be achieved. John Bowers of University of California-Santa Barbara (UCSB), together with Arlon Martin of Kotura Inc of Monterey Park, CA, discussed work on MEMS-based photonic switching and silicon waveguide photonic lightwave circuit (PLC) devices.

## OFC/NFOEC technical conference

The OFC/NFOEC conference was also well attended, with over 13,000 visitors. Topics discussed included plastic optical fiber, biophotonics, IPTV, high-speed devices and detectors, coherent detection, FTTx, WDM PON (passive optical networks), fibers, high-power fiber lasers, radio over fiber, and networks.

One of the principle themes in the transmission and network side of the technical papers was the continued study of high-bit-rate systems and new modulation formats. This has direct implications for integration and next-generation components.

Several papers discussed the impact of modulation schemes, and gave examples of transmission at greater than 100Gb/s using DQPSK or other coding schemes. The optical communications industry currently faces two challenges: bandwidth demand and transmission technology. These two themes play into all aspects of the different approaches currently underway.

For example, Alcatel-Lucent presented a paper on 107Gb/s transmission over standard transport equipment (LamdaXtreme). Both NEC and Hitachi research laboratories discussed the role of modulation format for single-frequency high-speed transmission. Compared to the interconnect sector (i.e. data centers where parallel solutions are used for low-latency applications), high-speed transport over the backbone network is based on DWDM and single-wavelength sources. By encoding more information on the single-wavelength source, the transmission bandwidth can be increased.

The emphasis for transport was seen even across the market-watch segment of the conference, where again bandwidth and 100Gb/s transmission were discussed. What was interesting was the session on coherent communication. This has the eventual advantage over current techniques of eliminating fiber nonlinearities by



**Infinera's photonic integrated circuits.**

using digital signal processing (DSP). Whether DSP can ever become fast enough is a question for the future. Several papers discussed the issues of coherent detection, including a paper by Yi Cai of Tyco Telecommunications.

At this point we must mention Infinera Corp of Sunnyvale, CA, a company that was honored at the OFC/NFOEC Plenary awards ceremony for advancing photonic integration. At OFC, the firm presented papers on the implementation of modulators on their existing optoelectronic integrated circuit (OEIC) to enable 40Gb/s transmission on each channel. This effectively allowed 400Gb/s down one fiber from the OEIC transmitter: a remarkable feat for a pioneering company in photonic integration. Infinera's core technology takes advantage of the integration capabilities of InP-based devices, which enables lower-cost transmission. As a system company effectively leveraging their core photonic integration technology, Infinera has set a path forward that challenges other firms to follow.

The drivers of bandwidth and speed are also impacting technology innovation in terms of integration. More complex modulation formats change the device technology for both reception (photodetectors) and transmission (lasers). Integration in these areas will continue to be needed as we move forward.

Regarding bandwidth, several other key points concern the interconnect sector, which is being led by IBM Research. A 300Gb/s 24-channel transceiver with transmitters operating at 12.5Gb/s built in CMOS is intended for use in computer interconnects.

Another demonstration of the importance of silicon photonics was in a paper by CMOS photonics firm Luxtera, which presented its 40Gb/s QSFP module device.

## Diversity to drive innovation

Overall, the OFC/NFOEC conference was upbeat, indicating a bright future for optical communications. Diversity in the different market segments and technology (e.g. plastic optical fiber, data centers and servers, long-haul transport and novel fiber and component technology) continues to drive innovation. Bandwidth is king and transmission speed is in great demand. As always, as new technology is being added, devices are becoming increasingly complex, so next year's event should see yet further technical development. ■

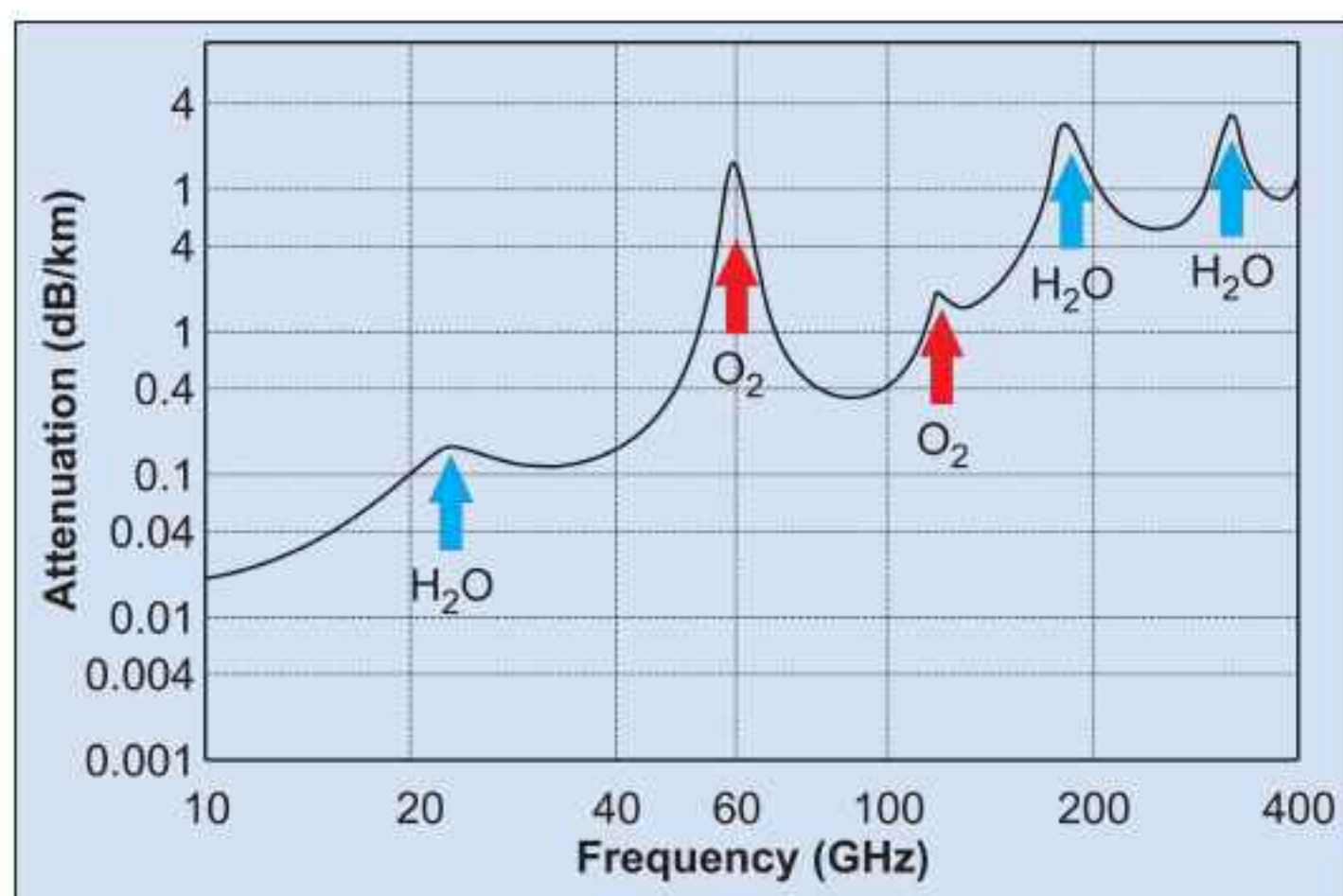
# CMOS reaches for 60GHz+ applications?

CMOS integrated circuit development has been full of surprises, more often than not wildly exceeding expectations. **Dr Mike Cooke** writes on developments designed to use the low-cost, highly integrated technology for extremely high radio frequency applications at tens of gigahertz.

**I**n the very old days, complementary metal-oxide semiconductor (CMOS) technology was 'just digital'. For analog radio-frequency (RF) applications, designers had to look to the much more expensive silicon bipolar (possibly mixed with CMOS in BiCMOS) or III-V semiconductor technologies; then, as CMOS' frequency reach came within the suitable ranges, a number of RF technologies have become part of the CMOS empire. For frequencies of the order of gigahertz (GHz), CMOS RF applications are mainly short-range technologies such as Bluetooth and WiFi wireless networking, operating mainly at about 2.4GHz. In mobile phones (generally operating at 0.8–2.2GHz, but with some operating at ~0.4GHz), which need to transmit over longer ranges, the dominant semiconductor technology for power amplification is III-V due to the smaller components and to the better power efficiency achievable. However, manufacturers would love to have a lower-cost CMOS component.

NXP (formerly Philips Semiconductors) is one of those seeking a single-chip CMOS mobile phone. In 2007, the company acquired the cellular communications division of Silicon Labs, a developer of CMOS RF power amplifiers (PAs) with some take-up in China for very low-cost mobiles. However, the balance between cost, size and battery-life dictates that III-V components are generally preferred for this application at present. On the other hand, low-noise amplifiers (LNA) for the receiver side are often integrated in CMOS in a single chip with the circuitry required to convert both ways, between digital signals of the baseband device and the modulated radio signal to and from the external network.

Having extended CMOS into many gigahertz-level RF applications, with new ones such as WiMAX (2.5–3.5GHz and other ranges) coming into view, researchers have in the past few years been looking beyond 10GHz for new CMOS RF applications. On the one hand, the higher frequencies are expected to enable much higher data rate communication; but on the other hand, the range 10–100GHz is obscured by various forms of atmospheric absorption (Figure 1).



**Figure 1.** Average atmospheric absorption at sea level with  $T = 20^{\circ}\text{C}$ ,  $P = 760\text{mm}$ ,  $\text{H}_2\text{O} = 7.5\text{g/m}^3$ .

One application that is planning to make a virtue out of absorption is wireless networking in the region of 60GHz. Up to now, this band's main use has been in satellite-to-satellite communication. The attraction, particularly for military/intelligence applications, is that this band is strongly absorbed by oxygen, making it practically impossible to eavesdrop on such communications from the ground. For wireless networking, the short range in oxygen makes interference from other networks less of a problem compared with lower-frequency systems, where complicated schemes can be needed to figure out which network is being used by a particular signal. In addition to oxygen, 60GHz signals are also blocked by walls and human skin (avoiding health concerns, it is argued).

While high data rates are desirable for most applications (where practical/cost effective), there are some new technologies where they are a necessity. One of these is the wireless communication of high-definition television (HDTV) signals. Compressed HDTV requires data rates that are about three to four times those of digital TV — about 15Mbit/s compared with 5Mbit/s for DVD quality. Also, 15Mbit/s is a rock-bottom figure: HD DVD or BluRay disks can need

up to 50Mbit/s; uncompressed signals used in studios and in some wall-mounted plasma displays can reach 1.4Gb/s. The high-definition multimedia interface (HDMI) standard requires data rates of up to 5Gbit/s and the newer DisplayPort 10.8Gbit/s. Although HDTV can be transmitted over 5GHz networks, the description is often 'and even', suggesting that the capability is at the limit, with very little wiggle room.

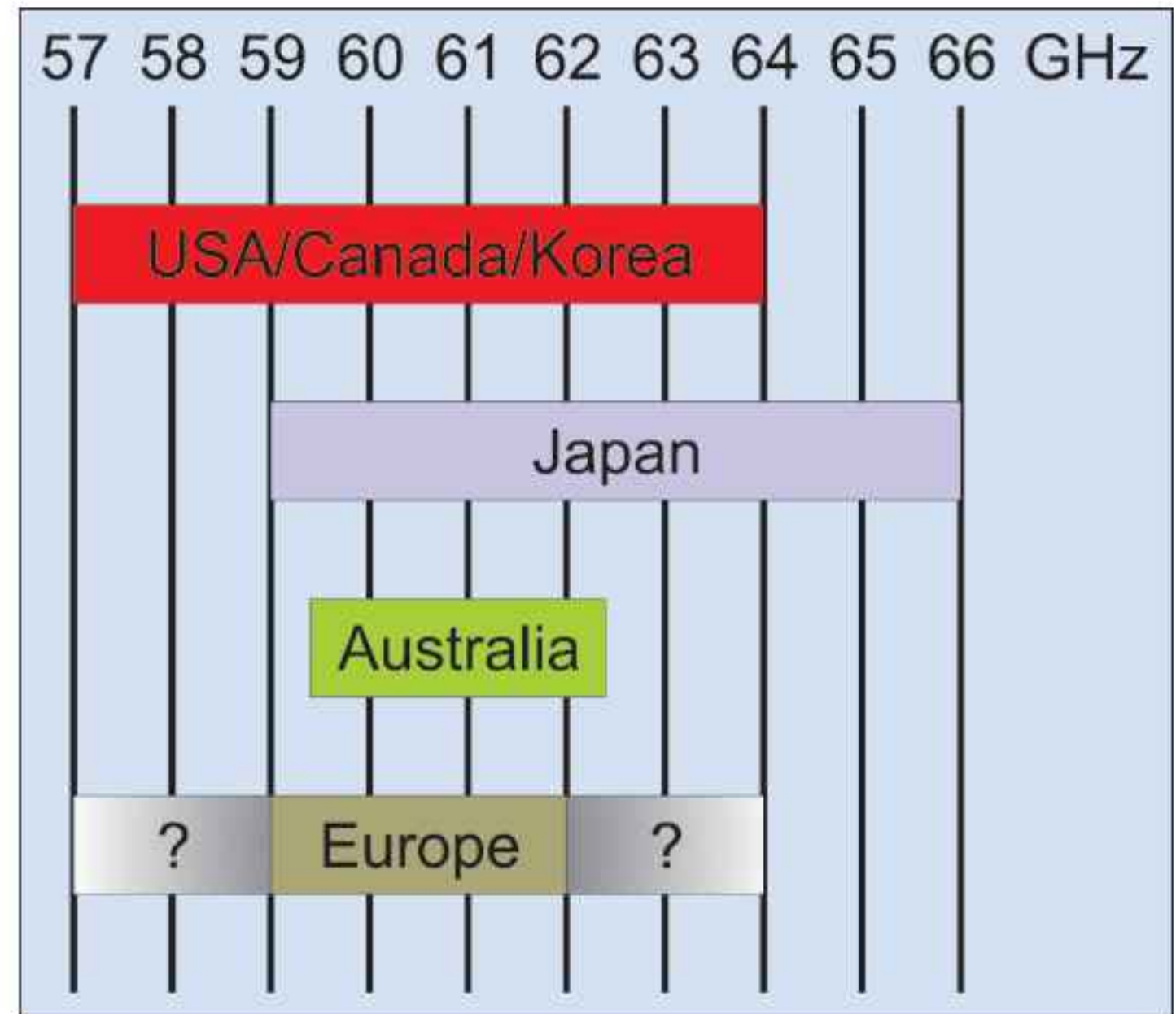
Proposals for 60GHz-band networking have bit rates of several Gb/s, with a range of up to 10 meters. This would be used to create wireless personal area networks (WPANs) and local area networks (WLANs), allowing wireless Gigabit Ethernet, laptop docking stations, mobile device synchronization (cellphones, iPods, MP3 players, cameras, handhelds/PDAs, etc.), broadband video distribution, and wireless Firewire (IEEE1394), USB 2.0, display and other peripheral connections. Such WPANs could be set up in offices, homes, hotel rooms, cafes and so on. Commercial kiosks in the street, airport, train station and so on could enable mobile downloads of DVDs to personal devices in seconds.

One strand of WPAN development is carried out under the IEEE802.15 standard, with the IEEE802.15.3c working group focusing on millimeter-wave (mm-wave) opportunities such as 60GHz. The term 'mm-wave' is commonly used to refer to the portion of the radio spectrum from about 30GHz up to 300GHz. The wavelengths of such radio waves cover the range from 10mm down to 1mm.

Another organization developing WPAN standards for 60GHz wireless is ECMA International, a body focused on Information and Communication Technology (ICT) and Consumer Electronics (CE). In February 2007, representatives met from the Electronics and Telecommunications Research Institute (ETRI) of Korea, Georgia Electronics Design Center (GEDC), Intel, IBM, Matsushita Electric Industrial (Panasonic), Newlans, Philips Semiconductors (now NXP), Samsung Electronics and Samsung Electro-Mechanics; a white paper describing a draft standard (TC48) was issued this February. The standard is designed to provide high-rate WPAN (including point-to-point) transport for bulk data transfer and multimedia streaming.

In addition, the WirelessHD standard plans to use the 60GHz band to stream high-definition multimedia content to displays. WirelessHD is supported by Intel, LG Electronics, Matsushita Electric Industrial (Panasonic), NEC, Samsung Electronics, SiBEAM, Sony and Toshiba. It is expected that the transmitted power will be extremely low (about 10mW or less).

License-free frequency bands around 60GHz have been allocated in Japan, North America (USA/Canada), Korea and Australia (Figure 2). In Europe there is a 59–62GHz band allocated for small-power, short-range device applications; one expects that, if a viable



**Figure 2. National proposals to use the 60GHz band for WPAN. In Europe, the 59–62GHz band is allocated to small-power, short-range device applications; one expects that, if a viable 60GHz-band networking market emerges, this may expand somewhat.**

market for 60GHz-band networking develops, this may expand somewhat and that further applications will be developed.

Another possibility for mm-wave applications is high-resolution measurement using radar techniques, such as in automotive collision avoidance systems. The 77GHz band is used for such applications. In addition, the 95GHz band is used in radar cloud detection, all-weather landing and 'active denial technology' (ADT). ADT radiation penetrates about 0.4mm into skin, causing nonlethal, invisible and inaudible pain (hopefully causing intruders to leave). Such an application would presumably need fairly high powers, putting it outside the scope of possible CMOS applications (for now, at least), apart from control circuits.

### The mm-wave space race

Conventional mm-wave circuits mainly use expensive but high-performance compound semiconductor technologies such as gallium arsenide or silicon germanium heterojunction bipolar transistor (HBT) devices. GaAs and other compound semiconductors are also difficult to integrate compactly with digital logic. Compound components operating at tens of gigahertz need to be combined with a number of other parts — including complex antennas, synthesizers, bonding wire, ceramic circuit boards — resulting in time-consuming, expensive and even manual production processes, with yields dependent on the weakest link. The final module is usually large compared to CMOS.

Meanwhile, standard CMOS technology can be highly integrated, with low manufacturing costs starting from

the silicon substrate. CMOS 'scaling' — the development of smaller 'critical dimensions' in ICs — leads to lower costs, lower power consumption and higher frequency, more complex components, and is now entering the mm-wave range in capability. In addition, multiple functions, including digital signal processors (DSPs) can be formed directly on the chip. Therefore it is hoped that one may be able to develop single-chip (or at least fewer chip) circuits and modules capable of converting a digital signal into a 60GHz modulated radio wave and vice versa with fewer assembly problems. The leading drawback is achieving high output power gain while maintaining sufficient long-term reliability.

Ten years ago and more, CMOS scaling was a relatively simple economic and technical process. Signal transmission could be considered almost instantaneous; gate current leakages (leading to power losses and heating) were relatively small. But since devices at the 0.13 $\mu$ m scale entered development (in about 2000), these statements are no longer true; development has become much more difficult and is getting harder.

Extra difficulties arise from the thinner layers, particularly in the gate insulator (traditionally silicon dioxide). These layers are approaching atomic dimensions; to slow this approach, new high-k dielectric materials are being introduced to allow the use of thicker layers. These materials need metal rather than polysilicon gate electrodes, adding to costs. Intel says it has such a metal electrode/high-k insulator gate stack in its latest 45nm production process. The 45nm node is expected to become mainstream for advanced applications in about 2010.

Further reliability problems are expected as the number of atoms across a layer become tens rather than thousands (i.e. the material is no longer 'continuous'). A wide range of potential solutions to these problems are being explored, e.g. channels strained with germanium or consisting of III-V material for higher mobility, new multi-gate transistor structures, silicon-on-insulator, and others.

In addition, the mixing of analog and digital circuitry that is needed for RF applications at tens of gigahertz has a number of further challenges. While pure digital ICs are interested in just two voltage levels, analog devices need smooth reliable performance over a range of voltage and current levels. This performance is deeply affected by issues such as parasitic capacitance and impedance matching to enable maximum signal throughput in amplifiers. If one wants to add DSPs onto analog RF front-end circuitry on one chip, one also has to deal with the noisier digital signals.

## CMOS champions

Despite the difficulties, universities and companies around the world are promoting development of CMOS ICs for 60GHz. Examples of progress in this work were

presented by a number of organizations at February's International Solid State Circuits Conference (ISSCC 2008) in San Francisco, CA.

Georgia Institute of Technology gave a presentation on a 60GHz single-chip, 90nm CMOS radio integrated with a signal processor that combines analog with multi-gigabit data rates. The super-heterodyne transceiver includes transmit and receive functionality across the 57–66GHz bandwidth. The device supports short-distance (1 meter) data rates up to 15Gb/s, with a total power budget of less than 200mW. At 2 meters 10Gb/s is possible, and at 5 meters 5Gb/s is possible. This is achieved using a quadrature amplitude modulation scheme with 16 'constellation points' (16-QAM). QAM keys the data into two sinusoidal signals (traditionally labeled 'I' and 'Q') that are 90° out of phase. Using quadrature phase-shift keying (QPSK), data rates up to 7Gb/s were achieved. A single-input-single-output (SISO)/multiple-input-multiple-output (MIMO) system was implemented, where user stations use single antennas for transmitting and receiving, while access points use multiple antennas to enable ultra-high data throughput.

The University of California at Berkeley (UCB) contributed three papers at ISSCC 2008 concerning the use of 90nm CMOS for 60GHz, detailing a front-end receiver, a two-stage differential PA and a broadband distributed amplifier.

The 24mW front-end heterodyne receiver has a gain-tuning range of 60dB and an average noise figure (NF) of 6.2dB using a 1V supply. The importance of modeling transistors, coplanar waveguide (CPW) transmission lines, metal-oxide-metal (MOM) capacitors and electromagnetic effects on chips is stressed by the researchers. "Excellent agreement" between measured and simulated performance was found, according to the conference paper.

The differential PA uses compact on-chip transformers for input, output, and inter-stage matching and has an area of 660 $\mu$ m $\times$ 380 $\mu$ m. On-chip transformers can be used to transform impedances and perform differential-to-single-ended conversion simultaneously with DC biasing. The UCB design uses a 1:1 vertical transformer formed from two coupled loop inductors. It is important to optimize the size of the transformers: too small and the impedance of the shunt magnetizing inductance becomes too small, losing signal current; too big and one finds substrate losses and increased series inductance leakage. Winding diameters of about 50 $\mu$ m are found to be optimum in terms of insertion losses. One PA device that was reported achieves a 1dB compressed output power of 9dBm (7mW) and a saturated power of 12.3dBm (17mW). [Note that power in dBm equates to  $10 \times \log_{10}(\text{power/mW})$ .] The peak drain efficiency is 32% and the peak power-added efficiency (PAE) is 8.8%.

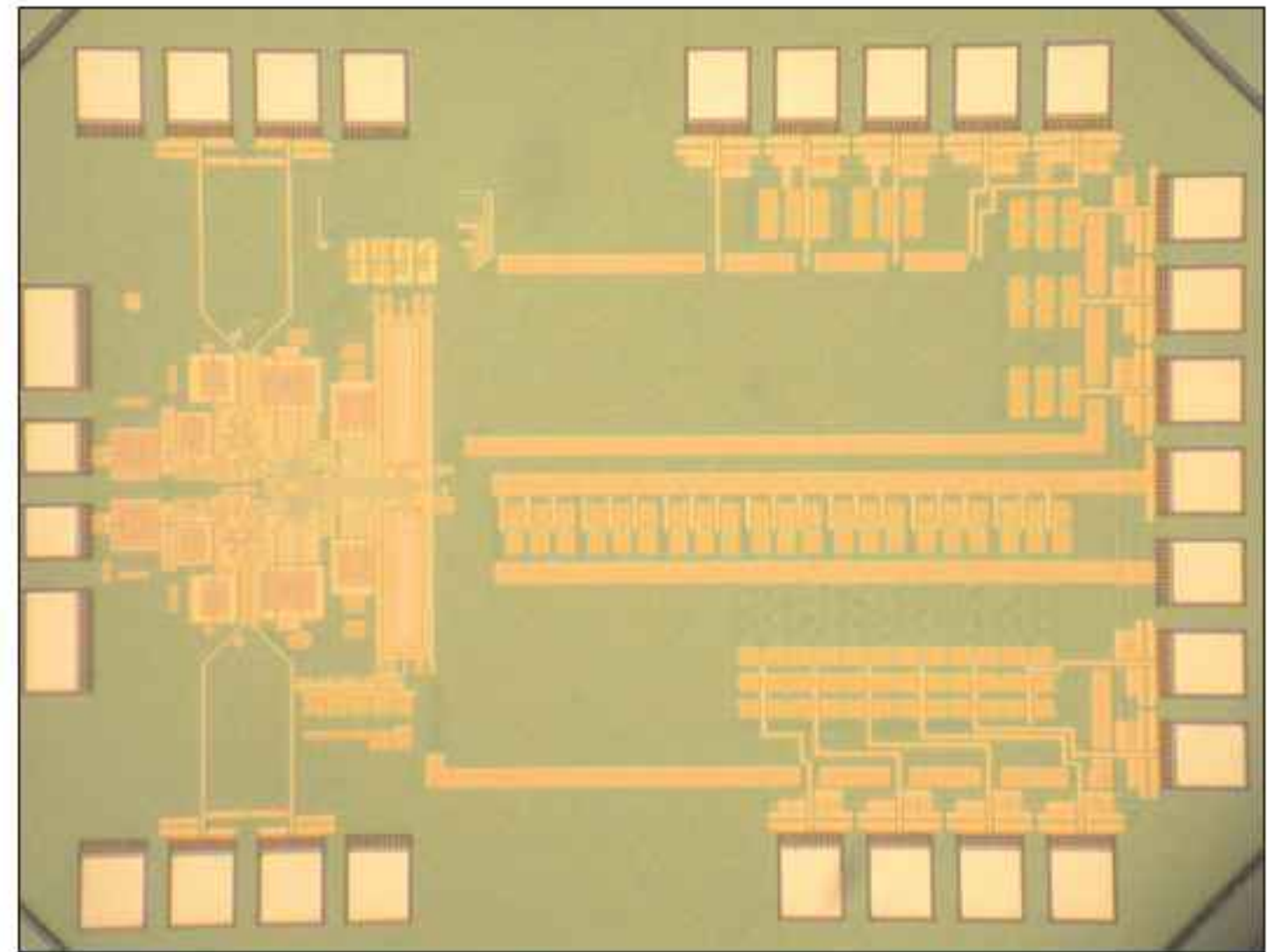
The broadband distributed amplifier uses internal feedback. Applications include high-speed links, broadband radio transceivers, high-resolution radar and imaging systems. The standard digital 90nm CMOS process used to create the broadband distributed amplifier has a cut-off frequency ( $f_T$ ) of 100GHz operating on a 1.2V supply. The gain-bandwidth product is 660GHz. The 1.19mm<sup>2</sup> chip consumes 84mW.

Also at ISSCC 2008, Belgium's IMEC microelectronics research center and Vrije Universiteit Brussel reported a prototype 60GHz receiver chip for multiple antennas made in a standard digital CMOS process (Figure 3). IMEC has also launched a 60GHz research program to collaborate with industry partners around the world. IMEC used digital CMOS to avoid the costs of alternatives or of a dedicated RF CMOS.

To overcome high path losses at mm-wave frequencies IMEC used a phased antenna array with on-chip programmable phase shifting of incoming signals to allow use of 'beam-forming' to boost reception or transmission in certain directions. The device contains two antenna paths, each consisting of an LNA and a down-conversion mixer. The devices use direct (homodyne) conversion to the digital baseband signal frequency rather than having an intermediate frequency (IF), as in heterodyne conversion. One advantage of homodyne conversion is simpler circuitry, but the technique can limit dynamic range.

The programmable phase shifting starts from the quadrature signals of an on-chip quadrature voltage-controlled oscillator (QVCO). IMEC boasts that its QVCO design combines the highest oscillation frequency with the largest tuning range ever reported in CMOS.

IMEC's multiple antenna receiver is seen as a first step towards a complete CMOS-based phased array transceiver for 60GHz WPANs. IMEC plans to implement four antenna paths using 45nm CMOS

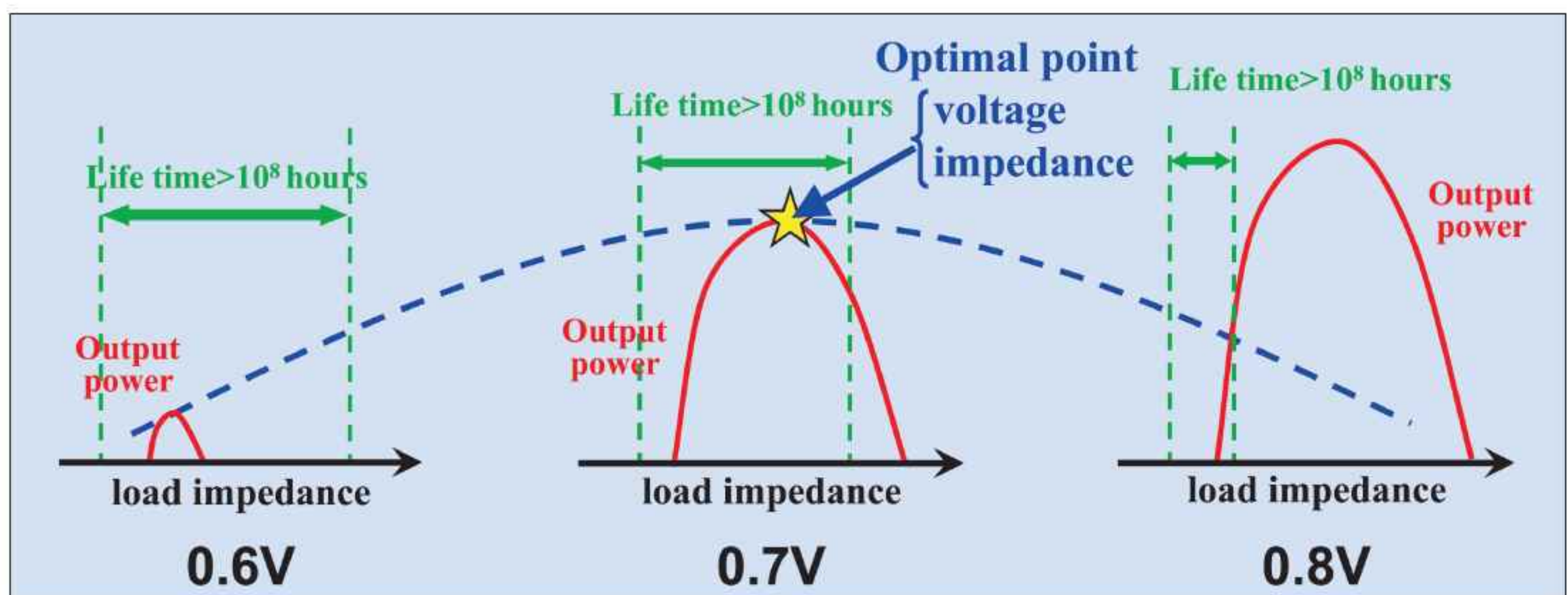


**Figure 3. Microphotograph of IMEC's full CMOS multiple antenna receiver for 60GHz (1400x1000µm).**

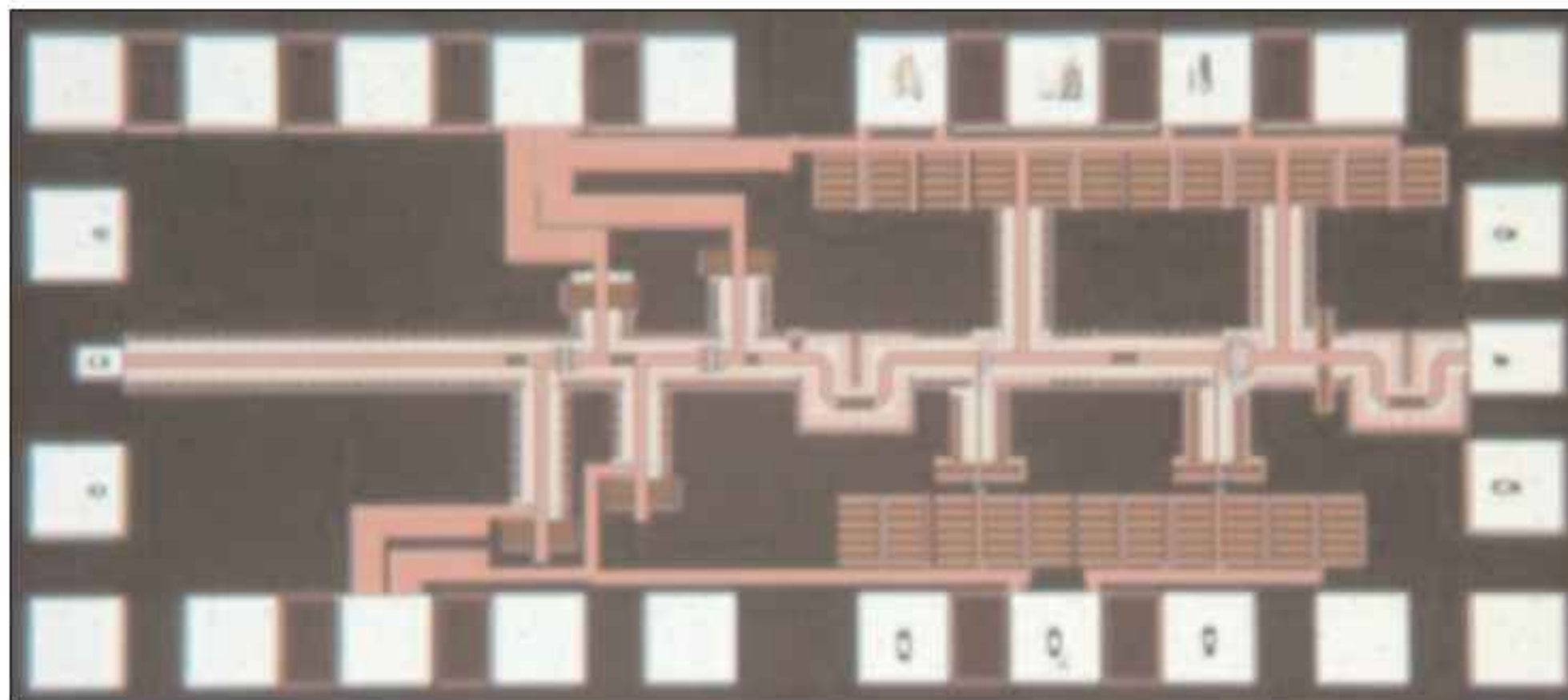
technology and to integrate other subsystems such as phase-locked loops (PLL), analog-to-digital converters (ADC) and patch-antenna arrays. IMEC will also begin initial experiments towards power amplifiers.

Japan's NEC has developed a two-chip standard 1V 90nm CMOS 60GHz wireless transceiver, claiming the world's highest output power of 7mW. A new design approach maximizes the output power delivered by the power amplifier, while maintaining sufficient long-term reliability, says the firm.

On top of the power amplifier, the transmitter chip contains gain and drive amplifiers and a quadrature modulator, while the receiver consists of two LNAs in series, followed by variable gain (VGA) and driver amplifiers, and then a quadrature (I/Q) demodulator. The complete chip achieves an output power of 6.0dBm (4mW) when it is used with 2.6Gb/s QPSK signals.



**Figure 4. NEC uses co-simulation to maximize reliability and output power with respect to the supply voltage and load impedance.**



**Figure 5. Fujitsu Labs' 77GHz power amplifier chip.**

To manufacture the design, NEC performed reliability analyses of CMOS transistors in large-signal operation, to maximize mm-wave output power (Figure 4).

The firm says that it will continue the research, with the aim of early commercialization for high-speed wireless solutions in home and office environments, possibly in the next couple of years.

Meanwhile, Fujitsu Labs has developed modeling aimed at minimizing signal loss to develop what it says is the world's first standard 90nm CMOS-based PA to operate at 77GHz (Figure 5). The company is also seeking to produce components for 60GHz wireless communication. The aim is to make a single chip with CMOS radio frequency (CMOS RF) front-end circuitry, including a power amplifier and a baseband DSP.

A short stub matching circuit was integrated with power-supply circuitry to further reduce critical signal losses. A 'short stub' is a short-circuited transmission

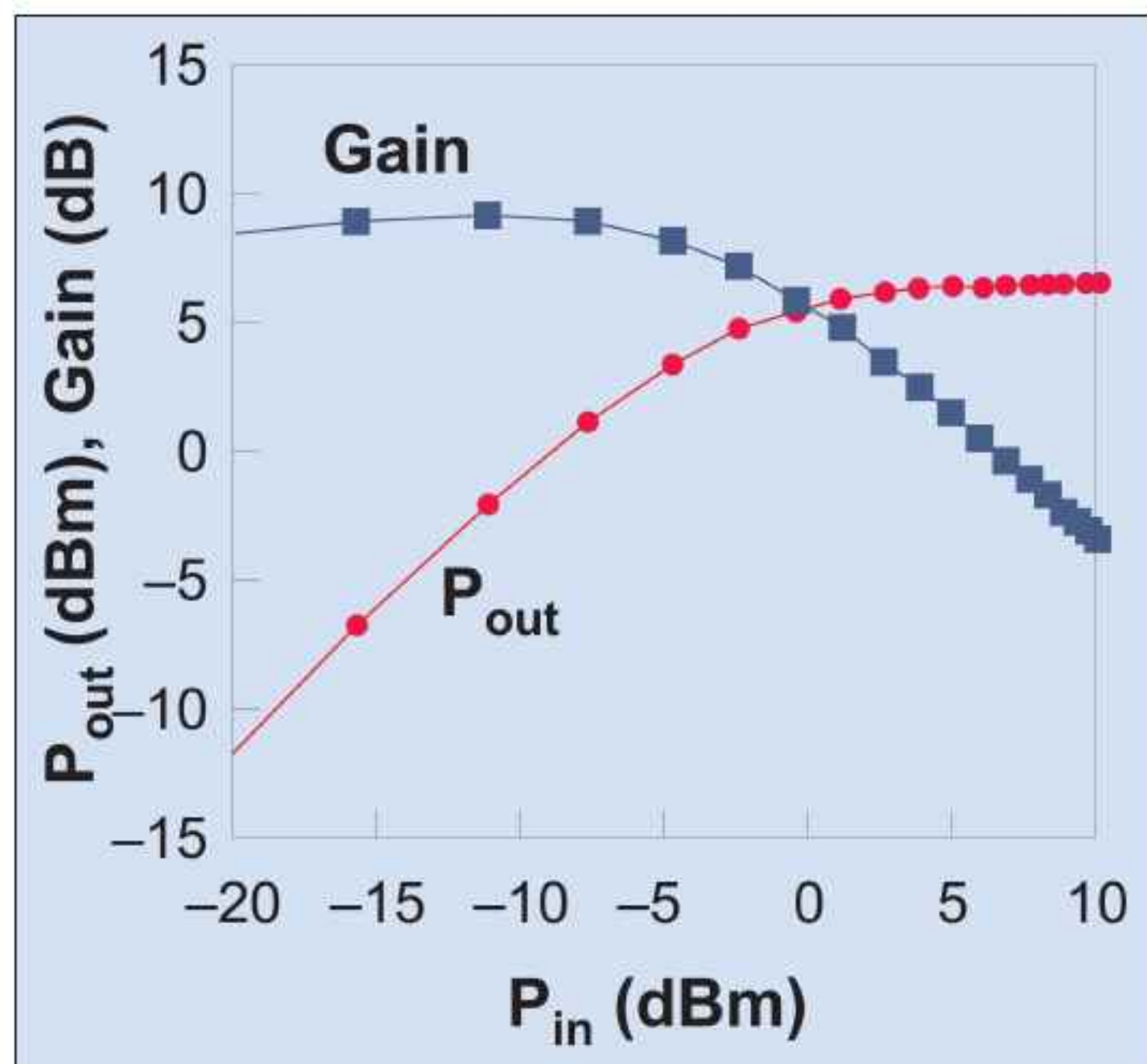
line where the impedance depends on its length. Short stubs compact the chip area required by the matching circuit to one-tenth of previous levels and reduce signal losses to 0.4dB. The power amplifier operating at 77GHz achieved 8.5dB of gain and 6.3dBm (4.3mW) of saturated output power from a 1.2V supply (Figure 6). Furthermore, a separate power amplifier operating at 60GHz was developed and achieved 8.3dB of gain and 10.6dBm (11.5mW) of saturated output power.

The University of Toronto, with help from STMicroelectronics, has developed a fully integrated 76–95GHz band receiver produced in 65nm digital CMOS. The researchers are seeking to develop technologies for double-sideband imaging, remote sensing and 10Gb/s communication. Further motivation is to explore the capabilities of advanced CMOS. Beyond 65nm, the researchers expect 45nm devices to handle 120GHz RF communications, and 32nm to handle 160GHz.

The 65nm transistor that was used has cut-off frequencies of 170GHz for  $f_T$  and 250GHz for  $f_{max}$ . The receiver includes an LNA, mixer, IF amplifier, fundamental-frequency VCO with buffers, and divider with 50Ω driver, all consuming 206mW. Operation up to 100°C was shown. The conversion gain is 12.5dB and NF is 7dB.

The University of California, Los Angeles reported on a 60GHz 36mW double-conversion heterodyne receiver using a 30GHz local oscillator fabricated in 90nm CMOS. The receiver achieves NFs of 5.7–8.8dB and gains of 18.3–22dB. Ruhr-Universität Bochum presented on a 60GHz 65nm CMOS 35mW LNA with single-ended input and differential outputs with 22.3dB voltage gain and NF of 6.1dB. The chip occupied 0.46mm x 0.46mm.

Although ISSCC 2008 presented a cross-section of ongoing work to develop tens of GHz RF CMOS, there were some notable absences. Toshiba is also working in this area. In 2007, it announced a low-cost 90nm CMOS process to achieve high-speed, highly integrated wireless communications over short distances for consumer applications, unveiling the technology at the VLSI Circuits symposium in Kyoto. It has realized a 60GHz CMOS receiver chip integrating an on-chip antenna, LNA, mixer with preamplifier and phase-locked loop (PLL) synthesizer in a die of 1.1mm x 2.4mm without pad areas. Toshiba believes its 90nm process achieves a performance close to that of GaAs devices. Element and wiring structures are optimized to restrain internal noise for stable operation. Beyond improving the receiver circuit, Toshiba plans to develop the high power required for a transmitter IC, aiming to achieve a practical mm-wave CMOS transceiver "at an early date". ■



**Figure 6. Input-output characteristics for Fujitsu Labs' 77GHz PA. The peak gain is measured as 8.5dB and the peak output power 6.3dBm (4.3mW).**



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# Semiconductor choices for wireless access

**Peter Gammel**, chief technology officer of SiGe Semiconductor, discusses the advantages and disadvantages of silicon technology such as SiGe versus GaAs for various applications in wireless connectivity.

**M**uch has been made about silicon versus GaAs. But, although it can make for dramatic reading, the truth is that there is a place for multiple semiconductor technologies in the wireless market.

GaAs is the technology most often chosen to manufacture the power amplifier (PA) used in a mobile handset voice signal chain, and the qualities of GaAs make it particularly well suited for this role. The growing trend for multimedia access, whether in a portable device or a wireless local-area network (WLAN) card, however, requires another type of signal chain, one that features a small footprint, multi-mode/multi-band performance, and low power consumption. All of these requirements point to the use of a silicon semiconductor process such as silicon germanium (SiGe). This article examines the qualities of SiGe, and how it compares to GaAs, especially for multimode wireless access applications.

Today's wireless devices are challenged by smaller footprints, more functionality, and lower-power operation.

At the end of the day, however, what really drives the success of an end product is the quality of the customer's experience. Throughout the semiconductor industry, the material of choice for high integration and low cost has always been silicon. When wireless devices began operating at higher frequencies, the limits of traditional silicon CMOS

processing were taxed, and more creative solutions were needed. Both GaAs and SiGe processes were in development at that time, and GaAs was the first to deliver on its promise for high-output-power, high-frequency applications. It has since found its niche in power amplifiers (PAs) for mobile handsets.

In the meantime, SiGe has entered high-volume production, and it is proving to be particularly well suited for high functional integration and operation from low, variable voltage sources, such as those in mobile devices.

**The power consumption and layout area of current-driven GaAs control techniques are incompatible with voltage-driven MOS techniques, so GaAs PAs require silicon control functions**

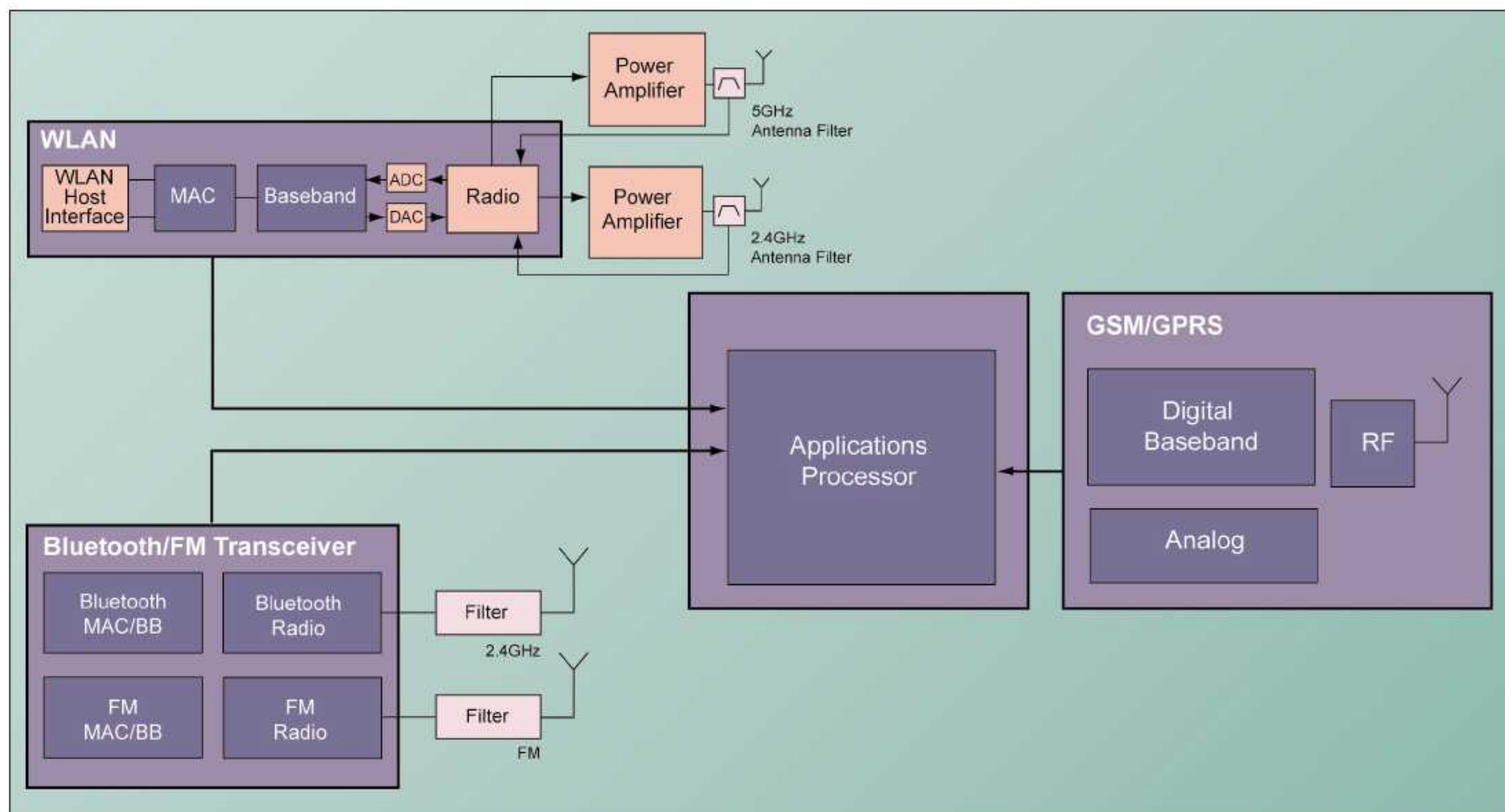
## Power amplifier design

There is a real need for semiconductor processes to support the changing needs of PA design. Ten years ago, the focus was firmly on separate functional blocks to maximize performance. The commercial mobile handset industry was still relatively young, and the advanced functionality of today's phones was not even imagined by consumers. When GaAs processing first became available, there was a real need for a PA that could deliver high output power. At the time, handset designs were shrinking in footprint, but the available real estate for the PA and its supporting circuitry was still quite generous.

Since then, the available real estate in wireless devices has changed dramatically, and wireless connectivity has moved well beyond the mobile handset. Now, functional integration and conversion in a single module is required by mobile and portable devices alike. Because it is a silicon-based process, SiGe is a material that is well suited to these new applications, as it can be used to integrate bias, regulation, control, interfaces, and filtering.

By comparison, all of these functions are difficult to achieve in GaAs due to a lack of NFET/PFET devices in standard foundry processes. In addition, the implementation of complex digital and analog functions using GaAs heterojunction bipolar transistors (HBTs) is limited by high npn turn-on voltages, which severely curtail circuit topology choices in low battery voltage environments. As a result, the low voltages and sophisticated logic and control functions required to interface with transceivers in 65nm and 90nm CMOS are incompatible with GaAs PAs. GaAs FEMS require an additional CMOS controller chip, not found in BiCMOS solutions. Complex analog and RF filtering options are an additional challenge for GaAs, due to lower passive component integration density and a lack of simple MOS-switched controls.

In reality, the 'RF signal chain' is only 20% of the story in PA design. It is the ability to integrate this supporting circuitry that makes or breaks the power amplifier function (see the block diagram of the cell-phone chain in Figure 1).

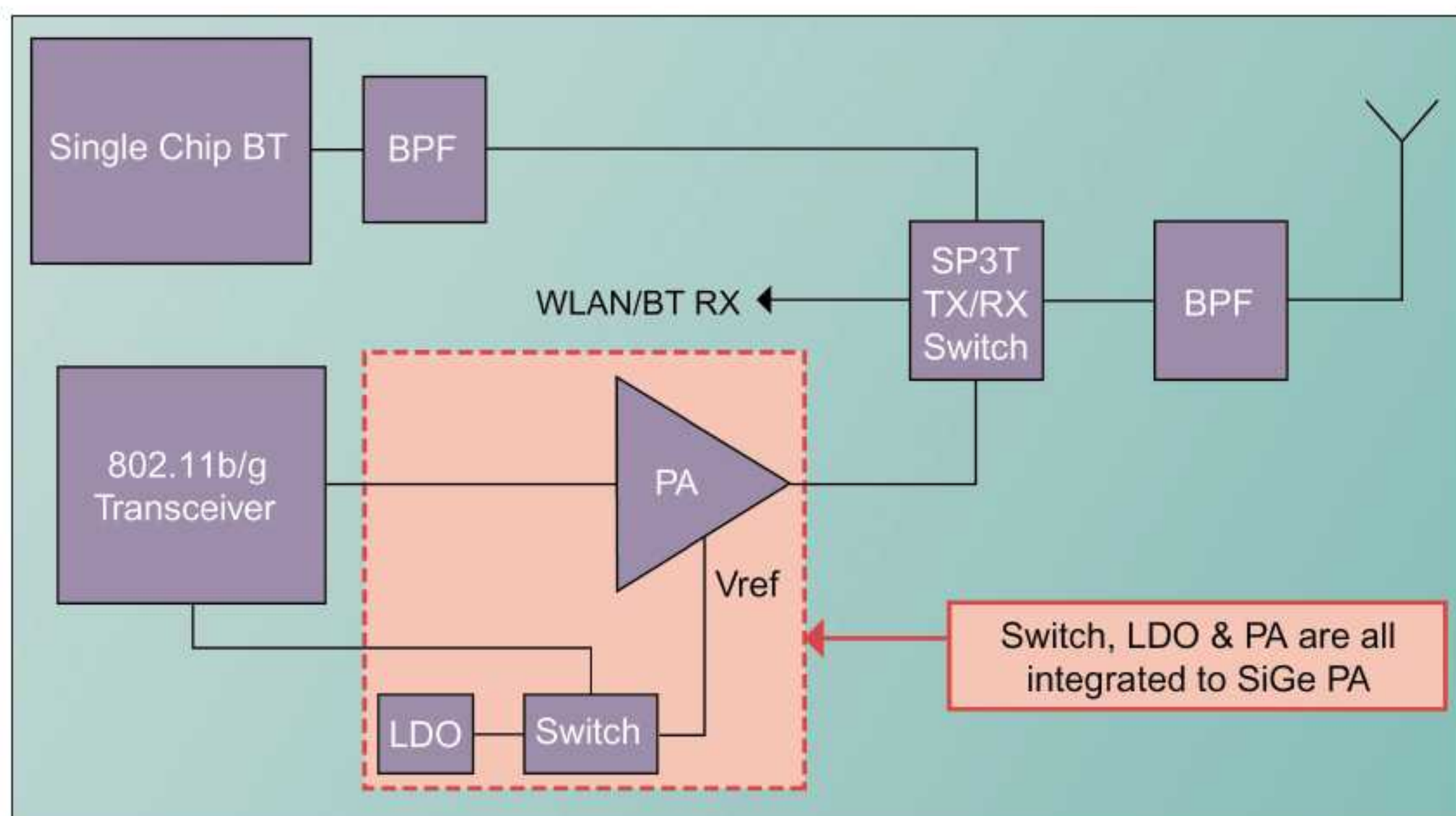


**Figure 1: Block diagram of a cell-phone chain.**

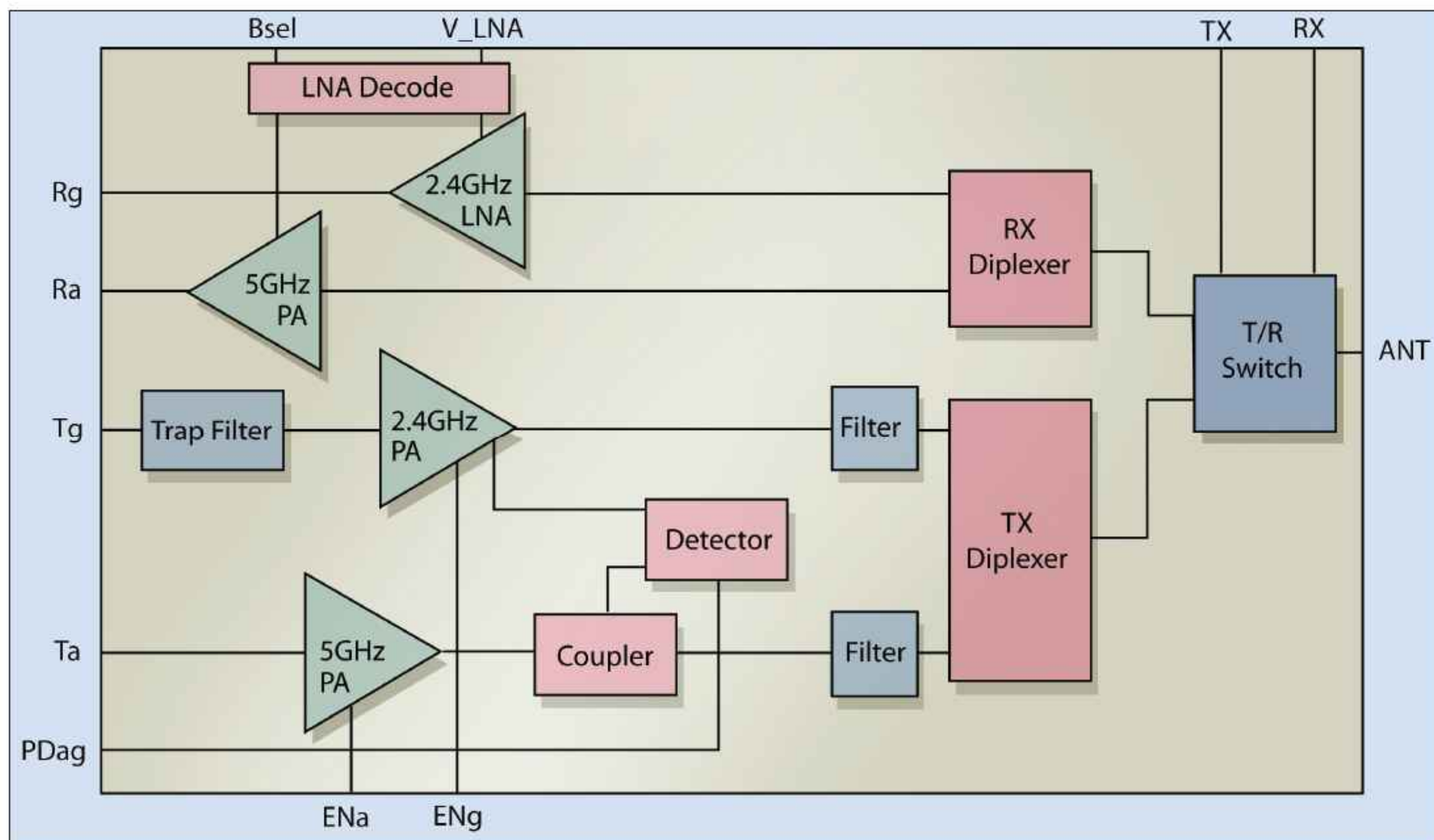
### Voltage needs

Most of the devices in mobile handsets are optimized for  $+1.8V_{DC}$  operation, and today's sub- $0.1\mu m$  silicon CMOS processes support RF transceivers and micro-processors operating from  $+1.8V_{DC}$ . Unfortunately, the GaAs RF power amplifier requires external regulators on the system level that need a  $+3V_{DC}$  supply to maintain a steady reference voltage (see the GaAs cell-phone block diagram in Figure 2). This voltage is typically converted into a simple current source through the addition of series resistance and is used to fix the bias point of the amplifier at a predetermined level via a simple emitter/follower circuit. Unintended modulation of this node can have disastrous results on amplifier performance and puts demands on the end user to maintain a well decoupled connection between the reference voltage and the PA. In Figure 2, note the relative size of the filter and low-drop out (LDO) regulators, which surprisingly have a much larger footprint than the actual power amplifier.

Also of note, silicon-based HBT and CMOS devices, such as those using SiGe, are fully active at  $+0.6V_{DC}$ , while GaAs HBT and pHEMT devices are not fully active until  $+1.3V_{DC}$ . The aim of handset designers is to achieve usable power under  $+3V_{DC}$ , which would allow them to move to lower-voltage, higher-energy-capacity batteries. With its ability to operate at low voltages and the capability of integrating BiCMOS control logic, SiGe is better positioned to achieve this goal. GaAs-based RF power devices, on the other hand, limit the value of moving to sub-3V batteries.



**Figure 2: GaAs cell-phone block diagram.**



**Figure 3: SiGe Semiconductor's SE2593 front-end module.**

## Applications

The optimal applications for SiGe and GaAs are really quite different, and they range across cellular handsets to GPS, WLAN, FM, Bluetooth, and WiMAX broadband technology.

As a general rule of thumb, the more the product requires integration, control and a good RF signal chain, the better it is suited for SiGe.

For small-die, single-function, high-frequency applications, gallium arsenide is likely to be the better choice.

Wireless connectivity in multimedia-capable mobile devices focuses on small footprint, multi-mode/multi-band performance, and low power consumption. The lower the functional integration, the more that GaAs-based technologies make sense for consumer electronics markets.

For instance, good GaAs applications include mobile handset PAs and USB dongles. The higher the functional integration, the more SiGe BiCMOS technologies provide clear advantages in cost and size while matching GaAs performance. Good applications for SiGe,

**For small-die, single-function, high-frequency applications, gallium arsenide is likely to be the better choice.**

**The lower the functional integration, the more GaAs-based technologies make sense for consumer electronics.**

then, would include wireless connectivity, multimedia, multiple-band applications, such as WLAN connectivity, wireless video distribution, and personal entertainment devices.

## Footprint needs: integration and modules

It is well known that, as technologies mature, they move towards modules and higher integration. Both SiGe and GaAs differ on integration techniques and the scale for available integration (the number of components that can be integrated in the same chip or module).

Wireless connectivity and mobile communications are benefiting most from a system in package (SIP) approach rather than a system on chip (SoC) approach. The SIP or modular technique allows designers to combine the best available semiconductor processing technologies with better performance trade-offs.

For instance, since analog RF requires bias and control in BiCMOS, an SIP could allow for the use of GaAs and silicon BiCMOS in the same package, where appropriate.

Designers using GaAs for power amplification are now achieving good integration of the PA with low-noise

**Since analog RF requires bias and control in BiCMOS, an SIP could allow for the use of GaAs and silicon BiCMOS in the same package, where appropriate**

amplifiers (LNAs) and switches. For instance, TriQuint Semiconductor recently announced GaAs RFICs for the front end with this level of integration. However, because it is implemented in GaAs, the device still requires external filtering and control circuitry that needs to be implemented in silicon.

The integration of SiGe bipolar RF performance with SiGe CMOS bias-and-control functionality onto a single, small-footprint integrated circuit is a key enabler for the rapid growth of wireless connectivity for multimedia services in mobile consumer electronics devices. The SE2593 front-end module (FEM) from SiGe Semiconductor Inc, for example (see Figure 3), integrates multiple power amplifiers, LNAs, a power detector, a T/R switch, filters, diplexers, and associated matching circuitry.

In a typical 802.11b/g PA, bias and control consumes about 15% of the die area of a SiGe BiCMOS solution. In GaAs, the silicon CMOS-based bias and control IC accompanying the GaAs RF front-end die represents about 35% of the total semiconductor die content in the module (interconnect pads represent about 8% of the CMOS die area: note that this interconnect is not required by the SiGe BiCMOS-based solution.)

## Manufacturing and economics

SiGe processing uses a standard CMOS process that benefits from magnitudes of scale, so costs get driven down. The technology is currently being processed at the world's largest CMOS fabs, which have extensive capacities and short cycle times. In fact, many of the world's largest foundries are converting their existing 200mm wafer capacity to support analog/RF BiCMOS. The high-volume manufacturing of SiGe analog/RF devices has continued to support production at 200mm.

While GaAs processing is typically carried out at captive fabs, SiGe is a part of the growing fabless semiconductor model in RF. The fabless model moves the industry away from captive fab to foundry usage, which is historically what every segment of the semiconductor industry has done. This has proven to be a more economical model with more assured availability, because it is supported by multiple foundries.

SiGe BiCMOS, for instance, is a widely available technology that is currently being supplied by the world's largest analog/mixed-signal semiconductor foundries, including IBM, Taiwan's TSMC, STMicroelectronics and Jazz Semiconductor. As a result, it is not suffering from capacity constraints that could limit the production of gallium arsenide.

**While GaAs processing is typically carried out at captive fabs, SiGe is a part of the growing fabless semiconductor model in RF.**

## Roadmaps: the future of silicon and wireless

GaAs is still the predominant technology for 5GHz applications and above, although there have been some interesting industry demonstrations of SiGe operating at 60GHz for low-power applications. SiGe is currently the dominant technology below 3GHz, especially for consumer electronics. We can expect that the boundaries will be pushed for power handling in SiGe.

As functional integration increases in both GaAs and silicon-based technologies, die sizes are likely to shrink, placing greater emphasis on package, assembly, and test cost reductions. For example, the single-die RF front-end IC capability of SiGe BiCMOS cuts package size and assembly cost with respect to GaAs-based RF FEMs.

Mostly, the big foundries all have well-established roadmaps that are based on BiCMOS. For designers, there is also a well-established roadmap for involving BiCMOS technology nodes and integrating additional standard blocks. Take, for example, a new RF FEM design where the customer requires a serial interface. Using BiCMOS, the designer downloads a pre-designed cell and adds it to the chip. In GaAs, the engineer must immediately begin designing transistors. As a result, BiCMOS has a distinct advantage over GaAs simply by the availability of many intellectual property (IP) blocks. So, with BiCMOS, instead of designing transistors for customized functionality, engineers can pull and license IP blocks for standard functions, focusing limited design resources on supporting customers and speeding time to market.

The pronounced limits of CMOS are constantly being exceeded. Note, for instance, the announcement earlier this year by Infineon regarding an RF CMOS switch. Most designers recognize the advantages of silicon CMOS, and many see SiGe as the natural bridge technology to silicon. In the end, BiCMOS technology uniquely combines the strengths of HBTs (PA, LNA, RF switch) and CMOS (bias and control) in a single manufacturing process. For designers, this translates to better design flow, integrated I/Os, and the use of IP blocks.

For the customer, it means faster IC samples and enhanced time to market with customized, highly integrated solutions. As a BiCMOS technology, SiGe is a proven semiconducting material for wireless applications, with products on the market including RF front-ends for WLAN, Bluetooth, GPS and WiMAX technologies. It is also being implemented for next-generation silicon-on-insulator (SOI) technologies. SiGe BiCMOS technology is key to enabling the small, low-power-consumption, high-performance multi-mode, multi-band RF front-end products that are critical to the integration of wireless connectivity for multimedia applications across the major consumer electronics markets. ■

*Author: Peter L. Gammel, chief technical officer and vice president engineering, SiGe Semiconductor Inc.*

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**12 Inspection equipment****Bruker AXS GmbH**

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[www.ums-gaas.com](http://www.ums-gaas.com)

## 19 Facility equipment

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## 20 Facility consumables

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## 21 Computer hardware & software

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[www.semitech.us](http://www.semitech.us)

## 22 Used equipment

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## 25 Resources

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

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[www.tms.org/Meetings/specialty/issled08](http://www.tms.org/Meetings/specialty/issled08)

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[www.Blue-2008.com](http://www.Blue-2008.com)

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**E-mail:** [wendy\\_larsen@nrel.gov](mailto:wendy_larsen@nrel.gov)

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Albuquerque, NM, USA

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**www.deps.org/DEPSpages/SSDLTR08.html**

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**www.movpe.umi2958.eu**

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**www.euroled.org**

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**www.intertechpira.com**

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**www.ledexpo.com**

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Beijing, China

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**www.ciled.cn**

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**www.wlf.co.jp**

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Laforet Shuzenji, Izu, Japan

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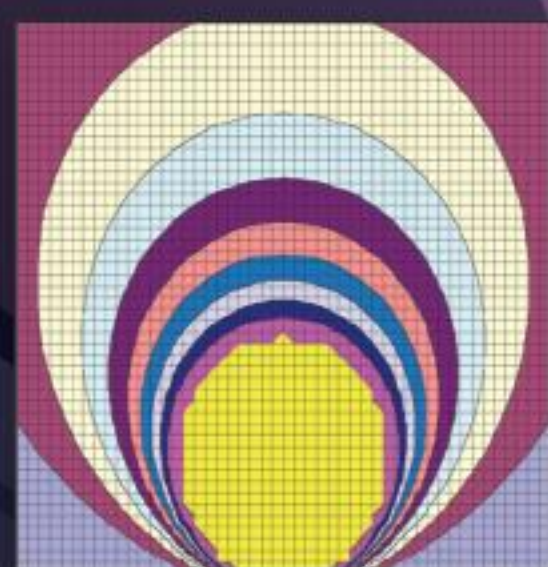
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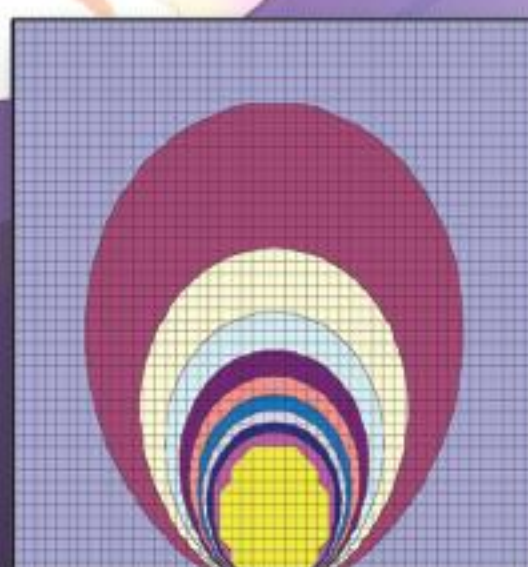
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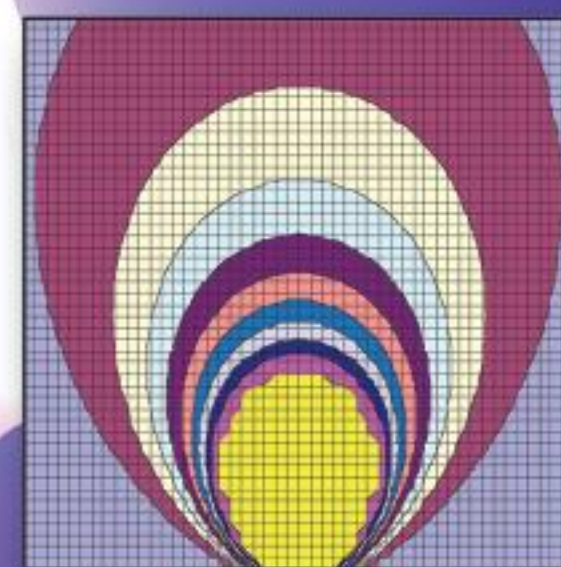
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