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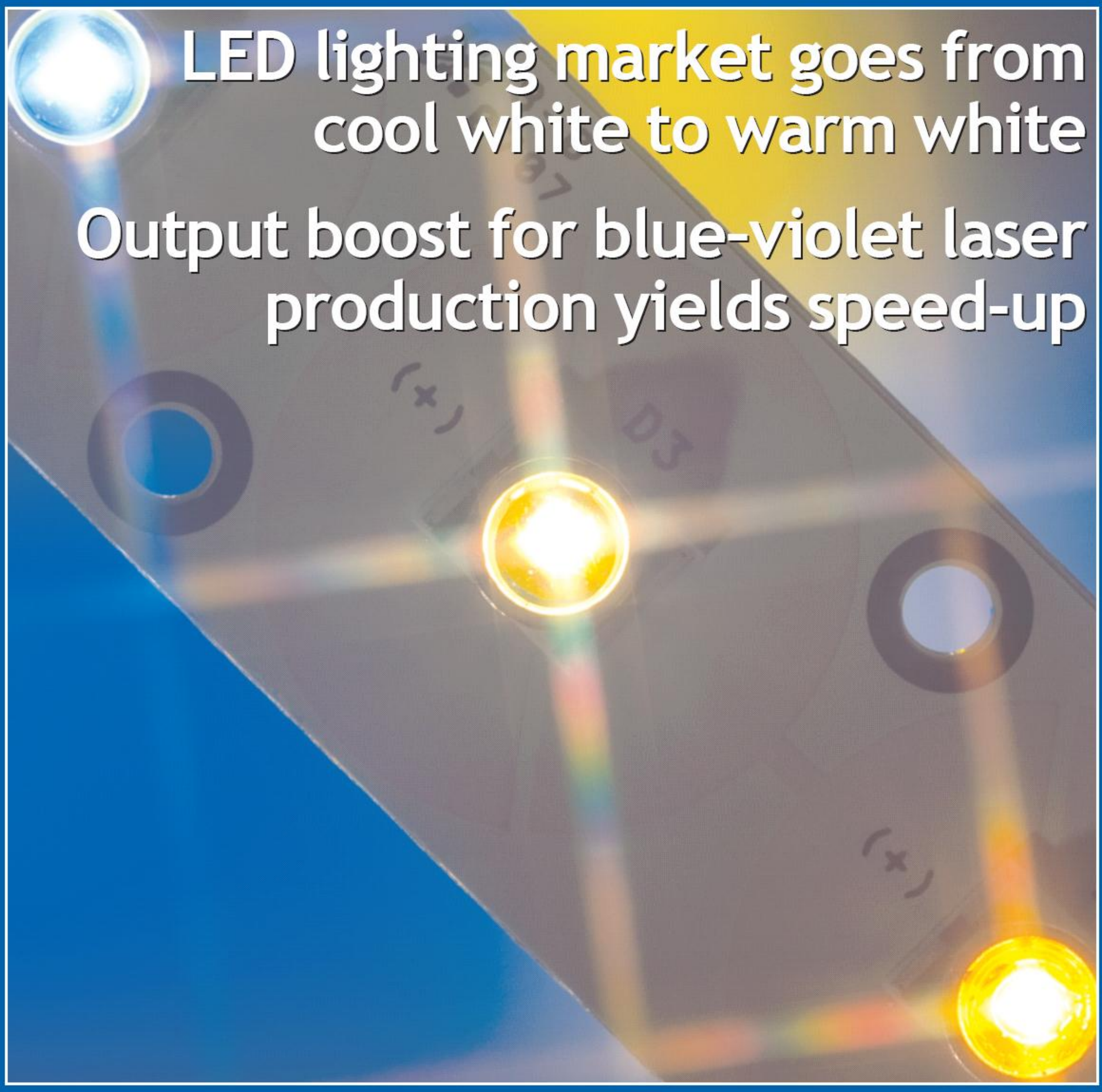

LED lighting market goes from cool white to warm white

Output boost for blue-violet laser production yields speed-up

Anadigics 6” GaAs fab for China • Nitronex expands to Durham
SDK builds 4” blue LED fab • Hitachi Cable prototypes 3” GaN

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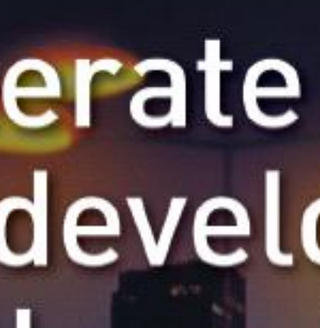
Veeco MBE Sources



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contents

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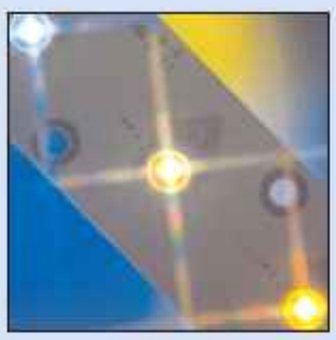
COMPOUNDS & ADVANCED SILICON

Vol. 2 • Issue 3 • April 2007

p12 Nitronex's new 69,000ft^2 HQ and GaN HEMT manufacturing plant in Durham, NC, USA.

p25 Panasonic's new white LEDs, which incorporates what it claims to be the first commercial blue LED chip to use a GaN substrate.

p37 Nichia's blue-violet laser, which has been boosted to an output power of 320mW for dual-layer HD DVD and Blu-ray Disc recording at 10x speed.



Cover: Cree has started shipping production volumes of 'lighting class' warm-white XLamp LEDs (bottom right) qualified to run at up to 700mA. The warm-white LED joins Cree's neutral-white (centre) and cool-white (top-left) XLamp LEDs, giving a range of correlated color temperatures down to 3000K. **p31**

editorial

GaN-based technology steps up

In most issues in recent months we have reported the rapid progress in luminous flux and efficiency made by white LED makers including Cree, Nichia, Philips Lumileds, Avago Technologies, and Seoul Semiconductor. In-roads are continuously being made, not just in performance but also applications, for example for automotive headlights, handheld flashlights, floodlights, outdoor displays and billboards etc. More recently, now that the quantity of light from LEDs is competitive with conventional lighting, the focus has shifted to the quality of white light, and more specifically the correlated color temperature (from earlier cool white LEDs, through neutral white, to the less harsh warm white hues that are more acceptable for indoor lighting, especially in domestic environments) — see page 26–33.

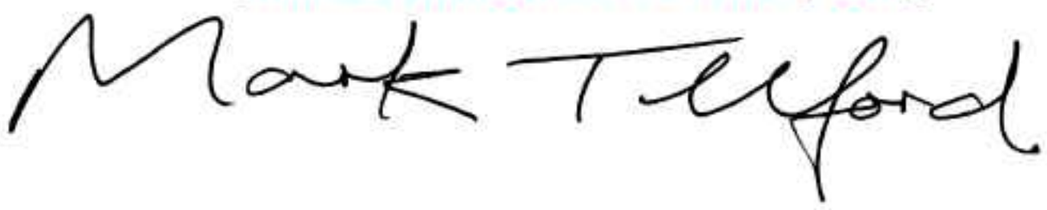
Apart from indoor lighting, outdoor lighting is being given a boost by the 'LED City' joint initiative of the city of Raleigh in North Carolina and Cree (see page 33). Cree's XLamp LEDs are also being used in streetlights in China (page 32), and the firm has extended both its product range and market reach by acquiring China-based LED lamp maker COTCO (page 30) to give access to what could be the world's key solid-state lighting market.

In Japan, SDK is building a fab to make the constituent GaN-based blue LEDs on increased-diameter 4" sapphire substrates (page 29), Matsushita has launched LEDs grown on GaN substrates (page 25), and Hitachi Cable has prototyped an HVPE-grown 3" GaN substrate, and says that 4" is feasible (page 22). Australian firm BluGlass has reported good-uniformity nitride deposition on 6" GaN-on-glass substrates (pages 23).

Meanwhile, Nichia and Sony are overcoming the problems with blue-violet laser manufacturing yield that have delayed the launch of the PlayStation 3 games console and Blu-ray Disc and HD-DVD players, and are ramping production volume (allowing Sony to start selling lasers on the open market), joined by Sharp (which started production late last year, using MBE rather than MOCVD) — see page 36. All three are also increasing output power, allowing faster-speed recording. All this promises to reduce the price and boost the popularity of the technology.

Regarding GaAs RFICs, following prolonged growth over many quarters, funds have been raised recently by main manufacturers RFMD, Skyworks and Anadigics, with the latter building a new 6" fab in China (see pages 6–7). In Q1/2007 RFMD was hit by a market-share loss specific to client Motorola and will see a dip in revenues until the September quarter. But as replacement handsets form an increasing proportion of mature markets, and low-cost handsets in emerging markets form a larger proportion of sales, the mobile handset market has slowed in year-on-year unit sales growth from over 20% to nearer 10%. RFIC makers were reporting their Q1/2007 results as we went to press (see www.semiconductor-today.com, as well as the next issue), but RFMD has already emphasized its focus on manufacturing efficiencies and investment in higher-margin technology such as GaN.

Mark Telford, Editor (mark@semiconductor-today.com)



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

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- 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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news

Emerging PVs grow at 43% annually

In 2006, the photovoltaic solar cell industry grew 30% to a consolidated figure of 2.1Gigawatts (GW) of generating power capacity, according to market research firm Fuji-Keizai U.S.A. Inc in its new report 'Global Market: Current & Next Generation Solar Cell & Related Material Market Outlooks'.

Currently, the market is dominated by solar cells based on mono- and multi-crystalline silicon technologies. In contrast, of the 2.1GW of total capacity in 2006, only 0.22GW used emerging technologies, i.e. thin-film amorphous, dye-sensitized cells, organic and polymer, nano-crystalline, and other thin-film technologies such as cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), copper indium diselenide (CIS), and gallium arsenide (GaAs).

However, the market for solar cells using emerging PV technologies is estimated to increase tremendously over the next 10 years at an average annual growth rate (AAGR) of 43.1%, capturing more than 13% of the total market (in MW capacity). Fuji-Keizai reckons that this growth is due to the demand for non-silicon-based solar cells, higher efficiency, cost reduction, and overall awareness of extracting energy from alternative sources.

The market for solar cells using emerging PV technologies is estimated to increase tremendously over the next 10 years at an AAGR of 43.1%

www.fuji-keizai.com

NA handset shipments 163m in 2007

North American handset sales will grow 6% in 2007 to 163m units, according to Strategy Analytics.

With aggressive subsidies at the heart of their strategies, operators will focus on driving 3G handsets across their user base: EV-DO sales will more than double from 23m in 2006; W-CDMA will approach 10m.

Motorola dominates the NA handset market, with a 38% share of shipments and a leading position in all the major US cellular interfaces.

LG, Samsung and Nokia have almost equal shares. Samsung is best positioned to emerge victorious, with positions at all major operators, but it will struggle to maintain focus on the NA market as it tries to balance global handset development priorities, reckons Strategy Analytics. LG will win the race if it can speed W-CDMA device launches to extend its 50% W-CDMA share position while balancing entry-tier and high-tier CDMA and GSM growth.

www.strategyanalytics.net

Thin-film solar cell equipment market to grow by almost 300%

As the solar cell industry moves toward thin-film technology amid severe polysilicon shortage, the corresponding market for solar cell production equipment (for coating, etching, diffusion and cleaning processes) will grow 275% from $1.2bn in 2006 to $4.5bn in 2010, forecasts The Information Network.

The crystalline silicon (c-Si) sector includes equipment for SiN anti-reflection coating, back reflectors, and contacts. The thin-film sector includes equipment for transparent conductive oxide (TCO), deposition, contacts, and automation tools. "Unfortunately, the market for these types of equipment is for the sectors of the industry that are projected to grow the slowest, namely c-Si and amorphous silicon (a-Si)," says Robert N Castellano, president of The Information Network.

But the real growth will be equipment for newer thin-film technologies such as cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIGS). Key innovations are roll-to-roll equipment and printable CIGS inks instead of sputtering and CVD.

Between 2006 and 2010 the compound annual growth rates (CAGR) will be about 40% for c-Si and a-SI, but nearly 75% for CdTe and 200% for CIGS. Other technologies, such as GaAs films, should also grow at triple the rate of silicon-based cells.

www.theinformationnet.com

GaAs device market $5bn and substrates $480m by 2011

Demand from cellular handsets will continue to be the primary growth engine for the GaAs industry, with Wi-Fi forecast to become the second largest market for GaAs, according to Strategy Analytics' 'GaAs Industry Forecast: 2006–2011'.

"Overall, the market for GaAs devices will exceed $5bn in 2011 and the corresponding market for GaAs substrates will be worth $480m," says report author Asif Anwar.

"VGF will be the underlying technology for bulk substrates, while epitaxial substrates will remain evenly split between MOCVD and MBE technologies," he adds.

www.strategyanalytics.com

Mobile broadband-enabled consumer electronics shipments 100m by 2012

Although the market for consumer electronics devices incorporating Wi-Fi has only just begun to gain traction, the market based on high-speed connections via 3G cellular technologies or mobile WiMAX is already starting to form as portable consumer electronics (digital cameras, media players, portable game devices, and more) are beginning to offer direct mobile broadband connections to the Internet, says ABI Research. By 2012, annual shipments of such devices will approach 100 million, according to its new study 'Mobile Broadband-Enabled Consumer Electronics'.

"Near term, connected portable devices will rely more on 3G cellular connections," says principal analyst Philip Solis. "But the 3G market is fragmented: there is EV-DO, there is HSPA; different carriers are using different frequencies in different regions...Such fragmentation represents a significant challenge. Also, such devices must compete against smartphones that increasingly include similar functions."

The first few products have already appeared, all from South Korea. Two portable video players (Digital Cube's iStationNetforce and Cowon's Q5) offer 3G connections through add-on HSDPA modules. "A modular approach makes it easier to support multiple carriers," says Solis, "but the connectivity is not seamlessly integrated." The first true device of this class, offering embedded HSDPA, is Samsung's VLUU i70 7.2 megapixel digital camera.

But ABI expects portable game devices and media players to dominate. Qualcomm's Snapdragon platform and Freescale's MXC (Mobile Extreme Convergence platform) will help enable cellular-based devices, and a wide ecosystem of WiMAX chip vendors will enable devices with embedded WiMAX.

"Longer term, WiMAX has more potential than cellular-based connections for these devices," says Solis. "It's an IP-based network with simpler architecture and better connection to the Internet. Sprint, with its commitment to WiMAX, will promote such devices heavily, in the process helping US markets keep up with Korea and Japan."

www.abiresearch.com

WiMAX developing rapidly in Asia/Pacific

Last year was remarkable for the development of WiMAX in the Asia/Pacific region, as a solid foundation was laid by the joint efforts of market regulators, operators and eager equipment vendors, says In-Stat in 'WiMAX in Asia/Pacific: A Well Laid Foundation for Prominent Future Growth'. From a lean base of 0.27m in 2006, total WiMAX subscribers in 16 countries should reach 31.43m by 2012, when the Asia/Pac WiMAX market will be $8bn.

"In emerging countries where current household broadband penetration rates are extremely low, governments have quickly built a pro-WiMAX regulatory framework," says analyst Victor Liu. Carrier spending of WiMAX and WiMAX-backhauled WiFi network equipment will escalate from $394.9m in 2006 to $2908.9m in 2012, he adds.

"One temporary setback, though, was WiMAX subscriber growth developing more slowly than expected in South Korea due to limited network coverage and lack of user devices." The South Korean version of mobile WiMAX, Wibro, was commercialized last June.

www.in-stat.com

Optical networking component market $8bn by 2012

The market for optical networking components will grow from about $2.8bn in 2007 to $7.9bn in 2012, according to analyst firm CIR.

The optical components business will experience a significant ramp-up in revenues over the next few years due to the expansion of optically addressable markets, the firm reckons. Bringing optics closer to the customer is enabling volume opportunities for components manufacturers that have not existed in the past. Optical solutions are, in some cases, the only means available to building cost-effective, high-bandwidth access and enterprise networks.

Factors driving demand include:

- Accelerating deployment in corporate networks and data centers of 10 Gigabit Ethernet (largely optical, whereas previous Ethernet versions have been dominated by copper media). The value of lasers used in Ethernet networks should grow from just over $300m in 2007 to $1.2bn by 2012, reckons CIR.
- Passive optical networks (PONs) are becoming the technology of choice for residential access networks. CIR expects more large carriers to adopt ambitious deployment strategies in the next few years, so by 2012 the market for PON lasers and detectors should exceed $800m and the market for PON splitters should almost double to $450m.
- Carriers are increasingly adopting agile wavelength division multiplexing (WDM) technology in their core transport networks. This should cause rapid expansion in demand for reconfigurable optical add-drop multiplexers (ROADMs), WDM filters and tunable lasers. Tunable lasers should be the fastest-growing major segment of the components market, reaching almost $1bn by 2012.

Due to these factors, the optical components market should experience a mini-boom over the next three years, but then settle down to annual growth of a very healthy 15%, forecasts CIR.

www.cir-inc.com

Inventory build-up trims growth in handset shipments to 12%

In Q1/2007 global mobile phone shipments grew a sluggish 12% year-over-year to 252 million units, according to Strategy Analytics in its report 'Q1 2007 Global Handset Market Share Update'. This was the first quarter in almost two years that annual growth has been below 20%.

"Worldwide cell phone shipments have been growing at an average annual rate of 25% over the past six quarters," says associate director Neil Mawston. "While Q1 growth is seasonally slower, the 12% growth registered in the first quarter of 2007 is markedly down on that longer-term trend."

"A moderate build-up of inventory in Q4/2006 led to weaker shipments during Q1/2007. We estimate a sizeable 9 million units of excess inventory were sold off worldwide during the first quarter," adds Bonny Joy, an analyst with Strategy Analytics. "Looking ahead to the second quarter, we expect more stock to be cleared from channels and the supply chain should eventually return to normal levels early in the second half of the year."

Shipments (in millions) and market shares.

Shipments	Q1/06	Q4/06	2006	Q1/07
Nokia	75.1	105.5	347.5	91.1
Motorola	46.1	65.7	217.4	45.4
Samsung	29.0	32.0	118.0	34.8
Sony Ericsson	13.3	26.0	74.8	21.8
LG Electronics	15.6	17.0	64.4	15.8
Others	46.9	49.4	192.6	43.1
Total	**226.0**	**295.6**	**1014.7**	**252.0**
Share	**Q1/06**	**Q4/06**	**2006**	**Q1/07**
Nokia	33.2%	35.7%	34.2%	36.2%
Motorola	20.4%	22.2%	21.4%	18.0%
Samsung	12.8%	10.8%	11.6%	13.8%
Sony Ericsson	5.9%	8.8%	7.4%	8.7%
LG Electronics	6.9%	5.8%	6.3%	6.3%
Others	20.7%	16.7%	19.0%	17.1%
Growth	**29.8%**	**20.4%**	**24.2%**	**11.5%**

Compared to Q4/2006, in Q1/2007 number-1 vendor Nokia's market share grew from 35.7% to 36.2% while Motorola's slumped sharply from 22.2% to just 18%. Nokia's lead over Motorola of 18.2% points is the largest gap between the two since Q4/2003.

Number-3 vendor Sony Ericsson's market share was almost unchanged at 8.7%.

Number-4 vendor Samsung rebounded with strong volumes (increasing its market share from 10.8% to 13.8%), while number-5 vendor LG strengthened its profit margins (while also increasing its market share, from 5.8% to 6.3%). These are tentative signs that the big Korean players are on the verge of a comeback, concludes Strategy Analytics. The collective market share of other vendors grew slightly from 16.7% to 17.1%.

www.strategyanalytics.com

RFMD hit by Motorola decline, but looks to investment

In Q1/2007 Motorola's mobile handset shipments fell by about 33% from Q4/2006's 65.7m to 45.4m (from a market share of 22.2% to 18% — see above).

This threatens to hit RFIC supplier RF Micro Devices of Greensboro, NC, USA, for which Motorola accounts for over 20% of its sales. RFMD's fiscal-2007 revenue (to end-March) was a record $1bn, but for fiscal Q1/2008 (to end-June) CFO Dean Priddy expects a slowdown in demand from "a top-tier customer" that will impact operating results. RFMD sees increasing strength with other customers (main client Nokia, which comprises 38% of RFMD's revenues, grew its market share). However, Priddy's overall forecast indicates a sequential decrease in revenue, margins and earnings per share.

Yet CEO Bob Bruggeworth thinks RFMD's investment in semiconductor technology, communications systems design and manufacturing capacity enable it to capitalize on the accelerating shift in value to the RF-based section of the communications path. "There are certainly challenges in the near term as we navigate through product cycles both at RFMD and at our leading customers. However, we are staying focused on the opportunities for long-term growth of our core business, diversification of our revenue and the realization of manufacturing cost savings from our investments in internal capacity."

RFMD will increase investments in its higher-margin diversified products in fiscal 2008. With initial orders being received, GaN products should begin ramping this fiscal year. WLAN PA revenue grew in the March quarter and should grow about 200% in fiscal 2008. There is also considerable interest in its GPS solution, says RFMD.

● In late March, RFMD announced the raising of $350m in funds in a private placement. Proceeds will be used for general corporate purposes, including working capital, acquisitions and future stock repurchases.

Anadigics to build 6" GaAs fab in China

To expand its wafer fabrication capacity beyond its main fab in Warren, NJ, USA, Anadigics Inc, which manufactures RFICs for the wireless handset and broadband communications markets, has entered into an investment contract with the Kunshan New and Hi-Tech Industrial Development Zone (KSND) to jointly construct a new 6" GaAs IC fab in the city of Kunshan in China's Jiangsu Province.

Kunshan is located at the center of Yangze River Delta, less than 50km from the cities of Shanghai and Suzhou. Its population of 0.6 million is less than 0.5% of China's total, but it has a 4% share of both China's foreign investment and gross domestic product (with a GDP per capita of $14,000, eight times higher than China's average).

Anadigics expects to invest $10–15m in capital expenditure over a two-year period, starting in Q4/2007 through to an initial production phase projected for Q1/2009. Anadigics' total investment over the facility's life-time (which could extend up to 50 years, the firm says) is estimated at $49.88m. In March Anadigics raised $98.8m for capital expenditure after completing a public offering of its stock (see March issue, page 10).

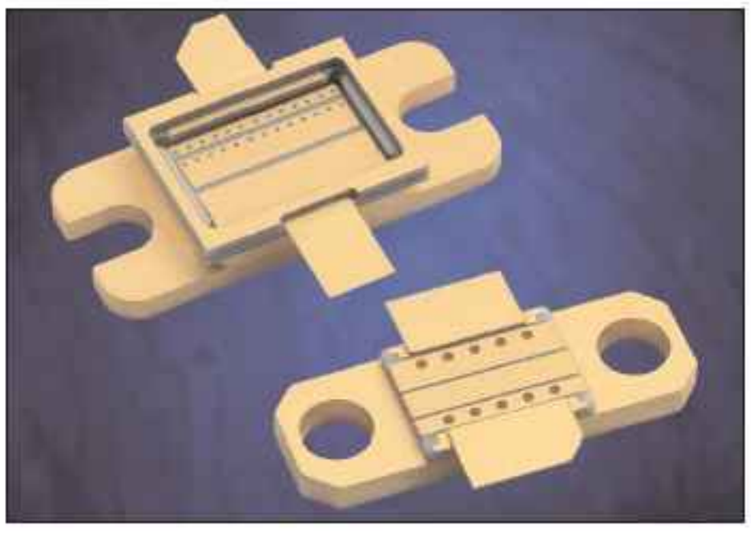
"This project is expected to provide us with an attractive cost structure and to enable us to meet our future fab capacity needs...as well as providing us with increased access to one of the fastest-growing markets for wireless and broadband communications," says Dr Bami Bastani, Anadigics' president and CEO.

www.anadigics.com
http://en.ksnd.gov.cn

BeO-based package for power devices

At the RF & Hyper Trade Show in Paris, France at the end of March, StratEdge of San Diego, CA, USA, which designs and produces packages for microwave, millimetre-wave and high-speed digital devices, released its Power Package Series (also to be featured at June's MTT-S show in Hawaii). The new series can be used in silicon, SiC, GaN, and other applications for power integrated circuits. Thermally conductive beryllium oxide (BeO) ceramic gives the packages excellent thermal properties, the firm claims. The packages also incorporate copper composite bases for enhanced thermal dissipation.

"We came up with a new hermetic package construction with improved reliability that still fits the industry-standard outlines," says senior applications engineer Jerry Carter. Hermetic packages are sealed with metal or ceramic lids with gold-tin solder preforms. Non-hermetic packages are sealed with cup-shaped ceramic or liquid crystal polymer lids with B-stage epoxy preforms.



StratEdge's Power Package Series.

"The way the packages are constructed is nearly identical to some of our existing package families," adds president Tim Going. "The manufacturing technology is very mature and stable."

www.stratedge.com

IN BRIEF

WJ completes closure of ex-EiC 4" GaAs fab

WJ Communications Inc of San Jose, CA, USA, which designs and supplies wireless infrastructure RFICs and multi-chip modules as well as RFID reader modules, says that it has completed its transition to a fabless business model with the closure at the end of March of its 4" GaAs wafer fabrication plant in Milpitas, CA. The fab was acquired as part of WJ's acquisition of EiC Corp's wireless infrastructure business in June 2004, but was considerably under-utilized.

WJ agreed in March 2006 to use pure-play III-V wafer foundry Global Communication Semiconductors Inc of Torrance, CA as a second source of GaAs and InGaP HBT wafers (starting last July). WJ subsequently decided at the beginning of November to go completely fabless, using GCS as its sole source of the products.

"Operating under a fabless business model will enable us to focus our resources on new product introductions for high-growth markets, including wireless small signal, wireless power, WiMax and RFID," says president and CEO Bruce Diamond. "The associated cost savings of $1–1.25m per quarter [$4–5m annually] will assist in further improving our financial performance in the coming quarters and years."

WJ is following the examples of former GaAs chip maker Mimix Broadband Inc Houston, TX, which decided to go fabless earlier last year, and Hittite Microwave of Chelmsford, MA. Both of these companies have since grown profits significantly over the last year.

www.wj.com

SiGe appoints president and CEO to lead expansion

SiGe Semiconductor Inc of Ottawa, Canada has appointed Sohail Khan as president and CEO. He will lead the firm in its next stage of development, as it expands as a supplier of RF front-end solutions for next-generation wireless systems for the consumer electronic markets.

Products allow the addition of wireless data and navigation capability in laptop PCs, personal digital assistants (PDAs), handheld game machines, cell phones and personal video players and are compliant with standards such as WiFi, WiMAX, Bluetooth, GPS, Galileo, GSM and UMTS.

Revenues grew 55% from $31.8m in 2005 to over $49m in 2006 (following growth of 59% from 2004's $20m, and growth from just $3.6m in 2003). This is due largely to SiGe's relationship with Broadcom, which has integrated SiGe's PA front-ends into reference designs for 802.11b/g and draft 802.11n solutions. SiGe shipped over 64m components in 2006 (up more than 30% on 2005), raising the total to 146.5m.

SiGe is one of the few private wireless semiconductor companies to successfully compete against much larger rivals in the consumer electronic market, says Khan.

SiGe's new president and CEO Sohail Khan.

Khan has over 25 years of experience in the communications and semiconductor industry, with a track record of building large, successful global businesses, creating new products, and developing new markets. "He has an impressive track record capitalizing on key market opportunities and maximizing profitability," says Pat DiPietro, managing general partner of VenGrowth Capital Partners Inc (one of the firm's that led SiGe's US$19.5m round of funding last August).

Khan joins from Bessemer Venture Partners, where he was an operating partner and entrepreneur-in-residence, responsible for evaluating communications deals and providing assistance to portfolio companies. Previously, he helped to execute Agere's initial public offering spin-out, and was executive VP of Infrastructure Systems and chief strategy and development officer. Khan was also president of Lucent's Integrated Circuits - Microelectronics division, growing its market position in cellular handsets and base-stations. He has also held management positions at NEC Electronics, Intel and the National Engineering Services of Pakistan. Khan currently sits on the board of directors for both venture-funded Intel spin-off GainSpan Corp and NASDAQ-quoted optics firm LightPath Technologies.

www.sige.com

SEMATECH using x-ray metrology system to evaluate high-k dielectric, metal gate, and SiGe materials

SEMATECH, the global semiconductor research consortium based in Austin, TX, USA, is to use an x-ray metrology system manufactured by Bede X-ray Metrology of Durham, UK to evaluate novel front-end materials needed for the 45 and 32nm CMOS silicon technology nodes and beyond, specifically the phase and degree of crystallinity present in high-k dielectrics and metal gate electrodes, and the strain in SiGe films.

"Our evidence shows that the phase and crystallinity in high-k material have an impact on a device's electrical characteristics," says Dr Alain Diebold, a senior fellow at SEMATECH. "Using XRD [x-ray diffraction] allows us to fine-tune the process, and speed up high-k development." In late January, SEMATECH members Intel and IBM (the latter working with development partners AMD, Sony and Toshiba) both announced separately that they had developed 45nm-generation transistors that use metal gate electrodes and a high-k gate oxide layer (a hafnium-based oxide deposited by atomic layer deposition, in the case of Intel) — see March issue, page 19. XRD is also a leading technique for measuring strain and composition in SiGe, Diebold adds.

- Last November, Bede shipped a BedeMetrix-F process control system with ScribeView (small spot optics technology) — designed for in-line high-volume manufacturing — to a "leading US semiconductor manufacturing consortium". The system is being used to control strain and relaxation in SiGe on product wafer metrology pads for their 45nm process.

Last August, Bede said that it was collaborating with Belgian research institute IMEC, which is using a BedeMetrix-L R&D system with Microsource and ScribeView optics in its 300mm facility to investigate the use of x-ray metrology for process control of new semiconductor materials, including strained silicon, for the 45nm node and below.

- Bede's 2006 revenues were £6m, down on 2005's £6.9m. But Q4 sales tripled year-on-year to £3.7m.

Orders in 2006 were £7.5m (up from 2005's £4.2m), boosted by Q4 orders tripling year-on-year to £2.1m.

Bede will continue to focus on the shift of silicon IC production from 90nm technology to 65nm and below, as well as strain-engineered devices, for which its tools are primarily designed.

www.bede.com

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Jazz launches 200GHz, 130nm SiGe BiCMOS technology

Independent wafer foundry Jazz Semiconductor of Newport Beach, CA, USA has released its 130nm SiGe BiCMOS process (SBC13) for high-speed wireless, optical communications and millimeter-wave applications, available for prototyping through a multi-project wafer (MPW) program offering 5mmx5mm tiles.

"The SBC13 process further extends our SiGe technology roadmap and addresses our customers' needs for a high-performance SiGe BiCMOS process by complementing our 200GHz 0.18µm process with a 200GHz process at the 0.13µm node," says Marco Racanelli, VP of technology and engineering.

The technology includes advanced analog components with high-density digital circuitry to provide scaling of both the analog and digital blocks in a system-on-chip (SoC) approach. "Our SBC13 offering provides our customers an advantage in both performance and power consumption, with the combination of a 200GHz transistor with 1.2V low-power CMOS," says Racanelli.

SBC13 uses a 1.2/3.3V dual-gate oxide process to form the base, industry-standard 130nm CMOS, and for high-performance RF and millimeter-wave ICs adds silicon germanium HBT NPN transistors, offering a range of f_T, f_{max}, and breakdown voltages (BV_{ceo}) for design flexibility (with an f_T up to 200GHz and a separate higher-voltage transistor). The process also supports up to six layers of aluminum metal, a 5.6 fF/µm^2 linear MIM capacitor, a triple-well module, Nwell resistor, MOS varactor, and low- and high-value unsilicided poly resistors. The top metal is 3µm-thick aluminum to support high-Q inductors. The technology is offered through Jazz's integrated design environment supporting the latest electronic design automation (EDA) tools and flows for fast and accurate design cycles of RF, analog and mixed-signal products.

Jazz also offers a comprehensive design and modeling environment tailored to address hurdles encountered in increasingly complex RF and analog designs. New PSP MOSFET models, statistical models, and a Process Control Model Tool (PCMT) are available. The new models and tools provide more accurate simulations, reduce design time and speed time-to-market, the firm claims.

www.jazzsemi.com

Amelio replaces Li after Acquicor's take-over of Jazz

In February, Acquicor Technology Inc and Jazz Semiconductor Inc (both of Newport Beach, CA, USA) completed their merger (agreed last September). Acquicor has become Jazz Technologies Inc, with Jazz Semiconductor as a subsidiary.

Acquicor was formed in August 2005 by Apple Computer Inc co-founder Steve Wozniak as chief technology officer, Ellen M. Hancock (former CTO of Apple and COO of National Semiconductor) as chief operating officer and president, and Gilbert F. Amelio (former chairman and CEO of Apple and National Semiconductor Corp) as chairman and CEO. Acquicor raised $172.5m in its March 2006 initial public offering, plus a further $166.75m in a private placement last December to fund the acquisition of Jazz. Acquicor subsequently made payments of $260.1m for the firm.

Jazz Semiconductor was formed in 2002 as a joint venture between Conexant Systems Inc (which contributed its Newport Fab LLC plant, and is now a fabless semiconductor company) and private equity firm The Carlyle Group (which invested $52m in a 55% controlling stake). The aim was to transition from a captive manufacturing facility within Conexant to an independent wafer foundry, focused on specialty CMOS process technologies (including high-voltage CMOS, SiGe BiCMOS and RFCMOS) for highly integrated analog and mixed-signal devices. This resulted in the expansion of Jazz's business from initial clients consisting of just Conexant and Skyworks Solutions Inc (created from the spin-off of Conexant's wireless business and the merger with Alpha Industries in June 2002) to over 300 design wins from almost 100 new customers.

Jazz Semiconductor expects its new status as a publicly traded firm to provide greater financial flexibility as it grows organically and through strategic acquisitions. Customers will benefit from the stronger balance sheet and access to increased capabilities of the combined entity, the firm believes.

● In late March Shu Li resigned as president and CEO of Jazz Semiconductor. Amelio will assume Li's duties and remain in the role for the foreseeable future.

"Shu has been with Jazz Semiconductor since its inception in 2002, and has overseen the company's growth," says Amelio. "Shu and his team have put a strong foundation in place," he adds. "As Jazz undertakes this latest phase in its evolution, I will work side by side with the Jazz management team and our employees to ensure that a smooth transition occurs."

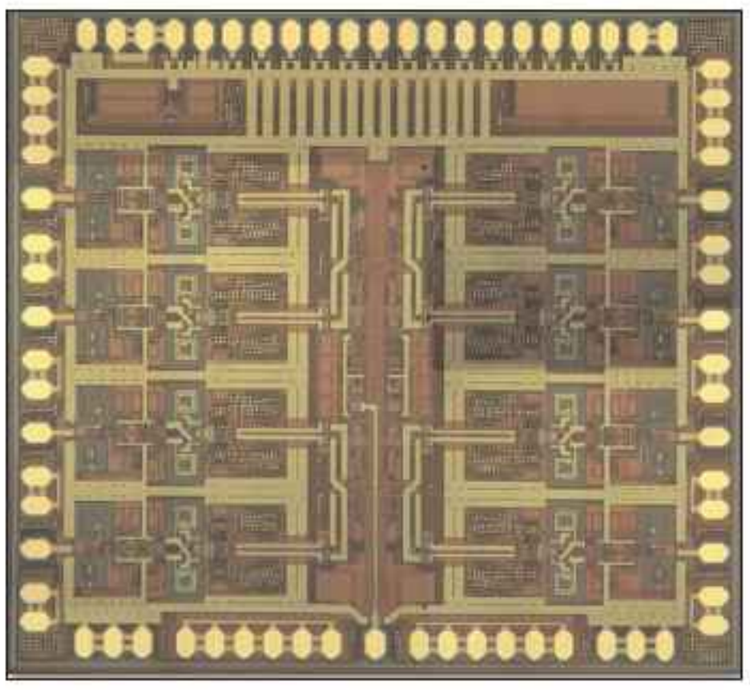
SiGe BiCMOS eight-element 6–18GHz phased-array chip

The University of California, San Diego (which is home to the Center for Wireless Communications and the DARPA S&T Center for RF MEMS Reliability and Design Fundamentals) has developed an eight-element phased-array receiver chip covering the 6–18GHz frequency range. This is the first demonstration of a single silicon chip with eight 6–18GHz phased-array receivers together with all the necessary CMOS controlling circuits, it is claimed.

The chip incorporates an RFIC that uses Jazz Semiconductor's proprietary models, design kit and SBC18HX 0.18μm SiGe BiCMOS process, which combines SiGe bipolar and passive elements with CMOS for high-speed networking and millimeter-wave applications.

The SiGe transistors have a cut-off frequency (f_T) of 155GHz and a maximum frequency of oscillation (f_{max}) of 200GHz, making them suitable for low-power, high-performance millimeter-wave and OC-192 and OC-768 circuits. The SBC18HX process comes standard with three bipolar (NPN) transistor types, 1.8V and 3.3V CMOS (dual-gate), deep-trench isolation, lateral and vertical PNP transistors, MIM capacitors, high-performance varactors, poly-silicon as well as metal and N-well resistors, high-Q inductors, a triple-well option, and six layers of metal.

The 2.2mm x 2.3mm chip contains eight silicon low-noise amplifiers operating at 6–18GHz, eight phase shifters with at least 4-bit of phase control, and an 8:1 active power combiner with very wide bandwidth, together with all the digital functions needed to control the chip (such as the address decoders for the eight individual elements, the memory latches for the phase settings, the clock enable functions to load the information on the chip, and power regulators). The chip consumes 140–200mA of DC current from a 3.3V power supply, provides RF gain of 12–24dB with a noise figure of 6dB, and can be integrated directly with eight planar antennas on a standard printed circuit board.



Design of the SiGe BiCMOS 8-element 6–18GHz phased-array receiver chip.

Jazz says that the chip replaces at least 16 GaAs chips, consumes 20x less power than traditional phased-array implementations, and allows a new generation of miniature and very low-cost phased arrays for X- to Ku-band applications.

The chip replaces at least 16 GaAs chips, consumes 20x less power than traditional phased-array implementations and allows a new generation of miniature and very low-cost phased arrays for X- to Ku-band applications.

Using the chip, UCSD has demonstrated independent amplitude and phase control at 6–18GHz of eight different antenna elements with at least 4-bit phase resolution. It provides commercial availability of highly integrated RFIC modules for X- and Ku-Band phased-array applications. The chip was designed and tested by Kwangjin Koh, a graduate student from UCSD's Electrical and Computer Engineering School, sponsored by the DARPA program SMART (Scalable Millimeter-Wave Array Technology) under the direction of Dr Mark Rosker, and under a subcontract from Teledyne Scientific Corporation of Thousand Oaks, CA.

The chip can operate over a narrow bandwidth for communication systems, or over an instantaneous 12GHz (6–18GHz) bandwidth while keeping its performance unchanged. This solves a key barrier to complex phased-array fabrication, it is claimed, while still leveraging standard low-cost RF packaging techniques. The application areas are in low-cost phased arrays for mobile satellite systems, smart-antenna wireless systems for high data-rate communications, and defense systems such as radars and high-bandwidth telecom links covering the X- to Ku-Band frequency range.

"UCSD believes that the silicon RFIC phased-array controller will be a disruptive element in the design of future phased-array systems and will enable low-cost phased arrays in the near future by integrating so many functions on the same silicon chip," says UCSD Electrical Engineering professor Gabriel M. Rebeiz, a co-developer of the chip.

"UCSD and Teledyne Scientific's use of the Jazz multi-project wafer (MPW) program provided a low-cost approach to enable an innovative, cost-effective silicon-based chip, designed to address the high data-rate communications and satellite-based systems markets," adds David Howard, Jazz's executive director of new product technology.

www.ece.ucsd.edu

Nitronex moves HQ to Durham as part of expansion

Nitronex Corp, whose existing 55 staff make GaN-on-silicon RF power transistors for the commercial wireless infrastructure, broadband and military markets, is moving its headquarters from its R&D facility in an office park near North Carolina State University (NCSU) in Raleigh to a manufacturing facility adjacent to the Research Triangle Park in Durham, NC, USA (home town also to rival GaN HEMT maker and fellow NCSU spin-off Cree Inc).

The expansion is part of a strategic decision to move all divisions into a purpose-built 69,000ft^2 facility that will enhance its manufacturing capacity and provide space for expanding R&D. Nitronex expects all operations to be consolidated in the new facility by Q3/2007, and anticipates ISO 9000 qualification by the end of the year.

Nitronex was founded in 1999 by graduates of the Department of Materials Science & Engineering's wide-bandgap program at NCSU. In June 2006, it raised $21.8m in a funding round led by Silicon Valley's Alloy Ventures and joined by new investors Arch Venture Partners of Albuquerque, NM, Diamondhead Ventures of Menlo Park, CA, and Durham-based Intersouth Partners. This increased total funding to $77m.

"To accelerate our new product development efforts, and ramp our production capacity in response to the growing demands of our customers, we have selected Durham, NC as the site for our new manufacturing facility and corporate headquarters," says president and CEO Charles Shalvoy.

After considering moving to California's Silicon Valley, in March Nitronex accepted an incentive package from Durham County for the reimbursement of $100,000 in moving costs and staff training. This will be phased in as Nitronex invests a projected $24m in the site over five years and creates about 200 manufacturing, engineering and administrative jobs (conditional on hiring a certain percentage of Durham residents).

"The Research Triangle Park area is an internationally recognized technological development community, with excellent local educational institutions [including NCSU, Duke University and the University of North Carolina at Chapel Hill], attractive and affordable housing, and a very comfortable, temperate climate," says Shalvoy.

The relocation enables the expansion of manufacturing capabilities and strengthens Nitronex's position to address many of the challenges facing the cellular, broadband and WiMAX markets, says Chris Rauh, VP of sales and marketing. The new HQ was designed for the firm's R&D and manufacturing operations and provides the necessary facilities for developing new product lines and ramping volume production, he adds.

www.nitronex.com

Nitronex's new 69,000ft^2 headquarters and manufacturing plant in Durham.

Director of technology made an IEEE fellow

The Institute of Electrical and Electronic Engineers (IEEE) has made Nitronex's director of technology, Dr Isik C. Kizilyalli, a 2007 Fellow for contributions in the field of IC technology. Kizilyalli manages Nitronex's process and device technology development department.

Kizilyalli received his PhD in Electrical Engineering from the University of Illinois in Urbana in 1988. Prior to Nitronex, he was with AT&T Bell Laboratories and its spin-offs Lucent Technologies and Agere Systems. Kizilyalli has authored or co-authored more than 60 technical papers and holds 39 US patents in CMOS, BiCMOS, LDMOS, GaN HEMTS and InP-based optoelectronics.

HRL demos first W-band GaN MMIC power amplifiers

HRL Laboratories LLC of Los Angeles, CA, USA has demonstrated what it claims are the first gallium nitride millimeter-wave monolithic integrated circuit (MMIC) power amplifiers targeting the W-band (75–110GHz) frequency range, which could enable ICs and solid-state modules up to ten times more powerful than existing W-band MMICs made in InP or GaAs, the firm says. Applications include communications, radar, and sensor systems, with potential increases of 300% in operating range for a communication system, and a 70% increase in range for a radar system.

These amplifiers have five times the power density of existing corresponding state-of-the-art InP and GaAs technologies. Besides those mentioned above, a specific application is cost-effective wireless transmission of data at 10Gbit/s (equivalent to 10,000 DSL lines). Three E-band spectrum segments (71–76, 81–86 and 92–95GHz) were recently allocated in the US for gigabit-rate wireless links.

Advantages of millimeter-wave systems in general include smaller and lighter antennas than their lower-frequency counterparts, and higher resolution for imaging systems. But, until the HRL breakthrough, most millimeter-wave systems at the higher-frequency range used GaAs and InP, which have limitations (e.g. temperature constraints, short-channel effects) that restrict performance. HRL's GaN W-band MMICs provide higher output power to produce the operating increases described above.

High power and low noise are key attributes of the heterostructure field effect transistor (HFET) structure that has enabled HRL's GaN MMIC development. Together, the materials system and structure can enable, for example, other promising W-band applications such as all-weather radar, surveillance, and reconnaissance, as well as the high-speed wireless data links that are allocated across the W-band.

www.hrl.com

INEX to develop process for DMD's diamond-based MESFET

Diamond Microwave Devices (DMD), a subsidiary of Element Six Ltd of Ascot, UK (E6), has signed a contract for INEX (Innovation in Nanotechnology Exploitation), a UK research and commercialization centre for microsystems and nanotechnologies sited within the University of Newcastle, UK, to provide processing technology for its electronic component development program.

E6 (formerly DeBeers Industrial Diamonds Ltd until 2002) claims that in recent years it has made considerable progress in synthesizing diamond using CVD processes, allowing single-crystal diamond to be manufactured to the high purity and consistency demanded for electronics applications. DMD was founded last December to develop diamond-based semiconductor materials and processing technology for next-generation high-power, high-temperature devices for use in microwave power amplifiers and transmitters. DMD hopes that it can use the material as a basis for a family of microwave devices that will offer new levels of performance in a range of commercial applications, from mobile to satellites. E6 also signed an agreement for GaAs device maker Filtronic of Newton Aycliffe, UK to collaborate with DMD on applying diamond semiconductor material to microwave device technology, combining their strengths in materials, semiconductor devices and circuit design. DMD says that the agreement with INEX marks an important step in its development of electronic devices fabricated in single-crystal diamond synthesized using CVD.

INEX is a specialist in emerging technologies such as microelectromechanical systems (MEMS) and nanotechnology. The facility has benefited from major government investment programs (European Commission, Department of Trade and Industry, and Regional Development Agency ONE NorthEast). In late 2004 it became the first of the UK government's national Nanotechnology Centres, acting as a contract manufacturer, performing multi-material processing on platforms up to 150mm.

INEX will work with DMD, E6 and Filtronic to develop new processing techniques and to fabricate prototype devices based on E6's proprietary diamond material and a device designed by Filtronic. The goal is to exploit the exceptional properties of CVD diamond as an advanced engineering material. The initial aim is to use CVD diamond grown by E6 to demonstrate a practical metal-semiconductor field effect transistor (MESFET) that provides useful power at microwave frequencies.

The MESFET has been identified as one of the most promising devices to be constructed in CVD diamond. Though there are many technical hurdles to overcome, diamond can operate at higher temperatures and higher breakdown voltages than conventional semiconductors. As an intrinsic material, diamond demonstrates extreme hardness, chemical inertness, high thermal conductivity, high hole and electron mobility, high dielectric strength, high breakdown strength and wide bandgap. Compared to competing materials for use in electronics including silicon and GaAs, the intrinsic properties of single-crystal CVD diamond are superior for applications where there are extreme demands, claims DMD.

"The impressive facilities and expertise within E6, Filtronic and INEX should help us achieve our ambition of creating diamond MESFETs that could revolutionize the design of future microwave power modules," said DMD's general manager, Dr Richard Lang.

"The collaboration with DMD gives us the opportunity to work at the cutting edge of next-generation technology," adds INEX's managing director, Ken Snowdon.

www.diamondmicrowavedevices.com

TranSiC appoints chairman of board of directors

TranSiC AB of Kista, Sweden, which develops and manufactures SiC power transistors, has appointed Jan Tufvesson as chairman.

Tufvesson is an electronic engineer from Stockholm's Royal Institute of Technology (KTH), from which TranSiC was spun off in December 2005. He started his career at the Royal Swedish Air Force and then moved on to Ericsson, working in R&D of advanced electronics and responsible for partnerships with key suppliers. After leaving Ericsson in 1998 Tufvesson then worked as a consultant in company management. He has been chairman of two international companies, which went public during his chairmanship.

"His in-depth business experience at both the volume and start-up level will help guide us," says TranSiC's CEO Bo Hammarlund. "With the latest developments in wafer quality, there is clearly a renaissance for SiC and TranSiC has today a number of customers with various applications to support."

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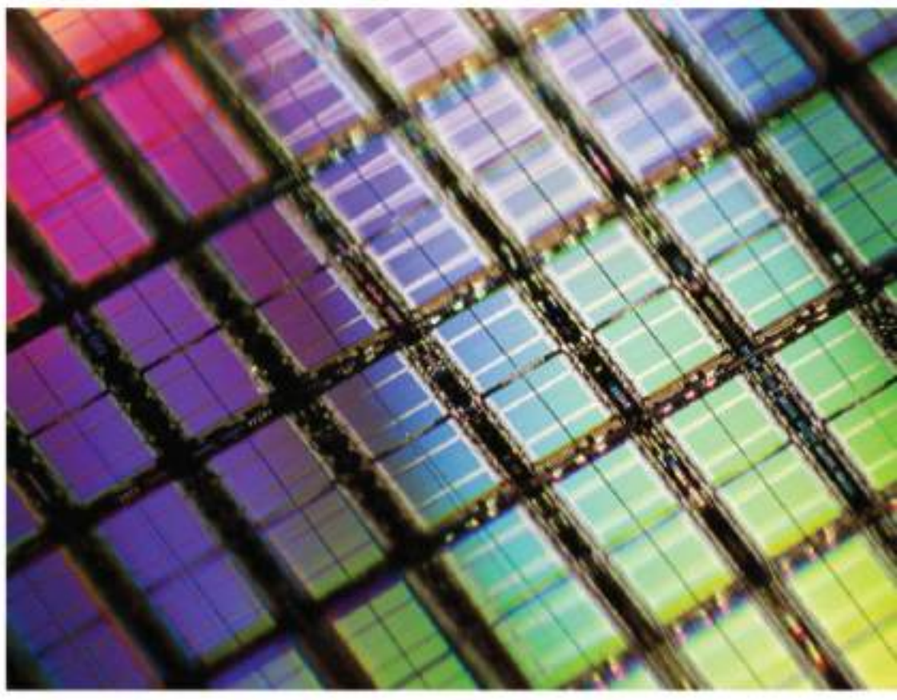

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IQE boosted by RF epiwafer acquisitions, but opto grows too

In its preliminary results for 2006, epiwafer foundry and substrate supplier IQE plc of Cardiff, Wales, UK reported revenues of £32.4m ($63.6m), up 55.2% from 2005's £20.9m. However, £5.5m of the £11.5m increase comes from IQE RF LLC (formerly Emcore's Electronic Materials Division until IQE acquired it last August). Revenues from Singapore-based MBE Technology (acquired at the end of 2006) will be consolidated from the beginning of 2007.

The number of wafers shipped by IQE in 2006 was 250,000 units (up 67.8% from 2005's 149,000).

Increased revenues and improved efficiencies yielded a gross profit of £2.5m (compared to 2005's loss of £0.8m). However, IQE posted an operating loss of £4.2m, albeit down 30.2% from 2005's £6.1m (not including exceptional items).

"Following the acquisitions, wireless communications products now account for over 75% of our revenues and the group is now the largest independent wafer supplier to the global wireless market [offering a complete range of products for wireless communication devices]," says IQE's chief executive Drew Nelson.

"The mobile handset market continues to be the primary consumer of IQE's products, with handset upgrades being the fastest growing part of the sector. These tend to be higher-speed, feature-rich, high-end products that use more GaAs materials for the added performance and functionality," says Nelson. "Our products are key to both current and future generations of wireless communications devices, including mobile phones, PDAs, GPS, Wi-Fi, WiMAX and laptop PC components."

Once IQE's main market, opto-electronic materials now account for 20% of its revenues. However, increasing demand for high-efficiency solar cells provides a great opportunity for these materials over the coming years, the firm says. IQE is currently making good progress in developing high-efficiency terrestrial solar cell materials, and expects limited pilot production to begin by the end of 2007, the firm says.

Wireless communications products now account for over 75% of our revenues... Once IQE's main market, optoelectronic materials now account for 20%

IQE's silicon-based epitaxial services accounted for about 5% of 2006 revenues. It has won several outsourcing contracts to provide its core products and epiwafer services, and says it has established a strong position in strained silicon, which it is further developing as a strained silicon-on-insulator (sSOI) product, which is likely to be a key offering for next-generation silicon-based electronic devices.

The significant increase in 2006 revenues brings IQE closer to achieving sustainable profitability in 2007 (with a full year of earnings from IQE RF and MBE Technology), says Nelson. "We believe the continuing growth in the end markets for our products, coupled with our strategic positioning in the wireless sector, place the group in a good position to continue to grow strongly."

In common with the rest of the wireless industry, trading for the first two months of 2007 has remained flat. However, orders and production upgrades have picked up strongly in recent weeks. The market conditions for IQE's product offerings, coupled with its strong position in the marketplace, provide a solid foundation for future growth, concludes the firm.

www.iqep.com

IQE secures over $2.4m of development contracts

IQE has secured two 12-month contracts with commercial partners, worth over $2.4m in total during 2007, to develop epitaxial materials for use in next-generation, ultrahigh-speed ICs using MBE at its US plants in Bethlehem, PA, and Somerset, NJ.

One contract focuses on further development of a method for using MBE to deposit films of strontium titanium oxide on silicon (STO/Si) with high quality and superior composition for future high-volume production. The other contract is to develop advanced material structures for increased processing speed for future ICs.

"We plan to aggressively pursue the metal-oxide on silicon market, where we offer unique and superior solutions for these advanced state-of-the-art materials systems," says Nelson. "Our entry into this market is important, as it further diversifies the group's product portfolio and underscores our position as the global leader in advanced semiconductor wafer production and R&D."

Total ongoing R&D contracts to date for delivery in 2007 now amount to almost $5m.

EpiWorks completes Phase I expansion for 6" HBT epiwafers

EpiWorks Inc, which manufactures epiwafers for optoelectronic and wireless applications, has completed the Phase I expansion of its plant in Champaign, IL, USA, boosting 6" HBT capacity to over 50,000 wafers per year. The equipment (including Aixtron 2600 reactors) was bought last summer. Wafers are already being qualified by customers.

EpiWorks produces both 4" and 6" MOCVD-grown InGaP HBT epiwafers. "Demand for our InGaP HBT technology has increased steadily over the past two years, and we are very pleased to have successfully completed the first phase of our capacity expansion in an aggressive time-frame," says president Quesnell Hartmann. "We expect to fill the new capacity by the end of the year and, as this new capacity fills, we plan to begin our phase II expansion. This will double our capacity by 2009 to over 100,000 6" wafers/year," he adds.

Aixtron 2600 MOCVD system identical to that installed in EpiWorks' recently completed Phase I expansion.

"EpiWorks has been working very closely with several InGaP HBT customers," says Hartmann. "In addition, we are focused on providing our customers leading-edge, next-generation technology," adds Dr David Ahmari, executive VP and co-founder. "The shift toward MOCVD-based pHEMT and integrated HBT/FET [BiFET] technologies has also resulted in the potential for large increases in the demand for our wafers." The new equipment can also be used to produce pHEMT and BiFET technologies.

www.epiworks.com

Linde sells BOC Edwards' Vac & Semi Equipment unit

Germany-based gas supplier Linde Group, the world's biggest industrial gas supplier, has sold the component business (vacuum pumps and semiconductor equipment) of BOC Edwards of Crawley, UK for €685m (£460m, or about $900m) to New York-based private equity firm CCMP Capital (via its affiliates CCMP Capital Advisors LLC and CCMP Capital Asia Ltd).

An extra payment of €65m (£45m, or about $85.5m) will be made if CCMP succeeds in developing the business and subsequently exiting its investment (through an initial public offering or a trade sale to a strategic investor). With over 4000 staff worldwide, the components business had turnover of €860m (over £0.5bn) in fiscal 2006.

The firms expect to close the transaction in May/June. Financing will be provided by Deutsche Bank, Lehman Brothers, Barclays Bank, and The Royal Bank of Scotland.

Linde acquired BOC Group for €12.4bn last September. But, aiming to focus on the industrial gases and engineering operations, it combined BOC's gases activities with the Linde Gas division into a new Gases Division and put the component business up for sale. Linde will continue to develop BOC Edwards' bulk and specialty gases businesses.

"Our new partner has invested over $10bn in strong, technology-led businesses such as ours [via over 375 buyout and growth equity transactions] since 1984. They have a similar global profile to BOC Edwards, with strength in Asia and the US, in addition to Europe," says BOC Edwards' CEO Nigel Hunton. "BOC Edwards has a rapidly growing Asian customer base, including semiconductor companies and equipment manufacturers in China, Korea, Japan and Singapore," adds John Lewis of CCMP Capital Asia. "We will support management, using CCMP's presence and experience in these markets, to help BOC Edwards get closer to their fast growing Asian customer base."

"We feel they [CCMP] have a real understanding for our business and its potential and that their financial strength and scale will support the company as we develop our operations worldwide and capitalise on our strong market position," adds Hunton. "This is the start of a new independent era for BOC Edwards in which we can focus on delivering world-class products and services... supported by the financial strength and scale of CCMP Capital."

"Under CCMP's ownership, BOC Edwards can move to a new level as an independent company and develop its technology in new markets whilst retaining leadership in its core areas," believes Stephen Welton of CCMP Capital Advisors.

● Following anti-trust conditions imposed by the European Commission arising from the acquisition of BOC Group, Linde has sold its non-BOC UK gases activities (including speciality gases for semiconductor manufacturing) to Air Liquide for €105m. Linde Gas UK had sales of about €60m in fiscal 2006 and currently employs about 280 staff.

www.bocedwards.com

Rohm and Haas licenses amidinate ALD precursors as alternative to hafnium-based high-k dielectrics

Harvard University's Office of Technology Development (OTD) has signed an exclusive agreement licensing Rohm and Haas Electronic Materials of Marlborough, MA, USA to manufacture and market rare-earth metal amidinate compounds, such as lanthanum, dysprosium and gadolinium. The metal-organic materials technology was developed by the lab of Roy Gordon, the Thomas D. Cabot professor of chemistry in the Faculty of Arts and Sciences.

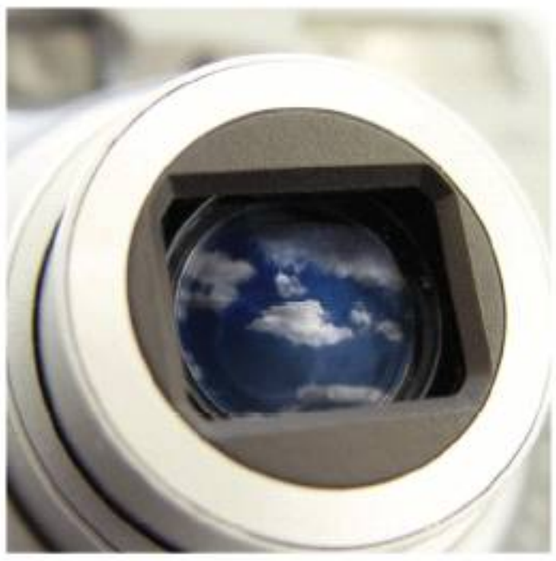
The amidinates can provide improved functionality, throughput and thermal stability as precursors in emerging atomic layer deposition (ALD) and chemical vapor deposition (CVD) processes. These are required for advanced high-k dielectric, metal gate and barrier/adhesion thin-film layers in CMOS silicon-based memory and logic devices with feature sizes of 45nm and below. In particular, the amidinate materials do not have the same integration challenges found with hafnium-based silicates, which were demonstrated recently by both Intel and IBM (as replacements for existing SiO_2-based gate dielectric materials) for 45nm CMOS devices scheduled to enter production in late 2007/early 2008, according to the International Technology Roadmap for Semiconductors (ITRS). Several large semiconductor manufacturers have already started to develop material integration schemes using the ALD and CVD processes, says Harvard.

"The industry's march toward smaller, more powerful semiconductors must include class-leading ALD and CVD processes and materials," says Dr Dominic Yang, business unit director for Rohm and Haas's Microelectronic Technologies business (which develops advanced CVD, ALD and MOCVD precursor materials). "Our work with professor Gordon and his team strengthens Rohm and Haas's existing precursor solutions and builds upon our broad suite of advanced materials for the semiconductor industry."

Rohm and Haas Electronic Materials will produce the compounds at its North Andover, MA, facility and collaborate with Harvard scientists to develop the materials technology further for ALD and CVD processes.

http://electronicmaterials.rohmhaas.com
www.chem.harvard.edu

Focus



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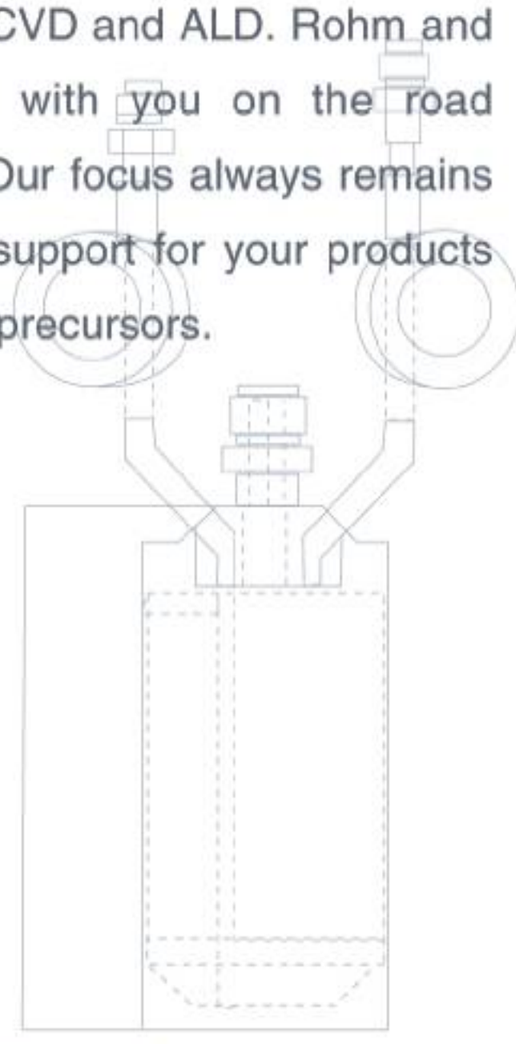

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IN BRIEF

Trion appoints Crystec as European distributor

Trion Technology of Clearwater, FL, USA, which makes plasma etch, strip and deposition systems, has established a strategic alliance for Crystec Technology Trading GmbH of Altoetting, Germany to distribute and support its full line of products throughout Europe.

"They [Trion] have a strong product range for RIE etching including ICP and microwave plasma generation as well as for PECVD," says Dr Ralph Lüdicke, Crystec's president.

www.triontech.com
www.crystec.com

EVG to distribute McBain's NIR wafer inspection tool

EV Group of St Florian, Austria has a global agreement to distribute the ZIII-NIR Wafer Inspection System of McBain Instruments of Chatsworth, CA, USA, in combination with EVG's process equipment (supplementing its bonding and alignment process systems).

The semi-automated system has a proprietary reflected-light, near-infrared optical package that gives NIR subnanometer resolution. High throughput and flexible software allows users to make alignment measurements and store images, suiting process monitoring. System configurations can be customized.

"The ZIII-NIR Wafer Inspection Tool allows EVG to have a metrology tool to check all bonded wafers either post-bond (McBain standalone tool) or pre- and post-bond (integrated in EVG tools)," says EVG product manager Thomas Wagenleitner. "This approach allows 24/7 production with minimum intervention."

www.evgroup.com
www.mcbaininstruments.com

Plant sale boosts Riber into profit

In January, MBE equipment maker Riber of Bezons, France reported revenue for 2006 of €20m (up 14% on 2005's €17.6m), with growth of 57% in production machine sales to €9.6m (driven by US sales doubling) and 11% in accessories and spare parts sales to €5.4m offsetting a 14% drop in research machines sales to €5.1m (see February issue, page 11).

Riber has since reported gross profit of €6.5m (33% of sales), down on 2005's €7.2m (41%) due to the negative impact of the weak dollar on the increased production machine sales to the USA, and to ongoing inventory reduction leading to lower sales margins.

Net profit was €10.4m. However, most of this was generated by income of €10.6m from the sale of the company's former site in Rueil-Malmaison (after its move to Bezons). Nevetheless, excluding that gain, operating profit was €0.1m, compared to a loss of €0.9 in 2005.

With an order backlog of €8.5m at the end of March, for 2007 Riber projects revenue of €16–20m (flat or slightly down on 2006) but higher operating profit.

www.riber.com

Aviza completes $55m credit facility led by Asia-focused US bank

Etch and deposition system maker Aviza Technology Inc of Scotts Valley, CA, USA has completed a new asset-backed credit facility led by United Commercial Bank of San Francisco, CA (a banking subsidiary of UCBH Holdings Inc) that will not exceed an aggregate principal amount of $55m and includes: a two-year revolving facility of up to $44m that is secured by accounts receivable, inventory and fixed assets; a three-year equipment term loan of up to $4m; and a four-year commercial real estate term loan of up to $13m. The credit facility replaces and refinances the firm's revolving line of credit with Bank of America, N.A. and a mortgage line of credit with iStar Financial Inc (which were due to mature in August and September, respectively).

"Securing this new credit facility is an important step in our growth," says Patrick C. O'Connor, executive VP and chief financial officer. "In addition to obtaining lower interest rates, we have restructured the long-term debt secured by the real-property that Aviza owns in Scotts Valley, CA. With the completion of our recent equity offering [raising $24m on Nasdaq at the end of February — see March issue, page 25] and the new credit facility, Aviza is a financially stronger company," O'Connor adds. "The new credit facility provides us with additional capital resources to fund investment in our core markets as well as the newer growth markets of atomic layer deposition and wafer-level packaging."

Johnny Lee, senior VP and manager of UBC's Technology Banking Group, says: "Our primary emphasis on companies doing business in Asia will help Aviza capitalize on its business opportunities in Asia." UCB claims to be the leading bank in the USA serving the Chinese community and American companies doing business in Greater China.

www.avizatechnology.com

OIPT appoints new managing director

Oxford Instruments Plasma Technology of Yatton, UK, which manufactures systems for plasma-enhanced deposition and etch, ion-beam deposition and etch, atomic layer deposition and molecular beam epitaxy, has appointed Andy Matthews as managing director.

Matthews was previously managing director of IMI Webber Ltd, a supplier of automotive and pneumatic components. Prior to that, he had product design and senior technical roles at companies such as British Aerospace and Schlumberger.

"Oxford Instruments Plasma Technology has enormous potential for growth and operational improvements. I have joined OIPT at an exciting time, especially with the upcoming launch of our new Nanofab products, Nanofab700 and Nanofab800Agile, which will deliver high-performance growth of nanotubes and nanowires with in-situ catalyst activation and rigorous process control," said Matthews. His experience in the demanding automotive sector will help to focus efforts to produce a lean efficient organization that delivers faster new product introductions, he says.

OIPT's new managing director Andy Matthews.

www.oxford-instruments.com

STS plans cost-cutting

Plasma etch system maker Surface Technology Systems plc of Newport, UK says that, while enquiry levels remain high, order levels in the year to date have been substantially below expectations. Trading for full-year 2007 is difficult to predict, but it is probable that the results will be significantly below original expectations.

As a result STS is considering a cost-reduction program to reflect the level of trading currently being achieved and anticipated.

STS is also in discussions with its parent company Sumitomo Precision Products Co Ltd about future financing of the business.

STS has also announced the resignation of Dr Mike Love, a non-executive director, from the board with immediate effect, following six years with the firm.

www.stsystems.com

Hitachi Cable prototypes 3-inch GaN substrate; 4-inch possible

At the 54th Symposium of the Japan Society of Applied Physics at Aoyama Gakuin University in late March, Hitachi Cable Ltd said that it has prototyped a highly reproducible 3-inch GaN substrate, according to the publication Nikkei Electronics. Current commercial GaN substrates are 2-inches in diameter. 3-inch GaN substrates have been announced previously, but Hitachi Cable claims that it is first to release photos and tangible data.

Currently, most GaN substrates are produced by hydride vapor-phase epitaxy (HVPE) deposition of a thick film of GaN on a base substrate of sapphire or GaAs, which is then removed by laser, etching or grinding. However, because the type of base substrate materials used have different linear expansion coefficients to GaN and substantial thermal stress accumulates, these methods tend to cause cracks in the GaN thick film during separation, making it difficult to improve the reproducibility.

The 3-inch substrate was made possible by Hitachi Cable's 'void-assisted separation' (VAS) method, which has been used previously to develop 2-inch products (see Japanese Journal of Applied Physics (2003) Pt.2 (1A/B) L1). During HVPE growth at 1050°C of the 600μm thick GaN film (at 140μm per hour), microscopic spaces (voids) are formed in openings in a titanium nitride film near the interface between the GaN film and the base substrate, creating a thin sacrificial layer. Because this has low mechanical strength, due to the thermal stress generated by the drop in temperature after HVPE growth the GaN thick film separates from the base substrate more easily and more reproducibly by itself.

We believe 4-inch products can be produced with no difficulty

Hitachi Cable claims that separation for 3-inch substrates was no more difficult than for their 2-inch products. Also, the radius of curvature is no greater. The carrier mobility of the 3-inch GaN substrate is 340–400cm^2/Vs.

In response to the question "How far can it grow in size?", Hitachi Cable replies "We believe 4-inch products can be produced with no difficulty if the production equipments are arranged accordingly," reports Nikkei Electronics.

www.hitachi-cable.co.jp

Cermet adds Rylance to advisors

Bruce Rylance, founder and president of the Wilmar Group LLC, a privately held business development and technology consulting firm in Lake Forest, IL, is joining the board of advisors of Cermet Inc of Atlanta, GA, USA, which develops and manufactures nitride- and oxide-based wide-bandgap semiconductor materials products with enhanced power output and energy efficiency in LEDs, optical storage devices and high-frequency devices.

Cermet says that Rylance is an experienced senior sales and marketing executive with an impressive record of success achieving revenue growth, launching new products, developing international markets, and implementing sales and marketing strategies within rapid-changing startup environments.

Rylance was the senior VP of sales & marketing for privately held sapphire substrate manufacturer Rubicon Technology Inc, which he took from a start-up to being the optoelectronic industry's leading supplier of sapphire substrates for blue LEDs.

New Cermet board member Rylance.

Rylance's key role will be penetration of the Asian market.

www.cermetinc.com

Sapphire wafer carriers

Meller Optics Inc of Providence, RI, USA has made available highly durable and transparent custom-fabricated sapphire wafer carriers for the thinning of GaAs, InP, silicon and other semiconductors, available in diameters of 2–6" and as thin as 0.018" (depending on diameter).

Stronger, more stable, and longer lasting than fused quartz, the optical-grade high-purity sapphire wafer carriers feature flatness and parallelism to 0.0025mm and can incorporate flats and laser markings.

Supplied polished or ground and custom perforated with patterns for vacuum hold-down or delamination, the wafer carriers are designed for repeated use.

www.melleroptics.com

BluGlass demos 6" substrates and CW blue LED emission

Gallium nitride-on-glass specialist BluGlass Ltd of Sydney, Australia, which was spun off from Macquarie University in late 2005, presented three technology developments in a worldwide road-show by CEO David Jordan over three weeks in March/April. These included:

- The demonstration of good-uniformity nitride deposition over a 6" wafer (nine times larger in area than the current 2" industry standard). BluGlass demonstrated highly uniform nitride deposition on 4" glass wafers last November. Larger-diameters enable a significant increase in manufacturing yield and improved efficiencies in downstream processing, further reducing LED manufacturing costs.
- The demonstration (via financial cost of ownership modeling by US-based Wright Williams & Kelly Inc) of the ability of BluGlass' low-temperature remote plasma chemical vapor deposition (RPCVD) GaN technology to reduce deposition cost compared to using rotating disc reactor MOCVD technology (through reduced reactive materials usage, the elimination of expensive and toxic ammonia, and the use of low-cost glass substrates). This, coupled with possible benefits in downstream device fabrication, indicates a significant reduction in the cost of blue, green and white LEDs for general lighting applications, BluGlass claims (see details below).
- The demonstration of continuous blue light emission from a hetero-junction LED structure deposited at a very low temperature on sapphire, as well as short-lived emission on commercial glass.

The engineered substrates used in the demonstrations were developed in a technical and engineering program with French materials group Saint Gobain, which last October signed an 18 month joint development agreement with BluGlass.

The advances boost BluGlass' plans to accelerate the development of cheaper and more environmentally friendly LED lighting.

"The high cost of LEDs has to date been one of the key factors in preventing their uptake in the general lighting market," says Jordan. The developments indicate that LED lighting could soon become much more cost competitive against current incandescent bulbs and compact fluoros in the general lighting market, he claims. Compact fluoros are the most efficient lighting on the market, and were promoted recently by the Australian Federal Government's energy savings strategy to phase out traditional incandescent light bulbs. "We welcome both the Australian Government and subsequent European Union's action to make lighting more energy efficient by banning the incandescent light bulb, and believe that LEDs are rapidly becoming the most energy efficient form of lighting," Jordan says.

www.bluglass.com.au

GaN-on-glass could yield 48% savings for LED epi

BluGlass' RPCVD GaN on glass substrates can cut the cost of manufacturing GaN-based LEDs at both the epiwafer and the assembled device levels, according to an independent assessment commissioned from Wright, Williams & Kelly Inc.

The model compares RPCVD on 2" buffered glass substrates versus MOCVD on similar-sized sapphire substrates, based on a 21 x 2"-wafer capacity commercial production tool. MOCVD data was collected by an independent industry expert and includes current best estimates of material and other input costs and productivity for a US-based manufacturing facility.

Wafer-level analysis shows a cost saving of 48% for RPCVD, driven by a 70% reduction in materials and consumables costs (mainly due to using glass rather than sapphire and replacing costly and toxic ammonia with nitrogen). Over a projected useful reactor life of seven years, operating costs are nearly $8m lower due to RPCVD's operating temperature of 700°C (300°C lower than for MOCVD).

Also (using a backend assembly process flow from an outside expert) an integrated downstream assembly cost model for a 0.35mm x 0.35mm square mesa-structured chip in a standard 'Blue LED T1' encapsulated package with a water-clear lens shows that RPCVD leads to a 10% cost advantage at the final assembly level for a simple blue LED (assuming no difference in post-epiwafer processing costs between MOCVD GaN-on-sapphire and RPCVD GaN-on-glass).

With millions of wafers and tens of billions of packaged LEDs produced each year, such cost savings translate to significant potential gains to LED makers. Current production costs have restricted their use to electronics, mobile handsets and special situations such as traffic lights and signage, limiting uptake for general lighting for homes, businesses and industry. The development of cheaper and more environmentally friendly LEDs should accelerate their penetration into the $100bn per annum general lighting market, reckons BluGlass. The market for high-brightness LEDs alone is valued at $4bn per annum and should rise to more than $7bn per annum by 2009, according to Strategies Unlimited.

BluGlass will continue its progress in demonstrating device and process performance and developing a professionally engineered manufacturing tool, says CEO Jordan. "In the coming months our new facility in Silverwater in Sydney will showcase the technology, the fabrication process and our commercial production demonstration equipment."

University of Braunschweig using Thomas Swan CCS reactor for GaN and ZnO optoelectronic research

Aixtron AG of Aachen, Germany says that a new Thomas Swan 3x2" Close Coupled Showerhead (CCS) MOCVD epitaxy reactor has been installed at the Institute of Semiconductor Technology at Germany's University of Braunschweig. The system is now in operation.

The new reactor will provide gallium nitride (GaN) as well as zinc oxide (ZnO) epitaxial materials for research on basic material properties and of optoelectronic devices. It complements the university's other materials research tools, which include an Aixtron AIX 200 MOCVD system.

ZnO is attractive as a material for short-wavelength and ultraviolet (UV) light emitters such as LEDs, lasers and light detectors. As a transparent and conducting substrate, the use of ZnO should produce brighter LEDs than the use of silicon carbide or sapphire substrates. When doped with magnesium, devices operating in the deeper UV region are possible, leading to application in solar blind detectors.

"The capabilities of the Thomas Swan system are well-suited to our needs for material uniformity, thickness, doping, and composition," says professor Andreas Waag, who is the director of the Institute of Semiconductor Technology.

"We require the newest generation of MOCVD processes for even more sophisticated optoelectronics and nanostructures." The CCS reactor will be the foundation for its research projects in the years to come, he adds.

www.iht.tu-bs.de

Tekcore stepping up from blue LED to blue–violet laser production

In fourth-quarter 2006, LED epiwafer and chip maker Tekcore Co Ltd, which is based in Nantou, Taiwan, ordered an AIX 2400G3HT 'integrated concept' (IC) multiwafer (11x2-inch) MOCVD reactor from Aixtron AG of Aachen, Germany. The reactor has been specified in sandwich configuration for the production of 405nm-wavelength GaN-based blue-violet lasers.

The reactor takes its place alongside Tekcore's multiple Aixtron (Planetary Reactor) and Thomas Swan (Close Coupled Showerhead) MOCVD systems. Established in 2000, up to now Tekcore has focused mostly on providing GaN-based high-brightness LED epiwafers and chips with wavelengths of 370–530nm (UV to green) for applications including lighting, displays, backlights and automotive applications.

"We are preparing to deliver the latest generation of laser diodes," says Tekcore.

www.tekcore.com.tw

TU Berlin orders MOCVD system for AlGaInN lasers & UV LEDs

The Technical University of Berlin's Institute of Solid State Physics has ordered a Thomas Swan MOCVD system from Aixtron for the development of high-aluminium-content GaN/(Al,Ga,In)N materials for lasers and high-brightness UV LEDs.

For use in the Eugene-Paul-Wigner Building alongside the university's AIX 200RF and AIX 200/4 systems, the small-footprint Close Coupled Showerhead (CCS) 3x2-inch wafer configuration Fliptop Platform has a new control system featuring digital mass flow and pressure controllers, along with a new safety system.

Professor Michael Kneissl, head of the Experimental Nanophysics and Photonics research group, concentrates on developing wide-bandgap semiconductor epitaxy and studying the optical and electronic properties of semiconductor surfaces and heterostructures for new optoelectronic devices. The focus is on controlling the formation of structures on the nanometre scale to tailor the electronic properties of materials such as InGaN multiple-quantum-well (MQW) high-power laser diodes; deep UV InAlGaN LEDs; laser diodes for the blue and green spectral range; microcavity disk lasers; and GaN-based VCSELs.

www.tu-berlin.de

SEMCO ramps blue & white HB-LEDs

After only recently expanding capacity with Aixtron Planetary Reactor systems, in January South Korea's Samsung Electro-Mechanics Co Ltd (SEMCO), the LED chip making subsidiary of consumer electronics firm Samsung, ordered two more Aixtron AIX 2600G3HT GaN MOCVD reactors, for volume production of high-brightness blue and white LEDs at its plant in Kyungki-Do.

"Samsung has become the number-one local supplier for GaN-based HB-LEDs in Korea," claims SEMCO's Dr Dong-Joon Kim. With market demand so high, additional reactors were needed, he adds. Since the processes are readily transferable, SEMCO anticipates that the new tool will be quickly ramped up to meet production needs.

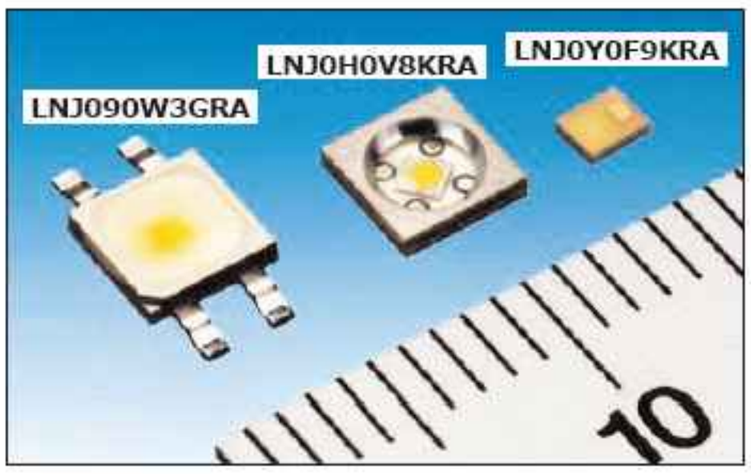
www.sem.samsung.com

Panasonic launches white LEDs using GaN substrates

Japanese consumer electronics firm Panasonic (Matsushita Electric Industrial Co Ltd) has developed what it claims is the first commercial blue LED chip using a GaN substrate. Volume production of white LEDs incorporating the InGaN-based chip started in mid-March.

Compared to conventional, low-cost sapphire substrates, GaN substrates cut the defect density in the light-emitting layer 100-fold or more and improves the performance at high drive currents, boosting LED output. GaN substrates also have a thermal conductivity about five times higher, plus higher electrical conductivity, suppressing the usual reduction in efficiency at higher drive current.

The GaN substrate also has a similar refractive index to that of the InGaN light-emitting layer, suppressing reflection at the interface and boosting light extraction efficiency to over 1.5 times that of the company's sapphire-based LED. The wavelength of emitted light is 460nm. The chip is flip-chip mounted on a submount (via an Au bump), so light is extracted from the substrate side of the chip. Panasonic has also added irregularities on the substrate's backside to prevent reflection completely. The radiation flux is 355mW, driven at a forward current of 350mA. External quantum efficiency is 38%.



Panasonic's white LEDs, based on GaN substrates.

Finally, the fluorescent layer (for converting the chip's blue light to white light) has uniform thickness, yielding minimal variation in color (unlike the conventional process for applying the fluorescent layer, which generates unevenness in color).

Compared to sapphire, the expense of GaN — about ¥1m ($8600) for a 2" diameter substrate — has been a bottleneck to commercialization. However, Panasonic says it decided to use the substrate because it can set a reasonable price for a high-output LED product. Samples are ¥500 ($4.30) per unit.

The white LED has three types: LNJ090W3GRA (with power output of 3W) for automotive and lighting applications, LNJ0H0V8KRA (with a reflector design) for camera flash applications, and LNJ0Y0F9KRA (a point source) for compact lighting applications. Luminous fluxes are 100, 80 and 90lm, respectively, when driven at 1A. Brightnesses are 35, 60 and 35lx, respectively, when the distance between the light source and the measurement device is set to 1m. The package sizes are 7.7mm x 4.2mm x 1.5 mm, 4mm x 4mm x 1.4mm, and 2.04mm x 1.64mm x 0.7mm, respectively (see picture).

http://panasonic.net

Fox appoints France distributor

The Fox Group Inc has appointed Opton Laser International of Orsay (France's 'Optics Valley') as its exclusive distributor in France for its nitride-based LED products, made at its Canadian subsidiary in Montréal using its FoxHVPE process. Opton Laser also provides design support and customer engineering services. Its president, Dr Costel Subran, is currently vice president of the French Optical Society and a board member of France's Comité National d'Optique et Photonique.

Opton Laser will design in and sell Fox's portfolio of UV and blue LEDs (at 360, 350 and 420nm peak wavelengths) to its customer base in medical, automotive, curing, forensics, biophotonics and military sterilization applications. Fox's president and CEO Barney O'Meara says it will work closely with Opton to address existing and emerging applications for LEDs, especially in biophotonics, medicine, biotechnology, and analytical systems using UV fluorescence. The peak wavelengths in the UV range are vital for replacing mercury-containing UV lamps with a durable, long-lived solid-state light source, the firm says.

All products are available as epi-wafers, individual die and packaged LEDs (in standard and power chip formats, as well as industry-standard and custom packages). Fox says that the radiant power output per dollar of its FoxUV LEDs has risen by over 100% in the past year.

Founded in 1999, Fox also sells FoxAlN single-crystal aluminium nitride substrates grown in Deer Park, NY, USA using a proprietary, modified vapor transport, 'true-bulk crystal growth process'.

www.thefoxgroupinc.com
www.optonlaser.com

Nichia boosts UV-LED

Japan's Nichia claims to be supplying the most powerful UV-LED on the market. The NCSU033A 'i-LED', in a 6.8mmx6.8mmx2.1mm package, has a typical peak wavelength of 365nm (matching that of i-line emission from mercury lamps).

Typical optical power is 250mW, binned into three categories: 190–230mW, 230–270mW and 270–310mW. The forward voltage is 3.8V (typical) and 4.4V (maximum). The lack of infrared emission suits use with heat-sensitive materials. The LED can operate from + 85°C down to –10°C and is usable in a vacuum. Applications include UV curing and photo-catalysts.

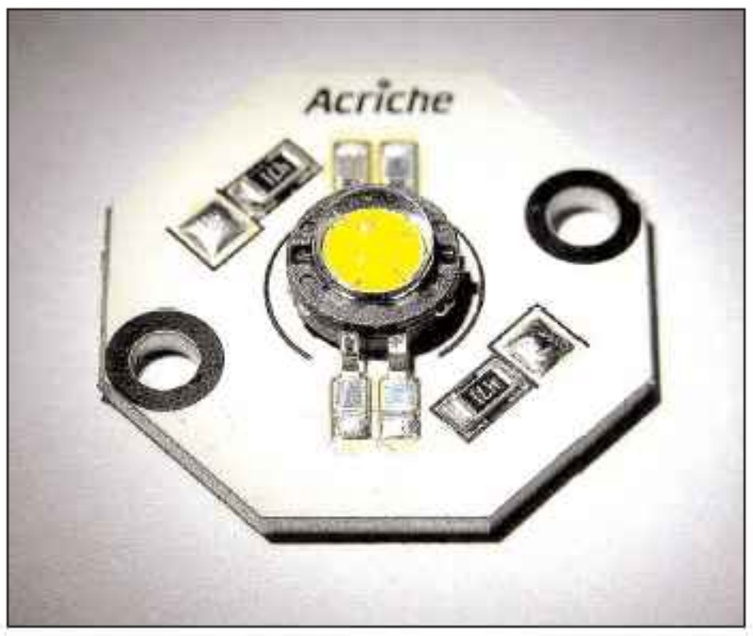
Nichia launched its first UV-LED in 2004, and up to now has supplied products emitting at 365nm, 380nm and, more recently, 375nm, with power outputs up to 100mW.

www.nichia.co.jp

SSC unveils 42lm/W warm white

Seoul Semiconductor Co Ltd (SSC), Korea's leading LED producer, says that its Acriche AC-LED can now achieve warm white light of near-daylight quality with a luminous efficacy of 42lm/W (20% more efficient than a conventional warm-white DC-powered LED with an efficacy of about 35lm/W). This makes Acriche (which Seoul Semiconductor claims is the first semiconducting lighting source that can be driven directly from AC power outlets, without the need for a converter or ballast) suitable for general and indoor lighting applications.

Actual system efficiency (which takes into account luminous efficacy, ballast efficiency and luminaire efficiency) is 39.9lm/W, which



Seoul Semiconductor's 42 lm/W warm white Acriche LED.

is higher than the 7.5lm/W for incandescent lamps and 30.6lm/W for compact fluorescents.

SSC has also launched a warm-white Acriche LED with an efficacy of 33lm/W that has a color rendering index (CRI) rating of 90. The CRI measures the ability of a light source to produce vibrant colors in objects: a CRI of 100 suggests that the light source is equivalent to daylight; a low CRI rating near 0 suggests that colors will appear unnatural under that particular light source.

The capability to produce a warm-white semiconductor lighting source that can also offer a high-quality CRI rating has been elusive for many years, says SSC. The warm-white Acriche's high CRI ratings suit environments that demand vibrant and accurate lighting, such as museums, luxury hotels, art galleries, show rooms and displays, the firm adds.

www.acriche.com

Seoul boosts efficiency of its Acriche AC-LED by 20%

In March, Seoul Semiconductor Co Ltd (SSC), Korea's leading LED maker and one of the ten biggest in the world, launched a new 2W single-emitter, octagon-type version of its Acriche AC-LED packaged as a single AC-LED on an octagonal PCB with a diameter of 25mm. Seoul Semiconductor claims that Acriche is the only semiconductor lighting source that can be driven directly from an AC power supply without an AC/DC converter, and has been mass produced since last November in versions featuring either two or four emitters on each PCB.

Seoul Semiconductor has since improved Acriche's luminous efficacy by 20% to the new 2W single-emitter's 48lm/W. The firm claims that this is equivalent to a conventional power LED with an efficacy of 57lm/W after AC-to-DC conversion losses of about 20% are taken into account, as well as exceeding the efficacies of halogen lamps (20lm/W) and incandescent lamps (15lm/W). Seoul Semicon-

Seoul Semiconductor's Acriche LED for AC current-based systems.

ductor aims to improve the Acriche's luminous efficacy to 80lm/W in Q4/2007 and 120lm/W in 2008.

Acriche's new single-emitter package design also enhances its use for various applications. "You can apply second optics (collimators) to the Acriche 2W octagon type to adjust for various lighting applications," said Do Hyung Kim, head of SSC's Acriche unit. "Lenses with narrow viewing angles can be used for lighting fixtures that focus on a certain area such as reading lamps, while lenses with wide viewing angles can be used to illuminate a wider space like a living room in a home or an office."

Seoul Semiconductor aims to also release an Acriche single-emitter without a PCB soon, in response to requests. "This will broaden the range of application for Acriche even more as our customers will be able to make the PCB type they need as well as array emitters on the PCB," said Kim.

Also, in response to strong demand, Seoul Semiconductor says that it has increased production of Acriche.

Acriche is being distributed in North America by both catalogue distributor Mouser (following an agreement last November) and global electronics distributor Avnet Electronics Marketing (after January's distribution agreement with Avnet's business unit LightSpeed, whose team of illumination-focused engineers work closely with customers in the areas of thermal, drive stage and optics design).

Taiwan forms LED industry association

The Taiwan Optoelectronic Semiconductor Industry Association (TOSIA) has been formed in Taipei by the government-sponsored Industrial Technology Research Institute (ITRI) and 14 Taiwan LED makers and LED chipmakers, including Epistar, Formosa Epitaxy, Arima Optoelectronics, Opto Tech, Tyntek, Ledtech Electronics, Unity Opto Technology, Para Light Electronics, Everlight Electronics, Bright LED Electronics, Kingbright, Lingsen Precision Industries, Ligitek Electronics and Lite-On Technology. The aim is to strengthen Taiwan's LED industry.

At the association's inauguration, Lite-On's CEO Teng Kuang-chung said TOSIA will strive to bolster cooperation and exchanges among companies and research bodies involved in the optoelectronics and semiconductor industries. The association also aims to: upgrade R&D on new technologies; push for the establishment of standards in the optoelectronics and semiconductor industries; sponsor conferences that are conducive to enhancing the industry's development; promote technological cooperation on an international basis; and help the Taiwan administration enact relevant policies to help the industry's progress.

The Ministry of Economic Affairs' senior technology adviser Chan Wen-hsin says it will continue to help integrate upstream, mid-stream and downstream companies in the industry as well as governmental resources to propel the development of lighting and optoelectronic display products and applications. The aim is to eventually make Taiwan the leading LED manufacturing country (pulling clear of third-place Korea and overtaking Japan).

Members of the first TOSIA board include Teng and Chan, as well as Lin Keng-hua, a member of Academia Sinica; Liu Jong-sheng, director of the Institute of Photonics Technologies of National Tsing Hua University; and Chan Yi-jen, deputy director of the ITRI's Optoelectronics and Systems Laboratories.

Touchtek and Uni Light merge

LED chipmakers Touchtek Corp and Uni Light Technology of Taiwan plan to merge in August (with 1.7 shares of Uni Light being swapped for each Touchtek share), according to filings with the Taiwan Stock Exchange at the end of March. The merged company will retain the name Touchtek.

Touchtek was founded in 1992 (although its LED business was only set up in 2000), has a plant in Chunan Industrial District, Miaoli County, and went public last June. Uni Light Technology was founded in 1998, has a plant in the Taoyuan Kuishan Industrial Zone, and also makes LED epiwafers. The two firms aim to combine to reduce production costs and the risks of monopolization of LED materials.

The combined capital will be NT$1.06bn, with Taiwan Oasis Enterprise still the largest Touchtek shareholder (with 30–40%), says the Economic Daily News (EDN).

Uni Light focuses on AlInGaP LED chips, but also has nine MOCVD reactors for blue InGaN-based LED chips (at 32m units per month), says EDN. Touchtek has an LED chip capacity of 700m units per month.

www.touchtek.com.tw

Arima spinning off laser business as Hua Xin Optronics

Arima Optoelectronics Corp of Taoyuan, Taiwan has decided to spin off its laser diode division as the subsidiary Hua Xin Optronics on 1 August, according to a filing with the Taiwan Stock Exchange (TSE) and DigiTimes website.

Arima Opto's aim is to focus on its LED chip manufacturing business (this year it expects to continue expanding monthly LED chip capacity from 600m to 1bn units for AlGaInP LED chips and from 200m to 300m units for blue LED chips).

After being founded in 1998, Arima Opto established its laser business in 1999, with Sony and Mitsubishi Electric as major partners. In 2006 the division generated about NT$1bn ($30m), accounting for 32% of Arima Opto's revenues.

Arima plans to seek strategic partners for Hua Xin, and will invite Sony and Mitsubishi to invest, says Taiwan's Apple Daily publication.

- Arima Opto plans to expand its LED chip capacity significantly in 2007. Monthly capacity of ultrahigh-brightness (UHB) red/yellow MS LED chips is more than doubling to 150m units from Q2/2007 amid rising demand for traffic light and car rear lights, says president PJ Wang.

Also, AlGaInP LED chip capacity is being boosted nearly 70% to 1bn units per month in 2007 amid stronger demand due to handset replacement, falling prices and improving brightness, Wang says.

Monthly blue LED chip capacity will grow by a relatively conservative 50% to 300m units, due mainly to technology constraints and patent deployment from manufacturers such as Nichia and Cree, Wang says.

- In February, to improve economies of scale and lower production costs and risks, Arima Opto agreed that in June it will acquire Taiwan-based Cleavage Enterprise Co Ltd, which specializes in cutting and inspecting LED chips (and is already cutting and grinding chips for Arima Opto).

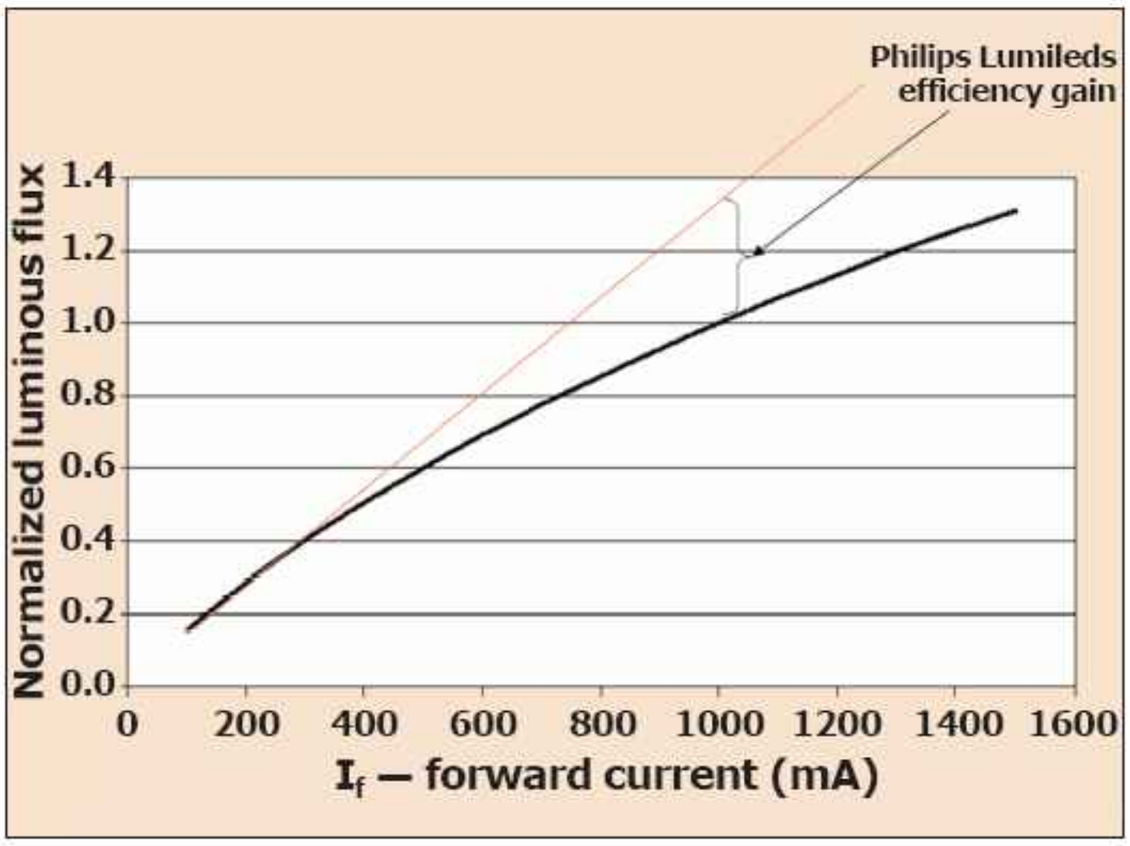
www.aocepi.com.tw

Lumileds solves LED efficacy 'droop' for 1000mA operation

Philips Lumileds of San Jose, CA, USA claims that it has solved the problem of efficacy 'droop', a phenomenon common to white power LEDs in which the lumens per watt decreases as current increases. The breakthrough enables efficacy to continue to increase even as drive current increases. The new technology will be implemented in 2007 in the firm's Luxeon LEDs, which already deliver light output at drive currents of 1000mA and higher. Sampling of products was due to begin by mid-May, with full production in Q3/2007.

Increased light output and efficacy for white LEDs should open up new lighting markets and expand the reach of LED lighting into residential lighting segments, says Philips Lumileds . Incorporating the new epitaxial technology will allow it to deliver what it claims will be the industry's first high-power LEDs that deliver 70 or more lm/W at drive currents of 1000mA and higher.

"While 350mA devices continue to improve in light output, they cannot deliver the light output of devices operated at 1A, 2A or even higher," says Frank Steranka, executive VP research & development. "Most LED manufacturers have acknowledged the need to move beyond the 350mA space and have recently announced devices that can operate at currents up to 1000mA. The Luxeon K2 already supports a maximum current of 1.5A, and with our focus on power LEDs we will continue to expand that operating range," he adds.



Luminous flux versus current: normal droop (black); Philips Lumileds' results (red).

As part of its expansion efforts, including its new fab in Singapore, Lumileds is adding the necessary equipment and technology to its production lines so the new technology can be implemented quickly.

www.philipslumileds.com

Avago launches 3W power LED for solid-state lighting

Avago Technologies of San Jose, CA, USA has launched the ASMT-MW20 power LED high-power (3W) InGaN-based white surface mount (SMT) LED, which can be driven at a high current of 700mA to deliver up to 160lm of light output.

The high drive current capabilities and brightness of the low-profile LED suits solid-state lighting applications that require a high-output light source where space is limited. Typical applications include portable torch lights and miner's headlights, billboard and sign backlighting, decorative accent lighting, architectural facade lighting, street lights, reading and track lights, and lighting for machine vision equipment.

"LEDs are increasingly being used for a wide variety of solid-state lighting applications due to the high-brightness, long-life, energy efficiency and space savings they provide designers," says Ng Kee Yean, business development manager for solid-state lighting. "As a result, more lighting manufacturers need robust LED packages that are reliable and capable of emitting high light output to provide the level of brightness they require for their applications," Yean adds.

Avago's ASMT-MW20 white SMT LED, with an output power of 3W.

With an exposed pad design at the back of the package, the ASMT-MW20 incorporates InGaN technology to offer low thermal resistance, which allows it to efficiently transfer heat from the package to the motherboard, maintaining long-term device reliability.

Also, the ASMT-MW20 can easily be soldered using conventional surface mount technology (SMT) reflow soldering, minimizing production costs.

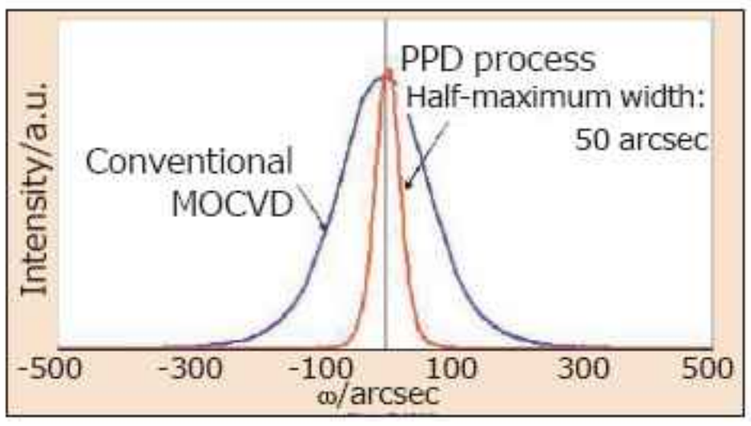
www.avagotech.com/led

SDK building 4" blue LED fab

To meet demand for blue/white LEDs, Japan's Showa Denko K.K. (SDK) has developed a new 'Hybrid PPD' process for growing high-quality GaN (and other nitrides), which combines conventional MOCVD with its proprietary plasma-assisted physical deposition (PPD) process.

The process gives higher production efficiency than conventional MOCVD, yielding single-crystal nitride epilayers on 4" sapphire substrates with improved crystal quality (as shown by x-ray rocking curves).

Using the process, SDK has developed blue LEDs with exceptional brightness, it claims, which it will start shipping commercially this year from a 4" epiwafer production line it is building at its Chiba site. Due to the larger wafer size and the new line, SDK's blue LED production capacity will rise from the current 30m units a month to 100m units a month by the end of 2007.



X-ray rocking curves for (0002) crystal face of GaN epilayers

SDK is aggressively expanding its ultra-bright LED business under its ongoing 'Passion Project', centered on GaN-based semiconductors (last December SDK announced a scale-up of its AlGaInP LED production capacity from 30m units to 100m units by Q3/2007). The firm aims to strengthen its presence in the growing LCD backlighting and general illumination markets. It also plans to develop other emission wavelengths and colors, as well as higher brightness and power.

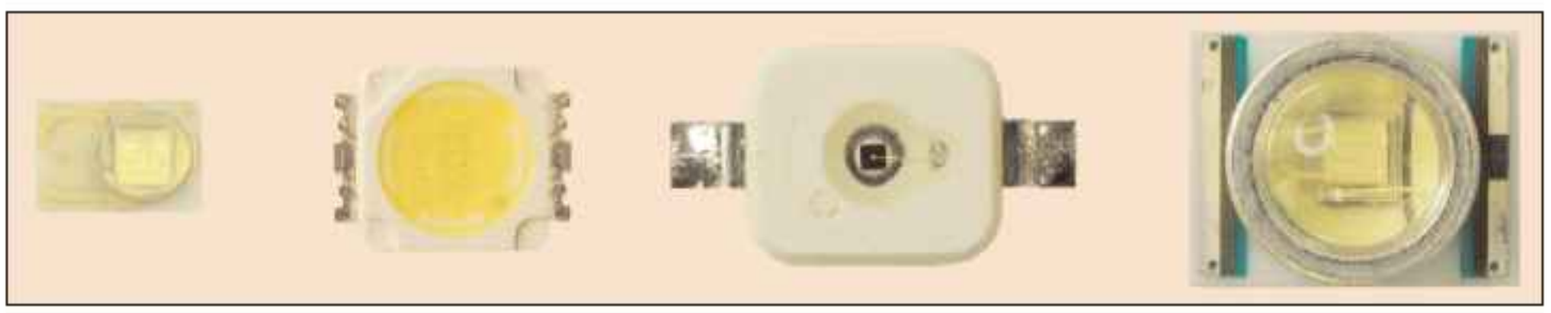
www.sdk.co.jp

Philips Lumileds launches its first warm white LEDs

Philips Lumileds of San Jose, CA, USA has launched the Luxeon Rebel family of power LEDs, providing the most complete color palette for lighting design, it claims (available in all standard LED colors). As well as standard InGaN and AlInGaP colors (royal blue, blue, cyan, green, amber, red-orange and red), the Rebel is Lumileds' first power LED offering warm-white, neutral-white and cool-white hues, with typical correlated color temperatures of 3000K, 4100K and 6500K, respectively (binned in ranges of 2670–3500K, 3500–4500K, and 4500–10,000K).

New chip packaging technology has dramatically reduced LED size (2.1mm high by just 3mm x 4.5mm, giving a footprint 75% smaller than other surface-mount power LEDs, it is claimed). This and the low profile enable reduced color mixing and diffusion depths, allowing luminaire designs up to 50% slimmer than using conventional power LEDs.

Engineered for a maximum operating current of 350–700mA for AlInGaP die and 1000mA for InGaN die, the Rebel is the first power LED to offer guaranteed minimum performance, it is claimed. This enables greater design and manufacturing consistency and allows the purchase of light output appropriate for each application.



Luxeon Rebel (far left) has a footprint area up to 75% smaller than other surface-mount power LEDs, but delivers the same or greater light output.

"Luxeon Rebel takes advantage of our latest chip, phosphor and packaging technologies to accelerate the use of LEDs in a wide range of lighting applications, particularly residential and other white lighting applications for which LED options have been limited," says product manager David Eastley.

For maximum efficacy, cool- and neutral-white versions can exceed 70lm/W at 350mA (a luminous flux of a minimum 80lm). For maximum light output, it can deliver more than 160lm at high drive currents. At 700mA, luminous flux increases to typically 145lm, with efficacy dropping to about 61lm/W.

As with other manufacturers, the warm-white LEDs are rated at a lower efficiency and luminous flux (a minimum of 60lm at 350mA and typically 110lm at 700mA).

"We also recognize that there is a technical communication gap between the semiconductor and lighting communities, so we are taking the lead in defining new references for reliability (lumen maintenance and lifetime) and tools that allow reliability to be analysed, based on temperature and drive current variations," adds Eastley.

Despite being small, the ceramic-based package has a maximum junction temperature of 150°C. Lumileds claims that it is the first power LED for lighting to be rated for unlimited shelf-life, simplifying inventory management and manufacturing. The small size also reduces PCB area, cutting costs.

Warm- and neutral-white LEDs are sampling, for production this year.

www.philipslumileds.com

Cree acquires COTCO to expand China LED market share

LED maker Cree Inc of Durham, NC, USA, which makes SiC- and GaN-based LED chips and packaged devices, has acquired privately held COTCO Luminant Device Ltd of Hong Kong, which was founded in 1982 and manufactures and sells packaged high-brightness LED products for applications such as large-scale video screens, traffic signals and automotive lighting.

Cree will pay its parent company COTCO Holdings Ltd about $200m in stock and cash ($70m in cash plus 7.6m shares of Cree stock, valued at $130m). Up to $125m extra, tied to the business achieving certain financial targets over the next two fiscal years, could take the deal to more than $320m.

COTCO Holdings has also agreed that it can only sell or transfer half of the Cree shares it receives a year after the acquisition's closing date, and the remaining half two years after. A COTCO Holdings subsidiary will also enter into a long-term supply agreement at closing that will require it to purchase a quarterly volume of LED lamp products, consistent with historical purchases, on competitive terms.

COTCO has already been a customer of Cree's for 10 years and is among its top-five largest buyers. In Cree's last financial year, COTCO comprised for about $25m of Cree's total revenue from LED chips.

Cree says the acquisition will pay off quickly by providing it with a quick way of getting strategic access to the fast-growing Chinese solid-state lighting market. It will also provide a low-cost manufacturing platform in a key market, helping Cree to leverage its LED chip expertise and intellectual property, as well as its investment in sales and marketing, to offer more value-added products in key markets.

Cree reckons that the COTCO acquisition should increase its annual revenue by 15–20% over current estimates for fiscal 2008

As well as having a production base in China, COTCO Luminant Device is able to engineer and design high-performance LED products for applications including full-color video screens, information signs, traffic signals, automotive lighting and specialty lighting.

Cree, which had a $29.8m profit on revenues of $192.7m through its first six months this fiscal year, also would gain four more packaged LED products that COTCO makes for applications ranging from video screens to car taillights. Cree currently has only one solid-state LED lighting product, the XLamp, which is used in products like bay fixtures for lighting parking decks.

The deal will produce immediate positive financial benefits. Cree reckons that the COTCO acquisition should increase its annual revenue by 15–20% over current estimates for fiscal 2008. "This acquisition is the next step in our strategy to enable the solid-state lighting revolution," said Cree's chairman and CEO Chuck Swoboda. COTCO Luminant Device's management team will join Cree. "We are excited about having the COTCO management team join the Cree family and continuing to build on their success," Swoboda adds. "We look forward to working together to expand our business in China and to transform Cree into a truly global company."

The merger will provide COTCO Holdings with access to Cree's technology and IP resources, strengthening its position in the solid-state lighting supply chain, says the firm's chairman and founder Paul Lo.

● Cree and COTCO have worked together for a decade. Previously, in July 2005, Cree had licensed COTCO subsidiary COTCO International to manufacture InGaN-based white LEDs under US patent 6,600,175, using Cree-supplied die and phosphor conversion technology.

www.cotco.com

Nichia seeks injunction against products incorporating COTCO LEDs

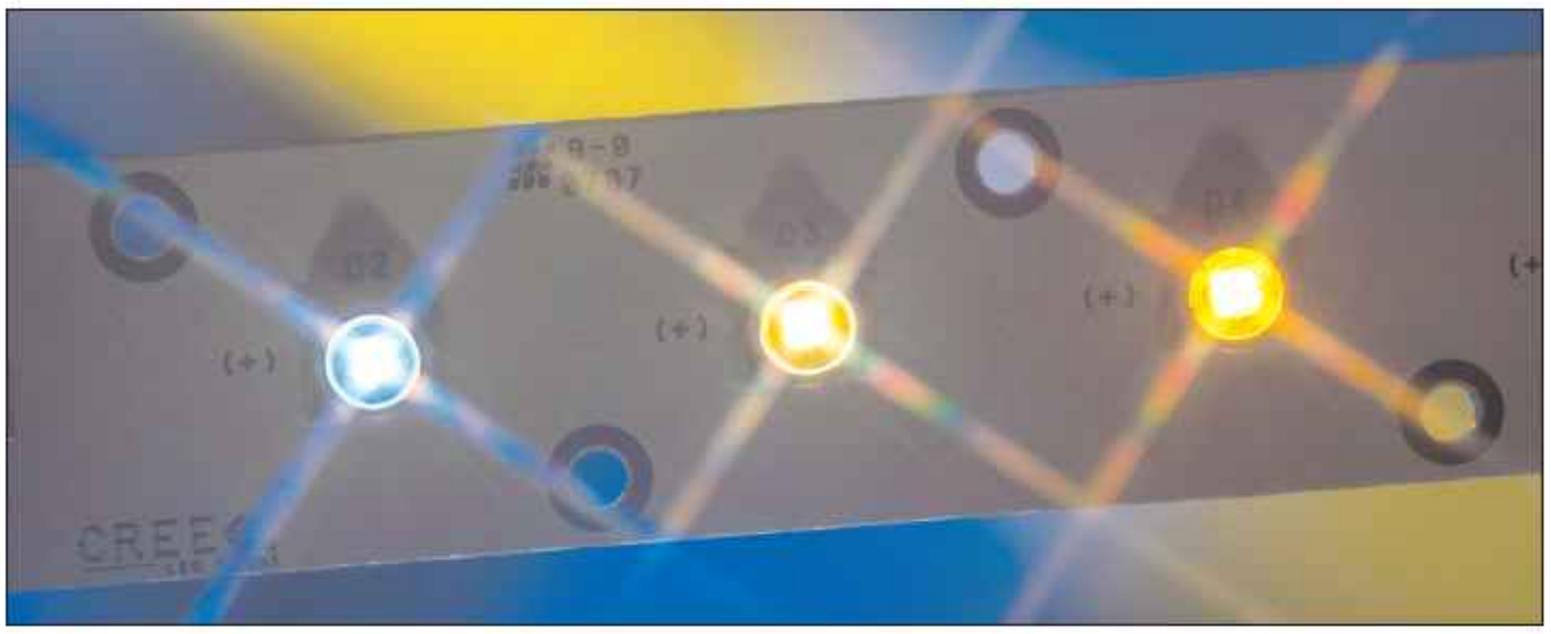
LED maker Nichia Corp has filed a provisional injunction action in the Tokyo District Court seeking to prohibit Tokyo-based distributor Sterling Inc from alleged infringement of its patent no. 3065263.

Nichia says it has warned Sterling and conducted negotiations several times about the firm's possible infringement of Nichia's patents due to the white LED (a blue LED chip with a single wire-bond structure combined with a yellow frequency down-conversion phosphor) manufactured by COTCO International Ltd in Hong Kong, China and installed in products such as the 4505 LED Palm Radio Light imported into Japan and marketed by Sterling.

Back in May 2005, COTCO licensed from Cree a US patent relating to white LEDs. The patent covers the combination of blue or UV LEDs with certain types of down-conversion materials. The same patent was included in a patent cross-licensing agreement between Nichia and Cree, dating back to February 2005.

Cree shipping lighting-class warm-white XLamp LEDs

Cree Inc of Durham, NC, USA has started shipping production volumes of warm-white XLamp LEDs qualified to run at up to 700mA (compared to 350mA for most warm-white power LEDs) with lighting-class efficiency and brightness (up to 124lm) and a correlated color temperature (CCT) of 3000K (comparable to the incandescent lightbulbs preferred for indoor home lighting applications, says Cree). This is the industry's first demonstration of 'lighting class' warm-white LEDs, it is claimed.



Cree's range of XLamp LEDs, from cool white to warm white.

The new warm-white XLamp LED is available in both the XLamp XR-E and XR-C power LED families and is now sorted (binned) by both light output and color point, according to the proposed ANSI chromaticity standard for LEDs (based on specifications for compact fluorescent lamps). This allows lighting manufacturers to select LEDs the same way they select bulbs.

The availability of high-performance LEDs across a full range of color temperatures can allow lighting manufacturers to build cost-effective LED fixtures for many indoor home and office applications, says Cree, helping to meet the need for energy-efficient, environmentally friendly lighting.

"The LED industry has struggled to boost the brightness and efficiency of warm-white LEDs, which have historically offered significantly lower performance than cool-white LEDs," says Norbert Hiller, Cree Lighting general manager and VP. Also, color point stability has traditionally proved difficult in producing warm-white LEDs, but Cree says that the new LEDs have minimal shift in correlated color temperature. "The new XLamp warm-white LEDs hold a stable color point [over their 50,000-hour life-time] and offer lighting designers and architects the first lighting-class warm-white LED light source for general illumination applications that have traditionally been lit with incandescent light sources," he claims.

www.cree.com/xlamp

Cree broadens XLamp range with lower-priced XR-C

Cree has extended its XLamp high-power LED family to offer a full range of LED performance options for portable and general illumination applications. Available in production quantities, the XLamp XR-C white LED delivers luminous flux at 350mA of up to 74lm (60lm/W), and typically 60lm.

The LED shares the same form factor as Cree's flagship XR-E LED, allowing re-use of design elements. It also features the same durability and surface-mount characteristics as other XLamp LEDs and provides an alternative for applications that do not require the highest brightness (compared to the XR-E's luminous flux at 350mA of typically 80lm).

"Cree recognizes the market need for a high-performance, lower-priced power LED," says Norbert Hiller, VP and general manager for XLamp LEDs.

Cree's XLamp XR-C white LED.

Cree has also launched the EZBright 700 LED power chip, which is the latest InGaN-based blue-emitting chip product based on its flagship EZBright LED platform.

Fitting between the EZ1000's 980µm x 980µm and the EZ290's 280µm x 280µm, Cree claims that the EZ700 is the brightest, most cost-effective LED chip of its size (680µm x 680µm), with a typical output of 260mW at 350mA and 440mW at 700mA.

"With the mid-size format EZBright 700, we're expanding the EZBright line to address a broader range of lighting markets," says David Davito, director of marketing for optoelectronics. The new chip is targeted at general lighting applications including auto headlamps, streetlights, camera flash, projection lighting, personal lighting and indoor and outdoor display applications.

IN BRIEF

Cree signs WPI to distribute power LEDs in Asia

Cree has signed a distribution agreement with World Peace Industrial Co Ltd. (WPI) of Taipei, Taiwan to sell and support its XLamp LED products in China, Asia Pacific and Japan. WPI is a member of Asian electronics distributor WPG Holdings. Cree had a prior distribution agreement with World Peace Group Technology Ltd of Hong Kong.

"Expanding our distribution reach in Asia and Japan with WPI strengthens Cree's presence and ability to address the potential for high-power packaged LEDs in China, Japan and the Asia Pacific region," says Bob Pollock, Cree's senior VP, sales. "Our customers represent some of the most advanced and innovative lighting and backlighting manufacturers in the world," adds WPI's CEO Mike Chang. WPI claims to be one of the top three IC component distributors worldwide.

The agreement provides WPI's customers with access to Cree's family of high-power packaged LEDs. Among the Cree XLamp products available through WPI will be the 210lm XR-E LED, which is the first commercially released power LED that is as efficient as fluorescent sources, claims Cree.

WPI will provide full system-solutions support for optical, thermal, and control electronics design. Cree and WPI aim to work together to accelerate the adoption of solid-state lighting in Asia by providing high-power packaged LED products and services to manufacturers of lighting and backlighting products.

"With this agreement, Cree adds a third major distribution partner, advancing our plans to build a top-tier distribution network worldwide," says Pollock.

www.WPI-group.com

LLF shipping LED recessed downlight

Cree's XLamp XR-E LED is being used in the first product of LED Lighting Fixtures Inc (LLF) of Morrisville in the Research Triangle area of North Carolina, USA, which was founded in 2005 by former Cree executives and aims to extend LEDs into the residential and ultimately commercial construction markets.

LLF's LR6 ceiling downlight (in a standard commercial and residential 6-inch recessed housing) was demonstrated at February's NAHB 2007 International Builders' Show in Orlando, FL, USA. In March LLF won its first customer, becoming the exclusive supplier to Loyd Builders of Raleigh and Fayetteville, NC (which builds custom homes).

Delivering a luminous flux of 650lm at a wall-plug input power of just 10–12W (an efficacy of about 60lm/W), LLF claims the LR6 is the industry's most efficient general lighting fixture for home and office use, and the first affordable fixture powered by semiconductor emitters that can rival the output, appearance and lighting quality of a 65W incandescent bulb while offering a justifiable cost of ownership. With a color rendering index (CRI) of 92, it is available in both 2700K and 3500K color temperatures for warm and cool white applications.

"Our introduction of a viable LED product for general illumination will have historic implications for the lighting industry," claims CEO Neal Hunter (a co-founder and ex-chairman of Cree).

"This product takes maximum advantage of our new lighting-class LEDs," says Cree's chairman and CEO Chuck Swoboda. "This is the first LED downlight to deliver on the promise and capability of LEDs." Compared to typical incandescent and compact fluorescent lamps respectively, LLF's product is targeted to consume about 17% and 50% of the energy and last more than 20 times and 5 times longer.

LLF tested a number of LEDs in developing its design. "Cree's performance is unmatched with the new XR-E design and recent advances in its power-package technology," says LLF's chief technology officer Gerry Negley.

LLF aims to introduce a 4-inch recessed product later this year, and then expand into other permanent light fixtures such as florescent lights in offices and, longer term, flood-lights (e.g. for home security). However, LLF does not plan to replace low-cost light bulbs in household lamps.

www.llfinc.com

XR-E LEDs chosen for solar-powered streetlights in Guangzhou, China

Multi-Cell Semiconductor Lighting Technology Co Ltd is installing solar-powered streetlights based on Cree's XLamp XR-E power LEDs (with a typical luminous flux of 80lm at 350mA, yielding 70lm/W) in a 20-light demonstration project in Guangzhou, China.

Using the LED in its MZSLB-130 streetlight has significantly improved its performance, says Multi-Cell's general manager Peng Zhoulong. "The Cree XR-E is very bright and efficient but also exceptionally consistent and stable. Its package design is especially beneficial to the mass-production assembly line, providing a streamlined manufacturing process," he adds.

"The revolution in LED lighting offers the globally vital benefit of energy savings from an environmentally friendly technology," says Norbert Hiller, Cree's general manager and VP for XLamp power LEDs. "Especially in geographies of the world where conserving energy is a high priority, the demand for LED streetlights is growing rapidly."

www.mcledlight.com

'LED City' lighting initiative yields 40% energy saving

In February the municipal government of the City of Raleigh (North Carolina's capital) announced an 'LED City' initiative to test, deploy and promote LED technology (made by Cree Inc of Durham, NC). The aim is to create a 'living laboratory' to deliver the economic, environmental and usage benefits of LEDs for general lighting applications to Raleigh's residents, and to act as a model for other cities that are considering implementing energy-efficient infrastructure.

In the initiative's first installation (focused on validating both the cost savings and technology capabilities of LED lighting) in December the dull, orange high-pressure sodium (HPS) lighting in one deck of the Raleigh Municipal Building's car park was replaced with 141 low-bay fixtures (each containing an array of Cree's bright white Xlamp LEDs) designed by Lighting Science Group of Dallas, TX, using its proprietary Optimized Digital Lighting (ODL) technology. Progress Energy, Raleigh's primary electric utility provider, says that energy consumption has been cut by over 40% and light quality greatly improved. Raleigh's mayor Charles Meeker believes the city could save about $80,000 a year.

Also, in late March the results of two surveys (of 200 people each) were announced that were conducted last November (pre-installation) and this February (post-installation). This showed that, after the LED lighting was installed, opinions of the quality of the lighting improved threefold. Also, the number of respondents perceiving the garage to be 'very safe' grew by 76% after the LED fixtures were installed.

"LED technology provides a clear benefit to municipal infrastructure, as well as to the citizens it serves," said Meeker. "LEDs can do more than improve light quality." In addition to the proven environmental and energy efficiency benefits, the LEDs' bright white light can help improve public feelings of safety in city spaces, he adds.

Garage before (top-right) and after (bottom) installation of LED lighting (inset).

Raleigh estimates that lighting constitutes 30% of the city's total energy costs. So, over the next 18 months it plans to deploy LED lighting as broadly as possible in other applications (e.g. street-lights, signals, architectural and accent lighting, portable lighting, and pedestrian and walkway lighting) to test if it is best for the city to use LEDs wherever possible. Specifically, the city currently spends over $4.2m annually to power more than 33,000 street-lights, so Meeker targets large savings there too, as well as savings in maintenance costs (due to LED life-span being 20 times longer than that of incandescents, according to the Department of Energy).

"The economic benefits for municipalities to invest in LEDs are clear — they save energy, reduce environmental impact and improve the quality of light...it's our civic responsibility to invest in the future and ensure the highest possible quality of life and safety," says Meeker. "We believe that the cost savings and benefits of LED lighting are real and achievable today."

The announcement represents "a milestone toward large-scale adoption of clean, energy-efficient technologies," says Kateri Callahan, president of the Washington, DC-based Alliance to Save Energy (ASE). "Raleigh's progressive commitment to becoming the first 'LED City' will no doubt serve as a model for other cities seeking to improve energy consumption and reduce negative impacts on the environment. We commend Cree and the City of Raleigh for helping support our mission of achieving a healthier economy, a cleaner environment and greater energy security."

"The City of Raleigh is willing to set the pace and invite other municipalities to join in developing energy-efficient civic centers," says Cree's CEO Chuck Swoboda. The initiative establishes an important driver for LED adoption in the USA, he adds.

www.cree.com

CyOptics acquiring Apogee to expand 10 & 40Gb/s laser range

CyOptics Inc of Breinigsville, PA, USA (which makes InP-based chips and components for access, metro, and long-haul optical communications systems) has agreed to acquire Lehigh Valley neighbor Apogee Photonics of Allentown, PA, which makes high-speed, integrated optical components. The combined firm will have 415 staff and annual revenues of about $80m.

CyOptics' acquisitions include, in 2003, the optical component packaging capabilities of CENiX Inc in Allentown (co-founded by CyOptics' CEO and former AT&T/Lucent veteran Ed Coringrato in 2000) and, in May 2005, TriQuint Semiconductor's Optoelectronics Division (once part of Lucent, later Agere).

Apogee stems from T-Networks Inc (founded in 2000 by former Bell Labs and Lucent researchers) merging in 2005 with ASIP Inc of Somerset, NJ.

Compared to CyOptics' chips (mostly for short reach, e.g. FTTH), Apogee's products are complementary: uncooled laser sources (for the fast-growing 10Gb/s and emerging 40Gb/s markets) in links from short-reach TDM up to long-reach DWDM. This extends CyOptics' high-speed source laser capabilities and gives it a comprehensive portfolio of InP-based transmit and receive optical chips and components for telecom and datacom applications. "10Gb/s ports are really hitting their stride right now, accelerated by Ethernet at this speed," says Karen Liu, research director (Components) at market research firm Ovum-RHK. "10Gb/s ports overall will grow from 578,000 shipped in 2006 to over 3m forecasted for 2011."

Apogee's 10 and 40Gb/s 1550nm Laser Integrated Modulator (LIM) supports links of up to 110km and incorporates integrated InP lasers, modulators and optical amplifiers in a standard 7-pin electro-absorption modulated laser (EML)-compatible package while giving better output power and dispersion performance than standard, monolithic EMLs, it is claimed. Its uncooled 1310nm 10Gb/s EML supports both 10Gb/s Ethernet and SONET links up to 10km. Apogee is also developing uncooled coarse wavelength division multiplexing (CWDM) EML lasers operating at up to 25Gb/s to support the deployment of next-generation 100Gb/s Ethernet optical links.

"The optoelectronics industry is continuing its consolidation and CyOptics is growing its revenue by offering our customers one-stop-shopping for best-in-class component solutions," says Coringrato. "Our primary integration focus is to serve Apogee Photonics' customers with a continuity of supply, outstanding value and technical support, and continuous dialogue on our technology developments and product roadmaps."

Apogee's CEO Mike Decelle (also ex-AT&T) adds: "CyOptics is well positioned to address all of the high-growth markets for optical components, including 10Gb/s and 40Gb/s lasers and detectors for pluggable transceivers, tunable laser transmitters for agile optical networks, lasers and detectors in broadband access networks, and photonic integrated circuits (PICs)."

● According to Lehigh Valley news web-site The Morning Call, Decelle will stay on for up to six months while Apogee's 90 staff and manufacturing equipment transfer from its 50,000ft^2 fab. Some redundancies are likely.

The merger will allow CyOptics to lower production costs by making more use of its fab in Breinigsville (built by AT&T in 1987 as a research center; later expanded by Lucent). CyOptics does not own the property; TriQuint sold the 139-acre complex in 2005 to investors who converted it into the multi-tenant Tek Park.

www.cyoptics.com

CyOptics ships 1 million chips for fiber-to-the-home

CyOptics shipped over 1m laser and detector chips for fiber-to-the-home applications in 2006.

CyOptics supplies 1310nm distributed feedback (DFB) laser chips for the optical networking unit (ONU) and 1490nm DFB laser chips for the optical line terminal (OLT) enabling Gigabit passive optical networks (GPON) equipment, as well as avalanche photodiodes to support both ONU and OLT applications. The chips are sold either at the die level or in an industry-standard cylindrical TO-can package (manufactured by partners in Asia).

CyOptics says it has supplied more than 4m lasers with over 120bn service hours in telecoms equipment deployed since 2000.

"GPON is the fastest-growing portion of the PON market now, and this rate will be sustained," says Karen Liu of Ovum-RHK. "Ovum expects both GPON ONU and OLT shipments to more than double each year through 2011."

"We have been providing these key components to make FTTH a reality outside North America, and now we are ready to address the US market needs as carriers implement their plans for widespread FTTH deployments," says Kou-Wei Wang, CyOptics' director of chip product management & sales.

Emcore acquires Opticomm

Emcore Corp of Somerset, NJ, USA, which makes components and subsystems for broadband, fiber-optic, satellite, and solar power markets, has acquired Opticomm Corp of San Diego, CA, USA, including its fiber-optic video, audio and data networking business, technologies, and intellectual property, for $4m, as well as an earn-out payment based on its 2007 revenues.

Founded in 1986, Opticomm generated profitable revenues of $6.3m in 2006. Emcore expects it to provide about $7m of revenue for 2007, and for it to be operationally profitable upon integration.

Opticomm's flagship product is the Optiva Platform, a line of transmission systems built to address the primary optical communication requirements of markets including: broadcast and media; security and surveillance; healthcare; traffic and rail; and government and military.

"This represents a tremendous opportunity to increase Emcore's presence in the rapidly expanding video transport market," says Chris Larocca, VP and general manager of Emcore's Ortel division. "This transaction enables Emcore to integrate the complementary technologies added from the recent acquisition of Force Inc into a single, high-density and modular platform. The combined product line uniquely positions Emcore as a leading supplier of products to aggregate, process and transport video signals to IP, HFC, FTTx and wireless networks," he claims.

"Opticomm's product line, technology and worldwide market presence will both expand Emcore's current video offerings, as well as benefit from the increased resources and experience available in the Ortel Division," says Opticomm's president David Caidar.

www.emcore.com

Completion of Avanex France buy-out yields 3S Photonics

Optical communications component and module maker Avanex Corp of Fremont, CA, USA has finalized the sale of 90% of Avanex France S.A. to the subsidiary's director Didier Sauvage and France-based Global Research Company (owned by entrepreneur Alexandre Krivine). Formerly Alcatel Optronics until 2003, the firm has now become 3S Photonics, with a head office in Marcoussis, France.

Avanex has paid the purchasers nearly $17.3m in anticipated operating capital, including current liabilities for previous restructuring activities. Avanex maintains a 10% stake as well as privileged commercial partnerships (to assure a smooth transition and to ensure their customers' continuity of supply), and has retained the optical interface activity that was previously carried out by Avanex France (maintaining an innovation center in France comprised of about 20 staff, focusing on developing transmission products).

The new board of 3S Photonics includes Sauvage as chief operating officer (responsible for R&D) and main shareholder Krivine as president and CEO. Assisting them, Yannick Bailly is vice president of marketing and Michel Privat is vice president of sales. Etienne Barbry is vice president of finance.

3S Photonics has over 100 staff, specialized in semiconductor manufacturing (epitaxy, wafer and die processing, dicing, etc), assembly processes (optical, micromechanical, thermal, soldering, YAG laser welding, etc), reliability tests, and inscription of optical fibers with Bragg gratings, including fiber stripping, handling and recoating. The fabrication plant in Nozay has 2000m^2 of cleanrooms and is equipped with MBE, MOCVD, PECVD, reactive ion beam etching (RIBE), inductively coupled plasma (ICP), evaporation, UHV passivation, electron-beam evaporation, and ion-beam deposition. The firm claims that the chip manufacturing plant is unique in having GaAs and InP technologies under the same roof.

As well as providing epitaxial and wafer processing foundry services at its fabrication plant in Nozay, 3S Photonics designs and manufactures four product lines: optoelectronic chips (lasers and detectors) based on both GaAs and InP (with an annual production capacity of over 1000 wafers of each); transmission laser and detector modules; pump laser modules for both terrestrial and submarine applications; and filters, gain equalizers and pump stabilizers. Products in the area of telecoms already address the wide-area network (WAN) market: metro (city networks), the long haul (interconnection between cities), and submarine (undersea links). 3S Photonics forecasts sales of €27m for 2007.

As well as its existing product portfolio, the firm aims to base growth on a mid-term diversification strategy by broadening out to the datacom (inter-company network) and fiber-to-the-home (FTTH) markets. It is also targeting markets concerning defense and industrial lasers as well as the medical sector (with latest-generation lasers for bio-instrumentation, e.g. DNA sequencing, haematology and retinal imaging).

Also, the implementation of a network of partnerships with universities and research centres in Europe should allow it to maintain its strength in technology and to ensure long-term growth, the firm reckons.

www.3Sphotonics.com

Blue laser output boost

Nichia, Sony and now Sharp are all boosting both production and power output of blue-violet lasers, which should reduce HD-DVD and Blu-ray Disc prices.

Last year saw the advent of the two rival high-capacity, high-definition optical disc player formats — HD-DVD (championed by Toshiba) and Blu-ray Disc (championed by Sony) — as well as Sony's PlayStation 3 (PS3) games console (which incorporates a Blu-ray Disc player). For each, the pick-up head (PUH) that reads the disc integrates a gallium nitride-based blue-violet laser diode emitting at a wavelength of 405nm.

Current-generation DVD uses a red laser to read and write data, allowing a capacity of 4.7GB (about 2 hours of standard video). The shorter-wavelength blue-violet laser can be focused more finely on the disc surface, increasing storage capacity several-fold (15GB for HD-DVD and 25GB for Blu-ray, or about 13 hours) for higher-definition movies and video games.

Until recently, volume manufacturing of GaN-based blue-violet lasers was restricted to Japan's Nichia (the sole merchant supplier) and Sony (under a cross-licensing deal, with Nichia providing its MOCVD-based blue-violet laser manufacturing technology and acting as a second-source supplier to Sony).

Blue laser fabrication uses a free-standing GaN substrate epitaxially grown on sapphire (which is removed after the thick GaN layer is formed). But such substrates incorporate a high density of defects (dislocations). A lateral epitaxially overgrowth method is used to grow GaN films with fewer defects, but this often results in a mixture of high- and low-quality crystal. This, together with substrate bowing (which further compromises uniformity, e.g. for light exposure during photolithography), has proved to be a worse-than-expected limitation on the manufacturing yield of usable lasers subsequently fabricated on the wafer. For example, to accelerate production, Sony's Shiroishi fab installed multiple MOCVD systems, but "it was difficult to control these systems to grow uniform, high-quality crystalline films", the firm explained.

Sony has consequently been devoting nearly all its output to captive internal supply for the PS3 and its own Blu-ray Disc players. Nevertheless, the PS3's launch was delayed from spring to November 2006, when it shipped less than 200,000 in the USA and 100,000 in Japan (less than half the target) and just 1m in each region by end-2006 (down on a targeted 4m). The European launch was delayed to this March.

Sony also postponed the launch of its first Blu-ray Disc player, from July to after the launch of the PS3.

Nichia and Sony have hence been unable to meet the rapidly rising market demand for blue-violet lasers. This has led to an ongoing industry-wide shortage of pick-up heads at Blu-ray Disc and HD-DVD player manufacturers, which meanwhile have delayed their launches, leading to higher costs and slower adoption.

Sharp ramps up output

In contrast, Japanese rival Sharp used MBE to pioneer the development of infrared- and red-emitting lasers for optical data storage applications.

Although MBE is a more complex process than MOCVD, the dislocation density is orders of magnitude lower. Sharp has therefore developed a MBE-based fabrication of blue-violet lasers, aiming for higher manufacturing yield of components with lower power consumption and greater reliability/lifespan.

In response to market demand, last November Sharp joined Nichia and Sony to become the third manufacturer to enter volume commercial production of blue-violet lasers for HD-DVD and Blu-ray Disc players.

The initial GH04020A2GE model had a low maximum CW optical power output of 20mW for read-only operation. Costing ¥10,000 ($85), shipments of samples began on a new, dedicated line at its existing fab in Mihama, Hiroshima prefecture. By December production had been ramped up to 150,000 units per month.

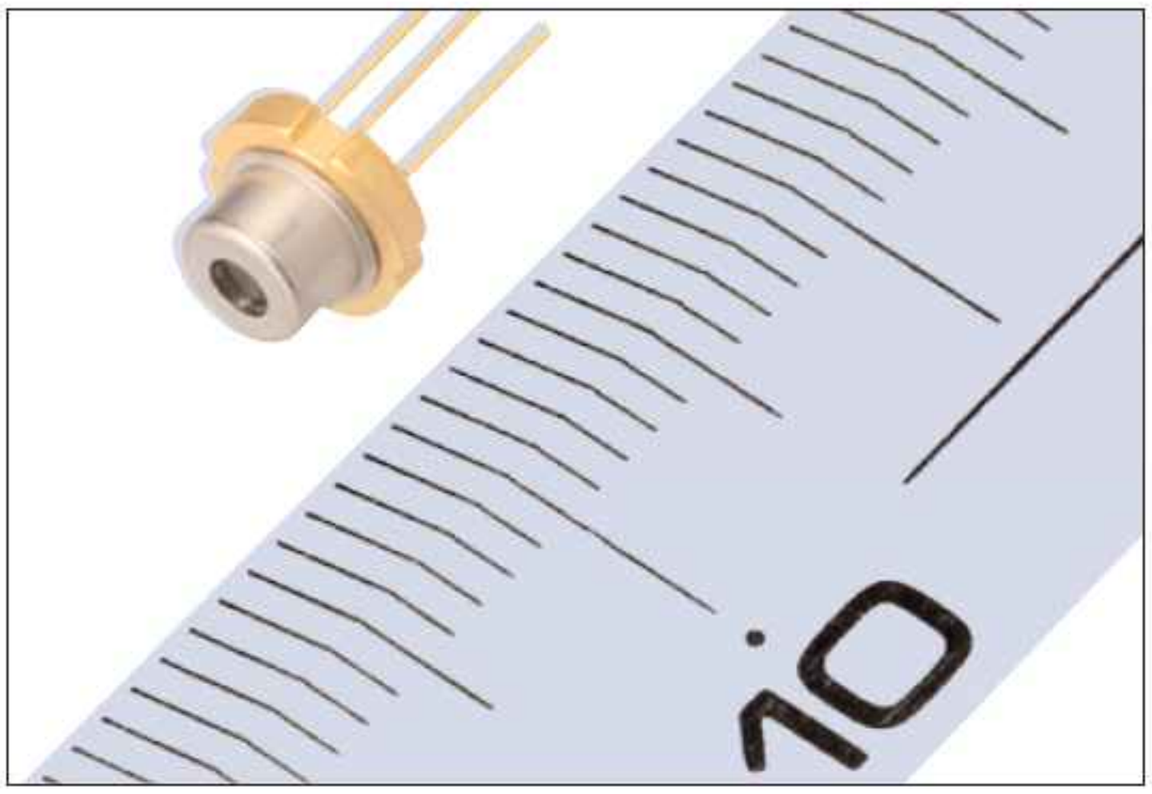
Sharp estimates that the market for low-power blue-violet lasers for playback applications will grow to 50m units in 2008 and 100m units by as soon as 2009, and that the market for high-power lasers for recording will grow to 100m units about two years later.

So, aiming to expand its market share, at the start of April Sharp released samples of what it claims is the industry's highest-power blue-violet laser available, at a cost of ¥50,000 ($430) initially in a standard 5.6mm-diameter CAN package (for volume production in May). The GH04P21A2G model's maximum optical output power is 210mW in pulsed mode and 105mW in continuous-wave mode.

The enhanced output enables higher-speed (6x) recording on dual-layer discs. Most recorders currently shipping have 2x record speeds, although a few are 4x.

Also, the service life is claimed to be an industry-leading 10,000 hours (pulsed at 210mW and 75°C).

Sharp says it has achieved such high output and long lifetime by developing a new laser chip with a proprietary facet structure.



Sharp's210mW GH04P21A2G blue-violet laser.

Nichia's blue-violet laser.

As well as the GH04P21A2G model for optical storage applications, a companion model (GH04P21A2GE) for other general light-source applications will enter volume production in June.

Including all models, Sharp plans to spend several billion yen on increasing monthly production capacity from 150,000 units to 250,000 by June and to 500,000 by end-2007.

Sharp's goal is to surpass Nichia. "We are aiming at over 50% share," says Naotaka Ohtsuka, division general manager of Sharp's compound semiconductor systems division. The firm is targeting annual sales of about ¥15bn ($127m) in the first fiscal year, according to the Nihon Keizai Shimbun business publication.

Sharp forecasts demand for output power of 250mW by 2008 for 8x speed recording and 350mW by 2009 for 12x speed recording (both on two-layered discs). It adds that it has completed work on a laser with a 350mW pulsed-mode output and a lifetime of an estimated 6000 hours. "We'll introduce the 350mW diode depending on market demand," said Ohtsuka.

Nichia achieves 320mW pulsed operation

Nichia's blue-violet lasers have pulsed output powers of 130mW, although it has sampled a 180mW laser. "We are watching how much output power is required on the market," the firm says. "If the market demands a higher power diode, we are ready to supply it."

In February Nichia said that, by improving its laser chip, it had developed a prototype with a pulsed-mode output of 320mW (2.5 times larger than its 130mW production laser). This output power meets the requirements for 10x speed recording on dual-layer (and 2x recording on four-layer) discs, says Nichia.

Nichia has verified stable operation for 1000 hours under 320mW pulsed operation at 80°C, and estimated that the lifetime is more than 10,000 hours. The firm targets mass production in first-half 2008.

In the meantime, Nichia aims to ramp up its monthly production capacity from about 500,000 units last summer to 2 million units by Q3/2007, and to improve product quality. Investment totals ¥17bn ($146m).

Sony enters merchant market

To reach its goal of selling 6m PS3 consoles by the end of March, Sony has also been increasing its production capacity. Following a rapid increase in demand for Blu-ray Disc players and game consoles, in mid-April it established an 'industry-leading' blue-violet laser production capacity of 1.7 million units per month. This enables it to not only meet the needs for captive-only supply for use in its own products but also to join Nichia and Sharp on the merchant market supplying external third-party customers.

Targeting Blu-ray Disc applications, Sony has started sampling lasers with an output power of 170mW for 4x speed recording: the SLD 3234VF and the SLD3234VFI (in 5.6mm and 3.8mm diameter CAN packages) at prices of ¥4500 ($38) and ¥5000 ($42), respectively. These will be joined in June by low-power 20mW lasers for playback only: the SLD3131VF and SLD3131VFI, costing ¥900 ($7.60) and ¥1000 ($8.40), respectively. Then, in November, Sony aims to introduce higher-power 240mW lasers for 8x speed recording: the SLD3235VF and SLD3235VFI, costing ¥4500 ($38) and ¥5000 ($42), respectively (the same as for 170mW).

Sony says it aims to gain market share through expanded production capacity and lower prices. It has already made preparations to increase capacity further by installing front-end wafer processing equipment capable of monthly production of 5 million blue-violet lasers, and will also strengthen its post-processing assembly capacity (depending on future demand).

Such increases in supply should ease the shortage of pick-up heads in 2007 and help to reduce the price of Blu-ray Disc and HD-DVD players, stimulating c onsumer acceptance of the new technology.

www.sony-shiroishi.co.jp
www.nichia.com
http://sharp-world.com

Eliminating bowing in blue LED and laser epi

LayTec and Ferdinand-Braun-Institut describe new in-situ technology for optimizing the growth of blue LEDs and laser diodes by reducing wafer bowing during epitaxial growth.

A new in-situ sensor from LayTec that provides simultaneous in-situ strain, temperature and reflectance measurements is helping blue LED and laser development and production. The sensor is being applied successfully to optimize MOCVD growth of GaN-based devices at research institutes and industrial companies worldwide. Recent results at Ferdinand-Braun-Institut in Berlin, Germany illustrate the method's effectiveness.

MOCVD growth of GaN-based LED and laser structures

Metalorganic chemical vapor deposition (MOCVD) is the most important method for manufacturing nitride-based microelectronic and optoelectronic devices. If the high-brightness white LED is going to replace the incandescent light bulb, then its price per lumen of light output must fall substantially. To achieve this goal, better understanding of the GaN growth process and improvements in the reproducibility are essential. Furthermore, high-volume LED production needs efficient multiwafer growth equipment with reliable in-situ process control. One major task for LED manufacturers worldwide is process yield optimization. In this regard, the improvement of wavelength homogeneity across the wafer diameter is of crucial importance.

For blue and white LEDs, thin (Al,In,Ga)N films are grown on foreign substrate materials such as sapphire or silicon carbide, because GaN substrates are still expensive and scarce. Due to the lattice mismatch and different thermal expansion coefficients between the substrate and the epitaxial film, strong stresses evolve during III-Nitride growth and cause the wafer to bend on a macroscopic scale.

An important impact of wafer bowing during growth is the change in thermal contact between the wafer and the substrate holder. This is especially important for indium-containing compounds, since In incorporation during MOCVD is known to be very temperature sensitive [1]. This implies that bowing during growth will cause inhomogeneities in the active layers (quantum wells) of the device.

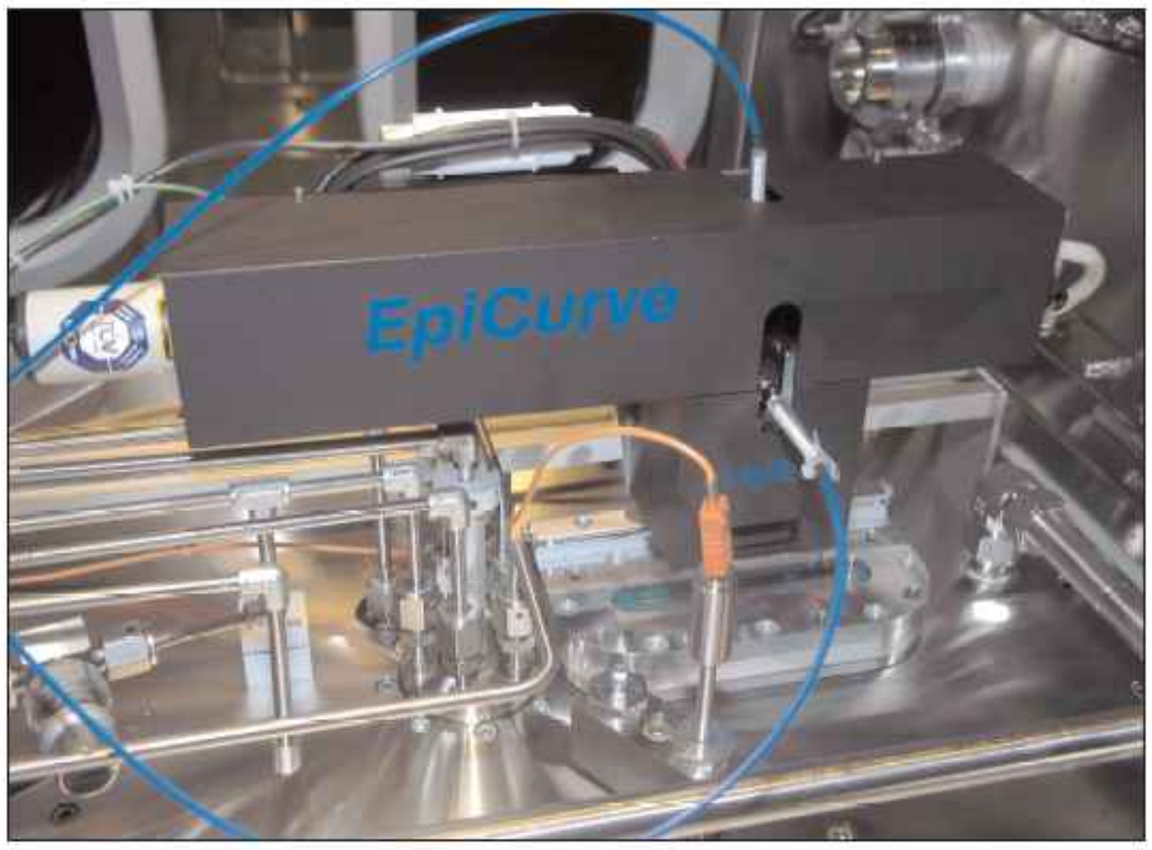


Figure 1. A production-scale MOCVD reactor at FBH, equipped with an EpiCurve TT curvature sensor for the determination of strain, temperature and growth rate during GaN deposition.

Therefore, to understand and optimize the growth process, it is essential to monitor in-situ how lattice mismatch and differences in thermal expansion coefficient contribute to the total stress at growth temperatures.

To enhance this understanding, LayTec has developed EpiCurve TT — a sensor that provides curvature measurements, emissivity-corrected pyrometry for wafer temperature measurements, and reflectance at two wavelengths (see Figure 1). The curvature sensor has a bowing resolution of $\delta(1/R_c) = \pm 1 km^{-1}$ (where R_c is the radius of curvature). The relevant basic experimental set-up has been published in [2]. The MOCVD system has to be equipped with a standard optical viewport for normal incidence access.

Accurate wafer-selective susceptor surface temperature (T_{wafer}) measurements, in parallel with the bowing measurements, are necessary to gain deeper insight into the growth process. T_{wafer} is the most important parameter in MOCVD, as it determines both the gas-phase decomposition and the surface processes. The susceptor surface temperature immediately under the wafer often differs from the process temperature measured at the susceptor back-side, since the gas-foil rotation of the satellites or cold process gases tend to

cool the front side of the substrate holder. Therefore wafer-to-wafer and run-to-run reproducibility of T_{wafer} have to be checked carefully.

The integrated reflectance measurement at 405nm and 950nm gives access to the growth rate, composition and surface morphology during growth, and for each wafer separately. Again, statistical process control (wafer-to-wafer as well as run-to-run) can be applied to verify the reproducibility in a production-line multiwafer MOCVD system. The 405nm signal is ideally suited to monitor InGaN quantum wells, as at this wavelength the GaN layers are absorbing.

How to eliminate the bowing

The active region of devices emitting in the blue and green spectral range typically consists of InGaN multiple quantum wells (MQW). Reducing wafer curvature at the InGaN growth temperature should directly improve the composition uniformity and yield of optoelectronic devices. The Ferdinand-Braun-Institute has therefore conducted studies of how to design the process to reduce the wafer curvature at critical growth steps [3]. The dependence of wafer bowing on substrate properties, growth temperature and the insertion of strain-compensating interlayers was carefully examined to improve the uniformity of light emission.

Figure 2 shows the wafer curvature (lower graph) and reflectance at 950nm and 405nm as well as the emissivity-corrected wafer temperature (upper graph) during growth of a GaN-based laser diode test structure. As can be seen, already the initial curvature of sapphire wafers from different batches varies by about 20km^{-1}. This difference in $1/R_c$ is sustained during the whole growth process and has an impact on wafer-to-wafer reproducibility. Here, multiple wafer in-situ measurement substantially reduces the effort of pre-characterization of substrates from different batches.

During the high-temperature desorption step prior to growth, the sapphire substrate has a concave bow due to the temperature gradient between the wafer backside (heated by the hot wafer carrier) and the wafer topside (cooled by the process gases and radiation towards the cold reactor top). SiC substrates (not shown here) behave differently to sapphire wafers: according to their much better thermal conductivity, no thermal-induced concave curvature is observed during heating.

While low-temperature GaN nucleation on sapphire leads to a slight convex wafer bowing, the following high-temperature growth of GaN layers is characterized by increasing concave wafer curvature (Figure 2). The origin of this tensile stress during high-temperature GaN growth can be assigned to the process of coalescence of the nucleation layer islands. For example, the number and size of GaN grains during nucleation is known to affect the magnitude of tensile stress during GaN growth. Additional tensile stress is generated by

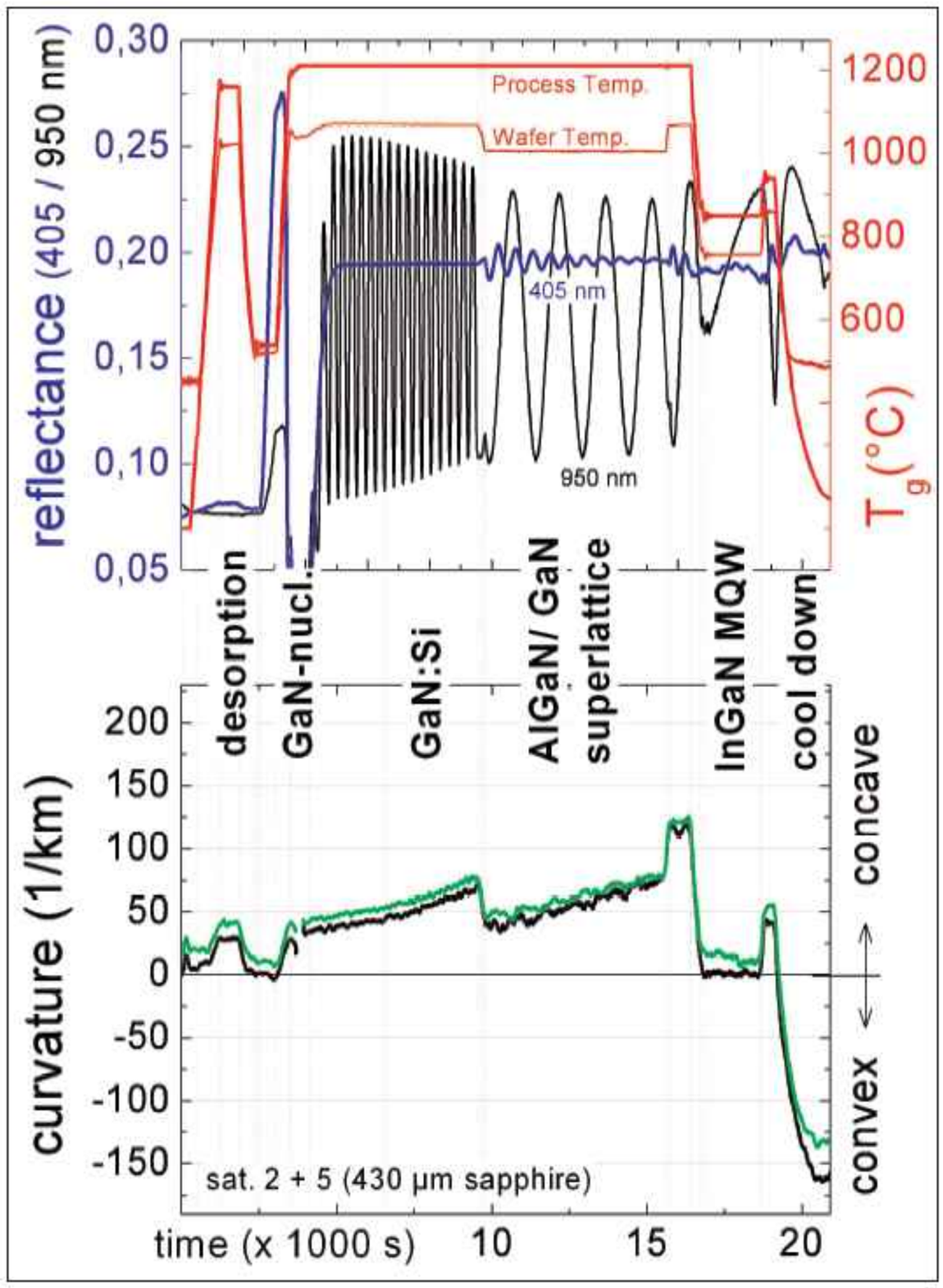


Figure 2. In-situ measurement of reflectance and surface temperature (upper graph) as well as wafer curvature (lower graph) during growth of a GaN-based laser test structure.

adding Al to the compound, since AlN has a smaller lattice constant than GaN. Accordingly, during growth of the cladding layer (Figure 2: AlGaN/GaN superlattice) the change in curvature shows a larger slope compared to the GaN buffer.

As the temperature varies, the bowing changes due to the different thermal expansion coefficients of the epitaxial layers and the substrate beneath. For example, when cooling down from the growth temperature, the GaN layer becomes convex, since the thermal expansion coefficient of GaN is smaller than that of sapphire. Since a different bowing rate with cooling for different substrate thicknesses can be observed, the temperature of zero bowing also depends on the substrate thickness.

For the growth of the light-emitting active layer, the wafer should be as flat as possible. Otherwise, temperature inhomogeneities across the wafer during InGaN growth lead to inhomogeneities in the emission wavelength of the final device. This can be achieved by selecting an appropriate substrate thickness and by optimizing the growth temperature. However, the growth temperature is a very restricted parameter to

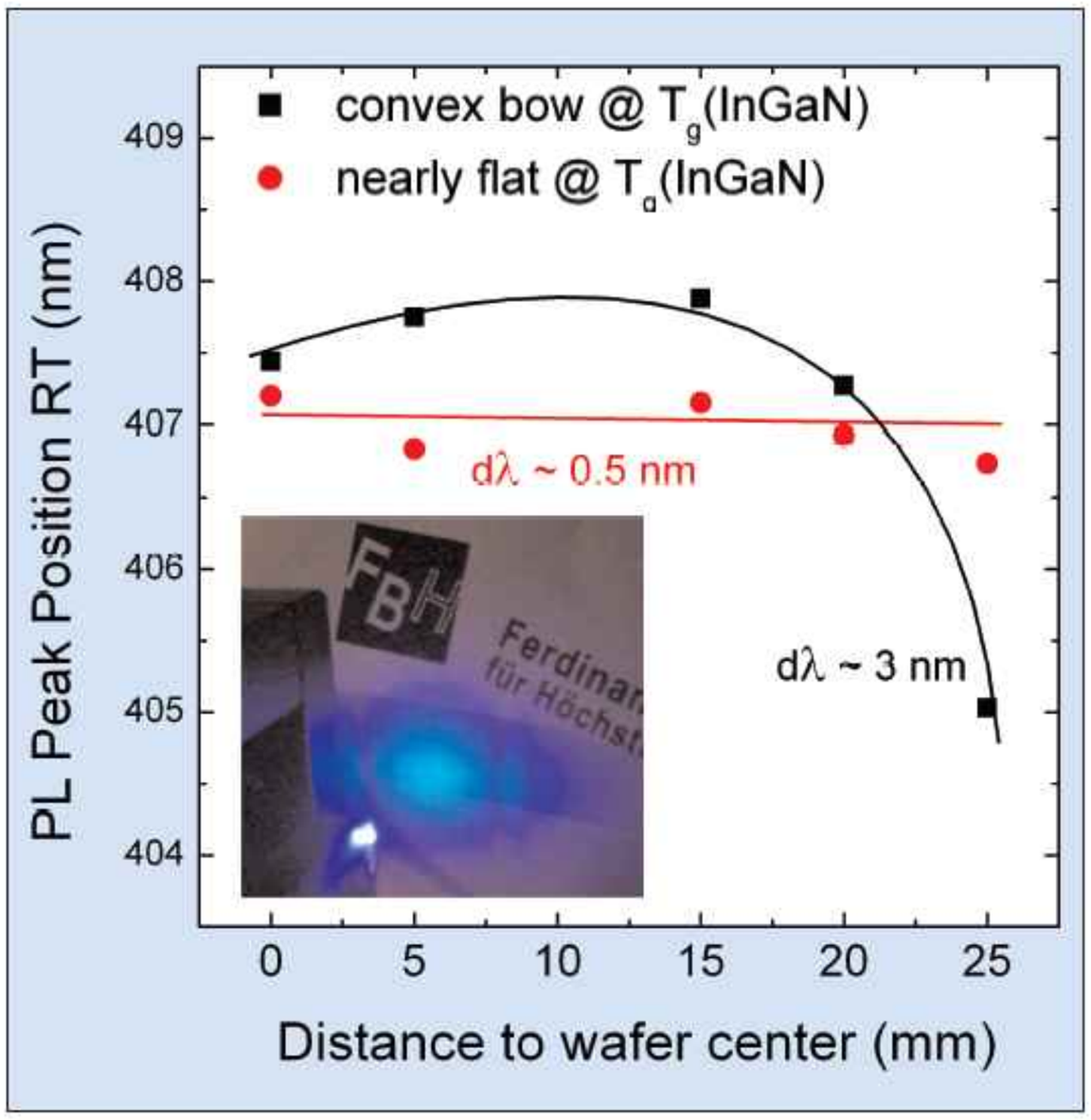


Figure 3. Uniformity of room-temperature PL peak position, comparing wafer with high and low convex bow at InGaN growth temperature. The inset shows 400nm light emission from an optically pumped laser structure.

adjust for flat wafer growth conditions, since the material quality and composition in the InGaN active layer are strongly affected.

As a consequence, further ways of controlling the bow by introducing compressive stress are desirable. Solutions for engineering the built-in stress in GaN include low-temperature (Al,Ga)N interlayers with an Al concentration above 60% and InGaN compliance layers. While AlGaN with such high Al content and AlN suffer from having insulating properties, n-type doping of InGaN can easily be achieved, offering vertical current transport in the optoelectronic device structure. For example, the insertion of a 100nm-thick Si-doped $In_{0.06}Ga_{0.94}N$ layer within a GaN/AlGaN heterostructure introduces convex curvature of about 20km^{-1} [3].

Figure 2 shows an example of reduced wafer bow during growth of the active layer in a laser diode structure: The wafer in pocket 2 (black line) is nearly flat at the InGaN growth temperature. Accordingly, ex-situ characterization with room-temperature photoluminescence (PL) demonstrates the impact on device properties. Figure 3 displays the variation of the peak wavelength over the 2-inch wafer radius for substrates exhibiting either a high or low convex bow at the InGaN growth temperature. In contrast to the emission non-uniformity of about 3nm in the case of unoptimized growth, flat wafer conditions result in very good wavelength homogeneity (~0.5nm).

Summary

The unique combination of curvature measurements with temperature and reflectance monitoring makes EpiCurve TT a technological breakthrough in developing and manufacturing high quality crack-free wafers. The real-time access to wafer bowing enhances growth uniformity and yield, which finally leads to greater efficiency in R&D and an immense reduction in time and costs for production facilities. In the future, a quantitative analysis of wafer bowing throughout the full epitaxial process retracing the lattice constant mismatch between the substrate and every single layer of the growing structure will be possible. Apart from MOVPE, the sensor is applicable to MBE and HVPE reactors.

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References

1. W. Van der Stricht, I. Moerman, P. Demeester, L. Considine, E.J. Thrush, and J.A. Crawley, MRS Internet J. Nitride Semicond. Res. **2**, 16 (1997)
2. G. Strassburger, A. Dadgar, and A. Krost, Patent 10361792, DPMA München, Germany, 2003
3. F. Brunner, V. Hoffmann, A. Knauer, E. Steimetz, T. Schenk, J.-T. Zettler, and M. Weyers, J. Cryst. Growth **298**, 202 (2007)

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(NASDAQ: AXTI)

Coherent emission from exciton-polariton lights

Researchers in Switzerland and the UK have developed a GaN microcavity to produce phenomena that are usually only seen at much lower temperatures in other materials. Dr Mike Cooke describes their achievements and hopes.

Despite the large number of different laser sources available today, finding new techniques is always important. Producing laser light, especially ultraviolet, is often difficult and wasteful of energy due to the high threshold energies resulting from the need to create population inversion.

Researchers from the University of Southampton in the UK and École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland have used an optically pumped exciton-polariton system in bulk GaN microcavities to achieve room-temperature inversionless coherent emission (i.e. lasing without the electron population in the higher 'excited' electron energy level needing to exceed the electron population in the lower energy level to which the electron transitions) [1]. The optical pumping is performed at a non-resonant frequency with a photon energy of about 4eV, while the emission energy is near the GaN exciton emission frequency of 3.4eV, giving an ultraviolet light wavelength of 365nm.

The cavity's optical resonance is tuned to the exciton emission wavelength to create the conditions for the mixing of excitons (electron–hole bound states) and photons into polaritons. The term exciton-polariton is used to distinguish this system of photon mixing from those involving other excitations such as transverse optical phonons (phonon-polaritons).

The emission threshold is an order of magnitude smaller than that for optically pumped (In,Ga)N quantum-well surface emitting lasers (VCSELs). For example, while an optical pumping threshold for lasing of the order 5mJ/cm^2 has been seen in InGaN VCSELs [2], the polariton emission threshold is around 1mW (a pulsed energy density of about 30μJ/cm^2).

One interesting feature of polariton lasers is that lasing without population inversion is possible. This drastically lowers the threshold requirements for such systems. Lasing without population inversion uses quantum coherence effects to reduce reabsorption of emitted light by the medium. The researchers see possible applications for polariton lasers as low-threshold emitters, nonlinear optical elements and amplifiers, and quantum correlated sources.

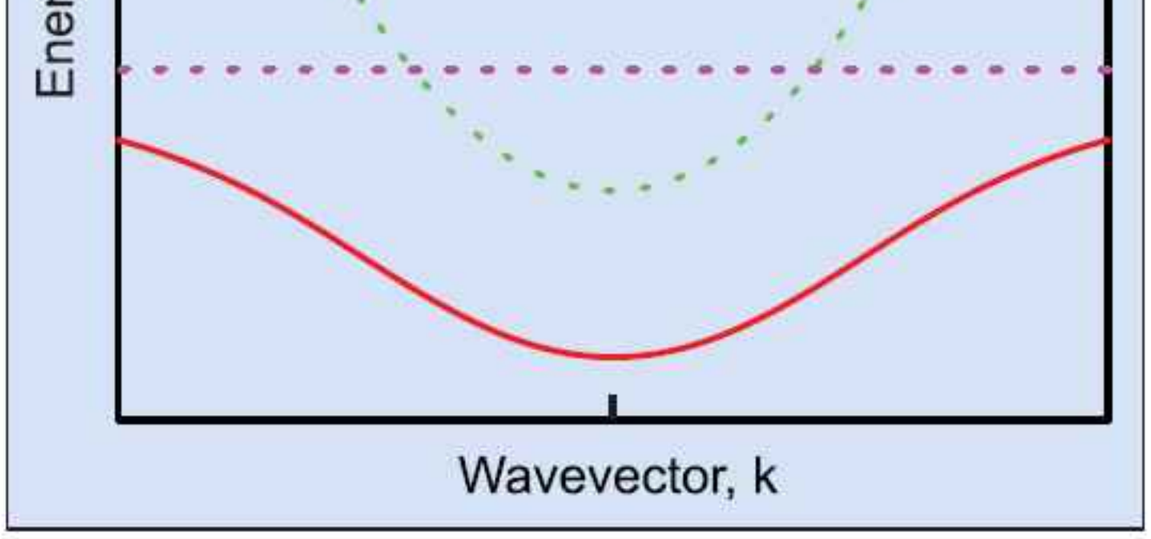

Figure 1. Dispersion relation from coupling between GaN microcavity exciton and photon: vertical axis, polariton energy (or frequency); horizontal axis, wavevector magnitude in the plane of the cavity. For large wavevectors the upper polariton tends to the photon dispersion relation and the lower to the exciton energy (the exciton's kinetic energy is negligible). The cavity thickness (210nm) fixes the wavevector perpendicular to the cavity plane. The 3λ/2 cavity makes the perpendicular wavevector component 45μm^{-1}. The difference between the upper and lower polaritons in GaN is of the order of 50meV. The exciton energy is of the order of 3.4eV. Parallel wavevector scale extends to about 10μm^{-1}.

In 2002, numerical calculations suggested that a GaN microcavity system could meet the properties required to produce polariton lasing [3]. This calculation also suggested that the critical temperature for Bose–Einstein condensation of exciton-polaritons in an n-doped GaN microcavity could be as high as 460K,

room-temperature path to future prospects

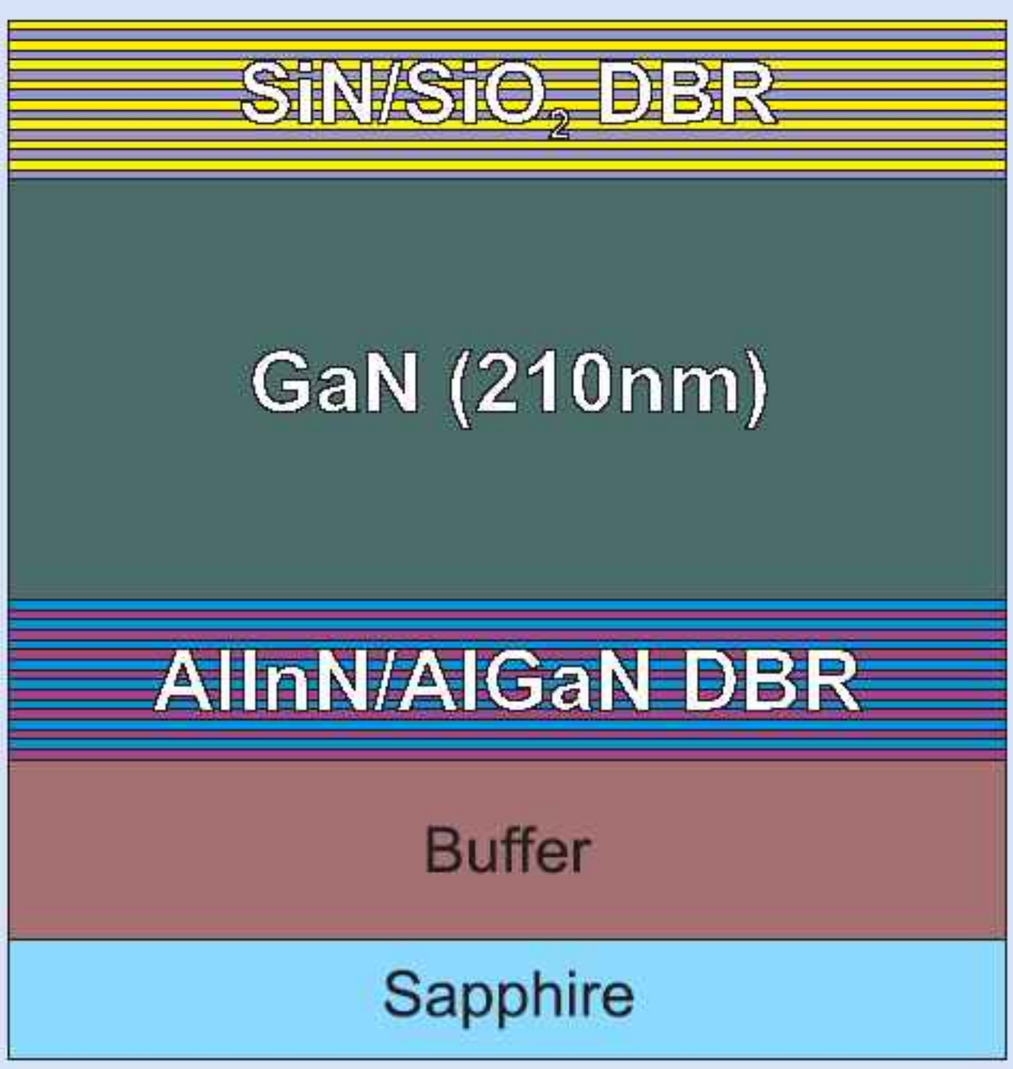

Figure 2. Schematic structure of bulk GaN cavity used to produce polariton lasing.

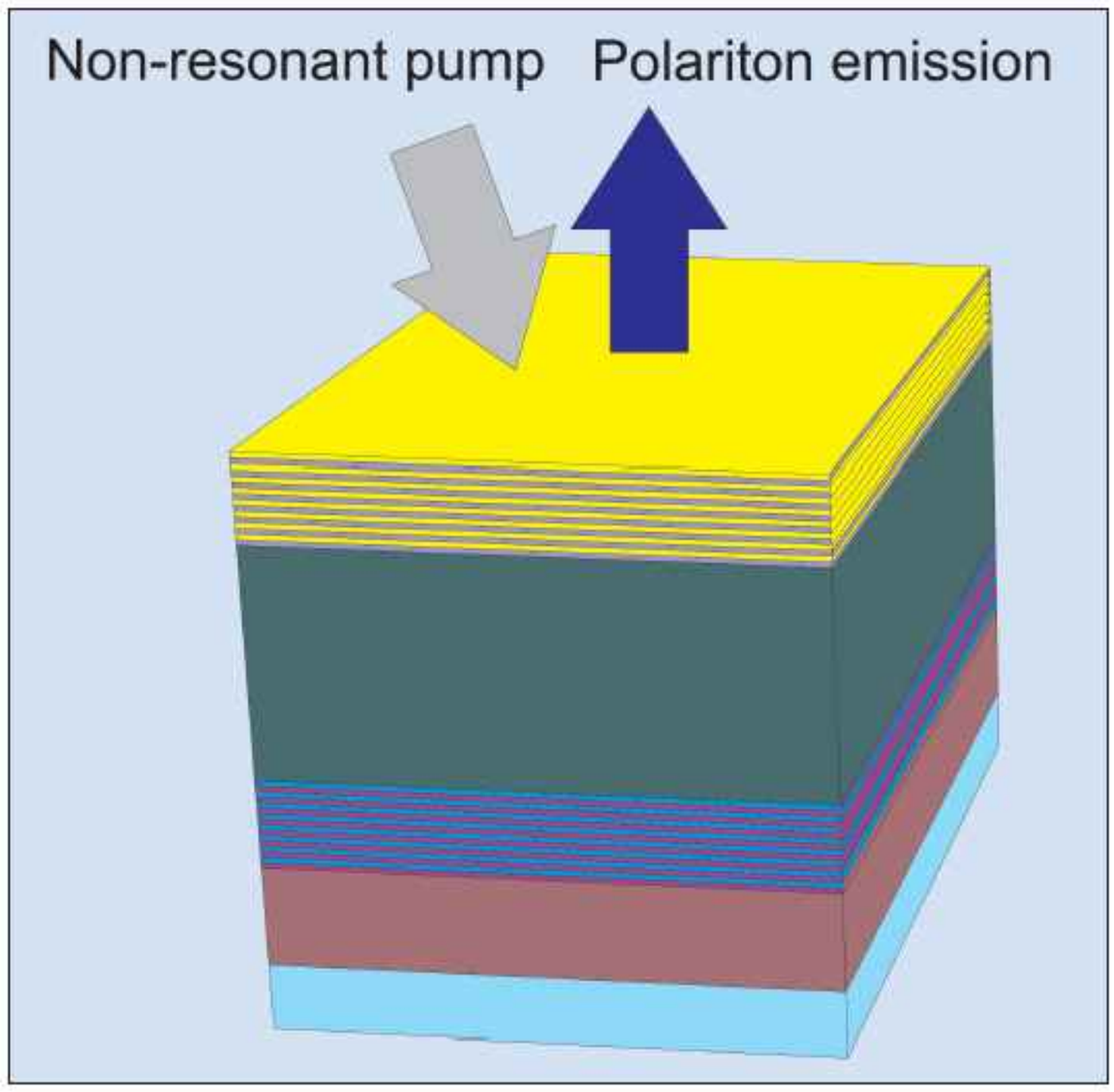

Figure 3. Optical pumping of the polariton laser is performed non-resonantly (4.14eV, λ ~ 300nm) at an angle to the structure to emit UV radiation at 3.4eV (λ ~ 365nm). The optimum angle is about 20°.

compared with a temperature of the order of 100K for GaAs cavity exciton-polaritons or a fraction of a Kelvin for theoretical Mott–Wannier excitons. More recently, cadmium telluride (CdTe) systems have seen polariton emission, but thermal decoherence sets in at 220K, destroying polariton phenomena [4].

A key factor for enabling the raised temperature performance in GaN is its large exciton binding energy (~28meV, equivalent to a temperature of about 325K, compared to about 300K for room temperature).

A further key factor is that the exciton–photon coupling (oscillator strength) is much stronger than for other III-V materials. The exciton–photon coupling produces two types of exciton-polariton — upper and lower polaritons (see Figure 1). The splitting for long wavelengths ($\lambda = 2\pi/k$) can exceed 50meV (Rabi splitting) for GaN bulk microcavities, which is an order of magnitude larger than for other III-V semiconductor cavities. In practice, it is the lower polariton that is important for emission — the upper polariton resonance is broadened and almost completely attenuated by the exciton continuum at the same energy.

Despite the theoretical green light, it has taken five years for the researchers to develop the techniques to enable the growth of high-quality cavity mirrors (distributed Bragg reflectors) from GaN alloys (in Switzerland) rather than the more usual SiN/SiO_2. The 35-period AlInN/AlGaN bottom DBR is lattice matched with the bulk GaN cavity to reduce strain during growth in order to avoid defects and dislocations (Figure 2). The top mirror is a 10-period SiN/SiO_2 DBR.

It was decided to use bulk GaN rather than quantum-well structures. Although QWs allow the optimization of light–exciton coupling, the linewidths for such structures are currently too broad. Further, QW structures in nitride-based semiconductor materials are 'plagued' by the quantum-confined Stark effect (QCSE), where stray electric fields (e.g. piezoelectric fields from strain in the well, small variations in well thicknesses, or alloy composition, etc) can reduce the exciton binding (and hence polariton formation at high temperature) or even break the electrons and holes apart. Another QCSE effect is the strong localization of any exciton states.

Optimum pumping of the structure (Figure 3) was determined to be at an angle of 20° to the sample at

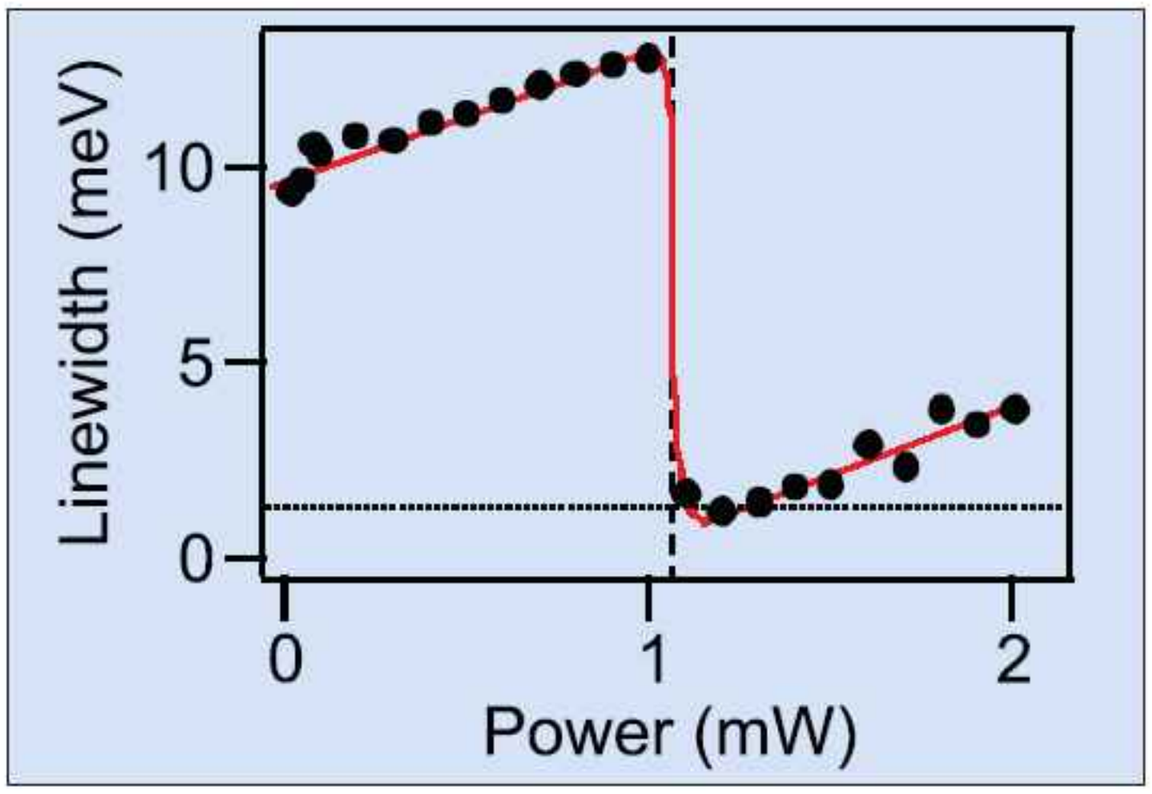

Figure 4. Polariton emission — the linewidth collapses above a threshold intensity of 1mW. The dotted line is the detection limit.

4.14eV. At a pumping power of 4mW, the emitted power is 80μW into a 5° half-width at half maximum (HWHM) cone. These parameters are used to estimate that there are 10^6/polaritons/pulse/state, giving occupations of greater than 10 at threshold. The energy width also collapses at threshold below the detection limit of 1.7meV. The polariton density at threshold is about $10^{18}cm^{-3}$.

A number of factors push the polaritons towards coherence. These are mainly various scattering events — the 2002 model [3] used three scattering terms: polariton–acoustic phonon; polariton–polariton; and polariton–electron. In addition, because the polaritons have bosonic statistical properties, stimulated scattering can take place where final states that are already occupied are favored for further scattering events. The polaritons are converted into ultraviolet (365nm) light as they leak out of the cavity. It is the separation of the stimulation and emission that enables lasing without inversion.

Since observation of a threshold (Figure 4) is not sufficient to show coherence of the emission, two further criteria are applied: spatial coherence of the emission spots that collapse from being of the order of the pump spot down to 5μm above threshold (Figure 5); and Michelson interferometry of the resulting light, where fringes continue to be seen, with differences of up to 700fs between the paths (Figure 6). The 700fs delay matches the ultra-short emission lifetime.

These results have implications for creating room-temperature Bose–Einstein condensates (BECs). Although the experiment described here has not strictly achieved this, it is akin to a non-equilibrium BEC. For a strictly defined BEC, one needs thermal equilibrium. "We are optimistic that BECs at room temperature can come soon as the GaN technology progresses through our EPFL colleagues," says Southampton University professor Jeremy Baumberg, one of the researchers.

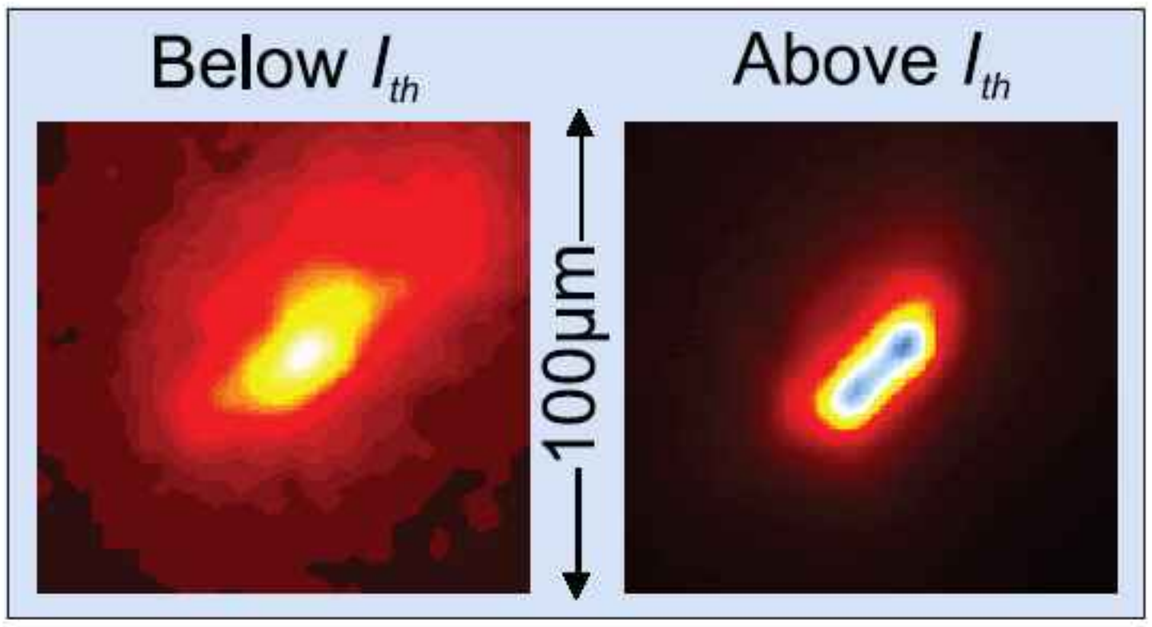

Figure 5. Spatial coherence of the emission spots collapses from being of the order of the pump spot below threshold down to 5μm above threshold.

Baumberg adds: "Such systems would allow construction of interferometer chips for high-precision measurements. But a lot of work remains before such possibilities can be achieved: the GaN material is still under development, and electrical pumping needs to be developed (though in principle there are no roadblocks for this). However, the consistent progress seen over the last seven years indicates the rich potential in basic science and novel technologies awaiting polariton devices."

References

1. Christopoulos et al, Phy. Rev. Lett. vol. **98**, p126405, 2007
2. Tawara et al, App. Phys. Lett., vol. **83**, p830, 2003
3. Malpuech et al, App. Phys. Lett., vol. **81**, p412, 2002
4. Richard et al, Phys. Rev. B, vol. **72**, p201301, 2005; Richard et al, Phys. Rev. Lett., vol. **94**, p187401, 2005; Saba et al, Nature vol. **414**, p731, 2001

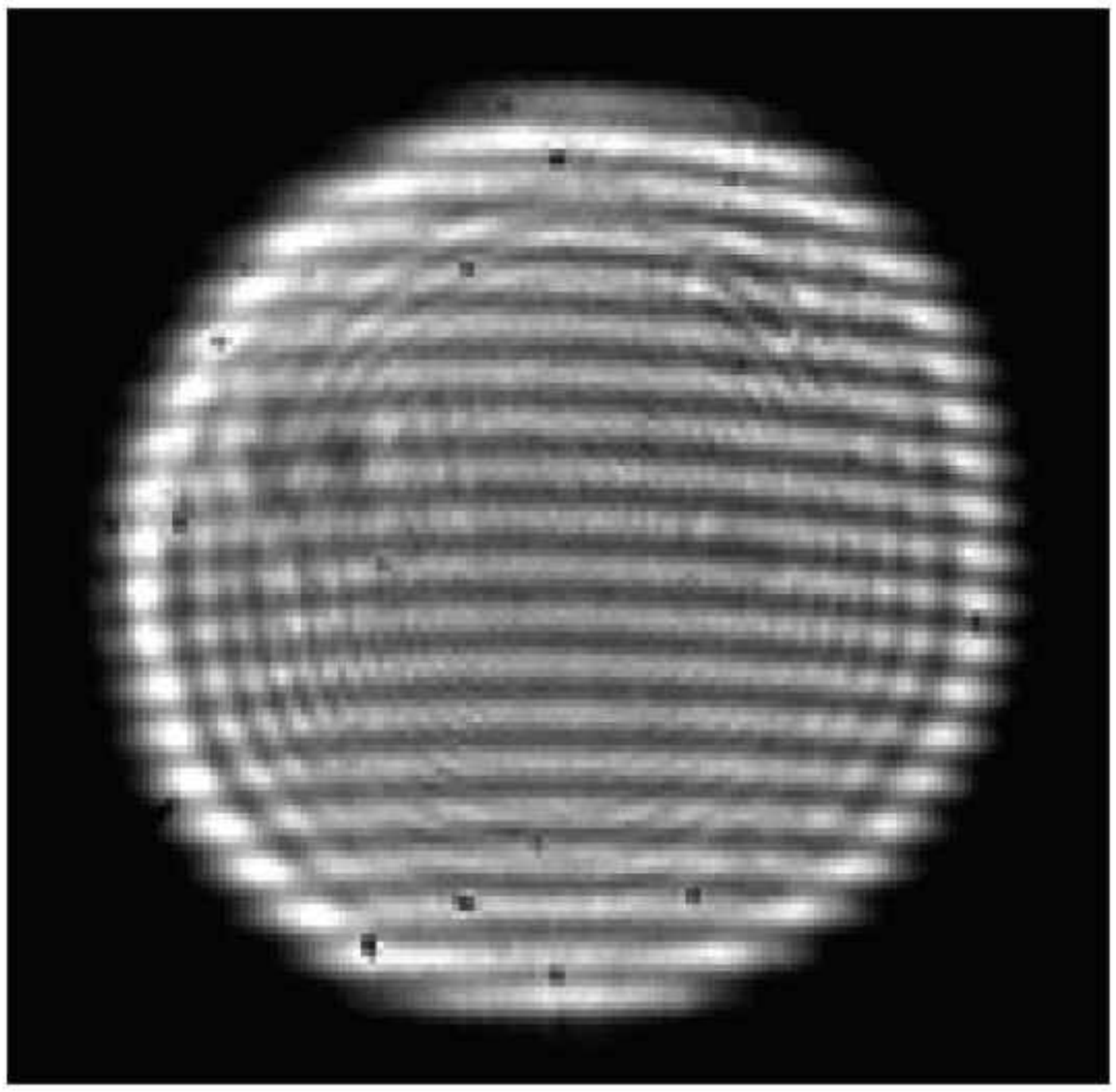

Figure 6. Michelson interferometry k-space image for time delay of 256fs. Coherence of the emission is seen at up 700fs delay between recombined paths.

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Restructuring the cascade for Bloch gain

Although semiconductor materials couple to light in a variety of ways, the main route for creating light emitters and lasers is direct transition between bands. Dr Mike Cooke reports on a group that has designed and investigated a quantum cascade laser that emits in a scattering-assisted indirect mode called Bloch gain.

The Université de Neuchâtel in Switzerland has been investigating quantum cascade lasers (QCLs) for some time, both experimentally and theoretically. One of its professors, Jérôme Faist, worked at Bell Labs and was among the authors of the original paper describing the construction of the first QCL [1]. Researchers from Neuchâtel, plus another researcher from the University of Tokyo, have reported in Nature Physics a QCL that demonstrates a new mode for electromagnetic radiation for mid-infrared photon energies in the range 140–180meV (~7–9μm wavelength) using a Bloch gain mechanism [2].

Among the possibilities that the researchers hope to develop are QCLs that are more robust in temperature performance, since the transition does not require a global population inversion between sub-bands to achieve optical gain. While the Bloch gain-based QCL in the Nature Physics paper has a higher threshold current density, its value varies less when compared with a QCL based on direct transitions. The Bloch-based QCL shows a linear rather than the usual exponential temperature variation in threshold. This could be useful where the gain is affected by the presence of thermal photons, such as in far-infrared lasers ($\lambda > 70\mu m$). The researchers say that, while weaker temperature behavior is expected from the model, more detailed experimental and theoretical work is needed to confirm that this is related to the gain mechanism.

The paper comments on the performance of its Bloch gain sample, N258 (see Figure 1): "The threshold current density at 300K of N258 is a factor of about five larger than recent results achieved in optimized structures, yet the level of performance of sample N258 is still surprising as its doping level and injection barrier thickness were optimized for the visualization of Bloch gain and not for sheer performance."

The present research has concentrated on producing Bloch gain, and Romain Terazzi, co-lead author on the Nature Physics paper, comments that the absorption side needs more investigation. While detectors using the principle are possible, they might be of low efficiency.

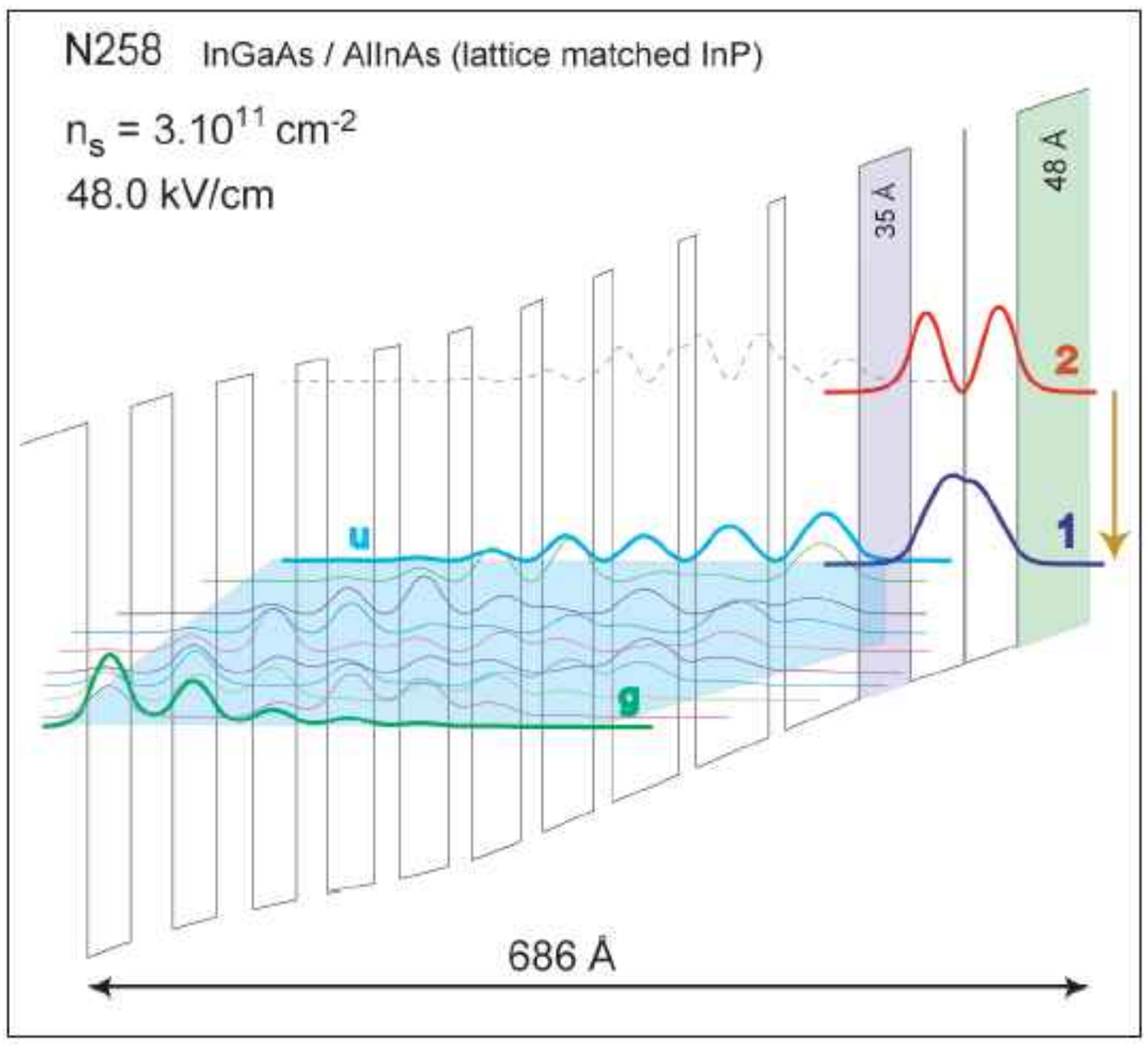

Figure 1. Heterostructure Bloch gain sample N258.

Bloch gain is related to the theoretical Bloch oscillations first described in 1928 [3]. In normal conduction, as electrons are accelerated they lose energy in scattering events, leading to resistance. But if one can accelerate electrons so that they cycle through their energy (frequency)-wavevector dispersion relation without scatter, a naive semi-classical calculation suggests that, instead of moving through the material, they respond to a constant electric field by oscillating at a frequency set by the magnitude of the field. These cyclic electron motions are called Bloch oscillations. Where electrons oscillate, one expects coupling to electromagnetic waves.

In practice, Bloch oscillations are not seen in bulk semiconductor materials, since scattering is almost certain to take place before the electron reaches the top of the conduction band. In fact, one of the early motivations in developing superlattice technology was to split the conduction band into sub-bands, reducing the period distance in reciprocal wavevector space ($k = 2\pi/\lambda$, where λ = wavelength) of the conduction

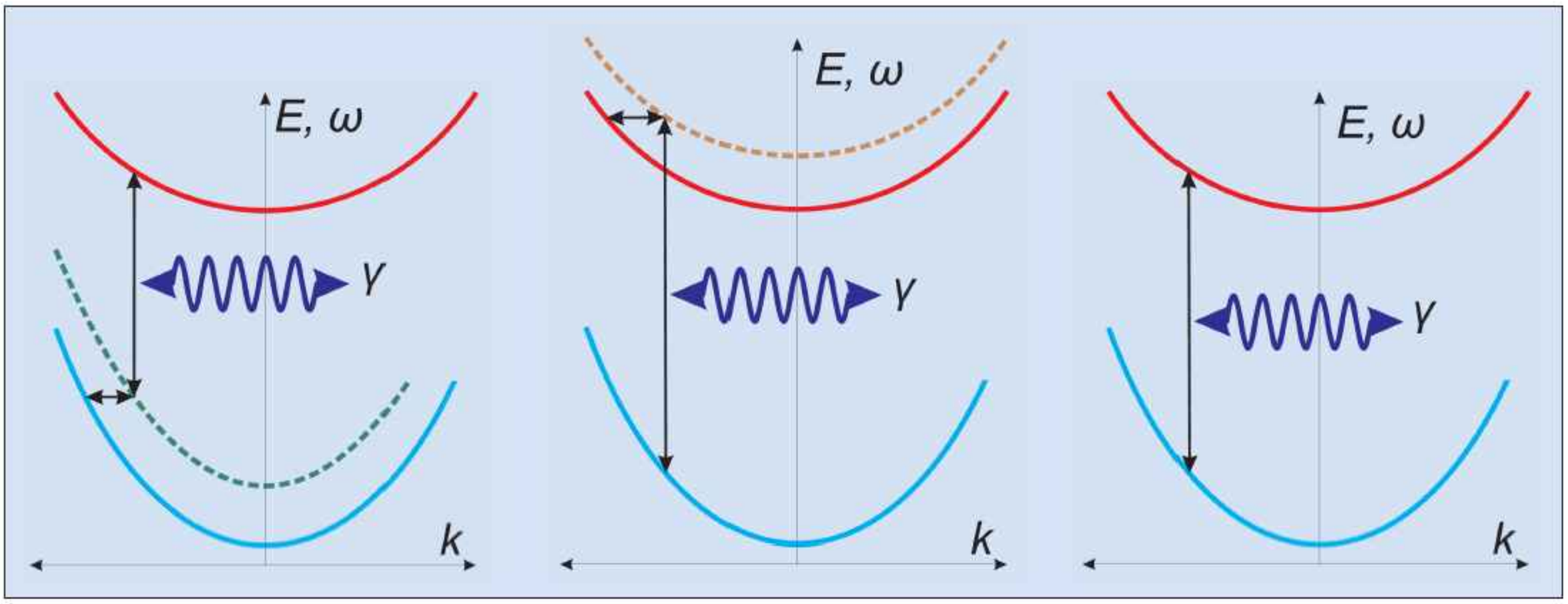

Figure 2. (a) Indirect transitions between sub-bands where an additional scattering event (horizontal line) allows more latitude in satisfying quantum conditions such as energy and wavevector conservation for photon emission and absorption (vertical line). When the photon energy is less than the vertical distance between the sub-bands, thermal factors favor emission over absorption. Dashed curve represents a virtual, second-order sub-band. (b) Indirect transition, with photon energy greater than vertical distance between sub-bands. Thermal factors now favor absorption over emission. (c) Direct, first-order transition.

band to enable Bloch oscillations to be observed. Further, it was hoped thereby to achieve a tunable source of electromagnetic radiation. These early hopes were dashed, since the resulting structures were electrically unstable in steady-state operation. However, in recent years the topic has been revisited in light of the development of more sophisticated heterostructures, such as QCLs, in which the related phenomenon, Bloch gain, is at least theoretically possible.

More sophisticated semi-classical [4] and quantum calculations at Neuchâtel and Universität Erlangen [5], and by Andreas Wacker of Technische Universität Berlin [6], suggest that electromagnetic waves impinging on a Bloch oscillation system with a frequency less than the Bloch frequency will show gain, while waves with a frequency higher than the Bloch frequency are absorbed. The system is transparent to electromagnetic waves at the Bloch frequency. The radiation couples to the electrons through indirect transitions between sub-bands where an additional scattering event (impurity, phonon or electron–electron) allows more latitude in satisfying the quantum conditions such as energy and wave-vector conservation (Figures 2(a) and (b)). However, such transitions require second-order perturbation and are often suppressed compared with direct, first-order transitions (Figure 2(c)). When thermodynamic factors are included in the calculation, it is found that emission predominates over absorption when the light frequency is less than the Bloch oscillation frequency. Because of the second-order nature of the transition, one requires only population inversion between particular states for stimulated emission and not over the whole sub-bands, as for normal lasing action in QCLs.

Applying these considerations to superlattice and QCL structures, and including the usual direct transitions, further calculations suggest that, for high population inversion, direct transitions dominate but, as population inversion is reduced, Bloch gain/absorption processes will become apparent. For the direct transition, the shape of the gain curve appears to be roughly symmetric. Since the Bloch gain becomes absorptive above the oscillation frequency, its curve dips below zero (Figure 3).

A quantum cascade laser consists of a series of quantum wells separated by injection and extraction

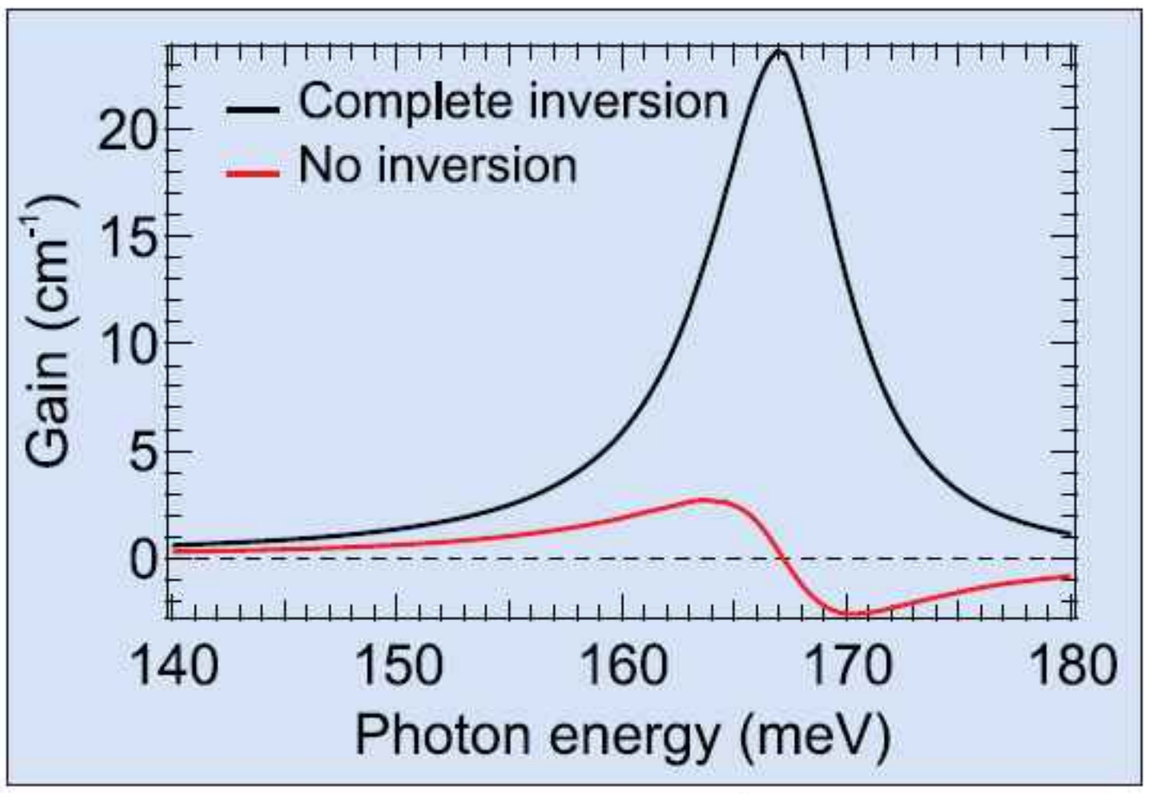

Figure 3. Gain according to Neuchâtel model for zero population inversion (equal number in upper and lower states) to complete population inversion (zero lower states filled), computed in generalized formalism of Nature Physics paper. All parameters are typical for a mid-IR QCL. Transition energy is 167.2meV, dipole is 19A, populations for are $10^{10}cm^{-2}$. Gain is cm^{-1}.

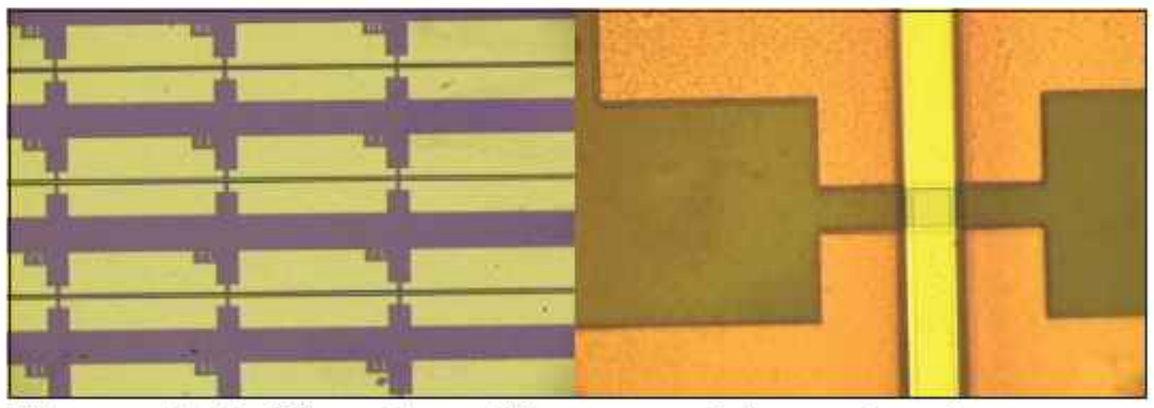

Figure 4. Multisection ridges used for net gain measurement (left), and (right) close-up of etched region between sections (electrical insulation but unbroken optical cavity).

barrier regions. For normal laser operation, one wants to trap electrons in the upper state of the lasing transition and rapidly depopulate the lower state to create population inversion. Depopulation is achieved by making the extraction process fast through a high coupling through the barrier by varying its width. To see Bloch gain, the researchers suppressed this normal process through reducing the inversion to the minimum that is possible for operation. This was achieved by designing a QCL structure in which the inversion could be varied over a wide range, mainly by changing the extraction barrier width. The well and barrier materials were $In_{0.53}Ga_{0.47}As$ and $Al_{0.48}In_{0.52}As$, respectively. Some of the injector layers are doped with silicon at a concentration of $3x10^{17}cm^{-3}$. Some 35 periods of the structure were grown on an InP substrate. The designed electric field bias is 48kV/cm.

Measurements were carried out at liquid helium temperatures (~4K) on two samples: one a reference high-inversion QCL (Figure 4); the other the minimum-inversion QCL designed to show Bloch gain. At lower current densities towards threshold, the normal QCL continues to have gain with a symmetric frequency shape, while the second shows the 'dispersive' shape of Bloch gain. Careful checks were made to exclude other possible explanations of the Bloch gain shape, such as from parasitic absorption lines. Comparison with essentially parameter-free theoretical calculations gave good agreement in terms of shape, but the absolute values of the gain were overestimated by factors of three for both the normal and Bloch QCLs. The researchers attribute part of the discrepancy to the experimental technique. They also feel that the theoretical model was too simple in using just optical phonon scattering and neglecting other scattering processes that could reduce the gain.

References

1. Faist et al, Science, vol. **264**, p553, 1994
2. Terazzi et al, Nature Physics, doi:10.1038/nphys577, published online 01 April 2007. www.nature.com/naturephysics
3. Bloch, Z. Phys., vol. **52**, p555, 1928
4. Ktitorov et al, Fiz. tverd. Tela., vol. **13**, p2230, 1971; Ignatov et al, Phys. Status Solidi B, vol. **73**, p327, 1976
5. Willenberg et al, Phys. Rev. B, vol. **67**, p085315, 2003
6. Wacker, Phys. Rev. B, vol. **66**, p085326, 2002

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The broad scope of the compound semiconductor related topics covered by CS MANTECH is reflected in the range of contributors it attracts. This year's event sees 73 presentations, of which 35% are international, and representatives come from over 40 industry, government and university fabs and labs.

CS MANTECH begins with workshop sessions on Monday 14 May, where attendees can select from a total of seven topics, running in two parallel sessions. Opening Session One will be a characterization tutorial followed by a series of two workshops, one of which covers space flight qualification procedures and offers a tutorial on intellectual property. In the parallel session, there is a tutorial on high-speed and optical networks. Following this is two topics on SiC device processing and optimization for power switching devices: a SiC MOS tutorial and an historical overview of SiC material/device processing with a wide-bandgap introduction. The workshop ends with a non-parallel session on 'TCAD Simulation of Compound Semiconductor Electronic Devices'.

The exhibition opens on the evening of Monday 14 May (6:00pm to 9:00pm) with the Exhibits Reception social event, and continues all day Tuesday. An Exhibitors' Forum follows immediately after the Exhibits Lunch on Tuesday, at 1:35pm to 3:30pm.

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Downtown Austin, Texas, the venue for this year's CS MANTECH event.

Technical sessions start on Tuesday 15 May, with the Plenary Session focusing on the state of the compound semiconductor industry and a review of business in Europe. This will be followed by an overview of solar cells and bulk acoustic wave devices.

During the conference introductions on Tuesday, the authors of the best paper and best student paper of last year's CS MANTECH 2006 event will receive their awards.

Specifically, the authors of the Best Paper, Toshihide Kikkawa, Kenji Imanishi, Masahito Kanamura and Kazukiyo Joshin of Fujitsu Laboratories, will receive the He Bong Kim award for the paper "Recent Progress of Highly Reliable GaN-HEMT for Mass Production." Meanwhile, the authors Nasim Morawej and Douglas G. Ivey of the University of Alberta and Siamak Akhlaghi of Micralyne Inc will receive the Best Student Paper of the 2006 Conference for "Improvements in the Process for Electrodeposition of Au-Sn Alloys."

The general Technical Sessions of this year's event commence in parallel on Tuesday afternoon and continue all day Wednesday and in a single session on Thursday. Included are papers on: manufacturing, HBTs, FETs, HEMTs, wide bandgap technology, processing, materials, reliability, test, and optoelectronics.

There are two 'all invited' sessions: on Wednesday there is a review of the three extant approaches to III-V MOSFETs, and on Thursday there is a review of approaches to mixing pHEMT or MESFETs with HBTs in one epi growth.

Also on the Wednesday (7:30pm to 9:00pm), the SEMI Compound Semiconductor (GaAs, InP and SiC) Committee invites conference attendees interested in the development of internationally approved standards for wafer specifications to attend the SEMI Standards meeting. Topics covered include: GaAs, InP, and SiC dimensions/orientations and electrical properties, epitaxial layer specifications (which properties should be specified, and how they are to be verified), and non-destructive test methods.

Other highlights of the event include the International Reception (on Tuesday evening), Rump Sessions (on Wednesday evening), and an Interactive Forum (on Thursday), which comprises a poster session containing papers on a range of topics, as well as posters of all the presented papers.

Following immediately after the Interactive Forum, the conference ends with a Closing Reception, where a raffle will be drawn, and this year's Best Poster and Best Beautiful Picture Awards will be presented.

Conference at a glance

Monday 14 May	
8.00am–5.00pm	Workshops
6.00pm–9.00pm	Exhibits reception
Tuesday 15 May	
8.00am–8.30am	Opening ceremonies
8.30am–10.30am	Session 1: Plenary
10.00am–5.30pm	Exhibits open
11.00am–12.30pm	Session 2: Backside Process I
1.35pm–3.30pm	Exhibitors' Forum
3.50pm–5.30pm	Session 3: Reliability
3.50pm–5.30pm	Session 4: Devices & Models
7.00pm–10.00pm	International Reception
Wednesday 16 May	
8.00am–9.50am	Session 5: GaN Reliability & Testing
8.10am–9.50am	Session 6: Process 1 — Etch & Clean
10.20am–12.00	Session 7: Novel substrates
10.10am–12.00	Session 8: Backside Process II
1.00pm–2.40pm	Session 9: Power Transistors
1.00pm–2.40pm	Session 10: Frontside Process
3.10pm–4.40pm	Session 11: GaN & SiC Power Devices
3.10pm–4.40pm	Session 12: III-V MOSFETs
6.30pm–7.30pm	Rump Sessions
7.30pm–9pm	SEMI Standards Meeting
Thursday 17 May	
8.00am–10.00am	Session 13: BiFET Technology
10.30am–12.10pm	Session 14: Manufacturing and Yield
1.10pm–3.10pm	Session 15: Interactive Forum
3.10pm–3.40pm	Reception & Conference Close

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Newport,
Wales NP10 8UJ,
UK
Tel: +44 (0)1633 652400
Fax: +44 (0)1633 652405
www.stsystems.com
A leading manufacturer of plasma etch and deposition equipment, including DRIE, ICP, RIE & PECVD technologies used in the fabrication and packaging of semiconductor devices.

Synova SA
Ch. de la Dent d'Oche,
1024 Ecublens,
Switzerland
Tel: +41 21 694 35 00
Fax: +41 21 694 35 01
www.synova.ch
Inventor of Laser MicroJet® technology, Synova is an experienced supplier of water jet-guided laser solutions for dicing and micro-machining applications.

Tegal Corp
2201 S McDowell Boulevard,
Petaluma, CA 94954,
USA
Tel: +1 707 763 5600
www.tegal.com

Oerlikon Wafer Processing
10050 16th Street North, Suite 100,
St. Petersburg, FL 33716, USA
Tel: +1 727 577 4999
Fax: +1 727 577 3923
www.oerlikonoc.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737, Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo, CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

10 Process monitoring and control

k-Space Associates Inc
3626 W. Liberty Rd.,
Ann Arbor, MI 48103,
USA
Tel: +1 734 668 4644
Fax: +1 734 668 4663
www.k-space.com

LayTec GmbH
Helmholtzstr. 13-14, Berlin, 10587
Germany
Tel: +49 30 39 800 80 0
Fax: +49 30 3180 8237
www.laytec.de

11 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

KLA-Tencor
160 Rio Robles, Suite 103D,
San Jose, CA 94538-7306,
USA
Tel: +1 408 875 3000
Fax: +1 510 456 2498
www.kla-tencor.com

12 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508
USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

13 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems
228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

14 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

15 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283,
La Chaux-de-Fonds, 2301,
Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

J P Sercel Associates Inc
220 Hackett Hill Road,
Manchester, NH 03102, USA
Tel: +1 603 518 3200
Fax: +1 603 518 3298
www.jpsalaser.com

16 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

17 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH, UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

18 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014, USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

19 Facility consumables

W.L. Gore & Associates
401 Airport Rd,
Elkton, MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

20 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

21 Services

Henry Butcher International
Brownlow House,
50-51 High Holborn,
London WC1V 6EG, UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart, Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

22 Resources

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

event calendar

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14–16 May 2007
8th International Conference on Mid-Infrared Optoelectronics: Materials and Devices (MIOMD-VIII)
Bad Ischl, Austria
E-mail: miomd8@jku.at
www.hlphys.jku.at/miomd8

14–17 May 2007
CS MANTECH (2007 International Conference on Compound Semiconductor Manufacturing Technology)
Hilton Austin, TX, USA
E-mail: csmantech@csmantech.org
www.gaasmantech.org

14–18 May 2007
19th International Conference on Indium Phosphide and Related Materials (IPRM '07)
Matsue, Japan
E-mail: iprm07@ech.co.jp
www.iprm.jp

15–20 May 2007
14th Semiconducting and Insulating Materials Conference (SIMC-XIV)
Fayetteville, AR, USA
E-mail: simc@ibiblio.org
www.ibiblio.org/simc

20–23 May 2007
WOCSDICE 2007 (Workshop on Compound Semiconductor Devices and Integrated Circuits), including WOGATE (Workshop on the GaN Advancement Technology in Europe)
Venice, Italy
E-mail: wocsdice2007@woscdice2007.org
www.wocsdice2007.org

20–24 May 2007
5th International Conference on Solid State Crystals & 8th Polish Conference on Crystal Growth (ICSSC-5 & PCCG-8)
Zakopane, Poland
E-mail: zakopane@unipress.waw.pl
www.ptwk.org.pl/ICSSC-5-PCCG-8.html

29 May – 1 June 2007
LED & Solid State Lighting Expo 2007
KINTEX, Seoul, South Korea
E-mail: info@ledexpo.com
www.ledexpo.com

3–6 June 2007
12th European Workshop on Metalorganic Vapour Phase Epitaxy (EW-MOVPE)
Bratislava, Slovakia
E-mail: ew-movpe@savba.sk
http://elu.sav.sk/EW-MOVPE/index.html

5–7 June 2007
euroLED 2007
Birmingham, UK
E-mail: ninab@photonicscluster-uk.org
www.euroled.org

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13–16 June 2007
Photonics Festival 2007 (OPTO Taiwan 2007 and LED Lighting Taiwan 2007)
Taipei World Trade Center, Taiwan
E-mail: pamela@mail.pida.org.tw
www.optotaiwan.com

28–29 June 2007
Hetero-SiC'07 Workshop (International Workshop on 3C-SiC Hetero-Epitaxy)
Grenoble, France
E-mail: Didier.Chaussende@inpg.fr
www.lmgp.inpg.fr/Hetero-SiC

9–13 July 2007
OECC/IOOC 2007:
12th OptoElectronics and Communications Conference
16th International Conference on Integrated Optics and Optical Fiber Communication
Yokohama, Japan
E-mail: oecc_iooc2007@ics-inc.co.jp
www.ics-inc.co.jp/OECC_IOOC2007

11–13 July 2007
InterOpto'07 (International Optoelectronics Exhibition)
Makuhari Messe, Chiba, Japan
E-mail: interopt@oitda.or.jp
www.oitda.or.jp

16–20 July 2007
SEMICON West 2007
San Francisco, CA, USA
E-mail: ktorres@semi.org
www.semi.org

22–27 July 2007
Defects in Semiconductors : 24th International Conference (ICDS-24)
Albuquerque, NM, USA
E-mail: icds24@sandia.gov
www.icds24.org

5–11 August 2007
13th International Summer School on Crystal Growth
Park City, UT, USA
E-mail: aacg@att.net
www.crystalgrowth.us/isscg13/index.php

12–17 August 2007
15th International Conference on Crystal Growth, and 13th Conference on Vapor Growth and Epitaxy
US Biennial Workshop on Organometallic Vapor Phase Epitaxy
Salt Lake City, UT, USA
E-mail: aacg@att.net
www.crystalgrowth.us/iccg15/index.php

19–24 August 2007
11th International Conference on the Formation of Semiconductor Interfaces: (ICFSI-11)
Manaus, Amazonas, Brazil
E-mail: secretary@icfsi2007.com
www.icfsi2007.com

21–24 August 2007
7th Topical Workshop on Heterostructure Microelectronics (TWHM2007)
Chiba, Japan
E-mail: twhm@aecl.ntt.co.jp
www.twhm.net

26–30 August 2007
Optics & Photonics (including 7th International Conference on Solid State Lighting)
San Diego, CA, USA
E-mail: jeannea@spie.org
www.spie.org/app/conferences

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