

COMPOUND SEMICONDUCTOR

April 2006 Volume 12 Number 3

CONNECTING THE COMPOUND SEMICONDUCTOR COMMUNITY

BiFETs

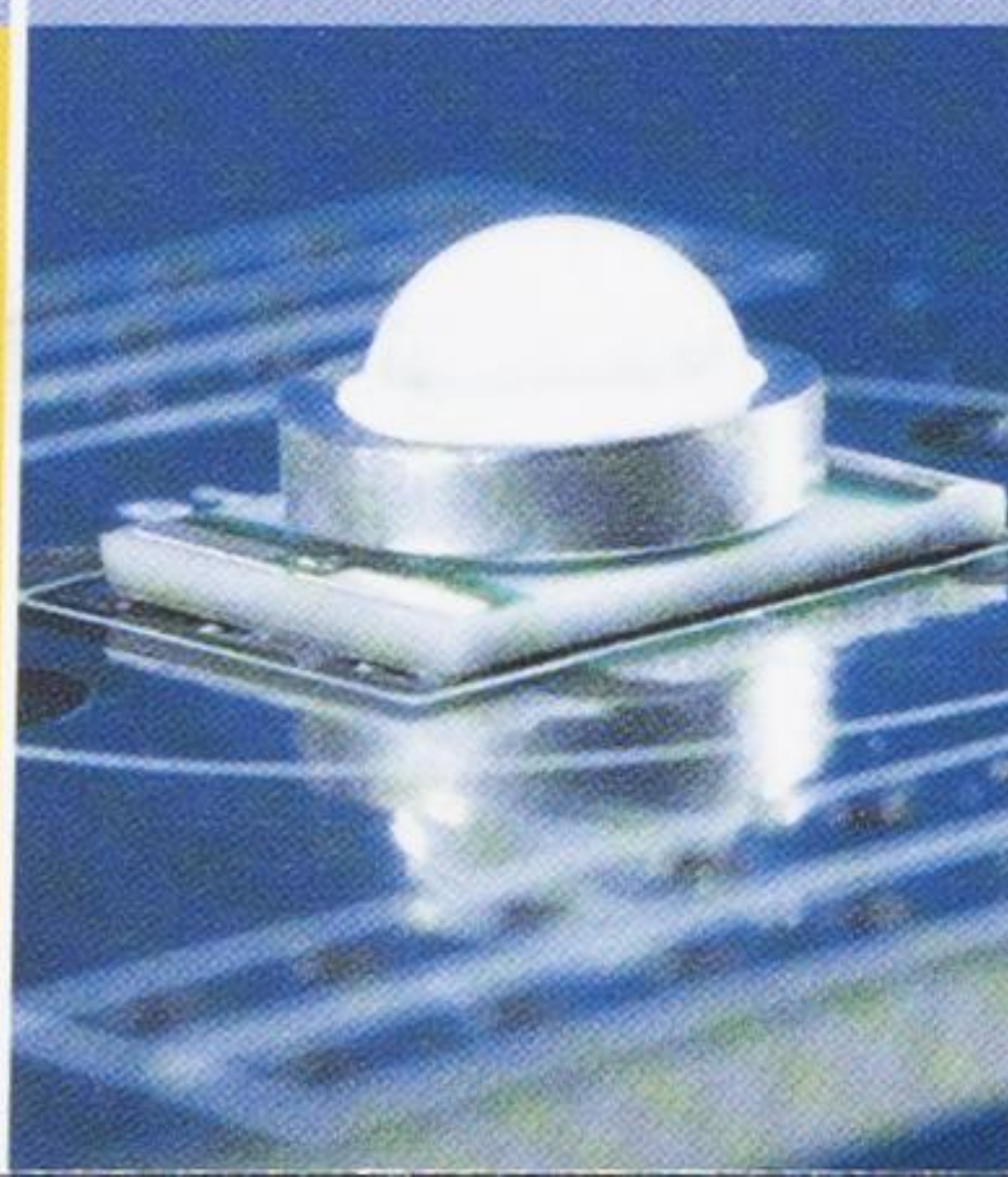
**Anadigics' strategy
pays off as consumers
get the 3G bug**



MAPPING OUT MANTECH

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TECHNOLOGY



Switched on

Warm-white LEDs from Cree and Nichia get into residential lighting. **p5, 32**

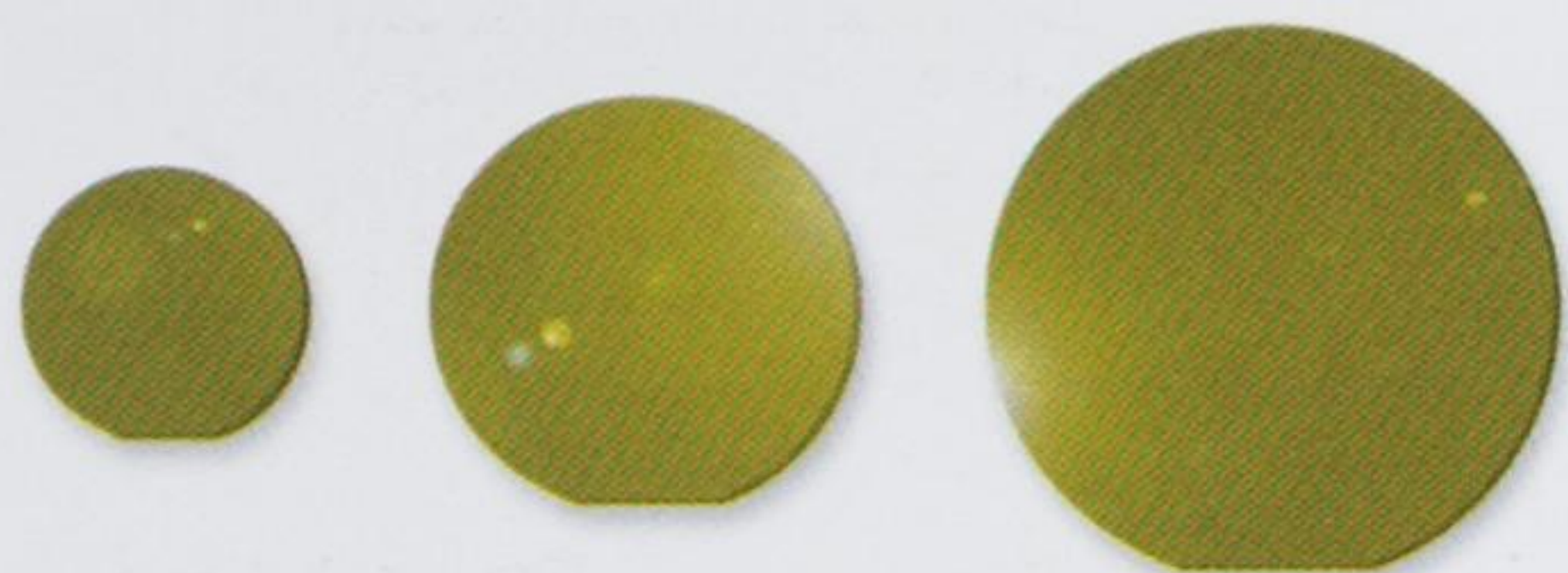
INTERVIEW



China crisis?

Not according to industry veteran Phil Yin, who is busy reversing the fortunes of substrate vendor AXT. **p18**

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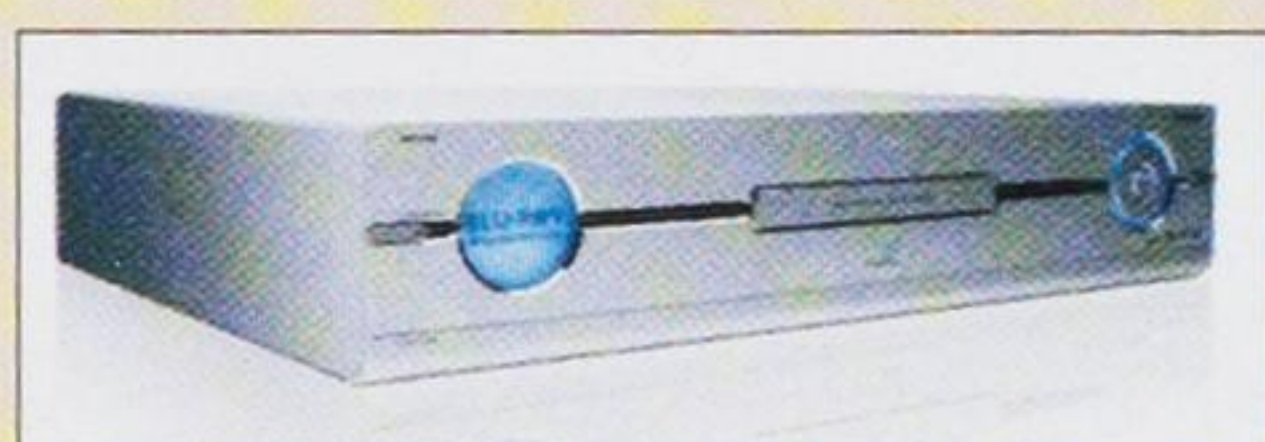
Switched on

Has the time come for LEDs to light up our homes? **p5**

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Sony gets the blues

Problems with the Blu-ray drive have delayed the launch of Sony's PlayStation 3 until the end of the year. **p11**

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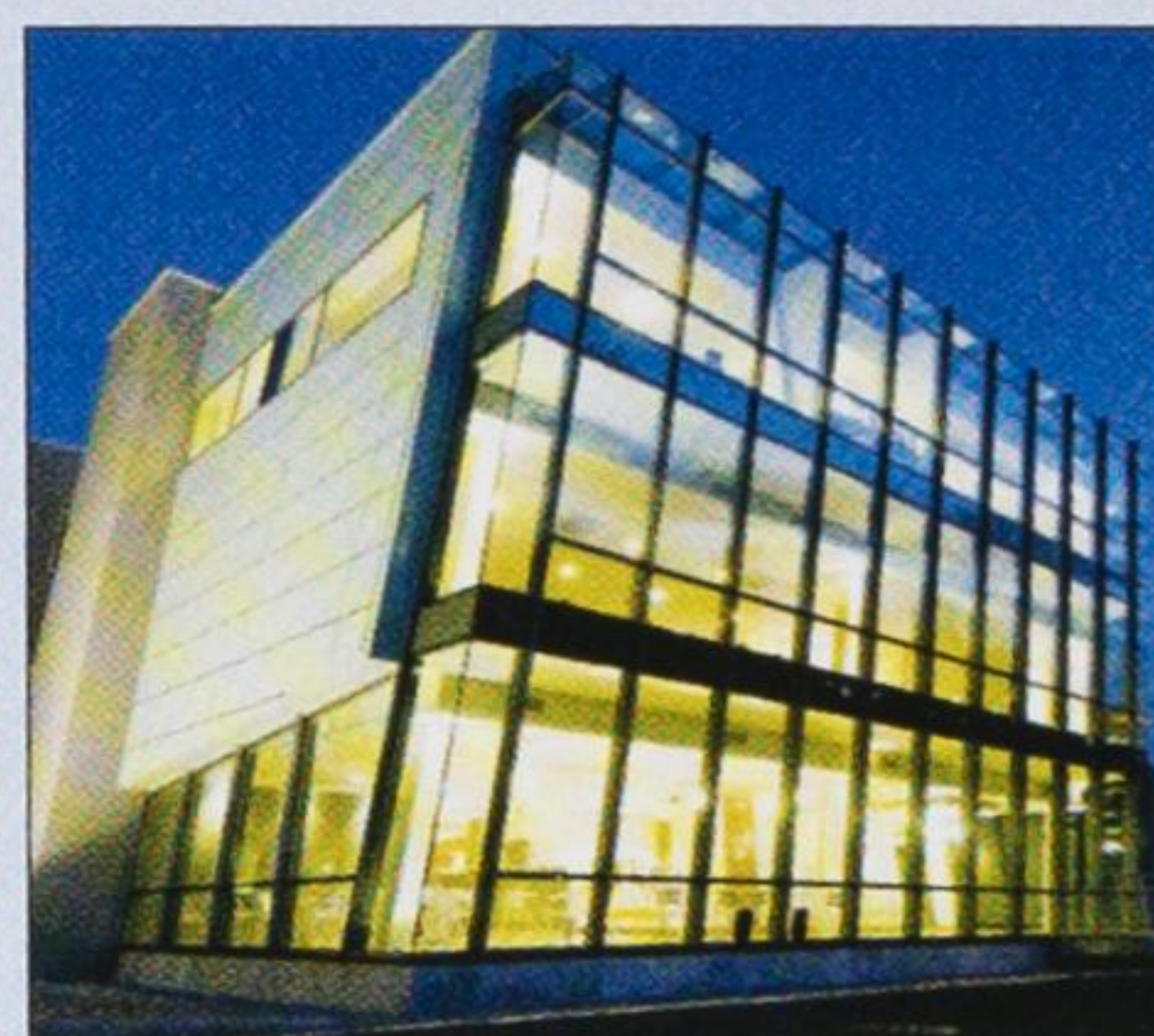
Main cover image: After introducing its BiFET process back in 2003, Anadigics is reaping the rewards with increased fab utilization and is moving towards profitability. Credit: Anadigics.

TECHNOLOGY

- 20** **SiC growth rockets with hydrogen chloride addition:** The standard growth process for SiC produces high-blocking-voltage devices, but suffers from long processing times. These delays are hindering commercialization, says Francesco La Via, who believes that the problem can be overcome by adding hydrogen chloride into the cell.

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Customer focus

The traveling-wave amplifier MMICs made at ECIT in Belfast can be fine-tuned to individual requirements. **p25**

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LEDs in the home: is now the time?



It's been called the "holy grail" for the HB-LED and compound semiconductor community, and it might be coming sooner than you think. As soon as this summer, in fact.

While great strides have been made with white LEDs for general illumination, small chips are still widely regarded as being too dim, while the much larger, brighter "power LEDs" produce a lot of heat that is difficult to dissipate. Both are thought to be just too damned expensive for general lighting applications at the moment. As a result, the received wisdom is that LED-based lighting of the home is still a fair distance away – anything between two and 10 years, depending on who you ask.

These are just some of the reasons why the US Department of Energy is still ploughing cash into solid-state lighting research, recently approving 16 different R&D projects, including the development of quantum-dot structures, photonic crystals, and novel GaN alloys incorporating scandium or yttrium.

But is all this extra development really necessary? Progress Lighting seems to think not, and to feel that HB-LED technology is ready for prime-time right now. This summer the company, which touts itself as the largest source for residential lighting in the US, is launching what it calls a complete line of LED-based products under the HI-EFTM brand.

It may not exactly be the snappiest of names, but if the technology catches on with the US public it will be great news for Nichia and Cree, the companies that are supplying the GaN-based chips that lie at the heart of these fixtures.

While the launch of these products could provide a major boost for makers of white LED chips, one note of caution should be urged. If it comes too soon, it may cause longer-term damage to the nascent SSL industry. Nothing creates bad publicity in the consumer sector quite like products that fail to live up to expectations, and that can kill a new technology stone dead. Progress needs to make sure that that doesn't happen with LEDs.

Michael Hatcher *Editor*

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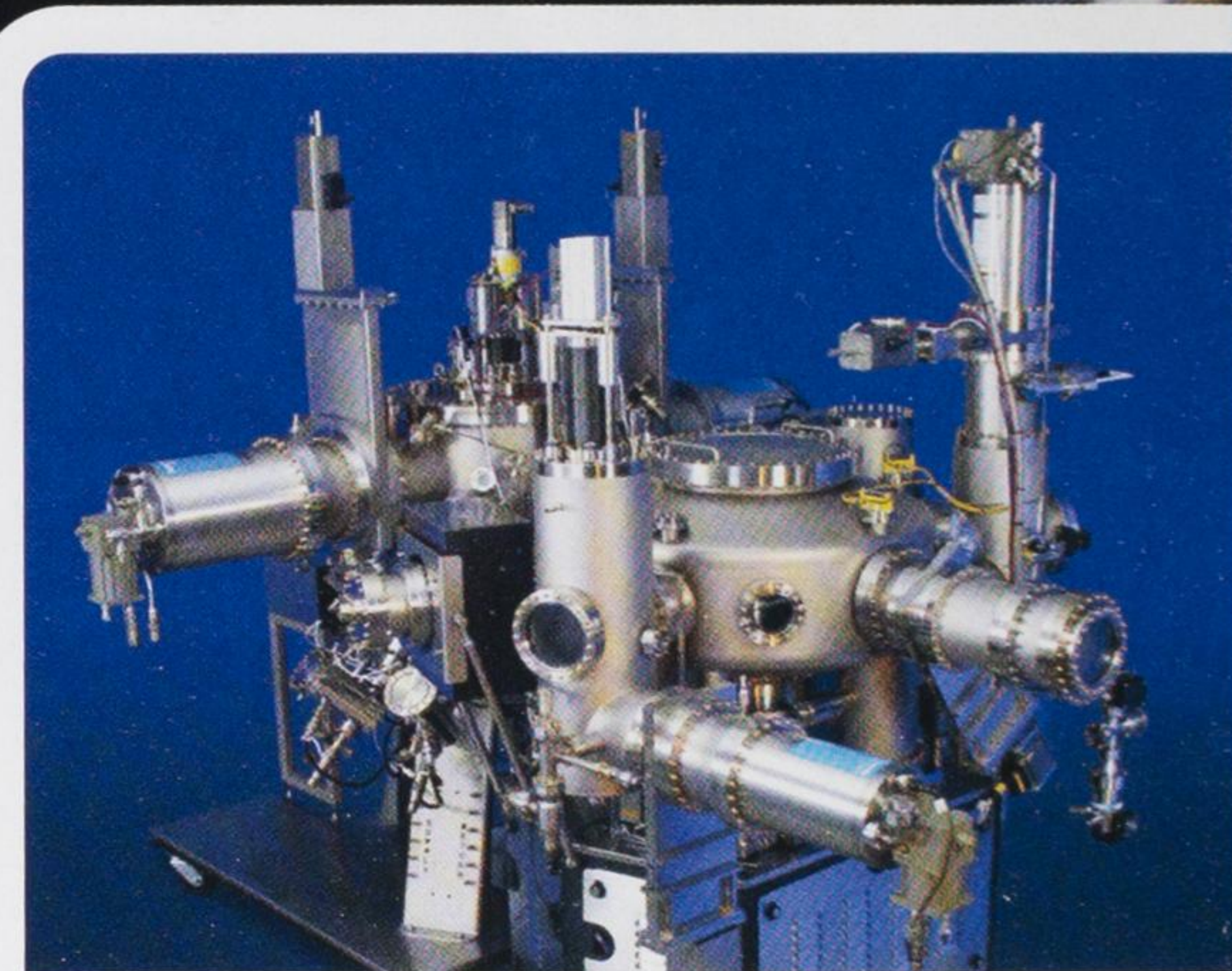


Photo of Veeco Silicon-Style Cluster Tool.

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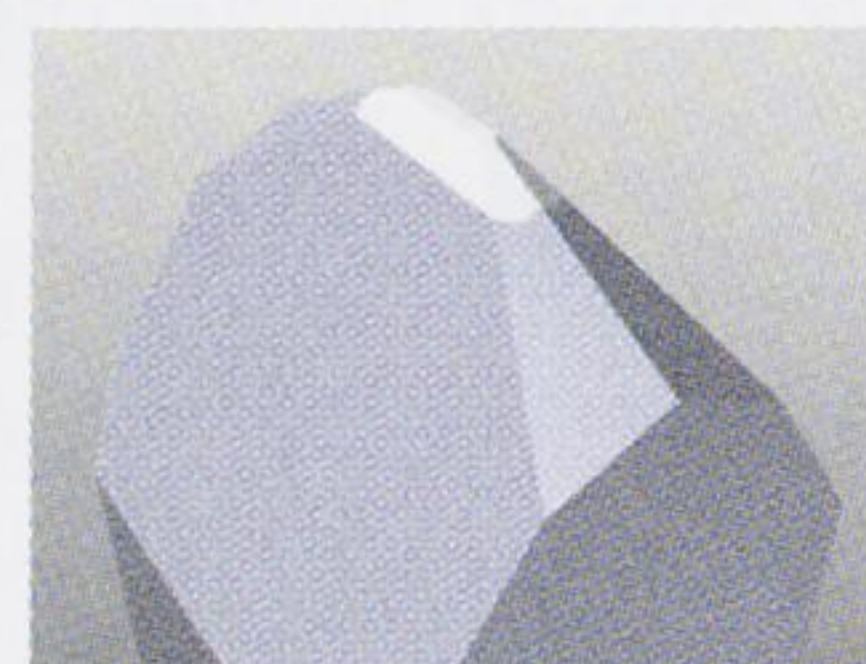
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SOLID-STATE LIGHTING

White LED makers get residential boost

LED-based lighting is set for a boost in the US, with leading supplier Progress Lighting gearing up for a summer 2006 launch of products featuring chips made by Cree and Nichia.

The two chip companies will supply 40 lm/W warm-white LED sources to Permlight Products, which has developed a low-cost thermal management solution for residential applications that it sells to Progress. Permlight already uses Nichia die for ceiling lights and Cree chips for "below-the-eye" applications. Permlight says that this is because Nichia products are better suited to illuminating people's faces.

"Progress Lighting believes now is the time for LED systems to illuminate our homes, not two to five years from now like most industry



Switched on: Progress Lighting believes that now is the time for LEDs to be used to light up homes.

analysts predict," said Jim Decker, vice-president of brand management at Progress Lighting. "Progress will offer a home lighting fixture solution that incorporates warm-color dimmable LED lighting fixtures that appear and operate like incandescent sources. Progress will be using Permlight's breakthrough LED technology as the core of this new product line."

Permlight CEO Manuel Lynch said that the product launch "will be much sooner than later, and a much larger offering than most would expect. We have demonstrated repeatedly that the time for LEDs to light our homes is now. This is the light source from now on."

● For more information, see the HB-LED/residential lighting feature on p32.

EQUIPMENT

Jump in orders at disciplined Aixtron suggests possible recovery

After a tough couple of years, a sharp increase in orders may signal a better 2006 for equipment vendor Aixtron. The industry's key supplier of metal organic chemical vapor deposition (MOCVD) machines is hoping to break even in 2006, after recording a huge financial loss in 2005.

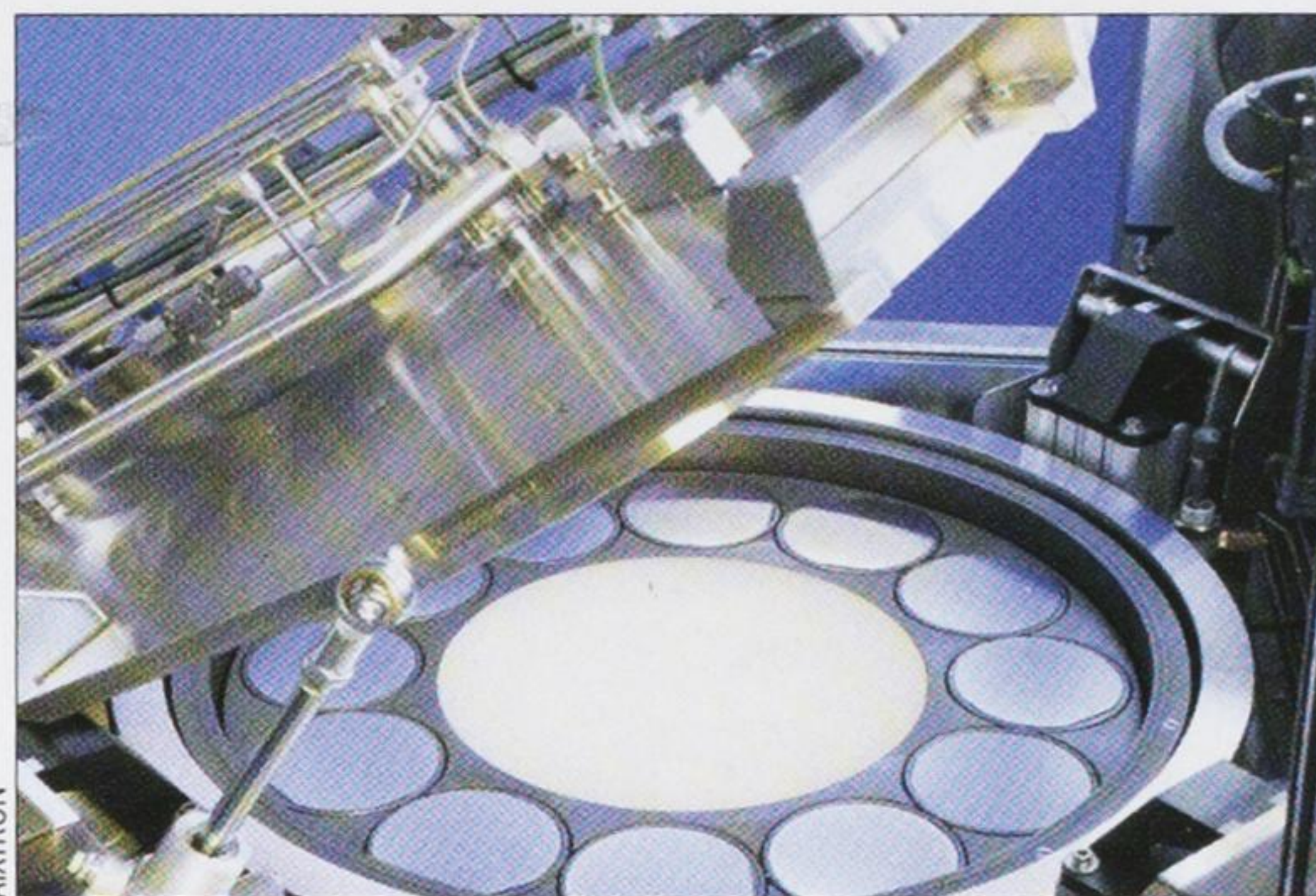
Aixtron, which believes it has a 60% share of the MOCVD equipment market, returned an overall net loss of €53.5 million (\$64.4 million) in its 2005 financial year. While much of that figure can be attributed to balance sheet adjustments that CEO Paul Hyland described as financial prudence, Aixtron said that its net loss would have been €14.6 million if recorded using standard US accounting methods.

Hyland added that "light" demand from customers, particularly LED manufacturers, had made the last two years among the most difficult in Aixtron's history – at a time when it has experienced the added complication of consolidating its acquisition of the atomic vapor deposition company Genus.

Overall, Aixtron's revenue remained flat at around €140 million from 2004 to 2005. However, this masked a big decrease in annual MOCVD reactor sales from €114.8 million to €80.9 million during the period.

Revenue from the new Genus business, which was negligible in 2004, accounted for 23% of sales in 2005, or €32.1 million.

Aixtron's disciplined response to the slack demand for its core products has been to cut staff numbers, introduce temporary plant closures and more common platforms, as well as



On the up? Aixtron CEO Paul Hyland is staying cautious about 2006, despite a sudden upturn in orders.

to delay certain research projects. Those measures should have an impact on costs over the next year, during which Aixtron expects to break even on sales of around €150 million.

Though keen to remain cautious, Hyland pointed to a sudden jump in order intake in the final quarter of 2005 as a possible indication of a better year to come.

At €37.6 million, orders in the final quarter were double those of the equivalent three-month period in the previous year. Those figures were not influenced by the recent order for five MOCVD machines placed by Taiwan-based LED maker Epistar (see p8), which is being recorded in the first quarter of 2006.

Hyland and his colleagues will be hoping that the improving business environment is not a repeat of the "false dawn" witnessed in early 2004, when orders reached a similar peak before slumping back down.

CONVERGENCE

Sematech goes back to the future with plans for germanium channels

Sematech, the collaborative semiconductor research and development partnership, has launched a project to investigate alternative materials for metal oxide silicon field effect transistor (MOSFET) channels, the critical pathways in silicon-based transistors.

The project will focus on germanium and SiGe primarily, while III-V compounds could feature in the longer term. Sematech's front-end processes (FEP) division will be at the forefront of the investigation and will aim to develop process technology that increases channel mobility beyond silicon's physical limits without compromising on reliability.

FEP associate director Larry Larson said: "SiGe and germanium are currently the most promising materials for replacing silicon in planar channels in CMOS manufacturing." Larson described the initiative as a major new effort that could have far-reaching implications for the semiconductor industry.

Freescale's Hsing-Huang Tseng will manage FEP's new program. "Continued CMOS scaling means we need to find new materials to replace silicon in these functions," he explained. "Germanium, SiGe and potentially III-V compounds could provide even bigger benefits for mobility enhancement." Freescale already has plans to develop a GaAs-based MOSFET for commercial deployment, which it announced details of recently, while strained-silicon specialist Amberwave and Purdue University are also teaming up on III-V integration in a project headed up by Peide Ye at Purdue.

FAB EXPANSION

RFMD set for huge volume ramp

Leading GaAs chip manufacturer RF Micro Devices (RFMD) is to increase the wafer capacity of its Greensboro, NC, fab by 40% with an investment of \$80 million.

The move comes amid rising demand for RFMD's power amplifiers, which are widely deployed in mobile handsets. Sales of advanced handsets, which require multiple power amplifiers and more GaAs content, are rising particularly quickly as 3G services become more popular.

"RFMD is making this strategic investment to capitalize on the rapid increase in worldwide demand for GaAs technology," said company CEO Bob Bruggeworth. "We are the leader in wideband-CDMA power amplifiers, and expect wideband CDMA to be the world's fastest growing air-interface standard."

RFMD has a history of making large investments in GaAs capacity, and this is the fifth such expansion in its 15-year history. "RFMD views its continued investment in manufacturing capacity as key to its revenue and earnings growth," said the company in a statement.

Having already begun the expansion through an investment in additional processing equipment at its existing cleanroom facilities, RFMD says that volume production with the new kit will kick off in late 2006. It expects to add 300 new positions once the expansion is completed.

The company has received a \$4.9 million handout from the State of North Carolina through a job development incentive grant, and local county governments have pledged \$1.5 million to the same end.

Industry forecasts suggest that more than 900 million mobile handsets will be shipped this year, representing a 15% increase on the 2005 figure. One-hundred million of those are expected to be 3G handsets, while RFMD says that the growing market for wireless LAN compatibility in handsets is increasing GaAs demand still further.

The capacity expansion is expected to reduce RFMD's overall cost per wafer, as it shifts to in-house production of the GaAs PHEMTs that are critical to its transmit module products.

FINANCIAL RESULTS

Demand for HBTs helps Kopin to record profits

Kopin Corporation generated a record annual profit of \$11.7 million for fiscal 2005, compared with a \$13.8 million loss for the previous year. The US-based manufacturer of HBT epiwafers, LEDs and microdisplays posted sales of \$24.9 million for the fourth fiscal quarter, and a profit of \$3.7 million.

Demand for HBTs increased revenue at Kopin's III-V products division, with sales worth \$13.5 million in the recent quarter, up \$2.7 million sequentially and \$4.9 million year-on-year.

According to CEO John Fan, the increase in HBT revenue has been driven by an uptick in sales of cell phones with greater functionality that require multiple power amplifiers.

"With an 80% share of the merchant HBT market, Kopin benefits from this trend because the move towards larger and more advanced power amplifiers increases the amount of our transistor content per phone," added Fan. The III-V division is expected to continue to produce steady sales growth based on the strength of orders.

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...Freescale clarification

In our March issue we reported that Motorola's semiconductor products sector (SPS), now known as Freescale, had developed GaAs-on-silicon wafers in 2001. It has since been pointed out that this is not correct. The GaAs-on-silicon development took place at Motorola's Corporate Research Lab in Phoenix (now known as the Embedded Systems and Physical Sciences Laboratory), which was not part of the SPS or the Freescale spin-off. We are happy to clarify this.

...Nokia raises phone forecast

Leading cell-phone vendor Nokia has predicted that well over 900 million handsets will be sold in 2006, after revising its growth forecast upwards. CEO Jarmo Ollila said at Nokia's AGM in March that total shipments in 2006 would be at least 15% higher than the 2005 figure of 795 million.

...new center for Peregrine

Silicon-on-sapphire RFIC specialist Peregrine Semiconductor has opened its third engineering design center in Nashua, New Hampshire.

...Anadigics raises \$53 million

Six-inch GaAs fab owner Anadigics has raised \$53.4 million through a public offering of its common stock. Most of the proceeds will be used to pay off convertible notes due to mature in November this year. The remaining \$6.7 million will be used for general corporate purposes, including some capital expenditure. Anadigics has enjoyed improved financial results recently and has seen its share value rise steadily from just less than \$2 to more than \$7 in the past year.

...Sirenza bullish on demand

US-based RF specialist Sirenza Microdevices has raised its first fiscal quarter 2006 sales guidance from \$17.5–19 million to \$20–21 million. "Our updated range represents sequential growth of up to 8% over our fourth-quarter 2005 record results and a potential quarterly revenue increase of up to 73% year-over-year," remarked company CEO Robert Van Buskirk.

...WJ and GCS ink supply deal

US foundry Global Communication Semiconductors (GCS) has agreed to act as a second wafer source for RF chip maker WJ Communications. "We're pleased to add GCS as a foundry for InGaP HBT and GaAs technology,"

remarked Mark Knoch, vice-president of WJ's operations. "This advantage provides our customers with two qualified sources, thereby ensuring a steady supply of wafers."

...defect-free SiC debut

Intrinsic Semiconductor, a privately held manufacturer of wide-bandgap materials and devices, has commenced commercial shipments of SiC wafers completely free of micropipes, as well as 100 mm (4 inch) diameter SiC wafers.

...ST Systems bags £1million etch order

Processing tool supplier ST Systems has banked an order worth more than £1 million (\$1.74 million) from a GaAs chip manufacturer. The UK company, which designs and sells plasma etch and deposition equipment, says that it has received multiple orders from the same component manufacturer in North America.

...E-PHEMTs for 3G and WLAN

Avago Technologies has introduced two new RF products based on its GaAs E-PHEMT transistors. The modules are designed for 3G cellular infrastructure in the 1.8–2.2 GHz frequency range, and dual-band wireless LAN applications.

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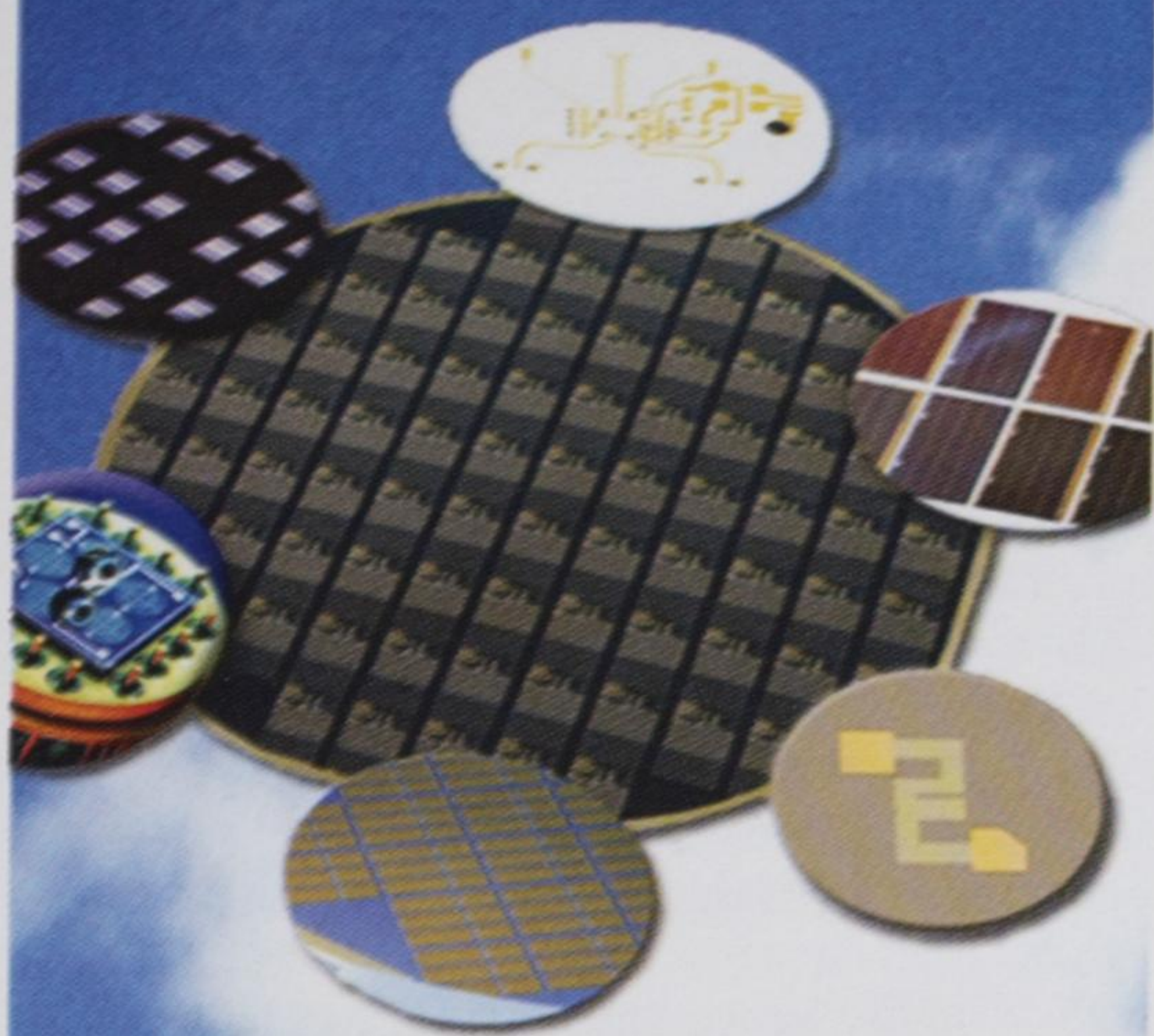
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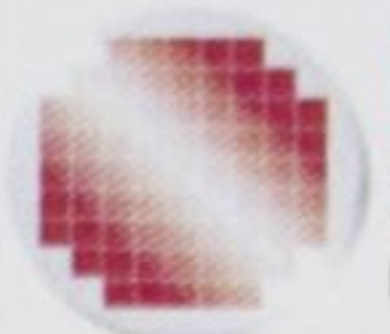
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SOLID-STATE LIGHTING

DoE to fill technology gap

The US Department of Energy (DoE) has selected 16 applications under a funding program aimed at developing core technologies for solid-state lighting (SSL).

Included in the selection are eight projects focused directly on III-V substrates, epitaxy and other processing techniques, with a strong emphasis on filling technology "gaps" such as developing more efficient green high-brightness LEDs. Other projects selected include the development of organic LEDs and quantum-dot technologies.

"The present selections represent the second round in a series that may span the next decade," said the National Energy Technology Laboratory (NETL), the DoE body through which the development is organized. "[These] are expected to represent a significant advancement in the SSL technology base."

III-V laboratories involved in the program

include the Georgia Tech Research Corporation, which will work on a sacrificial substrate technique to improve GaN LED efficiency, and Sandia National Laboratories, which will develop a growth technique for making large bulk GaN substrates in one of three projects (see box for details of all the selections relating to III-V compounds).

The ultimate aim of the NETL program is to develop SSL technologies that support a system efficiency of 50% by 2025. The US uses 21% of its total energy consumption on lighting, a figure that the DoE wants to see halved.

• Epitaxy equipment vendor Veeco Instruments has joined the solid-state lighting development center at University of California, Santa Barbara, which includes leading nitride researchers like Steven DenBaars and Shuji Nakamura.

Selected NETL projects (III-V related)

Georgia Tech Research Corporation

• A sacrificial substrate approach that will support a number of complementary growth and processing techniques to improve the overall quantum efficiency of GaN devices.

Purdue University

• Growth of hetero-epitaxial device structures on nanoscale substrates.

Rensselaer Polytechnic Institute

• A project that aims to fill the "green gap" by reducing the high dislocation densities in the active region and the huge polarization field effects throughout the LED structure. This should cut epi production costs and improve deep-green LED efficiency by a factor of two to three.

Technologies and Devices International

• Materials research for producing highly doped p-type GaN materials and device structures.

University of California, Santa Barbara

• Maximizing white LED efficiency by the use of photonic crystals to extract more light from the emitter structure.

Sandia National Laboratories

• Another project focused on deep-green LED development, this time by using strain-relaxed InGaN templates, possibly through epitaxial lateral overgrowth.

• A third project focused on deep-green LED development, through the use of novel alloys such as YGaN and ScGaN, which could lead to more efficient quantum wells emitting throughout the entire visible range.

• Development of a novel, scalable, cost-effective growth technique to make low-dislocation-density bulk GaN substrates, which will improve the internal quantum efficiency of GaN devices.

CHIP DEVELOPMENT

Nichia claims 1m/W breakthrough

Nichia has developed a 6 lm white LED that can deliver an efficacy of 100 lm/W at a forward current of 20 mA. The company says that it made a pendant lamp containing more than 4000 devices and a spotlight with over 400.

"There wasn't a big technical jump to reach 100 lm/W," explained Gen-inch Shinomiya, managing director of Nichia's R&D engi-

neering division. "We improved our technology incrementally and I believe we can reach the level of 150 lm/W in the same way."

The Japanese company plans to begin sampling the 100 lm/W chip in June and will start volume manufacturing later in the year. The first product will be a lamp package measuring 5 mm in diameter.

PROCESSING

Epistar orders five of Aixtron's reactors

Aixtron has received an order from Epistar for five multi-wafer reactors designed for GaN LED growth. The sale comprises four AIX 2600G3 reactors, along with Aixtron's new AIX 2800G4 that is claimed to have the largest capacity of any commercial reactor and can accommodate up to 42 two-inch wafers.

The recent order will reinforce Epistar's position as the leading manufacturer of LEDs in Taiwan in terms of capacity, which was established last year when it merged with UEC. "The additional tools will enable us to ramp up production capacity in response to market demand with excellent cost-efficiency," com-

mented Ming-Jiunn Jou, senior vice-president of Epistar.

Jou added that the company was looking forward to being the first customer for the world's largest-capacity epitaxy reactor for GaN growth.

According to Aixtron, the AIX 2800G4 features a redesign of most of the components, including the cell; offers easier operation and handling; and delivers improved reliability and reproducibility over previous designs.

Meanwhile, Samsung Electro Mechanics Co. (SEMCO) has placed an order with Aixtron for another AIX 2600 G3 HT MOCVD system. Since its first reactor purchase in 1997, SEMCO has continually increased its installed base for the mass production of a range of semiconductors including GaN-based LEDs for consumer optoelectronics. The latest order includes an EpiTune II *in situ* process monitoring tool.

Osram Opto Semiconductors has enhanced its Power TopLED line of LEDs. In particular, the addition of Osram's advanced thin-film chip technology to these TopLED packages makes them much brighter.

Osram has also refined the offerings in its lensed Power TopLED portfolio. These 30° and 60° devices provide matched radiation patterns in all colors, delivering higher-intensity light in a more uniform and focused beam for applications such as information displays.

The 30° Power TopLEDs produce 6300 mcd in super-red, 12,000 mcd in amber and 6500 mcd in yellow. The blue and green Power TopLEDs operate at a forward voltage of 3.4 V. This voltage is lower than that for conventional InGaN devices, says Osram.



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...easy attachment with Cree

Chipmaker Cree has released its new "EZBright" LED platform. Said to be a major advance in chip technology, EZBright LEDs feature Cree's highest brightness levels in a new, "easy-to-die-attach" chip. Cree's brightest chips can now be assembled into packages using industry-standard processes, says the firm.

...JPSA "solves" contamination problem

J P Sercel Associates (JPSA) has begun shipping solid-state UV laser wafer-dicing systems that are claimed to solve problems associated with GaAs and GaP contamination.

The Hollis, NH, firm says that it recently shipped multiple IX-300 "ChromaDice" UV laser wafer-processing systems to major GaAs wafer

producers, featuring JPSA's new "ProtectoLED" Technology – a proprietary, patent-pending system based on a water-soluble protective coating that is said to prevent contamination of the wafer during the dry-etch process.

...test probe for high throughput

SUSS MicroTec and Instrument Systems are developing a high-throughput test system for LED devices at wafer level. The German companies say that it will enable manufacturers to test up to 70,000 LED dice per hour.

Thomas Attenberger, Instrument Systems' LED product manager, said: "With this innovative solution, we are leveraging our combined know-how in LED testing to optimize throughput, achieving speeds never seen before."

Get the bows out

The new EpiCurve TT measures real-time wafer curvature.

As the demand for larger compound wafers rises, bowing measurements become indispensable. LayTec's new *in situ* monitor EpiCurve TT measures wafer curvature online during growth. Optimize your growth and maximise your yield with EpiCurve TT's unique combination of bowing, true temperature and growth rate measurement!

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...InP targeted for low-cost PV

A research collaboration based in the UK has won £235,000 (\$400,000) to develop low-cost photovoltaics based on InP substrates.

The project, which is being funded by the Engineering and Physical Sciences Research Council and the UK Department of Trade and Industry, is headed up by an Oxford University research group. Substrate specialist Wafer Technology and the Centre for Integrated Photonics foundry are also involved.

According to principal investigator Robin Nicholas, one of the key objectives of the project is to develop three-terminal devices based on the InGaAs/InP material system, which would improve the efficiency of so-called thermophotovoltaics (TPV).

Current TPV technology employs GaSb substrates, which are expensive and cover only a portion of the useful wavelengths that TPV is capable of exploiting.

...Advanced Photonix beats tax man

US-based optoelectronics manufacturer Advanced Photonix is set to receive tax abatement from the City of Ann Arbor in connection with the consolidation of its facilities.

Advanced Photonix is consolidating its California and Wisconsin semiconductor microfabrication operations into its Ann Arbor facility in Michigan, and is also moving its head office to that site. The company stands to receive up to \$94,000 over the five-year abatement period.

...quantum dots for solar?

Ryne Raffaele and co-workers at the NanoPower Research Labs at Rochester Institute of Technology have won a contract for \$0.85 million from the US Department of Defense to develop high-efficiency solar cells containing quantum dots.

The dots will be added to the central GaAs-based layer of triple junction solar cells, and will produce an enhancement in short-circuit current and an increase in overall efficiency.

"The use of quantum confinement offered by nanostructured materials provides us with a new means of breaking out of the normal design constraints associated with ordinary crystalline device growth," said Raffaele.

...Bookham sells fab, buys Avalon

Bookham has raised \$24 million from the sale and leaseback of its InP fab in Caswell, UK. And in an all-stock deal, the chip maker has acquired Swiss VCSEL specialist Avalon Photonics.

SUPPLY DEAL

Yokogawa and Fujitsu hook up on 40G technologies

III-V component manufacturer Yokogawa Electric has signed a strategic agreement with Fujitsu over the development of "ultra high-speed" communications networks. The networks will be based on optical packet switches that are set to be made at Yokogawa's huge new fabrication facility.

The two companies are planning to jointly develop the core technologies for faster optical networks, with Yokogawa focused on advanced compound semiconductor chips and Fujitsu working on transmission systems. Yokogawa will supply Fujitsu with 40 Gbit/s subsystem units.

"By combining Yokogawa's advanced compound semiconductor device technology with Fujitsu's expertise in network systems, the companies aim to achieve a faster transmission network infrastructure," said Yokogawa in a statement.

Last year, Yokogawa said that it planned to build a \$230 million fabrication facility near Tokyo to make optical packet switches and subsystems in volume. The all-optical switch can route signals without the need for electronic conversion.

Yokogawa told *Compound Semiconductor* that construction of the 28,000 m², five-storey fab is going according to plan so far, with initial production runs set for November. "Volume manufacturing is expected to start early 2007," said a company insider, adding that it would have enough capacity to make around one million modules per year.

The company is aiming to focus on local area network applications with the new technology. Yokogawa, which already has a global network comprising 18 manufacturing facilities, provides automation and control equipment to a wide range of customers including many in the power industry.

According to officials at the Japanese company, the compound semiconductor fab under construction will also be used to make sensor components that can be exploited in industrial control systems.

But high-speed fiber-optics will be the main driver. "It was obvious to anyone [at OFC/NFOEC] that the 40G market had finally started to pick up," said a Yokogawa source, adding that the subsystems may also be used for transmission speeds of up to 100 Gbit/s.

MARKET GROWTH

Optical telecom components: sales up 11% in market recovery

Sales of optical components used in fiber-optic telecommunications grew by 11% in 2005 to reach \$2.92 billion, according to new figures from Ovum-RHK.

The market research company said that while sales in the fourth quarter of 2005 were slightly weaker than in the equivalent period in 2004, the annual trend remained positive, driven by network build-out to support IP and video services.

"JDSU continues at the top of the heap, with Finisar and Sumitomo in second and third, respectively," said Ovum-RHK. "Rounding out the top five are Avago and Bookham."

The market recovery has had a positive impact on the financial health of the remaining companies in the ravaged sector. Average gross margins at nine publicly-traded optical component suppliers were 29% in the final quarter of 2005, representing a big improve-

ment compared with the third quarter.

In particular, Finisar has been profitable in its last two fiscal quarters (see Portfolio, p16). And while Bookham and Avanex are yet to break even, they have both looked to bolster their cash positions recently through public offerings of stock. Bookham raised around \$50 million and Avanex aimed to raise \$48 million before costs.

"Optical component suppliers are happily supplying arms to all equipment vendors engaged in the network build-out," said Daryl Inniss, VP of optical components at the market research company.

Inniss continued: "Growth is coming from all segments, including carrier metro, long-haul and access networks, and enterprise. Component vendors [that are] best equipped to meet the demand stand to grow and increase market share."

VENTURE FUNDING

Vertilas eyes expansion with new funds

German VCSEL specialist Vertilas has won \$4.4 million in new venture funding. Included in the latest round was new investor KfW Mittelstandbank, while High Tech Private Equity GmbH also added to its previous investment in the company.

Vertilas, which spun out of the Walter Schottky Institute (WSI) at the Technical University of Munich back in 2001, says that it will use the funds to "advance the commercialization" of its InP-based products. The company leases an MBE machine that is housed at WSI, where it makes about half a million chips per year on 2 inch InP wafers.

The company's current product range includes singlemode uncooled VCSELs operating at wavelengths of up to 2.3 μm . "We have a promising technology with a great growth potential," said Vertilas managing director Gerald Vollnhals.

Vollnhals told *Compound Semiconductor* that the new funds would be spent mostly on applications and prototype engineering. The company has no short-term plans to buy its own manufacturing equipment, but Vollnhals

did say that if business increases as expected, Vertilas may look to set up its own manufacturing operation around 2009.

The Vertilas VCSELs are used in industrial gas spectroscopy applications, mostly for monitoring levels of methane, carbon dioxide and humidity. The semiconductor, food packaging, and petrochemical industries are major customers. These gases all have molecular absorption peaks in the infrared region covered by the Vertilas VCSELs. Some of the new funding will be used to improve the detection limits of the VCSEL sensors, by reducing background noise levels and the effect of interference fringes in the device packaging.

Vertilas is also working to increase chip manufacturing volumes, partly through a move to 3 inch production, and partly through reducing the size of its chips from their current $500 \times 500 \mu\text{m}$ dimensions.

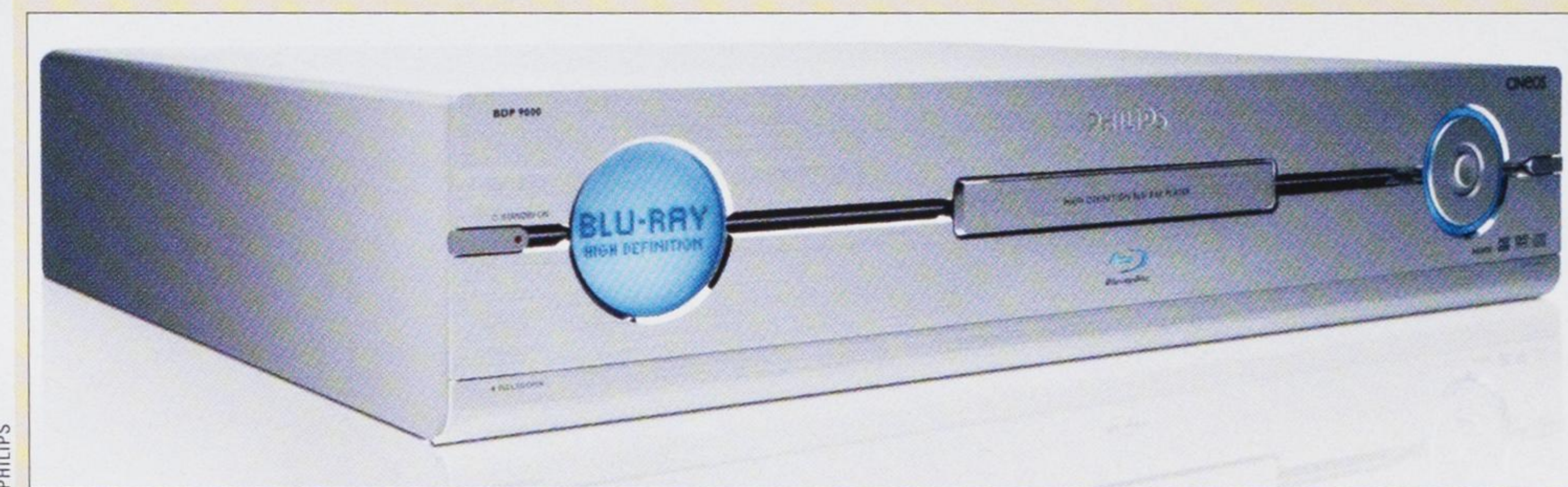
Long-wavelength VCSELs can also be used in datacom applications, and Vollnhals says that the emergence of fiber-to-the-home could lead to significant demand for the devices in around two years' time.

OFC/NFOEC

Show goes with a swing

The Optical Society of America says that its OFC/NFOEC 2006 event in early March was a resounding success. One of the most important meetings in the fiber-optic community's

calendar, the Anaheim show attracted 13,000 registrants in total. "There was a real sense of an industry upswing this year and leading analyst reports were optimistic about what 2006 has in store," commented the OSA. "Every indicator is showing that innovation is alive and well in the industry again."



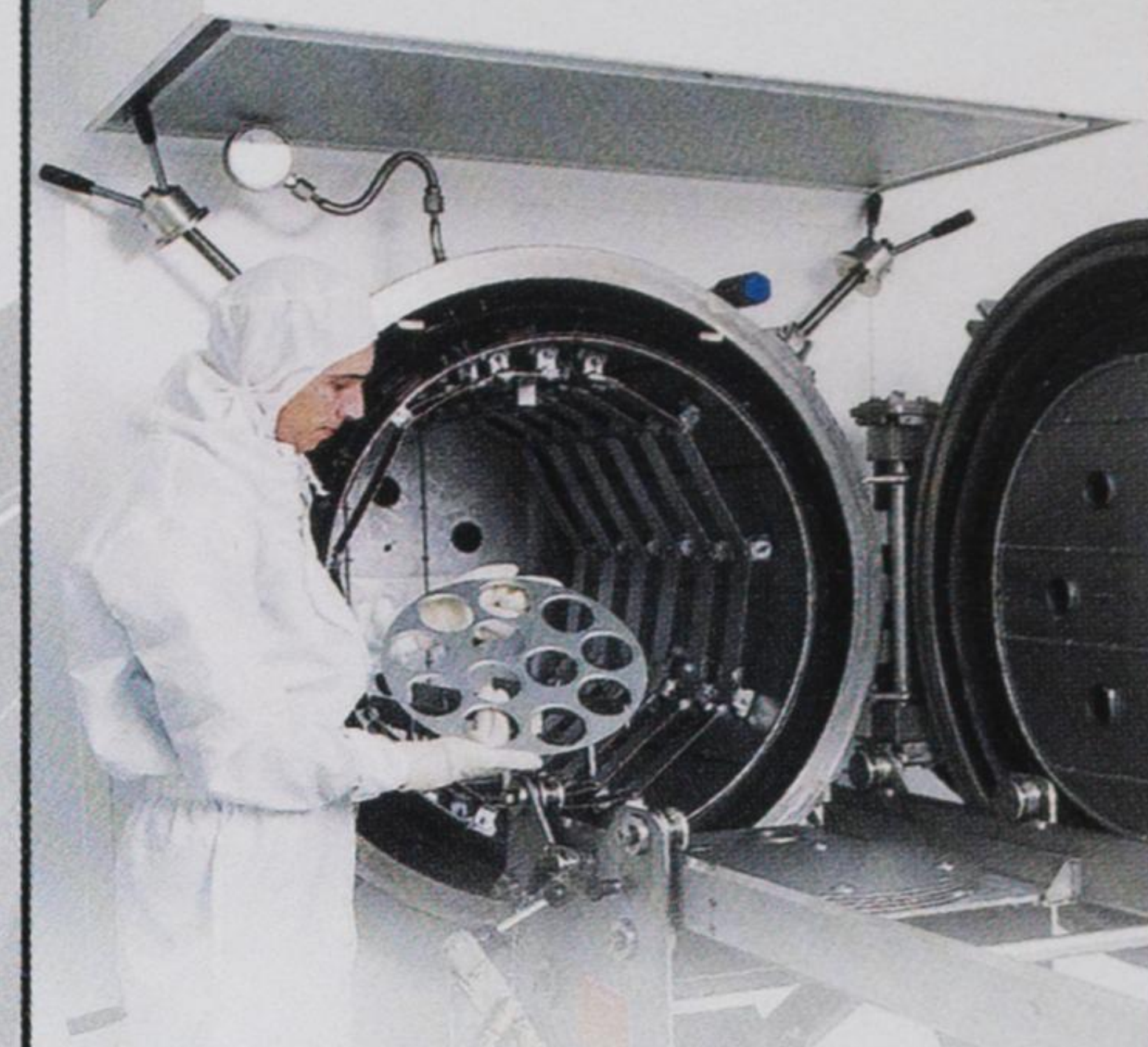
As had been widely expected, Sony has put back the launch of its PlayStation 3 games console until November 2006. Problems relating to the GaN-laser-based Blu-ray Disc format are thought to be at least partly to blame for the delay. The PlayStation 3 console will now be launched simultaneously in Japan, the US and Europe.

Analysts at Merrill Lynch commented in a recent research report: "It's now clear that the [PS3] box is extremely expensive to make. In particular, we think the problem points are the Sony Cell processor and the Blu-ray drive."

Whether or not the problem relates specifically to the fabrication of GaN lasers is unclear. There have been problems with GaN laser yields, but the Blu-ray copy protection software has also been a factor in the delayed launch of the technology.

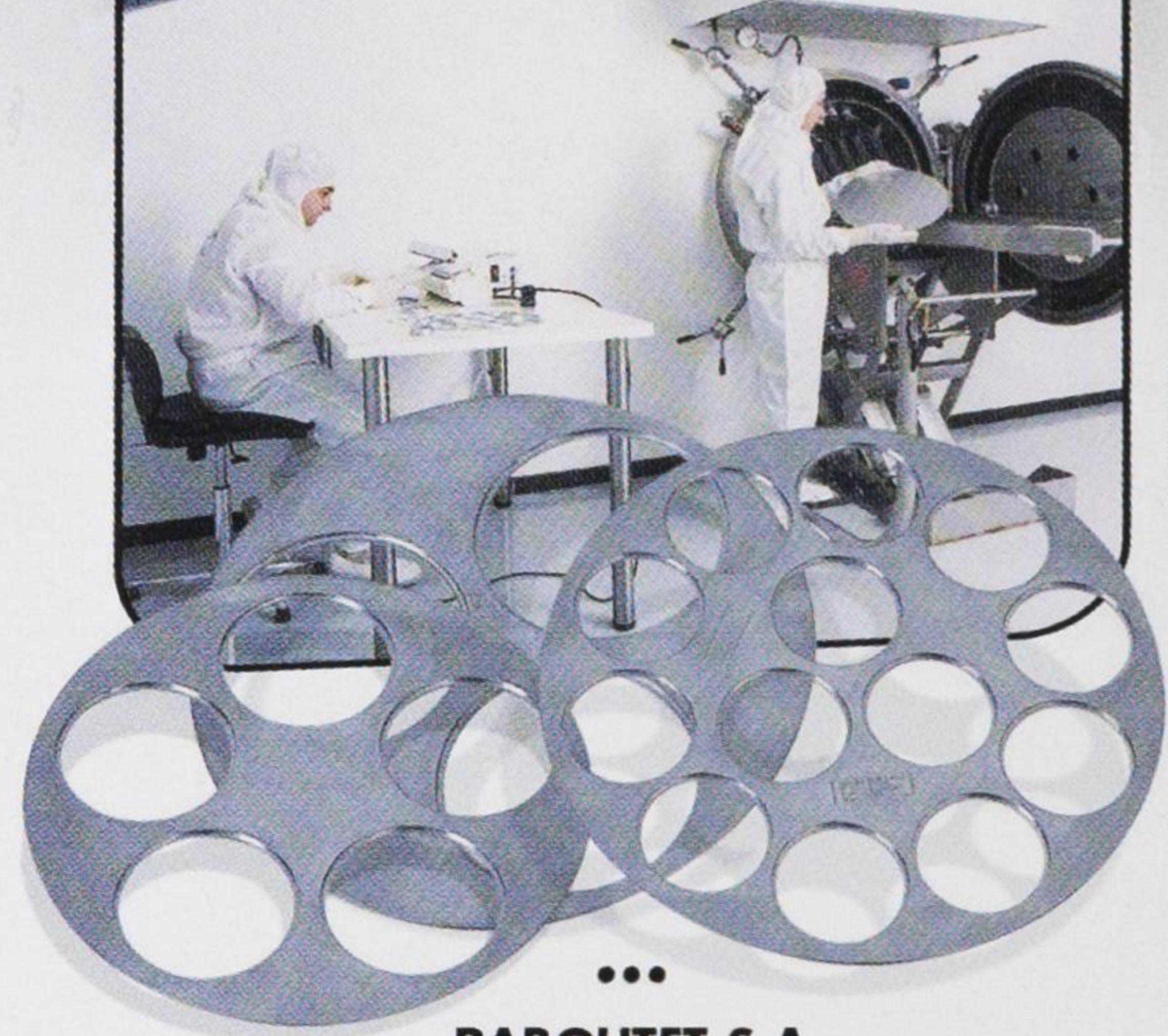
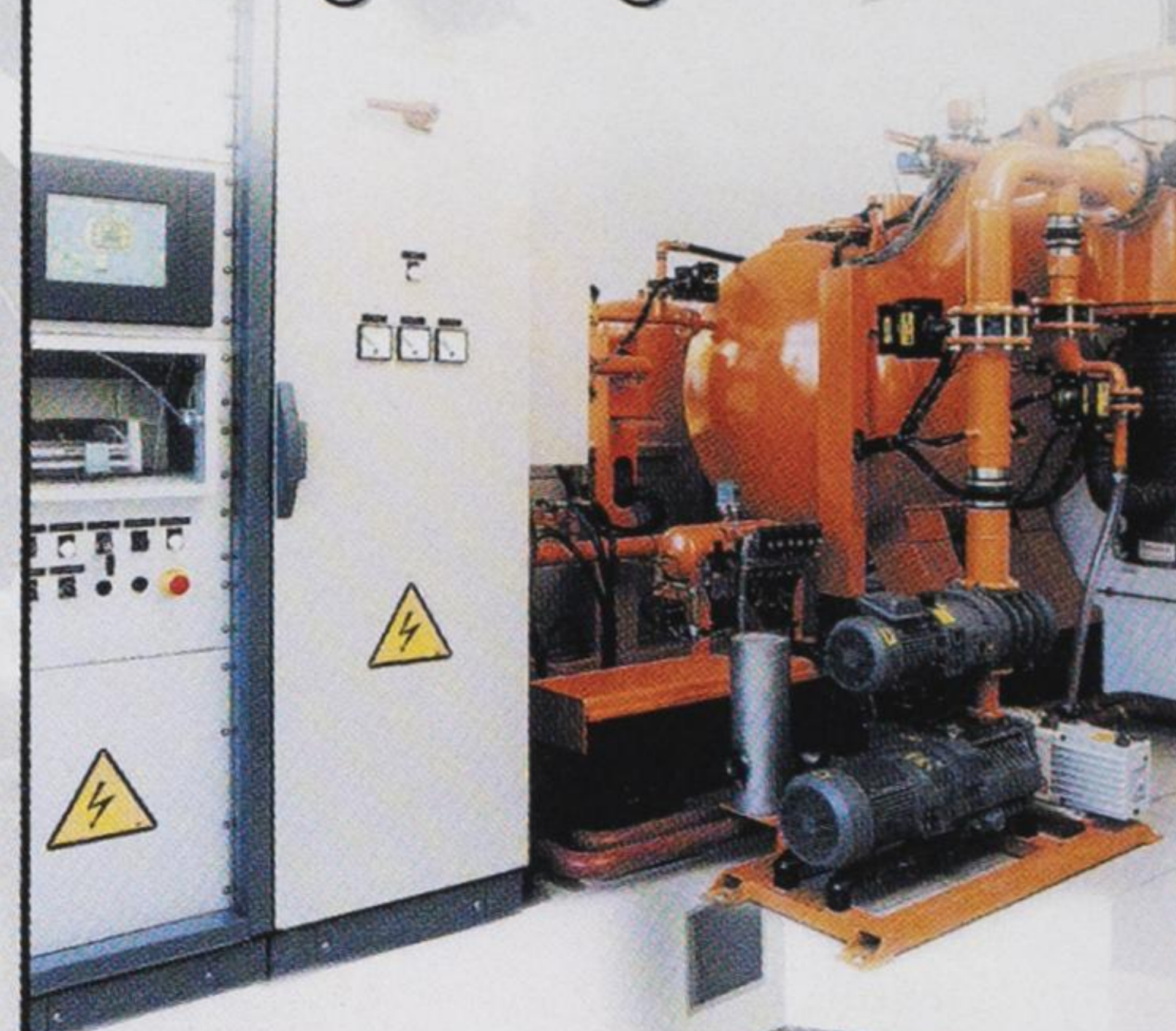
Sony's first Blu-ray Disc players and PCs featuring the concept are now expected to ship in July for around \$1000. In the meantime, Sony will be heavily marketing the signature blue color of the laser component by installing blue-tinted windows in its Sony Style retail outlets across the US.

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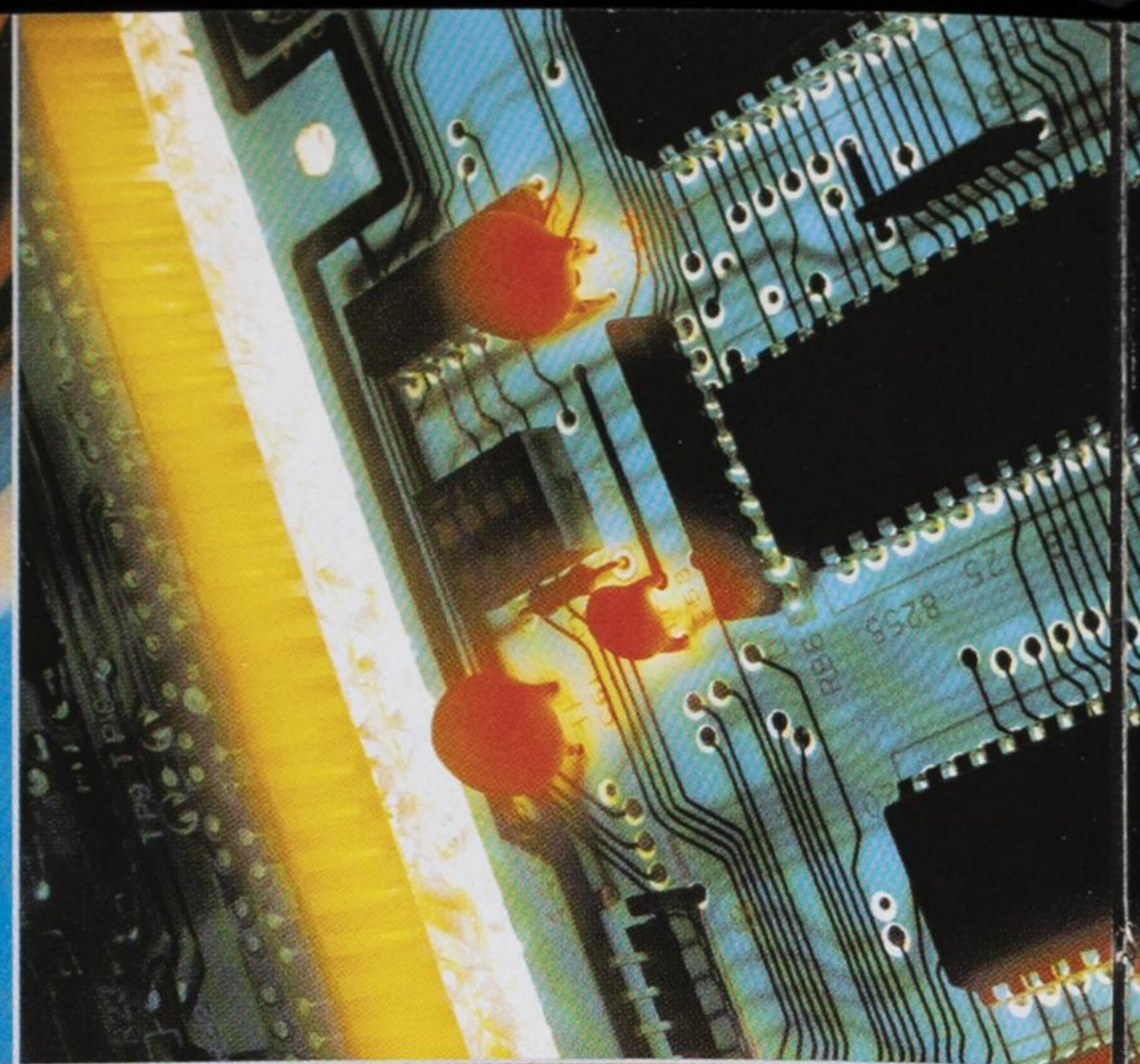
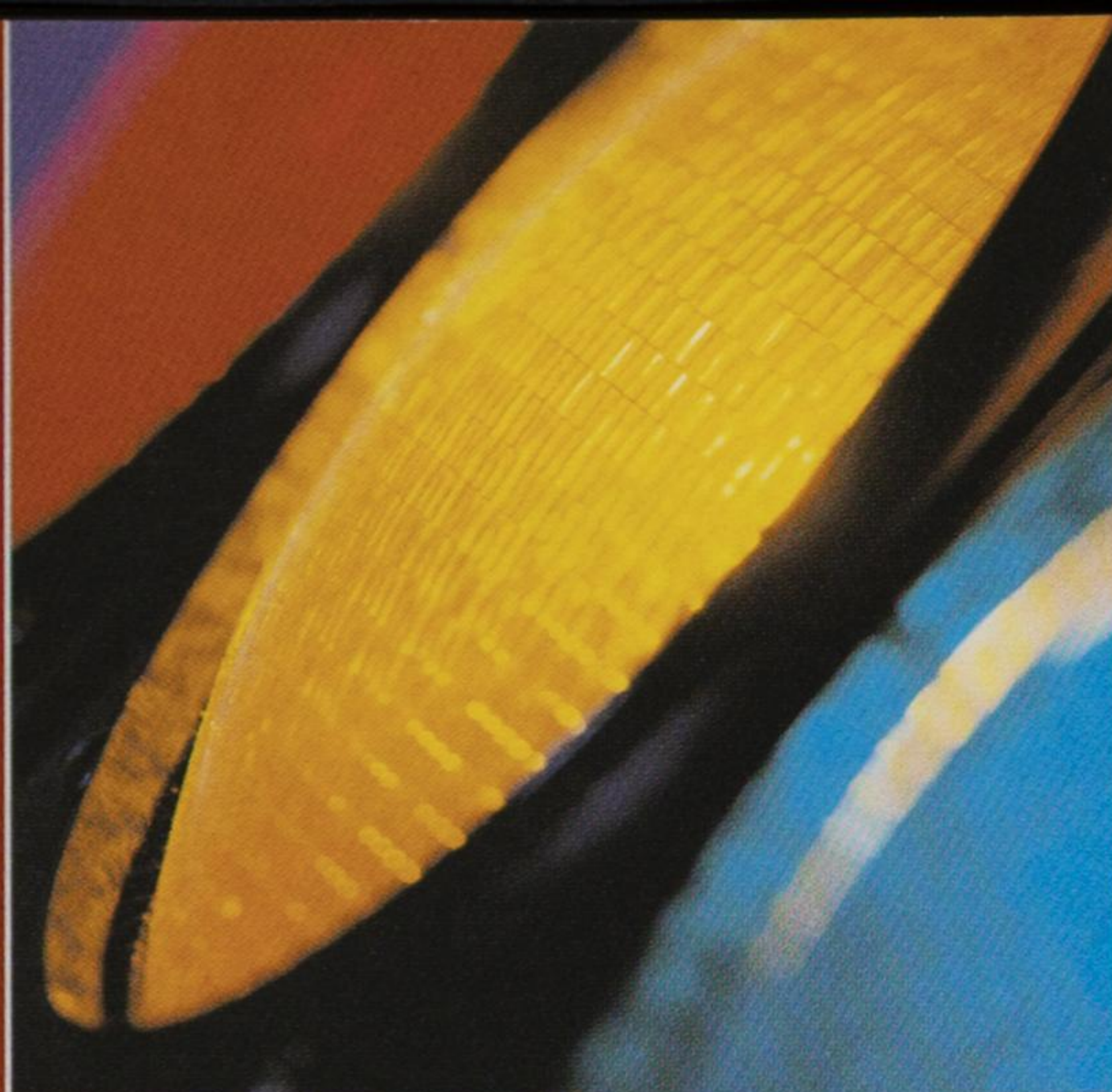
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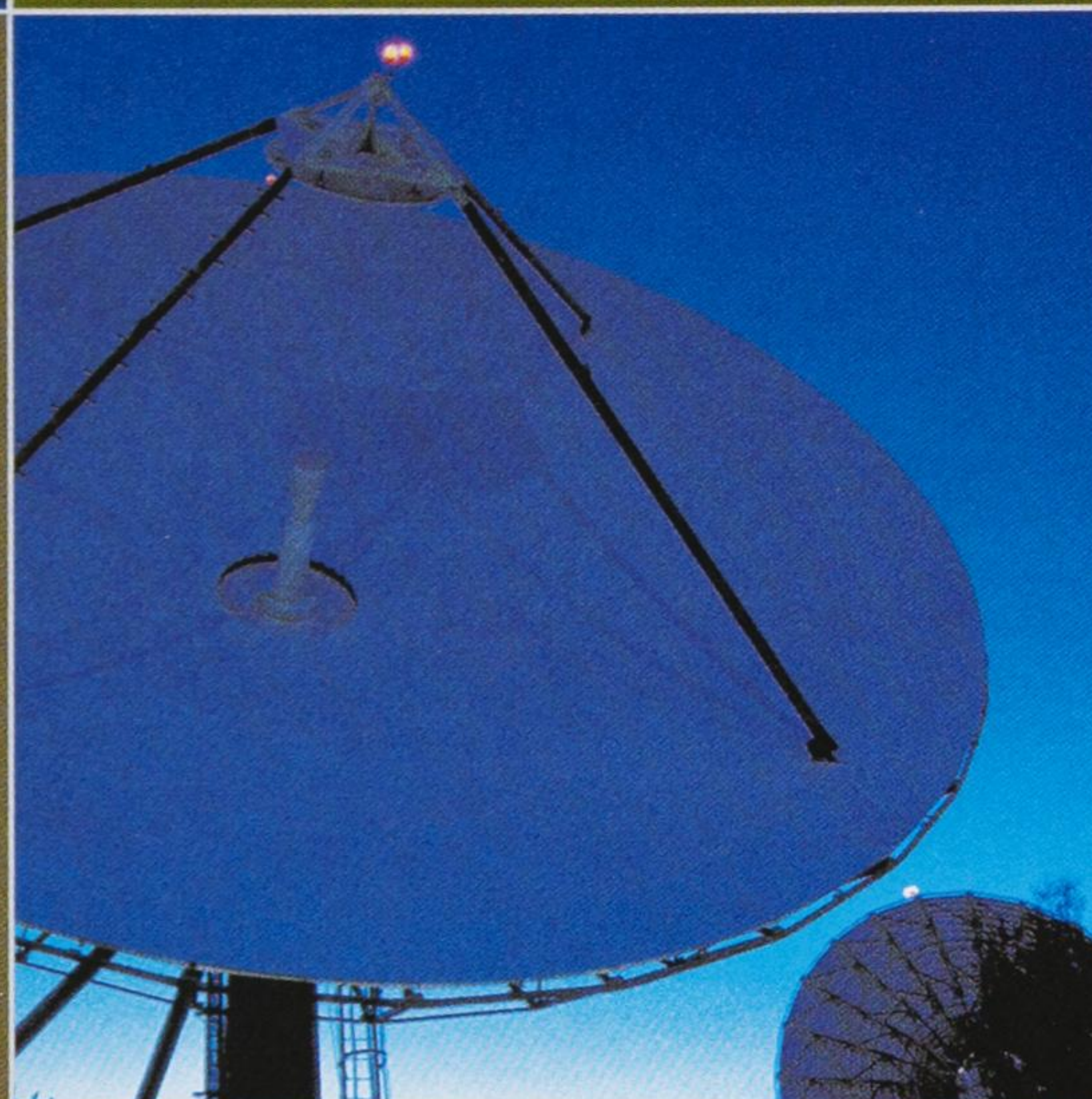
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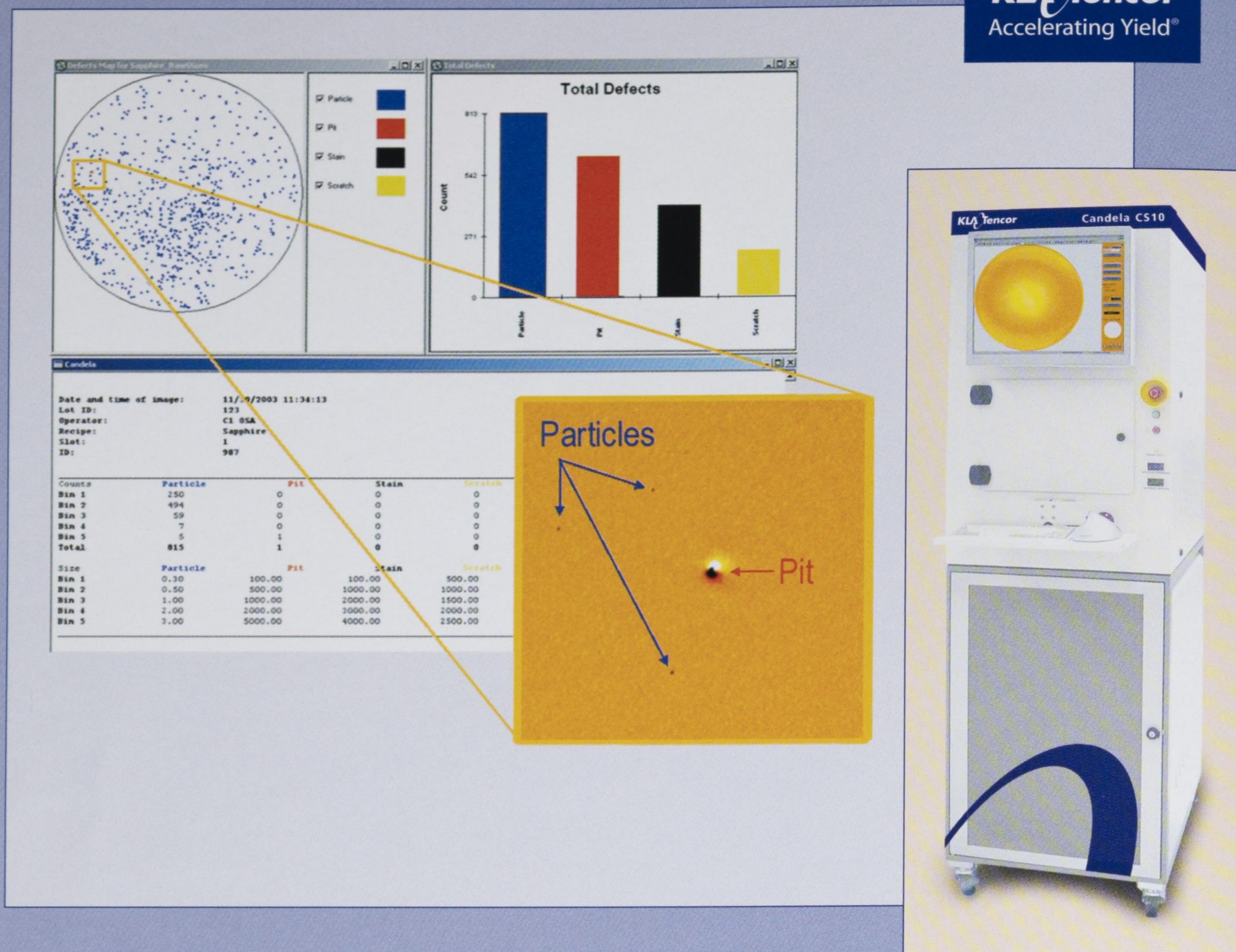
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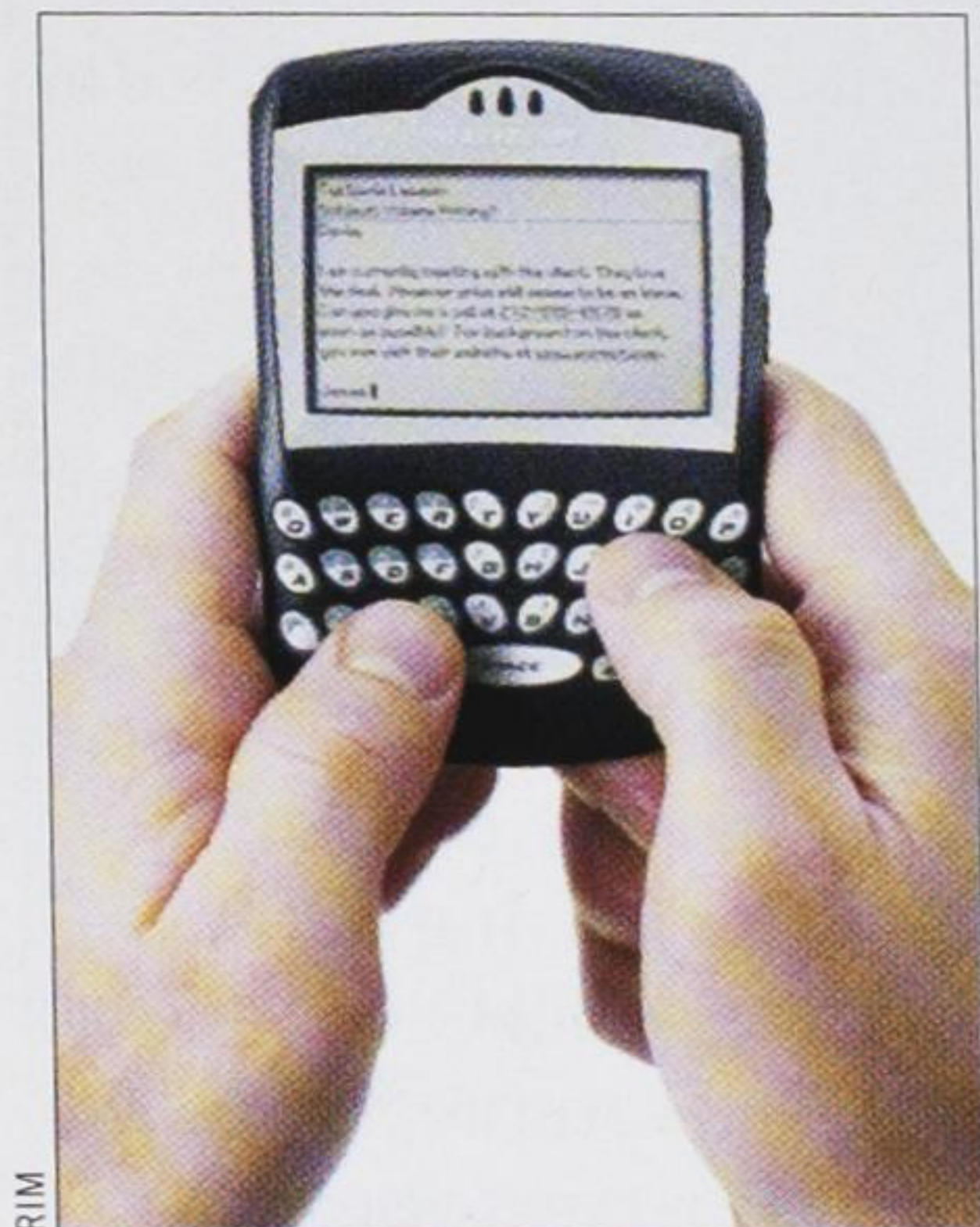
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ADVANCED RFICS

Anadigics charge hinges on BiFETs

Wafer-level integration of InGaP HBT and PHEMT structures is at the heart of Anadigics' strategy to return to profitability, hears **Michael Hatcher**.



The popularity of Research in Motion's Blackberry handsets, along with Intel's highly successful Centrino Wi-Fi chipset, has boosted Anadigics' sales, and WiMAX looks set to follow that trend.

After what has seemed a tortuous gestation period, 3G wireless is now with us and, it would seem, proving popular. According to leading vendor Nokia and others, the number of 3G handsets shipped in 2006 should approach 100 million, nearly double the 2005 volume.

At the annual 3GSM World Congress wireless industry get-together in Barcelona in February, the 3G push was very much in evidence. Ali Khatibzadeh from InGaP power amplifier (PA) supplier Anadigics was there. "As soon as you set foot in Barcelona you saw Samsung billboards advertising the first HSDPA phone," said the general manager of wireless products at the Warren, NJ, chip maker.

HSDPA stands for high-speed downlink packet access, and is a key area for Anadigics. That's because wireless industry giant Qualcomm is a big noise when it comes to this particular technology. "At the moment, if you're designing and building an HSDPA phone then you have to go to Qualcomm," explained Khatibzadeh. Anadigics now supplies the San Diego company with the PAs that feature in the reference design for these advanced chipsets.

"HSDPA and 3G chipsets are much more tied together than with 2G. It gives us a unique position because the barrier to entry for other suppliers that are not on the reference design is quite high," said Khatibzadeh.

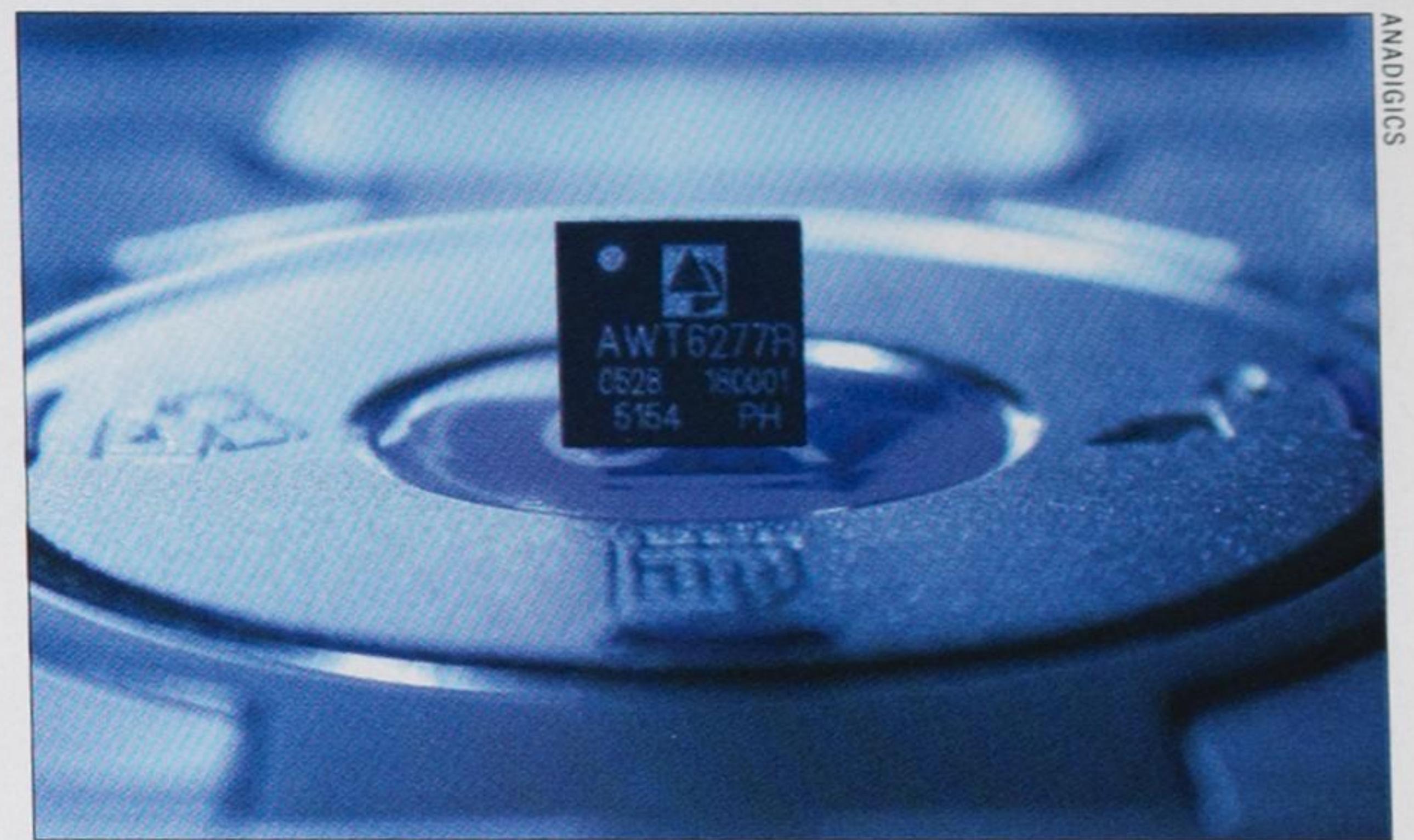
Because of the added complexity and resulting current consumption of 3G cellular, the linearity of the PA is even more critical, and this is where InGaP excels. Not only are handset unit shipments rapidly ramping up, so is the III-V content in each handset.

This is where Anadigics' BiFET technology offers a crucial advantage. Most of the chip maker's new products now feature the integrated InGaP HBT/PHEMT structures, which are manufactured on 6 inch wafers. Rivals like Skyworks Solutions, Triquint Semiconductor and RF Micro Devices are taking a similar approach. Skyworks has its own BiFET process that combines InGaP HBTs with FETs on the same substrate, while RFMD's approach has been to integrate PHEMTs and HBTs manufactured separately.

Skyworks continues to manufacture on 4 inch wafers, but Anadigics converted to the larger platform way back in 1999. Having previously led the PA pack in the early days of cellular with its GaAs MESFETs, Anadigics was knocked off its perch when RFMD became Nokia's key supplier of GaAs HBTs, as cell phones transitioned to 3 V operation in the late 1990s.

The combination of lost market share and the huge investment in its 6 inch GaAs fab has made life tough for Anadigics since then, but with the arrival of 3G, HSDPA and WiMAX the worm now appears to be turning in the company's favor.

That much is clear from a strong pick-up in revenue. In its February earnings call, sales for the holiday quarter were up 49% year-on-year, and Anadigics has



3G big-hitter Qualcomm is using Anadigics' power amplifiers in its latest HSDPA chipset, which powers the most advanced mobiles on the market. The power amplifiers used feature the InGaP-plus BiFET process, as do most of Anadigics' new products.

predicted an even stronger 2006.

Khatibzadeh sees a direct correlation between those sales increases and the introduction of BiFETs, which Anadigics transferred into volume production in 2003. "Looking at the strong relationships we have with key players such as Intel and Qualcomm, you could argue that this [BiFET] technology has been a key performance differentiator."

Anadigics already enjoys strong links with Intel on its Centrino Wi-Fi chipset for notebook PCs. With Intel now pushing the WiMAX equivalent – at its developer forum in March, Intel's Sean Maloney said that cards for mobile WiMAX would begin shipping in late 2006 – the new broadband connectivity protocol looks to be another boon for Anadigics.

"WiMAX is an OFDM system, which means that it really requires linear performance from the PA, and in general it also means greater power consumption," explained Khatibzadeh. "So having a good, low-power consumption PA with good linearity is important for 3G as well as WiMAX – and that means that it favors GaAs. Nobody's talking about CMOS PAs for 3G or WiMAX."

The Anadigics strategy now revolves around the BiFET advantages. "If you look at Skyworks or RFMD, there is more of a focus on 2G and 2.5G, with their Polaris and Helios platforms," said Khatibzadeh. "People expect to have 2.5G for the same cost as 2G. We think the real story is in 3G. Obviously, 3G features GPRS/EDGE as a requirement, but it is one part of the overall chipset."

While Anadigics does pick up some 2.5G business, it sees a much greater opportunity for revenue growth and, ultimately, a return to profitability in the more advanced platforms. "We go after 2.5G in an opportunistic way. For example, the Research in Motion Blackberrys use Anadigics' PAs, and we're very proud of that. This kind of market will exist and will grow, but we'd rather put our investments in 3G."

"The [2.5G] market will grow, but we'd rather put our investments in 3G."

Ali Khatibzadeh
Anadigics



FIBER-OPTIC COMPONENTS

Finisar and Avanex spring into life

Massive trading volumes and a rapid upturn in the valuations of **Finisar** and **Avanex** coincided with the year's biggest fiber-optic components show.

The first week of March marked the onset of some early spring growth for two of the compound industry's worst-performing stocks of recent years – Finisar and Avanex. Trading volumes went through the roof, with 80 million shares in Finisar (around a quarter of the company) changing hands on March 3 and a similar level of activity at Avanex. The market value of both companies doubled in the blink of an eye.

Why the sudden upsurge? Well, global warming might be changing some seasonal patterns, but it can't be held responsible for this one. The uptick coincided with the annual OFC/NFOEC trade show in Anaheim, and a deluge of public relations and marketing from fiber-optic component vendors of every kind. But that happens every year, and would have surprised nobody.

On the eve of this year's show, however, Finisar did report surprisingly good figures for its third quarter, which ended on January 31. Its stock price rocketed up more than 40% as a result of that, and dragged others, including Avanex, along with it.

Finisar made a profit of \$8.3 million in the quarter. Yes, you read it right – a profit. That hasn't happened for a while, although it was correctly predicted by the company a couple of quarters back (see *Compound Semiconductor* October 2005 p30). Analysts had only been expecting a breakeven quarter, hence the big spike. Another profit is expected in the current quarter, and the stock has maintained its value following the upswing.

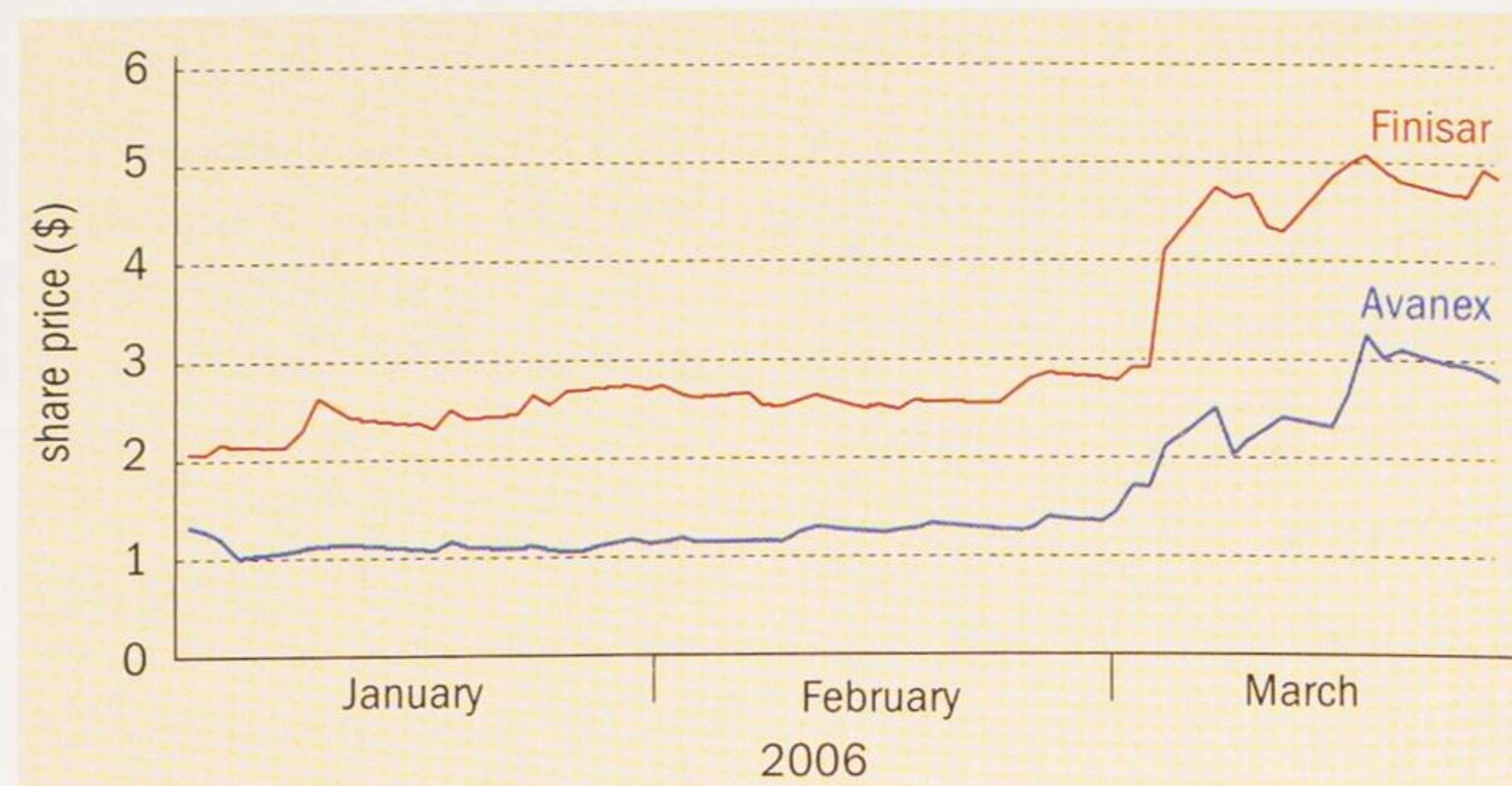
Finisar's strength is not in exactly the same areas as other component manufacturers like JDSU, Bookham and Avanex, but the market seemed to take a wider view that all optical components were back in vogue, fueling a rise in stock prices across the whole sector.

The much higher volume of trading in Finisar shares may indicate that the big institutional investors could be taking an interest in fiber-optics again. CFO Steve Workman must have little idea who some of his biggest investors are, given the rate at which the stock has been changing hands. Workman described the company as "a little different" to other firms in the optoelectronics space at the company's recent investor conference call. With profitability, it can boast a certain financial uniqueness too.

Vertical strategy

The decision by Finisar to become vertically integrated came after the telecoms crash, when it acquired the VCSEL manufacturing operations of Honeywell and the Fremont, CA, InP facility formerly belonging to Genoa. This is now a cornerstone of the company's strategy.

Finisar paid just \$3 million for the InP fab, while the previous residents had sucked up almost \$100 million in venture capital. Crucially, the volume of long-wavelength InAlGaAs laser and detector chips being made in Fremont is now ramping. This is one of the big reasons why Finisar's gross and operating margins are so improved, and why the company has pulled its bottom line out of the red.



Market movers: the value of both Finisar and Avanex more than doubled in early spring after Finisar posted a profit – as predicted by the company two quarters previously. Source: Yahoo Finance.

According to Joe Young, senior VP and general manager of Finisar's optics division, InP chip volumes in January 2006 were up 174% on January 2005. "Fremont is a big turnaround story for us," Young said. While volumes are currently at the 100,000 chips per week level, Finisar is expecting to make a lot more, he added. "We are investing in extra volume and increasing capacity."

The Richardson, TX, Advanced Optical Components (AOC) facility, where Finisar manufactures its 850 nm VCSELs, forms another critical part of the overall strategy. AOC's VCSELs are the acknowledged industry standard in datacoms, and Finisar is having mixed success in diversifying the applications in which they are used. Although the laser is featuring in advanced computer mice, with tens of thousands of integrated laser and detector chips shipping every week, Finisar admitted that scaling this volume up to the desired level of 100,000 per week is proving to be a struggle.

Communications will remain the key business driver for Finisar, however. Young expects that a strong ramp in the transceiver market of around 24% per year will propel company revenue upwards at a similar rate. Excluding passive optical networks, Young believes that Finisar's share of the transceiver market will have increased from just under 20% in 2004 to nearly 30% by the end of 2006.

Delivery of video content via the internet is going to be a critical consumer application that will drive volumes: "The big 'hog' for bandwidth is video," explained CEO Jerry Rawls in the investor call. "Thirty minutes of video is equivalent to one year of email." All that video is going to require a lot of storage too, and luckily enough, products for storage-area networks are a big part of the Finisar business too. Meeting that anticipated extra demand is the challenge now, concluded Rawls: "The number-one topic is capacity, and we plan to increase this. We know from history that rising markets are generally underforecast by our customers."

Having control over its own laser and photodetector supply will give Finisar an advantage if demand increases faster than has been suggested. The company has made the vertically-integrated model work, but others in the fiber-optic components business still have much to prove.

"The number-one topic is capacity, and we plan to increase this."

Jerry Rawls
Finisar

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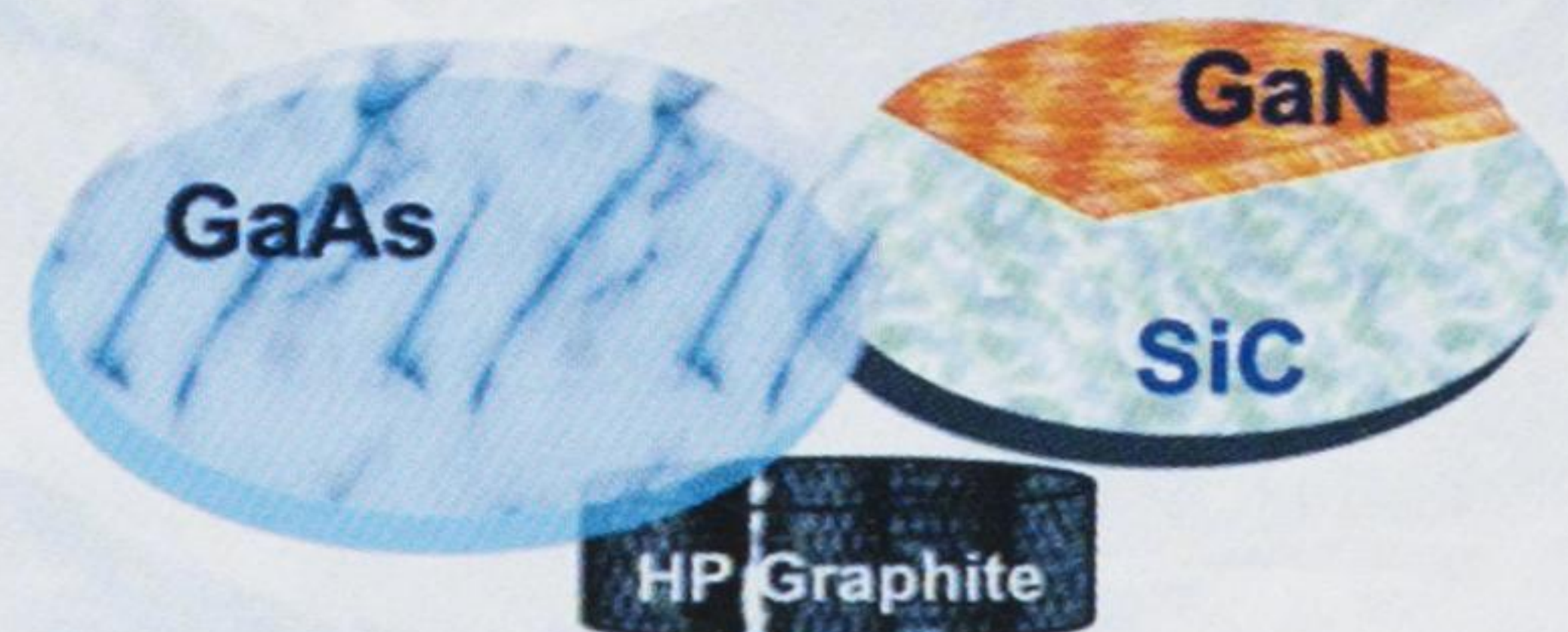
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AXT

Changing fortunes in the year of the dog

Dealing with a legacy of material quality problems, management issues and a plunge in market share doesn't sound like most people's idea of fun, but that didn't stop **Phil Yin** taking over the reins at substrate supplier AXT.



Phil Yin has made sweeping changes since joining AXT, and expects to reap the benefits in 2006.

AXT: the fall and rise?

May 1998: 12 years after being founded, AXT goes public with an IPO.

May 2000: 300% expansion of GaAs production planned in Fremont and Beijing. Don Tatzin becomes CFO.

August 2000: substrate sales near-double as GaAs demand ramps.

September 2001: sales hit by sudden weak demand.

April 2002: 6 inch VGF InP substrates released.

June 2003: optoelectronics division is discontinued.

May 2004: management reshuffled after substrate quality issues hit sales.

March 2005: Phil Yin appointed CEO; Tatzin leaves, Morris Young switches to CTO.

January 2006: suite of raw-materials products launched.

February 2006: AXT joins SEMI organization.

At its former manufacturing site in Fremont, the near-empty AXT car park suggests *Mary Celeste* comparisons. While that might be a little unfair, the California location is a shadow of its former self, when around 1000 people filled its four large buildings.

"2006 is a big turning point for us," says CEO Phil Yin, confidently predicting a revival in fortunes. Having revamped the senior management and dealt with operational problems, Yin believes that AXT's strong links in China will prove to be a big competitive advantage as demand for GaAs ramps up.

In Fremont, that Chinese influence is unmistakable: from the reception staff to the senior management; from the new red and gold corporate colors to the boardroom artwork. And China is where the company's heart now lies, along with more than 500 employees and five joint ventures that supply AXT with its critical materials.

Yin likes a challenge, which is just as well because when the industry veteran took over as its CEO one year ago, AXT was heading for the rocks. Just a few years after it was first to market with 6 inch vertical gradient freeze (VGF) material and held a market-leading position in GaAs substrates, things looked bleak.

The hangover that followed the 2000–2001 over-capacity binge hit AXT long and hard. It suffered a big fall in market share and revenue as rivals followed its pioneering VGF technology. Then came another blow – certain customers found that their AXT-sourced material suffered from poor surface morphology, causing "post-epi haze", and went to find alternative suppliers.

Combine that with [as yet, unproved] accusations of malpractice by former employees on health and safety grounds, a merry-go-round in senior management as operations switched from California to China, and the distraction of a damaging dispute with rival supplier Sumitomo Electric Industries, and Yin's task must have taken on nightmarish proportions.

But this is what Yin calls the "old AXT", one of damaged reputation. "We had bad baggage," he admits.

For the AXT board, enough was enough. Something had to be done. So they called Yin, a veteran of – among others – Aixtron, ATMI Epitaxial Services, Crysteco and IBM, to sort things out. Luckily for them, Yin was up for the challenge. First came the management changes: out went interim CEO Don Tatzin, while company co-founder Morris Young switched from a wide-ranging role, including CEO of Chinese operations, to a more focused position as CTO. That move can't have been easy for Young, but Yin saw it as a critical one for the future of AXT. "Morris is back to what he did best during his Bell Labs days," Yin said.

Similarly, the appointment of a new operations chief in the form of Minsheng Lin in July 2005 has beefed up the company's focus on production issues and quality control. AXT's material quality woes had stemmed directly from some relatively trivial operational oversights, the primary cause being identified by Lin as the use of a polishing solution that had been made up to the wrong concentration.

Fixing this problem, as well as bringing in automated cleaning stations, megasonics and spin-rinse driers is all part of the "new AXT", along with a revamped corporate image and a customer-first attitude.

Following the setup of the five joint-venture companies to supply AXT with raw materials and equipment, the Chinese links are stronger than ever (see "AXT's five joint ventures" box, p19). These ventures, in which AXT holds substantial shares and board presence, allow the company control over its supply chain, says Yin: "We are not susceptible to capacity constraints or swings in raw-material prices."

Part-ownership of a furnace supplier also allows AXT to add capacity relatively easily. Yin says that the design of these furnaces is critical, and this remains the company's most closely guarded secret. AXT has never patented the design, Yin insisting that this would let the cat out of the bag.

While AXT can pressure the joint ventures on price to reduce its overheads, this is only one part of the solution. Above all else AXT needs to take back substantial market share to approach profitability. In recent

"First came the management changes: out went interim CEO Don Tatzin, while Morris Young was switched to CTO."

quarters there has been little sign of this – while revenue has begun to creep back up after a long downturn, the company continues to post a net loss. But Yin now expects to oversee a dramatic ramp-up.

That's partly because demand is increasing across the board, particularly as the latest cell-phone handsets devour ever more GaAs content. Crucially, AXT's rival suppliers, such as Freiberger, are struggling to meet the volumes demanded by their customers. As a result, AXT is brimming with orders, and has far better visibility on its customer requirements for the rest of 2006 than it has seen in recent years.

"Total requirements – in terms of square inches of material – could be close to double the 2005 figure by the year-end," predicts Yin. Aside from the squeeze on GaAs capacity, increasing demand for germanium looks like favoring AXT. The firm is one of only a handful of vendors, along with chief rival Umicore, to sell the germanium substrates used by Emcore and Spectrolab to make solar cells, and by Osram Opto Semiconductors in HB-LED fabrication. Osram's chip manufacturing volumes will no doubt continue to soar, while the use of multi-junction solar cells in terrestrial applications is at last beginning to take off. Again the Chinese operation is crucial – one of AXT's joint ventures controls a germanium mine in Mongolia, ensuring that material supplies are largely under control, while 4 inch germanium substrates are in volume production thanks to a large order from the Chinese government for two satellite applications.

As you would expect from somebody who spent a lot

AXT's five joint ventures



Name	Product(s)	AXT holding
Beijing Ji Ya	99.99% gallium	46%
Nanjing Jin Mei Gallium	99.9999(9)% gallium, B ₂ O ₃	83%
Beijing Bo Yu Manufacturing	pBN crucibles, MBE parts	70%
Xilingol Tongli Ge	raw germanium	25%
Emeishan Jia Mei HPM	99.99% and 99.9999% arsenic	25%

of time in the silicon semiconductor business, Yin is keen on standards and roadmaps. As a result, AXT recently joined the SEMI organization as a corporate member. "Compound semiconductor [volumes] will not snowball unless we get standard specifications," he said.

For the Chinese community 2006 is the year of the dog, and as such is said to be one of reflection. If his expectations prove correct and market share flows back in AXT's direction, many will reflect that Yin has been the chief architect of AXT's long-awaited revival.

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SiC growth rockets with hydrogen

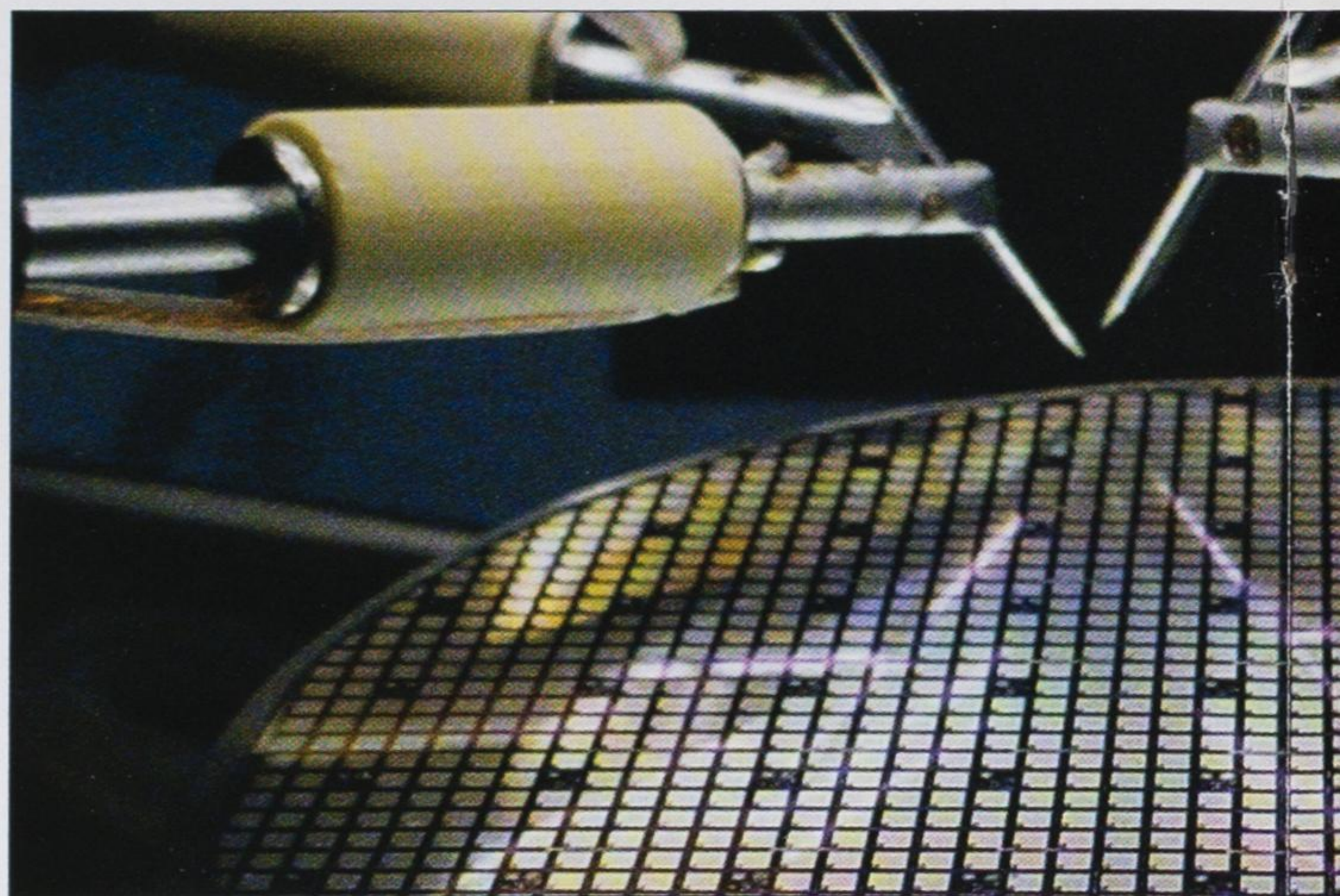
The standard growth process for silicon carbide produces high-blocking-voltage devices, but suffers from long processing times. These delays are hindering commercialization, says **Francesco La Via**, who believes that the problem can be overcome by adding hydrogen chloride into the cell.

Rapid improvements in substrate production and advances in the growth of high-quality epitaxial films by CVD have driven the development of SiC material that is ideal for high-power microelectronic devices. This has led to the fabrication of several types of device with blocking voltages of at least 10 kV, including power depletion-type MOSFETs, implanted JFETs, PIN diodes and Schottky barrier diodes. However, to obtain these breakdown voltages, epitaxial layers 80–100 μm thick are needed, which require processing times of 10 hours or more for conventional epitaxial growth rates of 6–8 $\mu\text{m}/\text{h}$. These long growth times equate to high processing costs, and this is hampering the commercial development of high-voltage SiC devices.

CVD using “step-controlled epitaxy” is the standard approach for homoepitaxial growth of α -SiC, the most common form of the material. With this method the polytype is controlled through the surface steps on off-axis substrates. Mirror-like surfaces can be produced with carbon/silicon ratios of 1.4–2.5 at a growth rate almost independent of the gas mixture. Within this regime the epitaxial growth rate is directly proportional to the silane flow rate, but at high silane flows silicon droplets are formed in the gas phase that are then deposited on the wafer.

Combining these observations with analysis of the gas-phase kinetics in the growth system has led us to conclude that epitaxial growth proceeds through silicon adsorption at atomic steps, followed by carbonization of hydrocarbon molecules. The main limitations of this process are the low growth rate that results from slow silicon species diffusion through the stagnant layer, and the limited silicon/hydrogen-gas ratio, which has to remain below 0.05% to prevent homogeneous nucleation of silicon droplets in the gas phase. Nucleation can also lead to a poor-quality surface through depletion of the gas-phase precursors that are needed for deposition.

An improved epitaxial process that overcomes the growth-rate problem has recently been developed independently by both our research team in Italy and scientists at the University of South Florida. The improvements include increasing the silane flow and introducing HCl gas into the deposition chamber, and have led to much higher growth rates combined with good surface morphology.



Our hydrogen chloride-based process can slash the growth times of silicon carbide.

Reactor comparisons

Reactor type	Planetary warm wall		
	7 × 2 inch	7 × 3 inch	6 × 10 inch
Reactor configuration	7 × 2 inch	7 × 3 inch	6 × 10 inch
Total useful wafer area (cm^2)	92	241	382
Growth rate ($\mu\text{m}/\text{h}$)	3	4.9	5
cm^2 of 100 μm thick epi per day	60.8	247.1	398.6
Wafer throughput	4.6	7.2	6.3
Thickness uniformity (σ/mean %)	3	1	3
Doping uniformity (σ/mean %)	7	5	9

Our research team's results using our horizontal hot-wall reactor compare favorably with those presented by SiCED at the *Materials Science Forum* 2005 **483–485** 137), and those presented by SiCED at Las Vegas, NV, which took place in Pittsburgh, PA. Although our LPE Epitaxial Technology reactor has a high degree of temperature uniformity and can accommodate either six 2-inch or three 3-inch substrates.

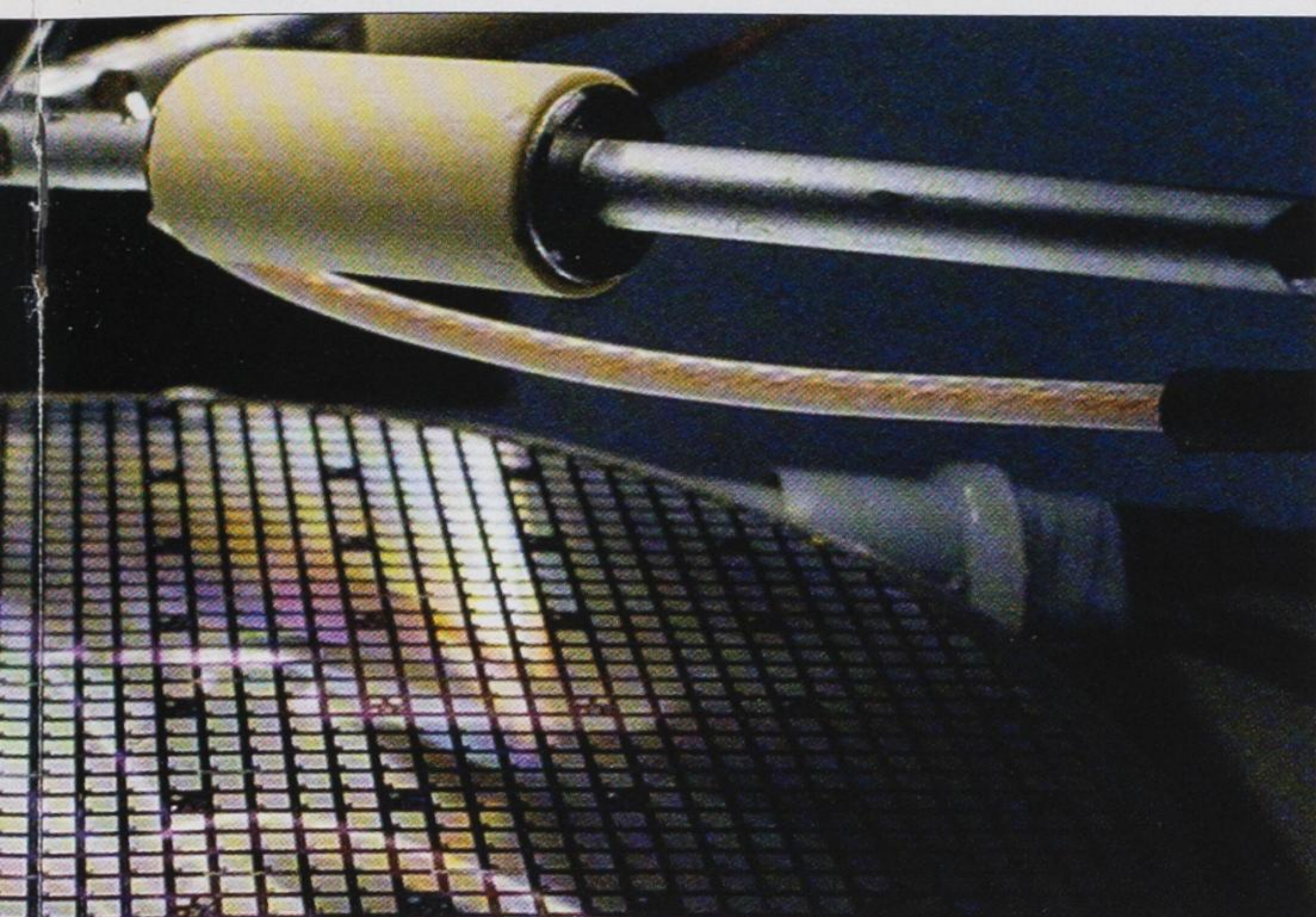
In our work, the 4H-SiC epitaxial films were grown using silane and ethene precursors in an LPE Epitaxial Technology ACSiM8 hot-wall reactor that has a high degree of temperature uniformity and can accommodate either six 2-inch or three 3-inch substrates.

HCl combines speed with quality

It turns out that HCl addition can significantly increase the silane concentration, while avoiding the homogeneous nucleation of silicon in the gas phase that usually occurs during the standard deposition process. With this limitation removed, high growth rates of up to 112 $\mu\text{m}/\text{h}$ that are directly proportional to the silane flux are possible (figure 1). No homogeneous gas-phase nucleation has been observed, even at the very high silane concentration of 0.6% that was used for the highest growth rate. Even higher growth rates might therefore be possible.

We characterized 100 μm thick epitaxial layers grown with the HCl-based process using AFM to determine the film's surface roughness. Measurements from

Hydrogen chloride addition



carbide devices by several hours, consequently reducing their production costs.

	Horizontal hot wall		Planetary hot wall
6 × 100 mm	6 × 2 inch	3 × 3 inch	5 × 3 inch
82	78	103	172
	112	112	6
98.6	480.9	635.0	209.9
3.3	37.0	18.5	6.1
	1.2	1.6	2
	7	8	9

ably with those produced at Cree using a planetary warm-wall reactor (see at last year's International Conference on Silicon Carbide and Related Materials, has a relatively low substrate capacity, the far higher growth rates that are the highest daily throughput for 2 and 3 inch material.

several regions of the wafers show that the average value is independent of growth rate and is typically 0.3 nm (figure 2). This roughness is similar to that of the standard HCl-free process.

Our potassium hydroxide etching experiments at 500 °C have also revealed that there are no major differences between the dislocation densities of the SiC epilayers produced with and without HCl addition.

We have also measured the minority-carrier lifetimes of both types of epiwafer to establish whether there are defects within the material that degrade device performance. These experiments were carried out with a modified microwave photoconductive decay instrument built by Semilab, which features a 350 nm laser excitation source. Figure 3 shows the minority-carrier lifetime distribution from a 100 µm thick epitaxial layer grown using HCl addition. The distribution peak shows that the average carrier lifetime is over 1 µs, which is a high value for SiC.

We confirmed the quality of the epitaxial layers

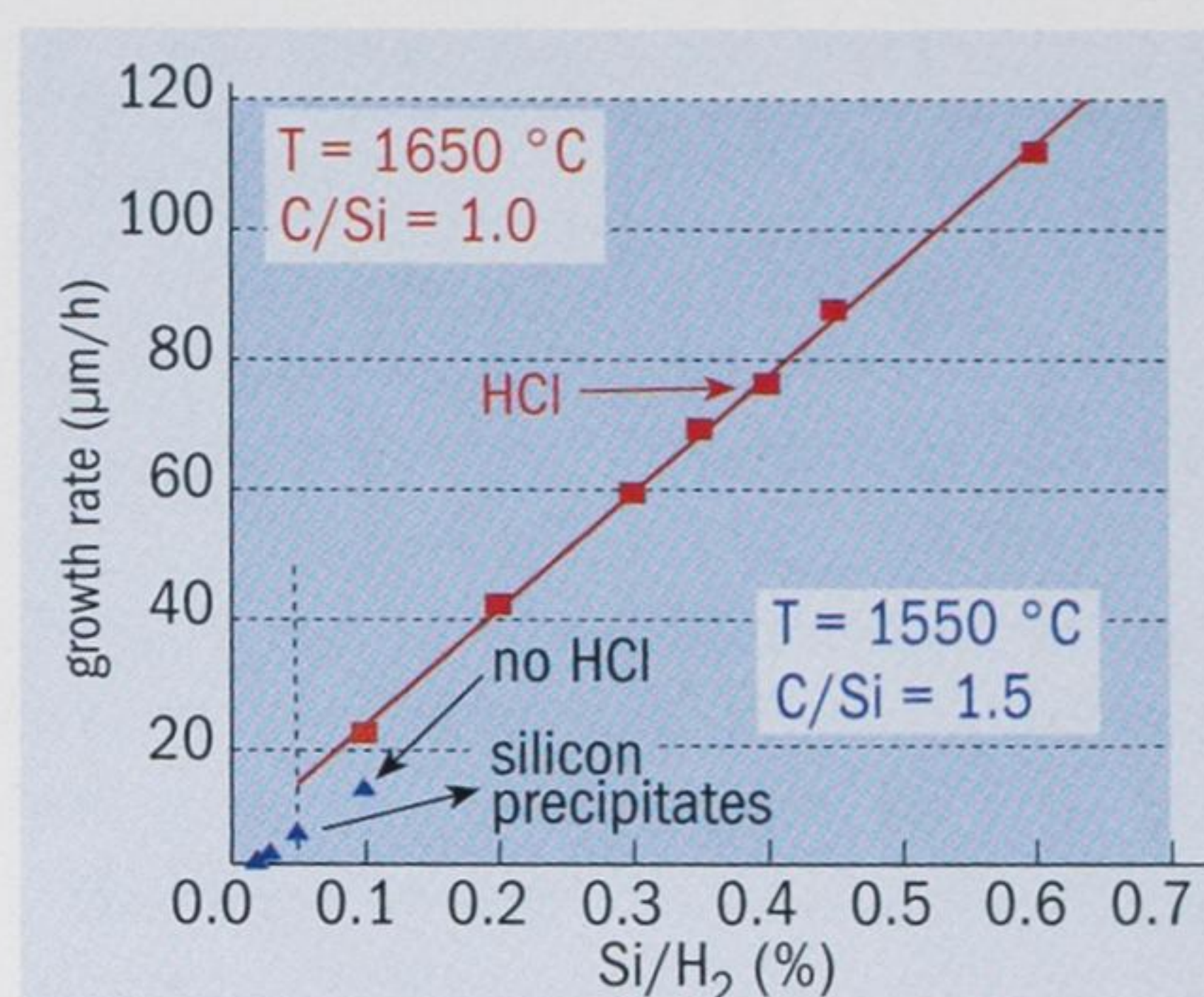


Fig. 1. The standard growth process (blue triangles) is restricted in growth rate to well below 20 µm/h, and at the higher end of this range silicon droplets tend to form in the gas phase and contaminate the wafer. The HCl process (red squares) is capable of far higher growth rates of up to 112 µm/h.

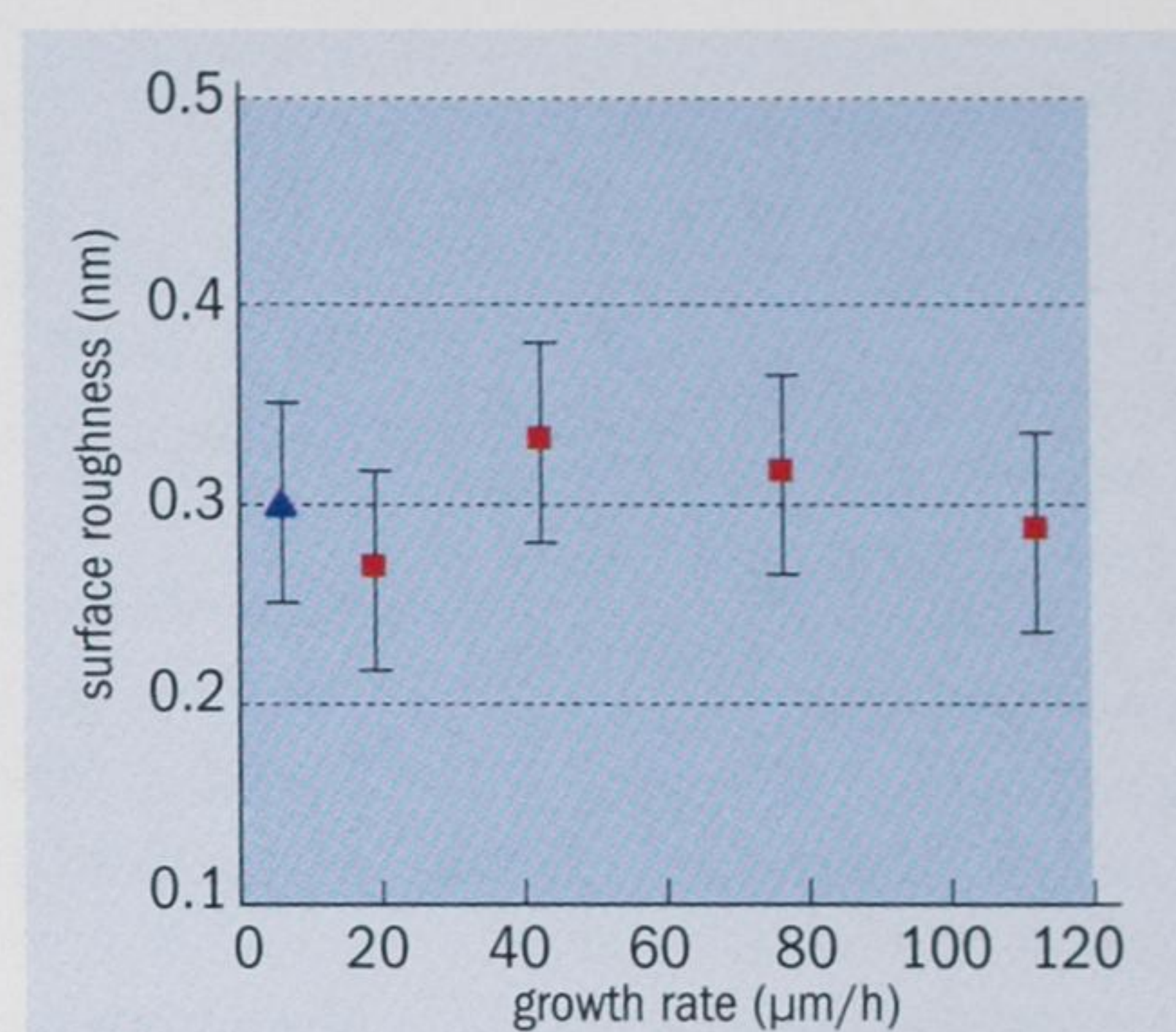


Fig. 2. Atomic force microscopy measurements of 5 × 5 µm areas of the surfaces of material produced by both the standard (blue triangle) and HCl-based (red squares) growth processes reveals that both of the methods produce similar values for surface roughness.

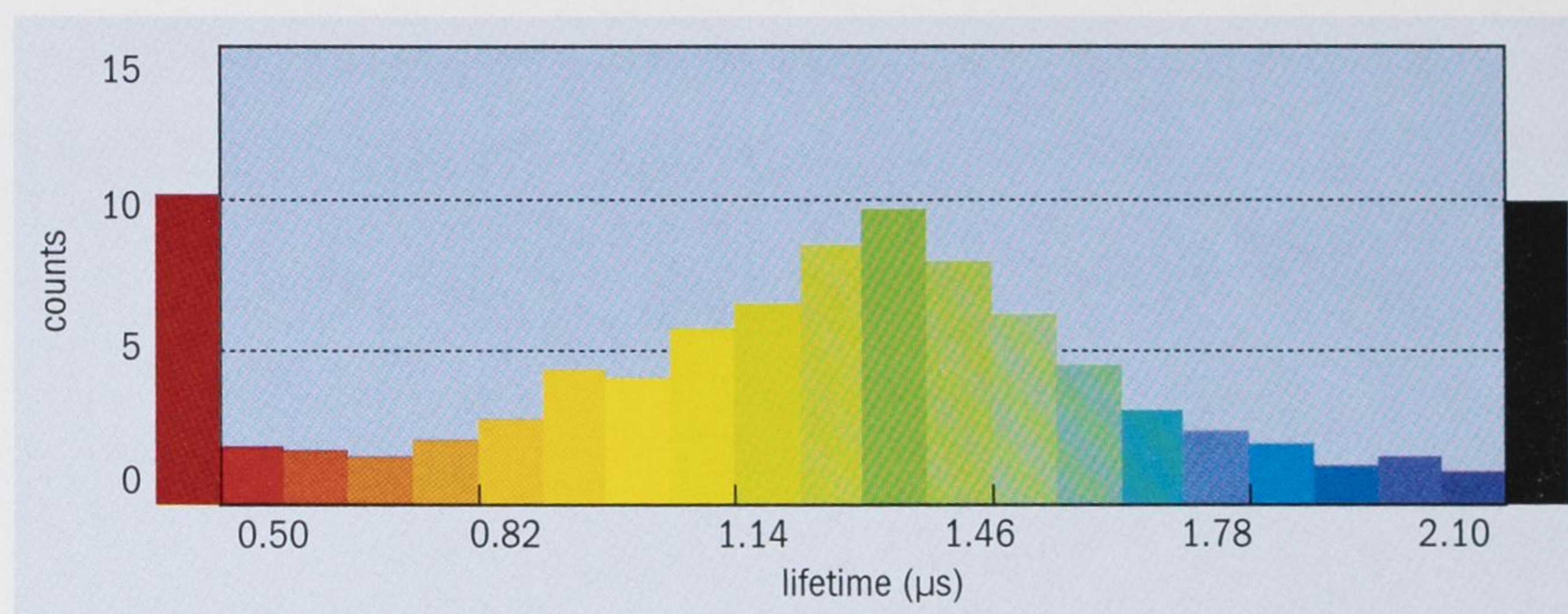


Fig. 3. Microwave photoconductivity measurements show that the HCl process produces an average value for the minority-carrier lifetime of just over 1 µs, indicating that this material has very few defects.

grown with HCl addition using deep-level transient spectroscopy (DLTS) measurements. Although films produced with both types of epitaxial process each contain only one defect level – the EH₇, which has an associated energy of 1.5 eV – the concentration of this defect is three times lower in the layer grown using HCl addition. The combination of the DLTS and the microwave photoconductivity decay results suggests that the faster process could also be used to produce high-quality bipolar devices and X-ray detectors.

We also know from capacitance-voltage measurements that the high growth rate process can produce low background doping levels of less than 1 × 10¹⁴ cm⁻³. This means that the HCl-based process can yield intentionally doped layers with low doping concentrations and good uniformity. Figure 4 (p22) shows the doping distribution for several wafers grown with the same process. The average doping concentration is 5.6 × 10¹⁴ cm⁻³, with a standard deviation of 6.7%.

The faster process also delivers extremely good thick-



About the author

Francesco La Via is a senior researcher at the Institute for Microelectronics and Microsystems, National Council for Research (CNR-IMM), in Italy, where he leads the department of SiC growth and epitaxy research.

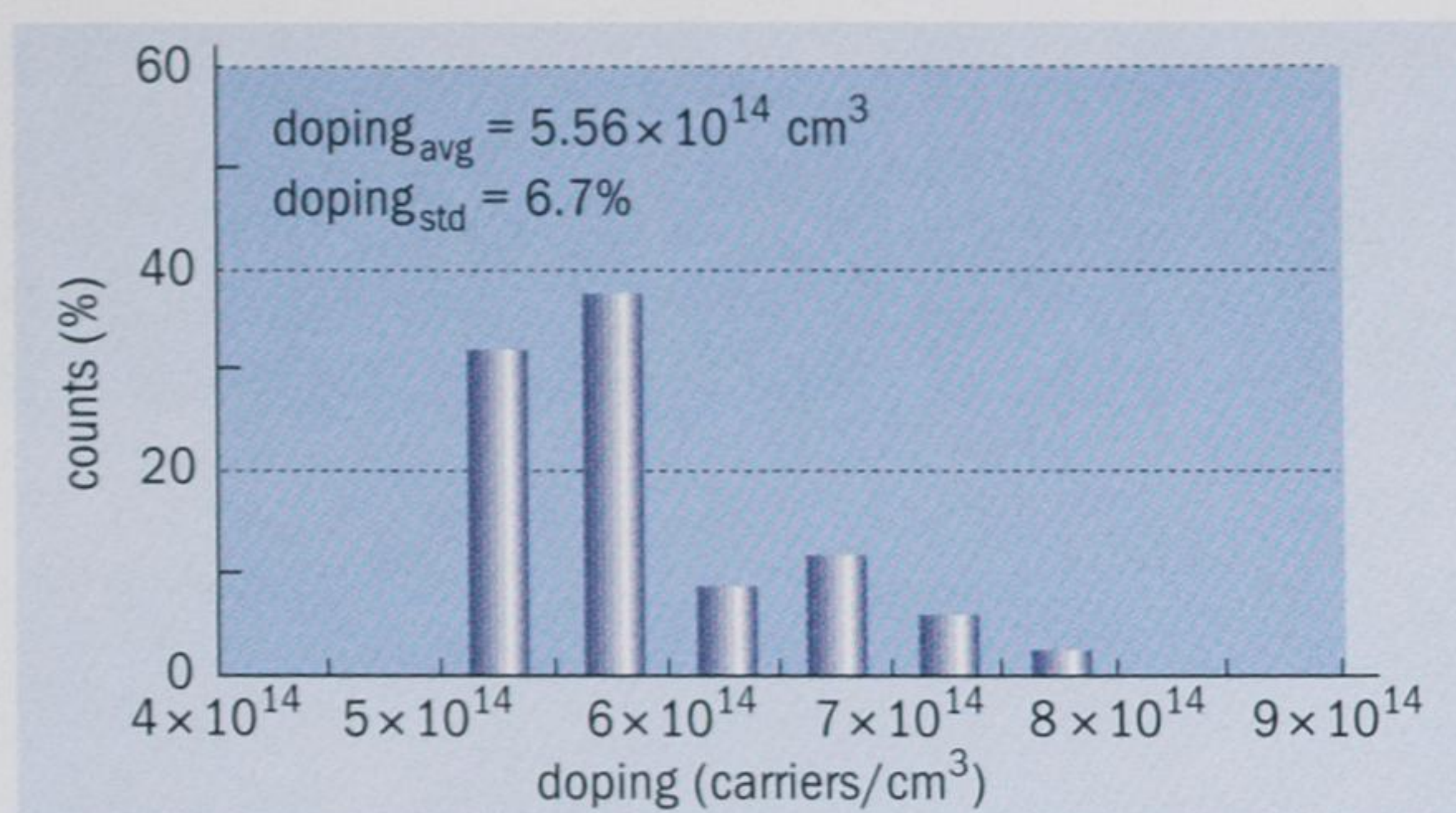


Fig. 4. The HCl-based process can produce SiC epiwafers with a high degree of uniformity, in terms of the doping concentration.

Acknowledgements

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ness uniformities. Our Fourier transform infrared spectroscopy measurements of several epiwafers have shown that the standard deviation in the film thickness for layers with an average thickness of $56.8 \mu\text{m}$ was just 1.2%.

Very high wafer throughput

Although the ACSiM8 has a significantly lower capacity than the reactors used by Cree or produced by SiCED (see table, p20), its far higher growth rate capability means that it can deliver a higher wafer throughput for 2 and 3 inch material. In addition, the epilayer thickness uniformities produced with the LPE reactor compare very favorably with those reported elsewhere.

We have also started to investigate the performance

of devices grown with the high growth rate process. We compared Schottky diodes grown on different substrates and produced by either the HCl-based process at a growth rate of around $20 \mu\text{m/h}$ or the standard process. Electrical measurements showed little difference between the leakage current distribution of both types of diodes – the average leakage current is 10^{-5} A/cm^2 at -600 V in both devices. The forward voltage distribution at 20 A/cm^2 is also very similar for both processes, indicating that both approaches give good electron mobility. In the near future we will characterize Schottky diodes fabricated with the much faster $112 \mu\text{m/h}$ growth rate.

Our new process, which can routinely produce 50–100 μm thick epilayers with good morphology and low background doping, will provide the SiC industry with a lower cost production technique for high-blocking-voltage devices. This will aid the growing interest in these devices for a wide range of applications, including electrical power converters in ships and automobiles, and voltage transformers for electrical grids. ●

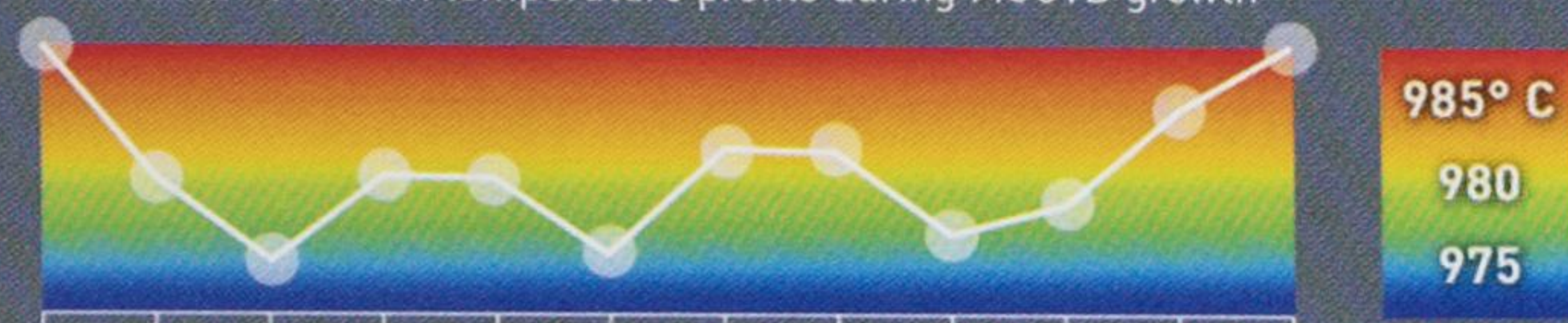
Further reading

- D Crippa *et al.* 2005 *Mat. Sci. Forum* **483–485** 67.
M Das *et al.* 2005 *Mat. Sci. Forum* **483–485** 965.
A Elasser *et al.* 2002 *Proc. IEEE* **90** 969.
J Zhao *et al.* 2004 *IEEE Elec. Dev. Lett.* **25** 474.
J Zhao *et al.* 2003 *IEEE Elec. Dev. Lett.* **24** 402.

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Crystal growers push nitride envelope

Michael Hatcher

reports on a flurry of recent development activity in III-N materials that has seen numerous funding deals and the commercial shipment of AlN substrates.

There's never been any doubt that developers and manufacturers of nitride-based devices would benefit hugely from native nitride substrates on which to grow their epitaxial structures.

But, compared with silicon, GaAs and, to a lesser extent, InP, nitride substrates have proved far more troublesome. The main problem is the extremely high temperature and pressure required for molten crystal growth.

Recently, a few developments among a select band of crystal specialists suggest that makers of GaN, AlGaIn and InGaIn structures are increasingly set to follow in the footsteps of the more mature semiconductor materials through the use of native substrates and epiwafers.

One of these companies, Kyma Technologies, follows Cree and Nitronex as a spin-out of the influential Bob Davis research group at North Carolina State University. Unlike some, Kyma's aim is to develop a boule growth process similar to that which has proved successful for other semiconductor substrate materials. Although this is more technologically challenging than a faster growth method such as, say, hydride vapor-phase epitaxy, Kyma co-founder Drew Hanser maintains that in the longer term, the boule growth approach will prove essential.

Kyma has recently set up a number of development programs with the US Department of Defense. Two of these take place under the wing of the Missile Defense Agency, where the main aim is to develop larger substrates that will be essential for cost-effective manufacturing of relatively large transistors for RF applications, such as radar and X-band communications. Kyma has also signed two collaborative R&D agreements, this time with the US Navy and Air Force, under which it is supplying substrates for FET development and increasing its focus on material characterization.

Kyma indicated to *Compound Semiconductor* that its 2 inch GaN wafers would be shipping in substantial volumes within a year, with the first 3 inch material suitable for devices set to follow in mid to late 2007.

Encouragingly, a wide range of devices – including various transistors, Schottky diodes and optoelectronics – have already shown excellent performance on Kyma material, even from initial growth runs (e.g. a 600 V Schottky diode and 10 GHz FETs). “What we've seen with these early experimental devices is corroboration of the basic theoretical arguments in favor of a native substrate,” said Kyma CEO Keith Evans.

As with any starting material, dislocation density is the critical attribute where device manufacturers want to see progress. Typically, Kyma's epiwafers feature etch-pit densities of around 10^6 cm^{-2} , although a 10-fold improvement on that has been seen in Kyma's best “hero” result. Further improvement will be necessary, however, with laser manufacturers specifying a defect density of 10^4 cm^{-2} . The way to improve quality is to make larger boules, and the nuances of this process are at the root of another development that Shuji Nakamura believes could

Thermal conductivity of typical substrate materials

Material	Thermal conductivity (W/m/K)
GaN	220
AlN	200
CVD diamond	1200
SiC	350–490
Silicon	149
Sapphire	40
InP	68
GaAs	46

Source: Group4 Labs

revolutionize the whole field – non-polar GaN.

“Non-polar GaN material looks relatively enticing on paper,” Evans said, explaining that the dislocation networks that develop in boule growth of c-plane GaN have geometrical aspects that may benefit non-polar substrates cut from those boules. Kyma has already produced some low-defect-density non-polar and semi-polar GaN. According to Hanser, semi-polar GaN could also ease some of the difficulties with epitaxial growth.

Like Kyma, LED and materials supplier The Fox Group is focused on developing a true boule growth process for AlN, a material that if anything is even more difficult to produce than GaN. But thanks to its proprietary crystal growth technology, based on a tantalum carbide crucible, The Fox Group is now shipping small quantities of epi-ready monocrystalline 15 mm diameter AlN substrates to a number of different device researchers, and is working on increasing wafer size to the 2 inch minimum requirement for future commercial use in devices with aluminum-rich active layers, such as ultraviolet LEDs and solar-blind detectors.

Barney O'Meara from the company, which grows AlN at its facility in Deer Park, NY, says that while dislocation density measurements are difficult to ascertain with any certainty, the quoted figure for its material is less than 10^7 cm^{-2} .

While the recurring theme in native wide-bandgap substrate materials is that of defect density reduction, innovation in non-native wafers continues apace. Californian start-up Group4 Labs is focused on improving the operation characteristics and reliability of GaN-based devices through the use of diamond substrates.

Because of the lattice mismatch between the two, the GaN layer is transferred – rather than deposited directly – onto diamond, but company founder Felix Ejeckam says that the defect density, quoted at around 10^9 cm^{-2} , is unaffected by this process.

Having announced its presence with a square, nitrogen-facing epiwafer, Group4 has swiftly followed up with gallium-facing material measuring a full two inches in diameter. “Never before have customers had access to a nitrogen-facing as well as a gallium-facing GaN epiwafer,” claims Group4.

“Non-polar GaN material looks relatively enticing on paper.”

Keith Evans

Kyma Technologies

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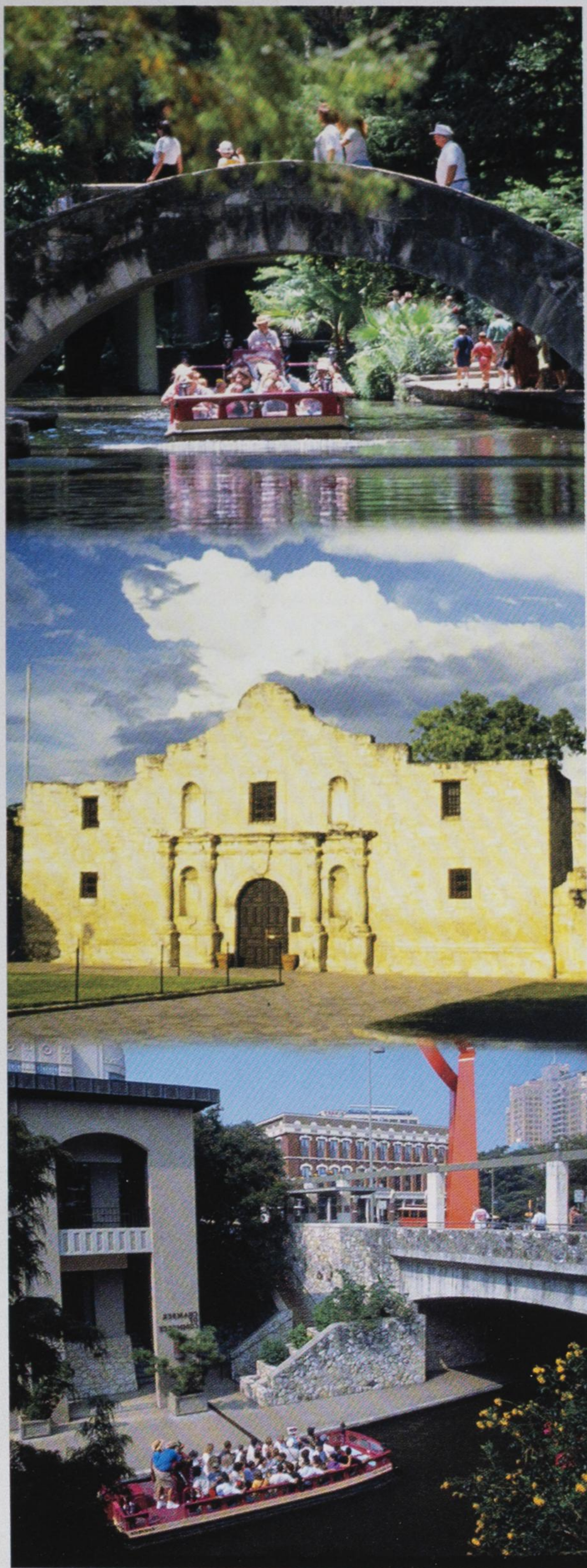
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Bespoke MMICs aid radar, phased array and oscilloscope applications

High-performance traveling-wave amplifiers for oscilloscopes, radar and phased-array equipment can be made cheaper and simpler by switching to custom-built designs, claim **Mark Kelly** and **Thorsten Brabetz**.

Traveling-wave amplifiers – also known as distributed amplifiers – are not new products. Their roots can be traced back to 1936 when they were built using valve technology. Today they are available as standard products featuring amplification up to 40 GHz that are being used in broadband communication networks and pieces of electrical measurement equipment.

However, these off-the-shelf products are not ideal for radar, phased array, or oscilloscope applications because in these cases the performance specifications need to be specifically tailored. Targeting these needs, here at the Institute of Electronics, Communications and Information Technology (ECIT), at Queen's University, Belfast, we are designing and building bespoke traveling-wave GaAs amplifiers with very low gain variations with frequency and very low phase distortion. Our designs include amplifiers with a small variation in gain over their frequency range, which are used for testing the electromagnetic compatibility of various RF components, and for addressing the problems associated with signal reflection from antennas. We also produce amplifiers with low phase distortion that are suitable for applications that do not need a wide frequency response but do require a faithful reproduction of the pulse's shape. This feature makes these amplifiers ideal for use in radar, phased arrays, oscilloscopes, and also in optical receivers, where they can be used to amplify the photodiode's signal without distortion.

Traveling-wave amplifier MMICs operate by absorbing parasitic shunt capacitances – which come from the insulator that separates the gate and the conducting channel – into artificial transmission lines. This removes the active device's main cause of frequency dependence, and also ensures a very low phase distortion during amplification.

One of our traveling-wave amplifiers is shown in the "ECIT's traveling-wave amplifiers" box on p26. It features a 0.5–18 GHz bandwidth, 12 dB gain with less than ± 1 dB ripple and a 17 dBm 1-dB compression point – defined as the output power for which the gain has dropped by 1 dB. The design occupies



The \$70 million-funded Institute of Electronics, Communications and Information Technology at Queen's University, Belfast, is located off campus in the Northern Ireland Science Park.

Institute of Electronics, Communications and Information Technology

ECIT – the Institute of Electronics, Communications and Information Technology – combines the expertise of the electronics and computer-science departments of Queen's University, Belfast, in one building. Since its launch in 2003, the research center has received \$70 million of funding from the European Union, Invest Northern Ireland, and the country's Department for Employment and Learning.

The center has a high-frequency electronics group that is developing and commercializing wireless front-end technology. The group has various interests, including high-performance GaAs and sub-micron silicon integrated chips, self-adapting antennas and monolithic packaging strategies.

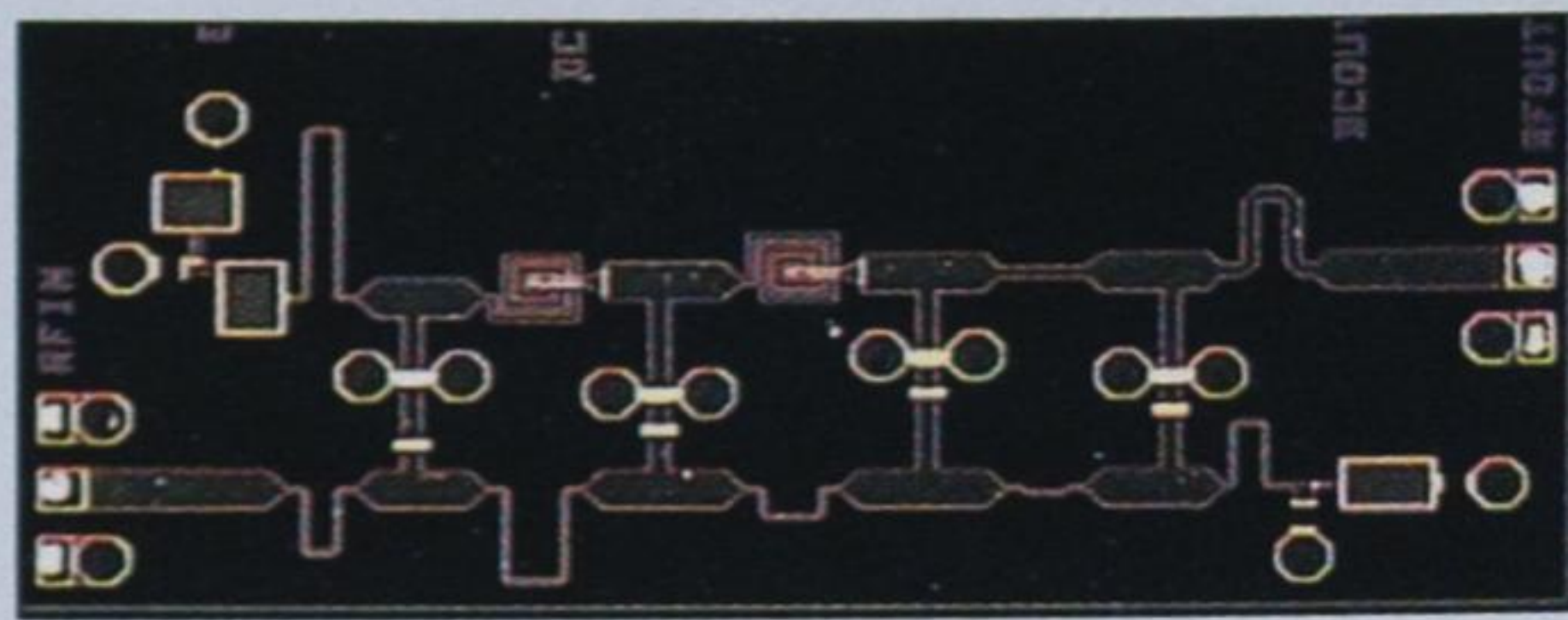
The commercial division is focusing on the production, integration and packaging of microwave and millimeter-wave semiconductors to customer specifications, including a customer-driven project involving the fabrication of traveling-wave amplifier MMICs.

3.0 × 1.25 mm of die area and was fabricated using the D01PH power process at OMMIC, the France-based compound semiconductor foundry owned by Philips.

Some of the performance characteristics of these amplifiers can be seen in figures 1 to 3 (p26). The measured gain from 10 of our MMICs produced from a single batch is shown in figure 1. The pairs with the highest and lowest gain were then selected, and their

ECIT's traveling-wave amplifiers

The traveling-wave amplifier MMICs made at ECIT feature low gain variations with frequency and low phase distortion, making them strong candidates for radar and phased-array applications, and amplifiers for oscilloscopes and photodiodes in high-speed optical networks. This amplifier, which was fabricated using OMMIC's D01PH process, contains four $6 \times 15 \mu\text{m}$ PHEMTs with $0.13 \mu\text{m}$ double-recess mushroom gates. Artificial transmission lines are formed with inductor/capacitor "tee" circuits that interconnect the gate and drain lines. The



series inductors can be created with either spiral or distributed inductors from thin, high-impedance transmission lines. The shunt capacitance that is needed to complete each tee cell is provided by the gate-to-source and drain-to-source parasitic capacitances of the active devices.

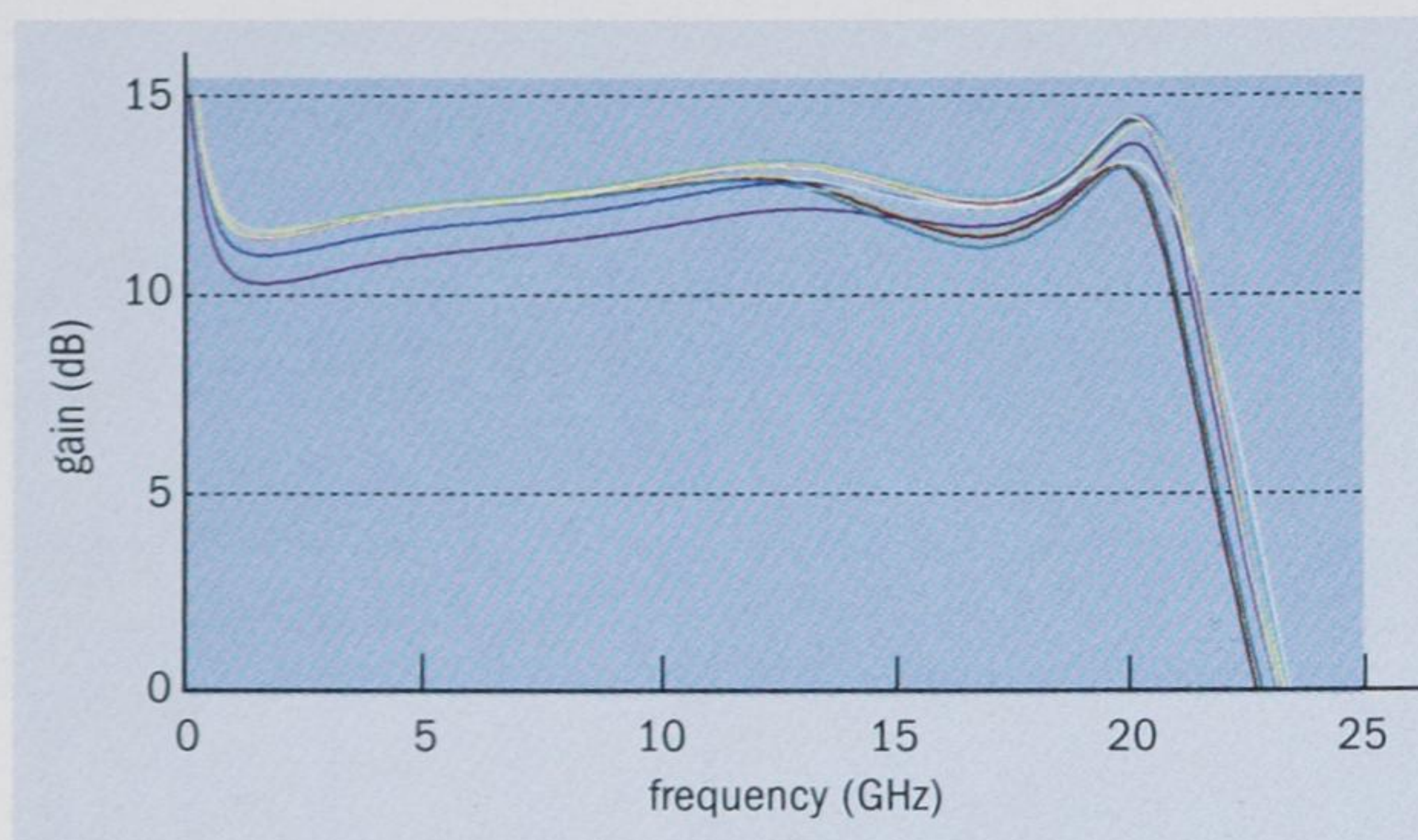


Fig. 1. Ten of ECIT's amplifiers that were produced in a single batch provide gain in excess of 10 dB between 0 and 20 GHz.

output power recorded as a function of input power (see figure 2). The phase performance of three of our amplifiers can be seen in figure 3.

The original circuits were designed without any on-chip DC blocking or bias circuitry to improve yield and minimize performance variation. However, this approach requires DC blocking capacitors to be added off-chip (see figure 4a), alongside a more complex biasing network, and leads to large modules that are not easy to assemble.

Greater integration

Because it is planar, a traveling-wave amplifier is well-suited for complete integration as a GaAs MMIC, and we have integrated all the necessary circuit components onto the die. This approach offers many advantages, including less board space, lower module cost, and a reduction in the number of solder joints. The increased integration also means that no external capacitors are required, and the external inductors that are difficult to source because they require a flat frequency response from 0.5–18 GHz can be replaced with cheaper versions that just have to block low frequencies. The level of integration has been extended even further by constructing traveling-wave MMICs with an on-chip bias network that do not require an off-chip bias "tee". This enables the first stage to directly feed the second one, eliminating the need for an interstage network (see figure 4b).

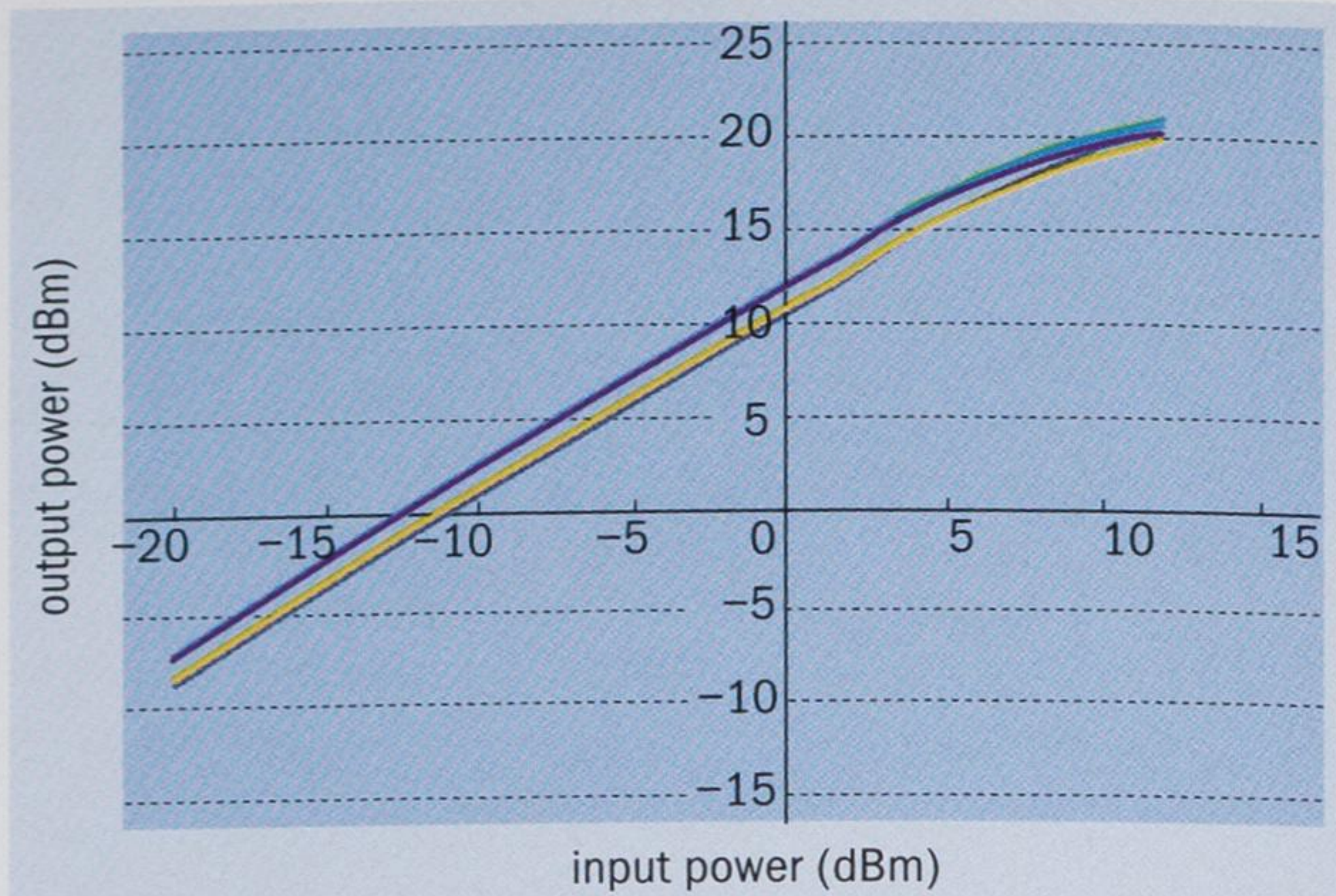


Fig. 2. A plot of output power as a function of input power, which is used to determine the 1-dB compression point, shows that the gain starts to reduce at an output power of about 17 dBm.

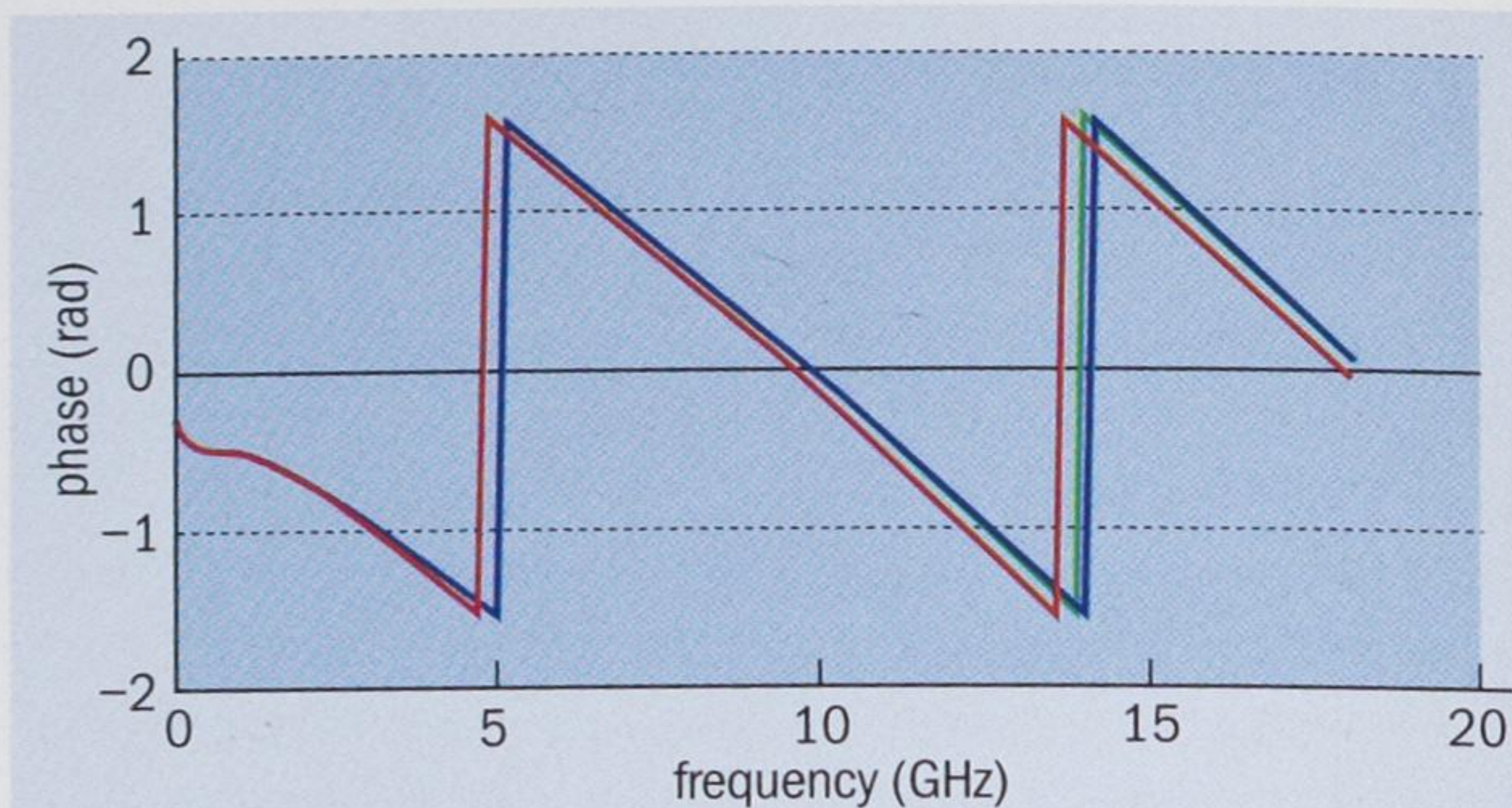


Fig. 3. The saw-tooth profile of three of ECIT's amplifiers reveals their low-phase noise performance, which is a requirement for radar, phased-array and oscilloscope applications.

We have also built traveling-wave amplifiers that do not require a negative gate bias for a non-mobile communications provider that did not have a negative voltage supply. Our MMIC made the off-chip charge pump that was used with the amplifier redundant, and cut the module size by half. The changes also introduced some downsides – a higher DC current consumption and reduced drain efficiency – but these drawbacks were not a major concern because the MMIC was powered by mains electricity.

Building on this existing experience we are now developing traveling-wave amplifier MMICs with an improved 1 dB compression point. Conventional designs are restricted by artificial transmission lines that are relatively lossy, which causes input signal strengths to decrease significantly as the signal travels along the gate line, and means that consecutive stages are driven with declining power. The consequence is that only the first few stages receive sufficient power to be driven into gain compression. Although adding further stages can increase the saturated output power, it does not improve the 1 dB compression point.

To reduce this effect we have redesigned our circuits to minimize gate line losses and have developed a traveling-wave amplifier design with a predicted 1 dB compression point of 22 dBm. This year our commercialization division plans to launch these improved devices commercially and extend the

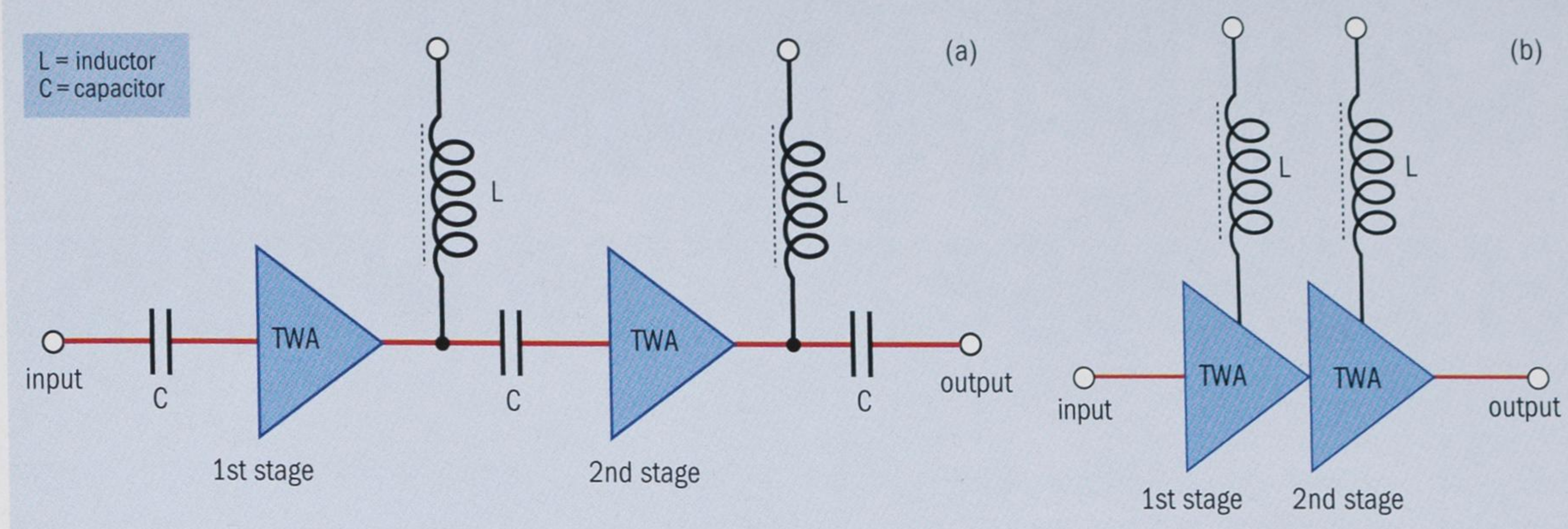


Fig. 4. ECIT's original MMICs did not feature any on-chip DC blocking or bias circuitry (a). This improved yield and minimized performance variation, but also had its downsides: a large board space; many solder joints; and the need for expensive external inductors and capacitors with a flat frequency response from 0.5–18 GHz. Many of these issues have been addressed by increasing the level of integration (b). Although this circuit still needs external inductors, lower cost versions can be used because in this configuration they only need to block low frequencies.

frequency range of our existing amplifier designs to meet customer demand.

Our development and commercialization of traveling-wave MMIC amplifiers has shown us that for certain applications these products are a better choice from a performance and manufacturing perspective than standard products, even if the dies themselves are more expensive than the off-the-shelf circuits. This is because the different characteristics of the distributed amplifier vary in their importance from application to

application, and bespoke designs can target the specific needs that they serve. It is an approach that is helped today by computer-aided design packages that enable the characteristics of a traveling-wave amplifier to be fine-tuned precisely. These factors lead us to conclude that for relatively low-volume high-performance circuits, ECIT's bespoke MMICs not only improve the amplifier's performance and reduce its size and complexity, but create a more cost-effective circuit that does not require expensive hybrid assembly steps. ●



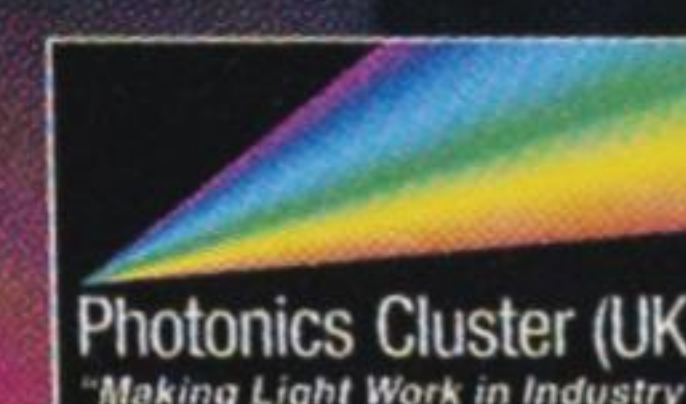
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Analysis tool helps project managers expose hidden pitfalls

Project management specialist **Tal Levanon** reveals how a new analysis tool can reduce cleanroom expansion costs at a semiconductor wafer fab by 25%.

Delivering a successful project on time and inside budget is a rewarding experience that can enhance your career. However, for many of us projects rarely turn out like this, and instead we find ourselves up against deadlines, distracted by minor issues and constantly firefighting. We also fail to foresee problems and then respond in a reactive, rather than proactive way, or allocate insufficient time for tasks, which ultimately leads to spiraling costs and missed deadlines. So, instead of improving our reputation with good project management, we end up jeopardizing our careers and being labeled as irresponsible managers with poor organizational skills.

However, the need for good project management, whether it is the installation of a new reactor, the design and assembly of a new product, or the merger of two fabs, is now greater than ever. This is because companies today need to provide more accurate estimations of project costs, face expensive contract penalties for delays, and often need to commit to new projects safe in the knowledge that current ones are not under risk. In addition, many companies form part of a supply chain, so any delays have wider implications, including the possible loss of future revenue.

Today, many projects kick-off with the creation of a project network detailing various pieces of information about each task, including its duration, cost, the resources needed, and which tasks must precede and succeed it. All this data is then put into a Gantt chart that presents all the tasks in a table and illustrates them graphically as bars according to their start and finish date. The Gantt chart contains an enormous amount of data, but extracting valuable information from it is very difficult.

This is because project networks are like icebergs – only around one-ninth is visible and so can be seen and planned for, but eight-ninths are hidden under the surface. In other words, many of the project's details are buried in its network and only rear up after the project has begun to catch us by surprise. So, in order to manage a project well, the hidden details must be exposed.

Critical and non-critical paths

Many of today's projects involve analysis of the critical path (CP), which identifies the sequence of tasks that together last the full duration of the project and present the primary risk for the project overrunning. But what about all of the other activities, and the other paths in the network? For example, in a 12 month project, a non-critical path that lasts 11.5 months is theoretically an almost critical path, but for all practical purposes it is a critical path. Until now, no attention has been given to



Project networks are like icebergs. Only around one-ninth can be seen and planned for, but eight-ninths are buried out of sight. The hidden critical paths method reveals the concealed details that would otherwise catch the company and the project team by surprise.

these “hidden critical paths” (HCPs), and they are only noticed when they expose a problem, but such surprises in real time can prevent a project hitting its deadline.

The new method for project network analysis – the patent-pending HCP method – identifies both the CP and HCP. It provides the project manager with several tools to handle the project by exposing the various difficulties that can occur along the way. The first is the HCP score, which reflects the project's complexity and robustness, and is calculated from the project network. The score ranges between 1 and 0. A project with just one CP and nothing else is the least robust, and receives a score of 1. If a project consists of many HCPs, which each have a large slack time, then the score will be low, indicating a stable project. So, if your project has a HCP score of, say, 0.94, you can conclude that it's high risk and the chances to complete it on time, on budget, and on spec are low.

Although this analysis reveals that delays to various tasks could prevent your project running on time, at least you are in a good position to limit the damage. For example, you can show the results to your manage-

Case study: putting HCP into practice

MAX International Engineering Group, a global engineering consultancy for the semiconductor and compound semiconductor industries, is based in Closter, NJ, and won a factory expansion contract for a US silicon wafer fabrication facility. The project had three key parts: the design and building of a 10,000 sq. ft. cleanroom for a new product line; the installation of capital equipment and its qualification; and finally the initial production.

The project contained 165 tasks and 189 connections, began on August 6, 2004, and was scheduled to end by May 11, 2005. The MAX team onsite requested hidden critical paths (HCPs) analysis on October 8, 2004, two months after the project had begun. This analysis, which took three days, uncovered 46 paths with a slack of 0–20% of the project's total length. Those paths included two critical paths, two HCPs with two days of slack, two HCPs with 3.2 days of slack and one HCP with 5.3 days of slack. The HCP score was 0.72, indicating that the overall project network was not particularly robust.

The HCP analysis exposed important findings that could not be determined by any other form of



analysis. For example, it revealed that while the scheduled project duration was 198.7 days, the actual duration was only 173.1 days. In other words, 25.6 work days had no work scheduled. Most of these were lost in the first two months, before HCP analysis was used, but there was also one future task that caused an unaccountable four work-day delay. In addition, the analysis uncovered a future HCP that had 5.3 days of slack.

By acting on the information provided by the HCP analysis, the project was completed three

weeks ahead of time. Financially, it was also a great success, as the \$250,000 contingency budget was untouched, and the project's total cost was \$1.8 million, \$0.7 million below budget.

Some will argue that a proportion of the budget was saved due to its early finish, while it can also be claimed that the success was driven by a talented project manager. Although both views are valid, MAX's seasoned project manager commented that "the HCP is a very powerful tool for project managers".

ment, convince them that there is a problem, and suggest taking action that generates additional time, such as delaying customer shipments. You can also redistribute your resources more effectively, because the analysis can highlight exactly where and when additional resource is required. The HCP approach can also drive a task reorganization, either in terms of running order or priority, or the breaking down of lengthy tasks into more manageable ones.

The HCP method can also expose all the hidden critical tasks within the project network that risk its completion. Until now the standard approach to uncovering a project's risks consisted of organizing a meeting involving everyone in the project, and encouraging each participant to outline their concerns regarding issues that could cause the project to miss its deadline. This would then be followed by a risk-control methodology. However, by using this HCP tasks list, there is no need to guess all the points of risk, as they are easily found. Once they are exposed, a risk-control methodology can be carried out to minimize any potential delays.

In addition, the HCP tasks list allows project managers to determine the "red warning lights" for the project's hidden critical resources. For example, the method can uncover a HCP task on a path with five days of slack that has a hidden critical resource – can we replace the person performing this task within five days? Or, if this task requires an expensive resource, but management delays its acquisition, the HCP analysis can show that because there are only five days of slack on the whole path, dragging the decision by more than that time can risk the whole project!

A further advantage of the HCP method is that it can locate days that have no work allocated to them. By acting on this information, time can be sliced off the project and money saved. This situation is not uncommon in big project networks. It can also identify tasks that have a relatively long duration. These "long duration" tasks are shown to the project manager, who determines whether they should be left or broken into shorter tasks. Long-duration tasks have specific difficulties associated with them as they are difficult to monitor.

The HCP method's primary strength is its ability to predict the likelihood of a project's success – on time, on spec and on budget. This calculation is based on the project network and its findings, which were previously hidden. This analysis provides upper management and project entrepreneurs with the ability to rapidly assess all their projects and drill down quickly and simply to the key problems – both the obvious and the hidden.

Project management companies and their subcontractors can use the HCP method to identify all the expected and unexpected obstacles they will face before they occur. Problems can then be addressed shoulder-to-shoulder, and solved ahead of time, rather than getting a nasty surprise when it is too late, and apportioning blame. Using these methods helps companies to build trust and form good relationships with contractors.

In addition, HCP analysis provides project managers with the opportunity to control projects in a new way. Instead of constantly firefighting, events can be controlled and problems foreseen. This can save employers a lot of time and money, and help to breed success through proficient, organized project management. ●



About the author

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CHARACTERIZATION

Electroluminescence mapping tool accelerates LED development

MaxMile Technologies has launched the first non-destructive electroluminescence mapper for unprocessed LED epiwafers. The tool is claimed to offer quick feedback that can speed LED development and improve quality control. **Richard Stevenson** investigates.

LED manufacturing usually involves optical measurements of epiwafers at various stages of production. Photoluminescence is frequently used after epitaxial growth to obtain a quick assessment of the optical properties of the material, while electroluminescence characterization is usually only carried out after full device fabrication.

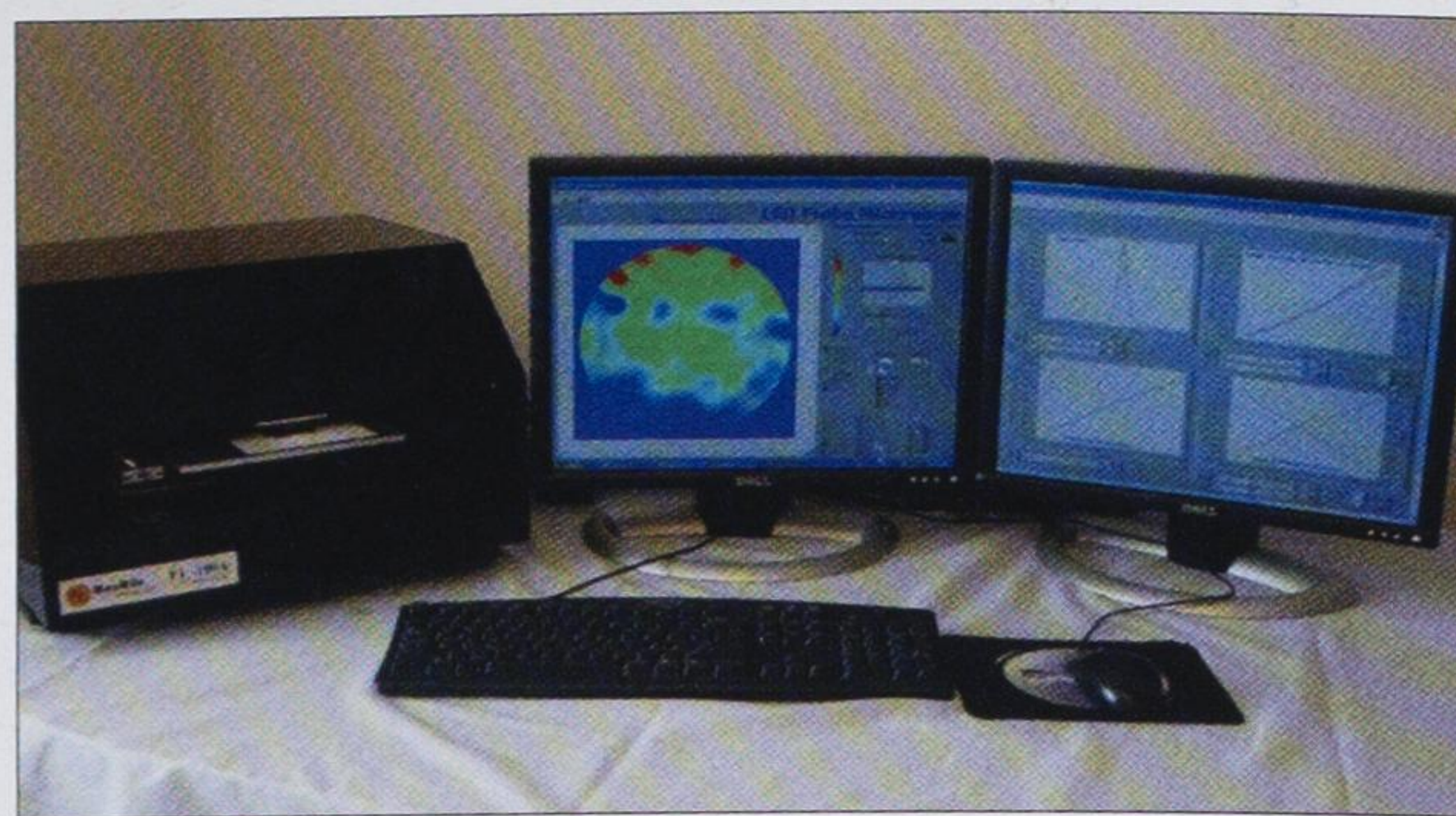
This approach has several downsides, though, because these two optical measurements involve different physical mechanisms and produce different spectra. Photoluminescence is governed by the material's optical properties, but electroluminescence also depends on the physical structure of the layers, the electrical properties of their doped regions, and the properties of the electrical contacts.

The difference between the two spectra has several consequences. For example, it means that a measurement of the photoluminescence spectrum cannot directly predict the electroluminescence peak – in fact, for green LEDs the top contact can produce a significant wavelength shift in the photoluminescence. The difference also suggests that photoluminescence data should not be used to optimize device performance, and explains why epiwafers with high photoluminescence efficiency may not actually lead to devices with good electroluminescence characteristics.

Addressing the need for a tool that can provide epiwafer measurements is MaxMile Technologies, a characterization start-up headquartered in Lexington, SC, that has just released the first instrument that can provide electroluminescence mapping of as-grown LED epiwafers. This feature differentiates the tool from other LED wafer testing instruments such as the "BlueRay" system being developed by Suss MicroTec, which can only map the characteristics of LED die.

MaxMile's chief research scientist Max Ma revealed that it is the company's probe technology that has enabled it to make electroluminescence measurements on as-grown epiwafers. The instrument operates by using a metallic probe with a relatively large tip to form an LED in the epiwafer, which avoids any physical damage to the material as the tip is not sharp enough to scratch the surface. The probe's low current of 100 μ A also prevents damage due to device heating, says Ma, although it does result in a small offset compared with the packaged LED's emission peak wavelength, which is due to the differences in current density and operating temperature.

"We came to this idea from the research perspective, where we felt there was a need for a tool that can quickly determine device performance," explained Ma. The tool enables fast, non-destructive measurements of the epi-



MaxMile's EL-100 uses a metallic probe to form an LED in the epiwafer. It can record the electroluminescence spectra at specific currents and voltages, the current or emission intensity as a function of voltage, and the output intensity's dependence on driving current.

wafer's electroluminescence, which can speed device development and lower the associated costs.

Volume LED manufacturers can also benefit from the rapid acquisition of electroluminescence data because they can use this information to optimize growth. This is not the only benefit the instrument can bring to the fab, though, says Ma, because it can also be used to streamline LED production by screening material immediately after it comes out of the reactor. The electroluminescence efficiency of a new LED design can even be predicted once an epiwafer featuring that design has been fully processed, as the data can provide a form of calibration. This reference data is required because the detected emission intensity can be influenced by various factors, including the type of substrate and whether it is polished.

The instrument can map various characteristics of 2, 3 and 4 inch epiwafers, and can complete four electrical or optical measurements on 100 sampling points in 10 minutes. It can determine the external quantum efficiency of the LED formed in the epiwafer, and its peak wavelength and total emission intensity. Other forms of LED characterization are also possible, such as the electroluminescence spectra at specific currents or voltages, and the device's current-voltage behavior and peak emission wavelength at various drive currents.

MaxMile's first instrument in the range, the EL-100, is available with either an ultraviolet-visible or visible-infrared detector, making it suitable for all forms of LED. In the coming months the company will also launch two other versions of the instrument, an EL-300, which can provide photoluminescence spectra, and an EL-500, which is capable of detecting diode currents as low as 1 pA, six orders of magnitude below the detection capability of the EL-100.

"There was a need for a tool that can quickly determine device performance."

Max Ma
MaxMile Technologies



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Chip makers and lighting specialists get switched on to new possibilities

The manufacturers of high-brightness LEDs and their customers in the general lighting industry now seem to be on the same wavelength, discovers **Michael Hatcher**.

Penetrating applications outside the mobile phone handset is no longer simply desirable for makers of high-brightness LEDs – it has become absolutely critical to ensure profitable growth.

Any doubts some may have held about that fact would have been dispelled by industry analyst Bob Steele at February's Strategies in Light conference in San Francisco. In his annual review and forecast of the HB-LED business, Steele declared that the recent rapid growth seen in the mobile applications sector had finally run out of steam.

In fact, for the first time since the dawn of the cell phone, sales of LEDs into this market sector fell slightly to \$2.1 billion in 2005. A much bigger drop was only averted because many more cell phones were shipped last year than was originally expected. Since the entire HB-LED market is valued at just under \$4 billion, it presents chip manufacturers, especially makers of GaN-based white devices, with a bit of a dilemma. While the still-huge mobile sector cannot be ignored, the falling prices of most white LEDs means that it will no longer generate meaningful revenue growth.

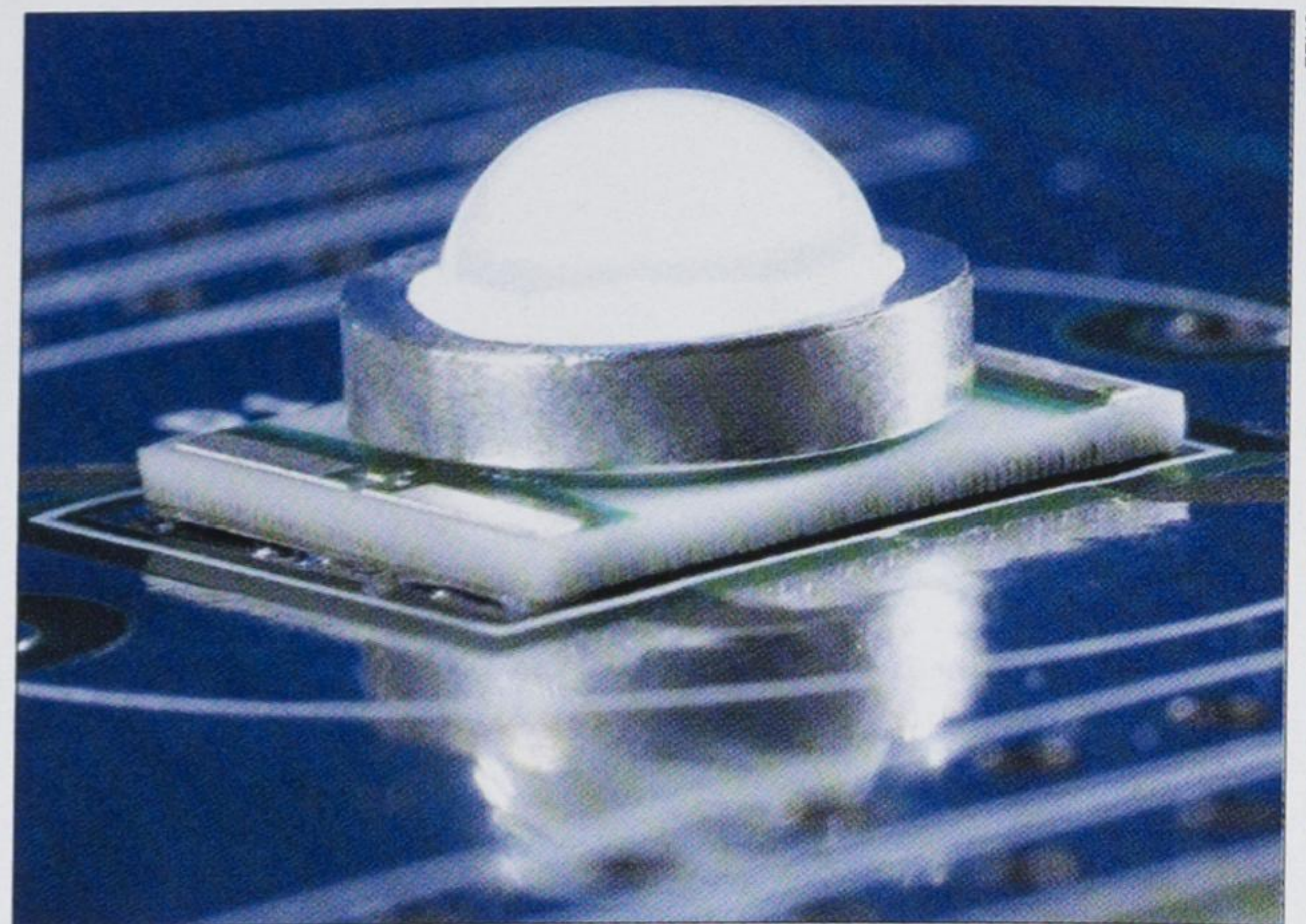
It is time to think beyond mobile phones, then. And that message was exactly the focus of this year's Strategies in Light. In the short term, it will likely be backlighting of large LCD screens that provides a new engine of growth for HB-LEDs of every hue, with automotive headlights likely to present a sizeable market for high-power white emitters beginning in the second half of next year.

But the fastest growing sector in Steele's analysis was illumination, which now represents a \$250 million annual market for packaged HB-LEDs. Though dwarfed by the mobile sector, illumination offers much better profit margins for the cutting-edge chip makers, and Steele reckons that its value will quadruple by 2010.

Culture clash

One of the problems in solid-state lighting (SSL) has been that the makers of HB-LEDs and their potential customers in general lighting have not really been on the same wavelength. However, this communication problem is now showing signs of being overcome.

At the San Francisco conference, Niels Haverkorn from Philips Lighting described the chip and lighting



Cree's XLamp 7090 warm-white LEDs are being used by Permlight Products in residential lighting products. The chip manufacturer believes that its 1 W devices offer the best "sweet spot" combination of total light output, efficacy and heat management.

communities as being at the "shaking hands and meeting" stage. Leonard Hordyk from TIR Systems, a Canadian lighting company that has focused on solid-state illumination in recent years, described two separate industries with different priorities: "The SSL industry is technology-focused, whereas the general lighting industry is application-focused."

Part of that distinction is the different view of technological innovation, necessary though it is. In the LED chip world this innovation is regarded as critically important, as the efficiency of new devices and the cost of each emitted lumen is pushed to the limit. In the lighting industry's view, such innovation can be a double-edged sword, however: "The semiconductor [innovation] life-cycle is very, very short," explained Hordyk, contrasting the 'cutting-edge-to-obsolescence-in-two-years' world of Moore's Law with the much longer life-cycle inherent to lighting. "Whereas we [the lighting industry] want the same components to be available in 10 or 15 years' time. The challenge is to bridge that gap."

Where lighting is focused on industry standards, long product cycles, standard color temperatures and light distribution, the LED industry is more familiar with proprietary standards, short product life-cycles and limited color and light distribution. So says Hordyk, although he is confident about future progress: "Over the next five years, we will be surprised by the number of applications enabled by SSL."

Now in full control of Lumileds Lighting, Philips is a critical player with a big foot in each side of the indus-



COLOR KINETICS/PERMLIGHT

Restricted mainly to special lighting projects and colored installations until now, white LEDs are beginning to feature in some high-end residential applications. This dining room in a Mexico City home features warm-white LED lighting installed by the US firm Color Kinetics, while (inset) Cree's XLamp 7090 products are used in lighting applications such as this Californian garage by Permlight Products. Permlight also uses Nichia LEDs in residential applications, specifically for downlighting.

try. Its current vision for SSL is to exploit the characteristics of LEDs in a way that adds extra atmosphere or "ambience" to the normal lighting experience – for example in the retail sector by responding to the likely mood of shoppers throughout the day by changing the light accordingly. Philips is also a big player in the medical industry, and hospitals are another environment where Haverkorn sees this kind of mood-altering light as a major application area.

Both of these applications could be seen as special projects outside of the more general residential illumination sector, and Haverkorn expects five more years of this type of activity before SSL moves into general use through what he described as the "unprecedented paradigm shift" offered by LEDs – a development in an industry that is simply not used to such rapid change.

Even when that does happen, the HB-LED industry should not view its produce as a replacement for the light bulb. "SSL will have a huge impact, but the light bulb won't go away," commented Haverkorn. "After all, people still buy candles over a century after the bulb was invented."

Haverkorn and Hordyk both see the tunability of white-light illumination as perhaps the key attribute that will allow it to make an impact in the home. At Strategies in Light, Hordyk demonstrated the power of tunable white light using TIR's 1000 lm LEXEL SS lighting system. Unlike conventional illumination, where the color temperature of the light source changes when the lamp is dimmed, the tunability of TIR's system means that the color temperature can be maintained independent of brightness, thanks to a feedback mechanism. Alternatively, the color temperature can be tuned according to preference over the course of the day and night.

Compared with recent years, the Strategies in Light meeting was less focused on laboratory-based chip innovation, with a greater emphasis on production devices, standards, test procedures and calibration. Though subtle, the change may indicate a maturation of the SSL business. Undeniably important though the lm/W metric is, many other factors come into play with the subtleties of general lighting, a fact that Haverkorn was keen to stress. His view is that there is no real lm/W "tipping point" at which SSL suddenly becomes viable, because there are so many other factors that contribute to illumination.

While Cree, Nichia and Lumileds have all been keenly promoting their latest progress recently, their emphasis has been on production devices rather than any "hero" results from the laboratory. Lumileds launched its latest high-power (around 3 W) K2 LEDs in late January. The white versions of K2 emit up to 140 lm, and Lumileds' SSL offering is now based around these devices.

Meanwhile, Nichia has developed a 100 lm/W efficacy lamp based around its 6 lm output devices that operate at 20 mA, and plans to begin volume manufacturing of these small chips later this year. Having reached the milestone earlier than expected, Nichia has adjusted its technology roadmap and now plans to pass 150 lm/W in 2007.

Hitting the sweet spot

Nichia's US rival Cree has made similarly high-efficiency devices in the laboratory, but is focusing on mid-power designs when it comes to general lighting applications. According to Cree's Mark McClear, it is the 1 W devices that offer the "sweet spot" combination of good lm/W efficacy, overall brightness and manageable thermal

"Now is the time for LED systems to illuminate our homes."

Jim Decker
Progress Lighting

"The SSL industry is technology-focused, whereas the general lighting industry is application-focused."

Leonard Hordyk
TIR Systems

effects: "350 mA (1 W) is the optimal drive current for light output, power dissipation and the overall cost and complexity of the design," said McClear. Rather than record laboratory results for LED chip efficacy, Cree has instead talked up its production XLamp packaged devices, which produce 47 lm/W at 350 mA.

Although Cree's view of the "sweet spot" was not shared by everyone at the February conference, it does appear that the company is finding some success with the approach. For example, its 1 W XLamp products are now featuring in a range of residential luminaires made by the lighting specialist Permlight Products. The Permlight "Embryten" fixtures are designed for use in hallways, stairwells and bathrooms, and come with a consumer-friendly price tag.

Permlight buys both Nichia and Cree chips for its luminaires, but because of subtle differences in the white colors produced, it uses them for different types of applications in the home. Cree's XLamps feature in lamps used to illuminate floors, stairs and counters, whereas products incorporating Nichia chips are used in ceiling lights because the warmer white color from the Japanese company is said to work better with natural skin tones.

Unsurprisingly, California is at the cutting edge of residential SSL, with high-end homebuilders now incorporating LED lighting into new-build houses as a matter of course. Permlight's Fernando Lynch says that all types of LED fixture – interior and exterior – are now

available. He thinks that SSL has passed the "litmus test" already, offering those who install the products a pay-back time of just 24 months on reduced energy bills.

Progress Lighting – one of the leading residential lighting companies in the US – agrees. It is launching a range of LED-powered products featuring Cree and Nichia chips this summer. "Now is the time for LED systems to illuminate our homes – not two to five years from now," says Jim Decker, vice-president of brand management at Progress.

Some new state laws could also help that penetration. Title 24 in California dictates that up to 50% of the lighting in new homes must come from high-efficacy sources such as LEDs and halogen lamps. Even more recently, the title 22 law on hazardous waste has added further LED-friendly restrictions by outlawing unauthorized dumping of mercury-containing fluorescent lamps.

With the respective priorities of the lighting and LED industries now becoming clearer, the future manufacturing supply chain of SSL is becoming more defined. Communication between the two is clearly an essential part of that process. Bill Kennedy from GaN LED specialist Toyoda Gosei is one of many to have issued a rallying call for interested parties to join the SSL section of the National Electrical Manufacturers Association industry group to ensure that the improved communication throughout the supply chain continues. ●

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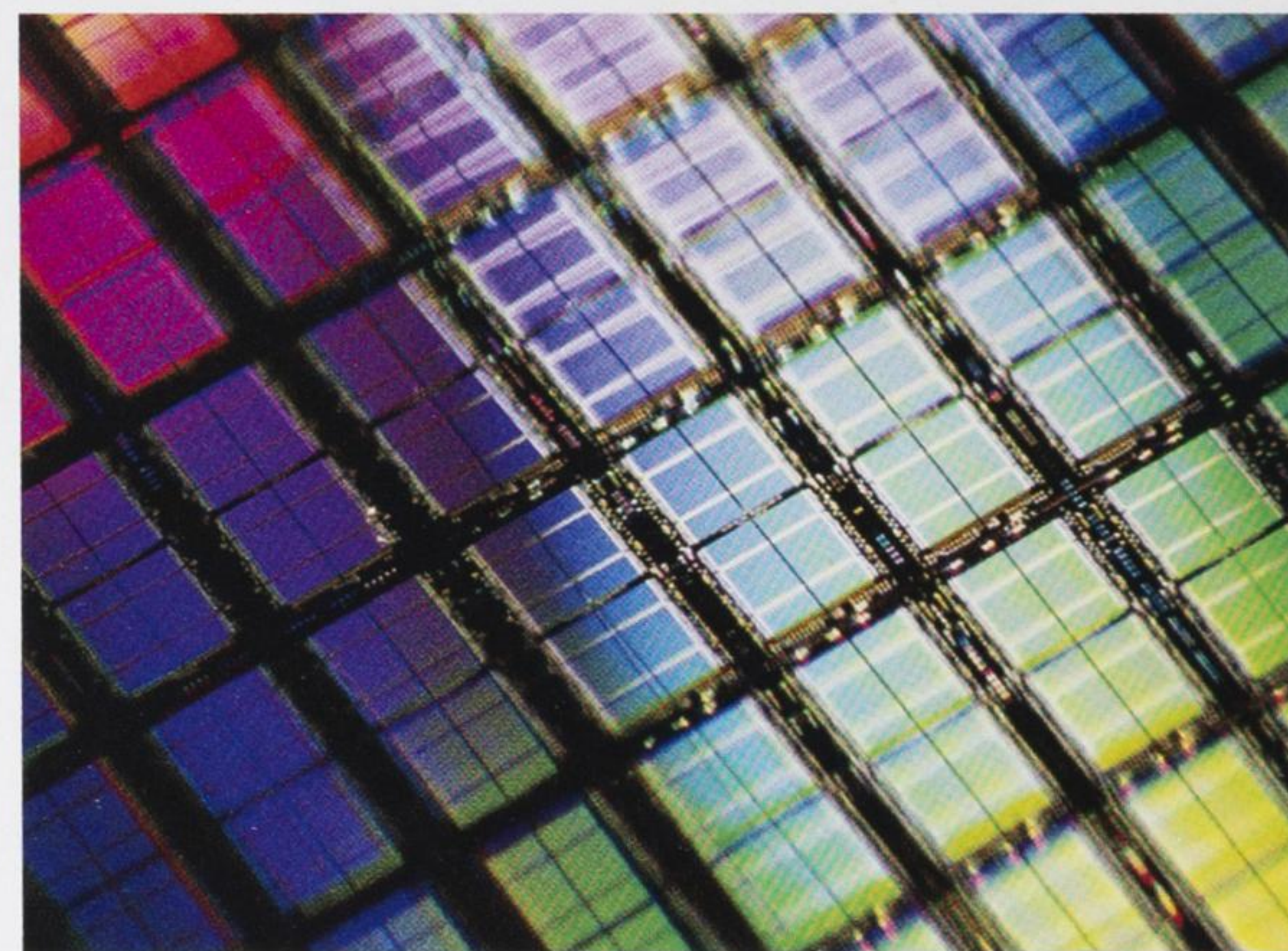


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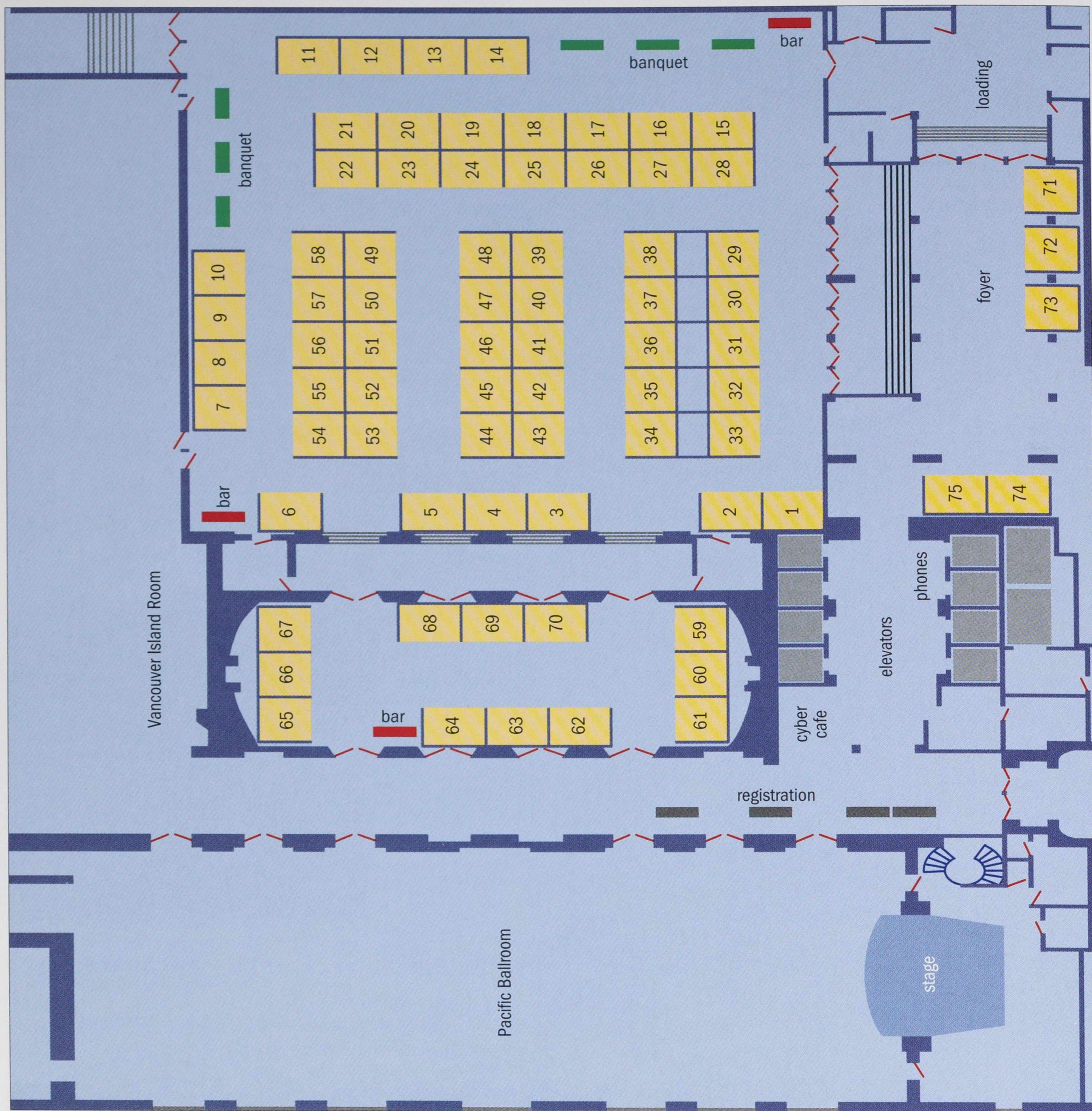
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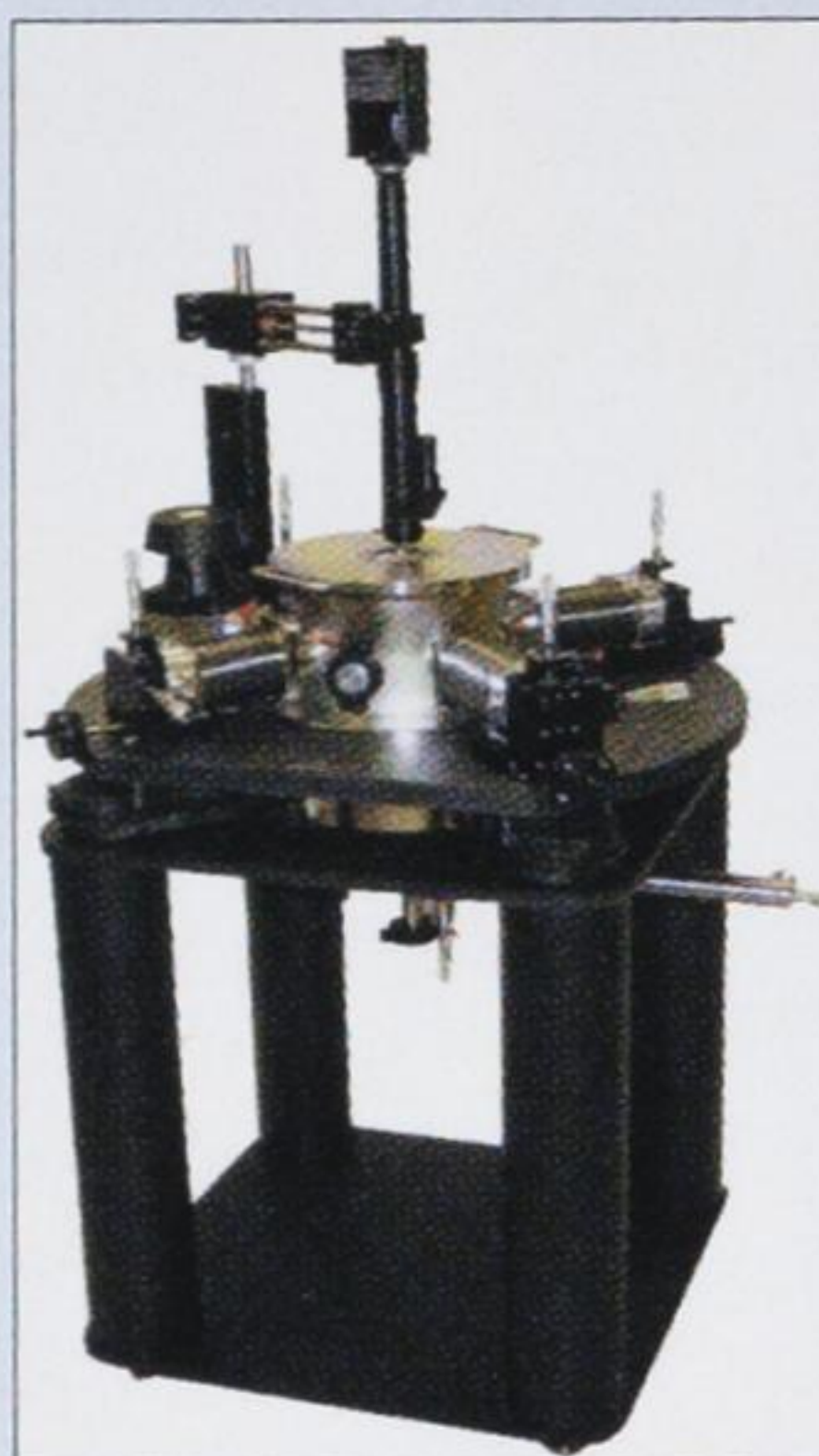


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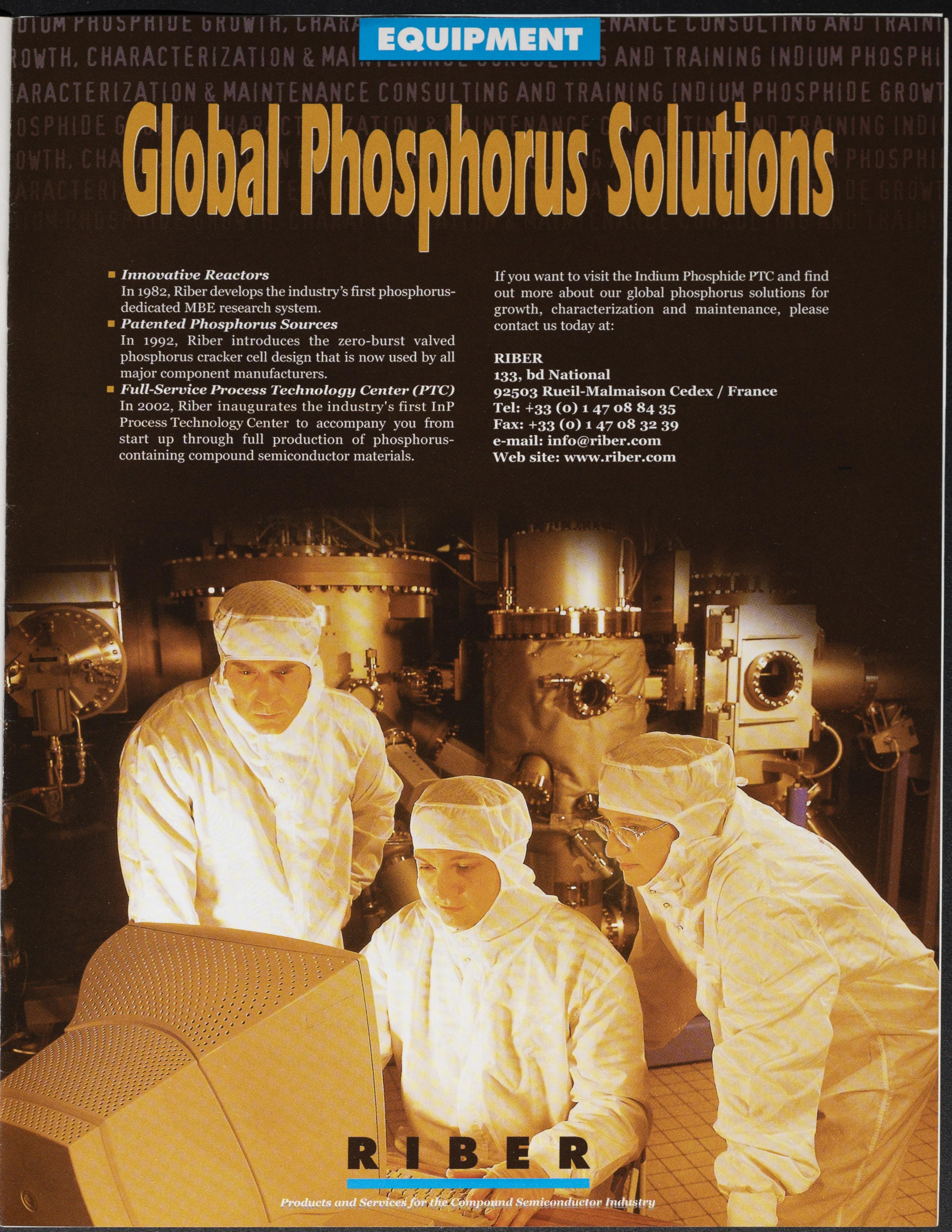
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Stanford's C-band VCSELs provide cheaper alternative for networks

Researchers from Stanford University claim to have produced the first electrically pumped dilute-nitride VCSEL emitting in the C-band (1530–1560 nm).

The team says that its lasers could benefit local and metro-area networks that have been hampered by a lack of inexpensive lasers. The dilute-nitride lasers are cheaper to fabricate than their InP-based counterparts deployed in existing networks, because they are grown on lower cost GaAs substrates.

The researchers also held the previous record for long-wavelength electrically injected VCSELs of 1460 nm. The emission wavelength was extended, explained team-

member Mark Wistey, by increasing the nitrogen content in the active region while ensuring that the material did not phase-segregate.

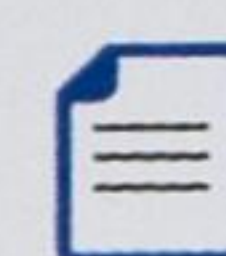
The Stanford team's laser was grown by MBE on an n-doped substrate and featured three 7.5 nm thick $\text{Ga}_{0.62}\text{In}_{0.38}\text{N}_{0.03}\text{As}_{0.94}\text{Sb}_{0.03}$ quantum wells surrounded by 21 nm thick $\text{GaInN}_{0.04}\text{As}_{0.96}$ barriers and a 14 μm diameter aperture. The VCSEL emitted at 1534 nm under operating conditions of -48°C , a drive current of 110 mA and a 0.67% duty cycle.

At room temperature the spontaneous emission from the device peaked at 1585 nm, which didn't match the cavity dimensions that were designed for lasing at 1540 nm. The redshift

was unintentional, but consistent with other samples grown on the same day.

Cooling of the VCSEL was seen to reduce the emission wavelength. Lasing started at -25°C and was most intense at -50°C , the limit of the cooling apparatus.

Wistey says that the group's GaInNAsSb VCSELs should soon be delivering continuous-wave emission at room temperature, based on the low threshold currents and relative temperature insensitivity of broad-area lasers produced at Stanford and elsewhere.

**Journal reference**

M Wistey et al. 2006 *Electron. Lett.* **42** 282.

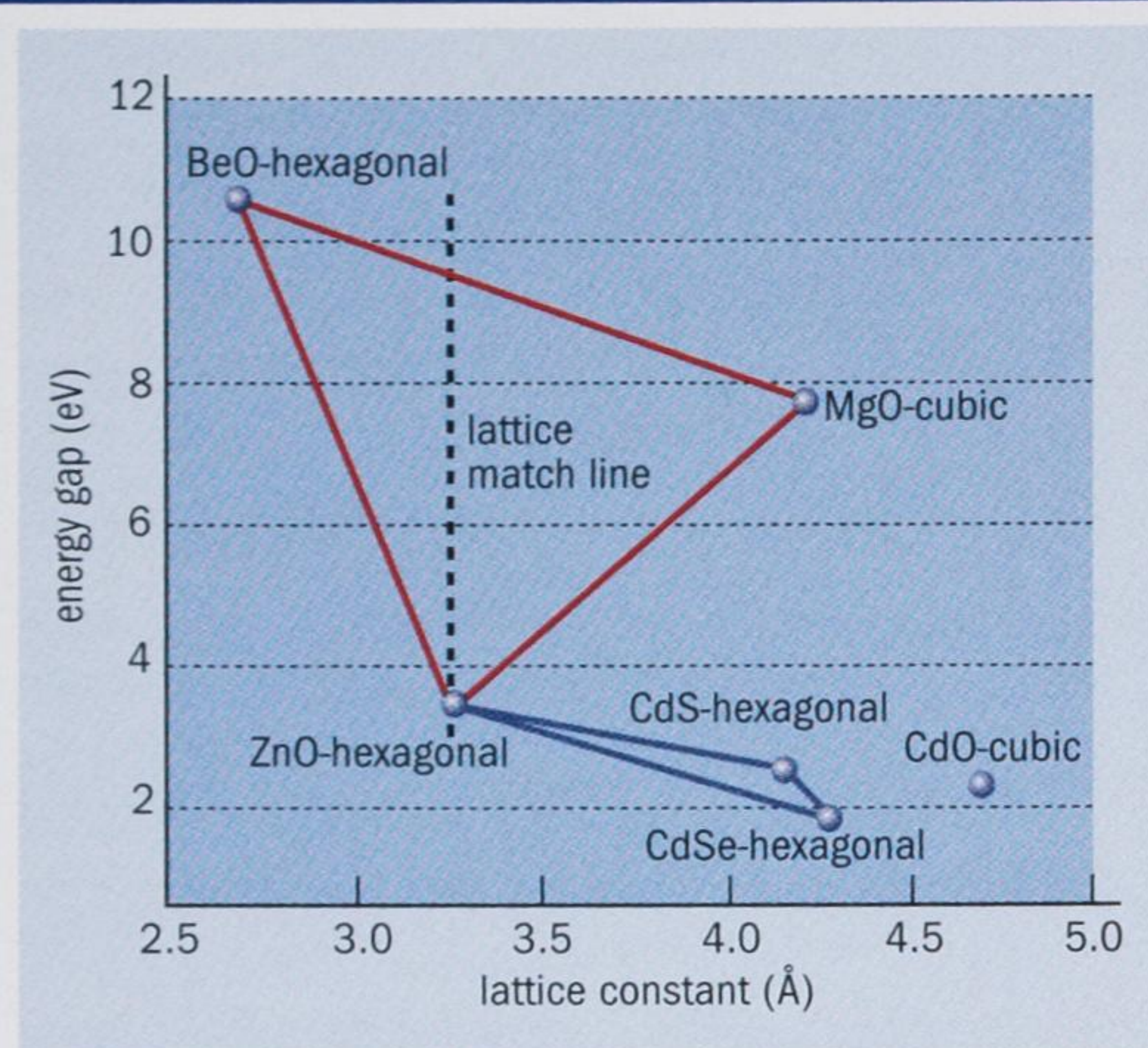
WIDE-BANDGAP ALLOYS

BeZnO films suggest improved devices

High-efficiency ZnO device development has been hampered by a lack of suitable wider bandgap materials, which are needed in order to form the barriers for quantum wells and superlattices.

But that could be set to change thanks to a US–Korea collaboration that has grown the first BeZnO films. The team says that this material is better suited to ZnO devices than the previous candidate, MgZnO, because BeZnO does not phase-segregate into two separate alloys.

The collaboration comprised MOXtronics and the University of Missouri in the US, and Seoul National University, Jeonbuk National University, Changwon National University and Moxtronix (a separate com-



BeZnO has a wider bandgap than ZnO, and is suitable for the barriers in ZnO-based quantum wells and superlattices.

pany) in Korea. They fabricated 0.3–0.5 μm thick films of BeZnO on sapphire substrates using a hybrid beam-deposition technique involving polycrystalline ZnO, radical oxygen

and beryllium sources.

Using a spectrometer to measure their alloy's transmission characteristics at room temperature, the researchers deduced that the BeZnO bandgap can be tuned from 3.3 to 10.6 eV. X-ray diffraction measurements of various films showed that the alloy does not phase-segregate into ZnO and BeO.

Researcher Yungryel Ryu from MOXtronics (the US firm) said that the team has not measured BeZnO's surface roughness, but suggested that mirror-like smoothness would have a surface roughness of less than 1% of the film's thickness.

Ryu also revealed that the collaboration has made recent progress in incorporating the BeZnO films into devices. These include various ZnO/BeZnO heterostructures featuring single or multiple quantum wells, including ultraviolet LEDs.

**Journal reference**

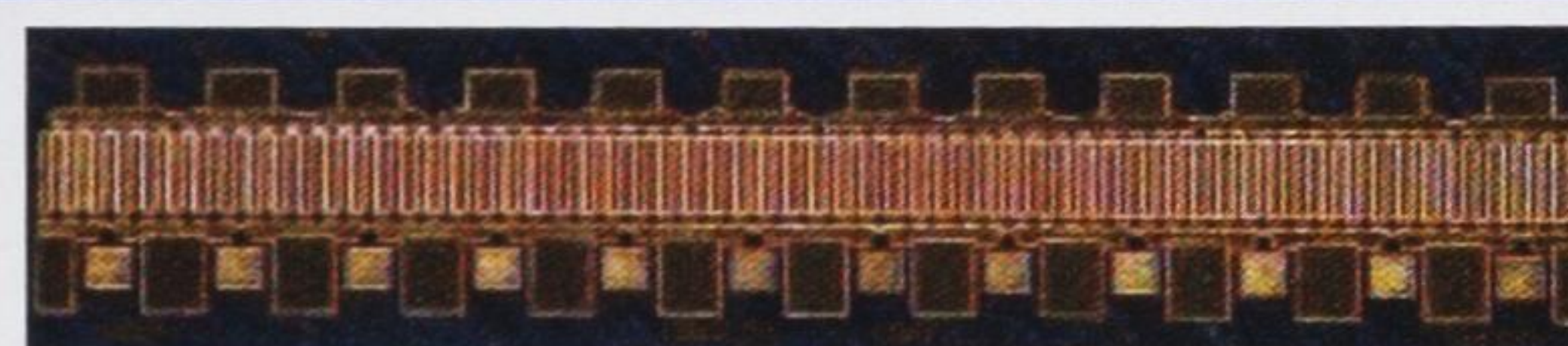
Y Ryu 2006 *Appl. Phys. Lett.* **88** 052103.

GAN FETs

Amplifier delivers record power at 5 GHz

Next-generation mobile and satellite communication is set to benefit from the record output power of a solid-state amplifier built by NEC Corporation that features high-efficiency GaN field-effect transistors (FETs).

The high-power amplifier, which was fabricated at NEC's research labs in Japan, is suitable for fixed point-to-point access systems



NEC's record power-output amplifier is formed from 12 cells containing 10 GaN FETs built on SiC substrates.

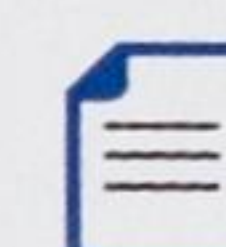
and can produce a continuous-wave output of 100 W and a pulsed output of 155 W.

The amplifier is formed from AlGaN/GaN FETs that feature field plates and a recessed gate structure, and have a gate length and a gate-drain spacing of 0.5 and 3.5 μm , respectively.

To generate the high-power performance,

sets of 10 FETs are arranged together to form a "cell" with an input port and an output port. Twelve of these cells are connected together to produce the amplifier, which has a total gate width of 24 mm.

The record continuous-wave output was delivered with a power-added efficiency of 31% at a 56 V drain bias. A slightly lower gate bias of 50 V was used to produce the 155 W pulsed output using a 10 μs pulse width and a 1% duty cycle.

**Journal reference**

Y Okamoto 2006 *Electron. Lett.* **42** 283.



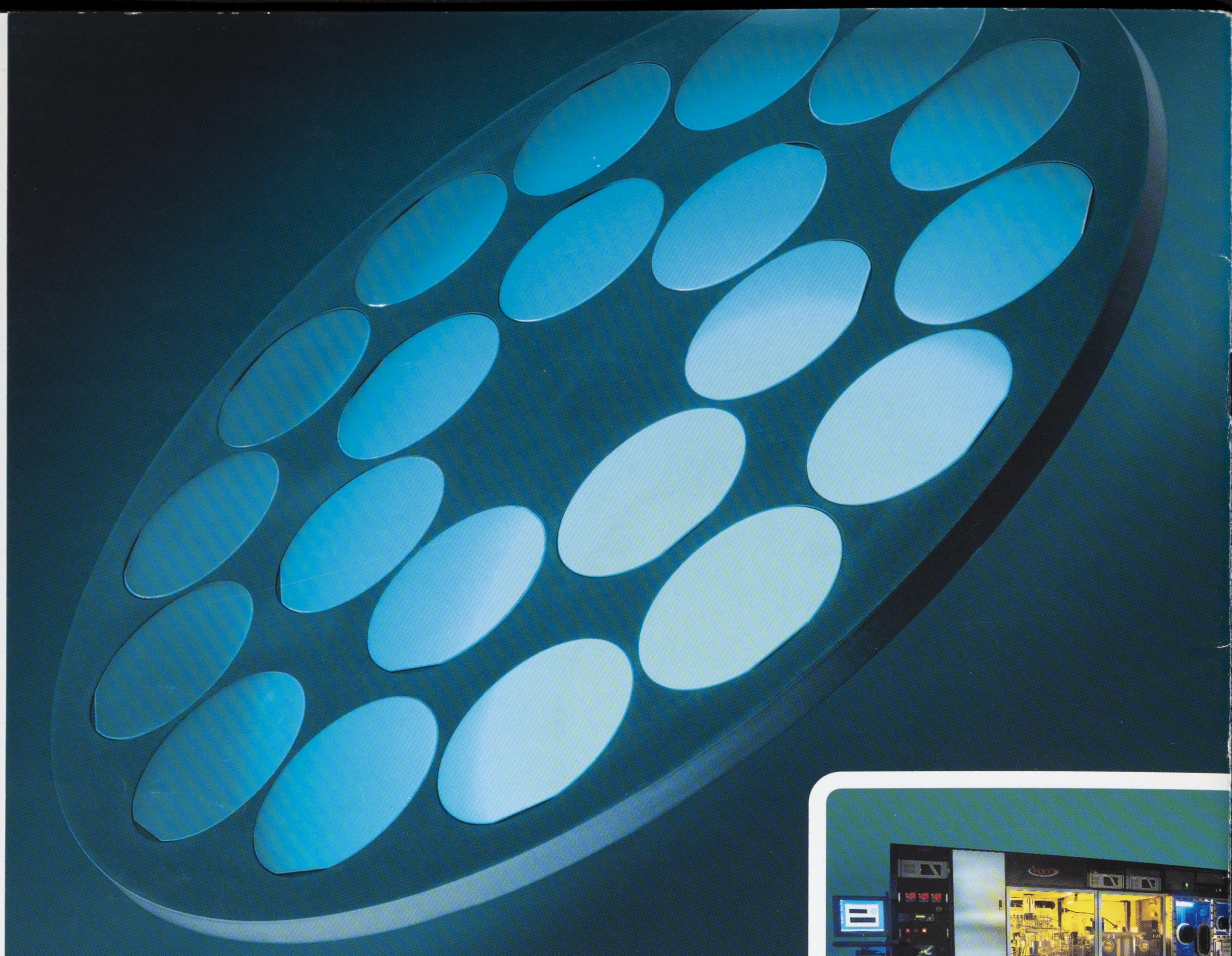
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