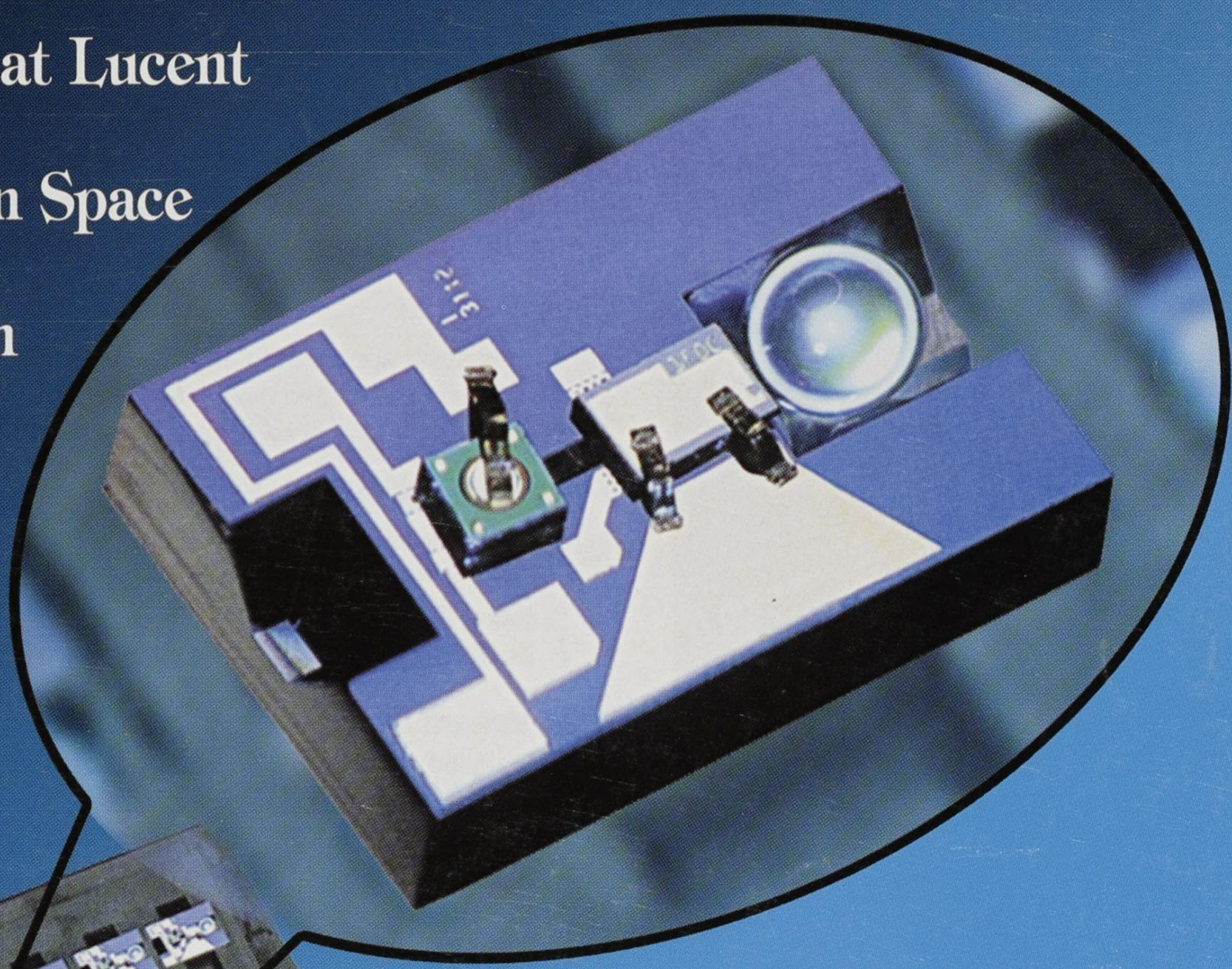


COMPOUND SEMICONDUCTOR

Fall I - October, 1998 *Volume 4 Number 7*

Semiconductor Lasers

- Laser 2000 Manufacturing at Lucent
- Diode Lasers in Space
- Polaroid's High Power Lasers



Also in this Issue:

- Thermophotovoltaics
- IBM's New SOI Process
- First Half Earnings From Publicly Traded Companies



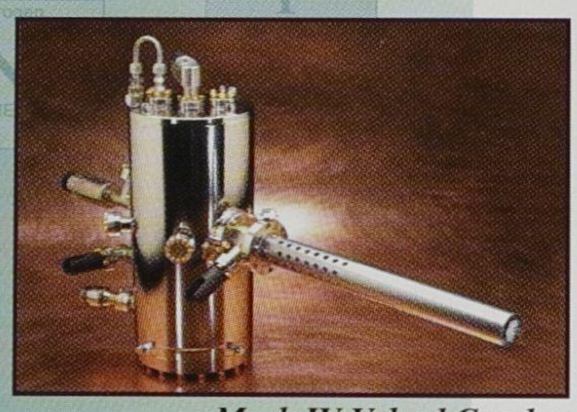
Aluminum SUMO™ Source
Patented



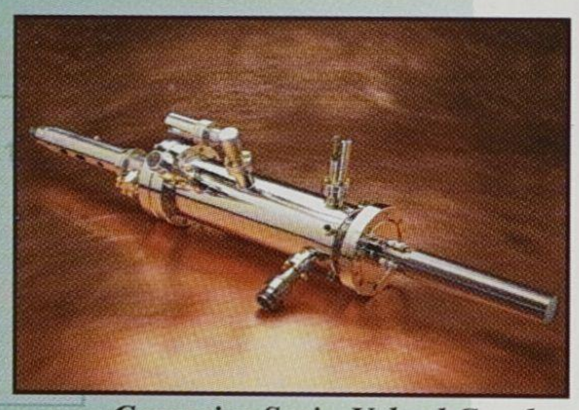
UNI-Bulb™ RF Plasma Source
Patented



Valved Cracker for Arsenic
Patented



Mark IV Valved Cracker for Phosphorus
Patented



Corrosive SeriesValved Cracker
Patented



Production Effusion Cells for Multiwafer MBE

EPI *MBE Products Group*

High performance components to make the most of your MBE system

For over a decade, EPI has led the MBE industry in offering innovative designs and breakthrough technologies specifically to enhance and optimize the performance of new and existing MBE systems. Ongoing development programs continually enhance existing products as well as create new products to meet the increasing demands of the compound semiconductor research and production marketplace.

Since each element has unique evaporation characteristics, EPI designs effusion cells, crackers, and valved crackers that are specifically tailored to optimize the performance of any MBE system. Examples of EPI's technological advancements include:

SUMO™

This novel approach to effusion cell design enhances material quality by reducing Ga related oval defects while increasing useful capacity which allows users to maximize system up-time.

UNI-Bulb™

The leak-free, one-piece PBN bulb, in conjunction with the water-cooled coaxial RF coil, provides the most efficient RF Source for nitrogen available today. Previous problems associated with low GaN growth rates in MBE have been addressed with demonstrated results of 1.0 µm/hr.

Valved Crackers

Installed in the most reputable universities, research labs, and production epi facilities worldwide and are considered to be the industry standard. Valved crackers are utilized by users who need precise group V control in the demanding area of GaInAsP quaternary growth. In addition, users benefit from the ease of calibration and large useful capacity.

Corrosive Series Valved Cracker

Designed specifically for corrosive elements such as antimony and tellurium. The novel PBN crucible and valve mechanism has proven to provide the capabilities to grow complex structures not previously possible with conventional sources.

Please contact EPI to discuss your growth and deposition needs.

Visit the EPI web site at http://www.epimbe.com

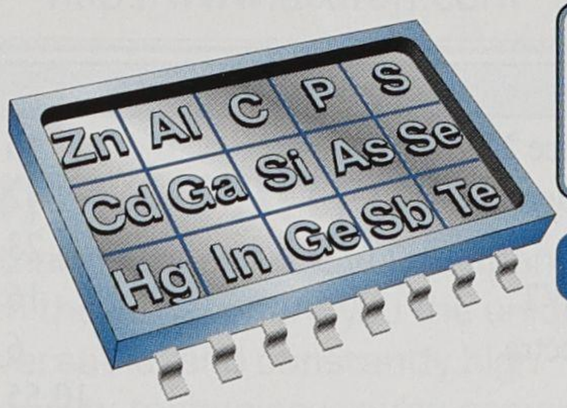
Note: new St. Paul address and phone numbers as of July 12, 1998

EPI
4900 Constellation Drive
St. Paul, MN 55127 U.S.A.
Phone: (651) 482-0800
Fax: (651) 482-0600
E-mail: info@epimbe.com

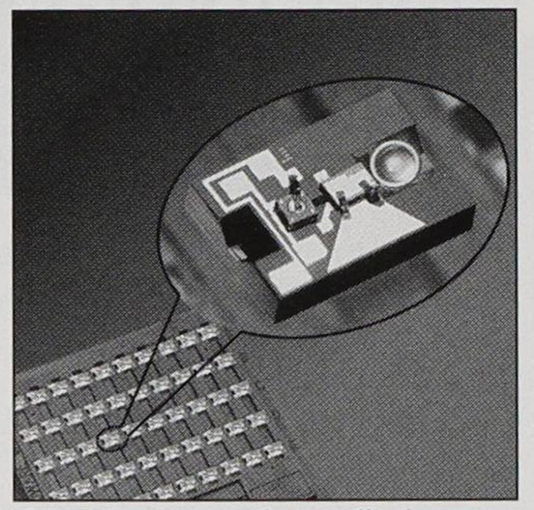
EPI Europe
147 Chorley New Road
Horwich, Bolton BL6 5QE
Greater Manchester, U.K.
Phone: (+44) 1-204-668366
Fax: (+44) 1-204-668466
E-mail: europe@epimbe.com

Japan
Vieetech Japan Co. Ltd.
1316-3 Katsukura
Hitachinaka Ibaraki 312
Japan
Phone: (+81) 29-272-8161
Fax: (+81) 29-272-9814
E-mail: vieetech@mito.ne.jp

FALL I - OCTOBER 1998 VOLUME 4 NUMBER 7



COMPOUND SEMICONDUCTOR



As the demand for high performance laser diodes continues to grow, manufacturers are moving towards fully automated device assembly and test operations. Lucent's Manufacturing Realization Center produces optical sub-assemblies with components aligned on a silicon optical bench. The cover illustration shows an optical sub-assembly at right, with 50 such modules in a plastic carrier at left. Coverage begins on page 17. Photographs courtesy of Lucent Technologies.

COVER STORY - SEMICONDUCTOR LASERS

17 Hands Off - Laser Manufacturing at Lucent
Lucent's automated assembly line for its Laser 2000 product series combines a low cost and flexible production process with an efficient working environment.

19 Lots in Space, Part 2 - Semiconductor Lasers in Space
In the second part of our series on space-based applications, we discuss the use of laser diodes for high speed fiber-optic and free-space data links, both within and between satellites.

23 Polaroid Develops a Market For High Power Lasers
Although best known for photographic products, Polaroid was also third in dollar volume sales of high power laser diodes in 1997. We investigate how this business has evolved from the development of a high resolution medical laser imager.

OTHER FEATURES

10 Markets
The market for wireless GaAs reached $1.35 billion in 1997, with Fujitsu the leading supplier ... Asymmetric Digital Subscriber Line (ADSL) will emerge as the leading broadband access technology in the US ... the total worldwide market for broadband satellite services should reach $4 billion by 2007.

12 Silicon Update
IBM unveils its new silicon-on-insulator (SOI) process, which could improve chip performance by up to 35%.

28 Research Review
Microelectronic Devices and Circuits: InAlAs/InGaAs Heterojunction FETs ... MOSFETs Using $Ga_2O_3(Gd_2O_3)$ ... SiC/Si NDR Switch ... P-pocket GaAs MESFET
Compound Semiconductor Materials: Characterization of GaN p-n Junctions ... Atomic Intermixing Brought To A Halt ... Metal-GaN Schottky Diodes ... GaN/AlN Valence Band Discontinuities
Optoelectronic Devices: 1300 nm VCSELs ... Laser with AlInAs-Oxide Current Confinement ... VCSEL with an Sb-Based DBR Mirror ... InAlAs APDs ... VCSELs with 48 nm Tuning Range

33 Technology Update - Thermophotovoltaics
Thermophotovoltaic energy conversion involves the transformation of an infrared heat source to electricity. JX Crystals of Issaquah, WA, now manufactures heat and electricity co-generators incorporating GaSb TPV cells. In a second article on thermophotovoltaics, experts from Lockheed Martin discuss the numerous design issues involved in assembling efficient TPV systems.

42 Portfolio
All but one of the 20 publicly-traded companies in the recently expanded portfolio section have announced results for the second quarter of this year. We review the unsettled conditions that resulted in 8 companies making a profit and the other 11 recording losses.

NEWS

4 News Briefs
IBM and AMCC announce long term agreement for SiGe BiCMOS ... National Research Council issues guidelines on optics ...Litton sells Solid State division ... Power Spectra suspends operations ... Cree and Kansai enter SiC agreement.

7 Nitride News
More on the role of dislocations in nitride emitters ... UCSB announces first nitride HBT.

14 New Devices
TriQuint and Vitesse announce new products for the Fibre Channel storage market, a hot application for digital GaAs ICs.

16 Vendor News
Bede and Bio-Rad collaborate on PL and x-ray equipment ... Bell Labs and Emcore to collaborate on epi technology.

DEPARTMENTS

2 Index

51 New Products/New Literature

53 Calendar

55 Patents

58 Employment

COMPOUND SEMICONDUCTOR

Compound Semiconductor
is published nine times yearly by

Franklin Publishing
163 Cabot Street
Beverly, MA 01915 USA
TEL [1] 978 927 9994
FAX [1] 978 927 9893
Individual annual subscription price: $90 U.S., $115 foreign.
Library rate: $300 U.S. and foreign.

Please note our new address

Editor
Marie Meyer
mmeyer@compsem.com

Assistant Editor
Tim Whitaker
tim.whitaker@compsem.com

Contributing Editors

Microelectronics
Robert A. Metzger
Georgia Inst. of Technology
rametzger@aol.com

Optoelectronics
Gary Wicks
University of Rochester
wicks@optics.rochester.edu

Materials
Colombo Bolognesi
Simon Fraser University
colombo@cs.sfu.ca

©Copyright 1998 by Franklin Publishing - all rights reserved.

POSTMASTER
Send address changes to:
CS Subscriptions
163 Cabot Street
Beverly, MA 01915 USA

Organization Index

Company/Organization	Page
A, B, C	
Ahead Optoelectronics	26
Aixtron	50
Allied Business Intelligence	10,11
Alpha Industries	10,42
American Xtal Tech.	42
AMCC	4
Anadigics	10,42,55
APA Optics	42
ATMI	42
Australian Nat'l Univ.	30
Ball Aerospace	19
Bede	16
Bell Labs	16,28
Bio-Rad	16
Boeing	33
Celeritek	42
Cheng Kung University	28
CIBC Oppenheimer	10
Coherent	23,42
Cree Research	6,7,42
D, E, F, G	
Emcore	16,42
EPI MBE Products	16
Epitaxial Technologies	16
Epitronics	30
ETRI (Korea)	55,56
France Telecom	32
Filtronics	6
Fujitsu	10
Furukawa	32
Gore Photonics	30
H, I, J, K	
IBIS	13
IBM	4,12
JPL	19
JX Crystals	33
Kansai Electric Power	6
Kopin	42
L, M, N, O	
LG Electronics	55
Litton Solid State	6
Lockheed Martin	36
Lucent	17,55
M/A-COM	10
Matra Marconi	20
Matsushita	10,55,56
Mitsubishi Denki	55,56,57
Mitsubishi Electric	10
Motorola	10
Murata	55
NCSU	30
NEC	10,28,55,56,57
Nichia Chemical	7
Nikon	56
Oki Electric	10
P, Q, R	
Performance Mat'ls	16
Plasma-Therm	42
Polaroid	23
Polaron CVT	16
Power Spectra	6
Raytheon	10,55
Research Triangle Inst.	57
RF Micro Devices	10,42
Rockwell	10
S, T	
Sandia Nat'l Lab	57
Sarnoff Corp.	23
SDL	20, 24,42
Siemens	10,57
SLI	23,42
Sony	55,57
Spire	42
Sumitomo Electric	56
Teledesic	10,19
Texas Instruments	10
Toshiba	10,29,55,56,57
TriQuint	10,14,42
U, V, W, X, Y, Z	
Uniphase	42
Uniroyal Technology	7,42
Univ. of Ca Santa Barbara	7,29, 32,57
Univ. of Ca. San Diego	30
Univ. of Delaware	57
Univ. of Oklahoma	56
Univ. of Texas	32
Univ. of Utah	30
Vitesse	14,42
W.L. Gore Assoc.	56
Xerox	56

Advertiser Index

Addon	16
Aixtron	3
American Xtal Technology	41
Bede	49
Bio-Rad Micromeasurements	25
Compound Semiconductor '99	52
CVD Equipment Corporation	15
Dynatex	13
Emcore	31
Epitaxial Products Int'l	OBC
EPI MBE Products	IFC
Epitaxial Technologies	6
Loomis	21
Performance Materials	29
Philips	39
Quantum Epitaxial Designs	34
Solkatronic Chemicals	IBC
Struers	5
Thomas Swan	11
VG Semicon	8, 44
Wafer Technology	27

The CVD Engineering Company™

Web site address:
http://www.aixtron.com

IT'S A FACT

that no other MOCVD company in the world offers you the **unique, versatile,** and **constantly high quality** technology you're assured of from AIXTRON, whether you're producing LED's, Lasers, Detectors, HEMTs, HBTs, OEICs...
...And we can prove it!

FACT!

No other company in the world offers you a complete MOCVD reactor line, based on a proven scaling concept, from R & D up to full-scale production (1x2" up to 95x2" wafers or equivalent 3", 4" wafers).

FACT!

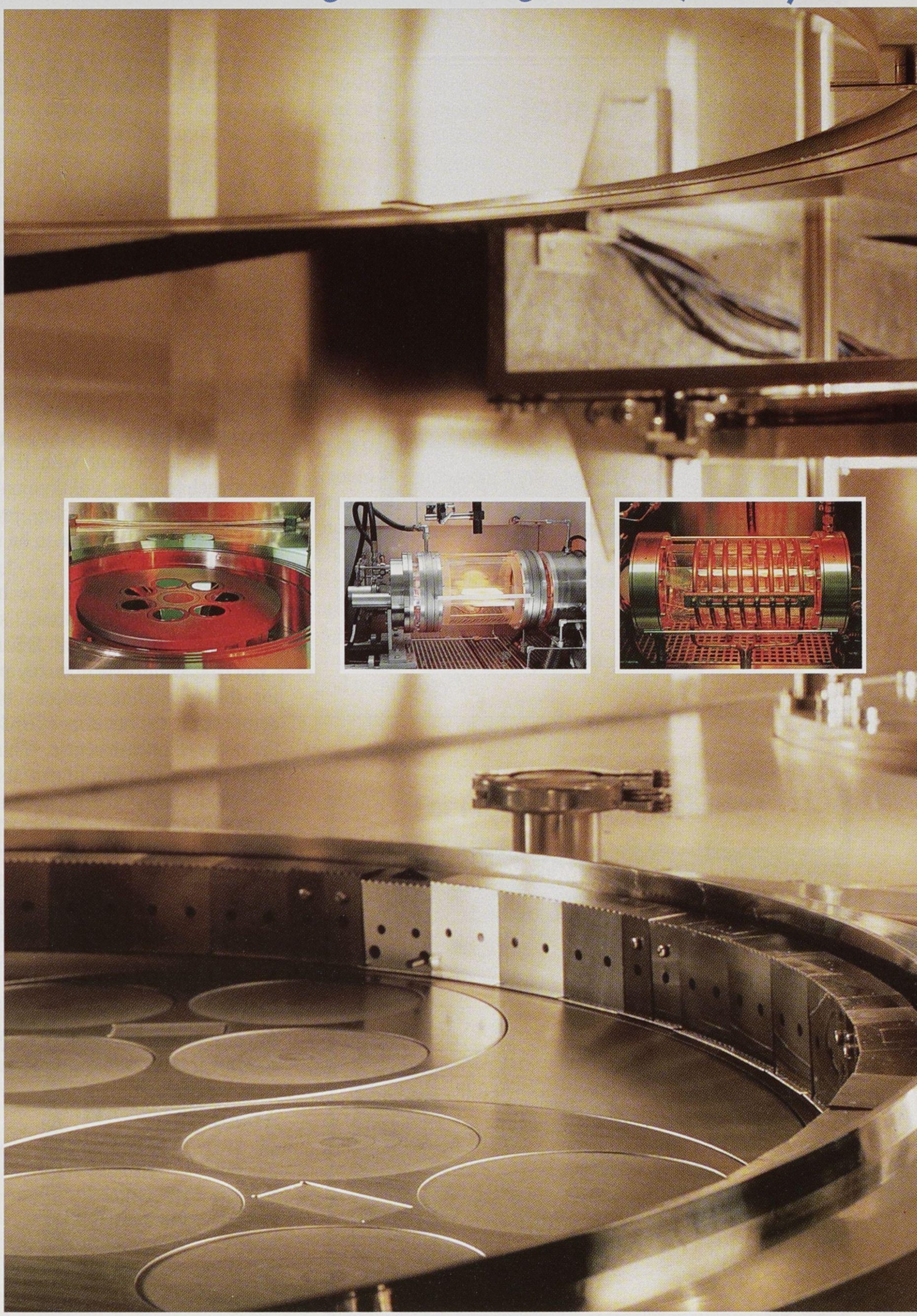
AIXTRON is the only company in the III-V epitaxy field offering proven processes from mono layer thickness up to more than 200µm/h.

FACT!

AIXTRON was the first MOCVD company worldwide to receive the ISO 9001 Certification - the internationally recognized quality symbol.

CERTIFIED QUALITY SYSTEM DIN 9001 ISO

WHAT BETTER GUARANTEE OF OUR *Commitment to AIXcellence*



AIXTRON®

European Headquarters
Aachen, Germany
AIXTRON AG
Kackertstraße 15-17, 52072 Aachen
Germany
Phone: +49 (241) 89 09 - 0
Fax: +49 (241) 89 09 - 40
Customer Service Line
Phone: +49 (241) 89 09 - 91
e-mail: info@aixtron.com

US Headquarters
Chicago, IL
AIXTRON Inc.
1670 Barclay Blvd.
Buffalo Grove
IL 60089 USA
Phone: +1 (847) 215 73 35
Fax: +1 (847) 215 73 41
e-mail: info@aixtron.com

Sales and Service
Tokyo, Japan
Moritani & Co., Ltd/AIXTRON
2nd Section, 12th Machinery Dept.
Industrial Machinery Division
1-4-22 Yaesu, Chuo -ku
Tokyo 103, Japan
Phone: +81 (3) 32 78 - 61 31
Fax: +81 (3) 32 78 - 61 21
e-mail: KYP00751@niftyserve.or.jp

Also in this Issue:

Litton To Sell Solid State Division – page 6

Power Spectra Suspends Operations – page 6

Cree Signs Development Agreement– page 6

The Role of Dislocations in InGaN – page 7

Nitride News Briefs – page 7

GaAs for Wireless worth $1.35B in 1997 – page 10

IBM & AMCC in SiGe Pact

Applied Micro Circuits Corp. (AMCC) of San Diego, CA, announced on July 22 that it had signed a long term agreement with IBM entitling AMCC to "advanced access and use of IBM's current and future generations" of SiGe BiCMOS processes and libraries. AMCC, which at times looks as though it is trying to become the next Vitesse, offers ICs for SONET, ATM, Gigabit Ethernet and Fibre Channel markets. The new SiGe products that will result from this agreement are intended for the SONET OC-192 (10 Gbps) market. The first new products are expected next year. AMCC has also suggested that some of its existing product families may also be converted over to the SiGe process.

"This agreement with IBM reinforces our vision that silicon-based technologies will dominate the fiber optic network at all speed grades," stated Dave Rickey, president and chief executive officer of AMCC. "We are pleased to be working with a leading-edge, credible player like IBM."

"As the leader in SiGe technology, we're seeing it take hold in a wide array of applications," said Ron Soicher, vice president of Analog & Mixed Signal Development for IBM Microelectronics. "Working with AMCC, a key player in high-bandwidth connectivity for the telecommunications market, gives us the opportunity to demonstrate the benefits of SiGe technology in an important piece of the network infrastructure. This is yet another testament to the cost-effectiveness and manufacturability of this technology."

"This early access agreement with IBM not only positions AMCC to lead the emerging OC-192 market, but enables us to pursue additional segments of our primary market," said Brent Little, director of Strategic Marketing for AMCC. "IBM's SiGe BiCMOS is a superlative technology; we're excited about passing its incredible performance, power and integration advantages on to our customers."

The SiGe BiCMOS process, which is produced at the IBM fab in Burlington, VT, adds 65 GHz f_{max} HBTs to a standard 0.4 micron CMOS process. See table, left, for other key figures of merit. According to IBM, their SiGe process promises superior performance and integration, while significantly reducing power consumption.

IBM's SiGe BiCMOS Process
Key Figures of Merit

f_T	46 GHz
f_{Max}	65 GHz
Beta	100
Base resistance	Under 125 Ohm
Emitter resistance	10 Ohms
B-E capacitance	10.8 fF
C-B capacitance	3 fF
C-E breakdown (open base)	3.3 V
C-B breakdown	10.5 V
Min. noise figure @ 2 GHz	Under 1 dB
1/f-noise corner frequency	373 Hz
All values are for a 0.5 micron x 2.5 micron emitter device at V_{CB} = 1 V	

Key figures of merit for IBM's SiGe BiCMOS process. Two versions of SiGe HBTs are available: a standard device targeted at high-speed, small signal applications, and a high-breakdown device target at power amplifier applications. The data in this table is taken from the former.

About AMCC

AMCC was founded in 1979, and went public in 1997. Like Vitesse, they target the high speed communications infrastructure market – but unlike Vitesse, their products are all silicon based. AMCC provides ATM and SONET/SDH physical layer transceivers and clock recovery and synthesis units for the OC-3 and OC- 12 standards, and is currently developing an OC-48 chip set. In the data communications market, the AMCC provides physical layer transceivers for Gigabit Ethernet and Fibre Channel applications as well as crosspoint switches for serial backplanes. Other areas of interest include high-speed computing, for which AMCC provides PCI controllers and high-frequency clock drivers and clock generators. Formerly, the company had developed a market niche by supplying

high-performance, low-power application-specific integrated circuit (ASIC) products for the automated test equipment (ATE) and military markets, but these efforts have been overshadowed as of late by the rapid growth in the telecommunications markets.

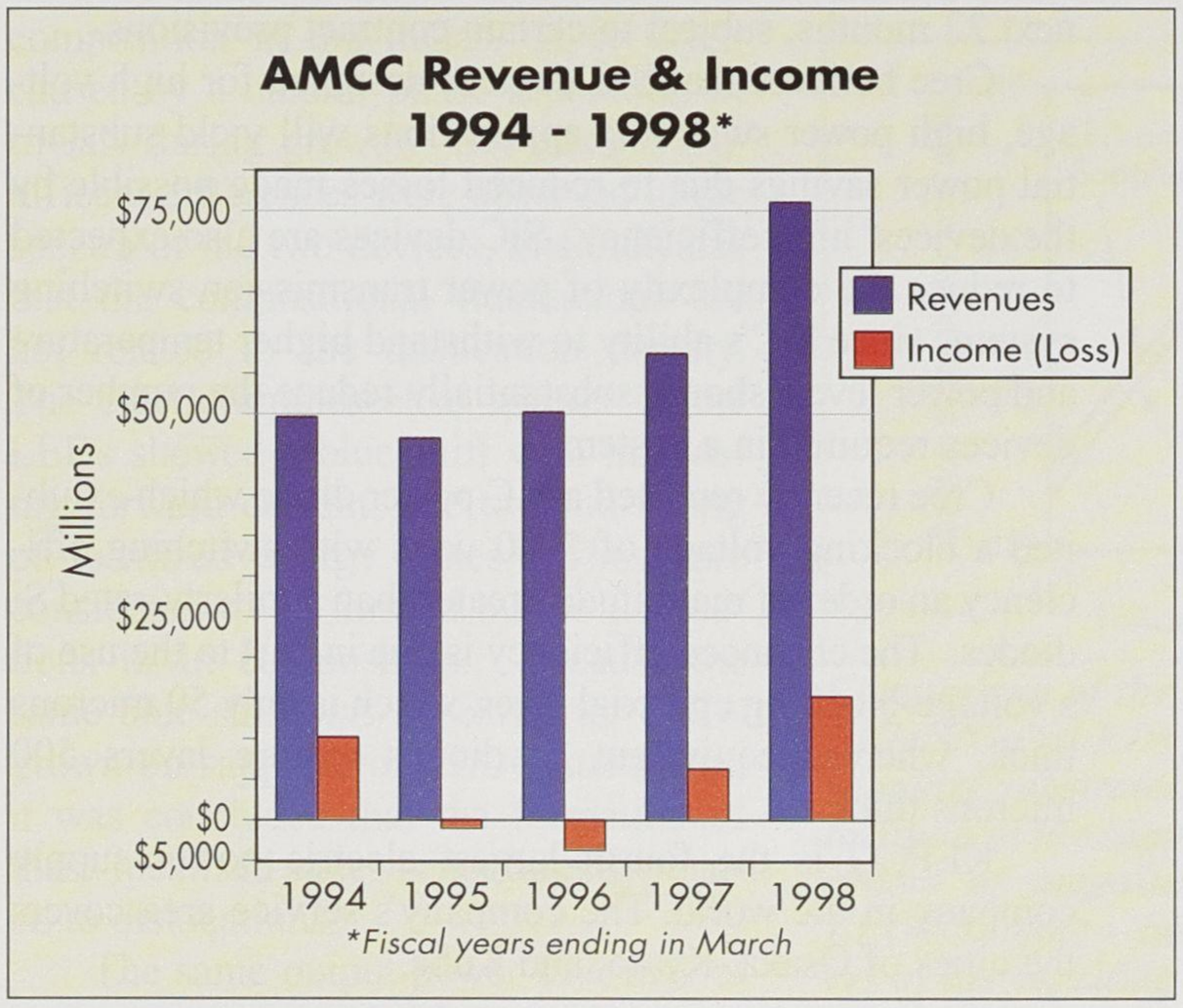
In the telecommunications and data communications markets, AMCC competes primarily against Vitesse and TriQuint, as well as competing with Si bipolar products from companies such as Hewlett-Packard, Maxim and Sony. In the ATE market, AMCC competes primarily against Vitesse and silicon ECL and BiCMOS products offered by semiconductor manufacturers such as Analog Devices, Lucent Technologies and Maxim.

Dataquest estimates that the worldwide SONET/SDH market for ICs was approximately $240 million in 1996 and will increase to approximately $700 million in 2000 and that the ATM market for ICs was approximately $130 million in 1996 and will increase to approximately $700 million in 2000. Dataquest estimates that the combined markets for Fibre Channel and Gigabit Ethernet will be approximately $300 million in 2000, up from negligible values just a few years ago.

AMCC's biggest customer is Nortel, which accounted for 17 – 21% of their sales in each of the last three fiscal years. Other major customers include 3Com, Alcatel, Cisco Systems, Compaq, Hughes Electronics, Nortel, Sun Microsystems and Teradyne.

The company currently manufactures the majority of its products at its 4" Si bipolar and BiCMOS fab in San Diego, though there are tentative plans for the construction of a new 6" fab that would begin production in 2000. All of AMCC's CMOS products are fabbed at four outside foundries: AMI Semiconductor, IBM, Kawasaki CSI Japan and Taiwan Semiconductor Manufacturing Corporation (TSMC). The company says that it has no plans for setting up its own CMOS line.

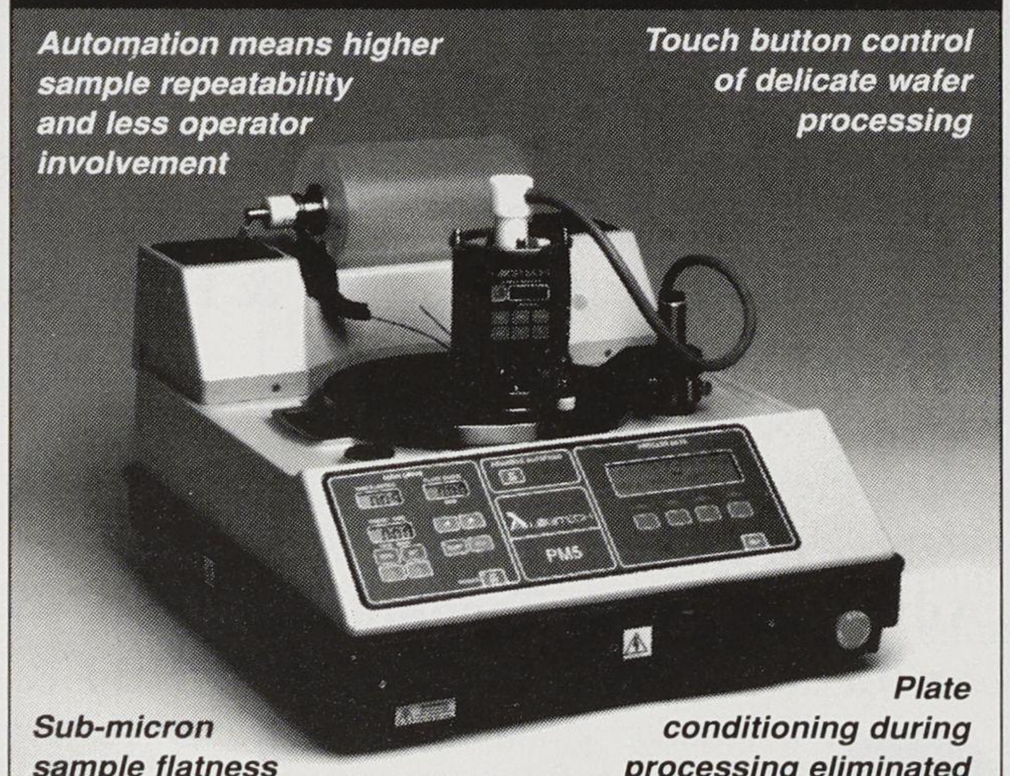
For its most recent fiscal year, ended March 31, 1998, AMCC reported net income of $15.2 million on revenues of $76.6 million. These results were up 58% and 25%, respectively, over the previous year. The company employs approximately 375 people.



NRC on Optics

The field of optics should be acknowledged as an integrated area of knowledge, technology and industry, and the U.S. Government should restructure its job and patent classifications in recognition of this fact, according to a recently released report from the U.S. National Research Council. In their report, entitled "Harnessing Light: Optical Science and Engineering for the 21st Century", the NRC makes several other recommendations, including:

- The U.S. Congress should "challenge industry and its regulatory agencies" to ensure the rapid deployment of fiber-to-the-home.
- Regulatory agencies, including DOE and EPA, should coordinate efforts to enhance new lighting sources that will reduce energy consumption.
- DARPA and the DOD Manufacturing Technology Program should be funded for programs that ensure the existence of domestic manufacturing infrastructures capable of supplying low-cost, high-quality optical components that meet DOD needs.
- High-power lasers should be pursued as a DOD key technology.
- Agencies should focus attention on femtosecond optics and sources as an opportunity for "dramatic impact on science and technology".

For Precise Wafer Processing
PM5 auto-lap
Confidently achieve a high quality surface finish and flatness on your II-VI & III-V materials
Automation means higher sample repeatability and less operator involvement
Touch button control of delicate wafer processing

Sub-micron sample flatness
Plate conditioning during processing eliminated
Quality Materials Processing Technology
LOGITECH
Materials Technologists & Engineers
Logitech Product Group,
A Division of Struers Inc.
810 Sharon Drive, Westlake, Ohio 44145
Tel. (440) 871 0071
Fax. (440) 871 8188
http://www.logitech-us.com

Litton To Sell Solid State Division

On August 3 Litton Industries, Inc. announced that it has agreed to sell its Solid State Division to Filtronic plc of Bradford, Yorkshire, UK, subject to government approvals. The purchase price is approximately $43 million. The parties intend that most or all of the division's approximately 260 full-time employees will be retained by Filtronic.

Litton Solid State, located in Santa Clara, CA, designs and manufactures microwave and millimeter wave semiconductors, components and integrated assemblies. Their operations include a GaAs/InP fab specializing in 0.25 micron InGaAs PHEMT MMICs for applications up to 40 GHz. Other catalog items include MESFET MMICs, Discrete FET and PHEMT devices, and Gunn diodes. Its customers include commercial wireless infrastructure manufacturers, automotive electronic suppliers, military system original equipment manufacturers, and aerospace contractors. The company also offers GaAs/InP device foundry services.

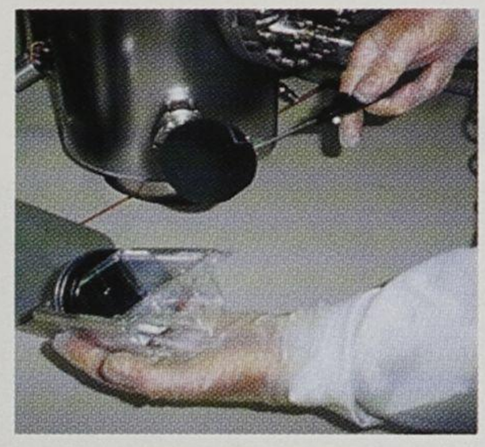
The division is being sold because Filtronic, a manufacturer of microwave components and subsystems, will be better able to capitalize on its potential, according to a Litton Industries spokesperson. Solid State was not considered to be a good fit with Litton's plans to emphasize information systems as its strategic focus.

Michael R. Brown, Litton's president and chief executive officer, said, "Solid State's value and growth potential can best be realized through its sale to a company focused on similar markets. Litton will reinvest the proceeds of the sale to build value for our shareholders."

Litton still retains ties to the compound semiconductor industry – its Airtron division is a leading supplier of semi-insulating GaAs wafers.

The deal is expected to close within the coming weeks.

EPITAXIAL WAFERS



Epitaxial Technologies offers standard and highly challenging epitaxial layers on GaAs, InP, GaSb, InSb and InAs.

Wafers that meet your needs
- High quality, low cost, fast turn-around

Wireless and RFICs
- GaAs MESFET, p-HEMT & HBT

Infrared Sensors
- GaAs, GaInAs & Sb-based QWIPs

Optoelectronics
- VCSELS, MSM, PD & APD

Advanced Device Technologies
- InP- & Sb-based FET, HEMT, HBT & RTD

ET EPITAXIAL TECHNOLOGIES LLC

Tel: 410-455-5594
Fax: 410-455-5595
e-mail: epiwafers@erols.com
1450 South Rolling Road, Baltimore, MD 21227

Helping You Grow Your Business!

Power Spectra Suspends Operations

On August 27 Power Spectra, Inc. of Sunnyvale, CA, announced that it had laid off all its employees and suspended all its operations due to lack funds. A company spokesperson said that the company "is aggressively pursuing multiple other financing opportunities" in the hopes of resurrecting itself. Power Spectra was engaged in the design and manufacture of ground penetrating radar (GPR) systems, laser rangefinders, and high-output-power impulse generators for industrial and military applications, utilizing its proprietary high-speed GaAs switching devices.

Cree Signs Development Agreement with Kansai Electric Power Company

Cree Research recently announced that it has entered into an agreement with The Kansai Electric Power Co., Inc. (KEPCO) of Osaka, Japan to undertake a cooperative program for the development of SiC power devices with a blocking voltage in excess of 5 kiloVolts for use in power transmission systems. Cree and KEPCO will collaborate in designing the devices, while Cree will fabricate prototypes for testing. KEPCO has agreed to contribute program funding of up to $3 million in development fees over the next 32 months, subject to certain contract provisions.

Cree believes that SiC devices designed for high voltage, high power switching applications will yield substantial power savings due to reduced losses made possible by the devices' high efficiency. SiC devices are also expected to reduce the complexity of power transmission switching systems since SiC's ability to withstand higher temperature and power levels should substantially reduce the number of devices required in a system.

Cree recently reported a SiC power diode which exhibited a blocking voltage of 5900 volts with switching efficiency an order of magnitude greater than similarly-rated Si diodes. The enhanced efficiency is due in part to the use of a voltage-blocking epitaxial layer, which is only 50 microns thick, whereas equivalent Si diodes require layers 500 microns thick.

KEPCO is the fourth largest electric power supply company in the world. The company's service area covers the cities of Osaka, Kyoto, and Kobe.

The Role of Dislocations in InGaN

It is a question which has been posed many times – how is it possible for nitride-based emitters to function, given the very large number of defects present in even the most carefully prepared layers of GaN and related materials?

As we discussed in our last issue, recent investigations have suggest that the dislocations in GaN act as non-radiative recombination centers, but the carriers are prevented from reaching them because their diffusion length is extremely short. See *CS* 4[6], p. 18.

While that explanation is interesting insofar as bulk GaN is concerned, the situation is not necessarily the same for InGaN active layers. But a recent paper from Nichia Chemical [T. Mukai et al, Jpn. J. Appl. Phys., 1998, 37(7B), L839] looks at that issue.

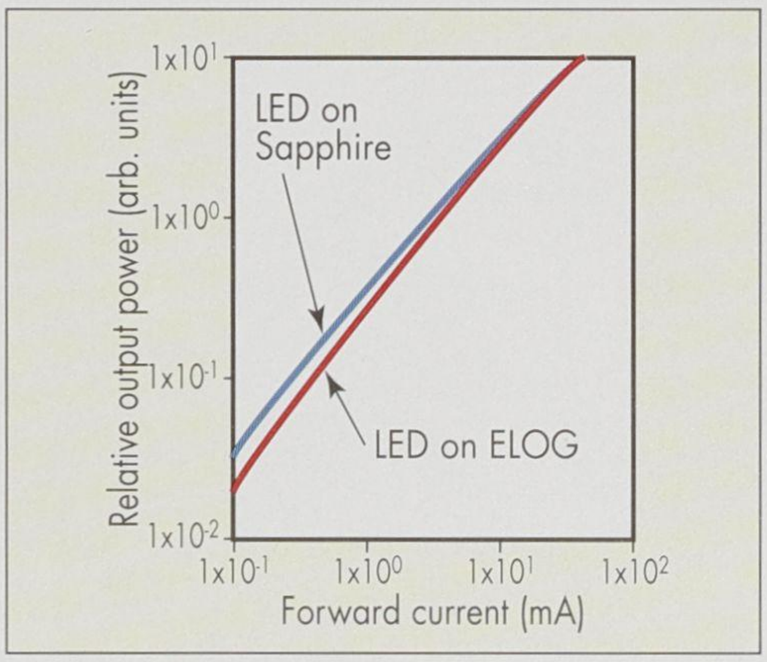
The Nichia researchers examined the role played by dislocations in InGaN by comparing InGaN SQW LEDs grown either on sapphire or on epitaxially laterally overgrown (ELOG) substrates. The average dislocation densities for the material grown on sapphire were much higher than for material grown on the ELOG substrate - $1x10^{10}$ cm^{-2} for the former, and $7x10^{6}$ cm^{-2} for the latter.

In both cases, broad emission spectra were observed due to variations of In composition in the InGaN SQW layer, caused by a natural phase separation of InGaN during growth. Because no significant differences were observed in the spectra of the two devices, this indicates that the compositional fluctuations are not related to the dislocation density. The electroluminescence spectra of the LEDs showed a blue shift with increasing forward current, due to band-filling of localized energy states. These are considered to be formed by the fluctuations in In composition. Because the same blue shift was observed for LEDs grown on sapphire or ELOG substrates, it was concluded that the formation of these localized states is not directly related to dislocations.

The same output power of 6 mW at a current of 20 mA (external quantum efficiency of 11%) was observed for both LEDs, showing that the output power is not affected by the dislocation density. This was interpreted as evidence that dislocations do not act as non-radiative recombination centers in InGaN – otherwise, one would expect the output power of the LED on the ELOG substrate to be much higher than that of the one grown on sapphire, due to the much lower number of dislocations in the ELOG sample.

A possible alternative explanation, not discussed in the paper, is that the dislocations could act as non-radiative recombination centers, but the carriers don't reach them. The diffusion length in InGaN may be unusually short (as it is in GaN). It has also been suggested that the segregation of indium in the InGaN layer leads to the spontaneous formation of quantum dots, which confine the carriers and prevent them from reaching the dislocations.

The Nichia paper also looked at the reverse bias I-V characteristics of the devices. At a reverse bias of –20 V, the current in the ELOG device was 0.009 mA, compared to 1 mA in the LED grown on sapphire. This indicates that dislocations form the primary current leakage pathway in InGaN.



Comparison of the output power of blue InGaN/GaN LEDs grown on ELOG and sapphire substrates. The number of dislocation in the sapphire sample was ~3.5 orders of magnitude higher than the ELOG sample – but yet the output powers of the resulting devices are similar.

Nitride News Briefs

First AlGaN/GaN HBT... Researchers at the University of California at Santa Barbara report that they have demonstrated the first AlGaN/GaN HBT. Details will be presented in an invited talk at the 25th International Symposium on Compound Semiconductors, to be held in Nara, Japan October 12-16, 1998. The authors are L. S. McCarthy, P. Kozodoy, S. P. Denbaars, M. Rodwell, and U. K. Mishra.

Cree Update... Cree Research recently revealed that for their 1998 fiscal year, which ended June 28, their shipments of blue LEDs increased 132% over the 1997 fiscal year. This compares with an increase of 70% over the previous twelve months. Much of the increase was attributed to Cree's volume purchase agreement with Siemens.

As part of its efforts to find additional customers, Cree plans to introduce higher brightness blue and green LEDs by the end of this year. Cree believes that it will also be necessary to reduce prices substantially. During fiscal 1998, Cree's LED prices dropped 32% over 1997 levels, and the company says that further reductions are expected in 1999.

In addition to the sharply higher blue LED sales, the company reports that sales of SiC wafers and other materials were up 56% in fiscal 1998, primarily due to greater demand from the research community. Cree's total revenues were $42.5 million for the twelve month period, up 46.5% over the 1997 fiscal year.

UTC Update... On July 22 Robert Soran, President of Uniroyal Technology Corp. (UTC) told analysts that the company was ready to begin ordering equipment for its new blue LED venture which will be located in Tampa, Florida. The new fab is scheduled to open in February, and Soran said that it will have an annual sales capacity of $75 to $100 million. The operation, to be known as Uniroyal Optoelectronics, is a joint venture between UTC and Emcore.

ThermoCell™ technology...



...the most important MBE development of the decade



VG Semicon's new ThermoCell™ range of effusion sources is nothing short of revolutionary. Resulting from an intensive three year research program, ThermoCell™ technology brings a new dimension to process reproducibility, stability and uniformity. It is now easier than ever to stay within your process window for extended campaigns, enhancing yield and increasing throughput.

No wonder it has been hailed as the single most important MBE development of the decade.

The ThemoCell™ range draws on the most advanced computer modeling, backed up by years of extensive field trials. The result is a technology which truly enables the next generation of MBE equipment. Technology which is available now, exclusively to our V100 customers, and soon for users of our research equipment.

We are the World's leading MBE company so you're probably already a customer. If not, and you value working with the only MBE company that has the financial and technical resources to offer innovative solutions time and time again, call us.

You owe yourself a profitable future.

UK	(44) 1342 325011
USA	(1) 800 888 7007
	(1) 978 524 1041
Japan	(81) 3 3639 9652
France	(33) 1 6092 3610
Korea	(82) 2 548 2983
Taiwan	(88) 63 535 9771
Benelux	(31) 184 490909
Nordic	(46) 8 629 2400
Australia	(61) 2 898 1244

mbesales@vgsemicon.com

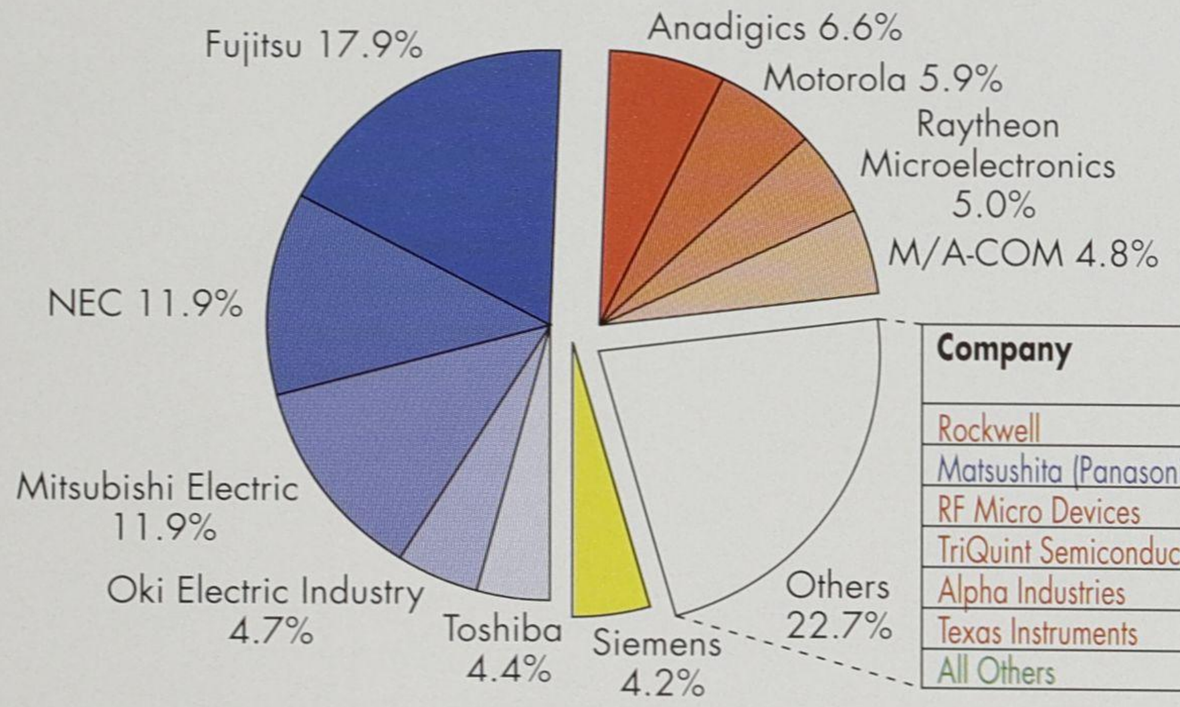
VG Semicon
The MBE Company

GaAs For Wireless Worth $1.35 Billion in 1997

The total world market for GaAs semiconductors in wireless applications reached $1.35 billion in 1997, according to a recent report from CIBC Oppenheimer. [1] Compared to 1996, this represents a dollar value growth of around 35%, while the unit volume of shipments increased by almost 60%. The top ten suppliers, of which five are from Japan, four from the US and one from Europe, accounted for over 75% of the market (see figure). The top three companies (Fujitsu, NEC and Mitsubishi Electric) had a combined market share of 41.7%. However, CIBC Oppenheimer reports that although Fujitsu and NEC retained their rankings from 1996, these giants suffered a decline in the dollar value of their shipments due to depreciation of the yen, and the aggressive decline of the average price of discrete components.

In contrast, all the major US analog GaAs suppliers recorded a significant increase in the dollar value of their shipments between 1996 and 1997, with the exception of Texas Instruments. The total sales revenue for US-based companies increased from $290 million in 1996 to $477 million in 1997, representing an overall growth rate of almost 65%, close to double the growth rate for the market as a whole. The more traditional military/defense companies such as Raytheon, M/A-COM, Alpha and particularly Rockwell, all showed strong growth in their wireless businesses; Rockwell's revenue increased by 275% between 1996 and 1997. CIBC Oppenheimer predicts that the strong growth shown by Alpha and RF Micro Devices (104% and 84.3% respectively) should continue in 1998, whereas Anadigics is expected to lose market share this year. Following the January 1998 purchase by TriQuint of the Texas Instruments fab, it is interesting to note that the combined 1997 revenues of the two operations would have placed TriQuint on the top ten list. However, TriQuint experienced a loss in market share in 1997, whether considered separately or jointly with TI, and this trend is expected to continue in 1998.

Wireless GaAs Production in 1997
Total Market Value $1.35 billion



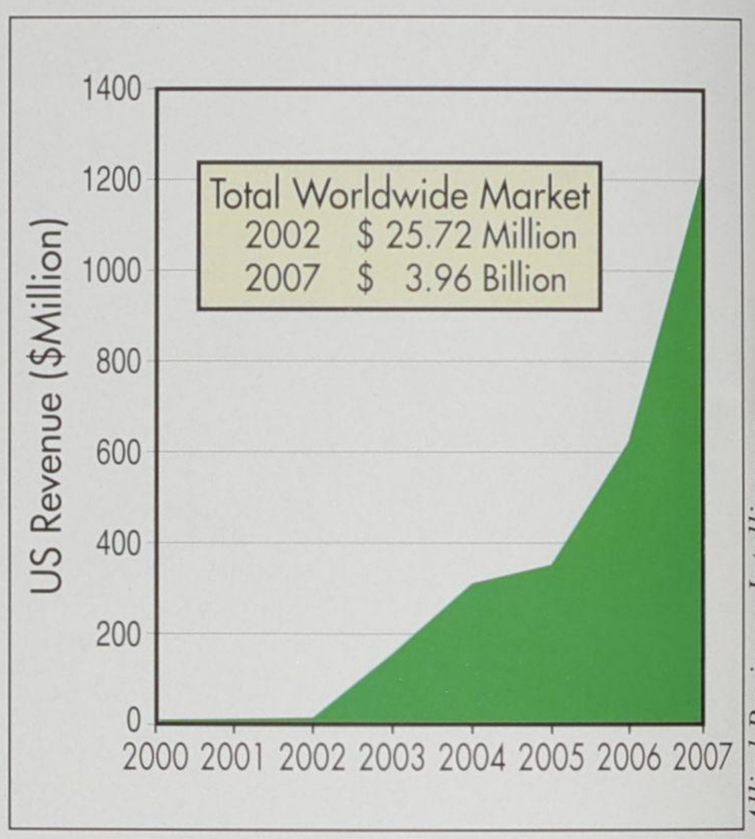
Company	Market Share (%)
Rockwell	3.3
Matsushita (Panasonic)	2.9
RF Micro Devices	2.7
TriQuint Semiconductor	2.6
Alpha Industries	2.0
Texas Instruments	1.9
All Others	7.3

CIBC Oppenheimer

Fujitsu was the top producer of GaAs chips for wireless applications in 1997, according to figures recently released by CIBC Oppenheimer [1]. This chart presents estimates of market share held by 16 of the top suppliers. Japanese companies are shown in blue, US companies are shown in red, and the lone European entrant, Siemens, is shown in yellow.

Broadband Satellite Services Revenues Predicted To Take Off

A recent report from Allied Business Intelligence [2] predicts that the revenues from broadband satellite services in the United States will rise from $8.2 million in 2002 to $1.21 billion in 2007, as the various satellite constellations such as Teledesic become operational (see *CS* 4[6], p. 25). In the rest of the world, the market is predicted to rise from $17.52 million in 2002 to $2.75 billion in 2007. ABI's report examines satellite-based voice, short messaging and broadband applications, and the companies offering these services.



Allied Business Intelligence

Annual revenues for broadband satellite services in the United States

---

[1] "Wireless Communications" by Dale Pfau and Earl Lum, CIBC Oppenheimer Corp., 580 California Street, Suite 2300, San Francisco, CA 94104; Tel [1] 415 434 5877 or [1] 800 820 6726, Fax [1] 415 438 3023.

[2] "Bandwidth On Demand Satellite Systems: 1998.", available from Allied Business Intelligence, 202 Townsend Square, Oyster Bay, NY 11771, USA; Tel [1] 516 624 3113, Fax [1] 516 624 3115; Web site www.alliedworld.com

[3] "Broadband delivery in the Local Loop: The Access War Begins. Competitive technology and Market Outlook", available from Allied Business Intelligence, 202 Townsend Square, Oyster Bay, NY 11771, USA; Tel [1] 516 624 3113, Fax [1] 516 624 3115; Web site www.alliedworld.com

ADSL To Lead Broadband Technologies in the US

Wireless technologies such as local multipoint distribution service (LMDS) and broadband satellite will continue to gain market share in the US as the number of subscribers for broadband access in the local loop increases, according to a recent report by Allied Business Intelligence (ABI) [3]. By 2003, ABI predicts that 12% of the 14.5 million broadband subscribers in the US will use broadband satellite services, while LMDS will capture a 9% market share. Technologies such as millimeter-wave radio and fiber-to-the-home/fiber-to-the-curb fall into the "others" category totaling less than 5% of the market. (see figure).

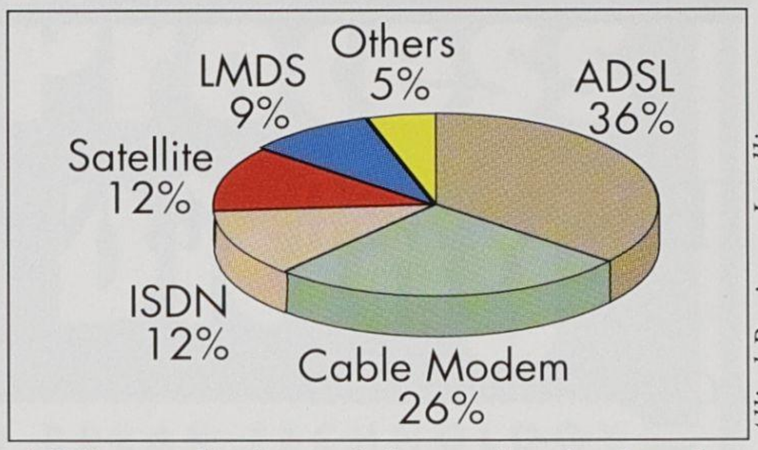
At present, 95% of the 2.3 million broadband subscribers in the US use ISDN (integrated services digital network). By 2003, ISDN will have been eclipsed by both ADSL (asymmetric digital subscriber line) and cable modems.

Basic Internet access is currently provided by **POTS** (plain old telephone service) and a modem. POTS can transmit data at speeds up to 56 kbit/s along ordinary, twisted pair copper telephone wires.

Both ISDN and ADSL are technologies for transmitting digital information over existing copper phone lines. **ISDN** offers data rates of up to 128 kbit/s for homes and small enterprises on a basic rate interface (BRI) and up to 1.544 Mbit/s on a T-1 line with a primary rate interface (PRI).

ADSL offers much higher data rates ranging from 1.544 Mbit/s to 8 Mbit/s. "Asymmetric" indicates that most of the channel is used to download data to the user, with a much smaller proportion assigned to the return link. In fact, there are several different DSL arrangements, of which ADSL is one, often grouped under the generic term "xDSL".

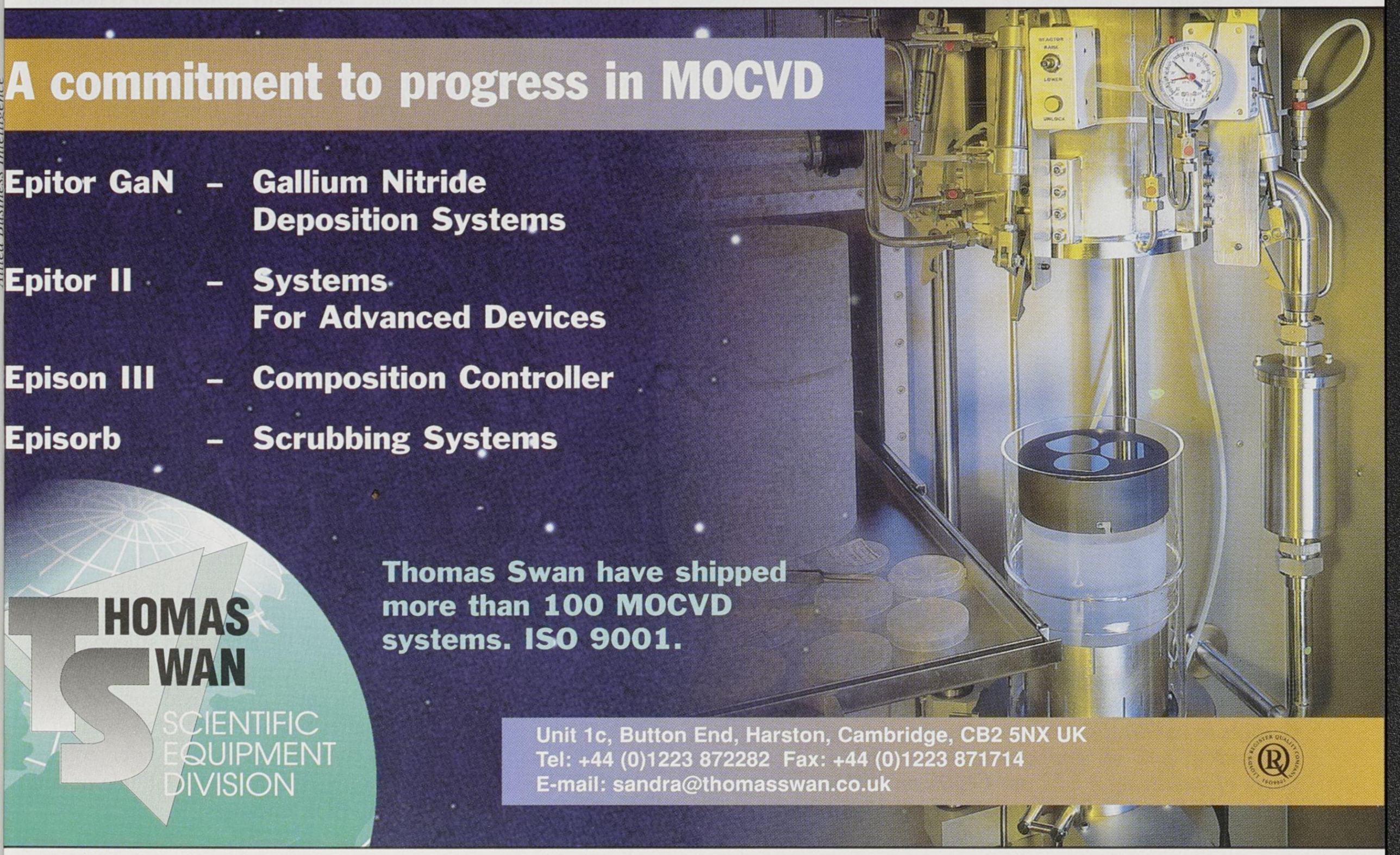
Cable modems provide broadband access along a co-axial cable TV line, with speeds ranging from 512 kbit/s to 52 Mbit/s.



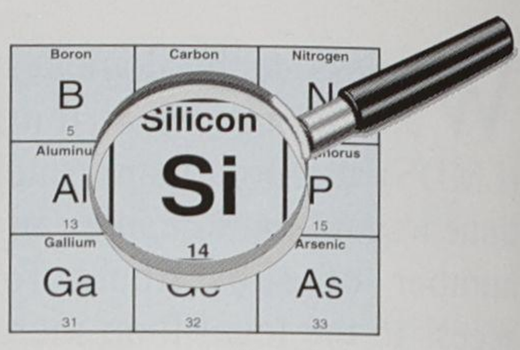
Allied Business Intelligence

ABI's prediction of the technologies that will be used by the 14.5 million broadband subscribers in the United States in 2003.

ADSL has three big advantages; it is compatible with most existing phone lines; it allows analog voice signals to be simultaneously transferred down the same line, something you can't do with ISDN; and installation can be carried out on a single customer basis. Competing technologies, particularly satellite systems and fiber-to-the-curb, require a huge initial investment to provide access, and then require the participation of large numbers of users in the areas covered to ensure profitability.

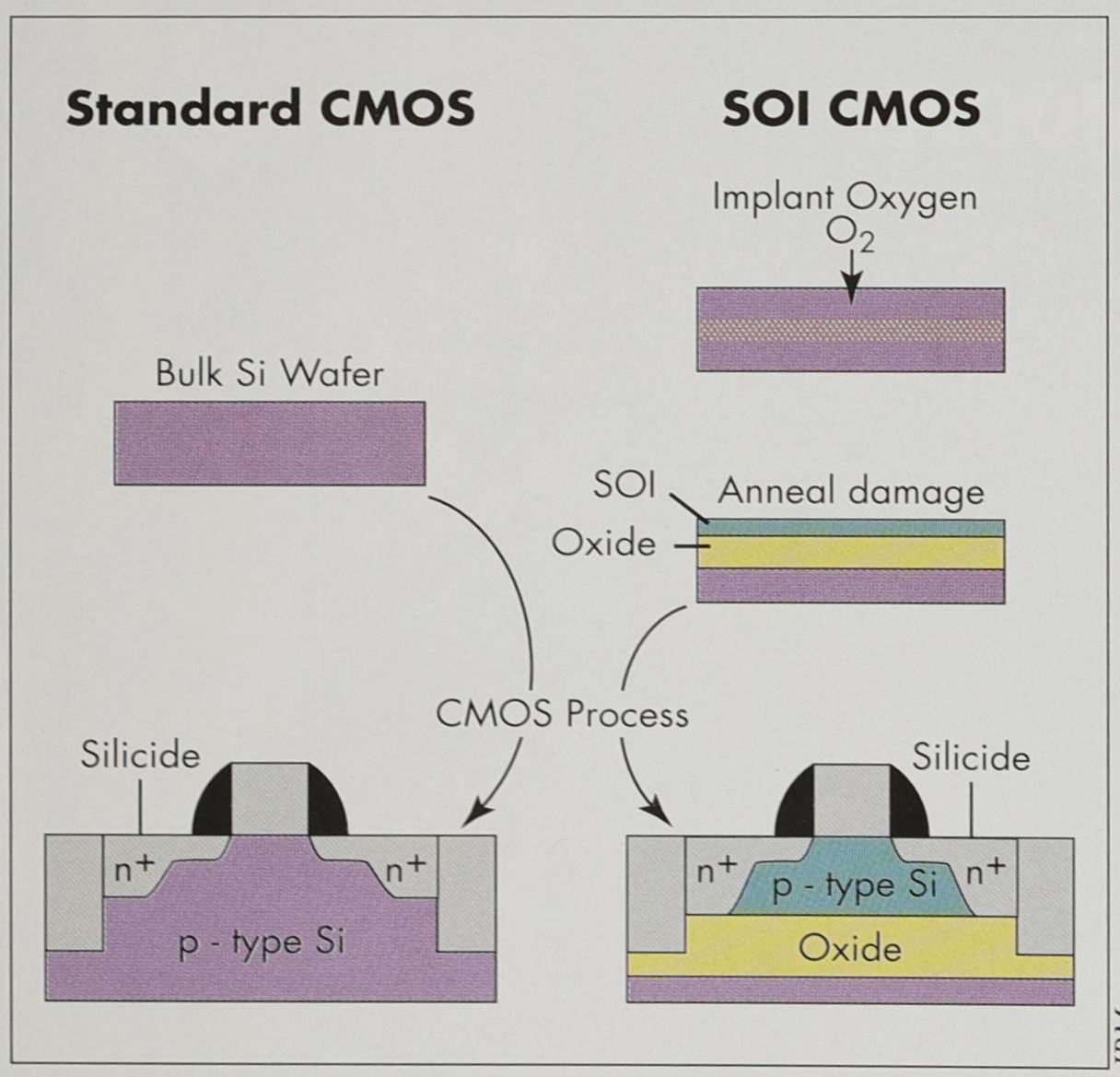


IBM Unveils Its New SOI Process



ROBERT A. METZGER

With the PR machine turned on full blast, IBM has announced its new SOI (silicon-on-insulator) process, a technology which IBM describes as being capable of improving chip performance by up to 35%, transforming 400 GHz microprocessors into 500 GHz devices. This improvement is due to the reduced junction area inherent to an SOI technology, which in turn cuts down on device capacitance. This same reduction in junction area also reduces leakage currents. In addition, subthreshold slopes are improved, allowing the devices to operate at lower voltages as compared to standard CMOS configurations. Areas targeted for this technology include VLSI CMOS applications to improve high frequency performance and reduce power consumption, and in small circuits that go into portable applications, where lower power consumption translates into longer battery lifetimes.



Schematic of the SIMOX CMOS process. After the SOI wafer is made using oxygen implantation and annealing, the circuit is formed using standard CMOS processing. There are minor differences in the details of the process, but it uses the exact same lithography, tool set and metalization. IBM is in the final stages of qualifying a 0.22 μm CMOS on SOI process and are in the initial stages of development of a 0.15 μm process.

What Does This Mean To Us?

Much of the initial interest in this new development is related to microprocessors and other very highly integrated digital chips - markets where III-Vs have little-to-no penetration. Of greater interest to those who work in the compound semiconductor industry is how SOI might impact the high frequency and low power market segments from which most III-V IC manufacturers earn the bulk of their revenues.

To answer that question it is necessary to provide some background information – because not all SOI processes are created equally. There are two basic methods to fabricate SOI substrates. The first is called **Separation by Implanted Oxygen (SIMOX)**. In this approach, a high current, high energy O^+ implantation (100 mA at 200 keV, for a total dose of $1.8x10^{18}$ cm^{-2}) is performed into a silicon wafer to produce a buried layer of oxygen below the silicon surface. This implant is typically followed by 6 hours of annealing at 1320°C which regenerates the crystalline quality of the silicon layer remaining over the oxide and drives the formation of a buried stochiometric oxide layer (SiO_2). This typically creates a 400 nm thick buried oxide (BOX) layer beneath a 200-400 nm single crystal silicon layer. There is also a lower dose SIMOX process that utilizes a total dose of only $4x10^{17}$ O^+/cm^2 and which produces a thinner 80 nm thick BOX. Crystalline defects such as threading dislocations and small stacking fault pyramids on the order of $3\text{-}15x10^5$ cm^{-2} are typically obtained in the top silicon layer utilizing this technique.

The second method is that of **Bond and Etch Back SOI (BESOI)**. In this approach, two silicon wafers, both with thermally grown oxide layers, are bonded together using Van der Walls forces, in which the combined oxide layer formed by the two bonded SiO_2 layers will become the BOX. Subsequent annealing increases the mechanical strength of the bonded oxide interface. After wafer bonding, one of the substrates is thinned down, so that the remaining silicon on the thinned wafer is now situated above the BOX. This thinning process can be performed by mechanical means (polishing or grinding), or by wet etch means in which epitaxial etch stops are placed in the original wafer prior to oxidation. Final silicon thicknesses can range from 50 nm to 50 μm, depending on the amount of silicon etched away, and the BOX can range from 50 nm to several μm in thickness, depending only on the thickness of the oxide on the original wafers. This process requires two starting wafers, adding to the expense of the process as compared to the one wafer required for SIMOX fabrication, but offers much greater latitude in both the final silicon thickness and BOX thickness.

SIMOX Beats BESOI

For many years, IBM had backed the BESOI camp. Their efforts included a joint venture with MEMC called SiBond, which was formed in 1994 to commercialize BESOI technology. However, the added expense of having to use two substrates in order to produce one SOI wafer made it very difficult for BESOI to compete with the SIMOX process. As a result, IBM parted company with SiBond and the BESOI process. IBM has now purchased several high energy/high dose oxygen implanters from IBIS for the purpose of making their own SIMOX wafers.

While the SIMOX process is certainly cheaper, it is not as versatile as BESOI. It is limited to a narrow range of BOX thicknesses and is not really capable of producing silicon layers much thinner than 150-200 nm, since the oxygen must be implanted deep enough so that the implant tail does not encroach into the single crystalline top layer where the devices will be placed.

When the top silicon layer is 100 nm or less in thickness, the film is fully depleted. This removes all problems of latch up, and allows maximum packing density since the parasitic bipolar transistor action which plagues CMOS is no longer an issue. However, this is not the case in thicker silicon layers, such as those which IBM is utilizing, which are only partially depleted, so that parallel conduction paths may still be an issue.

Possible Impact on GaAs

On the basis of the data that is currently available, it seems likely that IBM's SOI technology can encroach on many III-V low power applications. This is due to the greatly reduced junction areas (up to a factor of 25 as compared to standard CMOS), and the potential of lower operating voltages.

However, it offers fewer advantages in the area of RF analog circuits (the bread-and-butter of the GaAs IC industry). This is because the SIMOX process produces a relatively thin buried oxide layer. In a III-V device there are hundreds of microns of insulating substrate beneath the active device. But in a device on SOI, the highly insulating layer is just 200-400 nm think. Due to RF parasitic coupling, in the SOI RF environment the substrate still looks much like conventional silicon, and at higher operating frequencies, performance will be severely degraded. So it seems likely that in high frequency, high power regimes, SOI will have trouble competing.

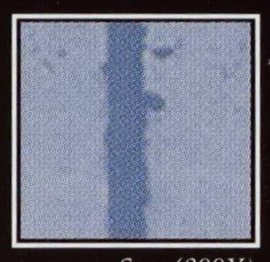
Nevertheless, one would do well to remember that even conventional CMOS is increasingly competitive in the RF field, especially in applications where noise levels are not a critical issue. CMOS based front ends operating up to 1.9 GHz are already being made, and if implemented in this new SOI technology, their performance will only be improved.

III-V's better keep a sharp eye on this one, and keep the other eye wide open, always on the look out for ever- higher frequency applications and emerging markets.

Dry Process III-V Dicing

SCRIBE AND BREAK TECHNOLOGY

SPEED	*120,000 die per hour 250µ x 300µ*
CONTROL	*Fully programmable*
VERSATILITY	*Multiple die size capability*
DRY PROCESS	*No D.I. or toxic waste water*
YIELD	*Superior yield & improved efficiency*



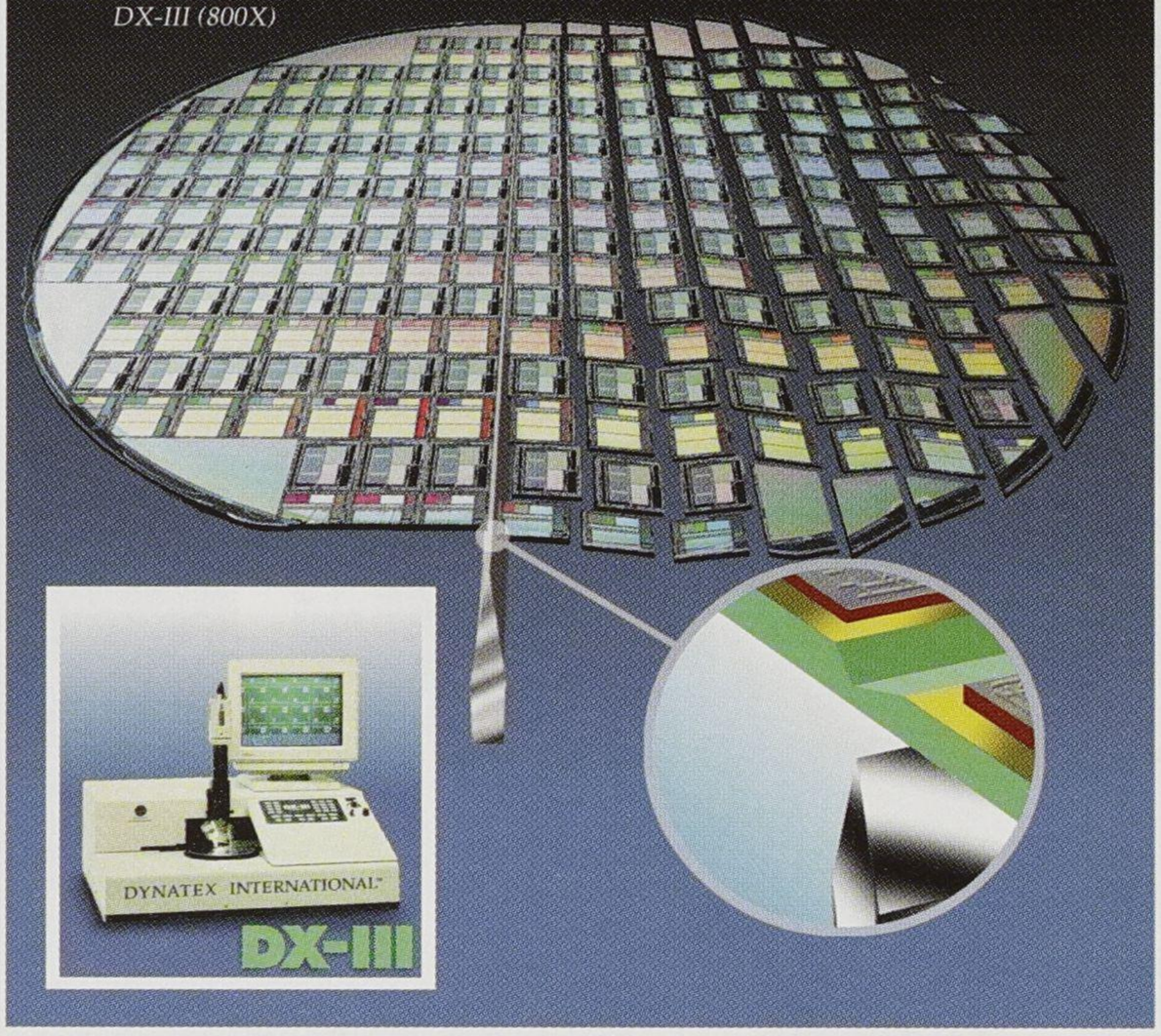
Saw (800X)



DX-III (800X)

Dynatex is your source for Dry Process Dicing equipment that has become the industry standard for processing III-V materials. Integrated Scribe and Break technology has the versatility for placement in any production environment where yields and an investment return are critical.

The DX-III is *the SAW alternative.*



DYNATEX INTERNATIONAL™

5577 Skylane Boulevard
Santa Rosa, CA 95403

Phone: 707-542-4227
Fax: 707-579-8599
E-mail: sales@dynatex.com

PRODUCT TYPES:
- *MMIC's*
- *RF Amplifiers*
- *Transistors/Caps*
- *Diodes*
- *Lasers*
- *Ceramic Hybrids*
- *O-E Components*
- *Glass*
- *MEMS*

APPLICATIONS:
- *Telecommunications*
- *RF/Wireless*
- *Displays*
- *Sensors*
- *Biomedical*
- *Optics*
- *Electro-Optics*

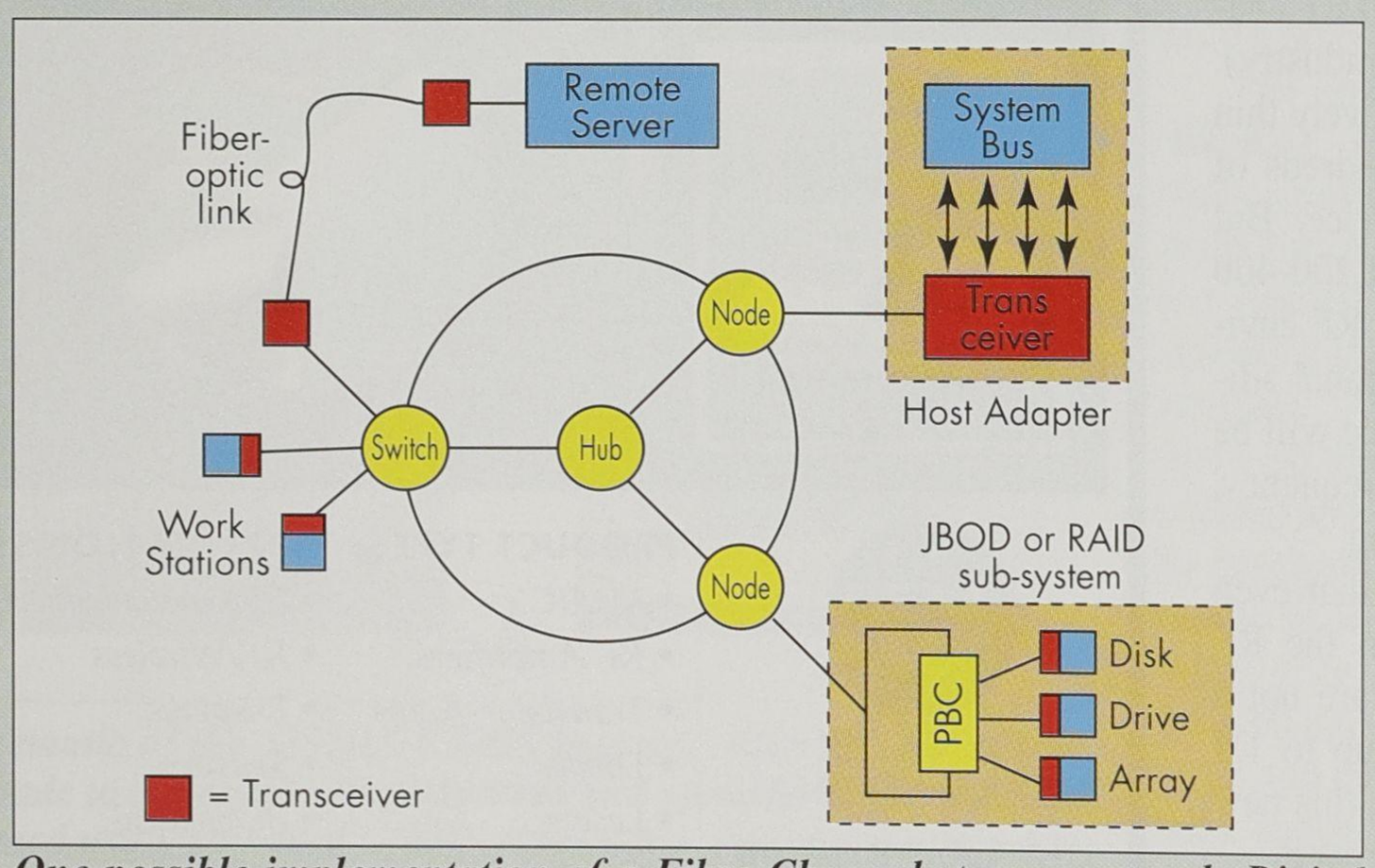
Fibre Channel Storage Systems

Fibre Channel is a technology for transmitting data between computer devices at a data rate of up to 1.0625 Gbit/s (4 Gbit/s is under development) and is especially suited for connecting computer servers with shared storage devices and for interconnecting storage controllers and drives. Since it is three times as fast, Fibre Channel is expected to replace the Small System Computer Interface (SCSI) as the transmission interface between servers and clustered storage devices. It is also more flexible; devices can be up to 30 km apart, using fiber-optic extenders, whereas shorter distances use cheaper coaxial cable and ordinary telephone twisted pair. And it is becoming a hot application for digital GaAs ICs.

Fibre Channel offers three main interface configurations; simple point-to-point interfaces, switched networks employing high bandwidth digital crosspoint switches such as TriQuint's TQ8033 (see right), and loop interfaces. Loops consist of a hub linking seven to ten nodes, or ports, which share the available bandwidth. The hub opens a point-to-point connection between two nodes to allow data transfer, then automatically reconfigures the loop to set up another connection. Each node contains a port bypass circuit (PBC) which automatically closes the loop if the node is non-functional. This arrangement permits "hot-swapping" - adding or removing a device at any of the nodes without shutting down the system. Vitesse's VSC7140 (see right) contains two hub node functions as well as repeaters to boost the signal as it travels through the loop.

Fibre Channel signals originate and terminate at the adapter of a terminal such as a workstation, disk drive or server. In the host adapter, a transceiver IC takes parallel data streams from the system bus and serializes the data to provide the signal required by the Fibre Channel system. Vitesse supplies 10- and 20-bit parallel-to-serial, serial-to-parallel transceiver ICs, and also manufactures opto-electronic transceivers compatible with Fibre Channel fiber-optic links.

Fibre Channel disk sub-systems, such as JBOD (Just a Bunch Of Disks) and RAID (Redundant Array of Independent Disks), utilize a back plane with a built-in arbitrated loop. Each disk location (port) has a PBC, which closes the loop if the disk is not available and allows hot-swapping. Vitesse's VSC7128 (see right) provides 6 ports on the same IC for this purpose.



One possible implementation of a Fibre Channel storage network. Digital GaAs ICs such as those recently introduced by TriQuint and Vitesse (see right) may be found in the transceivers, the PBC, the crosspoint switch or the hub nodes.

TriQuint Introduces 1.5 Gbit/s 64 x 33 Digital Crosspoint Switch

Hillsboro, OR. TriQuint Semiconductor has announced a digital crosspoint switch IC capable of supporting greater than 1.5 Gbit/s per channel. The TQ8033 has 64 inputs and 33 outputs, and is designed for high performance, high capacity switching applications such as Fibre Channel and Gigabit Ethernet. The non-blocking architecture, featuring 33 independent 64:1 multiplexers, allows each output channel to be programmed to any input, thus supporting both broadcast and multicast applications.

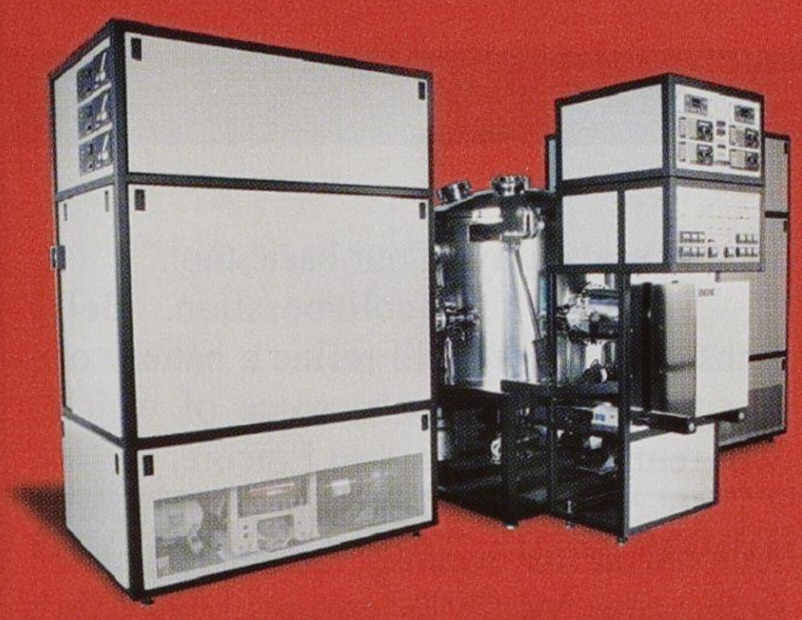
The device is highly suited for building larger switch arrays, having twice the number of inputs to outputs. A 64 x 64 switch array can be built with only two TQ8033 switches, with data passing through only one device. Other solutions require four 32 x 32 devices or sixty-four 8 x 8 devices, with data passing through 2 or 8 devices respectively. The 33rd channel on the TQ8033 allows data monitoring for system diagnostics or routing of system-level data.

Vitesse Launches New Fibre Channel ICs

Camarillo, CA. Vitesse has announced two new GaAs ICs for the Fibre Channel storage market. The VSC7140 Dual Repeater/Hub Node incorporates two repeater and two hub node functions onto a single chip. The IC combines a signal detect unit to detect the presence of valid Fibre Channel encoded serial data, a clock recovery unit to re-time the data, and two port bypass circuits (PBCs) that isolate non-operational devices from the loop. In addition, the VSC7140 can be used as a serial data repeater to "clean" incoming and outgoing signals for sub-systems such as disk arrays.

The VSC7128 Hex Port Bypass Circuit/Dual Repeater contains six PBCs and forms a six-port arbitrated loop in the backplane of Fibre Channel disk sub-systems. This IC also includes two repeaters, which clean up the incoming and outgoing serial data streams. The ICs contain selectable 106.25 MHz or 53.125 MHz reference clocks and use a single 3.3V power supply.

Our UHV/CVD deposition system offers a unique advantage in precision control of film thickness, composition and concentration profiles. Operation at a low temperature in the molecular flow regime enables the system to produce uniform, ultra-high purity layers having abrupt alloy and dopant profiles with a wide dynamic range. SiGe based ICs operate at speeds previously thought to be beyond the reach of



silicon technology and are becoming the first real challenge to GaAs in volume, high speed telecommunications and wireless applications. The benefits from this technology are its reduced cost and improved manufacturing ability. Cost reduction results from the compatible manufacturing of SiGe with high volume silicon based CMOS fabs and the productivity improvement of processing larger wafers.

Silicon Germanium (SiGe)

Multi Wafer - Multi Tube

CVD™
EQUIPMENT CORPORATION

For further information contact:
CVD Equipment Corporation
1881 Lakeland Avenue, Ronkonkoma, NY 11779
Phone: 516-981-7081 Fax: 516-981-7095
Email: info@cvdequipment.com

Bede & Bio-Rad to Collaborate

Bio-Rad Semiconductor Systems Division, Hemel Hempstead, England, and Bede Scientific, Durham, England, announced a collaborative engineering program which will ensure compatibility of Bio-Rad's new RPM2000 series of Rapid Photoluminescence Mappers and Bede's QC range of X-Ray characterization and mapping systems.

Bio-Rad's General Manager, Steve Blight, said that the complementary nature of the two companies' product lines, and requests from customers that they should work more closely together, has led to this agreement. While recognizing the two companies' individual strengths in terms of their respective products, there are customer benefits to be gained from making sure that the instruments work as a compatible pair.

Neil Loxley, Managing Director of Bede said, "Bede are always looking to explore synergistic benefits of any form of collaboration which results in new, leading edge products. The real winners of this partnership will be the customers."

Bell Labs & Emcore to Develop Epi Technology

Bell Labs and Emcore have teamed to develop technologies to grow materials required for devices used in advanced optical networks. The research team will focus on developing new epitaxial growth machines, diagnostic tools, and control software. The research will occur at the Emcore facility in Somerset, N.J., and a recently enhanced facility at Bell Labs.

"Developing this technology will allow for the incorporation of the largest number of source materials ever included in any TurboDISC compound semiconductor production tool," said Reuben Richards, Emcore's president and CEO. "It underscores the importance of taking a highly integrated approach to next-generation compound semiconductor equipment development. The keys to increasing yield and lowering the cost of devices are achieving progressively higher levels of automation and enhancing the versatility and scalability of our basic tool."

Through this collaboration, Bell Labs and Emcore will refine a battery of in-situ diagnostic tools, some of which will remain proprietary to Emcore.

In other news, on July 10 Emcore announced that recently received 11 new orders for MOCVD systems, twice as many as in the previous quarter. Six orders were for the newly introduced SpectraBlue GaN production system, and five were for the Enterprise 400 systems. Of these, two will be used to produce high brightness LEDs, two will be used for solar cell production, and one will be used for VCSELs.

Emcore also recently announced that it has received ISO 9001 and QS 9002 certification. The ISO certification was awarded to the company's headquarters in Somerset, New Jersey, and the QS certification, which relates directly to the automotive industry, was awarded to EMCORE's Pegasus device fabrication division in Somerset.

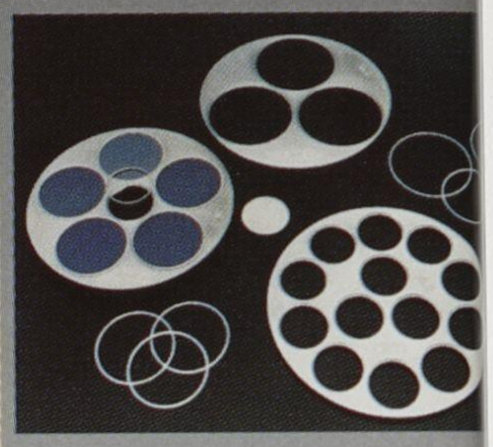
Briefly…

EPI MBE Products Group was recently award a patent for its Sumo effusion cell design. The company also recently announced the delivery of a 4" Mod Gen II MBE system to the General Motors Research Center. This is the first Mod Gen II System to be originally manufactured for growth on 4" substrates.

Epitaxial Technologies LLC was named winner of the 1998 Incubator Microenterprise Client of the Year Award, presented by the national Business Incubation Association. The award was based on employment and sales growth, uniqueness of product, and successful collaboration with a business incubator to accelerate the successful development of an entrepreneurial enterprise.

Performance Materials Inc. has established a new site on the WWW offering technical information on Pyrosyl™ brand PBN and other products. Visit *www. performancematerial.com*

EFFUSION CELLS FOR PRODUCTI
An integral
part of MBI
processing.
The economics of MBE epilayer fal
demand round the clock production.
keep your MBE running day and nig
every aspect of our new large capaci
effusion cells are designed
(in collaboration with the leaders in t
field of production MBE) to enhanc
reliability, performance and shorten
maintenance downtime.


Advanced features
benefits of ADDON
cells include :
- A careful selection of construction mater
- Non-clogging feedthroughs for power a
T/C connections.
- Strong no-weld, no-wrapping, no hot sp
heater filaments.
- Double T/C for each thermal Zone.
- A global ease of mainteanance in your
factory.
- A rigorous prior to shipment cleaning a
outgassing plus clean inert packaging.
- Two years warranty.

We know your production MBE
systems , we can deliver you the mos
appropriate cells from 50 up to 1150
capacity according to your needs and y
reactor design.
ADDON cells work with producti
and R&D MBE reactors from a
major suppliers.
ADDON
Créative Epitaxie Equipement
19, rue des Entrepreneurs
78420 CARRIÈRES sur SEINE - FRANC
Tél direct 00 33 1 39 15 39 99
Fax direct 00 33 1 39 15 56 36
e-mail mbecells@imaginet.fr
In JAPAN :
TECHSCIENCE Ltd
2-64 Miyamotocho, Koshigaya - Saitama 3
Phone 0489 64 3111 - Fax 0489 65 1500
e-mail tech-sc@cyborg.or.jp

Hands Off

Lucent's automated assembly line for its Laser 2000 product series combines a low cost and flexible production process with an efficient working environment

TIM WHITAKER

The need to supply higher volumes of telecommunication components for applications such as WDM and cable television (CATV) is forcing manufacturers to move towards fully automated device assembly and test operations. In some cases, it proves necessary to rethink the entire manufacturing strategy. With that in mind, Lucent's Manufacturing Realization Center (MRC) was opened in 1997 at the existing Lucent facility in Breiningsville, PA. "The MRC was established to re-engineer the way in which Lucent manufactures a number of its laser-based products," says Jim Dormer, MRC Manager. "We were looking to standardize the manufacture and assembly process across a number of different product families, creating a flexible line which could be easily adapted to cater for a different product mix or volume. Also, we sought to lower costs by reducing the amount of installed cleanroom infrastructure."

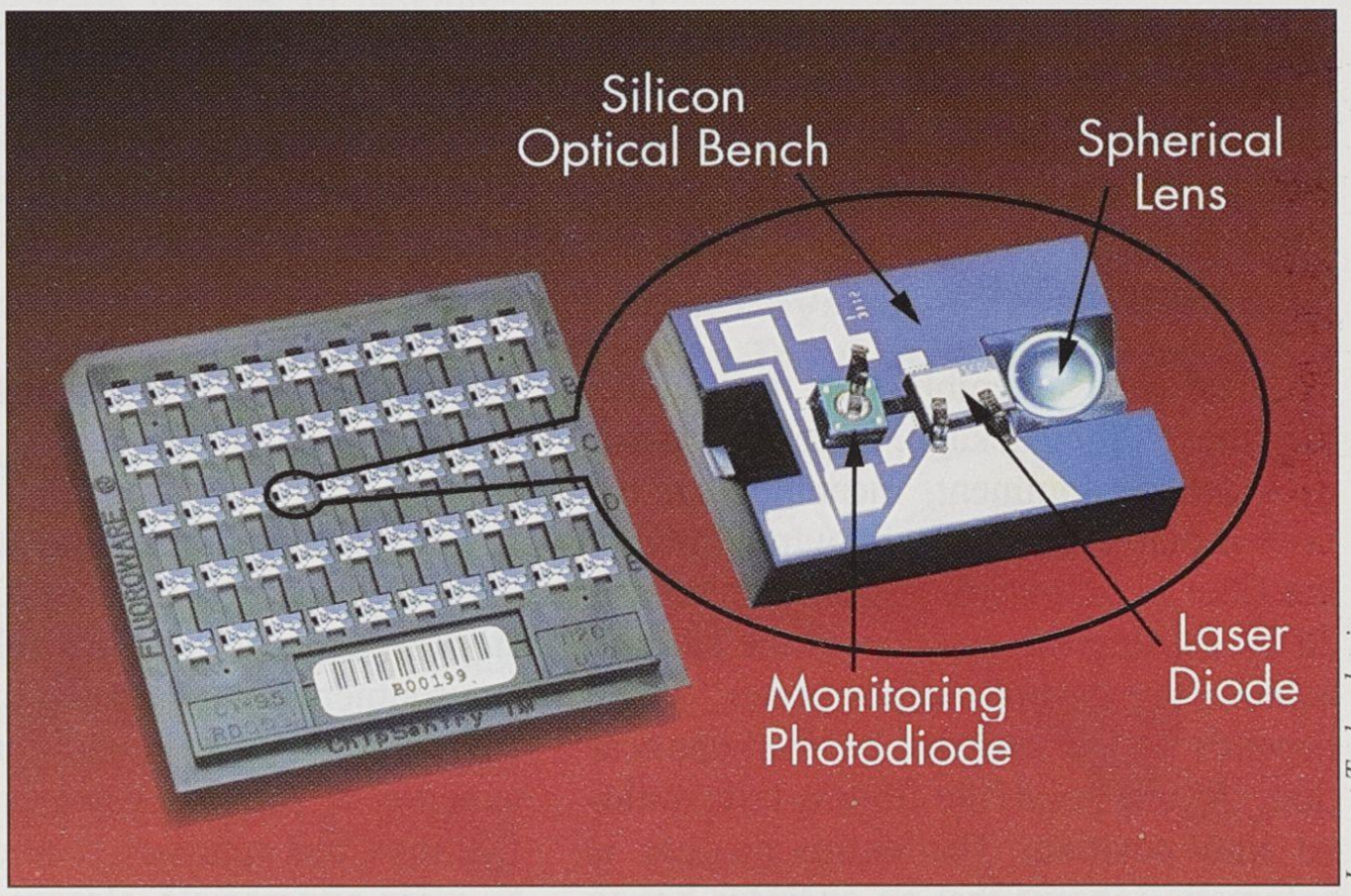
The principal MRC products are high performance, cooled lasers for WDM and CATV, which are designated the Laser 2000 series. The main building block of the Laser 2000 modules is the optical sub-assembly (OSA), constructed by bonding raw components onto a silicon optical bench, with precise alignment of each component to visible features on the silicon. OSAs are sealed into packages together with other parts such as thermoelectric coolers, and are precisely aligned to fiber pigtails. Laser 2000 products are generally housed in industry-standard 14-pin dual in-line (DIL) packages.

The MRC also assembles OSAs for other product lines, for example the FastLight series, which are assembled and tested at Breiningsville before being shipped to FiNet, Lucent's joint venture with Furakawa Electric (see *CS* 3[2], p. 19). FastLight products are uncooled laser modules for applications such as fiber-in-the-loop, which can be packaged in much smaller 6- or 8-pin mini-DIL packages.

The Optical Sub-Assembly

The Laser 2000 manufacturing process begins at Lucent's facility in Reading, PA, with the MOCVD growth of epitaxial heterostructures and device fabrication. Initial tests are performed on the devices to verify acceptable performance, before shipping them to the MRC.

On the assembly line at the MRC, a gantry robotic system is used to automatically place components, including laser diodes, photodiodes and spherical lenses, onto the silicon optical bench (see figure 1). Machine vision systems use registration features on the devices to automatically align them with etched features on the optical bench. The placement tolerances are prescribed by the design of the optical system being assembled, and are typically in the order of a few microns. When the OSA is subsequently placed into package body it is aligned to other features inside, so that the optical axis is positioned correctly within the package. As Dormer says, "When we get to the point of attaching the fiber and aligning it, we already know where the light's going to be." As well as the laser, the OSA holds a photodiode to monitor the output from the laser's rear facet, and a spherical lens which guides light from the laser's front facet to the outside of the package.



Lucent Technologies

Figure 1. A 2" by 2" waffle pack holds fifty optical sub-assemblies ready to be packaged and tested. The close-up shows the laser, monitoring photodiode and spherical lens aligned on a machined silicon optical bench.



Lucent Technologies

Figure 2. Lucent's MRC has localized cleanrooms operating from a single purge facility, creating a more relaxed and efficient working environment.

After completing the OSA, there is an automatic ribbon-bond step to provide electrical connections. The OSA is placed into a ceramic laser module package along with any other necessary components, such as the thermoelectric cooler, which are automatically selected by the pick-and-place system according to the product application. Some packages incorporate a hybrid integrated circuit to drive the active components, and future packages may include further levels of integration.

A resistance weld fastens the lid to the package and provides a hermetic seal. In some of Lucent's detector-based products, silicone gel is used to encapsulate and protect the components, and to prevent condensation in the optical path. This approach is only advantageous if the total cost is lower than hermetically sealing a lid onto the package.

Attaching Fiber

The final assembly step is to attach the fiber to the package. Lucent's process uses active alignment, meaning that the laser is biased and the light output through the fiber is examined. Coupling is adjusted by shifting the position of the fiber to achieve the desired output power, which depends on the intended product application. At this point, the fiber is laser-welded into position. The entire process is automatic (except that an operator has to load the package and fiber pigtail into the machine), unlike previous generations of assembly in which the operator was required to tweak the position of the fiber to maximize the light output.

Although active alignment is a time-consuming step, Lucent's engineers believe that it remains a necessary one. "Because of the size of the single mode fiber, and the need to couple the light accurately with the fiber, active alignment is probably going to be necessary for quite a number of years," says Dormer. "Future integrated assemblies incorporating waveguides may allow us to drop fibers into a groove on the silicon and have that directly coupled without biasing."

Device Testing

A three-step characterization process is applied to all laser modules, including testing at multiple temperatures to verify stability (the "burn-in"), and performance testing according to customer's specifications. This might include testing a laser on a specific WDM channel. After that, the products are labeled and shipped. The MRC features a central database of test data, providing traceability from the final packaged module back to the precise area of the wafer from which the laser was fabricated. The database also uses test data from all the individual steps to enhance the ability to test the device at a future step.

An Improved Manufacturing Environment

For the previous generation of products replaced by Laser 2000, assembly steps were carried out in a full clean room environment up to the point of welding the fiber onto the box. In addition to the huge expense of running extensive cleanroom facilities, this approach required personnel to wear appropriate cleanroom clothing, and prevented convenient access by support staff such as engineers and designers. Lucent's approach has been to construct mini cleanrooms around those equipment stations needing such an environment.

In most cases this involved building a box around the equipment (see figure 2), with all such boxes being supplied with clean air by a single air handling system. Previously, seven or eight similar class 1000 or 100 systems would have been required. But the new space is radically different; it is similar to a typical office area, with carpeted floors, and desks and cubicles nearby. The results are very positive. "We are able to tighten up on communication, and the working environment is much nicer," says Dormer.

OSAs are assembled in 50 piece lots, which are transferred by operators to the next piece of equipment after each step. This "islands of automation" approach is the most effective for relatively small parts, and allows flexibility as demand or the product mix changes.

Alternative Packaging Materials

Along with many other manufacturers, Lucent uses ceramic packaging, but is looking at possible alternatives. "We are looking at plastic packaging for the future, and I think that is where the industry is going to head," says Dormer. "There may be a raw material cost advantage, but the main benefit will be the elimination of steps in the assembly process, such as resistance welding a lid onto the box." There are a variety of issues such as conduction of the thermal energy generated by the active components, the manufacturability of the material and its mechanical stability and rigidity. The whole package needs to be mechanically stable, for example when exposed to the wide temperature swings experienced in some uncooled applications, otherwise coupling between the laser and the fiber can shift.

As demand for laser diodes continues to grow, one can foresee increasing need for alternatives to traditional piece-work assembly methods. Lucent's Manufacturing Realization Center has set new standards for efficient, highly automated production of laser-based modules, to meet the growing demands of telecommunication networks.

Semiconductor Lasers in Space

Lots in Space, Part 2

TIM WHITAKER

At the mention of lasers in space, thoughts naturally turn to *Star Wars*, villians from James Bond movies, or large orbiting platforms blasting intercontinental ballistic missiles out of the sky. It may be a while before semiconductor lasers are used in these applications, but there are plenty of other less destructive roles, involving fiber-optic and free-space optical data links both within and between satellites. In the second part of our "Lots in Space" series, we review progress in these areas.

Why Use Lasers?

The development of free-space optical links for space-based applications is being driven by the increasing need to transfer huge amounts of data at very high rates. For example, exploratory space missions such as those to Mars collect huge quantities of data which are sent back to Earth for processing.

In our previous issue, we discussed some of the many satellite "constellations" which will enter service over the coming months and years, providing voice-based or broadband multimedia services on a global basis. Among these, Teledesic's broadband "Internet In The Sky" system proposes to use laser-based links between satellites to provide a multi-Gigabit trunk network across the heavens. In contrast, the Iridium constellation uses RF links between satellites.

Free-space optical communication offers many advantages over RF links, in particular a significantly higher data rate capacity, an uncontrolled spectrum, and reduced size, mass and power. The principle disadvantage is attenuation by the atmosphere, which is why all the projected constellations are planning to use RF uplinks and downlinks to communicate between the spacecraft and Earth.

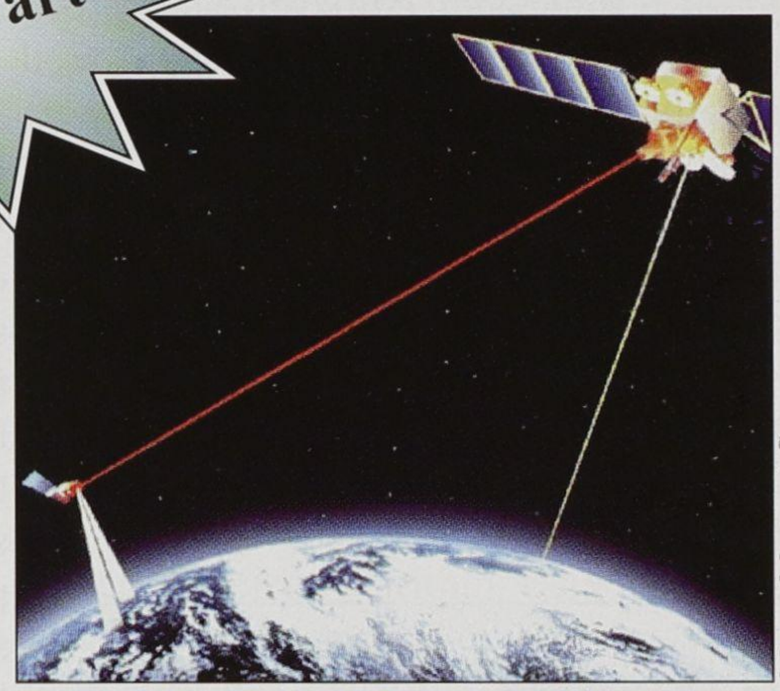
All RF links are subject to official allocation of a spectrum which is limited, even at Ka-band frequencies (26 - 40 GHz) and above. At optical frequencies (~10^{13} -10^{15} Hz), the desired bandwidth occupies only a very small proportion of the spectrum.

Satellite constellations are intended to provide a communications networks spanning the globe; such coverage requires a method for long-haul data transmission. The broadband systems which don't file for allocation of spectrum space for RF satellite crosslinks have two other choices; either they build optical inter-satellite links, or use terrestrial fiber-optic backbones. As demand for Internet and related applications continues to rise, the advantage of having dedicated bandwidth, free of outside influences such as service availability, is obvious.

Some analysts predict that demand for transatlantic undersea cable systems will outpace capacity early in the next century, supporting the use of satellite-based trunk routes [1]. In addition, it has been suggested that inter-satellite links could be significantly cheaper to build, in terms of $ per Gbit/s per m, than fiber-optic links, although this evaluation was carried out before the widespread implementation of DWDM.

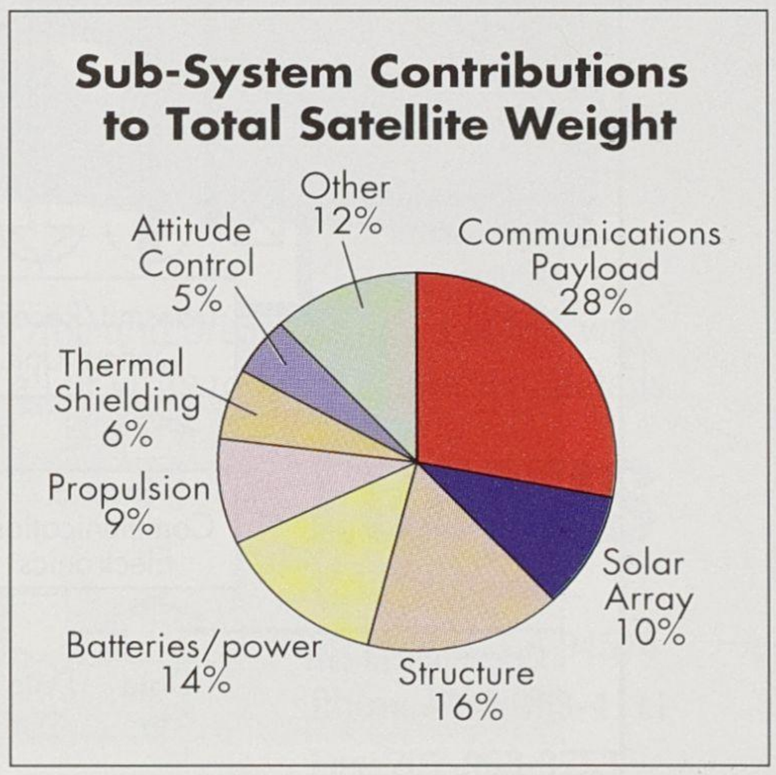
Weighty Issues

Another advantage of free-space optical links is the weight saving compared to RF payloads. Weight is an extremely important factor in determining the launch cost of satellites, which can be as high as $20,000 per kg. In large communication satellites, 28% of the total satellite mass is accounted for by the communications payload (see chart). Using RF links, the satellite mass increases in direct proportion to the total available bandwidth - more hardware is required for more channels. Optical systems offer an intrinsically higher data rate, and also have a much higher antenna gain, allowing use of smaller apertures for the same data rate. A study by Ball Aerospace found that optical links provide a means to increase total bandwidth by over an order of magnitude, compared to RF payloads having the same mass [2].



Matra Marconi Space

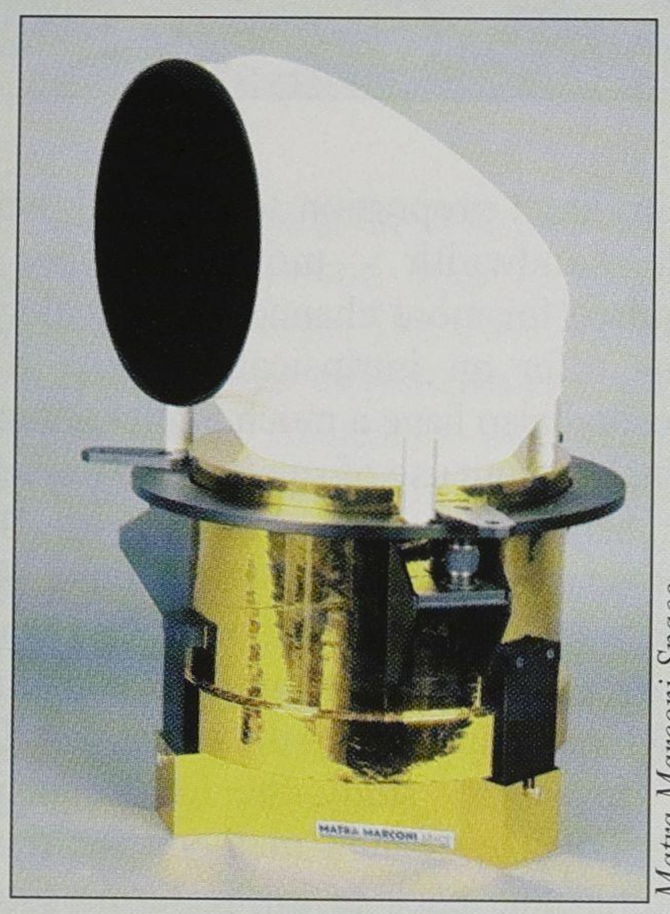
In another study, the Jet Propulsion Lab (JPL) evaluated methods for transmitting data back to Earth during future missions to Mars, and compared the benefits of using optical or RF (X- or Ka-band) links [3]. At a normalized data rate, optical modules offered a 2.5-fold weight advantage, and consumed 2x less power at the highest data rate of 10 Gbit/day.



From ref [2].

OMNIS - Optical terminal for Multimedia Networks In Space

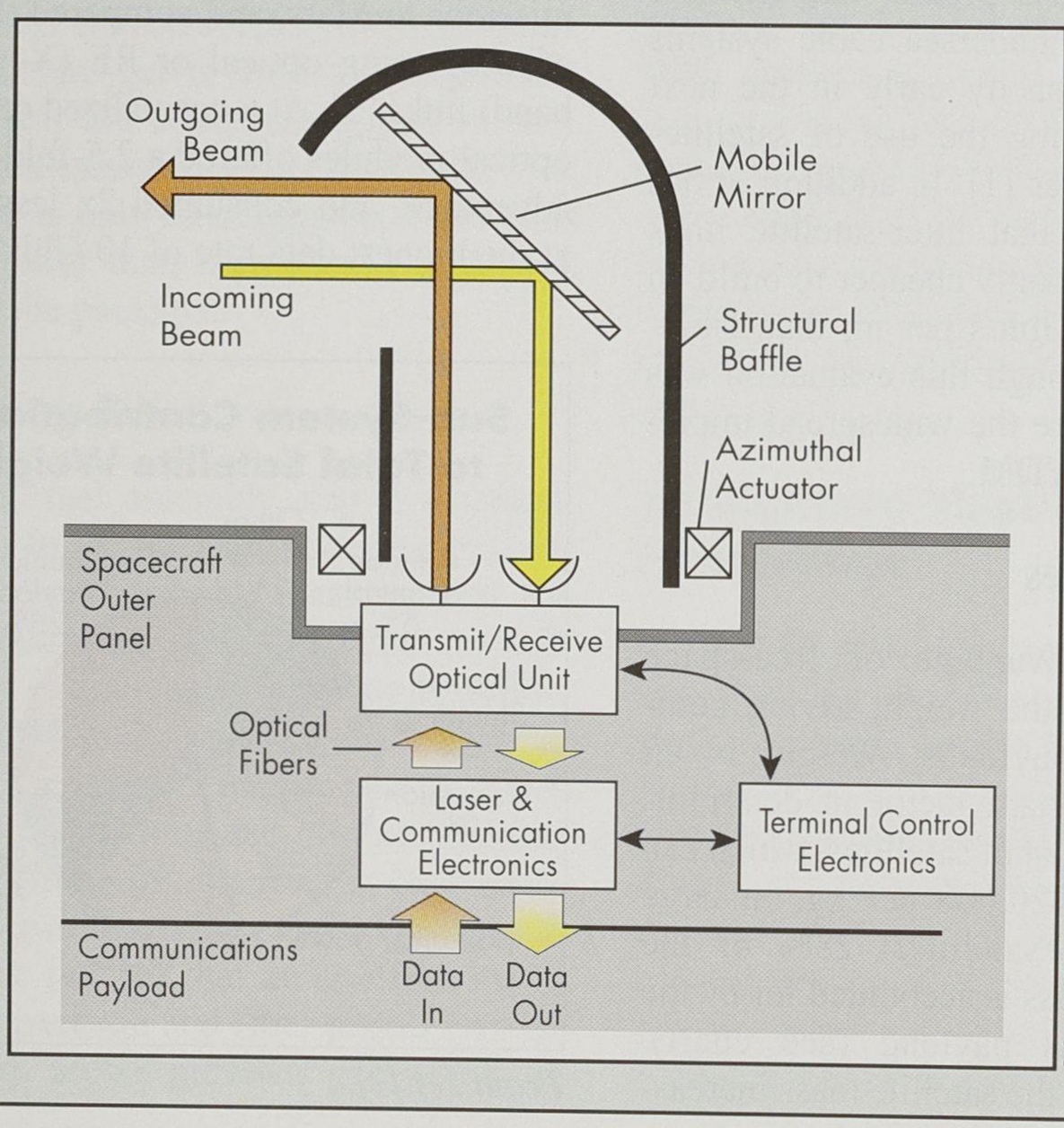
With their OMNIS terminal, Matra Marconi Space is among the frontrunners to provide optical terminals for the multimedia space-based networks. The terminal, currently under development, is designed to provide bi-directional links at high data rates of up to 2.488 Gbit/s over distances up to 7500 km, using high power 0.8-0.85 μm AlGaAs laser diodes.



Matra Marconi Space

OMNIS is specifically designed for LEO or MEO satellite constellations, to replace conventional RF payloads with light, compact and powerful optical antennas. Due to the number of terminals which might potentially be deployed in such constellations, the design emphasis is on simplicity, reliability and mass producibility. The Teledesic constellation of 288 satellites, by far the largest system under development, is likely to have as many as 6 optical terminals per spacecraft. Matra Marconi Space is one of the lead partners in Teledesic.

The OMNIS terminal weighs 20 kg and consumes 60 W of power. A front mirror is used to direct the beam (see figure), eliminating the need for a very large mobile part. The number of directional mechanisms and sensors is kept to a minimum, and counter terminal acquisition is achieved in less than 1 minute.



Matra Marconi Space

Demonstrating Free-Space Links

Although the concept of using lasers diodes to allow communication between satellites is about 10 years old, only a very small number of public demonstrations have been made, along with several classified military experiments. Richard Craig of SDL believes that "only 3 or 4 laser systems have already flown, with 3 or 4 more firmly committed over the next year or so." He believes that all of these missions used laser diodes supplied by SDL.

The main problem with this type of application is the large transmission distance; obviously the signal can't be amplified en route. "This requires a laser diode with at least an order of magnitude more power than a conventional communications laser," says Craig. "In the Japanese OICETS terminal (see below), single mode GaAs-based laser diodes are used, which have a peak power of 240 mW. In comparison, the average CD laser operates at 1 mW, and typical telecommunications lasers run at 10 mW. The challenge is to maintain a high beam quality, while at the same time getting plenty of power out there. Also, you need to ensure reliability over the 10 year life of the satellite, because you can't service the lasers."

The Semiconductor Inter-satellite Link EXperiment (SILEX)

Several experiments have been launched to evaluate the use of free-space laser communications between a spacecraft and Earth, including an atmospheric visibility monitoring program at JPL to gather data on atmospheric transmission. The first non-classified demonstration of a free-space optical communications system will be the Semiconductor Inter-Satellite Link EXperiment (SILEX). This will establish a 50 Mbit/s optical link between the French low earth orbit (LEO) spacecraft SPOT4 and the European Space Agency's geostationary earth orbit (GEO) satellite Artemis. SPOT4 was launched in March 1998, and Artemis will be launched in 2000. The optical terminals for both systems were manufactured by Matra Marconi Space.

SILEX uses 0.8-0.85 μm AlGaAs lasers supplied by SDL, with an average power of 60 mW and a peak modulated power of 120mW. To establish a link across 45,000 km of space, a complicated process of beam pointing, acquisition and tracking is essential. Based on the positional data of the two satellites, the terminals



Matra Marconi Space

One of the optical terminals for the Semiconductor Inter-Satellite Link EXperiment (SILEX) mission - the first non-classified demonstration of laser communication links between satellites.

point toward each other and one emits a bright, wide beacon which the other detects with CCD sensors. An automatic closed loop process then accurately determines the direction for the communication link to be established. The acquisition process takes 2 minutes and has a 95% probability of success. The terminal has a power consumption of 130 W, and a total mass of 150 kg, with a moving part weighing 70 kg to acquire and track the other terminal.

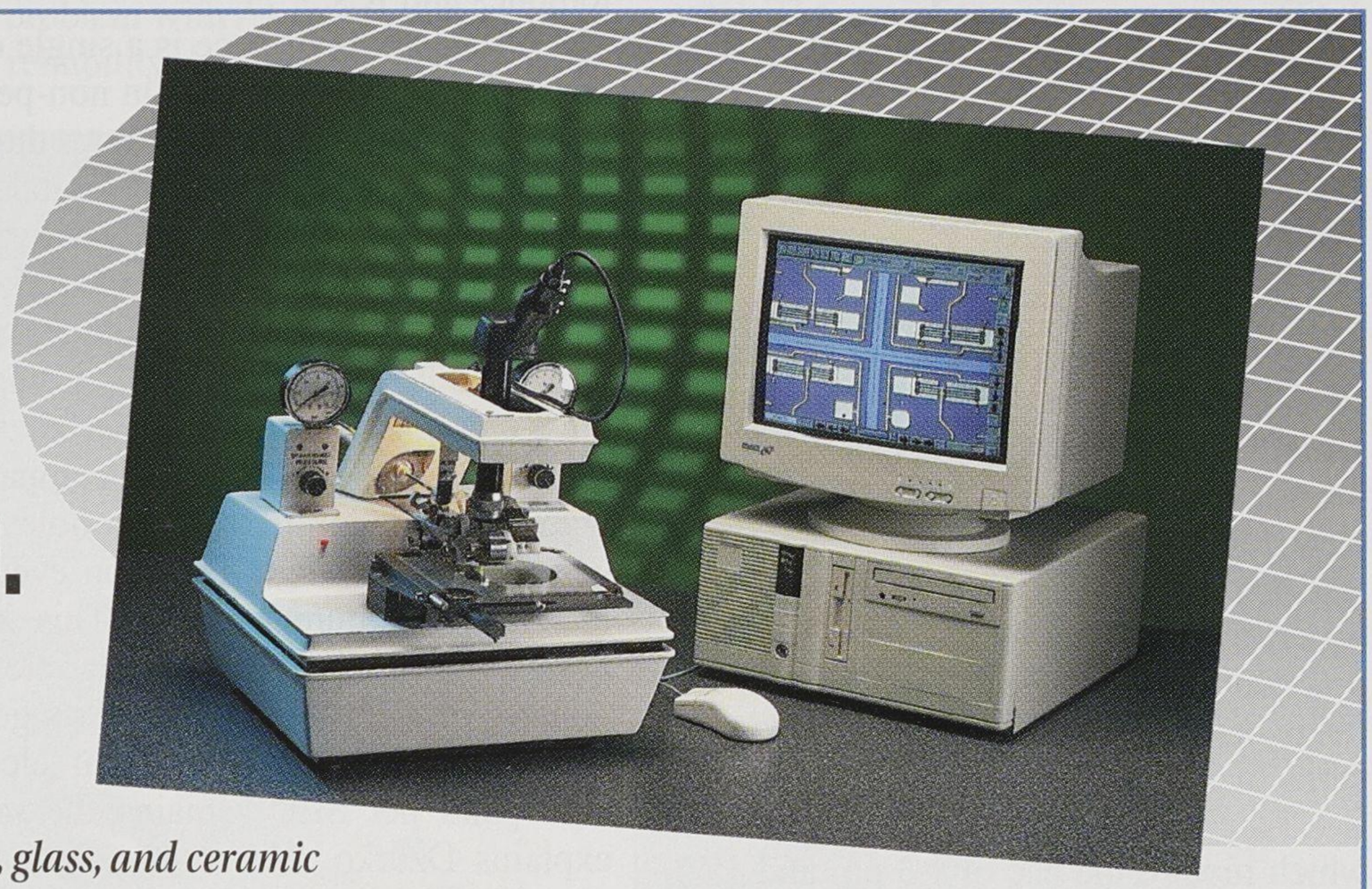
A link between Artemis and OICETS (Optical Inter-orbit Communications Engineering Test Satellite), launched by Japan's National Space Development Agency, is also planned. The OICETS terminal will use an 850 nm AlGaAs laser diode from SDL, to achieve a data rate of 50 Mbit/s with a bit error rate of $1x10^{-6}$. The diode has a peak power of 240 mW and an average, modulated power of 120 mW. Other specification requirements for the laser include a threshold current of 50 mA and a slope efficiency of 0.8 mW/mA.

Fiber-Optic, Intra-Satellite Data Links

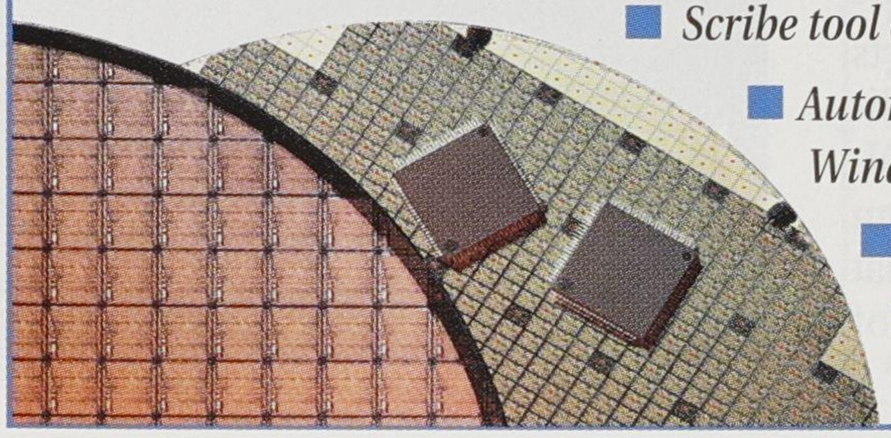
In the current generation of satellites, high speed links are implemented using heavily shielded co-axial cable, to provide electromagnetic immunity from the high radiation environment of space. As data rates increase, so does the number of coaxial cables and most importantly the weight of all their shielding. The Teledesic constellation plans to use laser-based inter-satellite links to transfer data at very high speeds between satellites; this will require that the data can also be routed efficiently within each satellite, linking the numerous optical cross-link terminals and space-Earth RF antennae. At data rates in excess of 1 Gbit/s, the use of photonics will almost be mandatory.

Fiber-optic linkages are naturally immune to EM interference, offer a very high bandwidth, and are lightweight. However, the use of fiber-optic links in satellites has been slow to take off, due to the need for extremely reliable diode

INTEGRATED SCRIBE & BREAK WAFER DICING SYSTEM GIVES 98-99% YIELD. DAY AFTER DAY.



- *Dice III-V material, thin silicon, sapphire, glass, and ceramic*
- *Sawframe or hoop presentation for pick and place operation*
- *Proprietary scribe tools perform repeatedly in rote fashion on all materials*
- *Scribe tool change requires only three minutes*
- *Automatic computer control utilizes Windows 95® and Starflight Vision System*
- *Clean, cosmetically perfect dice*
- *Unequalled throughput*



Scribe and break the new Loomis way.
Call or write today for complete details...

LOOMIS
1210 Church St.
St. Helena, CA 94574
Phone: 707-963-4111
Fax: 707-963-3753

lasers operating without the need for thermoelectric cooling in a harsh radiation environment and over a wide operating temperature range. The laser is required to exhibit stable parameters including threshold current, external efficiency, modulation bandwidth and intensity noise over these ranges.

Space-qualified 1.244 Gbit/s Optical Data Links

SDL has developed a fiber-optic link suitable for space applications, which operates over a wide temperature range without the need for active temperature compensation or optical isolators, and is compatible with the radiation environment encountered by a satellite in low Earth orbit. According to Ken Dzurko of SDL's space and avionics business unit, the key to the linkage lies in the use of 1 μm strained InGaAs quantum well laser diodes, which combine the desired attributes of high differential gain for high speed operation, with a very stable operation under variable temperature conditions.

"At the start of the development there wasn't a specific diode in existence that met all of those characteristics, certainly not at the production level," says Dzurko. "SDL's strategy was to take our 980 nm telecommunications-qualified EDFA pump laser and make some modifications to enhance the low power, high speed attributes of the chip. Rather than designing for maximum external quantum efficiency and highest peak power, we modified the cavity parameters to give stable operating current, voltage and light output power over a wide operating temperature range, and also address the feedback concerns of a fiber-optic link."

Fiber attenuation and dispersion, which require the use of 1.3 μm and 1.55 μm lasers for terrestrial long-haul applications, are not as critical for fiber-optic links of less than 100 m. This allows the use of InGaAs QW lasers at 1 μm, offering significant temperature, power and bandwidth advantages. Due to the relatively small variations in slope efficiency and threshold current in these lasers, the only feedback loop in the circuit is an average power control. "Many types of data-link for harsh environments require active slope compensation," says Dzurko. "In SDL's solution, the modulation current remains fixed, and the bias current is varied over a fairly narrow range to control the average power." This diode advance is key to the wide temperature performance demonstrated by the data-link (-55°C to +150°C).

Radiation Hardness

Components in the SDL linkage were selected for their intrinsic radiation-hardness. It is well known that GaAs-based lasers are intrinsically more radiation-hard than InP-based lasers. A photodiode with a small geometrical volume was chosen to minimize the radiation cross-section, and silicon bipolar IC technology was used for the driver circuitry due to stability and rad-hardness. There are two main types of radiation damage. Accumulated radiation (total dose) damage occurs from the prolonged exposure to ionizing radiation, which increases fiber attenuation and degrades the performance of lasers, photodiodes and ICs.

Of equal importance is a single event upset (SEU), which results in non-permanent degradation of bit error rates due to a change in the logic levels of digital data. "In addition to minimizing the active volume of the photodiode," says Dzurko, "it is important not to be overly aggressive in terms of the IC dimensions." Using 0.5 μm technology, the absolute current value at 1 Gbit/s will be large in comparison with the number of electron-hole pairs generated by a single radiation event, so the SEU signature is small. This is not always the case. "At higher data rates, the number of electrons per bit starts getting squeezed, while the number of electron hole pairs per SEU remains the same," explains Dzurko. "At some point, radiation shielding becomes a requirement, but is currently unnecessary at 1 Gbit/s."

According to Dzurko, InGaAs QW lasers are uniquely suited to high temperature digital communications, and all sorts of avionics and harsh environment applications are envisaged. More recently, SDL have demonstrated an improved 1 μm laser design for 2.5 Gbit/s modules that have operated at temperatures in excess of 200°C.

The Future

Both free-space and fiber-optic laser communication links in space are still emerging technologies, but will undoubtedly play a major role in future satellite systems. The only complete satellite constellation, Iridium, has not used optical links either between or within its satellites. Although the Teledesic network relies on the use of optical crosslinks, it is likely that the first generation of Teledesic satellites will use an established, off-the-shelf (coaxial) solution for internal satellite links. However, as technology upgrades push up the data rates, the use of a fiber-optic bus on the spacecraft will become imperative to complement the optical links between satellites. For these applications, both SDL and Matra Marconi Space will be ready.

References

[1] "Do future commercial broadband communication satellites really need laser intersatellite links?", J. Freidell, Proc. SPIE 2990, 1997, p. 122

[2] "Global trends and the future of laser communications", D. Begley, ibid, p. 134

[3] "Comparative study of optical and RF communication systems for a Mars mission", H. Hemmati et al, ibid, p. 200

In Our Next Issue



Part 3:

Solar Cells

Polaroid Develops A Market For High Power Lasers

TIM WHITAKER

The name Polaroid is most commonly associated with photography, in particular instant cameras. Less well known is that Polaroid also manufactures laser diodes, and that in 1997-98, Polaroid was third in dollar volume sales of high power laser diodes, behind SDL and OptoPower Corp. The majority of these devices are used in the Helios medical imaging system developed by Polaroid, and currently manufactured by Sterling Diagnostic Imaging (see page 26). The other major market for Polaroid's devices is in diode-pumped solid-state lasers.

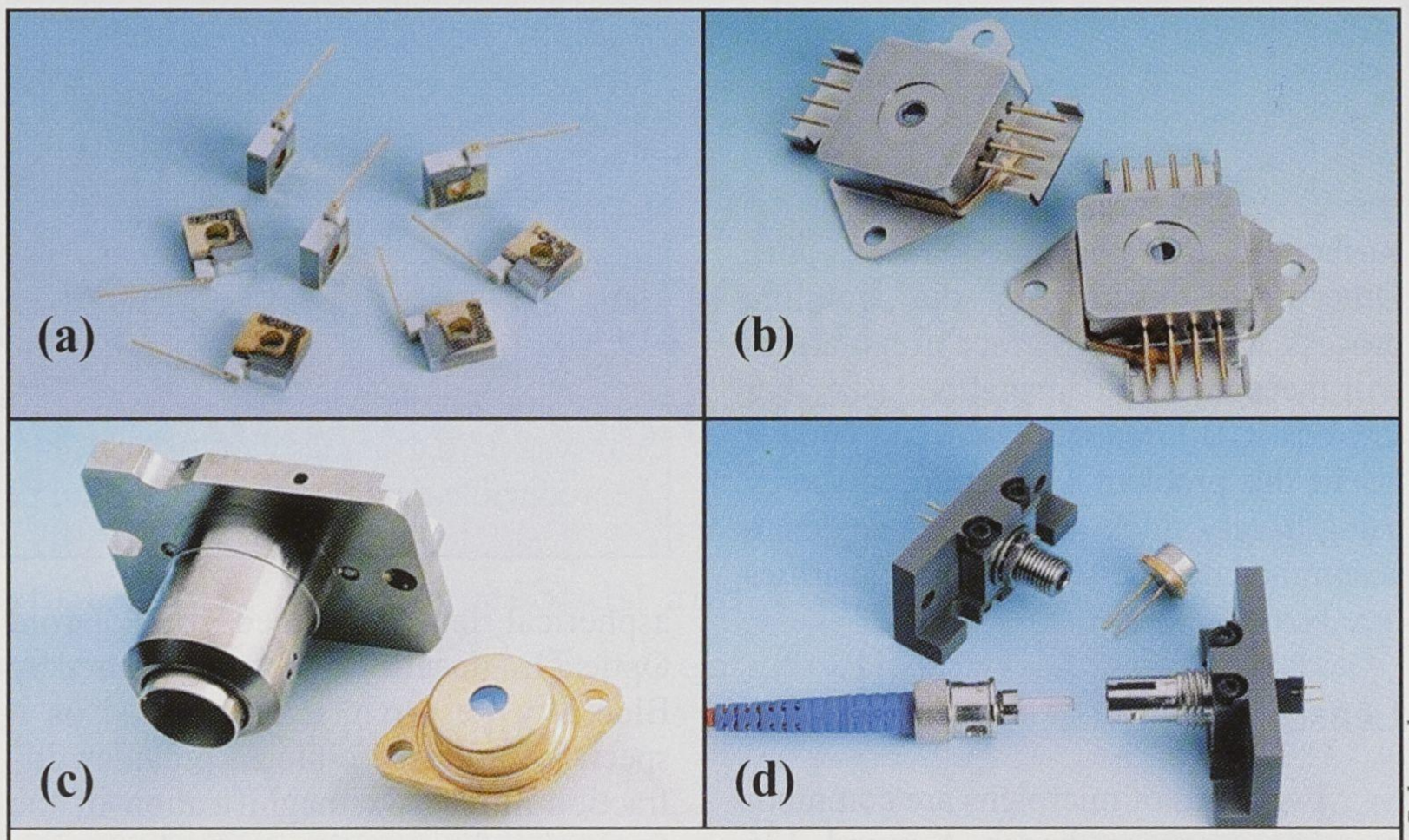
Polaroid's Microelectronics Laboratory (MEL) was founded in Cambridge, MA, in 1985, to develop semiconductor components for electronic imaging products. MEL designed and developed high power laser diodes for the Helios medical printer, then began manufacturing lasers when other companies failed to meet the demands of the Helios program.

The Polaroid Laser Diode Manufacturing and Development Group moved to a 16,000 foot^2 facility in Norwood, MA, in 1993, under the directorship of Dr. Aland Chin. As well as continuing to supply laser diodes for Helios, the group began supplying lasers to external customers in 1997. The fabrication facility processes 2" and 3" device epiwafers purchased from several merchant suppliers, the main vendor being Epitaxial Products International. A number of different devices are offered, including AlGaAs broad area lasers at 808 nm, AlGaAs ridge waveguide lasers at 840 nm, InGaAs laser diodes at 980 nm and AlInGaP broad area lasers at 660 nm.

The 808 nm devices are available with a variety of output powers and aperture sizes, including 1 W from a 50 μm aperture and 2 W from a 100 μm aperture. Most commercially available GaAs/AlGaAs lasers are limited to around 1 W for a 100 μm aperture, due to the onset of catastrophic optical damage (COD). This key failure mode of high power lasers is due to heating at the facets and is material-limited. The CW operating power specification is usually set at between one half to one third of the COD limit for the device. "We are able to offer 2 W from a 100 μm aperture laser due to the broadened waveguide structure developed through a long working relationship with Prof. Garbuzov and John Connolly at the Sarnoff Laboratories, NJ," says Dr. Chin. He takes a somewhat skeptical view of the "aluminum-free" approach adopted by some companies, including Coherent and Semiconductor Laser International. "The problem with Al-free devices is that their reliability has never been demonstrated in the manufacturing sense, and they appear to have higher threshold and lower slope efficiencies than GaAs/AlGaAs devices," he says.

Mounting and Packaging

The temperature rise during operation of high power lasers places stringent requirements on mounting and packaging. Polaroid offers a range of packages (see photos, below) such as the c-block, which can be used with lasers exceeding 6 W. The butterfly and TO-3 packages contain a c-block sub-mount and a thermoelectric cooler (TEC), and are used in applications where wavelength stability is vital. The use of the TEC limits the TO-3 package to 4 W.



Polaroid

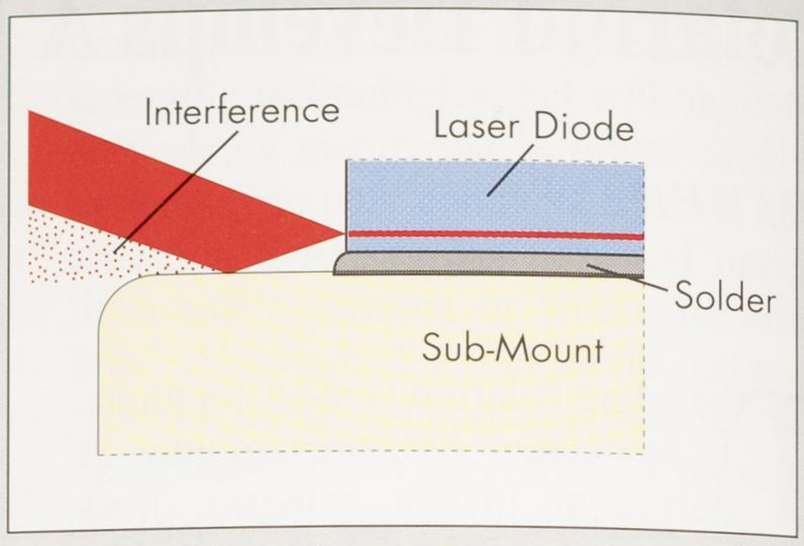
Some of the packaging options offered by Polaroid. (a) In the c-block, or open heat sink, the laser chip is bonded directly to the edge of a solid copper block measuring ~6.9 mm x 6.4 mm. (b) The butterfly package contains a c-block sub-mount and a thermoelectric cooler, and is ~50 mm wide. The window diameter is 3.6 mm. (c) The TO-3 package (right) measures 39 mm x 25 mm, with a 6 mm window. It can be combined with precision optics in the Monochrome module (left), for a precisely collimated output. (d) The 9mm package (center - the measurement refers to the diameter of the gold-colored base) is also available in a connectorized version for attachment to optical fibers.

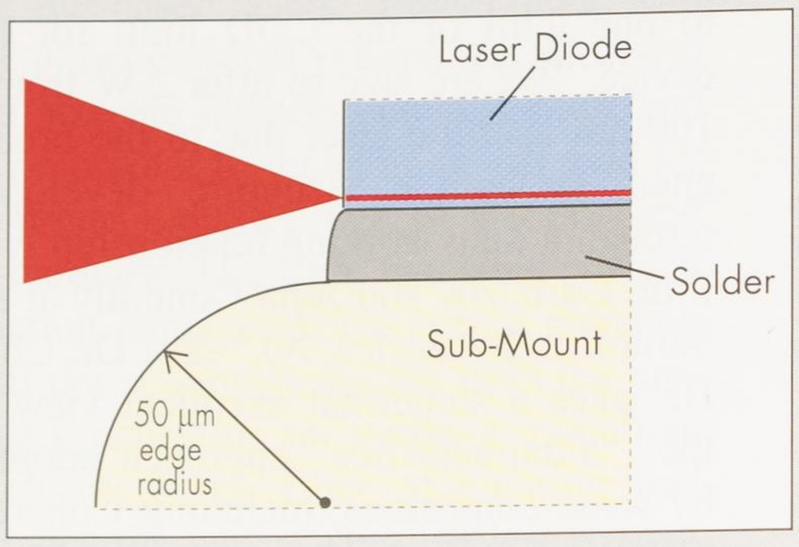
The much smaller 9 mm package is used as a low cost and compact alternative to the TO-3 . This package is solid copper and incorporates a diamond heatsink; both materials are used for their high thermal conductivity. According to Dr. Chin, the diamond heatsink is quite unusual. "The standard 9mm packages used by most companies are manufactured in Japan for optical disk applications," he says. "The steel package has very poor edge and surface qualities since it must be low price (less than 50 cents each in large volume), and is designed for a laser operating at less than 100 mW (typically 5 mW). The Polaroid 9mm package can be used with lasers emitting up to 2 W."

The quality of the surface to which the laser is bonded is very important. The epitaxial layers for laser diodes are about 4 μm thick, with the p-n junction lying about 2 μm from the surface. The final substrate thickness is about 100 μm, a dimension necessary to allow cleavage along (110) planes to form the Fabry-Perot optical cavity. Due to the heat density generated in the emission region (~5 kW/cm^2), the lasers have to be bonded with the epitaxial side towards the heatsink to minimize the thermal path. The bonding surface of the header needs to be smooth (less than 0.1 μm surface finish) relative to the distance from the surface to the p-n junction (~2 μm). Otherwise, during the die bonding process, the bonding surface irregularities will mechanically damage the laser. For low cost CD lasers and most high power lasers, this problem is generally solved by using a very thick (25-50 μm) solder to accommodate the surface irregularities (see box).

Mounting Challenges

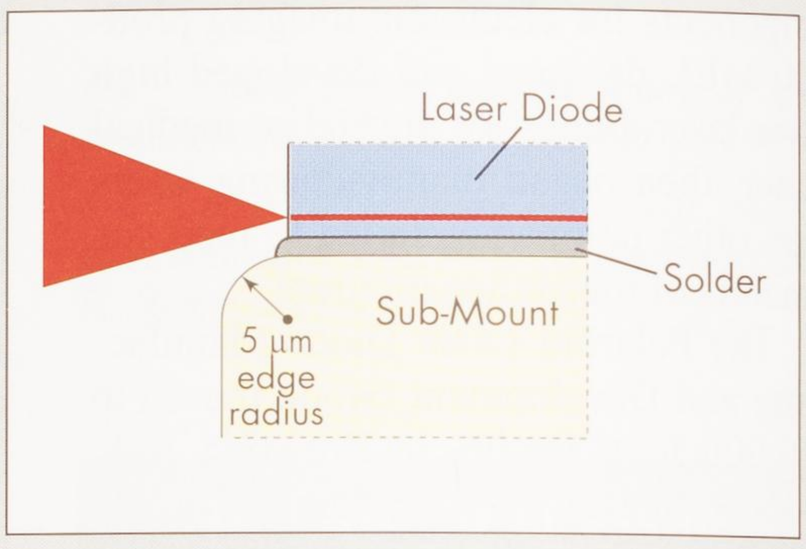
The position of the laser die relative to the edge of the sub-mount is very important for high power devices. If the laser overhangs the front of the sub-mount by more than ~5 μm, the laser's front facet will overheat. If the laser is mounted too far back from the edge, the divergent laser beam bounces off the sub-mount and gives an unacceptable interference pattern.





Standard machined blocks do not have sharp edges at the micron scale, which prevents the laser from being mounted within a certain distance of the edge (the edge radius). For CD headers with a 50 μm edge radius, the crude solution is to float the laser chip on a thick pool of solder, which also mitigates against surface irregularities.

A more elegant solution, used by Polaroid and SDL, is to have a small edge radius of less than ~5 μm, a very smooth bonding surface, and highly accurate pick-and-place machinery. This permits mounting close to the edge with a thin layer of solder, which not only fully utilizes the heat-sink properties of the mounting and allows precision alignment into any optical system (e.g. a microlens or the Helios optical head), but also results in much more reproducible device manufacture and performance.



Lenses

Two types of microlens are commonly used with these diodes. A round, 125 μm diameter anti-reflection coated optical fiber can be mounted to act as a cylindrical lens where maximized power collection into an aperture is the main consideration. When focussed for best collimation, these lenses reduce the FWHM of the fast (high divergence) axis from typically 40 degrees to less than 2 degrees. An aspherical lens, designed by Polaroid Optical Engineering and manufactured by Blue Sky Research, CA, mounted on a specially modified c-block, provides diffraction-limited 8x magnification of the fast axis, for exacting optical requirements such as re-imaging of the near field in printing applications.

Monochrome and Polychrome Modules

Polaroid makes several specialized modules offering precisely collimated beams at up to 8 wavelengths. The Monochrome laser module combines a TO-3 laser package with precision-aligned optics to provide a beam with a typical divergence of less than 20 mrad x 0.5 mrad at FWHM. Applications include laser welding, or coupling into multimode fiber. The Polychrome module combines the outputs of up to 8 customer-selected high power lasers into a single, collimated, 8-color beam. The units are also individually addressable, allowing an 8-way choice of power, or duty cycle, or wavelength.

The search for speed has taken many forms...



RACING TILLERS 1930's



RAPID PHOTOLUMINESCENCE MAPPER 1990's

Introducing the Bio-Rad RPM2000, now setting the pace in photoluminescence mapping...

At last, a system that makes PL mapping of every wafer a reality.
With its ability to produce whole wafer maps in seconds* and a wide range of options,
the RPM2000 is the system you can use between growth runs.

Call us for details.

* 2-inch wafer, 2026 point *integrated* PL map, 19 seconds
2-inch wafer, 2026 point *spectral* PL map, 25 seconds

www.bio-rad.com

BIO-RAD

Semiconductor Systems Division

Sales: sms_sales@bio-rad.com

USA	Bio-Rad Micromeasurements, 520 Clyde Avenue, Mountain View, CA 94043-2212 Phone 650-961-6900 Fax 650-961-6715
Europe	Bio-Rad Micromeasurements Ltd, Bio-Rad House, Maylands Avenue, Hemel Hempstead, HP2 7TD, UK Phone +44 1442 232552 Fax +44 1442 234434
Japan	Nippon Bio-Rad Laboratories KK, Cosmo Park Bldg, 5-7-18 Higashinippori, Arakawa-ku, Tokyo 116 Phone 03-5811-6288 Fax 03-5811-6273
Pacific Rim	Bio-Rad Pacific Ltd, Unit 1111, 11/Floor, New Kowloon Plaza, 38 Tai Kok Tsui Road, Kowloon, Hong Kong Phone 852 2789 3300 Fax 852 2789 1257

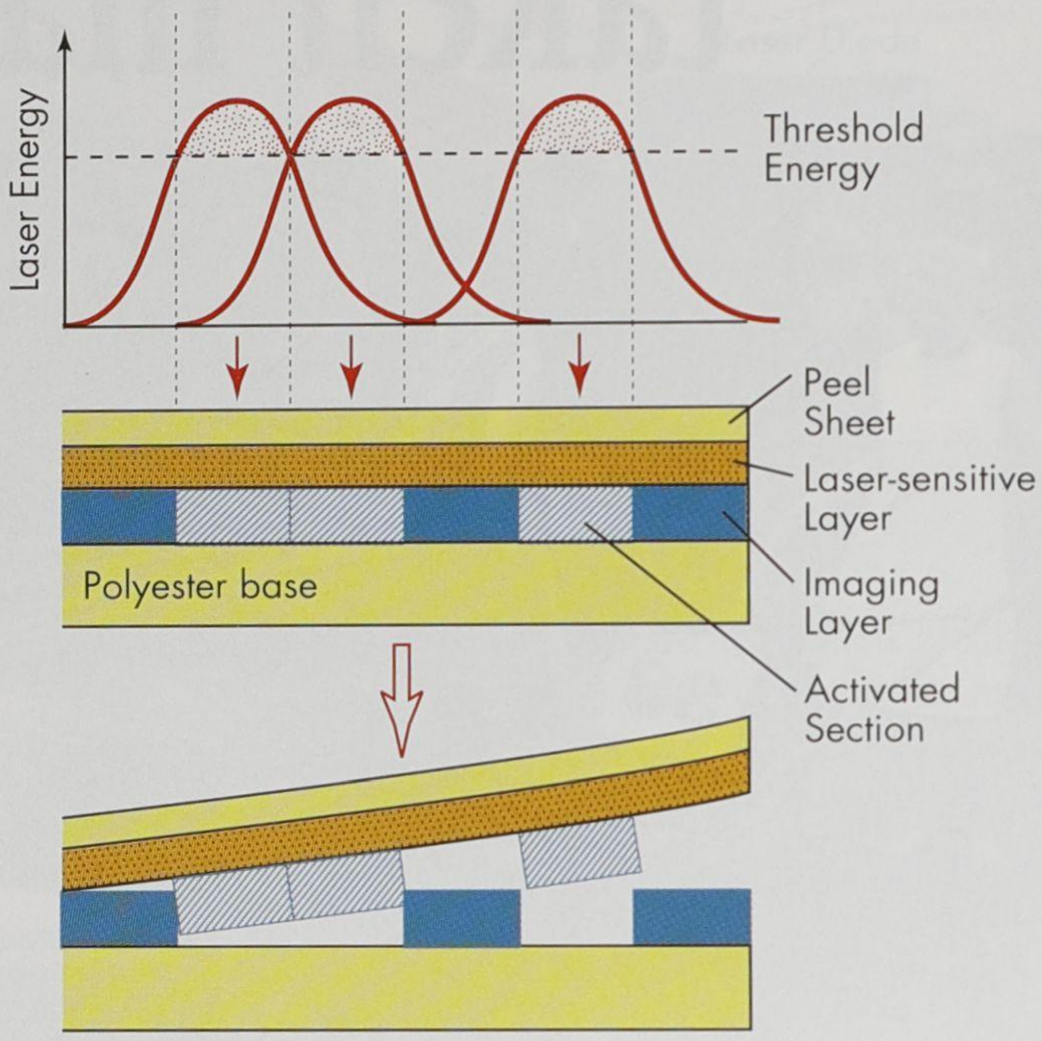
The Helios Laser Imaging System

Developed by Polaroid, Helios is a high resolution, fully digital system used to produce hard copy for medical scanning applications such as diagnostic radiology and ultrasound. The imaging system must accurately portray the spatial relationship of different tissue types, with a high dynamic range. Laser imaging systems have been around since the mid-1980's; these use an intensity-modulated laser source to expose spots across a standard silver halide film. Many variables determine the spot intensity, such as the size and distribution of silver halide grains in the film, and the processing chemistry. Also, if the pixel spacing of the laser imager is too great, an unimaged area is left between adjacent spots, whereas if the pixels overlap, summation of the Gaussian distributions of the laser intensities produces a gradient of intensity between the spots i.e. the spots become blurred.

Helios uses an entirely different process, without wet chemical development. The special film has a laser sensitive layer next to an imaging layer consisting of 50-100 Å diameter carbon particles embedded in a polymer matrix (see figure). Absorbed laser energy causes a phase transformation at the interface between these two layers, leading to strong adhesion at the absorption site and producing a spot or pixel element (pel) with extremely high definition. When the layers are mechanically separated, an image (according to the distribution of carbon particles) remains on one substrate, with the negative on the other.

The phase transformation is a binary process and only occurs where the laser energy exceeds a precise threshold value, making the pixel elements contiguous with sharply defined edges. Pels with areas as small as a few square microns can be written. In diagnostic radiometry applications, each 90 x 90 μm pixel is divided into 4320 pels. The number of imaged pels in the pixel determines the pixel's gray level, with over 12 bits (> 2^{12} shades) of gray scale value available. Medical applications commonly use 8 bit tonescales, providing 256 shades of gray.

Helios systems use single quantum well, separate confinement, double heterostructure GaAs/AlGaAs lasers at a wavelength of 840+/-20 nm. Under CW operation, the lasers exhibit failure of less than 0.3% of the device population per 700 operational hours. The output power is 1 W from a 100 μm aperture and is feedback-controlled to maintain a uniform pel size. The unit providing 8" x 10" images has 4 lasers per printer, and the 14" x 17" printer contains 8 lasers.



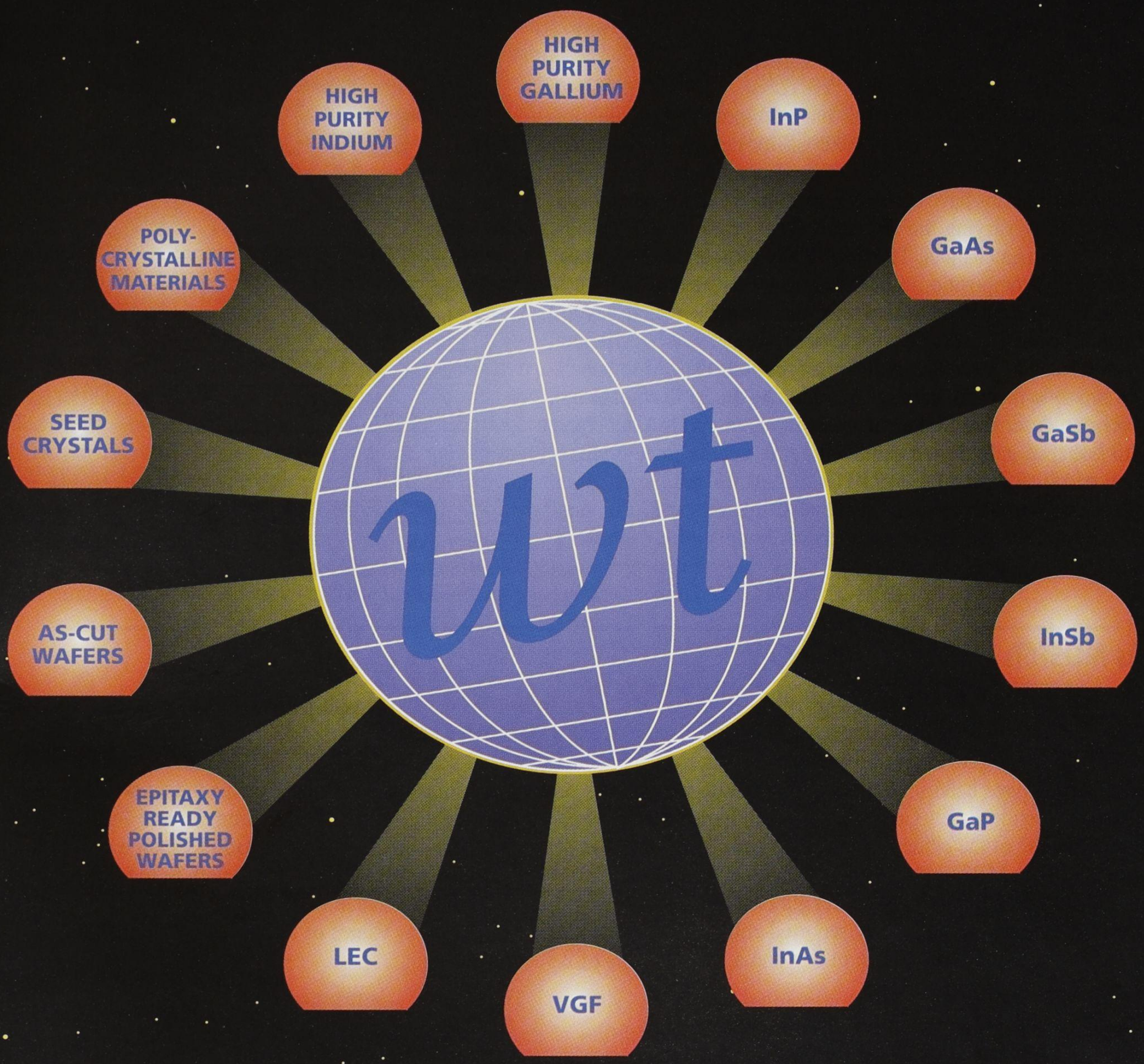
Schematic showing operation of the Helios imaging system. Where the laser energy exceeds a certain threshold value, it causes a phase transformation in the special multi-layered film, which bonds the imaging layer to the laser-sensitive layer. Mechanical separation of the film layers produces an image on one sheet, and its negative on the other.

Alternatively, the module provides a reliable, low cost method for fiber-coupling up to eight identical high power lasers. One application for these modules is in optical memory. "We are working with AHEAD Optoelectronics in Taiwan to develop optical memory applications, centered around the new phase-change rewritable optical CD disk," says Dr. Chin. "This has an active layer that is amorphous when the layer is deposited, but which needs to be crystalline when the disk is sold. The melting temperature of the active layer exceeds that of the plastic substrate and a thermal anneal is not possible, so a laser pulse is used instead to cause the amorphous-crystalline transition. The only system available commercially, from Hitachi, uses a single 1 W high power laser, while the system offered by AHEAD Optoelectronics using a Polaroid Polychrome head has six lasers and thus is faster."

Another application is in solid state optical pumps. Although most rare-earth doped crystals require a polarized beam, the standard fiber-coupled laser bar is not polarized. The Polychrome head uses mirrors to combine the beams, and thus provides a polarized output.

Polaroid has created a range of high performance, high power laser diodes, evolving from the Helios system. Dr. Chin sees these devices as an enabling technology for a host of medical treatments and methods of analysis in the future.

The Universal Choice



With an unrivaled range of crystal growth techniques and leading-edge finishing procedures Wafer Technology provides you with III-V materials tailored to your requirements.

Whatever your substrate demands we're equipped to respond.
Wafer Technology – for all your III-V needs

Visit us on the WWW at http://www.wafertech.co.uk
WAFER TECHNOLOGY LTD
34 MARYLAND ROAD • TONGWELL • MILTON KEYNES MK15 8HJ • UK
TEL: +44(0)1908 210444 • FAX: +44(0)1908 210443

Quality system approved to BS EN ISO 9002:1994

Research Review

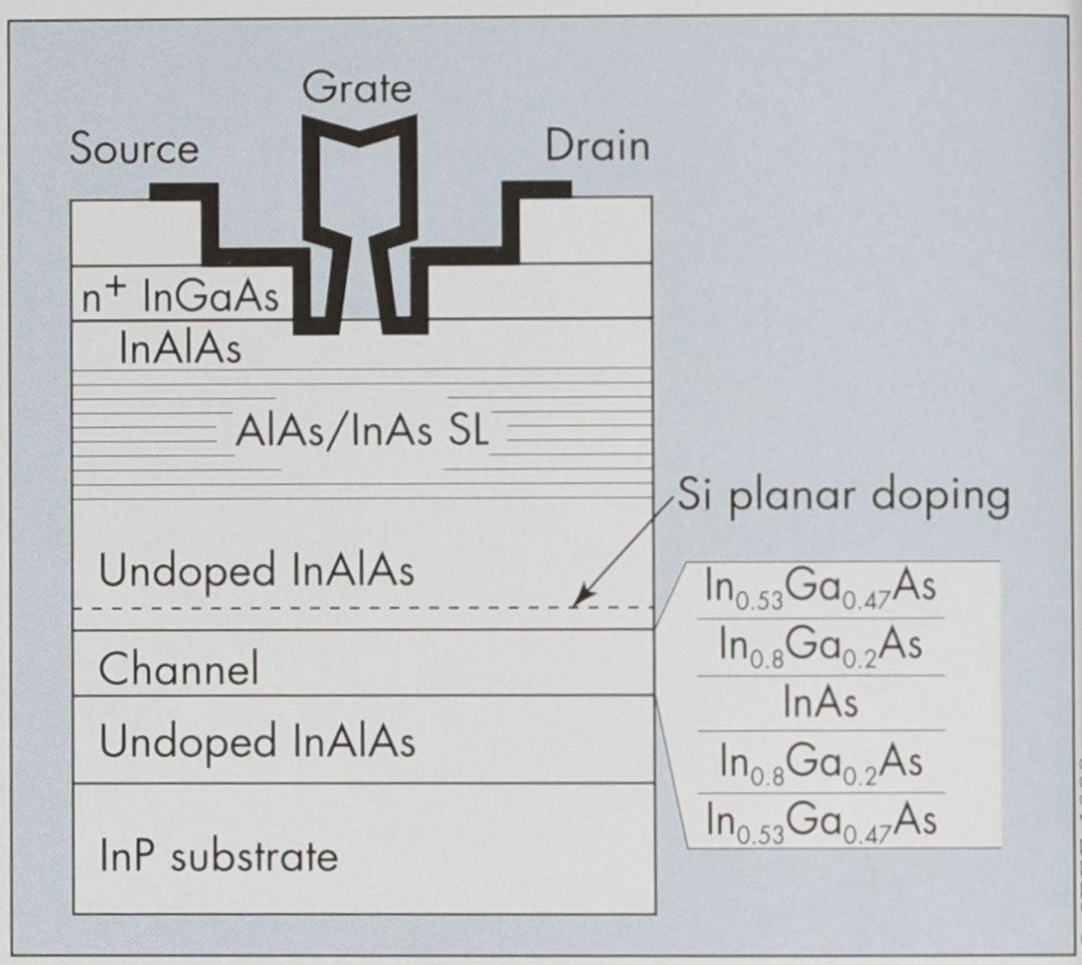
The following is a sampling of recent papers from a variety of international journals, compiled by the staff of Compound Semiconductor.

Microelectronic Devices and Circuits

High Performance InAlAs/InGaAs Heterojunction FETs

K. Onda et al, IEEE Electron. Dev. Lett., 1998, 19(8), p. 300

InAs channel HJFETs grown on InP have the potential to superior electron properties such as large sheet carrier density, high carrier confinement and high electron transport. Researchers from NEC Kansai Electronics Labs have developed a device structure optimizing these properties by varying the In composition of the InGaAs layers surrounding the InAs channel. The new device structure (see figure), termed a channel composition-modulated transistor, results in a 20% increase in electron confinement within the channel, which has an electron mobility of 18,300 cm^2/Vs. Devices were grown by MBE on an InP substrate. The structure includes a 5-period InAs/AlAs superlattice to improve thermal stability by reducing fluorine contamination, which can deactivate Si dopant atoms in the n-type InAlAs layer. A 0.2 μm T-shaped gate device exhibited a transconductance of 1370 mS/mm, f_T of 180 GHz and f_{max} of 210 GHz at a 1.0 V drain bias. High thermal stability was also demonstrated by DC life tests at 230°C, suggesting many microwave and millimeter-wave applications for these devices.



Layer structure of the channel composition-modulated transistor, which improves electron confinement within the channel by 20%.

InGaAs MOSFETs Using $Ga_2O_3(Gd_2O_3)$

F. Ren et al, IEEE Electron. Dev. Lett., 1998, 19(8), p. 309

Although InGaAs lattice-matched to InP has many advantages which should lead to high cut-off frequency and high switching speed devices, Schottky gate characteristics on InGaAs are very poor, and metal-semiconductor FETs (MESFETs) cannot be realized. Various insulators have been investigated to passivate the InGaAs surface and form metal-insulator-semiconductor (MISFET) structures. The mixed oxide $Ga_2O_3(Gd_2O_3)$ has a much higher dielectric constant than SiO_2, and this paper from Lucent Technologies' Bell Labs reports the use of the oxide as a gate dielectric. The oxide was deposited from a single crystal $Ga_5Gd_3O_{12}$ source by e-beam evaporation on top of the MBE-grown device layers. The source and drain regions were selectively implanted with Si to produce low resistance ohmic contacts. A 0.75 μm gate length device exhibited an extrinsic transconductance of 190 mS/mm, an order of magnitude improvement compared to previously reported enhancement mode InGaAs MISFETs. Values of f_T and f_{max} of 7 and 10 GHz respectively, were measure at a gate voltage of 3 V and a drain voltage of 2 V.

SiC/Si Negative Differential Resistance Switch

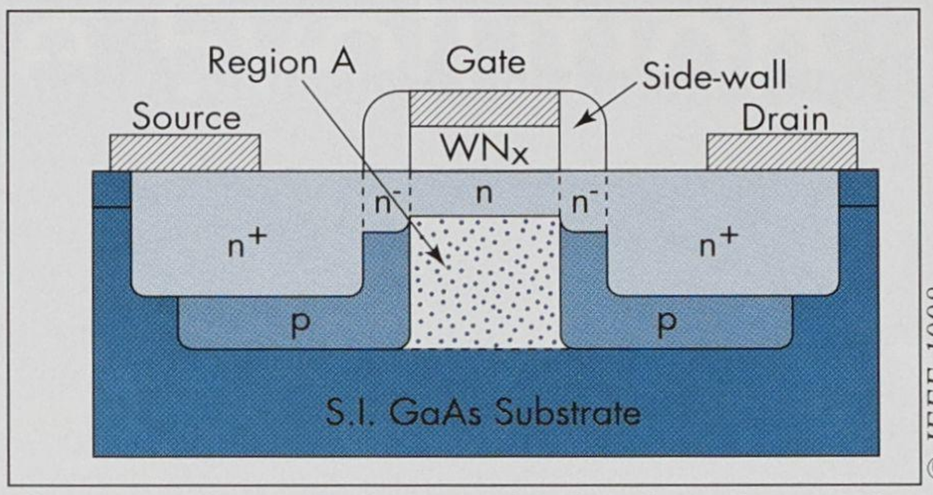
K-H Wu et al, IEEE Electron. Dev. Lett., 1998, 19(8), p. 294

The N-shaped I-V curve of negative differential resistance (NDR) devices can be exploited for logic and memory devices (see *CS* 4[3], p. 36) and also for high performance switches. This requires two stable operating states which have a large on/off current ratio. Many conventional NDR devices have a low off-state impedance which reduces the on/off current ratio and increases power dissipation. This paper from Cheng Kung University Taiwan, reports a p-Si/n-SiC device with a very low off-state current which also exhibits NDR up to 300°C. The device was grown on n-type Si (111) with a carrier concentration of ~10^{17} cm^{-3}, and consists of a graded composition layer (GCL) in which propane was introduced at a steadily increasing concentration into the SiH_4/H_2 gas mixture. Subsequently a 0.6 μm p-SiC layer was deposited. A peak to valley current ratio of 330 was obtained at room temperature. The valley region was very broad, with low current levels of 3.3-60 μA, resulting in highly effective switching performance with very low power dissipation. The observed behavior was not fully explained but is apparently related to defects in the GCL.

P-pocket GaAs MESFET

K. Nishihori et al, IEEE Trans. Electron. Dev., 1998, 45(7), p. 1385

Power amplifiers for the Japanese personal handy-phone system (PHS) require high efficiency, linear amplifiers that can operate from a single supply voltage. GaAs MESFETs with buried p-layers are widely used for these applications, however kinks in the I-V curve, caused by holes collecting in the p-layer under the channel, lead to a reduction in the power efficiency. This paper from Toshiba reports what they describe as a "p-pocket MESFET" (see figure) which has p-layers exclusively beneath the source and drain. The device, fabricated entirely by ion implantation, has a high drain efficiency of 48% under a low adjacent channel leakage of -59 dBc for 1.9 GHz operation, and is a promising candidate for next generation digital mobile phone communication systems.



© IEEE 1998

Cross-section of the newly developed p-pocket MESFET. Region A under the channel is undoped in this device, but is p-type in conventional buried p-layer MESFETs.

Compound Semiconductor Materials

Electrical Characterization of GaN p-n Junctions

P. Kozodoy et al, Appl. Phys. Lett., 1998, 73(7), p. 975

Lateral epitaxial overgrowth (LEO) of GaN above a mask region results in significantly reduced threading dislocation densities compared to regions regrown through the mask windows. This paper, from the University of California at Santa Barbara, investigates the effect of the lower dislocation density on electrical properties by measuring the reverse bias leakage current for p-n diodes grown on LEO GaN. The LEO region was ~8 μm thick, and the p-n junction was formed from 1 μm n-type ($n\sim 5x10^{16}$ cm^{-3}) and 0.5 μm p-type ($p\sim 1x10^{18}$ cm^{-3}) GaN. Devices measuring 2 μm x 20 μm were fabricated either in the LEO region, where most contained no dislocation densities whatsoever, or in the window region, where the diodes are expected to contain around 200 dislocations on average. I-V measurements revealed that the reverse bias leakage current was lower by several orders of magnitude in the LEO region; at a reverse bias of 25 V, current density was $9x10^{-4}$ A/cm^2 in the window region and $9x10^{-7}$ A/cm^2 in the LEO region. Temperature-dependent measurements indicated that a deep trap level limits device performance in the dislocation-free diodes.

performance materials

WHAT WILL YOU PUT IN YOUR PERFORMANCE MATERIALS?



At Performance Materials, we put everything we've got into our technical ceramics, so you can put your trust in them.

- 24-hour turnaround on stock orders.
- Custom designs of PerformancePBN™ in as little as 3 weeks.
- PerformanceSiC™ products of silicon carbide.
- Clean packaging.
- Technical troubleshooting any day, any hour.
- Unique shapes.

For more, talk to the experts in chemical vapor deposition: Performance Materials.

Performance Materials, Inc.
A material advantage.

4 Park Avenue
Hudson
New Hampshire 03051 U.S.A.
603-598-9122
fax 603-598-9126

info@performancematerial.com www.performancematerial.com

Atomic Intermixing Brought To A Halt

R.M. Cohen et. al., Appl. Phys. Lett., 1998, 73(6), 803

Controllable changes in the rate of atomic intermixing of semiconductor quantum wells during high temperature processing may prove technologically useful for GaAs and other related materials. Various encapsulants such as SiN, SiO_2, SrF_2 and WN_x have been used to try to control the interdiffusion rate in a reproducible manner. Researchers at the University of Utah and the Australian National University have demonstrated that the rate of interdiffusion of quantum wells can be slowed by at least 2 orders of magnitude. AlGaAs/GaAs quantum wells were grown and a capping layer of GaAs was thermally oxidized to produce a film composed largely of Ga_2O_3. Some oxidized samples were also covered with a thin film of Al, and samples were annealed together at 900°C. Photoluminescence showed that intermixing slowed dramatically when the oxide was covered by Al, by a factor exceeding 100x. This behavior can be understood by considering that (1) vacancies on the Ga sub-lattice control the interdiffusion rate, and (2) the free energy of formation of Al_2O_3 is much lower than that of Ga_2O_3. Thus, a film of Al will chemically reduce a gallium oxide film during rapid thermal annealing, to form Al_2O_3 and free Ga atoms. Ga atoms produced by reduction diffuse interstitially into the semiconductor and occupy most of the vacancy sites available for diffusion. These results suggest that with the proper choice of oxide and metal thickness, one may be able to generate reproducible concentrations of point defects and thus controllably reduce diffusion rates in many semiconductors.

I-V Characteristics of Metal-GaN Schottky Diodes

L. Yu et al, J. Appl. Phys., 1998, 84(4), p. 2099

The study of Schottky barrier contacts on GaN has great importance for high temperature, high frequency and high power devices. This paper, from the University of California at San Diego and Epitronics, uses I-V and C-V measurements to analyze Ni-GaN Schottky barriers. The results indicate that tunneling plays an important role in the transport of carriers across the Schottky barrier on n-GaN, even for doping concentrations as low as $1x10^{17}$ cm^{-3}. The enhanced role of the tunneling component is probably induced by the large amount of defects in GaN.

GaN/AlN Valence Band Discontinuities

S.King et al, J. Appl. Phys., 1998, 84(4), p. 2086

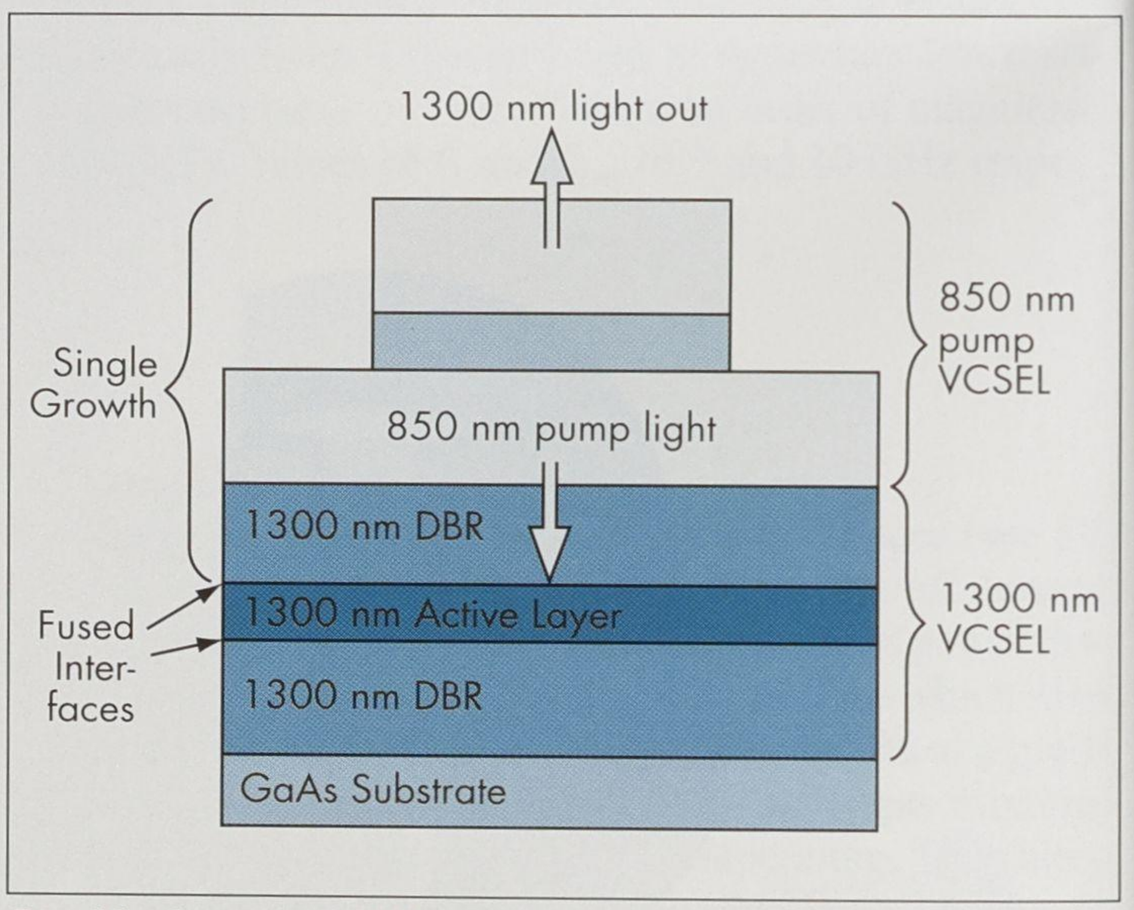
The valence band discontinuity (ΔE_V) between GaN and AlN influences charge transport and quantum confinement in devices featuring heterostructures of these materials and their alloys. This paper, from North Carolina State University, reports the use of x-ray and uv photoelectron spectroscopies to determine the value of ΔE_V at the GaN/AlN interface in films grown by GSMBE at different temperatures on SiC substrates. For GaN growth of AlN at 650°C, a type I valence band discontinuity of 0.5±0.2 eV was determined, whereas the value of ΔE_V for GaN grown on AlN at 800°C was 0.8±0.2 eV. These values can be correlated to different growth mechanisms. At 800°C, growth occurs via a two-dimensional (Frank van der Merwe) mechanism so that the GaN interface is strained to the AlN lattice, whereas at the lower growth temperature, three-dimensional growth is observed, and the GaN layers are free to grow in a relaxed manner.

Optoelectronic Devices

1300 nm VCSELs Operating at 70°C

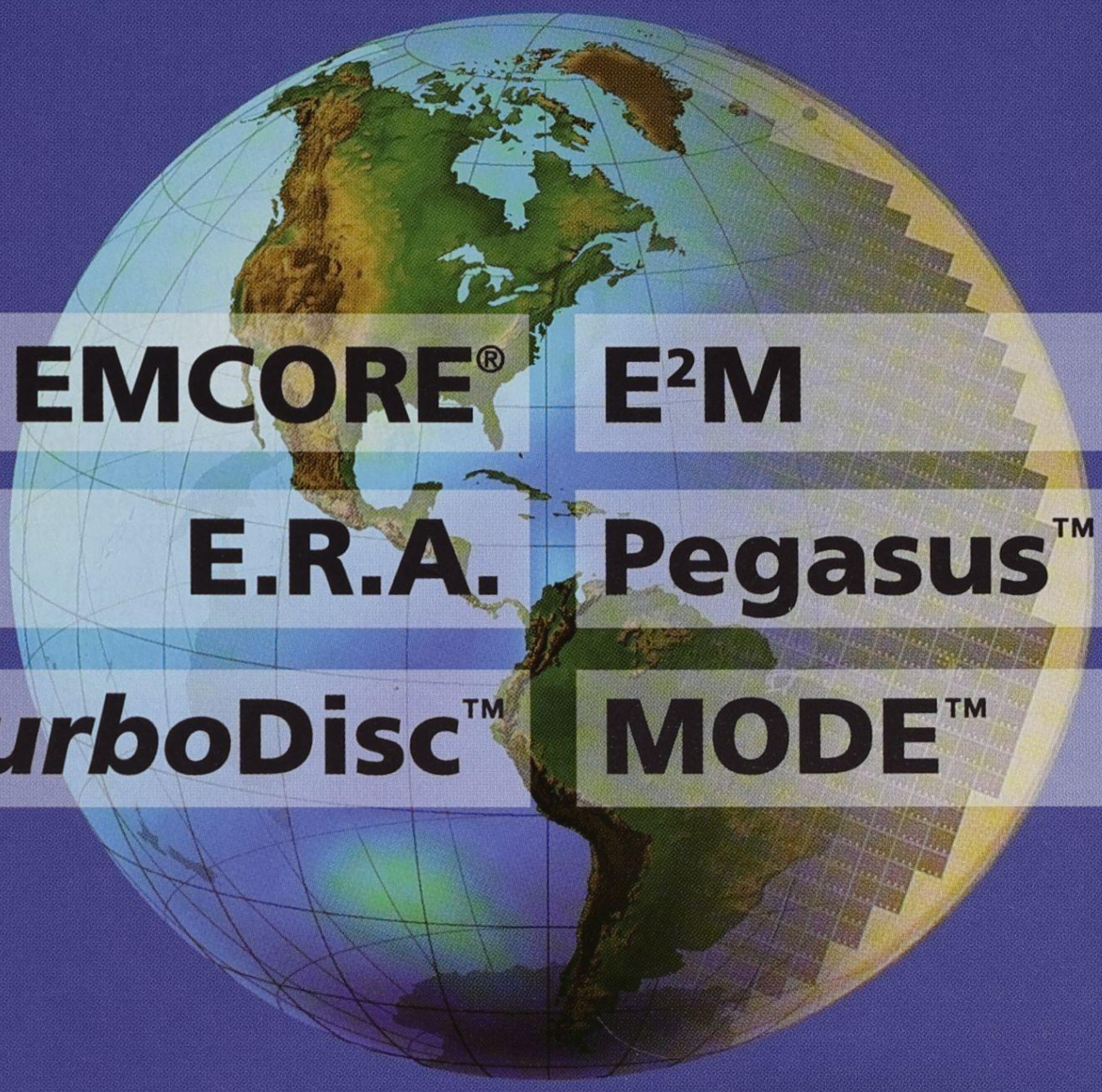
V. Jayaraman et al, Elec. Lett., 1998, 34(14), p. 1405

VCSELs compatible with commercial datacom requirements at 1300 nm have been demonstrated by Gore Photonics. The device structure (see figure) contains an 850 nm VCSEL, the output from which optically pumps the vertically adjacent 1300 nm VCSEL. The structure is assembled by wafer-fusing the undoped 1300 nm active region to two undoped DBR mirrors, one of which is grown as part of the 850 nm VCSEL epitaxial growth. The structure has many advantages; the undoped 1300 nm optical cavity has greatly reduced free-carrier losses; wafer fusion produces only optical interfaces, so the device voltage has the low value of the 850 nm VCSEL; and resistive heating is primarily confined to the 850 nm VCSEL. These devices operated at >0.38 mW single mode 1300 nm power over the range 0 to 70°C without heat-sinking. CW lasing continued up to 80°C, and the threshold current varied from 5 mA at 40°C to 6 mA, at both 0°C and 70°C. The devices also demonstrated up to 1.25 Gbit/s modulation speed.



Double-fused VCSEL structure; output from the 850 nm VCSEL optically pumps the 1300 nm device

Resources to Fuel the Evolution



EMCORE® **E²M**

E.R.A. **Pegasus™**

***Turbo*Disc™** **MODE™**

EMCORE Corporation is the leading provider of integrated compound semiconductor solutions. Due to superior uniformity, reliability and throughput, prominent manufacturers throughout the world turn to EMCORE. EMCORE's production systems, materials, and processes are the enabling technology behind a variety of advanced electronic and photonic applications.

- E.R.A.—the renowned EMCORE Research and Applications laboratory, where epitaxy technology is continually developed and improved
- *Turbo*Disc™—where most uniform, reliable, high volume Metal Organic Chemical Vapor Deposition (MOCVD) processing systems in the world are manufactured
- E²M—the worlds largest manufacturer of epitaxial wafers and provider of compound semiconductor wafer foundry services
- Pegasus™—where high brightness LEDs and advanced sensor devices are fabricated in partnership with OEM customers
- MODE™—manufacturer of Vertical Cavity Surface Emitting Lasers (VCSELs) for internet communication and leading edge optoelectronic applications

EMCORE Corporation Headquarters
394 Elizabeth Avenue, Somerset, NJ 08873 USA
Tel: + 1 (732) 271-9090 • Fax: + 1 (732) 271-9686
WEB: www.emcore.com • E-mail: info@emcore.com

ISO 9001 QMI REGISTERED QUALITY SYSTEM

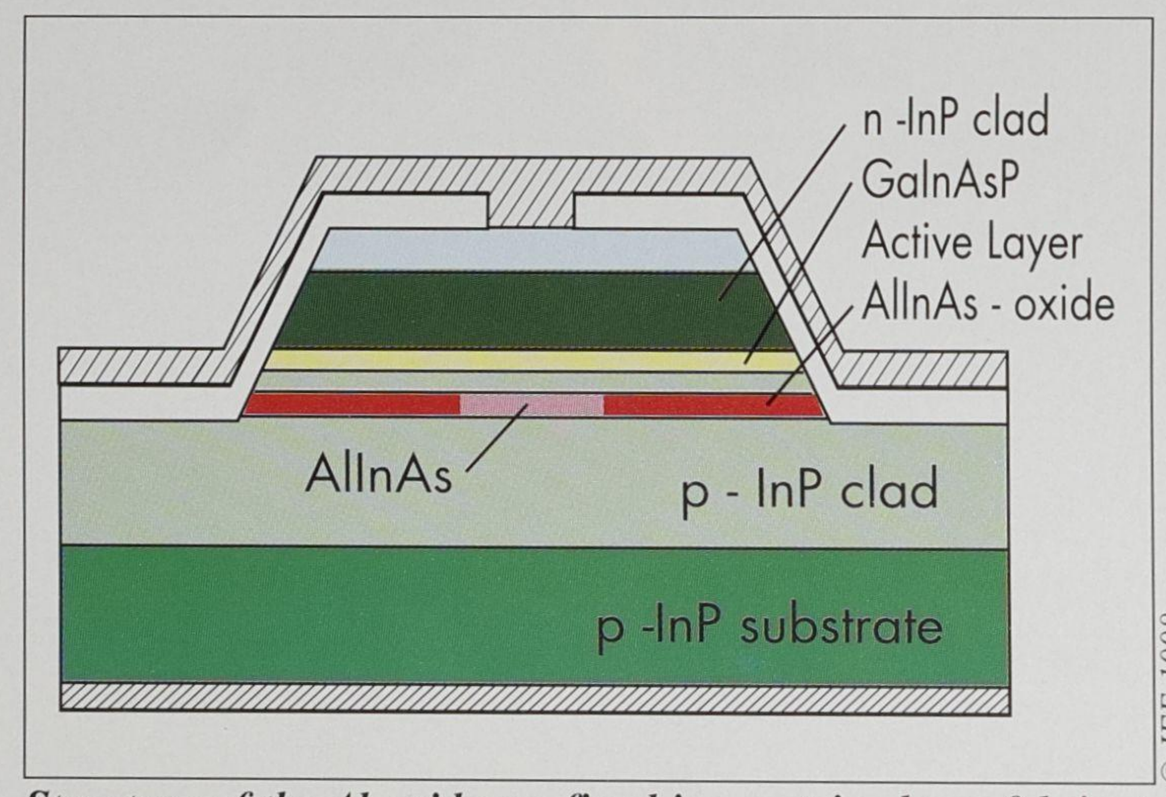
ISO 9002/QS-9000 QMI REGISTERED QUALITY SYSTEM

EMCORE
Integrated Compound Semiconductor Solutions

1.3 µm Laser with AlInAs-Oxide Current Confinement Layer

N. Iwai et al, Elec. Lett., 1998, 34(14), p. 1427

From the viewpoint of high frequency operation, it is preferable to fabricate laser arrays on p-type substrates for enhanced compatibility with superior performance silicon ICs containing npn-type transistors. In the case of ridge waveguide lasers fabricated on n-InP substrates, it is necessary to insert a current confinement layer into the n-InP cladding layer. This prevents current spreading from the active region into the cladding, and thus helps to reduce the threshold current of the device. This paper, from Furukawa Electric Co., describes the formation of a current-confining layer by selective oxidation of InAlAs, which overcomes the difficulty of growing highly strained AlAs on InP. The 1.3 µm devices, containing strained InGaAsP QWs in the active region, demonstrated a threshold current of 6.8 mA, a high slope efficiency of 0.55 W/A and single lateral mode operation.



© IEE 1998

Structure of the Al-oxide confined inner stripe laser fabricated on p-InP.

1.48 µm VCSEL with a Sb-Based DBR Mirror

G. Ungaro et al, Elec. Lett., 1998, 34(14), p. 1402

This paper, from France Telecom, reports the first room temperature, CW operation of a wavelength VCSEL containing an Sb-based DBR mirror. The lower mirror was grown by MBE on an n-InP substrate, and contained 20.5 periods of quarter-wavelength thick layers of n-$Al_{0.1}Ga_{0.9}As_{0.51}Sb_{0.49}$ and n-$AlAs_{0.56}Sb_{0.44}$ followed by an active region containing 8 compressively strained $Ga_{0.33}In_{0.67}As$ quantum wells with AlGaInAs barriers. The upper mirror was a wafer-fused 30 period $GaAs/Al_{0.85}Ga_{0.15}As$ structure. The device was optically pumped, and had an input power of 50 mW at 20°C with a minimum value of 27 mW at 230 K. The next stage of the work will be to replace the fused C-doped AlGaAs mirror with a Be-doped AlGaAsSb mirror.

InAlAs APDs with Thin Multiplication Region

C. Lenox et al. Appl. Phys. Lett., 1998, 73(6), p. 783

Avalanche photodiodes (APDs) are required to exhibit low multiplication noise for high frequency applications such as optical telecommunications. In an APD, internal gain occurs when photo-generated carriers within the multiplication region undergo impact ionization, creating further carriers. The process is much more efficient when either electrons or holes have a much higher ionization coefficient than the other type of carrier. This "asymmetric" multiplication reduces both excess noise and response time of the APD.

Although InGaAs lattice-matched to InP is widely used for fiber-optic detector applications, this material has poor multiplication properties, as do InGaAsP and InAlGaAs. This paper, from the University of Texas at Austin, investigates $In_{0.52}Al_{0.48}As$ p-i-n homojunction APDs grown on InP. The p-type absorber layer was optically pumped with laser light to provide injection of dominant ionizing carriers (electrons) into the intrinsic multiplication layer. The thickness of this layer was varied from 1600 nm to 200 nm, which caused a significant decrease in the noise figure, without sacrificing maximum achievable gain.

VCSELs with a 48 nm Tuning Range

A. Fiore et al, Appl. Phys. Lett., 1998, 73(3), p. 282

Densely packed, multi-wavelength VCSEL arrays are ideal candidates for WDM systems, but good control over the lasing wavelength is difficult to achieve. Previous methods to realize multi-wavelength arrays have included; varying the physical thickness of the cavity by varying the growth temperature over the wafer; varying the thickness by etching before regrowth of the top mirror; and changing the phase of the mirror reflection. Ideally, the technique for realizing different wavelengths in an array should involve modifying the optical cavity after a single epitaxial growth. This paper from the University of California at Santa Barbara, describes the use of wet oxidation of AlGaAs after growth has been completed, in order to change the thickness of the optical cavity and modify the wavelength. Two high Al-composition layers are used, a supply layer e.g. AlAs, and an $Al_xGa_{1-x}As$ (x~0.7-0.9) tuning layer. After mesa formation, the supply layer is laterally oxidized in a water vapor atmosphere at 400-500°C. The tuning layer is then oxidized vertically at a much slower rate, due to its lower Al composition. In an array of devices, the extent of oxidation of the tuning layer (which determines the change to the optical cavity thickness) is controlled by altering the size of the oxidation mesa. InGaAs/GaAs VCSELs demonstrated a 48 nm wavelength span in the range from 940 nm to 990 nm.

GaSb Shines Brighter Than The Midnight Sun

TIM WHITAKER

Solar cells converting the sun's energy to electrical power are widely used in space-based applications, and have been investigated as a safe, clean, renewable energy source here on Earth. However, the sun's energy is only available during daylight hours, and is of course strongly dependent on prevailing weather patterns. Converting infrared radiation from non-solar sources using thermophotovoltaic (TPV) cells is an attractive alternative, and JX Crystals Inc., of Issaquah, WA, has recently begun manufacturing commercial heat and electricity co-generators for the use of private individuals.

In contrast to the complex epitaxial structures required to implement TPV cells in InGaAs/InP or GaInAsSb/GaSb material systems, the first III-V TPV cells to be incorporated into commercial products are low cost, diffused junction GaSb devices. According to Lewis M. Fraas, President of JX Crystals, the lack of an epitaxial step is key to achieving a low overall cost per Watt. "Our thesis is that process costs dominate the cost of materials for single crystal devices," he says, "and therefore we copy silicon solar cell processing." The company uses converted silicon pullers for GaSb crystal growth, and diffusions to form the necessary junctions for the TPV cells. JX Crystals also offers GaSb substrates for sale.

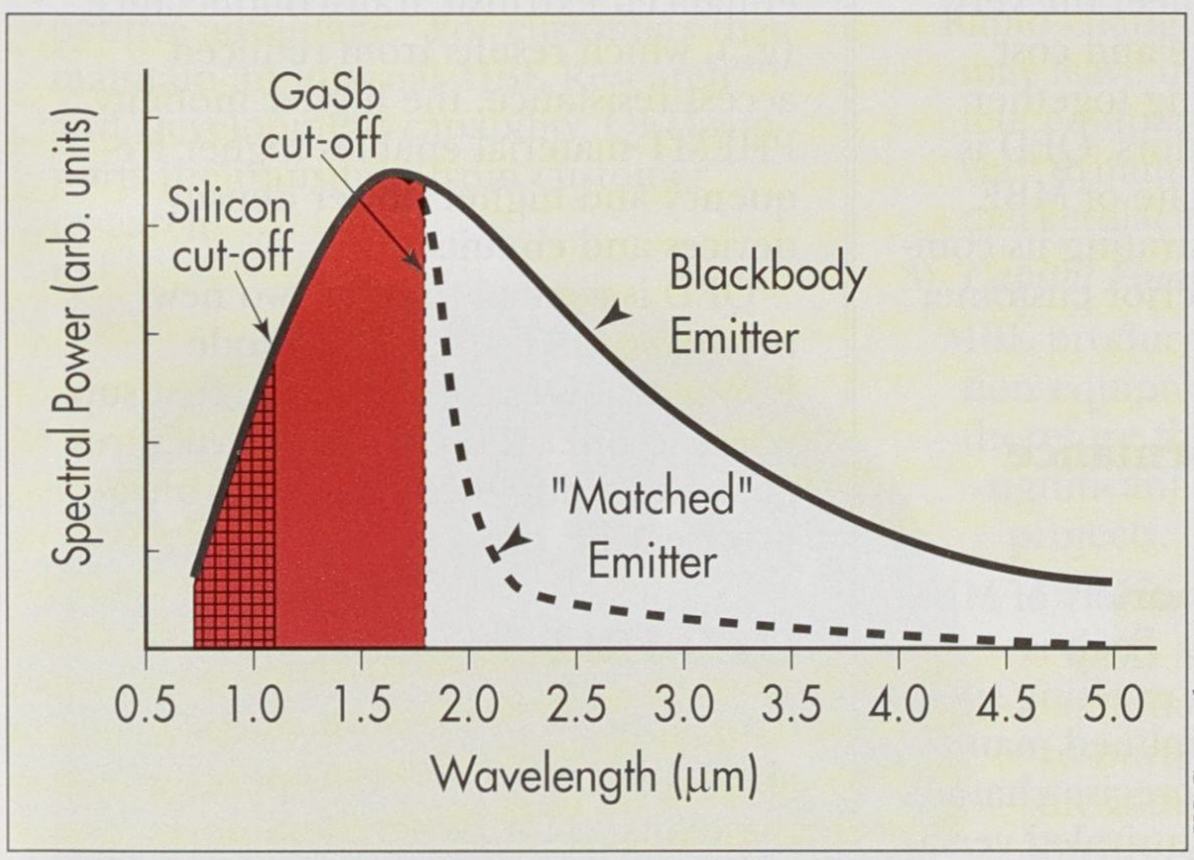
THERMOPHOTOVOLTAICS

Thermophotovoltaic (TPV) energy conversion involves the direct transformation of an infrared heat source to electricity. The concept is essentially the same as photovoltaic conversion of solar energy, except that the radiation source is an artificially heated radiator at a significantly lower temperature than the sun. In this Technology Update, we first describe a commercial application for III-V thermophotovoltaic diodes, while a second article reviews the many complex TPV system design issues.

Matched Emitter Is Key

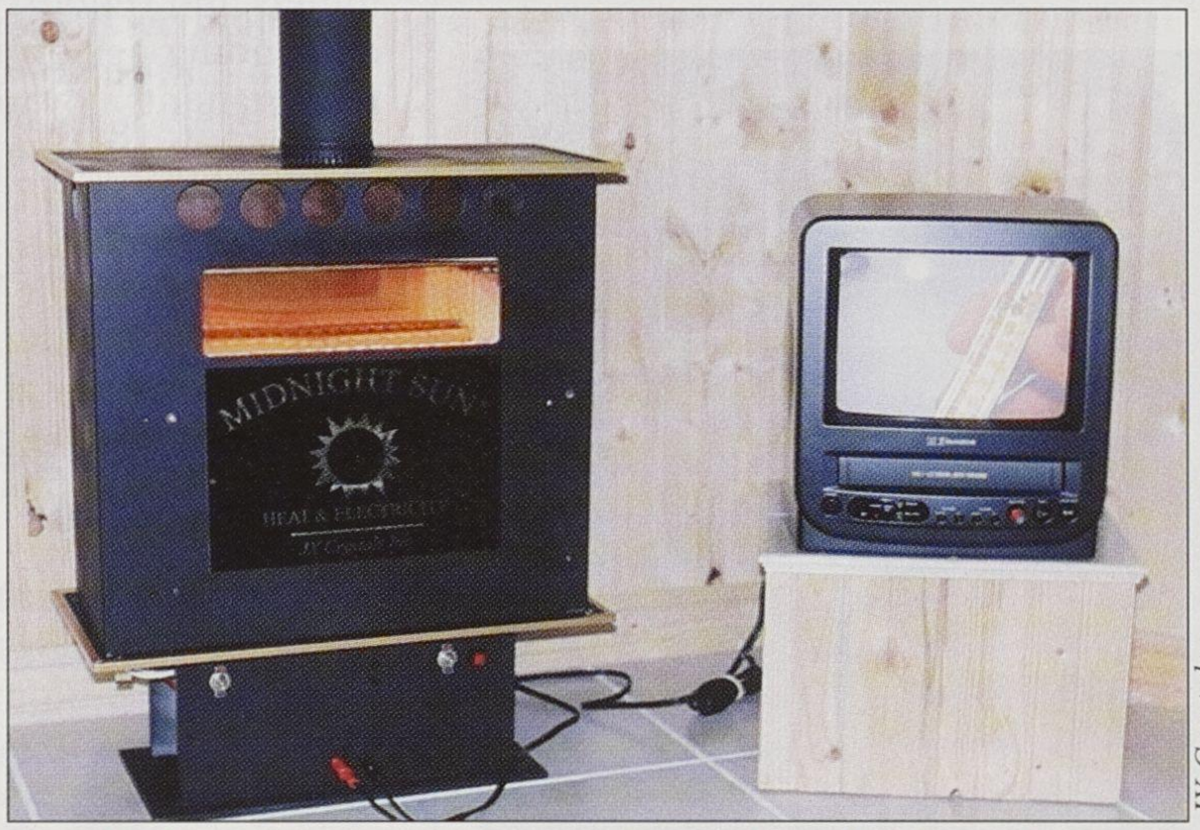
The technology behind the successful implementation of GaSb TPV cells was developed and patented by Fraas and co-workers at Boeing, and subsequently licensed exclusively to JX Crystals. Combustion of hydrocarbon fuel, e.g. propane, heats a ceramic body which emits IR radiation. The emitter temperature is limited to 1400-1700°C by the combustion temperature of the fuel and the durability of the ceramic material. The radiation from a blackbody at this temperature is mostly at wavelengths above 1 μm, while the response of a traditional silicon photovoltaic cell is limited to below 1.1 μm. However, GaSb responds to wavelengths as long as 1.8 μm, and the inclusion of a matched ceramic emitter, which emits strongly below 1.8 μm and weakly above this wavelength, greatly increases the conversion efficiency (see diagram, this page). The 1.5 cm^2 cells produced by JX Crystals generate around 2 W each, which represents about 100x the power density of a terrestrial solar panel in direct sunlight.[1]

[continued on page 36]



JX Crystals

A silicon TPV cell with a cut-off wavelength of around 1.1 μm captures only a very small proportion (hatched area) of the incident radiation from a blackbody emitter. The conversion efficiency is greatly increased by using a GaSb cell, with a cut-off wavelength of 1.8 μm, together with a matched ceramic emitter.



JX Crystals

The Midnight Sun Stove, manufactured by JX Crystals, generates 25,000 BTU/hour of heat and 100 W of electricity, enough to operate a television.

---

[1] The Siemens M55, one of the most common panels, is rated at 53 W and measures 50.9" by 13", giving a power density of about 0.0186 W in 1.5 cm^2.

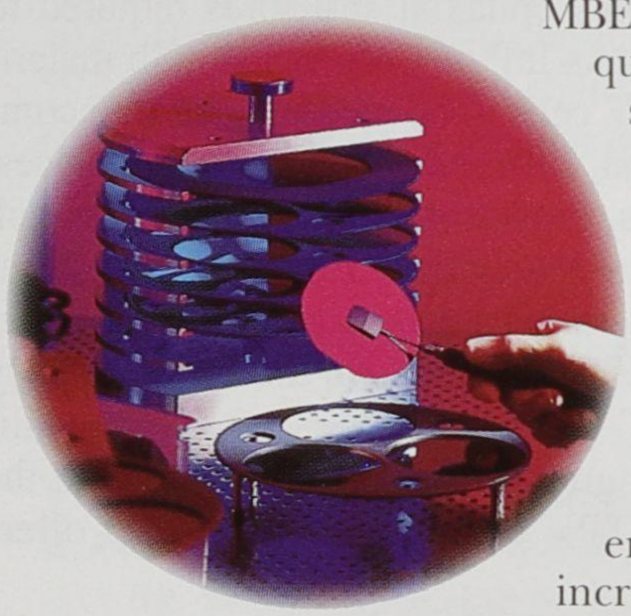
QED: Entering a New Era of Growth

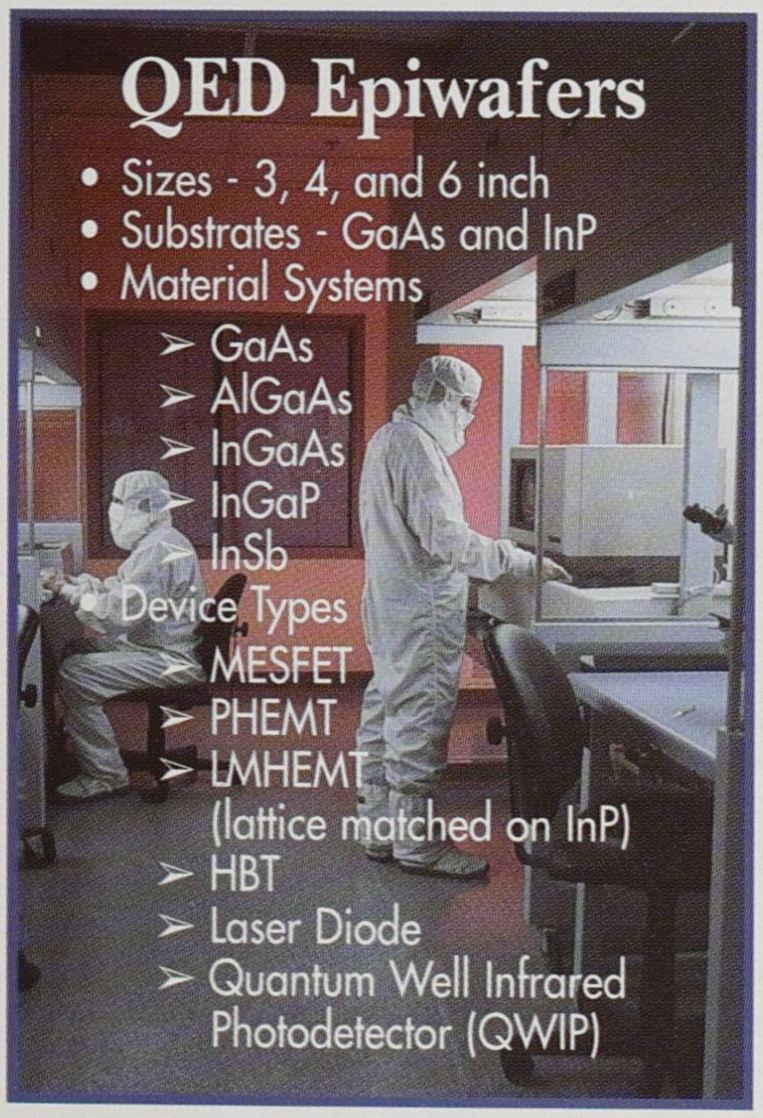
QED continues to support the ever-increasing demand for MBE epiwafers by offering the customer superior value. The company is poised to enter a new era of growth and is excited to offer two new products: HBT and Laser Diode Epiwafers.

Quantum Epitaxial Designs, Inc. (QED) has realized explosive growth over the past several years, primarily driven by the commercial acceptance of molecular beam epitaxy (MBE) epiwafers for high volume wireless communication applications. As 1999 approaches, QED is poised to enter a new era of growth built on providing the highest quality epiwafers and on offering its unrivaled MBE expertise to provide superior customer value. In addition to investing in state-of-the-art production and characterization equipment, and personnel resources to provide epiwafers at competitive prices, QED offers the customer additional value added services, including technical expertise, device simulation, and customer focused services.

Further demonstrating an ongoing dedication to support increasing customer demand, QED will accept a next generation MBE system by year-end 1998. The next generation system will provide a significant increase in material throughput, higher system up-time, and lower throughput costs. In addition to the next generation MBE system, QED operates four VG Semicon V-100 multi-wafer MBE reactors for high volume production requirements and two EPI GEN II single wafer MBE reactors for custom GaAs and InP structures and Research and Development activities.

QED is offering solutions that make the customer decision to "buy outside" rather than "make within" that much easier to justify. QED believes the success of MBE is dependent upon strategic alliances between customers and vendors to meet the very demanding performance and cost requirements. By working together with customers and vendors, QED is further advancing the state of MBE technology and demonstrating its commitment to provide superior customer value.





QED Higher Performance MBE Material

QED provides a large variety of MBE epiwafers – see box, left. Each is grown to the customer's exacting specifications, requiring disciplined manufacturing practices and precise characterization. MBE offers unrivaled versatility, consistently uniform layer thickness, and superior doping and composition control, in comparison to other III-V compound semiconductor epitaxial growth techniques. For PHEMT structures, another advantage of MBE is the growth control to insert etch-stop layers for improved gate recess control and etch uniformity. To eliminate AlGaAs device fabrication problems, QED offers an InGaP etch-stop layer that provides superior device performance and easier device processing compared to AlAs etch-stop layers. Saturation current (I_{dss}) and pinch-off voltage (V_{po}) are controlled by MBE growth, not by subsequent processing, thereby simplifying device fabrication. Recently, QED has developed a PHEMT growth process that results in significantly higher 2DEG mobility, for a given channel charge. Associated with the enhanced mobility is an increased electron saturation velocity. In addition to enhanced extrinsic transconductance (g_m), which results from reduced access resistance, the higher mobility PHEMT material enables higher frequency and higher power density devices and circuits.

QED is excited to offer two new products: HBT and Laser Diode Epiwafers. QED is one of the first suppliers to offer these types of structures grown by using the ultra-clean, ultra-precise MBE process.

QED HBT Structures

In addition to providing MESFET and HEMT epiwafers to support growing demand for power amplifier devices, QED has developed carbon- and beryllium-doped HBT epiwafers, on 3 and 4 inch substrates, for high volume applications. Working in collaboration with Penn State University and customers, QED has developed

high p-type carbon-doped (>3.0 x $10^{19}/cm^3$) HBT material with near 100% activation and very little dopant diffusion. The HBT material has demonstrated a dc gain greater than 100 (with a $5.0x10^{19}/cm^3$ doped base) and has low hydrogen incorporation, which provides higher HBT device reliability than competing epitaxial growth techniques.

QED Laser Diode Structures

QED is working in close collaboration with several prominent laser manufacturers to develop 730, 785, 808, 980, and 1060 nm high power laser diode epiwafers, on 2 and 3 inch substrates. These development efforts involve extensive characterization of critical laser diode properties, including wavelength uniformity, internal and external quantum efficiency, threshold current density, catastrophic optical damage (COD) limit, and operational lifetime under high-power conditions. QED has dedicated equipment and personnel resources to support this very demanding marketplace.

The Trend to Outsourcing

For customers that lack an internal MBE capability, QED utilizes its technical expertise to jointly develop epiwafers to provide the customer a competitive advantage. For customers that maintain an internal MBE Research and Development capability, QED supports the transition from customer research to QED production of epiwafers. For customers that maintain an internal MBE production capability, QED works with the customer to develop a reliable second-source for epiwafers. In all three scenarios, QED utilizes its full resources to provide the highest quality products and services to ensure superior customer value.

Recent studies have predicted that the trend to outsourcing MBE epiwafer requirements will approach 70% by the year 2001. QED believes that customers are recognizing the economic and technological advantages of outsourcing, for the following reasons:

QED is offering solutions that make the customer decision to "buy outside" rather than "make within" that much easier to justify.

1) ***Market Risk Reduction***

Outsourcing of MBE requirements offers the customer a low risk alternative to expensive capital investments to pursue business in a dynamic and sometimes unpredictable marketplace.

2) ***Technical Risk Reduction***

Rapid changes in MBE technology may leave the customer with obsolete equipment to compete in a very dynamic and cost competitive marketplace.

3) ***Capital Financing Issues***

MBE production and characterization equipment is very expensive, therefore the customer can free-up significant capital to pursue other projects.

4) ***Critical Mass Issues***

QED has the experience, equipment, and personnel resources that are unrivaled in the industry and has the production capacity redundancy to ensure on-time delivery.

5) ***Leading Edge Technology***

QED's only business is MBE, putting the company at the leading edge of the technology curve.

6) ***Product Quality***

QED has the production and characterization equipment to consistently provide high quality epiwafers to meet the customer's exacting specifications.

7) ***Demand/ Utilization***

In today's dynamic and sometimes unpredictable marketplace, it is difficult for the customer to operate in the most cost efficient manner. But QED is ideally positioned to respond to these types of fluctuations.

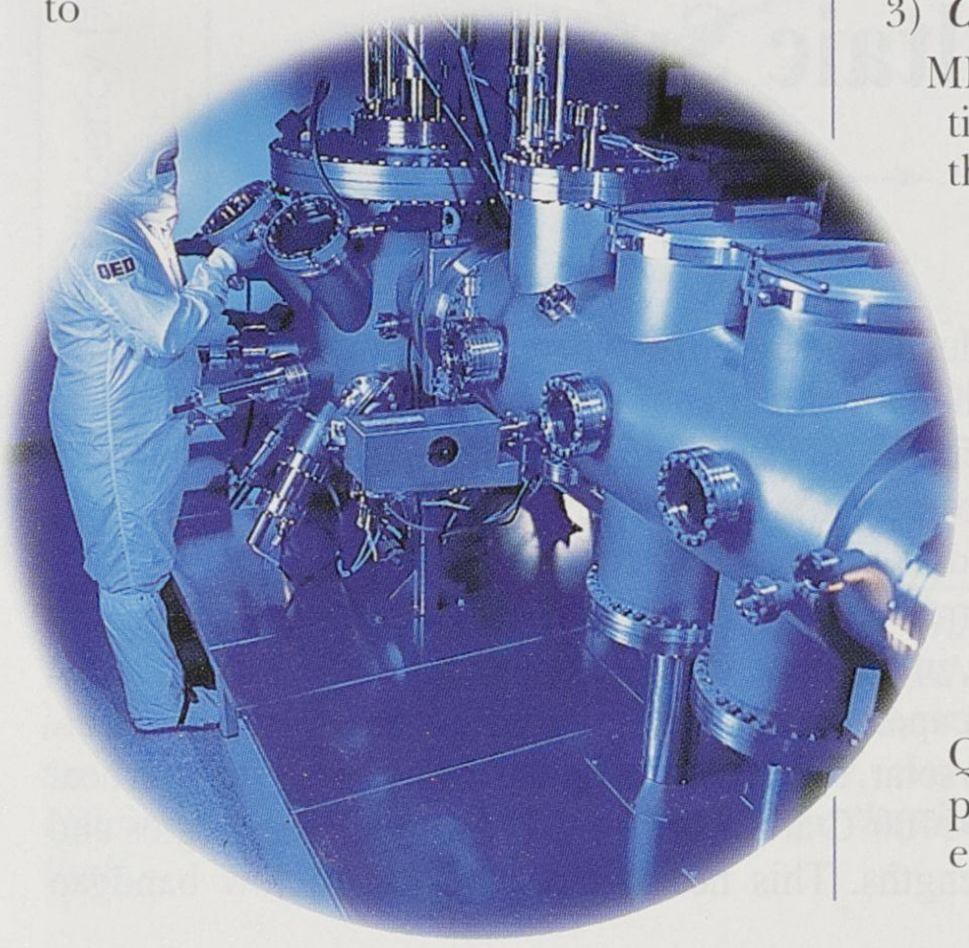
By establishing a track record of consistently delivering high performance MBE epiwafers, QED is enabling the customer to focus on what they do best - manufacture devices, rather than dedicate company resources to growing MBE material.

QED Commitment to Quality Assurance

With high volume insertion of MBE-based devices, QED must ensure that its MBE epiwafers satisfy the expectations and level of quality demanded by the customer. The ongoing QED commitment to provide the highest quality epiwafers covers the entire order process - from order inception, through on-time delivery, and after-sales service. QED utilizes Statistical Process Control (SPC) methodology for epiwafer production and characterization equipment calibration. A new production database system allows QED to characterize each epiwafer in real-time to ensure consistent wafer uniformity and wafer-to-wafer reproducibility. QED is also committed to the ISO 9002 certification process, which will strengthen the QED recognition as the world leading merchant MBE epiwafer supplier.

QED welcomes the opportunity to discuss each customer's specific requirements. For additional information, please contact QED.

Contact: Jim McKeown
Telephone: (610) 861-6930
Fax: (610) 861-5273
E-mail: jmckeown@qedmbe.com

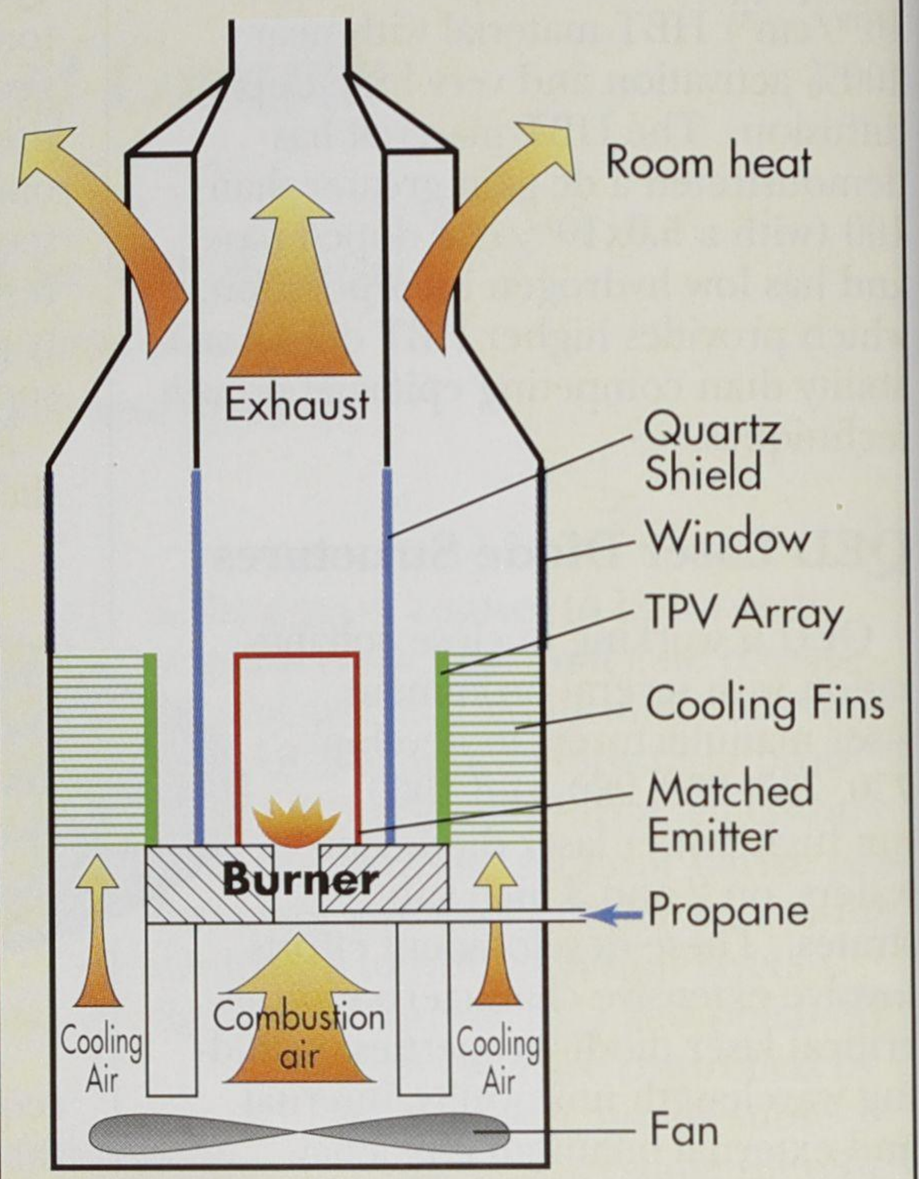


Midnight Sun Co-Generators

JX Crystals has introduced TPV technology to the commercial market in the form of the Midnight Sun range of heat and electricity co-generators. Initial target markets are "off-grid environments" - locations lacking a conventional electricity service. These include mountain cabins, sailboats and recreational vehicles, for which around 20,000 customers per year currently purchase solar panels. The TPV co-generator has the distinct advantage over solar panels of being unaffected by time of day and seasonal and local weather fluctuations.

The first product was a propane-fired co-generator capable of producing 8,000 BTU per hour, along with 30 W of electricity to charge a battery bank (see photo, this page). The propane burner inside the unit provides room heating, as well as heating the matched emitter, which is separated from the actively cooled TPV array by a quartz shield acting as a convection and conduction barrier (see diagram). The larger Midnight Sun Stove generates 100 W DC and 25,000 BTU/hr, and is capable of running appliances such as televisions (see photo, page 33).





JX Crystals

The 8,000 BTU/hour Midnight Sun unit burns propane to heat both its surroundings and the ceramic emitter. A cylindrical GaSb TPV array (shown in the photo with attached cooling fins) converts radiation from the emitter to produce 30 W electricity.

The Midnight Sun products also have strong potential for homes on the electric grid. Traditional gas furnaces will not operate without an electricity source to power the blowers which circulate heated air. During grid power outages caused by severe storms, the Midnight Sun is able to power its own blowers and continue to provide heat.

The largest market is potentially that of home co-generation, in which TPV cells are added to a home furnace in colder climates to provide the majority of the electricity consumed by the household. The challenge is to provide an AC supply, at a price below $2 per W. Detailed calculations by JX Crystals indicate this price target is achievable when the fab runs at a capacity of 1 MW (total power of all cells produced) per year, corresponding to a throughput of 25,000 3-inch wafers each holding twenty 2 W cells. The present production capacity is around 100 kW, which equates to 1,000 Stove units per year.

---

[2] BTU = British Thermal Unit. An "average" size furnace for a new three bedroom home in Seattle (mild climate) is in the range of 40,000 to 60,000 BTU/hr. The 8,000 BTU/hr Midnight Sun is big enough to heat a 35 foot boat, a recreational vehicle or the main room in a cabin. The 25,000 BTU/hr Midnight Sun is big enough to heat several rooms or a small home.

Design Issues in Thermophotovoltaic Systems

G.W. CHARACHE, D.M. DEPOY and P.F. BALDASARO
Lockheed Martin Inc., Schenectady, NY 12065-1072

Although the concept of thermophotovoltaic (TPV) energy conversion was first proposed in 1960, recent advances in low bandgap III-V materials and spectral control filters have renewed interest. Applications include: small lightweight portable generators, hybrid electric vehicles, electric grid independent appliances, and as an alternative to nuclear power generation in space. Radiator temperatures for these various applications range from 800-1700˚C. Lower temperature radiators challenge diode and filter design, while higher temperature radiators challenge structural material design. TPV systems have the potential to approach conversion efficiencies of conventional heat engines due to their ability to recuperate waste heat. In addition, TPV is the only direct energy conversion concept where the energy conversion devices function near room temperature, which leads to greater system reliability.

Compared to photovoltaic conversion of solar energy, TPV systems face many unique challenges that lead to differences in device design, including a lower temperature heat source and the ability to recuperate low energy (below-bandgap) photons. Compared to solar radiation, the photons emitted from a heat source at 800-1700˚C are distributed at much lower energies and longer wavelengths. This necessitates the use of low bandgap

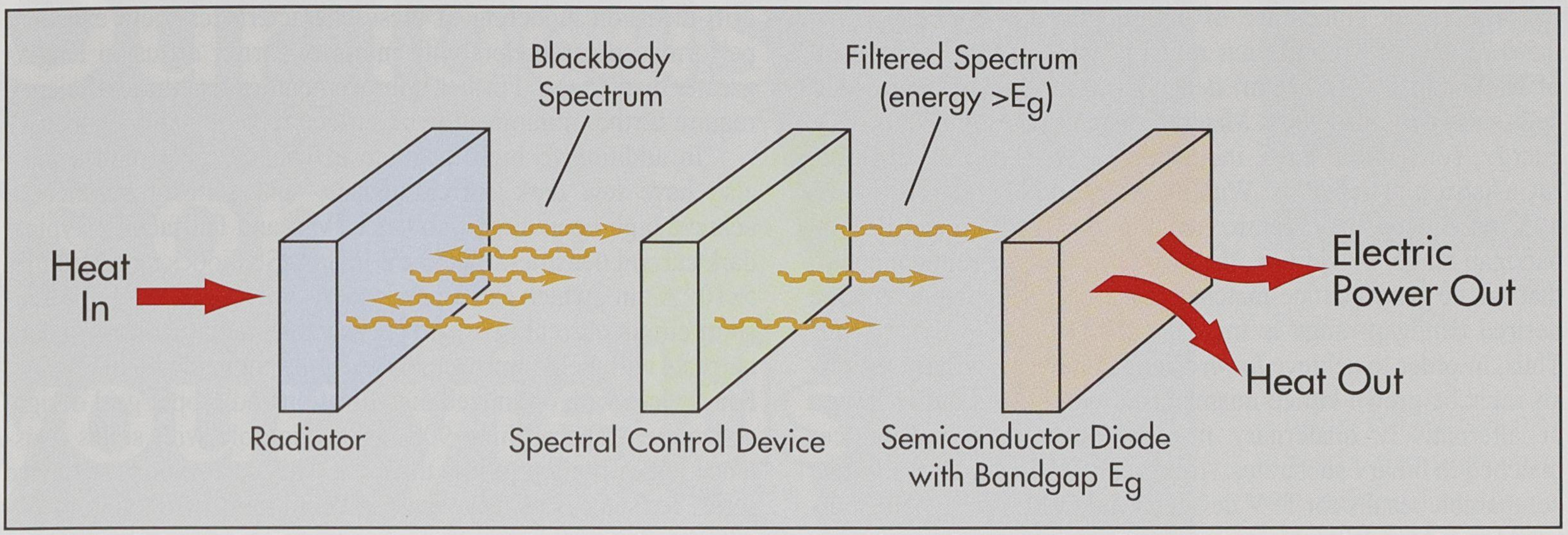


Figure 1. Schematic diagram of a thermophotovoltaic system incorporating a front surface filter as the spectral control device.

($E_g < 0.75$ eV) semiconductors for the TPV energy conversion diode in order to simultaneously maximize both efficiency and power density.

Recycling of below-bandgap photons is enabled by the close proximity of the radiator to the diode (e.g. compared to the distance between the sun and a solar panel), which allows the use of a spectral control device or filter. Finally, the non-normal incidence of the photons requires that the spectral control device be optimized for multiple angles of incidence.

TPV System Configurations

In the typical TPV system in Figure 1, the spectral control device is placed between the radiator and semiconductor diode and is termed a front-surface filter. The filter must perform two functions in this configuration: the transmission of above-bandgap light, and the reflection of below-bandgap light. As mentioned previously, this requires the development of a broadband filter that functions for all angles of incidence (0-90°). These requirements complicate the front-surface filter design, but allow essentially independent design of the TPV diode and filter. As an alternative it is possible to place the spectral control device on the rear of the TPV diode, and in this case it is termed a back surface reflector. The back surface reflector conceptually simplifies the filter design; however, the diode design must now be modified to minimize the absorption of below-bandgap photons (i.e. free carrier absorption) while maintaining low series resistance and maximizing the absorption of above bandgap photons in the diode active area.

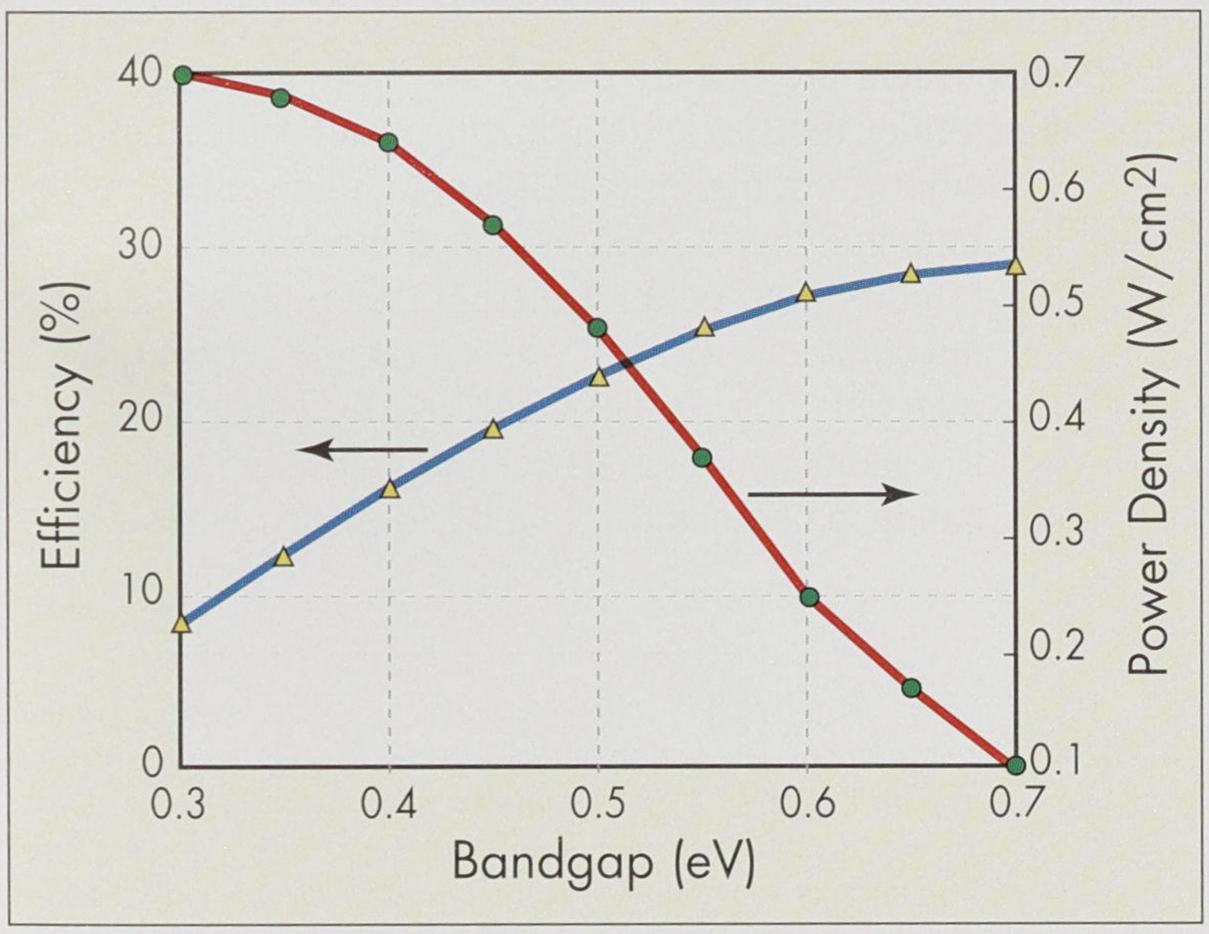


Figure 2. Modeled power density / efficiency trade-off versus III-V diode bandgap. This result was calculated with the following model parameters: radiator temperature = 800°C, radiator emissivity = 1, spectral efficiency = 0.9, average quantum efficiency = 0.95, and dark current is 10x the thermodynamic limit.

The spectral control filter is a key requirement for an efficient system because of the low fraction (20-30%) of convertible photon energy in excess of the TPV diode bandgap. If below-bandgap (low energy) photons are not returned to the radiator, they will eventually deposit their energy in the cooling water of the system as waste heat. By reflecting them back to the radiator (recycling them) it essentially takes less energy to keep the radiator at the same temperature.

Choosing the Correct Bandgap

For most applications, the bandgap of the TPV diode is placed near the peak of the incident greybody spectrum to simultaneously maximize both efficiency and power density. Figure 2 plots the modeled efficiency and power density trade-off for various TPV diode bandgap values, and illustrates that higher power density can be achieved by lowering the bandgap and thus capturing a larger fraction of the greybody spectrum. This occurs at the expense of increasing the diode dark current and lowering both the open circuit voltage and the fill factor[1], which limits attainable efficiency.

---

[1] *The fill factor defines power extraction efficiency and is an important figure of merit in TPV or solar cell design. It is the maximum output power divided by the product of the short-circuit current (current when V = 0) and open-circuit voltage (voltage when I = 0).*

The recent emergence of high-quality low-bandgap (E_g = 0.5-0.75 eV) TPV diodes has relied heavily on the development of III-V mid-IR (1.5-5 μm) detectors, lasers, and tandem solar cells since the mid-1980's. Material systems investigated for TPV energy conversion have included: GaSb, InGaAs, InGaSb, InGaAsSb, and InAsPSb. With the exception of GaSb (E_g = 0.72 eV), no binary III-V semiconductor exists within the desired bandgap range. In addition, the only ternary III-V semiconductor that can be grown lattice-matched to a binary substrate within the desired bandgap range is $In_{0.53}Ga_{0.47}As$ (E_g = 0.73 eV) on InP. Thus, in order to achieve lower bandgap devices, ternary materials must be grown lattice-mismatched with graded buffer layers, or alternatively quaternary materials can be grown lattice-matched to binary substrates. At present, MBE and MOVPE give comparable results for TPV devices, while LPE is also being pursued by various laboratories as a lower cost alternative.

Figure 3 illustrates the device architecture for a 0.50-0.55 eV InGaAsSb device grown lattice-matched on a GaSb substrate, and Figure 4 plots the internal quantum efficiency versus wavelength for typical high-quality 1x1 cm² diodes. One-dimensional drift-diffusion modeling of these characteristics yield excellent performance parameters with minority carrier diffusion lengths greater than 15 μm. Further improvements in quantum efficiency require further minimization of surface recombination velocity.

In addition to high quantum efficiency, TPV diodes must also have low dark current density and series resistance to achieve high open circuit voltages (V_{oc}) and fill factors. Typical dark current densities of 0.53 eV InGaAsSb diodes range from 2-5x10^{-5} A/cm², which corresponds to V_{oc} = 290-310 mV at 1A/cm² short circuit current density. If achievable, radiative-limited dark currents will yield improvements of approximately 40 mV in V_{oc}. For devices with optimized metallization and proper grid design, active areas approaching 90% are achievable with series resistance losses limited to less than 7%. This corresponds to device series resistances of less than 5 mΩ/cm² and fill factors of 68-70% for 0.53 eV devices.

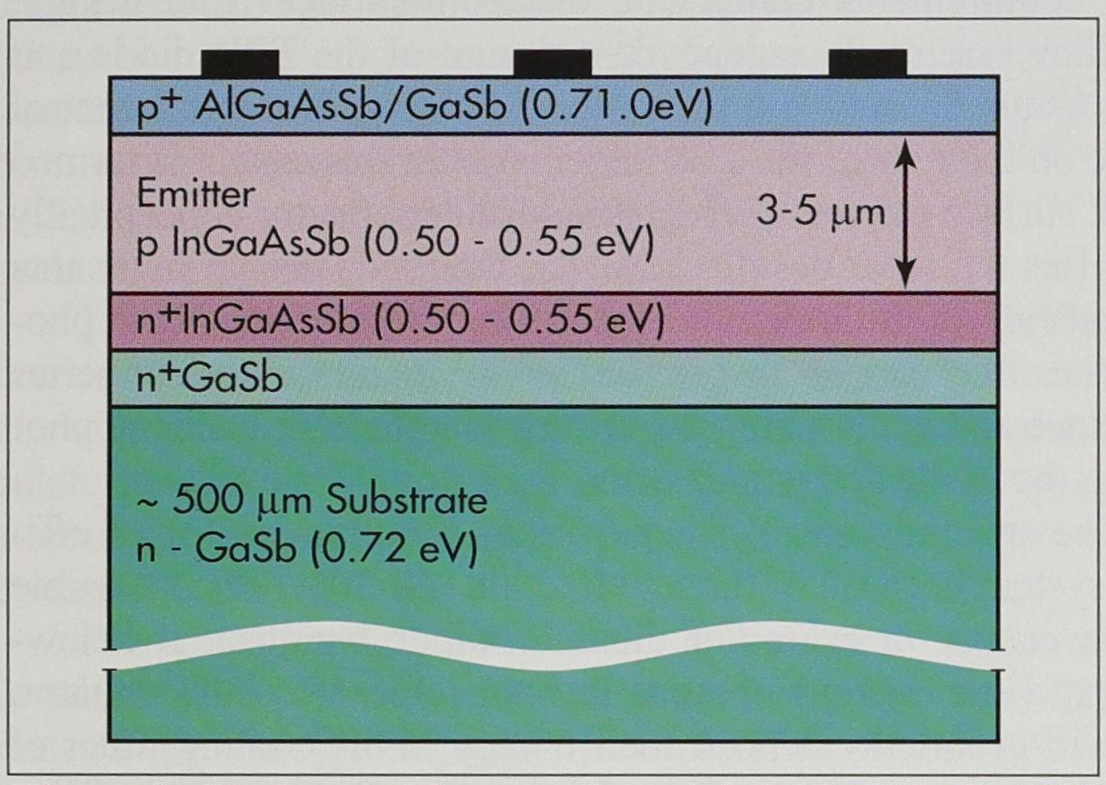


Figure 3. Device architecture for a 0.5-0.55 eV InGaAsSb TPV diode grown lattice-matched on a GaSb substrate.

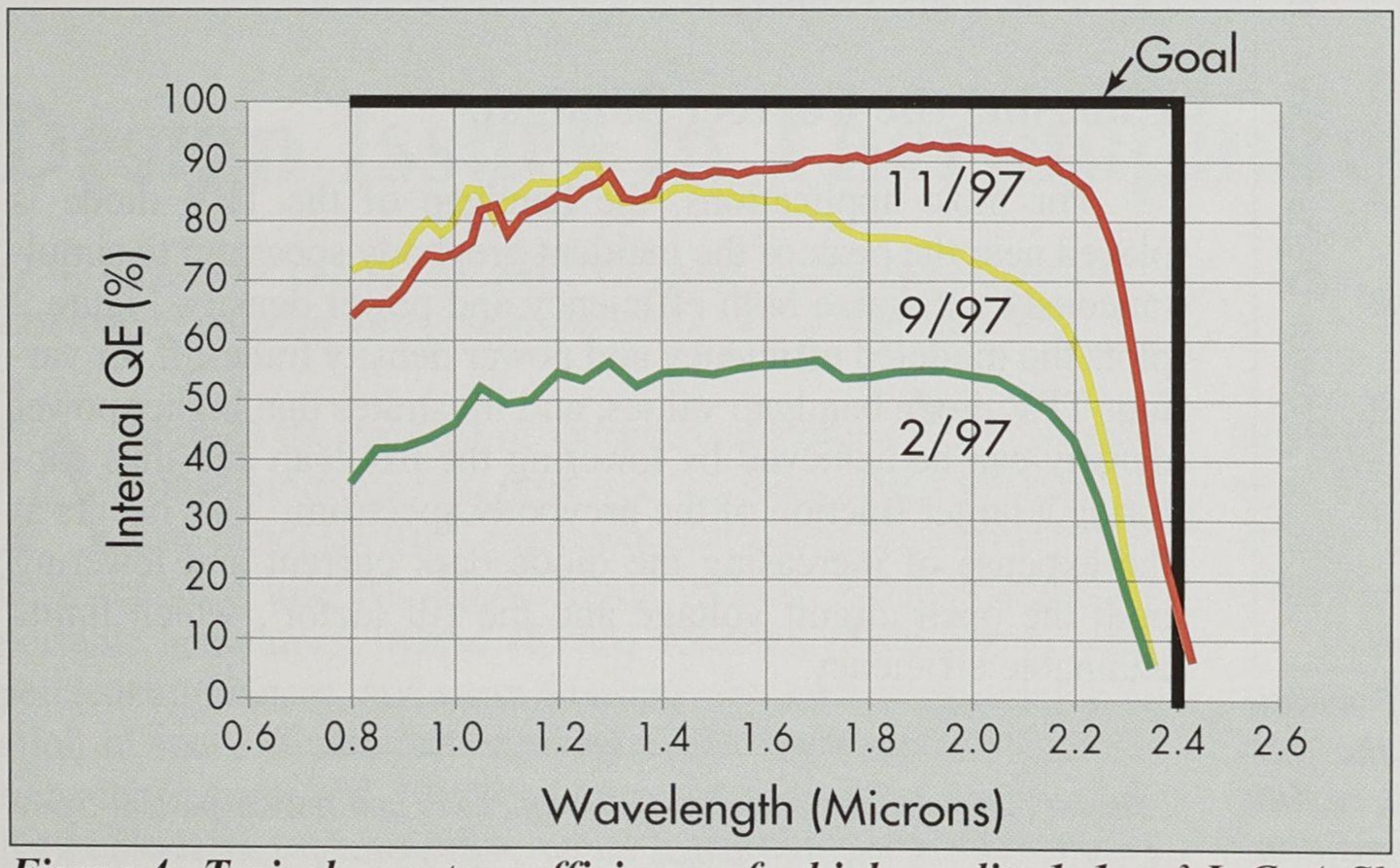


Figure 4. Typical quantum efficiency of a high-quality 1x1 cm² InGaAsSb TPV diode.

The Spectral Control Filter

The second critical component of a TPV system is the spectral control filter, since only 20-30% of the incident energy is above bandgap. Thus, an effective spectral control device that recuperates 70-80% of the incident energy is required. For applications that require simultaneous optimization of both power density and efficiency, this filter must have high transmission for wavelengths that range from the TPV diode bandedge (λ_g) to approximately $\lambda_g/2$, and high reflection for wavelengths that range from λ_g to approximately 10 microns.

Initially, interference filters (dielectric stacks) were investigated for this function, however the extreme broadband nature of this design requirement necessitates harmonic suppression techniques that increase the complexity of the filter to include greater than 50 layers. To overcome this obstacle, interference filters were combined with semiconductor plasma filters in a tandem configuration.

Plasma filters are heavily-doped n-type (n > 5x10^{19} cm^{-3}) semiconductors or transparent conducting oxide films that transition from high transmission to high reflection. The high mobility (>500 cm²/Vs) at these carrier concentrations required for a sharp transition has lead to the development of InAs-based single crystal III-V materials (e.g. InGaAs and InPAs). These nominally low bandgap materials become transparent to above-bandgap photons due to the Moss-Burstein[2] shift.

---

[2] The Moss-Burstein shift is a change of optical bandgap due to the filling of conduction or valence band states by free carriers. For an n-type III-V semiconductor with a small effective mass, the density of conduction band states near the conduction band minimum is very small. When the doping becomes degenerate, the extra free electrons fill progressively higher empty conduction band states, which thus become unavailable to receive optically excited valence-band electrons. Thus, as doping increases, the "optical bandgap" also increases. This is quite dramatic for InAs-rich materials such as InGaAs and InPAs. Nominally 0.5 - 0.6 eV material can have an optical bandgap of greater than 1.1 eV!

Our focus is on your yields



PLM-100 Photoluminescence Mapping System

Philips Analytical now offers a complete range of analytical equipment to provide the total metrology solution.

Typical applications include:

- **Thin film**
  - **opaque: metals**
  - **transparant: dielectrics**
  - **thickness, composition**
- **Contamination**
- **Stress**
- **Defects**
- **Crystal structure**

For more information:

Philips Analytical
Lelyweg 1
7602 EA Almelo
The Netherlands
Tel. : +31(0)546 534430
Fax : +31(0)546 534598

Internet:
http://www.analytical.philips.com

Let's make things better.

PHILIPS

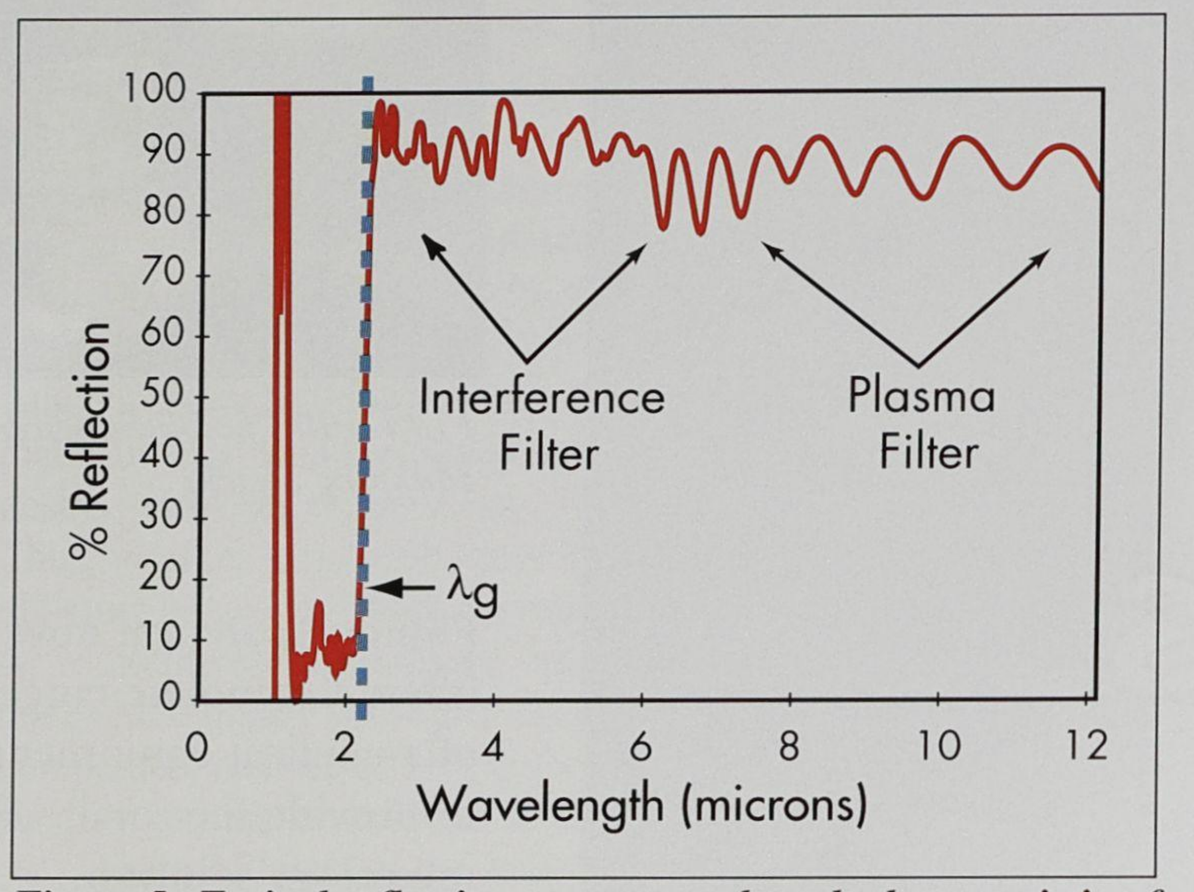


Figure 5. Typical reflection versus wavelength characteristic of an interference/plasma tandem filter.

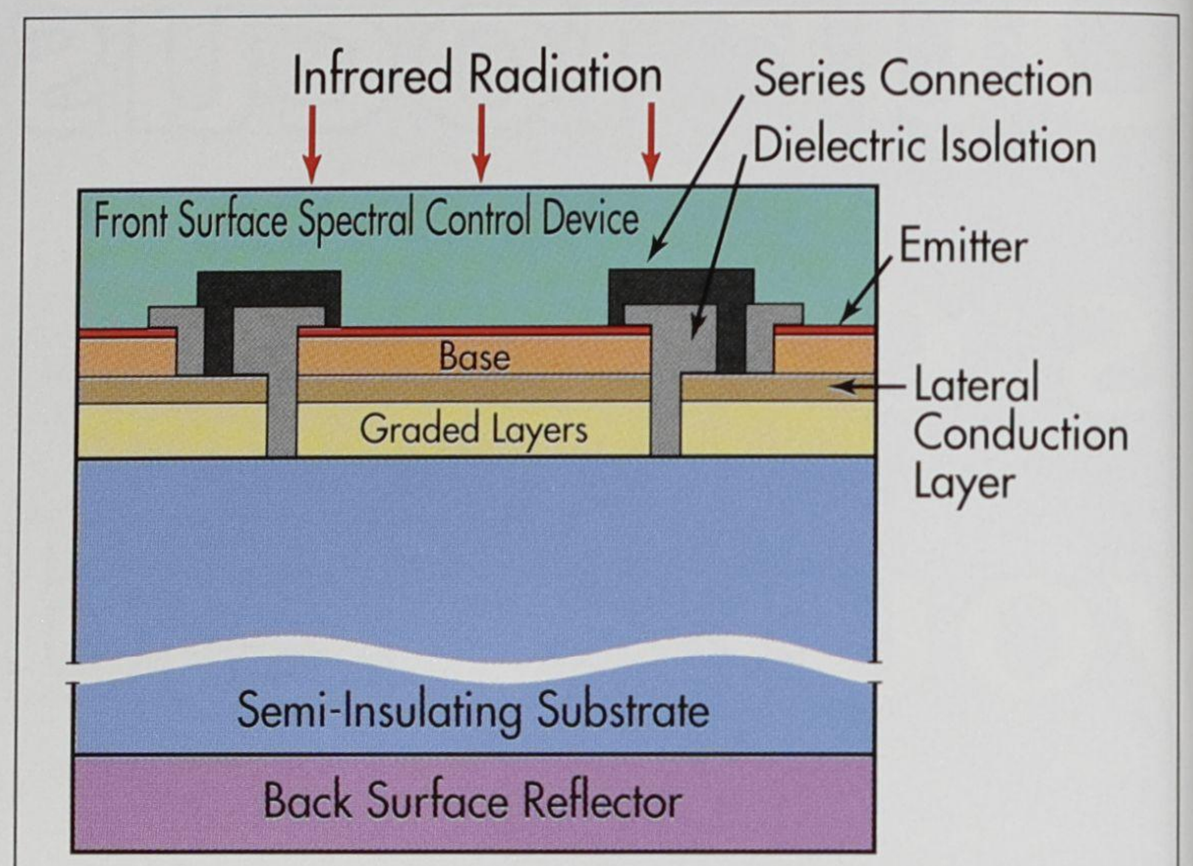


Figure 6. Device cross-section of a monolithically series interconnected TPV device with a back surface reflector.

Figure 5 illustrates the reflection versus wavelength for a tandem filter, which exhibits an average reflectivity of 90% and a spectral efficiency of 70% for a 1000˚C blackbody radiator (Note: a spectral efficiency of 80% requires an average reflectivity of 95%). Improved performance may be obtained with the development of new material system combinations for the interference filter and minimization of above bandgap absorption in the plasma filter or substitution of the plasma filter with metal dipole or photonic bandgap filters.

Back Surface Reflectors

Back surface reflectors (BSR) are conceptually much simpler than the front surface filter approach. For these devices, the spectral control device and diode are combined into a single unit and a highly reflective metallic surface is deposited on the back of the device. The BSR is inherently broadband and the diode itself selectively absorbs the above-bandgap photons. However, below-bandgap photons must pass through the TPV diode and substrate to reflect off the BSR, and then pass through the TPV diode again back to the radiator. This requires that free-carriers be minimized in the diode (to prevent absorption), and that the back surface reflector must be highly specular (to prevent total internal frustration).

These requirements necessitate the use of monolithic series-interconnected diodes (monolithically integrated modules, or MIMs) grown on wide band-gap semi-insulating substrates [Figure 6]. In this device architecture, the semi-insulating substrate has no intrinsic parasitic absorption, both the emitter and base contacts are co-planar and the BSR covers the entire back surface of the device. Individual diode sizes are optimized to maximize active area and minimize device series resistance. Another advantage of MIMs is the ability to build variable voltage in a small area, thus enabling a wide range of current-voltage combinations. MIM devices can also be used in conjunction with front surface filters if parasitic absorption limits effective BSR spectral control.

Both TPV diode and spectral control technologies are advancing rapidly due to the large optoelectronic infrastructure available today. In addition to the short review given here of these technologies, numerous heat source, radiator, waste heat recuperation, module and system configuration studies are being investigated. These studies will ultimately determine the feasibility of thermophotovoltaic energy conversion.

Further Reading

* www.tpv.org
* T.J. Coutts et al, "A Review Of Recent Advances In Thermophotovoltaics," presented at the 25th PVSC, p. 25, May 13-17, 1996.
* Proceedings of NREL Conferences on TPV Generation of Electricity, American Institute of Physics Conf. Proc. 321 (1994), 358 (1995), 401 (1997)
* T. Coutts and M. Fitzgerald, "Thermophotovoltaics", Scientific American, Sept. 1998, p. 90

Contributions Welcome!

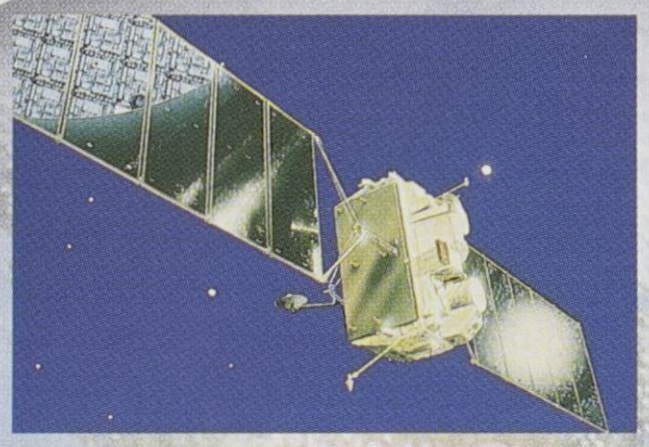
To enhance the quality of our coverage of the compound semiconductor industry and research community, we welcome contributed articles, news items or research reviews.

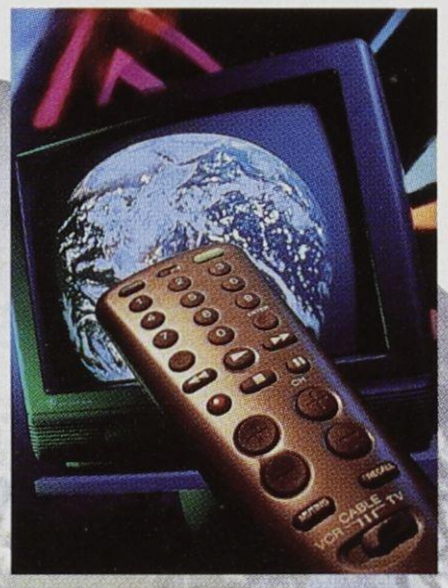
Please contact Tim Whitaker or Marie Meyer for further information:
tim.whitaker@compsem.com or mmeyer@compsem.com
Tel [1] 978 927 9994

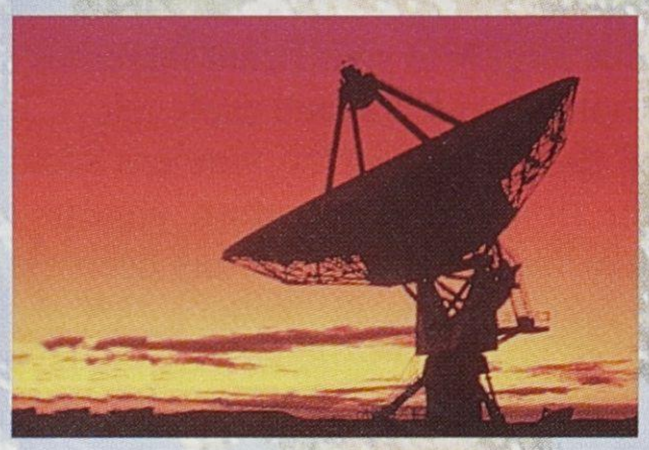
The Core of Advanced Communication Technologies

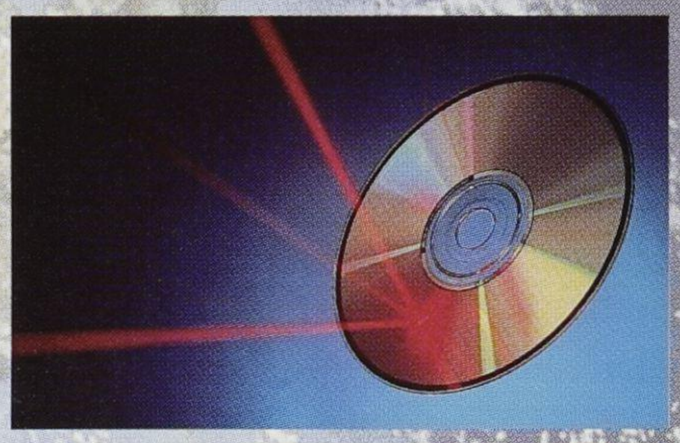
Call Us Today For:

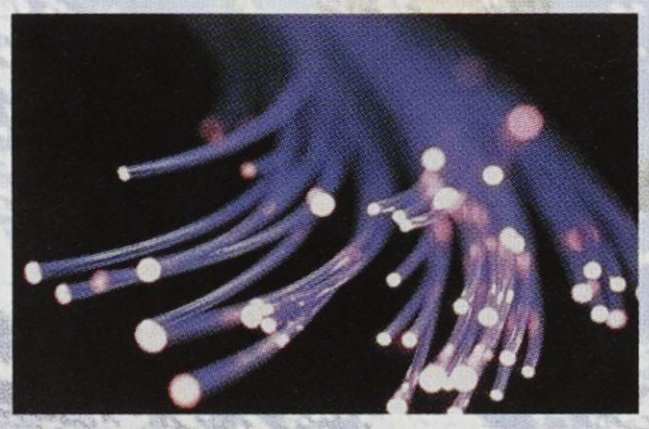
- Implant ready VGF GaAs Wafers
- 150 mm VGF GaAs Wafers
- 2" and 3" VGF InP Wafers
- 100 mm VGF Ge Wafers
- 2" VGF GaP Wafers





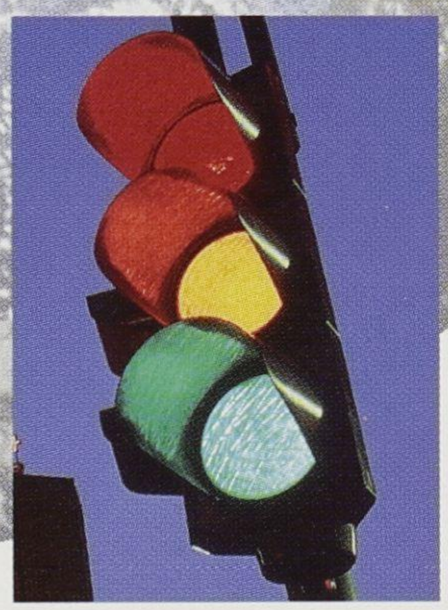












ISO 9002 SGS — QUALITY ASSURED FIRM — NATIONAL ACCREDITATION OF CERTIFICATION BODIES

American Xtal Technology

USA Head Office
American Xtal Technology
4311 Solar Way
Fremont, CA 94538
Tel: 510-683-5900
Fax: 510-683-5901
Email: sales@axt-vgf.com

Japan
AXT-Japan
565-15 Kitano-Machi
Hachioji, Tokyo 192, Japan
Tel: (81) 0426-56-2032
Fax: (81) 0426-56-6885
Email: axtjapan@cg.netlaputa.ne.jp

France & Germany
SO.FRA.S.I.L
109 Rue De Javel
75015 Paris, France
Tel: (33) 1-4554-4000
Fax: (33) 1-4554-4004
E-mail:
ralph_hananel@compuserve.com

United Kingdom
West Associates
46 Leigh Road, Cobham, Surrey
United Kingdom, KT11 2LD
Tel: (44) 1932-868-006
Fax: (44) 1932-860-932
E-mail: mwest@westassociates.co.uk

Taiwan
Conary Enterprises Co., Ltd.
10 F-2, No. 33, Sec. 2
Chien-Kuo North Road
Taipei, Taiwan, ROC
Tel: (886) 2-2509-1399
(886) 2-2509-3174/5
Fax: (886) 2-2501-6279
E-mail: conary@top2.ficnet.net.tw

Korea
Dong Kyung Electronic Industry
Co., Ltd.
#302 Daegun Bldg.
677-1 Ryeoksam Dong
Kangnam-Gu
Seoul 135-080, Korea
Tel: (82) 2-569-6723/5
(82) 2-568-5261/2
Fax: (82) 2-561-1185
E-mail:
dkekorea@nownuri.nowcom.co.kr

Second Quarter Earnings Round-Up

MARIE MEYER

The latest quarterly reports for the companies in the Compound Semiconductor Portfolio indicate rather unsettled conditions. Some of the companies reported impressive earnings growth – especially Cree (up 184%), AXT (up 128%), Plasma-Therm (up 53%), and, as always, Vitesse (up 55%). Even so, the companies which lost money outnumbered those that made money 11 to 8, and, perhaps more importantly, several companies offered warnings about subsequent quarters.

As this issue went to press, all of the Portfolio companies but Ortel had announced their results for the quarter ended June 28, 1998, as summarized below.

GaAs IC Companies

Alpha Earnings Up 250%

Alpha Industries reported net income of $4.0 million, up more than 250% compared with net income of $1.1 million for the comparable period last year. Net sales were $30.0 million, up 16% over $25.7 million for the same period last year. The Wireless Semiconductor sector (which makes GaAs ICs for handsets) had sales of $14.1 million and generated $814,000 in operating profit at a 39.3% gross margin. The Application Specific Products sector, which makes GaAs and Si devices for satellite, defense & other communications markets, had sales of $9.9 million and generated $3.3 million in operating profit, giving this sector a significantly better gross margin percentage of 55.3%.

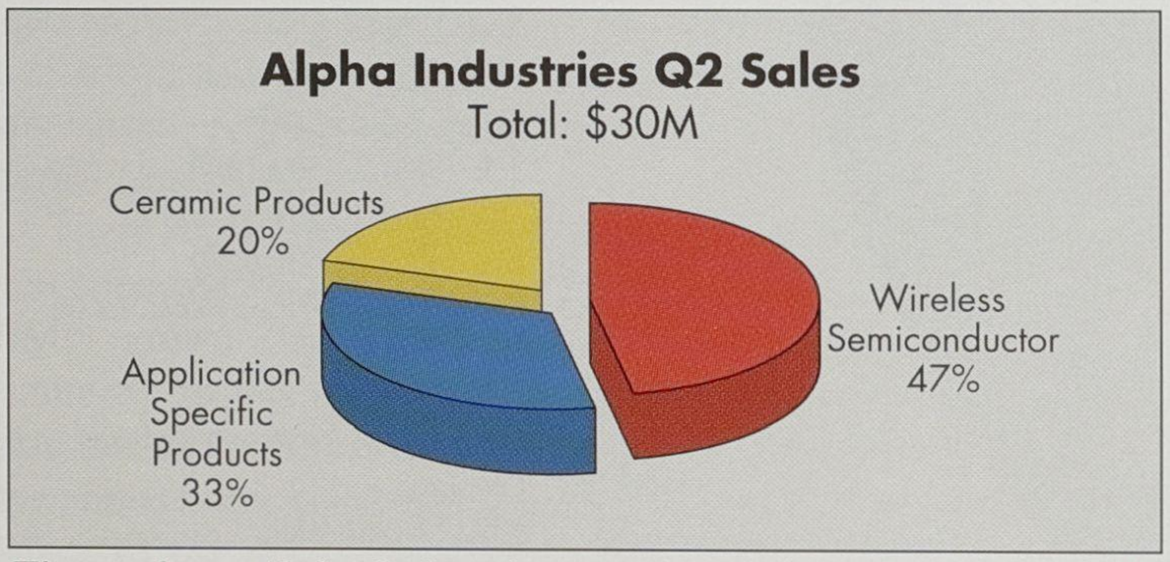


Figure One. Alpha Industries revenues for the June quarter, by product sector. The Wireless Semiconductor makes GaAs ICs for wireless handsets. The Application Specific Products (ASP) sector makes GaAs and Si devices for satellite, instrumentation, defense and other communications markets. The Ceramic Products sector makes technical ceramic products for wireless telephony infrastructure.

Commenting on the results, CEO Tom Leonard stated, "We continued to post improvements in margins and profits, demonstrating our ability to manage each sector of our business effectively, even in a challenging environment." He went on to predict that in the September quarter the company would report roughly similar revenues but improved margins and profits, due to "continuing emphasis on improving yields and controlling expenses". With regard to the future, he said "we expect to increase revenues and earnings as we expand our market share in the new wireless handset platforms scheduled for introduction later this summer."

Leonard also reported that Alpha's newest GaAs RFIC products, which use a PHEMT process, have been evaluated by customers "with very positive results". All of Alpha's previous products have been MESFET-based.

Deliveries to one major customer (believed to be Motorola) were 25% of Alpha's total sales for the quarter.

Anadigics: On the Mend?

Anadigics reported net sales of $22.7 million, and net income of $320,000. While this is down considerably from the year-ago levels, when sales were $25.0 million and net income was $3.6 million, it is still a substantial improvement over the previous quarter, when Anadigics reported net sales of $18.8 million and a loss of $1.1 million.

The improvement was due largely to significant increases in sales of GaAs ICs for fiber optics (up 52%) and cable television applications (up 37%). But the decline in the wireless sector, which was responsible for the first quarter downturn, appears to be on-going. Sales for cellular and PCS applications decreased 12% between the March and June quarters, following a 48% drop in the previous three months. The value of sales of integrated circuits for direct broadcast satellite (DBS) applications also declined, down 28% to $1.9 million. This was attributed to price erosion.

Not surprisingly, the company is looking at other markets to replace this lost business. "Anadigics GaAs ICs are increasingly finding application in broadband cable and fiber optics networks," said Ron Rosenzweig, President and CEO. "These trends were substantial contributors to the sequential growth in revenue we experienced this quarter as we delivered increasing quantities of new and existing products for gigabit Ethernet, cable modem, digital TV and broadband cable distribution amplifier applications."

Rosenzweig went on to say that the company has a positive book-to-bill ratio, and he also reported strong demand for a new generation of dual-band power amplifiers for use in wireless handsets.

Unfortunately, the future will also be bringing higher legal fees for the company. As a result of the sharp drop in the Anadigics' share price earlier this year, the company is currently defending against no few than seven shareholder class action lawsuits.

Loss, Layoffs at Celeritek

Celeritek reported revenues of $10.2 million, down 19% compared with revenues of $12.6 million in the year-ago quarter. The company reported a loss of $3.5 million, compared with net income $956,000 in the same quarter in 1997. Results include an inventory write down related to delayed or canceled contracts of $3.1 million.

Sales to commercial customers decreased 17%, due to previously announced delays by several subsystem customers. Defense revenues decreased 21% compared with those in the year-ago period.

"While our semiconductor business experienced solid growth, it was not enough to offset customer delays in both the subsystem and defense areas," said Tamer Husseini, CEO. "We anticipate that our defense revenues will see improvement in subsequent quarters, but that the subsystem market is likely to be sluggish through [the next quarter] and that semiconductor activity will return to historical levels," he added.

Husseini said that Celeritek has taken a number of steps that will reduce operating expenses beginning in the second quarter of fiscal 1999. These include laying off approximately 40 employees, or 10% of the company's workforce, and reducing the number of hours in the work week through the end of calendar 1998.

"We continue to believe in the long-term viability of the company's markets, but because of the near-term outlook, we felt these initiatives were necessary to keep expenses in line with anticipated revenues and will reduce our losses in the second quarter of fiscal 1999," Husseini said.

HBTs Boost RFMD

RF Micro Devices (RFMD) reported revenue of $23.4 million, up 86% from the previous quarter's $12.6 million and up 129% over revenues of $10.2 million for the same quarter last year. Net income for the quarter was $1.7 million, up 41% compared to the income of $1.2 million reported for the year-ago period.

GaAs HBT power amplifiers dominated shipments, accounting for 87% of sales. During the last 12 months, RFMD has shipped more than 10 million 3V GaAs HBT power amplifiers for wireless handsets. The company says that Si product shipments also showed strong gains, increasing 38% over the previous quarter, from $1.8 million to $2.5 million, and increasing 101% compared to the corresponding quarter in fiscal 1998.

Buoyed by a full orderbook for the next two quarters, the company issued a bullish forecast, saying that revenues could exceed $100 million over the next twelve months, which is 10 – 15% higher than earlier estimates.

Gross profit increased to $7.8 million versus $1.1 million in the March quarter and versus $5.1 million for the June quarter last year. However, gross margin as a percentage of revenue declined to 33.4% compared to 49.5% for the corresponding period in 1997. The company explained that the drop was due to lower average selling prices related to greater than expected sales volume, especially the GaAs HBT products that are based on 3" wafer processing.

RFMD's new 4" GaAs HBT fab passed internal qualification in June, ahead of schedule, and production shipments began in July. The company says that "wafer starts and line yield continue to meet or exceed plan". David Norbury, CEO, stated, "The qualification of our GaAs HBT fab was a milestone event…As it ramps up to full capacity, we will be able to meet the current and forecasted demands of existing customers as well as add major new customers. The cost for each integrated circuit will be reduced significantly, helping us improve gross margins, and the quicker cycle time will reduce our product development times and help us manage inventories."

"Demand for our GaAs HBT products, primarily power amplifiers, increased during the quarter" said Norbury. He went on the explain that this trend, coupled with the increasing interest in RFMD's silicon products, has given the company a record backlog and a positive outlook over the next several quarters.

Microwave Revenues Up at TriQuint

TriQuint Semiconductor reported record revenues of $27.9 million, including revenues from its newly acquired Millimeter Wave business (the former Texas Instruments GaAs operation). This represents a 50.3% increase over the $18.5 million in the comparable period of 1997. Net income was $2.0 million, compared to a net income of $2.3 million reported for the year ago period.

1st Half Profits

	Q1 & Q2 '98 in '000's	Comparison with 1st Half 1997
Alpha Industries		
Revenue	$61,809	Up 28%
Income	$7,656	Up $11.9M from loss of $4.2M [1]
ATMI		
Revenue	$49,006	Up 6%
Income	$5,999	Up 17%
American Xtal Tech.		
Revenue	$20,520	Up 82%
Income	$2,905	Up 128%
Coherent		
Revenue	$204,433	Up 6%
Income	$5,111	Down 75%
Cree Research		
Revenue	$22,219	Up 44%
Income	$3,634	Up 184%
Plasma-Therm		
Revenue	$27,275	Up 38%
Income	$3,054	Up 53%
SDL		
Revenue	$51,167	Up 20%
Income	$5,478 [2]	Up $35.0M from loss of $29.5M [3]
Vitesse		
Revenue	$86,320	Up 65%
Income	$25,983	Up 55%

Notes

[1] '97 results include $4.9 million of nonrecurring charges

[2] Includes $0.8 million of nonrecurring charges relating to an acquisition.

[3] '97 results include $31.0 million of nonrecurring charges relating to settlement of a lawsuit.

Throughput guaranteed...

...now and in the future



Right now you could probably use as much high quality GaAs epi as you can get hold of.

So its comforting to know that VG Semicon's V100 gives a higher yield than any other production MBE system. That's why, with over twenty-seven systems installed already and many more on the way, the V100 is the system of choice for the world's leading GaAs companies. Put simply, it's the world standard for production MBE.



And as your markets grow, rest assured that we are growing with you.

Our next generation V150 system is ready to meet your future expansion needs. The V150 offers more than three times the 4" or 6" wafer throughput of the V100. And it's designed with the same rigorous attention to simplicity and reliability that made the V100 so successful.

So if you value throughput, reliability and a process that delivers on time every time, talk to VG Semicon, the world's most successful MBE company.

UK	(44) 1342 325011
USA	(1) 800 888 7007
	(1) 978 524 1041
Japan	(81) 3 3639 9652
France	(33) 1 6092 3610
Korea	(82) 2 548 2983
Taiwan	(88) 63 535 9771
Benelux	(31) 184 490909
Nordic	(46) 8 629 2400
Australia	(61) 2 898 1244

mbesales@vgsemicon.com

VG Semicon
The MBE Company

According to the company, the increase in total revenues primarily reflects the inclusion of the new MMIC business, "as well as an increase in the volume of product sales to wireless communications customers, offset by reductions in sales to telecommunications and data communications customers." In commenting on the quarter results, Steven Sharp, CEO, stated that, "The second quarter of 1998 was an excellent quarter for TriQuint. Orders and revenues were at record levels."

TriQuint acquired the MMIC operations of the former Texas Instruments' Defense Systems & Electronics Group from Raytheon in January, 1998 for approximately $19.5 million in cash and $19.5 million in TriQuint stock.

More Records at Vitesse

Vitesse Semiconductor reported another quarter of record revenues and net income. Revenues were $46.1 million, an increase of 67% over the $27.6 million in the year ago and an increase of 15% over the $40.2 million in the March quarter of this year. Net income was $13.9 million, compared to $9.0 million or in the year ago quarter and net income of $12.1 million in the March quarter of this year.

Vitesse CEO Lou Tomasetta reported that "bookings continued to be strong in all of our focus areas". He also said that Vitesse continues to increase production by ramping up its new 6" GaAs fab in Colorado and by enhancing the company's back-end test capacity.

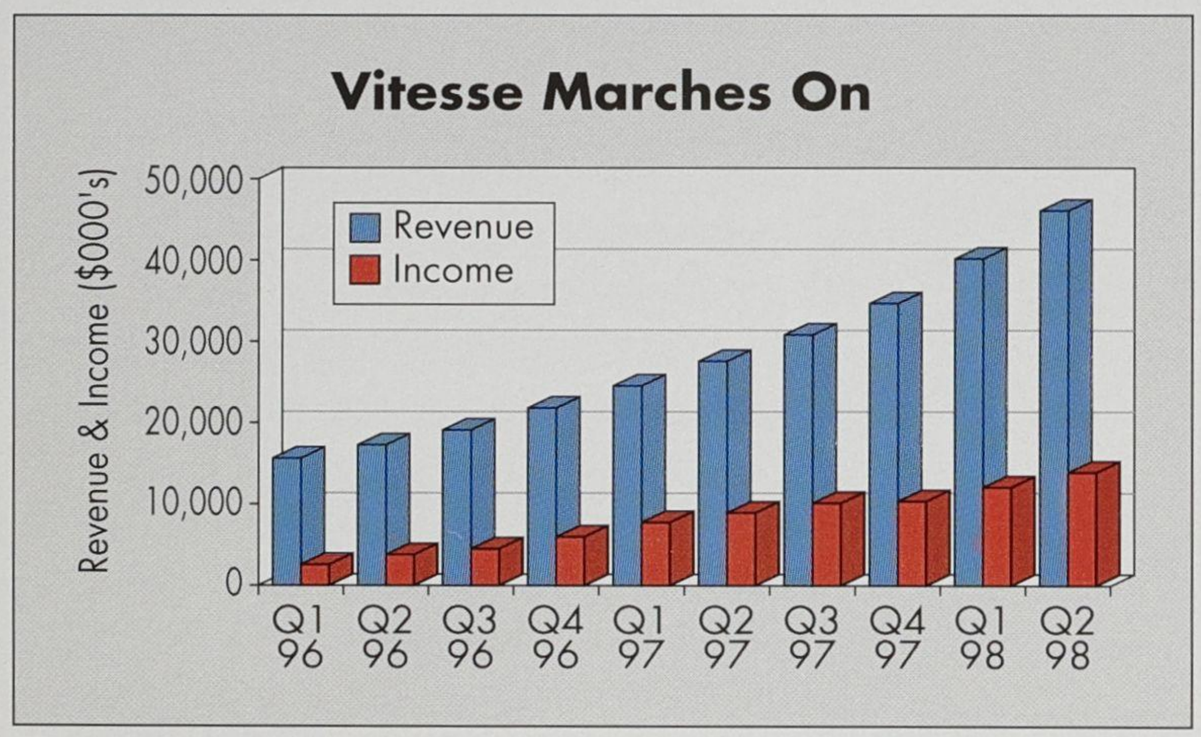


Figure Two. Vitesse continues to be the most impressive of the Portfolio companies, with steady growth in revenues and income. Not surprisingly, several analysts give this stock the highest possible rating – see page 50.

Optoelectronics Companies

Revenue Down, Losses Continue at APA Optics

APA Optics reported a loss of $478,145 for the quarter, as compared to the loss of $28,935 posted in the year earlier period. Revenues totaled $248,557, down significantly from the $661,640 reported for the same period in 1997. Anil K. Jain, CEO, said the loss could not be avoided as the company shifted its strategic course away from contract research toward higher-margin manufacturing. Operating costs for quarter included approximately $225,000 for operations at APA's Aberdeen, S.D. facility and product development costs of about $91,000. "We are experiencing the higher costs attributable to having manufacturing facilities," Jain said, "but are not yet benefiting from the revenues that we project our fabrication activities will ultimately produce."

The decrease in revenues is due to the substantial reduction in government contract activity. Product manufacturing revenues are minimal presently, although the company says that orders are being received for both its DWDM modulator and its GaN Schottky UV detector.

Coherent Disappoints

Coherent reported revenue of $98.6 million, down 4% from revenue of $102,335 reported for the same quarter in 1997. The continuing strength of the U.S. dollar was blamed for a $3.1 million shortfall in revenues. A net loss of $1.7 million was reported for the quarter, "due primarily to the poor performance of the medical group and the continued negative impact of the strengthening dollar against the Japanese Yen and other major foreign currencies". This compares to net income of $11.4 million during the same quarter last year, which included net income of $2.2 million on the sale of a building. Current quarter before-tax-income was $5.5 million for the electro-optical segment compared to $8.6 million during the like period last year. The medical segment incurred a before-tax-loss of $9.0 million during the current quarter, compared to before-tax-income of $5.9 million in the same quarter last year.

Income up 160% at Cree

Cree Research reported record revenue of $11.5 million, an 8% increase over the previous quarter and a 36% increase over the $8.5 million reported in the year-ago quarter. Net income increased 160% for the quarter to $1.9 million as compared to $724,000 reported in the year-ago period. The rise in revenue was primarily attributed to strong demand for Cree's GaN-on-SiC blue LEDs and material products.

Neal Hunter, CEO, stated, "We're especially pleased with the strong market response to our conductive buffer LED and continue to make advancements in the development of brighter blue and green products." Hunter also said that, in addition to LEDs, Cree is accelerating development efforts for microwave, gemstone, power and laser products.

Revenues Increasing at SLI

Semiconductor Laser International (SLI) reported revenue of $517,224, reflecting an increase of approximately 100% over revenues for the first quarter of 1998 and approximately 290% over revenues of $178,528 reported for the second quarter of 1997. SLI also reported a net loss from operations for the three months ended June 30, 1998 of $986,521.

Commenting on the results, Geoffrey Burnham, CEO, said "Customer confidence in SLI's products is evident in the finan

cial summary of our second quarter of 1998. With these results we are experiencing a trend of progression and a marked pattern of increasing sales. We expect this trend to continue as the company continues to grow."

SLI says it has a sales order backlog of approximately $2.6 million as of August 1, with requested customer delivery dates principally through the end of 1998. In their most recent SEC filings, SLI management says the company will need to increase sales to approximately $550,000 per month in order to reach break-even status. Their goal is to achieve this level of sales "some point prior to the end of 1998".

Business Booming at SDL

SDL reported record revenues of $25.8 million, up 20% compared to revenues of $21.6 million in the second quarter of 1997. Net income was a record $2.9 million compared to a net loss of $29.5 million for the second quarter of 1997. Commenting on the quarter, CEO Donald Scifres said, "Our second quarter growth represents the successful transition to and initial yield improvements gained from last year's investments in our new wafer fab facility and our manufacturing upgrades…[which] were intended to lower costs and substantially increase our chip capacity to meet customer demand. It has done both. In the first half of 1998, for example, we averaged chip yields in our 980 nm laser product line of more than three times the old line, and our new capacity is over 100,000 chips per year for this product."

Scifres continued, "We are particularly pleased with our performance in our communications markets where revenues increased by about 20% compared to the first quarter of 1998. Key contributors to this growth were the strong demand for 980 nm pump modules used in fiber optic communications and increased satellite communications shipments." He concluded with the opinion that SDL is "poised for rapid expansion".

Record Revenues at Uniphase

Uniphase reported record revenues of $48.9 million for the quarter, up 44% from the $33.9 million reported in the same period in 1997. Net income, excluding the write-off of one-time charges related to the acquisition of Philips Optoelectronics, was $9.9 million as compared to net income of $9.0 million for the year-ago quarter. With those charges factored in, the company reported an actual net loss of $96.4 million.

Results for the quarter include pretax charges of $113.6 million primarily for the acquisition and integration of the former Philips unit (now known as Uniphase Netherlands, or UNL), commencement of 1310nm cable television transmitter production, reorganization of the company's worldwide sales and management structure, and restructuring related to the company's Ultrapointe division. Charges for the acquisition and integration of UNL included a charge of $93.0 million for acquired in-process R&D.

Sales by Uniphase's laser and telecommunication businesses grew to $43.4 million from $28.5 million in year-ago quarter and $41.0 million in the March quarter of 1998.

1st Half Losses

	Q1 & Q2 '98 in '000's	Comparison with 1st Half 1997
Anadigics		
Revenue	$41,460	Down 13%
Loss	-$752 [1]	Down $7.5M from profit of $6.7M
APA Optics		
Revenue	$667	Down 57%
Loss	-$906	Down $1M from profit of $71K
Celeritek		
Revenue	$25,977	Up 7%
Loss	-$2,684 [2]	Down $4.6M from profit of $2.0M
Emcore		
Revenue	$22,882	Down 15%
Loss	-$7,409	Loss widened $5.0M [3]
Kopin		
Revenue	$12,150	Up 60%
Loss	-$786	Loss narrowed $3.0M
RF Micro Devices		
Revenue	$36,075	Up 86%
Loss	-$1,966 [4]	Down $4.0M from profit of $2.0M
Semiconductor Laser Int'l		
Revenue	$774	Up 335%
Loss	-$2,040	Loss narrowed $400K
Spire		
Revenue	$7,888	Down 28%
Loss	-$1,758 [5]	Down $2.6M from profit of $852K
TriQuint		
Revenue	$51,555	Up 46%
Loss	-$10,285 [6]	Down $14.3M from profit of $4.0M
Uniphase		
Revenue	$94,394	Up 55%
Loss	-$88,647 [7]	Loss widened $62.4 M [8]
Uniroyal Technology		
Revenue	$111,438	Up 4%
Loss	-$1,275 [9]	Down $1.3M from profit of $34K

Notes:

[1] Includes $1.1 million of nonrecurring charges related to a workforce reduction.

[2] Includes $3.1 million of inventory write down related to delayed or canceled contracts.

[3] '97 results include $2.8 million of nonrecurring charges relating to amortization of debt issuance cost.

[4] Includes $4.4 million of nonrecurring charges relating to revenue reduction and inventory write-down due to package related product returns.

[5] Includes $0.7 million of nonrecurring charges relating to settlement of a lawsuit.

[6] Includes $1.4 million of nonrecurring charges relating to settlement of a lawsuit and $8.8 million of nonrecurring charges relating to the acquisition of the MMIC business from Raytheon TI Systems.

[7] Includes $113.6 million of nonrecurring charges primarily relating to the acquisition of the Uniphase Netherlands business from Philips.

[8] '97 results $38.8 million of nonrecurring charges primarily relating to the acquisition of the Laser Enterprise business from IBM.

[9] Includes $5.6 million of nonrecurring charges related to early termination of debt.

Better Margins at UTC

Uniroyal Technology Corporation (UTC) reported sales of were $56.9 million, nearly level with the $55.7 million reported in the year ago period. Before allowances for an extraordinary item, income was $2.6 million, a gain of 196% versus

the $883,000 reported in the same period of the preceding year. After factoring in the extraordinary charge of $5.6 million (related to costs associated with the early retirement of debt), the company reported a net loss for the quarter of $3.0 million, compared to net income of $883,000 for the year ago quarter.

Materials & Equipment Companies

AXT Impressive in First Quarter of Public Trading

American Xtal Technology (AXT) reported revenues of $10.8 million, up 74% from the $6.2 million in revenues reported in the second quarter of 1997, and up 11% from the $9.7 million reported in the first quarter of 1998. Net income was $1.5 million. This compares with net income of $829,000 for the second quarter of 1997 and net income of $1.4 million the first quarter of 1998. This was AXT's first quarterly result since its IPO on May 21.

"We were pleased to report growth across all of our product lines despite difficult semiconductor market conditions," said Morris Young, CEO. "The company continues to enjoy solid market acceptance in our core product applications and we are focused on developing our market position in other key areas," he said.

ATMI Suffers From Chip Industry Slowdown

ATMI reported revenues of $21.6 million, down 8% from $23.5 million in the second quarter of 1997. Earnings for the quarter were $1.5 million, down 42% from the $2.6 million reported in 1997.

The company had warned analysts of an earnings disappointment on June 30, saying that demand for all of ATMI's products was "very soft" due to customers reducing wafer starts and, in some cases, turning off capacity. ATMI's Epitronics Division serves the compound semiconductor industry, whereas it's other divisions – ADCS, which makes thin film materials and delivery systems; EcoSys, which makes environmental equipment; and NovaSource, which makes sub-atmospheric gas delivery systems – all serve the silicon industry. And, as readers of this publication will likely be aware, the silicon industry is in the midst of one of its cyclical slumps.

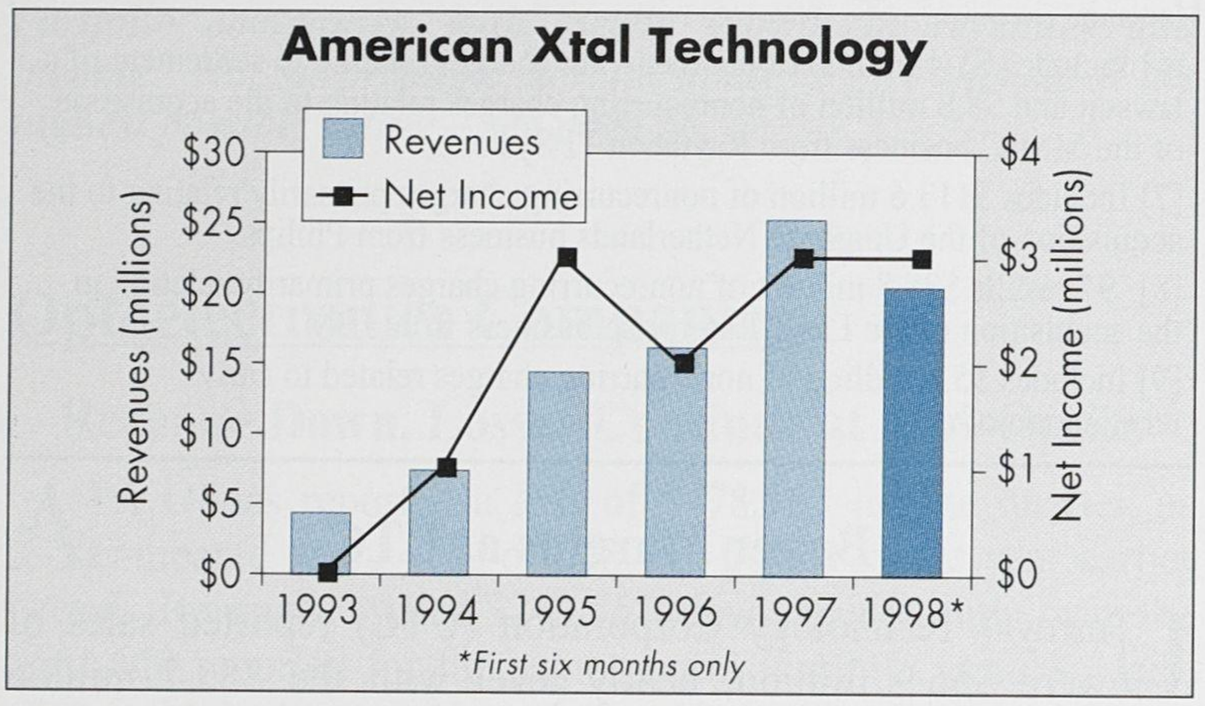


Figure Four. Through the first half of 1998 AXT is showing significant growth in revenue and income.

Commenting on the 2nd quarter results, Gene Banucci, ATMI CEO, said, "Obviously, the second quarter was difficult, both for ATMI and the semiconductor industry. As semiconductor unit volumes dropped, end-user sensitivity to inventories also increased, causing a severe early quarter drop-off in revenues and orders." He went on to say that this looks like the worst slump since 1983-84. While there are some indications that demand for consumables is picking up, Banucci warned that the equipment side of the business may continue to suffer "well into 1999."

Emcore Hurt by GM Strike

Emcore reported revenue of $9.1 million, as compared to $14.1 million in 1997, and a net loss of $7.4 million, compared to net income of $830,000 in the same period of 1997.

Much of the loss was due to the General Motors strike, which forced Emcore to halt deliveries of MR sensors, which are used in braking systems. GM is Emcore's largest customer.

Emcore's results were also hurt by a downturn in their equipment business, attributed to the Asian financial crisis, and the creation of a $1.2 million reserve for a bad debt. Shipments of MOCVD systems have decreased more than 40% over the past nine months to $15.6 million. The company expects that this trend will continue at least through the end of 1998.

But perhaps the worst is now behind them. Shipments to GM have resumed, and on July 10 the company announced that it has received 11 new orders for MOCVD systems. The company says its backlog increased 100% between the end of March and early August.

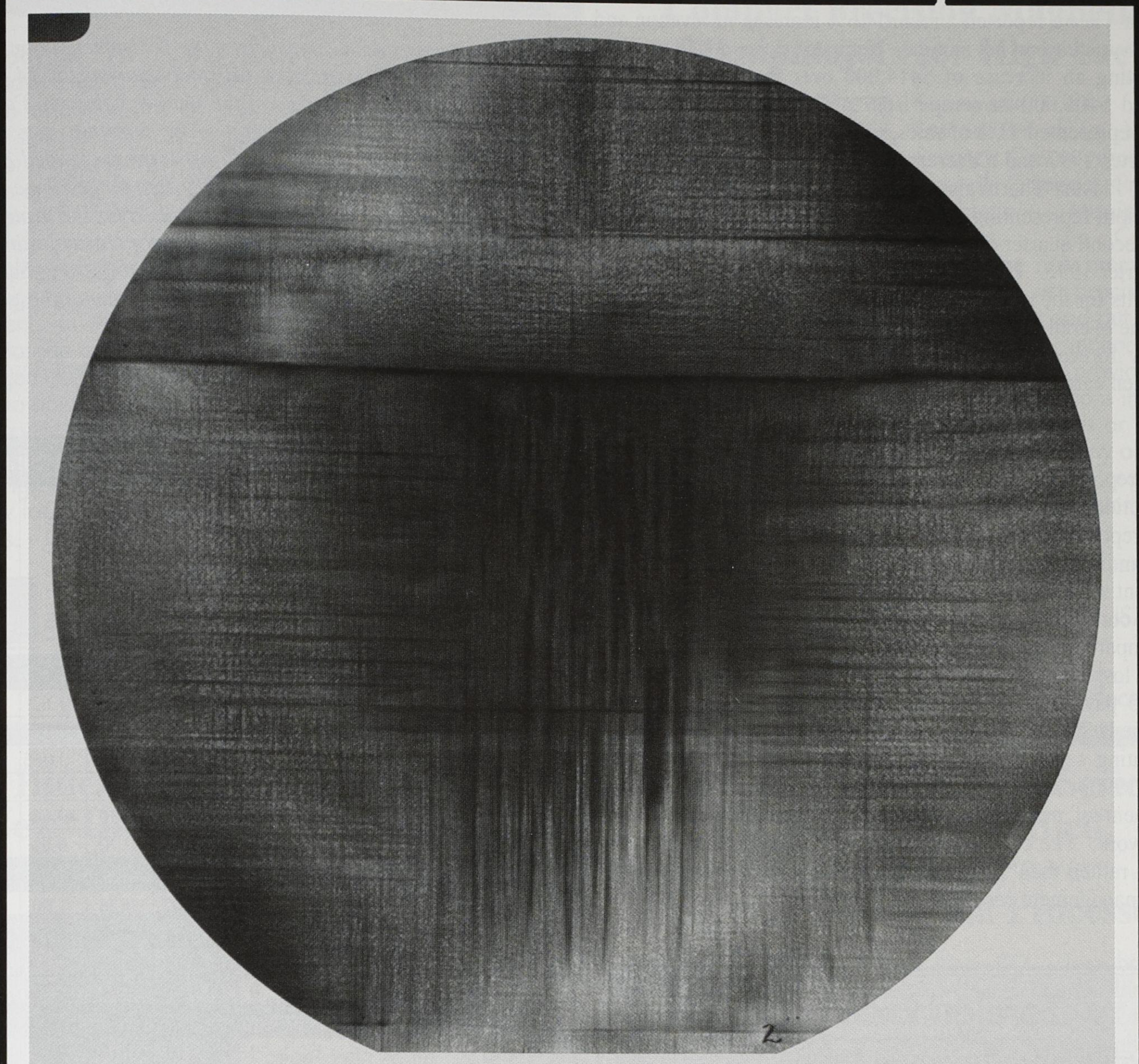
In other news, Emcore recently revealed that it has initiated efforts to develop high efficiency GaAs solar cells for use on communications satellites. The company already has other projects underway involving VCSELs (through their MODE subsidiary) and high-brightness LEDs (including a joint venture with Uniroyal Technology to produce blue and green LEDs).

Loss Narrows at Kopin

Kopin reported revenues of $6.7 million compared to $3.9 million for the same period last year, an increase of 72%. The net loss for the quarter narrowed to $174,909, compared to a net loss of $1.7 million for the comparable period last year, an improvement of 90%. Product revenues – derived from GaAs-based HBT epiwafers, as well as the company's CyberDisplay product line - increased 82% in the second quarter of 1998 to $5.7 million from $3.1 million in 1997. Epiwafer sales accounted for $ 4.6 million or 69% of total revenues. Sales of epiwafers in the June quarter were up 64% from the $2.8 million in epiwafer sales reported in the June quarter of 1997.

Dr. John C.C. Fan, Kopin's CEO, said "Sales of our gallium arsenide device wafers continue to be strong as a result of growing demand for high performance circuits in the wireless telecommunications industry, and the increase in circuit performance enabled by our device wafers. We are encouraged by the increasing acceptance of our device wafers in applications ranging from power amplifier circuits for cellular phones to gigabit circuits for fiberoptic transmission."

"Who needs X-rays?"



If you are serious about your wafer quality ...you do!

This 6" wafer was passed as good by two non-X-ray inspection systems designed to check for the presence of dislocations.

All of the horizontal and vertical lines shown in this Bede Scientific X-ray topograph are slip bands containing thousands of dislocations.

Bede scientific

Contact us for your local Bede sales and customer support organization:

Bede Scientific Instruments Ltd • Unit 13D • Bowburn South Industrial Estate • Bowburn • Durham • DH6 5AD • UK

Tel: +44 (0) 191 377 2476 • Fax: +44 (0) 191 377 9952 • Email: info@bede.co.uk • Website: www.bede.com

1978 BEDE SCIENTIFIC 1998 Twentieth Anniversary X-RAY TECHNOLOGY

Plasma-Therm Unbothered by Equipment Downturn – So Far

Plasma-Therm reported a record 46% increase in revenue and a 36% increase in net income. Net income was $1.58 million, representing an increase of $414,000 over the same period in 1997 and $106,000 in comparison to first quarter 1998. Net income represented 11% of sales, the same figure as for the second quarter 1997 and a decrease from 12% for the first quarter of 1998. Plasma-Therm also reported net sales for the quarter of $15 million, representing an increase of $4.7 million in comparison to second quarter of 1997 and $2.7 million in comparison to first quarter 1998. However, the company has issued a warning that results for the next two quarters may be more disappointing, due to the overall slowdown in the semiconductor industry. The company forecasts a 10 – 15% dip in revenues, and roughly break-even earnings.

Sales Down at Spire

Spire reported that its revenues decreased to $3.4 million, a reduction of $3 million or 46% compared to revenues of $6.4 million reported in the same period in 1997. Contract research, service and license revenues decreased 31% and manufacturing equipment sales decreased 69%.

The company reported a net loss for the quarter of $1.8 million, compared to net earnings of $702,000 for the year ago quarter. The loss was due to both the decreased revenue as well as a $547,000 payment to head-off possible legal proceedings. In March the U.S. Attorney's office notified the company that it was investigating seven research contracts awarded to Spire dating back to 1990. At issue was whether Spire failed to inform the government of pending or previously submitted proposals for similar work. The company says it chose to settle with the government rather than "continuing to incur the legal costs and expend management resources in litigating this matter".

Foreign Exchange

Sales and Revenue Up at Aixtron

Trading on Frankfurt's Neuer Market exchange, Aixtron reported revenues of DM 26 million / US$ 14.4 million for the quarter, and net income of DM 3.4 million / US$ 1.9 million. In contrast to the gloomy outlook that Emcore paints for the MOCVD reactor business (see page 48), Aixtron reports strong demand, with orders for 23 reactors received in the June quarter. For the first six months of 1998, orders were up a remarkable 109%. The company reports that Asia now accounts for around 40% of its business, and that they have not seen any negative consequences relating to the financial problems plaguing that region.

For the first six months of 1998, Aixtron reported revenues of $29.8 million and net income of $3.5 million – both 40% higher than the comparable period in 1997.

Analyst's Ratings

The following data summarizes the recommendations and forecasts issued by professional stock analysts for 14 of the Portfolio companies (some of the smaller companies do not attract professional coverage). The earnings per share (EPS) data represents quarterly net income, divided by the number of shares outstanding. EPS data for the June quarter are the actual results, whereas the data for the September quarter and the fiscal year(s) are consensus estimates. Analyst ratings usually include "Sell" and "Strong Sell" as the most negative recommendations, but none of these companies are currently rated lower than "Hold".

The source for all of this data is Zacks Investment Research, August 27, 1998.

	Analysts' Ratings			Earnings per Share			
	Strong Buy	Moderate Buy	Hold	June Qtr	Sept Qtr (Est.)	This FY (Est.)	Next FY (Est.)
1. GaAs IC Companies							
Alpha	4	0	0	0.37	0.38	1.62	1.59
Anadigics	1	5	2	0.02	0.03	0.09	0.72
Celeritek	0	0	1	-0.48	-0.21	-0.065	0.00
RFMD	3	1	0	0.10	0.06	0.35	0.64
TriQuint	2	2	8	0.21	0.30	0.66	1.46
Vitesse	8	4	0	0.18	0.20	0.66	0.83
2. Optoelectronics Companies							
Coherent	0	1	1	-0.07	0.26	1.00	1.26
Cree	0	0	1	0.14	0.14	0.72	NA
SDL	1	4	0	0.20	0.18	0.73	1.19
Uniphase	2	6	0	0.26	0.24	1.21	1.69
3. Materials & Equipment Companies							
AXT	2	1	0	0.10	0.10	0.42	0.59
ATMI	1	3	2	0.07	0.08	0.54	0.82
Emcore	0	0	2	-0.80	-0.27	-0.76	-0.01
Kopin	2	1	0	-0.01	0.03	0.05	0.72

FY Ends: Alpha – Mar; Anadigics – Dec; ATMI – Dec; AXT – Dec; Celeritek – Mar; Coherent – Sept.; Cree – Jun; Emcore – Sep; Kopin – Dec; RFMD – Mar; SDL – Dec; TriQuint – Dec; Uniphase – June; Vitesse – Sept.

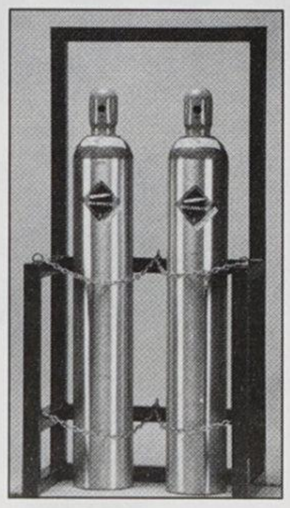
Change of Address

Please note our new address:

Compound Semiconductor Magazine
Franklin Publishing
163 Cabot Street, Beverly, MA 01915 USA
TEL [1] 978 927 9994, FAX [1] 978 927 9893
Email: info@compsem.com

New Products/New Literature

Cylinder Storage Systems



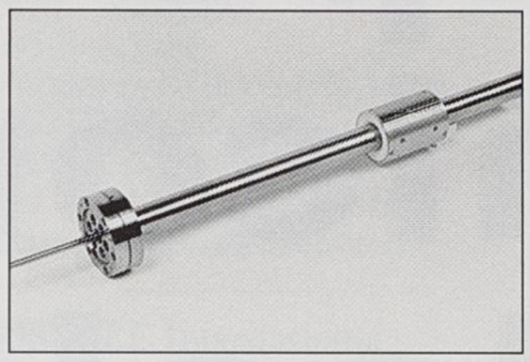
Plumsteadville, PA. The Equipment Technology Group at Scott Specialty Gases offers an extensive line of high-pressure cylinder storage and separation systems that organize gases by types in neat rows, minimize cylinder handling time and provide required separation of incompatible gases while in storage or in use.

Modular storage systems easily adapt to existing and new floor plans. All system components are removable and relocatable. Storage areas can also be expanded or reduced or rearranged quickly and efficiently at minimal cost and with little of no down time.

Scot cylinder separators and storage systems are constructed of 2" square tubular steel and are available with either single-chain or two-chain restraints. Two-chain models allow for the sage storage of both full size and C or CL cylinders.

For more information, contact:
Scott Specialty Gases
6141 Easton Road, PO Box 310
Plumsteadville, PA 18949 USA
TEL [1] 215 766 8861, FAX [1] 215 766 2476
or visit http://www.scottgas.com.

Compact Precision Magnetic Manipulators for High Vac



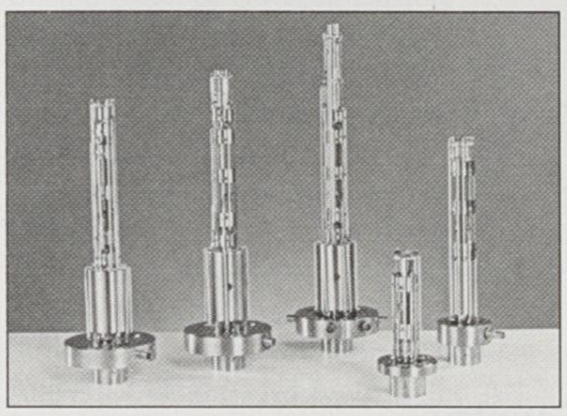
Sunnyvale, CA. The Surface/Interface Vacuum Products Group introduces a line of Compact Precision Magnetic Manipulators (PMMs). The Compact PMMS are new members of a family of precise and robust PMM products that move samples in and out of both high vacuum and UHV systems and control motion within those environments. Surface/Interface PMMs provide independent or simultaneous linear and rotary motions in a vacuum system and are used for actuating shutters or moving substrates as well as for sample introduction. They are ideal for sample introduction via loadlock in SEM, surface analysis, semiconductor and other thin film process systems.

For more information, contact:

SURFACE INTERFACE

Surface/Interface Inc.
260 Santa Ana Court
Sunnyvale, CA 94086 USA
TEL [1] 408 732 7111
FAX [1] 408 732 7191
Email: sii@surfaceinterface.com.

Hiden RC TGA Systems - New 'Hands Free' Automated Process Monitors



Warrington, England. RC RGA systems from Hiden Analytical are completely remote controlled, providing totally hands free operation with data storage, data interpretation and statistical control reports generated automatically from process step to process step. The RC system includes a programmable intelligent interface unit which is easily integrated to your specific process requirement. The RC RGA operates from prescribed recipes which are typically set up together with Hiden's application support group in consultation with the on site process engineers ensuring that the systems collect the important process data automatically.

For more information, contact:
Mark Buckley, Sales and Marketing Manager
Hiden Analytical Ltd., 420 Europa Boulevard
Warrington, WA5 5UN, England
TEL [44] 1925 445 25, FAX [44] 1925 416518
Email mbuckley@hiden.demon.co.uk, or visit
http://www.hiden.co.uk.

Brochures Describe PDX Series of Compact, CE-Certified, Mid-Frequency Power Supplies for Plasma Processes



Fort Collins, CO. Two brochures from Advanced Energy Industries, Inc. (AE) describe the PDX series of highly reliable, light-weight, compact, CE-certified, mid-frequency power supplies for plasma processes. The proven PDX series has an actual MTBF in excess of 1,000,000 hours in the field. These easy-to-integrate power supplies deliver precise power for such application as Plasma-enhanced chemical vapor deposition (PECVD; Etching; Dielectric sputtering; and Plasma polymer processes. The single-phase input PDX offers outputs of up to 1250 W with a frequency range of 325 to 450 kHz. The three-phase input PDX delivers up to 8000 W with a range of 235 to 460 kHz.

For more information contact:
Tom Grove, Advanced Energy Industries
1625 Sharp Point Drive, Fourt Collins, CO 80525 USA
TEL [1] 970 407 6313
FAX [1] 970 221 5583
or visit www.advanced-energy.com

Gorham/Intertech Announces A Must Attend Event For The Compound Semiconductor Industry

Compound Semiconductor Outlook '99

Trends • Forecasts • Manufacturing • Applications

March 1-3, 1999 • Biltmore Hotel and Suites • Santa Clara, California USA

CONFERENCE CO-CHAIRS:

Jennifer Palella, Strategic Marketing Manager, *Anadigics, Inc.*

William Kroll, Executive Vice President - Business Development, *Emcore Corp.*

Exclusive Media Sponsor:

COMPOUND SEMICONDUCTOR

Organized By:

GORHAM/INTERTECH CONSULTING
PO Box 250; 211 Mosher Road
Gorham, ME 04038 USA

To receive pre-registration information, please complete the following and fax to 207-892-2210. ***Space is limited!***

Name _____

Title _____

Company _____

Address _____

City _____ State _____ Zip _____ Country _____

Tel _____ Fax _____ Email _____

Questions? Call Chris Jones at 207-892-5445.

Please indicate your interest in the opportunities below by checking the box(es).

❑ Exhibiting at the Conference ❑ Being a Corporate Sponsor

❑ Hosting a Function at the Conference *(Please circle all those that you are interested in.)*

• Refreshment Break • Cocktail Reception • Continental Breakfast

Please be sure to provide the above information so that we may contact you with the details.

Learn more about us ... www.goradv.com *or* www.intertechusa.com

1998 U.S. Workshop on the Physics & Chemistry of II-VI Materials

The 1998 II-VI Workshop will be held October 20-22, 1998 in Charleston, SC. The purpose of this workshop is to bring together the universities and industrial and governmental communities that work with II-VI materials, including HgCdTe and other IR materials, II-VI semiconductor alloys used for X-ray and gamma-ray detectors, ZnSe-based II-VI photonic materials, and II-VI photorefractive materials.
Contact: Jay Morreale
Palisades Institute
201 Varick Street, suite 1006
New York, NY 10014 USA
TEL [1] 212 620 3371
FAX [1] 212 620 3379
Net or Web: jmorreal@newyork.palisades.org

1998 IEEE GaAs IC Symposium

The 1998 IEEE GaAs IC Symposium will be held Nov. 01 - Nov. 04, 1998 at the Westin Peachtree Plaza in Atlanta, GA.
Contact: Dr. William Stanchina
HRL Labs., RL61
Microelecteonics Lab
3011 Malibu Canyon Rd.
Malibu, CA 90265
TEL [1] 310 317-5089
FAX [1] 310 317-5450

194rd Meeting of the Electrochemical Society

The 194rd ECS Meeting will be held November 1-6, 1998 at the Sheraton Boston Hotel & Tower in Boston, Massachusetts. Symposia include: I1 - III-V Nitride Materials And Processes; J1 - Fifth International Symposium On Quantum Confinement: Nanostructures; N1 - Compound Semiconductor Power Transistors; N3 - Sixth International Symposium On Long Wavelength Infrared Detectors And Arrays: Physics And Applications; N4-State-of-the-Art Program On Compound Semiconductors (SOTAPOCS XXVIII); P1- Photovoltaics For The 21st Century.
Contact: The Electrochemical Society
10 South Main Street
Pennington, NJ 08534-2896 USA
TEL [1] 609 737 1902
FAX [1] 609 737 2743
NET or WEB:
ecs@electrochem.org
or http://www.electrochem.org

45th National AVS Symposium

The 1998 AVS National Symposium will be held November 2-6, 1998 at the Baltimore Convention Center in Baltimore, MD. AVS Technical Divisions include: applied surface science; nanometer-scale science and technology; surface science; vacuum metallurgy; electronic materials and processing; plasma science and technology; thin film; and vacuum technology.
Contact: Marion Churchill
AVS
120 Wall Street
New York, NY 10005 USA
TEL [1] 212 248 0200
FAX [1] 212 248 0245
Net: marion@vacuum.org
Web: http://www.vacuum.org

6th Int'l Workshop on High Performance Electron Devices for Microwave and Optoelectronic Applications

EDMO '98 will be held November 23-24, 1998 in Manchester, UK. Its purpose is to act as a forum for microwave and optoelectronic device designers, fabricators, modellers and general users to discuss the synergy between system needs and advanced electronic devices and circuits. Contributions concerned with the application of electron devices for microwave and optoelectronics are welcomed.
Contact: Dr. M. Missous
UMIST, EE& E Dept.
PO Box 88
Manchester M60 1QD UK
TEL [44] 161 200 4797
FAX [44] 161 200 4770
Net or Web: missous@fs4.ee.umist.ac.uk
or http:\\www.ee.umist.ac.uk\new\edmo98.html

1998 Fall MRS Meeting

The 1998 Fall MRS Meeting will be held November 30 - December 4, 1998 in Boston, MA. Symposia include: B) Growth Instabilities and Decomposition During Heteroepitaxy; D) Integration of Dissimilar Materials in Micro- and Optoelectronics; G) GaN and Related Alloys; H) IR Semiconductor Materials and Devices; and I) III-V and SiGe Processing Challenges for Commercial Applications.
Contact: Materials Research Society
506 Keystone Drive
Warrendale, PA 15086-7573 USA
TEL [1] 724 779-3003
FAX [1] 724 779-8313
Net or Web: webmaster@mrs.org or http://www.mrs.org

Lasers and Electro-Optics Society Annual Meeting

LEOS' 98 will be held December 1-4, 1998 at Walt Disney World, Orlando, Florida. Organizers are expecting more than 700 attendees, 200 invited talks, and 270 contributed papers, on topics including Semiconductor Lasers, Optoelectronic Materials & Processing, Optical Communications, and Electro-Optical Sensors & Systems. There will also be a Special Symposium on Oxidation Technologies of III-V Semiconductors.
Contact: IEEE/LEOS
445 Hoes Lane
Piscataway, NJ 08855-1331 USA
TEL [1] 732 562 3989
FAX [1] 732 562 8434
Net or Web: m.estrin@ieee.org
http://www.ieee.org/leos/meet.htm

1998 IEEE International Electron Devices Meeting

The 1998 IEDM will be held December 6-9, 1998 in San Francisco, CA.
Contact: Ms. Phyllis Mahoney
Widerkehr & Associates
101 Lakeforest Blvd., Suite 270
Gaithersburg, MD 20877
TEL [1] 301 527-0900
FAX [1] 301 527-0994
Net or Web: pwmahoney@aol.com

Conf. on Optoelectronic and Microelectronic Materials and Devices

COMMAD '98 will be held December 14-16, 1998 in Perth, Australia.
Contact: Lorenzo Faraone
Univ. of Western Australia
EEE Department
Nedlands, WA 6907 Australia
TEL [61] 8 9380 3104
FAX [61] 8 9380 1095
Net or Web: faraone@ee.uwa.edu.au
http://www.ee.uwa.edu.au/~COMMAD98

Photonics West

The 1999 Photonics West Conference and Exhibition will be held January 23-29, 1999 in San Jose, CA. The technical meeting will international symposia on High-Power Lasers and Applications, Integrated Optoelectronic Devices and Applications , and Electronic Imaging: Science and Technology.
Contact: SPIE
PO Box 10
Bellingham, WA 98227 USA
TEL [1] 360 676 3290
FAX [1] 360 647 1445
Net or Web: spie@spie.org or
http://www.spie.org

1999 Int'l Solid-State Circuits Conference

ISSCC '99 will be held February 15-17, 1999 in San Francisco, CA. The theme for this year is High-Bandwidth Systems.
Contact: ISSCC '99
Diane Suiters
Courtesy Associates
2000 L Street N.W. Suite #710
Washington, DC 20036 USA
TEL [1] 202 973 8667
FAX [1] 202 331 0111
Net: isscc@courtesyassoc.com

1999 IEEE MTT-S International Topical Symposium on Technologies for Wireless Applications

This conference will be held February 21-24, 1999 in Vancouver B.C., Canada. It is intended to highlight the application of RF, microwave and mm-wave technologies to all aspects of wireless communications.
Contact: Mr Bernard D. Geller
c/o LRW associates
468 Walden Trail
Waxhaw, NC 28173
TEL: (704) 841 1915
FAX: (704) 845 3078

New Entries

1999 IEEE MTT-S International Topical Symposium on Technologies for Wireless Applications
February 21-24, 1999
in Vancouver B.C., Canada

Compound Semiconductor Outlook '99
March 1-3, 1999
in Santa Clara, CA

1999 Spring MRS Meeting
April 5-9, 1999
in San Francisco, CA

GaAs MANTECH '99
April 19-22, 1999
in Vancouver
British Columbia, Canada

1999 Electronic Materials Conference
June 30 - July 2, 1999
Santa Barbara, CA

1999 Integrated Photonics Research Topical Meeting
July 19-21, 1999
in Santa Barbara, CA

7th Int'l Conf. on CBE
July 27-30, 1999
in Tsukuba, Japan

OFC 1999

The 1999 International Conference on Integrated Optics and Optical Fiber Communication will be held February 21 - 26, 1999 in San Diego, CA.

Contact: Ms. Lisa Myers
OSA Conference Services
2010 Massachusetts Ave., NW
Washington, DC 20036-1023
TEL [1] 202 416-1980
FAX [1] 202 416-6100
Net or Web: ofc.info@osa.org
http://www.osa.org

Compound Semiconductor Outlook '99

Compound Semiconductor Outlook '99 will be held March 1-3, 1999 in Santa Clara, CA. This conference, organized by Gorham/Intertech Consulting, will cover trends and forecasts for the compound semiconductor industry, as well as addressing manufacturing and applications-related issues.

Contact: Chris Jones
Gorham/Intertech Consulting
PO Box 205
211 Mosher Road
Gorham, ME 04038 USA
TEL [1] 207 892 5445
FAX [1] 207 892 2210
Net or Web: www.goradv.com or www.intertechusa.com

11th Int'l Conf. on the Microscopy of Semiconducting Materials

The 11th Int'l Conf. on the Microscopy of Semiconducting Materials will be held March 22-25, 1999 at the University of Oxford, UK. The conference will focus on the latest developments in the study of the structural and electronic properties of semiconducting materials by the application of transmission and scanning electron microscopy. The most recent advances in the use of other characterization techniques such as X-ray imaging and diffraction, scanning probe microscopy and atom probe microanalysis will also be featured. The materials of interest cover the complete range of elemental and compound semiconductors, as well as the dielectric materials and metallisation used in integrated devices.

Contact: Richard Beanland
GEC-Marconi Materials Technology
Caswell, Towcester,
Northants NN12 8EQ UK
Tel. [44] 1327 356363
Fax. [44] 1327 356389
Net or Web:
richard.beanland@gecm.com
http://www.iop.org

1999 Spring MRS Meeting

MRS is being held April 5-9, 1999 in San Francisco, California. Symposia for this year's meeting include: Physics and Technology of Dopant-Defect Interactions; Advanced Semiconductor Wafer Engineering; In-Situ Process Diagnostic and Modeling; Epitaxial Growth Principles and Applications; Semiconductor Quantum Dots; Wide-Bandgap Semiconductors for High-Power, High-Frequency, and High-Temperature Applications; and Compound Semiconductor Surface Passivation and Novel Device Processing.

Abstract Deadline: October 19, 1998
Contact: MRS
506 Keystone Drive
Warrendale, Pennsylvania
PA 15086-7573
TEL: [1] 724 779 3003
FAX: [1] 724 779 8313
Net or Web: info@ mrs.org
http://www.mrs.org

Int'l Conf. on GaAs Manufacturing Technology.

MANTECH '99 will be held April 19-22, 1999 in Vancouver, British Columbia, Canada. Papers that address solutions to real and potential manufacturing problems are sought in areas including: Manufacturing; Processing; Test & Reliability; Device Technologies; Materials; Packaging; Optical Devices; and Future Business Outlook. There will also be an "Ugly Picture Contest" - designed as an opportunity to present examples of process problems and solutions without submitting a full paper.

Abstract Deadline: Oct. 30, 1998.
Contact: Ding Day
NDI
1230 Bordeaux Drive
Sunnyvlae, CA 94089-1202
TEL [1] 408 734 9888 x 118
FAX [1] 408 734 9889
Net or Web:
dday@network-device.com or
http://www.GaAsManTech.org

9th Biennial Workshop on Organometallic Vapor Phase Epitaxy

The 1999 OMVPE Workshop will be held May 16 - 20, 1999 in Ponte Verda Beach, FL. Scientists from industry, academia and government labs are invited to participate by presenting OMVPE related papers. Technical sessions will cover the spectrum from fundamental to applied topics.

Abstract Deadline: October 30, 1998
Contact: Marlene Karl
TMS
420 Commonwealth Drive
Warrendale, PA 15086 USA
TEL [1] 412 776 9000 x234
FAX [1] 412 776 3770
Net or Web: karl@tms.org
http://www.tms.org

11th Int'l Conf. On InP & Related Materials

IPRM '99 will be held May 16 – 20, 1999 in Davos, Switzerland. The scope of the conference will include optoelectronics, electron devices, processing, epitaxy, bulk crystal growth and characterization and new materials and nanostructures.

Abstract Deadline: December 5, 1998
Contact: Hans Melchior
Swiss Federal Inst. Of Tech.
Inst. For Quantum Electronics
ETH-Hoenggerberg, HPT
CH-8093 Zurich Switzerland
TEL [41] 1 633 2101
FAX [41] 633 1109
Net or Web:
h.melchior@iqe.phs.ethz.ch
http://www.iqe.etz.ch/iprm99

1999 Electronic Materials Conference

The 41st EMC will be held at the University of California, Santa Barbara on June 30-July 2. This conference provides a forum of topics of current interest and significance in the areas of preparation and characterization of electronic materials. Individuals actively engaged or interested in electronic materials research and development are encouraged to attend this meeting , and papers in this general subject area are solicited.

Abstract Deadline: TBA
Contact: TMS
429 Commonweatlth Drive
Warrendale, PA 15086 USA
TEL: [1] 724 776 9000
FAX [1] 724 776 3770
Net or Web: csc@tms.org
http://www.tms.org

3rd Int'l Conf. on Nitride Semiconductors

ICNS-3 will be held July 5-9, 1999 in Montpellier, France. The objective of this conference is to provide a forum for active nitride researchers to exchange their knowledge by presenting their latest results and by carrying out in-depth technical discussions. This conference follows the tradition of the previous ones and will focus on all aspects of nitride semiconductor systems such as AlInGaN, GaNAsP, and other materials containing nitrogen as one of the major constituents. Growth aspects, characterization and devices applications will be addressed for either 3D, 2D, 1D and 0D systems.

Abstract Deadline: TBA
Contact: Pierre Lefebvre
Universitè de Montpellier
Case courier 074
34095 Montpellier Cedex 5 France
TEL: [33] 4 67 14 37 60
FAX: [33] 4 67 14 37 56
Net or Web:
icns3@ges.univ-montp2.fr
http://bilbot.ges.univ-montp2.fr/icns3.htm

1999 Integrated Photonics Research Topical Meeting

IPR '99 will be held July 19-21, 1999 in Santa Barbara, CA. IPR is a topical meeting specializing in the science and technology of photonics. Topics to be considered include: Active and Compound Semiconductor Devices; Dielectric Waveguides and Waveguides Devices; and Modeling, Numerical Simulation and Theory.

Abstract Deadline: March 17, 1999
Contact: OSA
2010 Massachusetts Ave
Washington, DC 20036-1023
TEL: [1] 202 416 1985
FAX: [1] 202 416 6100
Net or Web: info@osa.org
http://www.osa.org

7th International Conference on Chemical Beam Epitaxy and Related Growth Techniques

ICCBE-7 will be held July 27-30, 1999 in Tsukuba, Japan. The scope of this conference covers the entire spectrum of CBE, MOMBE, and GS MBE as well as MBE and MOVPE and other related growth technologies. Growth mechanisms and epilayer properties are the main focal points, but relevant characterization and growth techniques, physical properties and the relation between materials and device properties are equally addressed.

Abstract Deadline: Feb 15,1999
Contact: Dr. Makoto Konagai
Tokyo Institute of Technology
2-12-1, O-okayama,
Meguro-ku
Tokyo 152-8552 Japan
TEL: [81] 3 5734 2554
FAX [81] 3 5734 2897
Net or Web:
konagai@pe.titech.ac.jp or
http://solid.pe.titech.ac.jp/cbe-7

If you would like your conference to be included in future issues, send the appropriate information by E mail to calendar@compsem.com, or by FAX to [1] 978 927 9893, attention "Calendar" Contributions must be received by October 2 to appear in our next issue.

PATENTS

Patents related to compound semiconductors issued from June 30 - July 28, 1998
Headlines contain Patent # / Date Issued / Assignee.
Sources:
"05..."=U.S. Patent Office; "EP..." = European Patent Office;
"WO..." = World Intellectual Property Organization

Now includes International Patents

Microelectronics

05774017 / 1998 06 30 / Anadigics
Adar, Aharon
Multiple-Band Amplifier. A GaAs MMIC dual-band amplifier for wireless communications is disclosed for operation at either the 800 MHz or the 1900 MHz band and it provides desired gain and input and output impedance. Switching impedance networks are used at the input and output of the amplifier to provide matching input impedance and desired output impedance for operation in the two bands. Switching impedance networks are also used between any successive stages of the amplifier to provide proper interstage impedance. The dual band amplifier includes a bias control circuit which biases the amplifier to operate in A, B, AB or C mode. The amplifier can be used for the AMPS 800 or the GSM 900 operation or any other cellular operation such as the PCS 1900 and the it can be switched between the two operations by simply applying a proper control signal to the amplifier.

05773842 / 1998 06 30 / ETRI
Kim, G-O & Suh, H-H
Resonant-Tunnelling Hot Electron Transistor. A resonant-tunnelling hot transistor includes buffer layers undoped with impurities on either side of a collector or an emitter potential barrier having a quantum well structure. When a voltage is applied to the transistor, most of the potential drop occurs at the first buffer layer and the second buffer layer due to their thickness. This enables the inclination of the energy band of the collector barrier layer or the emitter barrier layer to be diminished, whereby the energy of the confined energy state E.sub.QW of the quantum well and the energy change of the confined state is diminished. In addition, the NDR region of I-V characteristics curve can be moved by controlling the biasing voltage, and the wave form of the curve maintains its original form.

05776805 / 1998 07 07 / LG Semicon
Kim, Chang Tae
Method for Manufacturing MESFET. Method for manufacturing a [MESFET]...in which a gate area contacting a semiconductor surface is diminished and a gate cross area is increased, to improve frequency characteristics of a device is disclosed.

05786610 / 1998 07 28 / Mitsubishi Denki
Nakanishi; Mamiko
Field Effect Transistor. The present invention relates to a...[FET] and, more particularly, to a dual-gate FET including two gate electrodes.

EP0851510 / 1998 07 01 / Murata
Inai, Makoto et al
MESFET With Recessed Gate.
Abstract not available.

05780879 / 1998 07 14 / NEC
Unozawa, Kosei
Field-Effect Transistor and Method of Manufacturing the Same. The present invention relates to a [FET]...having a channel layer consisting of InGaAs and, more particularly, to an FET which operates at a high frequency and a method of manufacturing the same.

05773897 / 1998 06 30 / Raytheon
Wen, C.P. & Wong, W. S.
Flip Chip Monolithic Microwave Integrated Circuit with Mushroom-Shaped, Solder-Capped, Plated Metal Bumps. Mushroom-shaped, solder-capped, small-diameter (approximately 50 to 75 microns or less), metal bumps are used in the flip chip monolithic microwave integrated circuits (MMICs) attachment process to provide devices having improved solder volume uniformity. The operation of the MMIC device is extended to millimeter-wave frequencies. The self-alignment property of the solder reflow flip chip attachment process is retained, and enhanced by the solder cap that extends beyond the periphery of the metal bump. Solder flux instead of solder paste patterns are printed on the assembly substrate to facilitate flip chip attachment. The metal bumps comprise electroplated silver pillars having a first diameter capped with electroplated solder having a second diameter, where the second diameter is larger than the first diameter, and are formed using a multi-layer negative photoresist, multiple exposure processing sequence.

EP0854568 / 1998 07 22 / Sony
Maekawa, I.; Ohgihara, T.; Tanaka, K.
Monolithic Microwave Integrated Circuit. The present invention relates to a microwave semiconductor integrated circuit for generating a bias voltage applied to an active circuit element, comprising: a FET whose source is grounded and whose gate and drain are connected commonly; a negative element for applying a power supply voltage to the gate-drain common connection point of said FET, and a high impedance element for supplying a potential at the gate-drain common connection point of said FET to said active circuit element as a bias voltage thereof.

05773873 / 1998 06 30 / Toshiba
Kuriyama, Yasuhiko
Semiconductor Device Having Multi-Emitter Structure. A semiconductor device having a differential amplifier circuit portion made of two multi-emitter bipolar transistors (BPT). Each multi-emitter BPT has the same number of a plurality of transistor elements each having an independent emitter electrode. Each transistor element of one multi-emitter BPT and a corresponding transistor element of the other multi-emitter BPT form a transistor element pair, with the emitter electrodes thereof being electrically connected. Each transistor element pair is electrically independent from other transistor element pairs, and the emitter electrodes of each transistor element pair are connected to an emitter current source independently from other emitter current sources.

Laser Diodes

05773318 / 1998 06 30 / Lucent
Chand, N. & Hamm, R.
In-situ Technique for Cleaving Crystals. This invention relates to methods for cleaving crystals in high vacuum and to deposit in-situ passivating layers on the cleaved crystal faces. It applies to a variety of technologies but is especially suitable for coating laser facets.

05787104 / 1998 07 28 / Matsushita Electric
Kamiyama; S. et al
Semiconductor Light Emitting Element and Method for Fabricating the Same. The semiconductor laser of this invention includes an active layer formed in a c-axis direction, wherein the active layer is made of a hexagonal-system compound semiconductor, and anisotropic strain is generated in a c plane of the active layer.

05781577 / 1998 07 14 / Mitsubishi Denki
Nagai, Y. & Shima,A.
Semiconductor Laser. The present invention relates to semiconductor lasers and, more particularly, to a semiconductor laser

Laser Diodes

having a window structure at facets and producing high-power light output.

05786234 / 1998 07 28 / Mitsubishi Denki
Nagai, Y. & Tada, H.

Method of Fabricating Semiconductor Laser. The present invention relates to a semiconductor laser including a ridge structure and a method of fabricating the semiconductor laser.

05776792 / 1998 07 07 / Matsushita Electronics
Naito, H. & Kume, M.

Method for Forming Semiconductor Laser Device. The present invention relates to a high-yield semiconductor laser device of real refractive index-guided structure operating at low current value, which is highly suitable for a light source for use in optical information processing and the like, and a method of the production thereof.

EP0853358 / 1998 07 15 / NEC
Dei, Yoshihiro

Semiconductor Laser Module Having Improved Metal Substrate on Peltier Element. In a semiconductor laser module including a laser diode chip, a metal substrate for mounting the laser diode chip thereon, and a Peltier element having a panel coupled by metal solder to the metal substrate, the metal substrate is formed by a first metal member having a larger thermal conductivity than about 290 W/m deg and a second metal member having a thermal expansion coefficient close to that of the panel.

05787105 / 1998 07 28 / Nikon
Okamoto, K. et al

Integrated Semiconductor Laser Apparatus. An integrated semiconductor laser apparatus is constructed in such an arrangement that a core layer is located in the proximity of an active layer so as to be in an evanescent-field area of light propagating in the active layer and that a carrier concentration of a second cladding layer is higher than that of a first cladding layer. Thus, most evanescent waves of light propagating in the core layer propagate in the first cladding layer of the low carrier concentration. Since the rate of evanescent waves absorbed by carriers is very low, the integrated semiconductor laser apparatus can propagate the light with small losses.

EP0852417 / 1998 07 08 / Sumitomo Electric
Ikoma, Nobuyuki

Semiconductor Laser and Method of Making the Same. The present invention relates to a semiconductor laser equipped with a novel window structure, thereby realizing higher output, and a method of making the same.

005780320 / 1998 07 14 / Toshiba
Kinoshita, Junichi

Method of Manufacturing a Semiconductor Laser Including Two Sets of Dicing Grooves. The present invention has been developed...to improve in productivity of a semiconductor laser by forming electrodes and notches in a wafer process, cleave a wafer by a simple method to mirror-finish both end faces of an active layer (resonant faces of the semiconductor laser), and maintain an ohmic contact of the electrodes without degrading the characteristics of the semiconductor laser.

05776794 / 1998 07 07 / Univ. of OK
McCann, Patrick J.

Method for Fabricating Semiconductor Laser. A semiconductor laser device, and method for making such, having higher operating temperatures than previously available. A semiconductor epitaxial layer is bonding to a cleaving assembly which allows the epitaxial layer to be manipulated without use of traditional substrate forms. The resulting semiconductor laser is bonded to a metal portion which serves as a heat sink for dissipating heat from the active lasing region. The resulting semiconductor lasers can be cooled by thermoelectric cooling modules, thus eliminating the necessity of using more bulky cryogenic systems.

VCSELs

05773319 / 1998 06 30 / ETRI
Chu, H-Y; Yoo, B-S; & Park; H-H

Method for Producing a Hydrogenated Vertical-Cavity Surface-Emitting Laser. The present invention relates to a method for fabricating a vertical-cavity surface-emitting laser and, more particularly to a method for producing a vertical-cavity surface-emitting laser comprising hydrogenating of some portions of a top mirror layer and active layer in an atmosphere of hydrogen plasma.

05774616 / 1998 06 30 / Matsushita Electrical
Matsuda, Kenichi

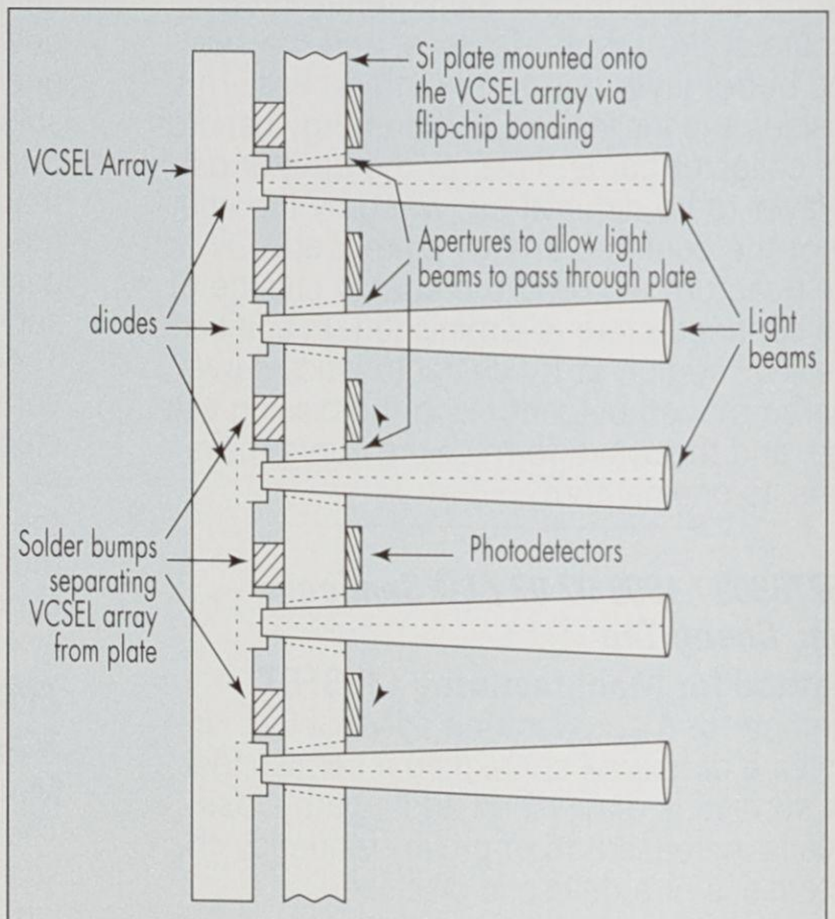
Semiconductor Laser Module and Method for Fabricating the Same. The present invention relates to a semiconductor laser module including a vertical cavity surface emitting laser which is optically coupled to an optical fiber tape, and a method for fabricating the same.

WO9831080 / 1998 07 16 / W.L. Gore
Jayaraman, V. & Welch, D.

VCSEL-Based Multi-Wavelength Transmitter and Receiver Modules for Serial and Parallel Optical Links. An optoelectronic module includes one or more VCSEL transmitters and/or photodetectors coincidentally aligned along a common central longitudinal axis. Differing wavelengths of light can be received and transmitted by the optoelectronic module optically coupled to a single optical fiber or in a free_space link. The optoelectronic module is able to receive two wavelengths and transmit one wavelength, or can transmit two wavelengths in the optical link.

05784396 / 1998 07 21 / Xerox
Guerin, Jean-Michel

VCSEL Integral Feedback Assembly Two-Etch Structure. There is disclosed a [VCSEL] assembly with an integral set of detectors for the purpose of individually monitoring and adjusting the output power of each laser diode.



U.S. Patent 0578496 - VCSEL assembly with integral set of detectors (Xerox)

Nitrides

EP0851542 / 1998 07 01 / NEC
Kimura, A. & Nido, M.

Gallium Nitride Based Compound Semiconductor Laser and Method of Forming the Same. A method of forming a current block layer structure comprising the steps of providing dielectric stripe masks defining at least a stripe- shaped opening on a surface of a compound semiconductor region having a hexagonal crystal structure, and selectively growing at least a current block layer of a compound semiconductor having the hexagonal crystal structure on the surface of the compound semiconductor region by use of the dielectric stripe masks.

05786603 / 1998 07 28 / Toshiba
Rennie, J. et al

Multilayer Structured Semiconductor Devices. At an n–n hetero-interface in a ZnSe-based or GaN-based multilayered semiconductor laser and light-emitting diode, an excessive voltage drop causing the operating voltage to increased is reduced, thereby lengthening the service life of the device. A single or plurality of n-type intermediate layers are provided in the n–n hetero-interface region where the excessive voltage drop develops. The excessive voltage drop developing at the n–n hetero-interface is decreased by setting the energy value at the edge of the conduction band of each intermediate layer to a mid-value between the energy values at the edges of the conduction bands of the n-type compound semiconductors adjoining both sides of the intermediate layer.

05773369 / 1998 06 30 / Univ. of Calif.
Hu, E. & Minsky, M.

Photoelectrochemical Wet Etching of Group III Nitrides. A method of processing semiconductor films and layers, especially Group III Nitride films, has been achieved, using laser-enhanced, room-temperature wet etching with dilute etchants. Etch rates of a few hundred ang/min up to a few thousand .and/min have been achieved for unintentionally doped n-type Group III Nitride films grown by MOCVD on a sapphire substrate. The etching is thought to take place photoelectrochemically with holes and electrons generated by incident illumination from 4.5 mW of HeCd laser power enhancing the oxidation and reduction reactions in an electrochemical cell.

05780355 / 1998 07 14 / Univ. of Calif.
Mishra, U.; DenBaars, S.; Keller, S.

UV Assisted Gallium Nitride Growth. A method for producing Group III nitride films with high indium content and superior optical quality…[a MOCVD] process in combination with a photochemical process reduces the growth temperature required to produce optical quality Group III nitride films.

Miscellaneous

05782979 / 1998 07 21 / Mitsubishi Denki
Kaneno, N. et al

Substrate Holder for MOCVD. The present invention relates to a substrate holder for MOCVD (Metal Organic Chemical Vapor Deposition) and, more particularly, to a substrate holder that provides a uniform crystal growth of compound semiconductor. The invention also relates to an MOCVD apparatus including a high-speed rotating susceptor supporting a plurality of wafers and a mechanism for rotating the wafers on the susceptor.

05780322 / 1998 07 14 / Sony
Tamamura,K.; Tsukamoto, H.; Ikeda,M.

Method for Growing a II-VI Compound Semiconductor Layer Containing Cadmium and Method For Fabricating a Semiconductor Laser. A method for growing a II-VI compound semiconductor layer containing Cd, such as Zn1-xCdxSe, by a molecular beam epitaxy method is disclosed. During the growth, the ratio of the intensity of molecular beams of a group VI element to the intensity of molecular beams of a group II element in terms of intensities of molecular beams actually irradiated onto a substrate, namely, the substantial VI/II ratio, is controlled preferably in the range from 0.7 to 1.3, to increase the Cd incorporating efficiency into the grown layer sufficiently high.

Other Optoelectronics

05780880 / 1998 07 14 / Research Triangle Institute
Enquist, Paul M.

High Injection Bipolar Transistor. An optoelectronic semiconductor device using stimulated emission and absorption to achieve the functions of detection, modulation, generation and/or amplification of light. In one embodiment, the device includes a waveguide heterojunction bipolar transistor (HBT) biased in the active mode where the minority carrier concentration in the base is designed with bandgap engineering to optimize optical gain in this region. This HBT configuration allows optical modulation at considerably higher frequencies and/or with improved efficiency compared to the prior art, and is particularly suited to the fabrication of direct or external modulated wideband fiber optic links.

05780867 / 1998 07 14 / Sandia
Fritz, I.J.; Klem, J. F.; Hafich, M.J.

Broadband Light-Emitting Diode. [A broadband LED]…comprises a plurality of III-V compound semiconductor layers grown on a semiconductor substrate, with the semiconductor layers including a pair of cladding layers sandwiched about a strained-quantum-well active region having a plurality of different energy bandgaps for generating light in a wavelength range of about 1.3-2 micron.

WO9827449 / 1998 06 25 / Siemens
Stegmüller, Bernhard

Optoelectronic Module. In an optoelectronic module, the optoelectronic active components are produced as a sequence of epitaxially grown layers on the top surface of a substrate. The waveguide layers located in these components are connected to one another, and/or to outer connection surfaces, by passive waveguides made of a material which differs from all the semiconductor materials of which the active components are made.

05777390 / 1998 07 07 / Univ. of Delaware
Berger, P. & Gao, W.

Transparent and Opaque Metal-Semiconductor-Metal Photodetectors. An improved metal-semiconductor-metal (MSM) photodiode, specifically a new high responsivity AND high bandwidth photodetector, resulting in a high gain-bandwidth product is disclosed. The disclosed device is an MSM photodiode in which the anode and cathode are made of different materials of differing opacity and possibly including different electrode dimensions as well.

The full text of any of these patents can be obtained by e-mail from MicroPatent for $2.00 each. See http://www.micropat.com and select the "PatentWEB™ option.

EMPLOYMENT

For rates and submission instructions for employment ads, contact the editor at
TEL [1] 978 927 9994; FAX [1] 978 927 9893 or e-mail: editor@compsem.com

SIEMENS

Siemens Semiconductors needs people like you. Experts full of ideas who enjoy their profession and help to shape their future and ours in the Opto Semiconductors Product Division. People who are purposeful, reliable and responsible, and want to contribute.

Opto Semiconductors

Shaping the future by innovation

You attach great value to productivity. The customer is the focal point of your work. And that in a division of Siemens AG where you have freedom to implement your ideas and can develop your career in line with your inclinations and abilities. In a climate that facilitates peak achievements. In a young and highly successful team.

As one of the leading manufacturers of optoelectronic components, we have set significant standards fora young and dynamic market and are a global player with fascinating prospects.

We want to expand our market position, and are therefore looking for new

Development Engineers

responsible for processing LEDs and lasers based on III-V semiconductors. Our products operate in the spectral range from IR, visible to UV. Positions are available in epitaxy (MOVPE, LPE), chip design and production processes as well as in analyses of materials and devices including simulation.

What we have to offer:
Demanding and challenging work in a future-orientated environment. We also offer freedom to develop your own initiative, excellent career advancement opportunities in Germany and abroad, and a comprehensive further training.

Curious? Then send us your application to convince us that you belong in our team!

Siemens AG
Bereich Halbleiter
Personalabteilung
HL R PA OS
Wernerwerkstr. 2
D-93049 Regensburg
e-mail: petra.kost@hl.siemens.de

www.siemens.de/
semiconductor –
the website with
prospects

COMPOUND SEMICONDUCTOR

Looking for a Career Change?

Compound Semiconductor is accepting applications for a newly created assistant editor position. Applicants should have excellent writing skills, knowledge of compound semiconductor technology, and an interest in both scientific and commercial developments.

Duties will include writing feature articles, editing news items, and reporting on developments in industry and research, as well as assisting in the preparation and layout of the final product.

If you enjoy analysis and writing, this is a fun and rewarding job, with opportunities for advancement.

The job will be located in our offices on Boston's North Shore. Applicants should be located in or willing to relocate to the Boston area.

Interested parties should contact:
Marie Meyer
Editor
Compound Semiconductor Magazine
163 Cabot Street
Beverly, MA 01915 USA
TEL [1] 978 927 9994
FAX [1] 978 927 9893
Email: mmeyer@compsem.com





Thinking Blue?

Think Blue Ammonia.™

If you're thinking blue lasers and blue LEDs, you should be thinking Blue Ammonia from Solkatronic Chemicals. With a minimum purity of 99.99994%, it's the purest on the market today. We've developed this higher purity ammonia for use in ultra sensitive Gallium Nitride (GaN) processes for the production of blue lasers and blue LEDs.

Blue Ammonia is packaged in Solkatronic's microPure® cylinders to ensure manufacture-to-delivery purity.
A Certificate of Analysis, with a complete gas and liquid phase metals analysis, accompanies each shipment.
If you're thinking blue lasers and blue LEDs, think Blue Ammonia from Solkatronic Chemicals.

Blue Ammonia Specifications

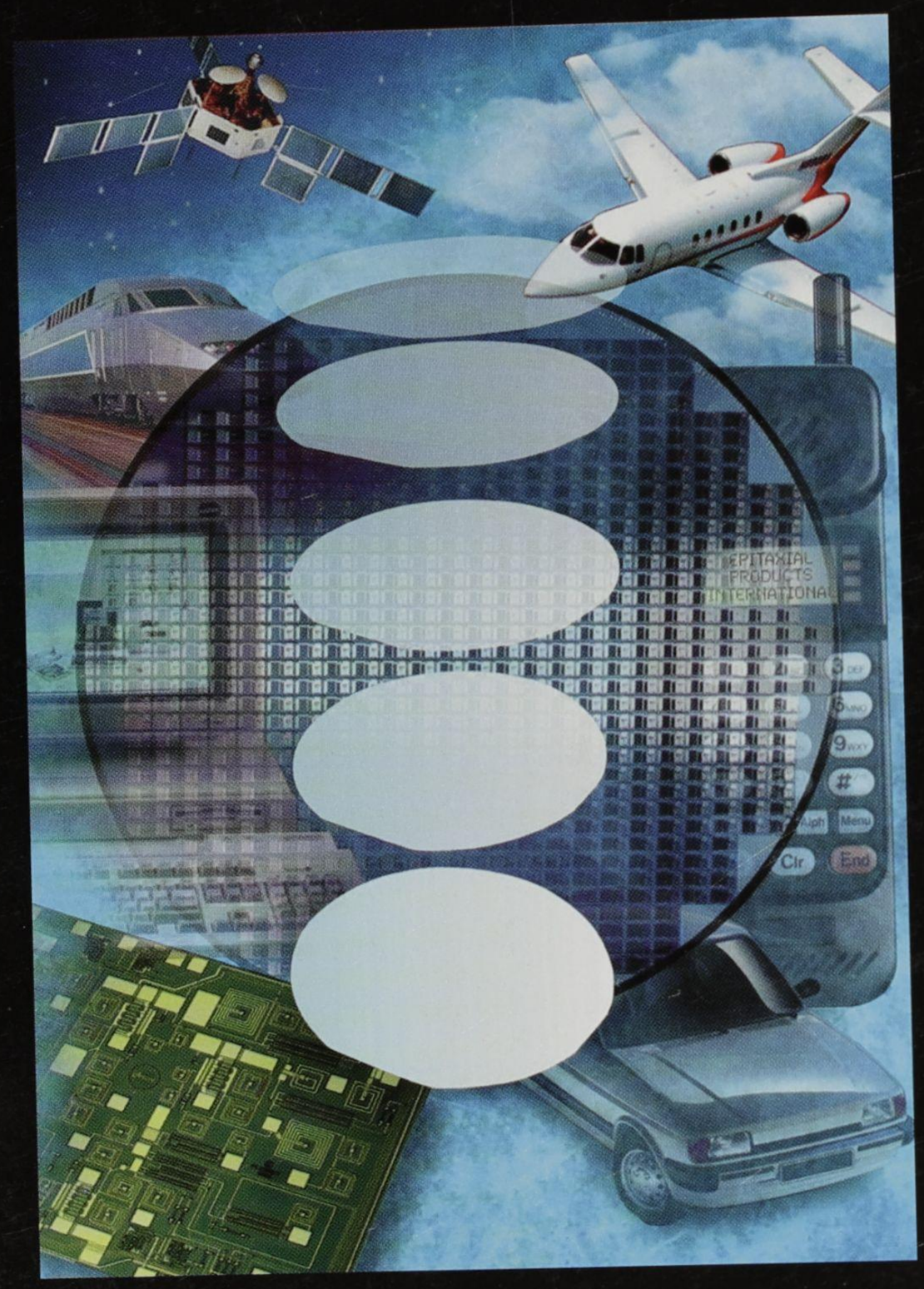
Argon	< 20 ppb	Oxygen	<100 ppb
Carbon Dioxide	<100 ppb	THC (as Methane)	< 50 ppb
Carbon Monoxide	< 50 ppb	Water	<200 ppb
Hydrogen	<100 ppb		

solkatronic®

Solkatronic Chemicals, Inc.
30 Two Bridges Road, Fairfield, NJ 07004-1530
Tel: 973-882-7900 • Fax: 973-882-7967
Toll Free: 800-521-3981
www.solkatronic.com

World Beating III-V Custom Epitaxy for a World of Applications

- Telecoms LDs / LEDs
- Telecoms PINs / APDs
- IR LDs / LEDs
- IR VCSELs
- Visible Lasers
- UHB Visible LEDs
- Visible VCSELs
- C-Doped HBTs
- InP HBTs
- P-HEMTs
- Solar Cells



- GaAs
- AlGaAs
- AlGaInAs
- GaP
- GaInP
- AlGaInP
- InP
- GaInAs
- AlGaInAs
- GaInAsP

Large volume foundry, pilot production or R & D

Multiple 2", 3" and 4" capacity

Whatever your epitaxy needs, however demanding, E.P.I. can deliver. High or low volume, each wafer is fully supported by extensive characterisation data and E.P.I.'s world leading MOVPE technology, ensuring absolute quality and ultimate consistency.

For more information about the world's foremost Custom Epitaxy service, contact Epitaxial Products International today.

Creating Profitable Business Partnerships

·E·P·I·

Epitaxial Products International Ltd

U.S.A./CANADA
Epitaxial Products Inc.
Hilltop Center, Building B
136 Harvey Road
Londonberry, NH 03053
U.S.A.
Tel. +1 (603) 641 2002
Fax: +1 (603) 641 2035
email:
73712.3265@compuserve.com

U.K./EUROPE
Epitaxial Products International
Cypress Drive
St. Mellons
Cardciff CF3 OEG
Wales, U. K.
Tel: +44 1222 794422
Fax: +44 1222 779929
email:
mscott@epitaxial-products.co.uk
wjones@epitaxial-products.co.uk

TAIWAN
Conray Enterprises Co. Ltd.
14F-3 No. 3
Lane 407 Min Sheng E. Road
Taipei
Taiwan
R.O.C.
Tel: +886 2250 93174/5
Fax: +886 2250 16279
email:
conray@top2.ficnet.net.tw

JAPAN
Electronic and Materials
Corporation Ltd.
11-11 Funado-cho
Ashiya 659
Japan
Tel: +81 797 34 6655
Fax: +81 797 34 5665
email:
eandmint@osk2.threewebnet.or.jp