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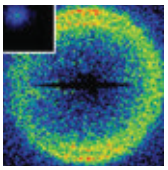
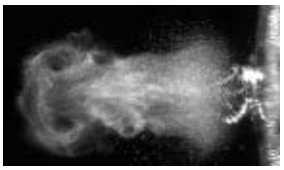




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**THE COVER**
This month's cover was inspired by our feature on silicon photonics. Technologies such as this 40-Gb optical modulator package from Intel promise inexpensive optical devices, easy integration with electronics and speedy data delivery. Image courtesy of Intel. Cover design by Senior Art Director Lisa N. Comstock.

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Volume 44 | Issue 3
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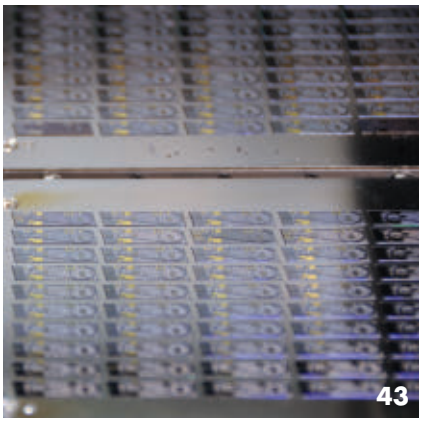
## FEATURES







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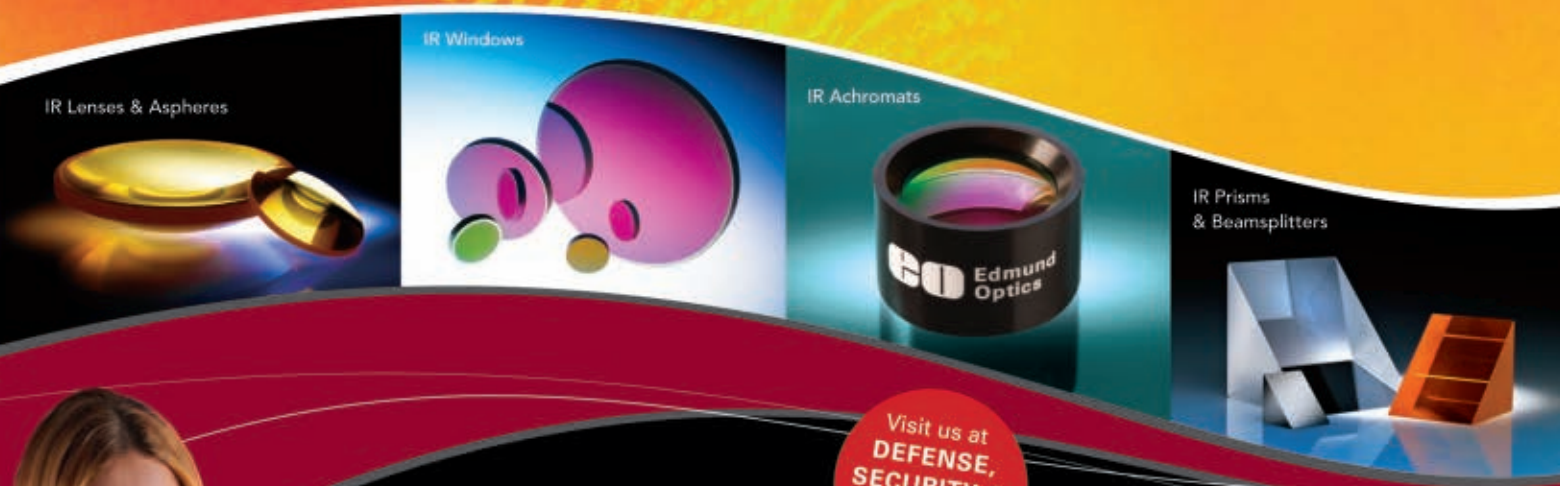


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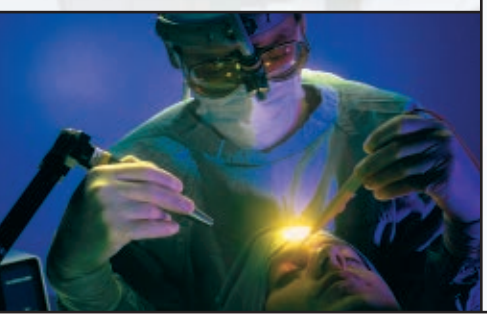


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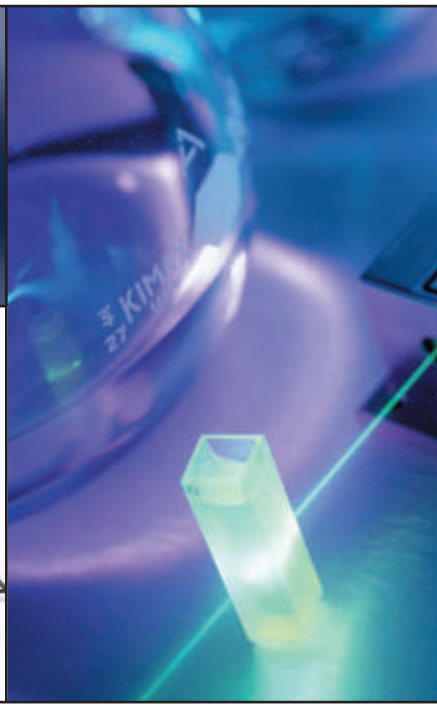

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# The challenge of finding funding

Venture capitalists invested fewer dollars in 2009 than in any other year since 1997, according to a recent report, and this was the second consecutive year of annual deal and dollar declines. Almost every industry was affected by the double-digit declines in investments – not even clean technology, software and the life sciences were immune.

This news would be depressing if not for one thing: The fourth quarter of 2009 showed promise for 2010, according to the *MoneyTree Report* by PricewaterhouseCoopers and the National Venture Capital Association (NVCA), based on data from Thomson Reuters. The number of deals went up 15 percent over the third quarter, which could signal that investors are feeling more optimistic. Another possible sign of optimism among investors is the fourth-quarter bump in first-time and early-stage deals that went through; this could mean that investment levels will rise again in 2010.

The NVCA attributes the slower investment pace in 2009 to a weak exit environment created by the combination of a challenged limited partner base and an unstable public market, but it expects to see more funding flow back into clean tech, information technology and the life sciences in the coming year.

So things are beginning to look better for startups. But what is the prognosis for researchers who are not ready to start up their own companies?

More than a year after the American Recovery and Reinvestment Act (ARRA) offered new opportunities, from Challenge Grants designed to jump-start areas of biomedical and behavioral research to funding for previously submitted grants that did not initially receive funds, editor Gary Boas takes a look at the impact the stimulus program has already had on research in the biomedical field. The feature article, on page 46 of this issue, addresses not only how the ARRA has affected these life sciences research programs but also what challenges it has faced since its introduction.

Is there a startup or researcher out there who couldn't use more money? Not likely. And here's hoping that 2010 will be the year the funding really starts flowing again.

Lee Mather

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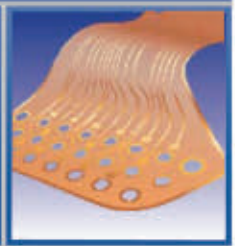

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This month's Web Exclusive explores the different ways the photonics industry is embracing sustainability efforts, and how this trend is as profitable as it is PC.

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## In the April issue of

# Photonics Spectra ...

**Displays for Military Imaging**
Sensor advances are increasingly allowing military imaging to capture critical data, and improvements to displays will allow the presentation of that data more and more clearly.

**Polymer Optics**
RPC Technologies explores the issues and performance capabilities of polymer optical components and materials.

**What's New with QDs**
Quantums dots aren't just dots anymore. In fact, they are appearing in as many shapes and sizes as the marshmallows in your breakfast cereal.

**GreenLight**
Researchers have demonstrated how to harvest chromophores from genetically modified tobacco plants for solar cells.

Plus all the news that affects your industry, from tech trends and market reports to the latest products and media.

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Check out a sample of the new digital version of *Photonics Spectra* magazine at www.photonics.com/DigitalSample. It's a whole new world of information for people in the global photonics industry.

# My Summer with MIRTHE

BY ALEXANDRA M. RITTER
STUDENT

I have never been particularly interested in the field of engineering. Physics? No thank you, I'll stick to English and history. So when my father came to me with the opportunity to work in a lab in Princeton for the summer, I was feeling more than a little apprehensive. But curiosity (and a desire to work somewhere that paid above minimum wage) got the better of me, and I signed up to be Princeton University's newest high school summer intern at MIRTHE, the National Science Foundation-sponsored Engineering Research Center on Mid-InfraRed Technologies for Health and the Environment.

MIRTHE, based at the university, leads the development of a new quantum cascade laser-based platform of trace gas sensor systems with improved high-performance and cost-effective sensing capabilities for environmental sensing, homeland security and medical diagnostics.

It also provides educational programs such as summer research opportunities to high school students in an interdisciplinary, collaborative research environment, and this was the program in which I worked. Students were immersed in local research teams, conducting original and hands-on laboratory work. Our activities included conference calls with students at MIRTHE partner universities; short courses offering insights into a wide range of research fields; informal social gatherings providing opportunities to network and to learn; and field trips to industrial and government laboratories in the area. We even got to present our research projects and results at the off-site MIRTHE Summer Workshop, an annual weeklong event that concludes the summer program each year.

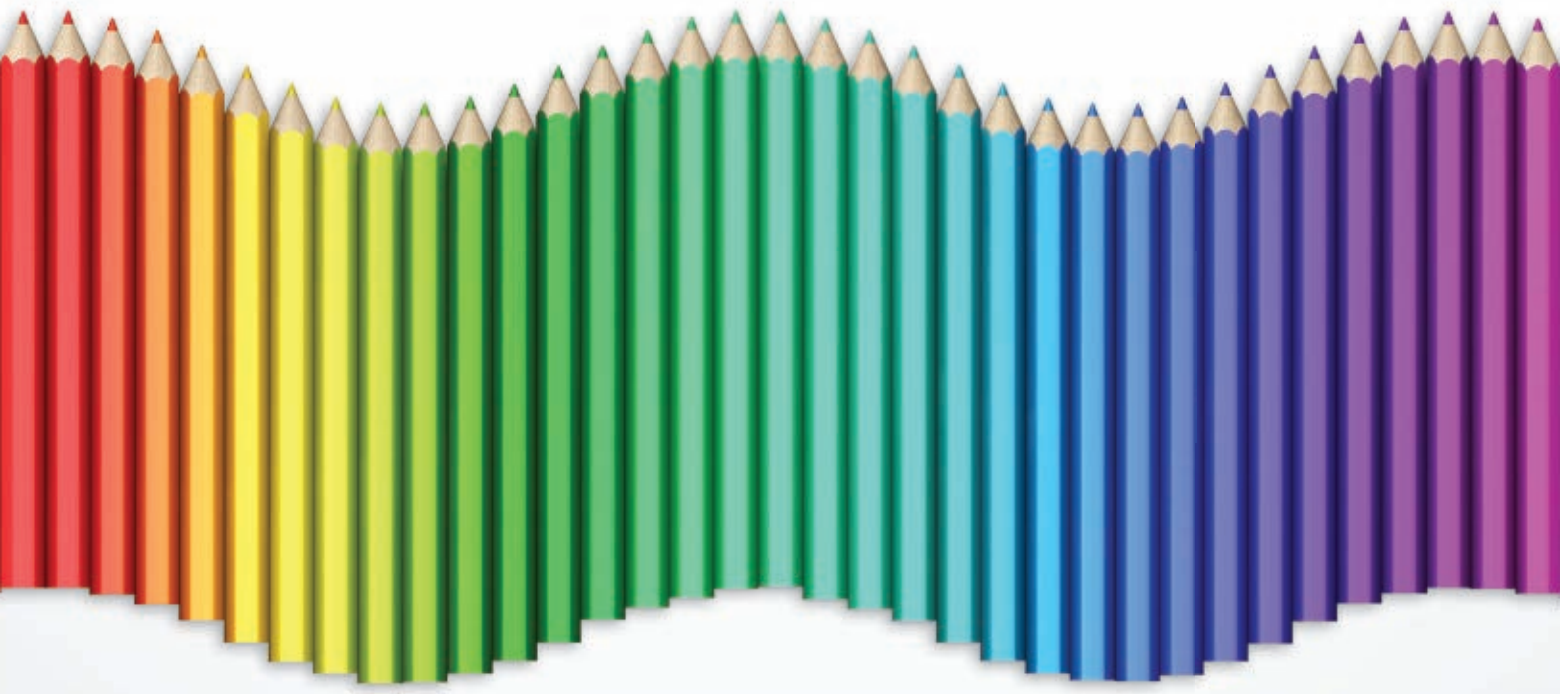
Our lab had the bulk of the people in the program. There was a good blend of high school students, soon-to-be college freshmen, undergraduates and graduate students. At first, the prospect of working with a bunch of older kids who were already majoring in engineering, a field about which I didn't have the first clue, was daunting. But throughout my summer internship at Princeton, I never met an undergrad or grad student who would turn me down if I asked for help – especially Princeton University graduate students Ekua N. Bentil and Wen-Di Li, whose project I joined.

For my project, titled "Optical Properties of Semiconductor-Based Sub-Wavelength Gratings for the Mid-Infrared Wavelength Range," I worked to improve quantum cascade lasers; for these lasers to be useful, the usually multimode emitters must be made single mode and tunable, one approach being by external feedback from a dispersive optical element, such as a grating. I evaluated the efficacy of subwavelength gratings fabricated by imprint lithography, not unlike those used at shorter wavelengths. In particular, I evaluated the optical properties – reflection and transmission – of semiconductor-based subwavelength gratings. My preliminary results demonstrate the utility of such gratings in the mid-infrared.

One of the best things about MIRTHE was how easy it was to learn so much new information on my project with so many

Students present their work at the MIRTHE Summer Workshop poster session at the City College of New York. Photos by Frank Wojciechowski, courtesy of MIRTHE.

# **Think** full spectrum



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people willing to teach. Even though our adviser seemed like the busiest person at Princeton, she still found time to come to see all of us high school kids in the lab and to talk to us about our projects, our lab notebooks, our abstracts, our posters, and any and all questions with which we could possibly bombard her. If she was busy, we also could talk to our graduate students. They handled every e-mail we sent with ease at any time of day, which is how we all came to the conclusion that they probably don't ever sleep.

The lab was the most interesting part of the experience. When I first walked in, it looked like a huge room with clutter on every available surface: equipment, samples, lab notebooks and whatever else people happened to leave strewn about. Eventually, the mess became ordered in my eyes, and by the end of the summer, my fellow interns and I could have told you where anything was in the lab. Encountering the equipment itself also was a fascinating new experience. The most advanced equipment I had used before that summer was a mass spectrometer, and

Professor Claire Gmachl and high school students, from left, Colin Montemarano and Joseph Schiavone, at the MIRTHE summer research internship.

now they wanted me to work with a Fourier transform infrared instrument?

It was hard at first to figure out all the tricks and sensitivities of the machine, but as with everything else, it took only some guided practice and a few mishaps to get a feel for what I was doing. Of course, the machinery and the samples we used never let us get too complacent: The old light-current-voltage (LIV) measurement setup would break, and everyone who used it needed time slots on the new LIV; a sample would snap in half in the process of transferring it to the sample holder; lenses were mysteriously scratched, and no one would own up to having done it. Every day there was a new problem to solve, whether planned or unplanned, and I managed to surpass even my own expectations by working out each one thrown my way. After a couple of weeks, we were running around looking for lost lenses, fighting over equipment time slots and forgetting where in the lab we had put a particular sample for safekeeping, just like everyone else in the lab.

I think the highlight of everyone's MIRTHE experience was our trip to New York for the weeklong MIRTHE conference, where we converged with the five other universities hosting the MIRTHE program – the City College of New York,

the University of Maryland Baltimore County, and Johns Hopkins, Rice and Texas A&M universities – and presented our research. We traveled with minimal chaperoning (no parents) and stayed in the dorms of St. John's University in New York – which, for me and my high school comrades, was really our first time away from home on our own.

From the second our adviser told us that we had better make a ton of noise when they called for the kids from Princeton to make themselves known, we knew that it wasn't going to be a completely boring scientific conference, and it sure wasn't. We had to sit through numerous graduate talks that were each 15 minutes long, but some of the grad students managed to make their talks interesting and captured our attention even beyond the introduction. Some were humorous, some had interesting research projects that made you sit up and listen, and some were good talkers who could make just about anything sound interesting. Most of them had one or more of these qualities, and it was very impressive that they could captivate all the high school students in the back row, who didn't have a clue what their research was all about.

Student Alexandra Ritter and her adviser, professor Claire Gmachl, work in the Princeton research lab.

We each also had to make a three-minute presentation on our own research. There were plenty of slipups, but for the most part, all of our practice and hard work allowed us to not embarrass ourselves too much. There was also the especially nerve-racking poster session. At first, I was especially anxious about being questioned by the other attendees because I wasn't sure I would be able to answer the questions of professors and other science-minded people, but I found that, as the inquiries began, after such extensive and thorough researching of my topic, I could answer most questions with barely any thought.

My summer with MIRTHE ended up being a completely different experience from what I had expected. I gained a new interest in science that I had never found in school, I learned how real research is conducted, and I also made friends with whom I remain in contact. It was challenging at first, but it truly paid off in the end. For more information about MIRTHE, including the internship program, visit www.mirthecenter.org.

### Meet the author

Alexandra M. Ritter attends Cinnaminson (N.J.) High School; she was a summer intern at MIRTHE, Princeton University, in 2009. In the fall of 2010, she will attend New York University.

# From the Industrial Age to the Nano Age

## Bringing science education into the 21st century

BY GARY BOAS
NEWS EDITOR

Neal C. Gallagher was enjoying being a parent. Retired, the one-time engineering professor wanted to get more involved with his two young children's schooling. He approached his son's first-grade teacher about instructing students in the gifted program about science and engineering, and she welcomed the idea.

After researching elementary school science experiments, however, he found that many of them are simply inadequate. "We aren't challenging the students," he said. "We aren't giving them the opportunities to expand their horizons and develop to their full potential." The problem stems in part from the fact that science curricula focus almost exclusively on fundamental principles, neglecting many of the advances and insights of the past 100 years. "In terms of what we're teaching," he said, "we're still in the industrial age."

So Gallagher developed a series of experiments – for his son's first-grade class, and eventually for other grades as well – probing areas such as quantum mechanics, where, for example, he used lasers and speckle to talk about the probability of photons behaving in certain ways. "Quantum mechanics can be taught at a level where kids can understand it," he said, "and it's full of interesting and profound questions regarding the nature of the world. If we don't get kids asking those questions, they're not going to want to be scientists."

The US is at a crossroads with respect to its dominance in the sciences. In recent years, as other nations have developed strong research programs, the US has lost ground, a result in part of cultural attacks and relatively flat funding of the sciences. Getting students excited about science again – especially about new fields and the cutting edge of research – is essential to the US holding onto its position, indeed to its remaining competitive edge in the global economy.

The question is: Who will teach these subjects? Elementary school teachers typically have little background in science and often are intimidated by it. Nor can high

The California NanoSystems Institute at the University of California, Los Angeles, has developed experiments to teach various topics in nanoscience, and in workshops, it shows teachers how to apply them in the classroom. Shown is a recent workshop about solar cells.

school science teachers and those developing science curricula be well versed enough in the many current areas of research to integrate that content into their lesson plans.

Fortunately, organizations such as the California NanoSystems Institute at the University of California, Los Angeles, and the Science & Health Education Partnership at the University of California, San Francisco, have taken up the challenge. The California NanoSystems Institute, or CNSI, was established in 2000 with the aim of encouraging collaboration between university researchers and industry and of facilitating commercialization of discoveries in nanosystems. But from the beginning, said Sarah Tolbert, a chemistry professor at UCLA and a member of CNSI, it included an outreach component.

CNSI offers the High School Nanoscience Program, which develops experiments that cover fundamental scientific concepts required by the Los Angeles Unified School District while introducing students to the relatively new field of nanoscience. The experiments address an array of topics in the field, including solar cells and photolithography. The institute shows teachers how to perform the experiments in their classrooms and gives them the necessary tools and supplies to do so in workshops conducted throughout the year.

The UCSF Science & Health Education Partnership, or SEP, also focuses on teacher training. In its Current Science Seminar Series, for example, researchers from the university – postdocs and faculty as well as graduate students relatively advanced in their studies – present their work to middle school and high school teachers. The program differs from other seminar series, however, in that the SEP coaches the presenters in how to make their research more accessible to the teachers: helping them develop appropriate analogies and interactive activities to promote understanding of complex concepts.

The SEP works with elementary school teachers as well – through its City Science program, for example – to make them more comfortable with scientific concepts, both new and old. “We find that a lot of the teachers simply lack confidence,” said Katherine Nielsen, co-director of the partnership, noting that many of them took the bare minimum of science classes in college. “A lot of what we do is showing them how best to teach science: getting them to ask questions, dispelling the idea that they need to know all the answers.”

The Science & Health Education Partnership at the University of California, San Francisco, also offers teacher training programs to help bring current scientific research into the classroom. Many of these – such as the City Science program – are taught by teacher-scientist teams able to address practical issues in the classroom and the scientific content, respectively.

The City Science program introduces teachers to curricula already adopted by the local school district, using kits developed for each grade level by the University of California, Berkeley, Lawrence Hall of Science. The workshops are led by teacher-scientist teams that work through the kits with the participants, encouraging them to engage with the material in ways they might not have otherwise.

The teacher-scientist model is an important part of the SEP’s efforts, Nielsen said. The teachers can help to address any practical issues that might arise in the classroom, while the scientists provide the scientific background for a given lesson.

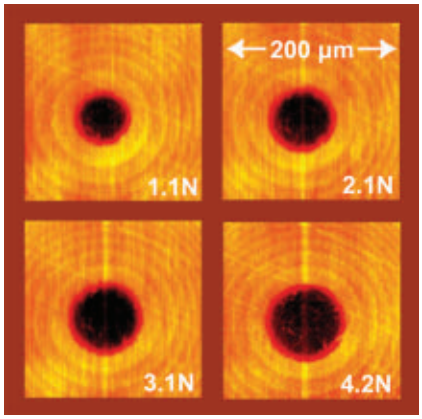
This sort of collaboration is key to the success of such programs, to the success of teaching students about recent advances in scientific research. At UCLA, Tolbert and CNSI teamed up with the outreach arm of the School of Education to organize the training workshops. “The education school people called us the ‘content providers,’ ” she said. “That really says it all. They would like to run the workshops, but they don’t have the content. And you’re not going to get that unless you’re immersed in the field.”

gary.boas@photonics.com

# Laser pulses reveal contact mechanics

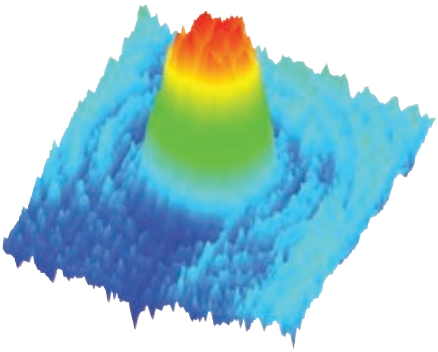
SAPPORO, Japan – The next time you are sitting at your desk full of papers, pens, files and perhaps a coffee mug, take a closer look at the points where these objects meet the desk. What do you see? If you could magnify the nanoscale interface of where the object meets the desk, you would actually see a world of mountain ridges and deep valleys.

These microscopic features and, more importantly, how these features mesh together are what help tires grip a road or a gecko's feet cling to a rock. Until now, however, there has been no way to study this complex landscape in detail while the objects are still in contact. The best researchers could do was to press one object into the other, remove it and then image the indentation it leaves using an atomic force microscope.

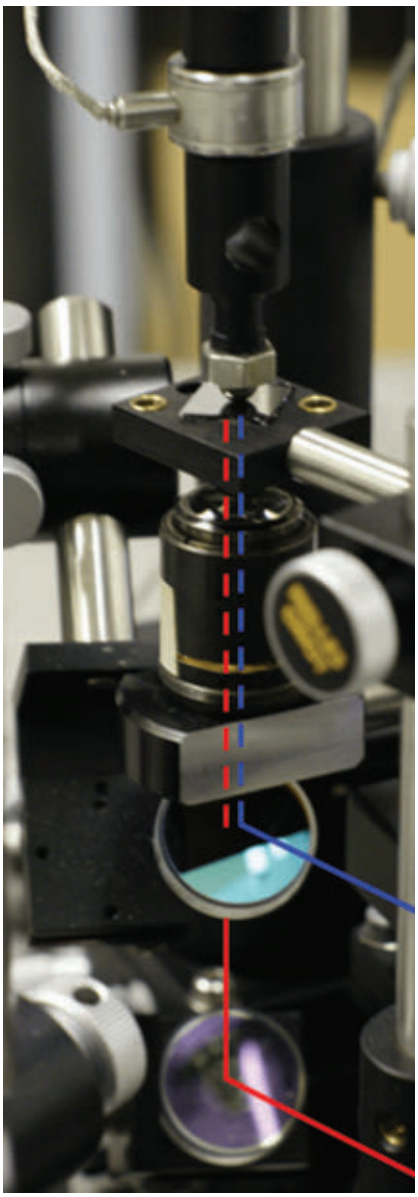



Thermal images of the contact between the sphere and the flat surface reveal that, as the sphere is pressed with greater force (increasing from upper left to lower right), the surface contact area increases. Images courtesy of Oliver Wright of Hokkaido University.

A close-up of the 6-mm-diameter ceramic ball attached to the mechanical arm.



A 3-D rendering of a thermal map of the sphere pressed into the surface with a force of 3.1 N highlights that the cooler contact areas in the center (red) occur where the heat loss from the surface is greater.



The mechanical arm presses the ceramic ball down onto the chromium surface. The red line is the excitation beam or pump laser, and the blue line is the detection beam or probe.

Now, professor Oliver Wright and his team at Hokkaido University have seen the microscopic terrain of a live contact. Their technique, reported in the December 2009 issue of *Physical Review B*, combines ultrafast laser technology with classical contact mechanics to image the interface between a ceramic ball and a flat surface of chromium.

"The properties of mechanical contacts between solids depend on how their microscopically rough surfaces mesh on the nanoscale, and a physical understanding of the contact area is vital in engineering and biology," Wright said. "We present a new way of probing contacting interfaces using ultrahigh-frequency sound and heat waves."

In the setup, a mechanical arm presses a 6-mm-diameter ceramic ball down onto a 110-nm-thick film of chromium coating a sapphire surface. Ultrashort laser pulses (less than 1 ps in duration) are fired at the sapphire surface, which heats the chromium, causing it to expand and send a short ripple of high-frequency sound and thermal energy toward the ball.

After the sound waves bounce off the ball, they are detected by a second, probe laser. The intensity of the reflection is a measure of the strength of the acoustic echo. The Hokkaido team found that the echoes from the contact region arrive earlier, enabling imaging of the nanometer-scale deformation of the metal film.

By scanning the probe light pulses, a two-dimensional map of the thermal contact can be built up. This thermal map highlights areas of dark and light, which correspond to, respectively, where the ball and film were in contact, and where there were air gaps.

While spatial resolutions in mechanical contacts on the order of 0.1 mm have been

obtained using megahertz-frequency sound waves, the nanoscale has never before been explored in this way.

"We implement an in situ acoustic and thermal profiling technique at frequencies of about 100 gigahertz and 1 megahertz, respectively," Wright said. "This is more than one thousand times higher than previously used in contact mechanics."

This work has applications in engineering for the study of friction, lubrication, and electrical or heat conduction, as well as in biology for the study of adhesion or joints.

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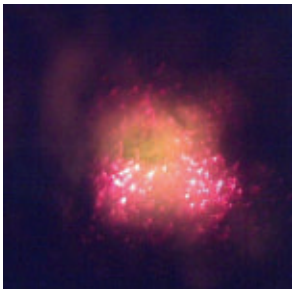
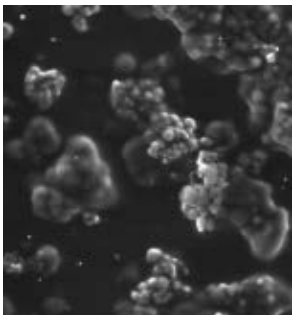
# Imaging microcavities sheds light on random laser operation



This photo shows a microscopic image of an electrically conducting polymer film that was pumped by a pulse of green light from a conventional laser, exciting tiny cavities within the film to produce red-colored "random laser" light. Photos by Randy Polson, Department of Physics and Astronomy, University of Utah.



A film of the polymer DOO-PPV, as seen through a microscope, shows clumps of undissolved polymer within the darker, dissolved material. Such irregularities are believed to create the tiny cavities that act as built-in mirrorlike resonators for random lasers.

SALT LAKE CITY – Researchers from the University of Utah's Dixon Laser Institute have managed to visualize the microscopic cavities responsible for laser action in random lasers, helping to explain how this relatively new type of laser really works.

Many see random lasers as one of the most exciting areas in current laser research. Discovered only about a decade ago, they come both with questions about what exactly makes them work and with exciting potential applications. As with other lasers, random lasers comprise a medium capable of light amplification via stimulated emission, with a structure that holds the light in the gain medium long enough to compensate for any energy loss. In normal lasers, the latter is typically achieved by carefully aligning reflectors forming a cavity; in random lasers, however, it is the natural structure of the material doing this job – hence the name.

Consequently, random lasers require special materials that not only amplify light but also reflect it many times, retaining it within the material for as long as possible. Offering these characteristics are many "distorted" gain media, such as semiconductors, liquid or

photonic crystals, or so-called nanocrystals such as zinc oxide clusters. Another option is adding a scatterer such as titanium dioxide into a medium – a dye, for example – that is already doing the job of amplification.

Of course, the gain medium of a random laser must be pumped to facilitate laser operation, but its output, unlike that of conventional lasers, will not be strongly directional after all the scattering. Nevertheless, the output exhibits narrow coherent spectral lines, or modes. These modes, another characteristic of laser emission, and their generation have been among the big unanswered questions about how random lasers work. In a "normal" laser, modes are established because only certain waveforms are allowed in a cavity, but with random lasers, where no well-defined mirrors exist, their existence is harder to explain. One model suggests that the modes – and the cavities generating them – are strongly localized but that their output is combined, whereas the other paradigm presumes nonlocalized distributed light paths inside the disordered medium, with the lines generated by specific photonic states in the medium.

The two models are the subject of a hot debate, "but our work shows that the emission from random lasers is generated by individual emitters," said Randal Polson, one of the Utah researchers in professor Z. Valy Vardeny's group, which has been pioneering random lasers since their discovery. In their most recent work, published in the Jan. 24, 2010, issue of *Nature Physics*, they pumped pi-conjugated polymer films with green conventional laser light and studied the dependency of the lasing threshold on the excitation area with and without titanium dioxide nanoparticles added to the polymer. Taking optical pictures, they found that, near the threshold, only one microscopic resonator technique linked the red output spectrum with the location where it was generated.

"With better understanding, almost certainly the commercial use of random lasers will gain pace," Vardeny said. One exciting observation Polson and he published in the Aug. 16, 2004, issue of *Applied Physics Letters* was that human tissue can support random lasing if it is infiltrated with a dye – and that malignant tissue exhibits more laser lines than healthy samples. This discovery could enable these inexpensive and easy-to-make lasers to automate cancer detection.

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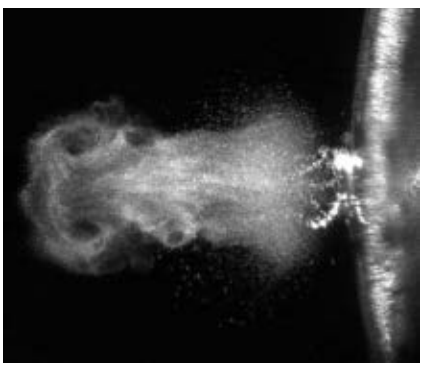
# Zooming in on plumes to improve mass spectroscopy

BATON ROUGE, La. – By using a high-speed camera to study plumes created by a tunable infrared laser, researchers at Louisiana State University have revealed some of the mechanisms involved in material ablation. The plume study technique could someday result in better mass spectrometer performance, said research team leader and chemistry professor Kermit K. Murray, and that could help life sciences and materials research.



Shown is a plume captured 24 µs after a 2.94-µm laser shot struck glycerol. By studying how such plumes evolve over time, researchers can improve how much material is ionized and thus becomes suitable for mass spectrometry. Courtesy of Kermit K. Murray, Louisiana State University.

When studying biomolecules and other macromolecules, investigators frequently make use of matrix-assisted laser desorption ionization. In this method, a laser pulse ablates material, and a mass spectrometer samples the ions in the plume.

The problem is that most of the material removed is electrically neutral and, therefore, undetectable. "If we can adjust the ablation conditions to maximize the conversion of the sample into ions, we will improve the performance of the mass spectrometer," Murray said.

In trying to understand just what is going on in a plume, researchers have

long turned to high-speed photography. Murray and graduate student Xing Fan added a twist to this idea. They combined a fast camera with a tunable mid-infrared laser, constructing it from an optical parametric oscillator and an Nd:YAG laser from Continuum of Santa Clara, Calif. This setup allowed them to adjust the pulse wavelength from 1.4 to 4.0 µm and to study how that changed material removal.

In their experiments, the researchers fired 5-ns pulses from this mid-IR source into a glycerol sample sitting on a stainless steel target. For illumination, they used an excimer KrF laser from Lambda Physik of Göttingen, Germany, triggering it after the first laser shot. As a result, the 248-nm, 8-ns pulses from this second laser illuminated the plume at specific times. To capture the plume's appearance, the duo used a CMOS digital camera from Vitana Co. of Ottawa.

Using this setup, they obtained one image per laser shot. Murray noted that an ideal camera would record a video from a single shot. However, the technology doesn't yet exist to strobe and record images at the necessary speed, he said.

Thus, reconstructing the plume evolution required that the researchers take multiple shots. They did so for wavelengths from 2.7 to 3.5 µm, finding that the greatest material ablation and the longest plume duration took place near 3.0 µm. That, they noted in the Jan. 28, 2009, issue of *Journal of Physical Chemistry*, corresponds to the stretch absorption of OH, a molecular constituent of glycerol. Modeling calculations suggested that the material removal was driven by a stress-confined phase explosion.

Murray said that tuning the wavelength and energy will allow optimization of laser desorption mass spectrometry techniques, especially those performed under ambient conditions. Maximizing the laser's effectiveness is important to various research areas, he said. "One of the most promising applications is tissue imaging, where the ability to remove the biomolecules from within the sample is critical to success."

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# Ultrasensitive sensor causes stir at show

PRINCETON, N.J. – A prototype laser spectroscopy platform developed by electrical engineers at Princeton University attracted a lot of attention when it was demonstrated during SPIE Photonics West 2010 in January. The sensor, a new development in wireless sensor networks for monitoring trace gases and chemicals, uses an infrared laser operating at 2 µm and can detect atmospheric carbon dioxide with a sensitivity of 113 ppb in an average time of 1 s.

A low-power, portable wireless laser spectroscopic sensor for atmospheric $CO_2$ monitoring attracted a lot of attention when it was demonstrated during SPIE Photonics West 2010 in January. The sensor uses an infrared laser operating at 2 µm and can detect atmospheric carbon dioxide with a sensitivity of 113 ppb (1$\sigma$ ) in an average time of 1 s.

"Several people stopping by the booth have expressed interest in commercializing the technology, which gives us a good impression that our efforts are going in the right direction, because we want to develop technology that is truly field-deployable and useful for many different applications," said Gerard Wysocki, an assistant professor of electrical engineering whose Princeton group developed the sensor in collaboration with MIRTHE (Mid-InfraRed Technologies for Health and the Environment), a National Science Foundation Engineering Research Center based at Princeton.

"Of course, there is large interest among scientists who consider this kind of development very useful because they could start new applications that are not possible with today's large and bulky instrumentation that is commercially available," Wysocki said.

His group, which includes postdoctoral scientist Stephen So and graduate student Clinton Smith, designed the tunable diode

Clinton Smith (center) and Stephen So, electrical engineers at Princeton University, and Lijun Xia (far right) from Johns Hopkins University test a prototype wireless $CO_2$ sensor developed in collaboration with MIRTHE (Mid-InfraRed Technologies for Health and the Environment), a National Science Foundation Engineering Research Center based at Princeton. In the field tests, the tunable diode laser absorption spectroscopic (TDLAS) sensor measured $CO_2$ respiration on a forest floor at the Smithsonian Environmental Research Center and produced results well correlated with a commercially available Vaisala sensor. Photos courtesy of MIRTHE.

laser absorption spectroscopic (TDLAS) $CO_2$ sensor to be lightweight, highly sensitive and extremely energy efficient, with the potential to operate for years on batteries or solar power.

"The main focus of this work was on developing ultralow-power operation of those sensors, and this particular sensor is based on a VCSEL [vertical-cavity surface-emitting] laser working at two micrometers, and the total power dissipation of the sensor is about 0.3 watts," Wysocki said.

The sensor can run several days on a single 10.5-Ah lithium-polymer battery (with continuous wireless transmission of data). It also has the capability for low operational duty cycles – 100 nA sleep current with short wake time – and it can be deployed with a solar panel or other energy-harvesting unit for continuous monitoring.

"Depending on the radio, we can get about 100 meters between sensors," So said. Using the cellular infrastructure means that the sensors could be placed miles apart. A critical requirement of the system, he said, is that it must use as little energy as possible so that it can be powered by batteries or solar panels, providing data continuously for years at a time.

"There's no technology currently available that can do that."

The main applications of the technology are focused on atmospheric science, for carbon monitoring, as well as on carbon sequestration science needed for monitoring carbon dioxide leaks over large areas.

"Basically, we've redeveloped all of the laboratory equipment and tried to jam it all into a small box, to make it portable, and so that we can actually go out into the field with these things and place them next to a tree or on top of a rock and have them wirelessly communicate their data over radio and send it to your computer in your office," said So, the lead researcher on the project. "And if you have a lot of these nodes, you can do some mapping and correlations to determine carbon flux and greenhouse gas flux."

The technology could be used in the future by governments needing to implement precise cap-and-trade systems for $CO_2$ monitoring, to help appropriately assign industrial carbon credits or for emission controls for industry to minimize atmospheric pollution, Wysocki said.

With their new sensor, "lasers can target particular absorption lines, and we can perform very precise and selective measurements of different molecules," Wysocki said. "The technology's also very universal. By changing the laser source and detector, we could target different molecules, and since the sensor is small, we can have several molecules in a reasonably small package at the same time.

"The main advantages of spectroscopic sensing is that we have both sensitivity and selectivity," Wysocki said. "So we can't run into the same problems standard sensors do when two molecules that cause similar response in the sensor can confuse

the sensor, and one molecule can be misinterpreted as another one."

The TDLAS sensor was field-tested for atmospheric $CO_2$ and soil respiration monitoring – which also produces high levels of $CO_2$ – by Princeton's MIRTHE partners from Johns Hopkins University at the Smithsonian Environmental Research Center. Tested against a commercially available sensor, the TDLAS produced well-correlated measurements.

"We are currently developing new sensing methods that can be used with the same electronics that we have developed for spectroscopic sensing in general, with flexible functionality," Wysocki said. "The same electronics can be used for oxygen sensing using a quite complex sensing method called Faraday rotation spectroscopy. This kind of method can provide much higher sensitivities and would allow for further miniaturization of the sensor – with the same capabilities or even better," he said.

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# Laser trapping gets tighter grip on larger particles

KARMIEL, Israel, ST. PETERSBURG, Russia, and SAPPORO, Japan – Using light to trap particles as small as atoms has been popular with researchers for some time, a technique that enables optical cooling and trapping, as recognized by the 1997 Nobel Prize in physics. Now trapping of bigger particles has moved up on the agenda, with potential applications in biological systems research or nanotechnology – although grabbing larger pieces is more challenging because light generates forces in the piconewton (pN = $10^{-12}$ N) range only.

Researchers from Israel's Pixer Technology Ltd., now part of Carl Zeiss SMT, and from St. Petersburg State University have reported a technique that traps bubbles in water with forces much stronger than those known previously (*Tech. Phys. Lett.*, 2009, Vol. 35, No. 3, p. 282). They used a laser emitting femtosecond pulses at a 100-kHz repetition rate to generate and hold a gas bubble in a firm location in the focus of the beam.

Optical trapping uses a strongly focused laser beam, and the effect can be explained by the dielectric particles being dragged by the field gradient into the strongest electrical field in the focus. However, if the particles are large (compared with the wavelength of the light), ray optics can be used to understand or describe this; i.e., each ray of light experiences refraction as it enters and exits a dielectric bead in the focused beam. This change of direction comes with a momentum change, which, according to Newton's law, provides an equal but opposite momentum change to the particle, kicking it toward the center of the beam. However, if the particle is exactly in the middle of the focused Gaussian beam, all rays are refracted symmetrically, leading to no net lateral force.

Once particles are trapped, the holding forces can be measured; e.g., by moving the trapped particle around and measuring the maximum velocity until it becomes detached. The researchers say that their gas bubble in water was held with ~200 pN, at least an order of magnitude more than previously known. They attribute this phenomenon to the continuous flux of short but intense laser pulses, which heat the gas inside the bubble, increasing its size and creating equilibrium between the heat absorbed by the surrounding water and the power from the next pulse – a strong returning force if this heat source is displaced and approaches the bubble wall.

More recently, a group at Hokkaido University in Sapporo published work using a near-infrared (1064 nm) laser beam to trap and manipulate small amino acid molecules in aqueous arginine solutions. The researchers reported that a particlelike assembly of objects grew gradually in the focal point during laser irradiation (*J. Phys. Chem. C*, online, Dec. 23, 2009).

Using confocal Raman microspectroscopy, they confirmed that a molecular assembly of arginine had formed, generating trapped clusters for other amino acids, including glycine, proline, serine and alanine. This revealed that the optical manipulation technique can be extensively applied not only to that of large-size biological structures but also to their manufacture.

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# Ultra-Low Noise Laser Diode Current Source


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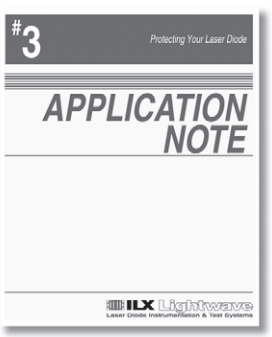


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# Outlook opportunistic for active optical cables

BOSTON and EUGENE, Ore. – Active optical cable revenue is expected to grow significantly over the next five years, according to a report from Information Gatekeepers Inc. (IGI) of Boston, a publisher and consultancy in fiber optics, optical networks, telecommunications and other fields.

Titled *Active Optical Cables 2010 Market Report* and published in December 2009, it notes that the global recession has had a significant impact on new active optical cable design, which is reflected in the estimated total revenue of $137 million for 2010. A strong increase in sales is expected in 2011-2012 as a result of new designs created in late 2009 and through 2010. Cumulative active optical cable revenue likely will be in excess of $7 billion, with more than $2.4 billion in 2014 alone, according to the company.

"The inability of copper cables to keep up with higher I/O [input/output] data rates and user desire to carry lighter, more flexible cables are the main drivers for the active optical cables market," said Tom Rossi, author of the report. "The market needs to drive toward lower costs and broader adoption rates," he added.

Rossi said that among the main applications for active optical cables are high-performance computers that will require cables with lane rates above 10 Gb/s, and with 12 channels rather than the four typically in use today. Thinner, lighter and more flexible cables also will be in demand for high-definition television, personal computers, consumer electronics and digital signal, he added.

Active optical cables carry digital I/O over optical fiber, using electrical-to-optical conversion inside the cable/harness connector itself.

According to the report, the number of active optical cables is projected to exceed 1.2 million units in 2010 and to grow to more than 48 million units by 2014. Heavier use of USB and high-definition multimedia interface (HDMI) active optical cables is predicted.

The report addresses new markets and technologies, including CXP, a 12-channel connector, and SAS, serial attached SCSI (small computer system interface), a common data storage transfer protocol. Further information about the report can be found at www.igigroup.com.

## Active optical vs. copper cables

"In the past year, I/O cable bandwidth has increased at the expense of copper cable length restriction, with reductions of maximum practical length for the latest forms of USB, HDMI and DisplayPort," according to the company. High-performance computer clients also are reporting a preference for optical InfiniBand cables above the 5- to 7-m length.

Active optical cables are likely to be used in applications instead of the thicker, bulkier copper cables now required to address bandwidth and power delivery issues.

"Copper cables cannot carry faster I/O rates without increasing their wire gauge/diameters. At some point, fatter copper wires cannot be used with the standard interface connectors only. The only solution is to reduce the wire length so the thinner copper cable can be made to work," Rossi said.

Light Peak, an optical technology initiative from Intel Corp. that is supported by Sony Corp., has technical elements heavily used by active optical cables. IGI suggests that, if Light Peak reaches volume markets, it could have a great impact on overall active optical cable cost structures. "Any active optical cable initiative from Intel Corp. tends to create a lot of interest across the computer industry, and, as such, merits watching," Rossi said.

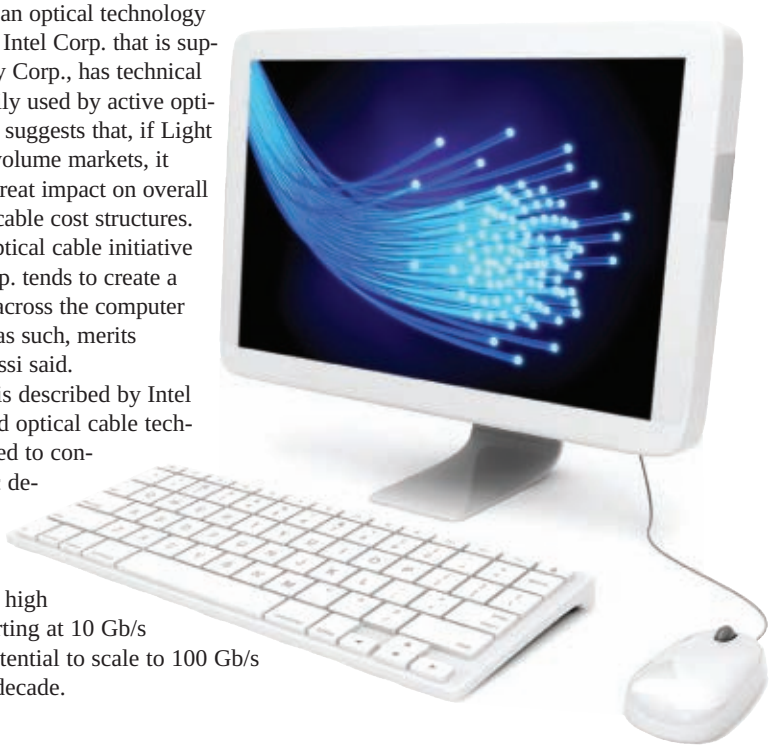
Light Peak is described by Intel as a high-speed optical cable technology designed to connect electronic devices to each other. The company says that it delivers high bandwidth starting at 10 Gb/s and has the potential to scale to 100 Gb/s over the next decade.

## Later growth predicted

"Active optical cables are poised to become a disruptive force within the communications market; technical innovations from this segment are promising, though applications in consumer electronics are not predicted until 2013," according to *The Active Optical Cable Market Analysis and Forecast Report* published in December 2009 by LightCounting Inc., an optoelectronics transceiver market research firm based in Eugene, Ore.

"Active optical cables will be very popular in the InfiniBand high-performance computing market but will not likely spread to other protocols until much later in 2012 and beyond," said Brad Smith, senior vice president and industry analyst at LightCounting.

"The consumer optical cable market – HDMI, USB, Light Peak, etcetera – is largely a 2012-2014 market for any significant volume, as it is well served by copper solutions today, and the prices are very low. Also, there just isn't the need in the consumer space with the supporting devices for either the very high data rates – 10 gigabits per second – or



the long reaches where the advantages of optical technology come into play," he added.

"Fueled mainly by the transition of cabling from copper to high-speed optical in high-performance computers, and seeking lower connectivity costs and power consumption, the market is expected to grow to 580,000 units and $192 million by 2013 and is expected to begin spreading to other communications protocols and market segments," according to the LightCounting report. The document notes that corporate data centers, undergoing upgrades and increasing data rates, are likely to drive the market, and if Intel is successful in bringing low-cost active optical cables to the consumer market, that market also will become a very interesting and active business segment.

### Differences of opinion

Smith takes issue with the IGI report. "I have talked with most active optical cable manufacturers, and they are flat-out upset with the hype from the Tom Rossi IGI report. Rossi talks for a $1.2 million and near $1 billion market for active optical cables, mainly in the Light Peak, optical HDMI space. Yet when I was at CES [Consumer Electronics Show], there was not a single product – either TV or cable – on display. Every cable company I talked to never [hears] of optical," Smith said.

"We had a fairly strong reaction to our report last year, even more amazing considering it was our initial service launch during the worst worldwide recession in more than 70 years," Rossi said. "In the past 60 days, we have held two 'webinars' – over 130 attendees combined – with lots of favorable comments received during and after the webinars. Several large companies have mentioned building strong cases internally for moving ahead with optical cables, thanks to the groundbreaking research and analysis we have brought to bear."

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**Phase I Projects** Boston Micromachines Corp. of Cambridge, Mass, a microelectromechanical systems-based deformable mirror provider, has received two Phase I contracts totaling about $200,000 from NASA's Small Business Innovation Research Program to further space imaging research. The first project is to develop a compact, ultralow-power, high-voltage multiplexed driver suitable for integration with the mirrors in space-based wavefront control applications. The other is for an enhanced fabrication development process for the high-actuator-count deformable mirrors required for wavefront control in space-based high-contrast-imaging instruments.

**Wafer Bonding Agreement** 3M of St. Paul, Minn., an advanced materials supplier for the semiconductor industry, and Tazmo Co. Ltd. of Okayama, Japan, an LCD manufacturing equipment and semiconductor supplier, have announced an agreement allowing the latter company to manufacture and sell equipment for temporary bonding of ultrathin wafers required for 3-D packaging. Under terms of the agreement, Tazmo will become a supplier for equipment configured to use 3M's wafer support system materials, including the Liquid UV-Curable adhesive and the Light-to-Heat conversion coating. Both companies also will work together to address customer demands for high-performance process solutions.

**Licensing Agreement** The University of California, San Francisco, has given Carl Zeiss

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MicroImaging GmbH license to commercialize a superresolution microscopy technique developed by scientists at the university. Called structured illumination microscopy, the technique combines a special illumination pattern with state-of-the-art computational image analysis. Compared with conventional microscopes, its resulting superresolution images have up to double the resolution in all three spatial directions. The agreement grants the company the right to integrate the technique into its microscope systems.

**Imaging Division Formed** Irvine Sensors Corp. of Costa Mesa, Calif., a vision systems company, has announced that its new subsidiary, Thermal Imaging Div., will be managed by company vice president Peter Kenefick. Irvine anticipates deliveries of its thermal imaging products, particularly clip-on thermal imagers, to increase from 100 units per month to more than 2000 over the next two years.

**Distribution Agreement** AMS Technologies AG of Martinsried/Munich, Germany, has finalized an agreement with Interfiber Analysis LLC of Livingston, N.J., to distribute the latter's Refractive Index Profiler in all European countries. The device scans the optical index of refraction for optical fiber along its length and performs multiwavelength fiber index profiling.

**$20 M Solar Order** Coherent Inc. has secured multiple orders totaling more than $20 million from crystalline silicon solar cell manufacturers for laser-based process tools. Three months after the release of its Equinox and Aethon products, the laser-based solutions provider's deliveries are scheduled for completion in the first half of calendar 2010. The tools are the latest addition to the Santa Clara, Calif.-based company's portfolio of laser and laser-based systems for photovoltaic production processes.

**UK Distribution** Elliot Scientific Ltd. of Harpenden, UK, has signed a distribution agreement with Akela Laser Corp. of Monmouth Junction, N.J., a high-power laser diodes and optomechanical subassemblies manufacturer. The latter company will complement the former's existing portfolio of products for the telecom industry and OEMs requiring compact high-power laser sources. Its products will enable Elliot Scientific to offer a complete range of laser diodes to customers in the UK and Ireland.

**Acquisition Finalized** Amersham, UK-based Halma plc, a global safety, health and sensor technology group, has acquired SphereOptics of North Sutton, N.H., a custom light-measurement technologies manufacturer. Halma's group of photonics businesses is merging with Labsphere, a light-metrology industry provider, to expand product portfolios and strengthen the global distribution network.

**New Facility** LightWorks Optics Inc., a custom precision optical components and integrated optics solutions provider, has opened a 14,000-sq-ft office and manufacturing facility adjacent to its headquarters in Tustin, Calif. The new plant will enhance product development efforts, optimize testing efficacy and significantly expand production capacity. This is the company's second expansion into new facilities in the past two years.

**Production Expansion** Machine and laser systems manufacturer LPKF Laser & Electronics AG has announced plans to double its production capacities for cutting and structuring lasers in Germany by the end of the first quarter and to boost its capacities further in the second quarter. The expansions are intended to satisfy the demand for laser systems for electronics production in Asia.

**Global Distribution** In Birkerød, Denmark, NKT Photonics A/S, a supercontinuum sources and fiber laser manufacturer, has announced the expansion of its global distribution partner's network with Photonic Solutions plc of Edinburgh, UK, Crisel Instruments srl of Rome, Applied Laser Technology of Benelux and Opto Science Inc. of Tokyo. The four distributors will sell and support NKT Photonics' SuperK supercontinuum sources and single-frequency Koheras fiber laser product families.

**European Expansion** Optical Zonu Corp. of Los Angeles, a supplier of Gigabit Ethernet and SONET/SDH single-fiber, full-duplex, coarse wavelength division multiplexing tranceivers, passives and testers, has announced the formation of Optical Zonu Europe to bring sales, marketing and support to customers in that region. The new operation will be headed by Dr. David Jenkins and Ian Richard.

**Glass Partnership** Holographic photovoltaic (PV) module manufacturer Prism Solar Technologies Inc. of Highland, N.Y., and PPG Industries of Pittsburgh, a global paint, coatings and optical products supplier, have partnered on a project to test the performance of various types of glass in both standard and holographic PV modules at incident and direct angles. The tests will compare PPG's Solarphire antireflection high-transmissive glass with patterned glass to determine the increase in energy yield.

**Optics Award** Photonics Products Group Inc. (PPGI) has received firm-fixed-price contracts for precision optical components from Lockheed Martin's Missile and Fire Control Business Unit in Orlando, Fla. The components include high-precision aluminum, beryllium and beryllium alloy optical mirrors for Lot 6 production requirements on the Arrowhead electro-optical system. The award is the sixth consecutive one for MRC Optics, a wholly owned subsidiary of PPGI, for the aluminum mirrors, and the second consecutive award for the beryllium and beryllium alloy mirrors.

**€2.5 M Contract** Sofradir, an advanced infrared detectors manufacturer in Paris, has received an additional €2.5 million contract to provide a second batch of 15-µm-pitch multilinear short-wavelength infrared (SWIR) arrays for the spaceborne Global Monitoring for Environment and Security (GMES) initiative. GMES is a joint venture of the European Commission and the European Space Agency. Sofradir previously received a €6.7 million contract from Astrium SAS to design a three-band SWIR for the GMES Sentinel-2 mission.


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THE PULSE OF THE INDUSTRY

# Sensing the rain

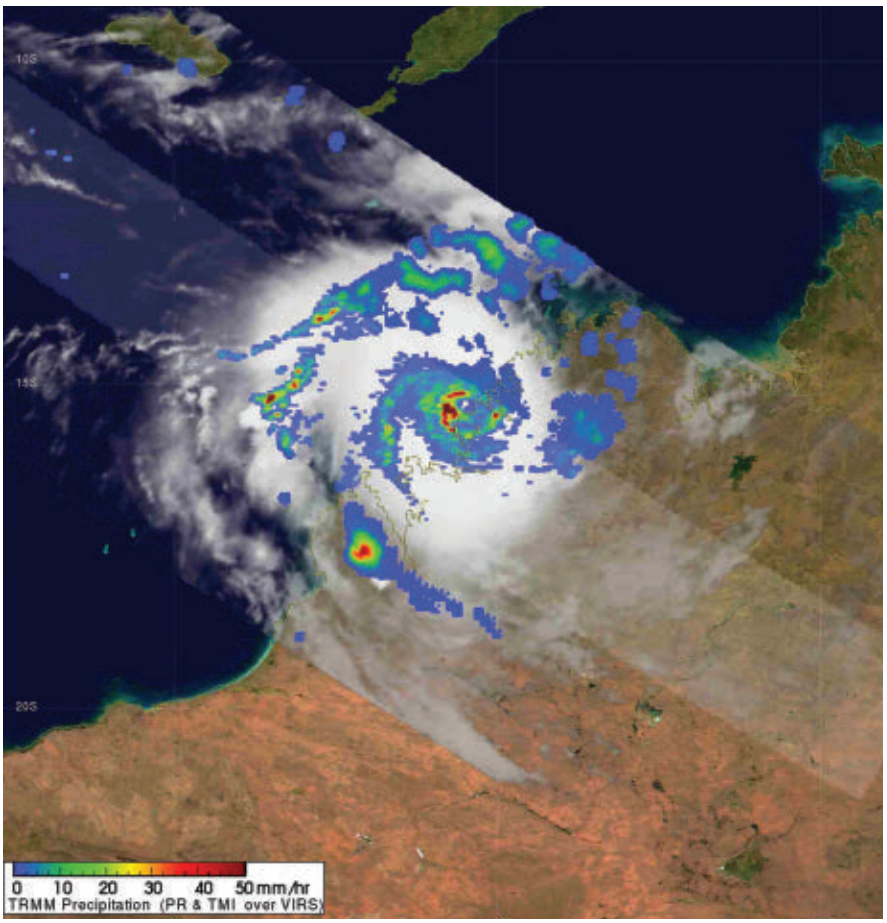
BY ANNE L. FISCHER
CONTRIBUTING EDITOR

The Tropical Rainfall Measuring Mission (TRMM) is a project run jointly by NASA and the Japan Aerospace Exploration Agency to monitor and study tropical rainfall. When tropical cyclone Laurence hit Australia in December 2009, TRMM determined that total rainfall exceeded 150 mm.

The three primary instruments onboard the satellite are precipitation radar, a microwave imager, and a visible and infrared scanner. Although radar devices have been used since World War II for meteorological applications on the ground, TRMM is the first attempt to use radar to measure rainfall quantitatively from space. To construct high-resolution, three-dimensional maps during the short period of time the satellite is flying over a storm, Japan's Communications Research Laboratory used a radar frequency about three times higher than that of typical ground-based radar, and the team designed a "phased array" antenna that would narrow the beam as well as steer it to the target area.

The microwave scanner onboard is an updated design of an instrument that dates back more than 20 years. It has an additional 10.7-GHz channel, which adds the sensitivity needed to record the higher rates of rainfall common in tropical regions. The visible and infrared scanner measures radiation coming up from the Earth in five spectral regions from 0.63 to 12 µm. The instrument's rotating mirror picks out individual cloud features as small as 2.4 km as it scans across an area 833 km wide.

Another instrument onboard is a lightning sensor that combines optical and electronic elements. One of these components is an imager that stares at one point on Earth for 80 seconds to find out whether a storm is growing or decaying, determined by how fast the lightning is flashing. The imager's expanded optics lens system provides a wide field of view and a narrowband filter that minimizes background light. It has a high-speed CCD detector array that creates an image of the lightning; then a real-time event processor extracts the signal, calculating when the lightning occurred. The system is designed to distinguish lightning even against bright sunlight.




Precipitation analysis done aboard TRMM shows that tropical cyclone Magda was dropping about 2 in. of rainfall per hour west of the eye, and some of the intense thunderstorms near the eye were as high as 16 km. Credit: NASA/SSAI/Hal Pierce.

The sensor was developed by the Global Hydrology Center at NASA's Marshall Space Flight Center in Huntsville, Ala., in conjunction with Lockheed Martin of Palo Alto and Kaiser Electro Optics of Carlsbad, both in California. Continued development may result in an instrument that helps weather forecasters see where lightning is striking Earth within 30 seconds of an occurrence.

The data generated by the instruments aboard the TRMM research satellite are intended to help increase our knowledge of the rainfall and heat release associated with weather in tropical and subtropical regions. It's understood that the atmosphere is propelled around the globe by solar energy as well as by evaporating water, so, by studying tropical rainfall, much can be learned about the global climate.

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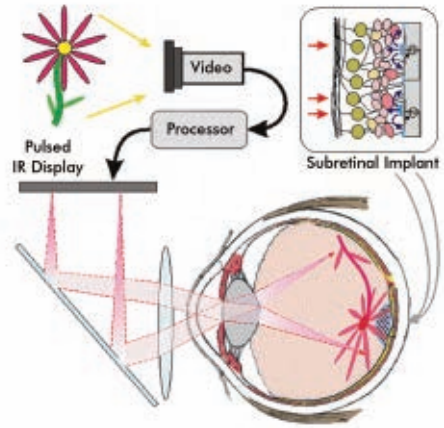
# Restoring vision with photovoltaic optoelectronics

As life expectancy increases, our eyes bear the brunt of aging; many of the elderly suffer from vision problems. One of the leading causes of eye problems in the Western world is macular degeneration. To correct this, retinal implants, generally consisting of about 60 electrodes, have been inserted into the back of the eye. The patient wears glasses incorporating a tiny camera that views what the patient normally would, and the camera sends the image data to a minuscule computer. The computer converts the data to electrical signals, which are sent to the implant and processed by the brain. While garnering attention, these implants have yet to truly restore vision that's any sharper than fuzzy images.

A multidisciplinary team led by Daniel Palanker from Stanford University in California is taking implants a step further using LCD technology, the infrared spectrum and photovoltaics. While the study subject is wearing what look like goggles with an LCD screen inside, the image on the LCD screen – the image the patient would normally see – is projected with pulsed infrared light onto photovoltaic cells implanted under the retina. The photovoltaic cells convert the light signals into electrical impulses, which then stimulate retinal neurons above them. The current design includes about 1000 photovoltaic pixels.




A diagram of the photovoltaic retinal prosthetic system includes a video camera, an image processor, a pulsed infrared microdisplay inside video goggles and a subretinal photovoltaic array.

There are some important differences between this approach and a traditional implant. One is the quality of the image produced, and another is the fact that patients don't have to move their heads, rather than their eyes, to perceive an image. With traditional implants, the image changes when the camera moves – that is, when the head rotates. In normal-sighted people, on the other hand, visual perception is dependent upon continual eye movement, which refreshes the image. The photovoltaic retinal prosthesis retains this natural link between image perception and direction of gaze.

Another advantage to this new method is that the implant is made of flexible silicon, so it can fold and bend over the shape of the retina. This allows for a close fit, which helps maintain a close contact between the electrons and neurons.

In people who are suffering from retinal degeneration, the photoreceptor cells slowly deteriorate while many of the retinal neurons that process the signals from the photoreceptors and send them to the brain still survive and are able to function. When those neurons are mechanically stimulated, so-called "phosphenes" are produced, which give the perception of light.

The challenge, however, is that thousands of pixels are needed to restore sight to a useful level. In addition, those pixels must be delivered at video rate, the electrodes must be very close to the target cells, and signal processing must sufficiently compensate for the partial loss of the retinal neural network, among other complications. The system designed at Stanford, therefore, was, by necessity, a multidisciplinary effort.

Included in the new implant system is a data stream from a video camera, which is processed by a computer. The images displayed on the LCD microdisplay are illuminated by a pulsed 0.5-ms near-infrared light (900-nm wavelength), which projects the image through the optics of the eye onto the retina. The infrared image is received by the photovoltaic pixels in the chip implant.

The team is currently working on fabricating and testing the photovoltaic arrays in vitro and in vivo. The researchers are also studying the effects of retinal degeneration on circuitry and are developing software that will take over some of the retina's functions, allowing patients to fine-tune their implants, much as an optometrist adjusts lenses according to our vision.

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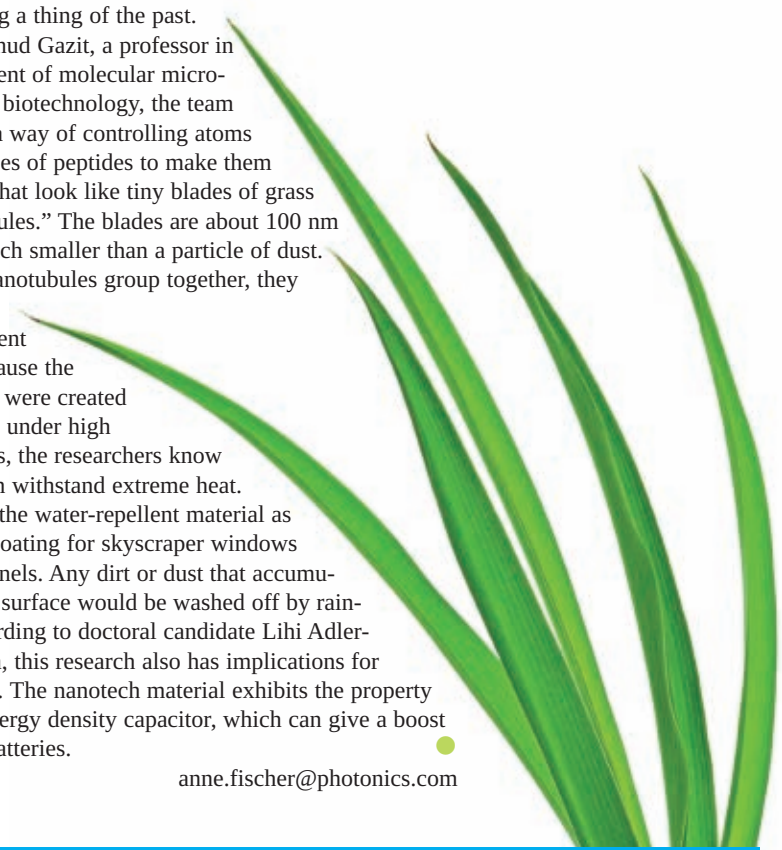
# Peptides do windows

Nobody really likes washing windows. And dirt and grime – the kind you find on windows – are the bane of a solar panel's existence. The good news is that a group of researchers at Tel Aviv University in Israel, which set out originally to find a cure for Alzheimer's disease, may have found a self-cleaning coating that will make window washing a thing of the past.

Led by Ehud Gazit, a professor in the department of molecular microbiology and biotechnology, the team discovered a way of controlling atoms and molecules of peptides to make them grow into what look like tiny blades of grass or "nanotubules." The blades are about 100 nm in size – much smaller than a particle of dust. When the nanotubules group together, they form tiny, water-repellent forests. Because the nanotubules were created in a vacuum under high temperatures, the researchers know that they can withstand extreme heat.



They see the water-repellent material as a potential coating for skyscraper windows and solar panels. Any dirt or dust that accumulated on the surface would be washed off by rainwater. According to doctoral candidate Lihi Adler-Abramovich, this research also has implications for electric cars. The nanotech material exhibits the property of a high-energy density capacitor, which can give a boost to electric batteries.

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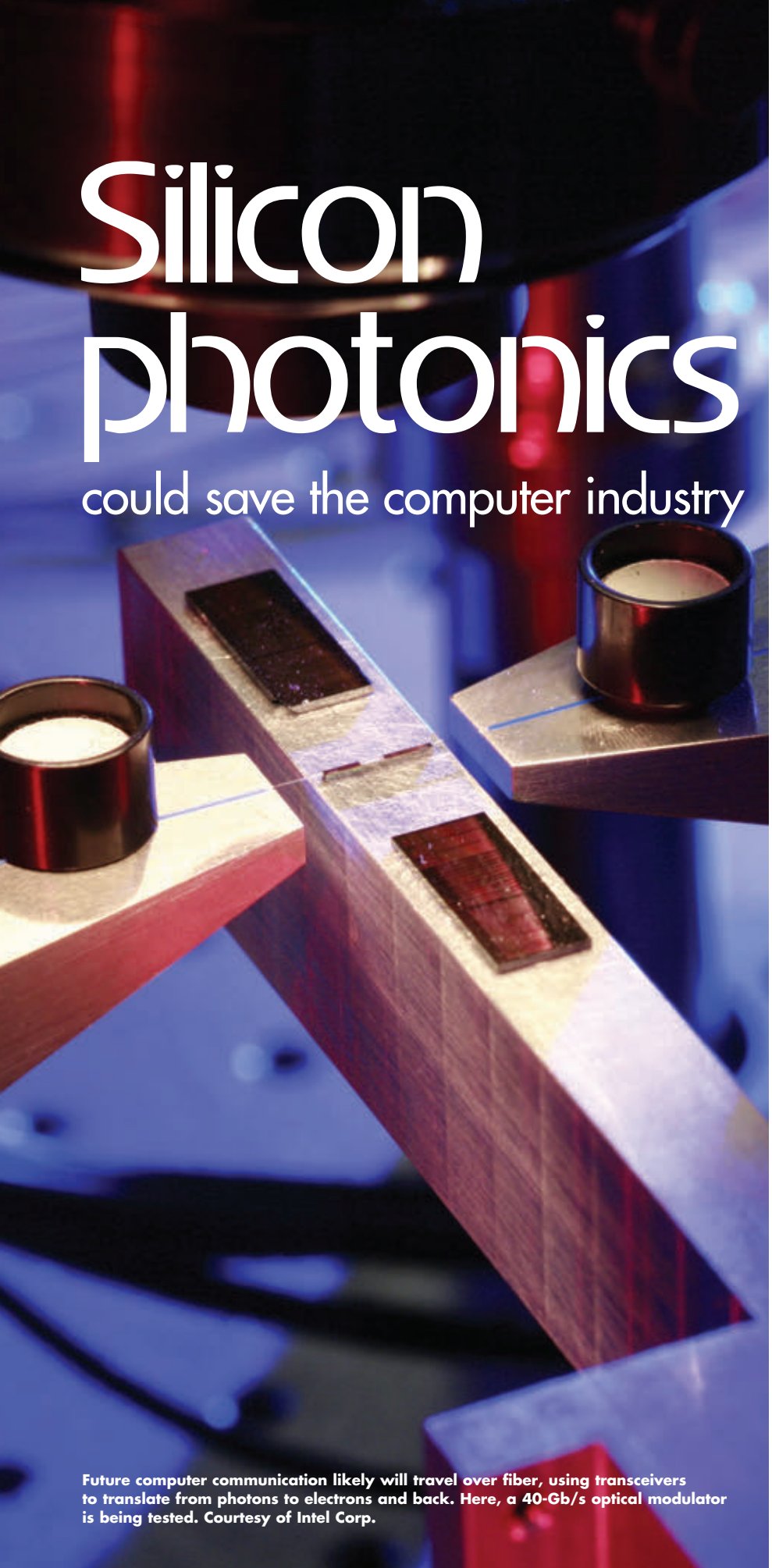
# Silicon photonics

## could save the computer industry



Future computer communication likely will travel over fiber, using transceivers to translate from photons to electrons and back. Here, a 40-Gb/s optical modulator is being tested. Courtesy of Intel Corp.

BY HANK HOGAN
CONTRIBUTING EDITOR

The future of computing may need a light touch – literally. As chips move more and more data around, the metallic wiring on and between them eventually won't be able to keep up.

The solution may be silicon photonics, a technology that employs silicon as an optical material. If compatible with standard CMOS semiconductor processing, silicon photonics promises inexpensive optical devices, easy integration with electronics and speedy data delivery.

First, though, researchers must grapple with a variety of issues, including reducing the cost to virtually nothing and finding ways to overcome a basic material drawback.

"The fundamental problem is silicon doesn't emit light. It's an indirect bandgap material," said John Bowers, a leading researcher in the field and a professor of electrical and computer engineering at the University of California, Santa Barbara.

Researchers are working to solve this problem by incorporating more emission-efficient III-V semiconductor compounds such as indium phosphide or indium gallium arsenide. Another possibility would be to produce the light off-chip and use silicon only for modulation, routing and detection.

With regard to the latter, silicon photonics can outperform existing approaches. For example, Bowers and others demonstrated a silicon-germanium avalanche photodiode with better performance than one built with more conventional III-V semiconductors.

Companies are already putting silicon photonics to work. A look at near-term prospects – and some far-out ideas – shows where the technology is headed.

### The five-meter solution

"We're not trying to solve the 100-km problem, like in telecom. We're trying to solve the five-meter problem," said Mario Paniccia, photonics technology lab director at the biggest chipmaker of them all, Santa Clara, Calif.-based Intel Corp.

Doing so would allow servers to talk to each other over fiber and solve some data center bandwidth, thermal and cost problems. That's because less power would be needed to move data, and having higher bandwidth could allow system architecture changes.

Being able to bridge 5 m with an inexpensive optical connection also would allow a single thin cable to connect devices in a home. Furthermore, notebooks could be thinner because connectors would be less bulky yet would offer higher bandwidth.

Intel recently announced its Light Peak optical interconnect technology, along with plans to ship product this year. On the photonics side, there's an optical transceiver chip that moves data over distances of less than 50 m.

Multiple vendors will supply the optical chips, Paniccia said. The first-generation modules will consist of 850-nm vertical-cavity surface-emitting laser-based technology. They will offer two independent channels at 10 Gb/s. In the future, the technology will boost the rate to 100 Gb/s.

Another silicon photonics approach comes from privately held Luxtera Inc. of Carlsbad, Calif. The company's philosophy, said vice president of marketing Marek Tlalka, is to route photons on a CMOS chip, much as is done with electrons, and to do everything in a mainstream CMOS manufacturing process.

Because silicon absorbs light in the visible and near-infrared ranges, those guidelines have implications for photonics, Tlalka said. "To transmit light on a CMOS chip, you need to operate at a longer wavelength, in the range of 1300 to just sub-1600 nm."

Luxtera has chosen to use 1490-nm lasers, which are surface-coupled into waveguides. These waveguides, in turn, send the light into silicon modulators that can toggle the beam on and off 10 billion times per second. Multiple modulators, arranged in parallel or multiplexing at different wavelengths, will allow scaling of data rates to the 100-Gb and, ultimately, the terabit ranges.

The technology today, the company claims, allows 10-Gb connections at a cost per port in volume of less than $50, one-tenth that of other optical technologies and comparable to the electrical equivalent. However, their silicon photonics technique uses less than one-third the power of an electrical approach.

Luxtera spent years perfecting its manufacturing recipe, working with partners on such things as the best way to deposit and then etch germanium, which is required for integrated photodetectors. In selling its products, the company faced a problem. Most data center optical connections are done using 850-nm light, a wavelength incompatible with Luxtera's technology. The company resolved this issue by making its first product what it called an active optical cable, which allows the longer wavelength to be employed without affecting users.

## Farther out and closer in

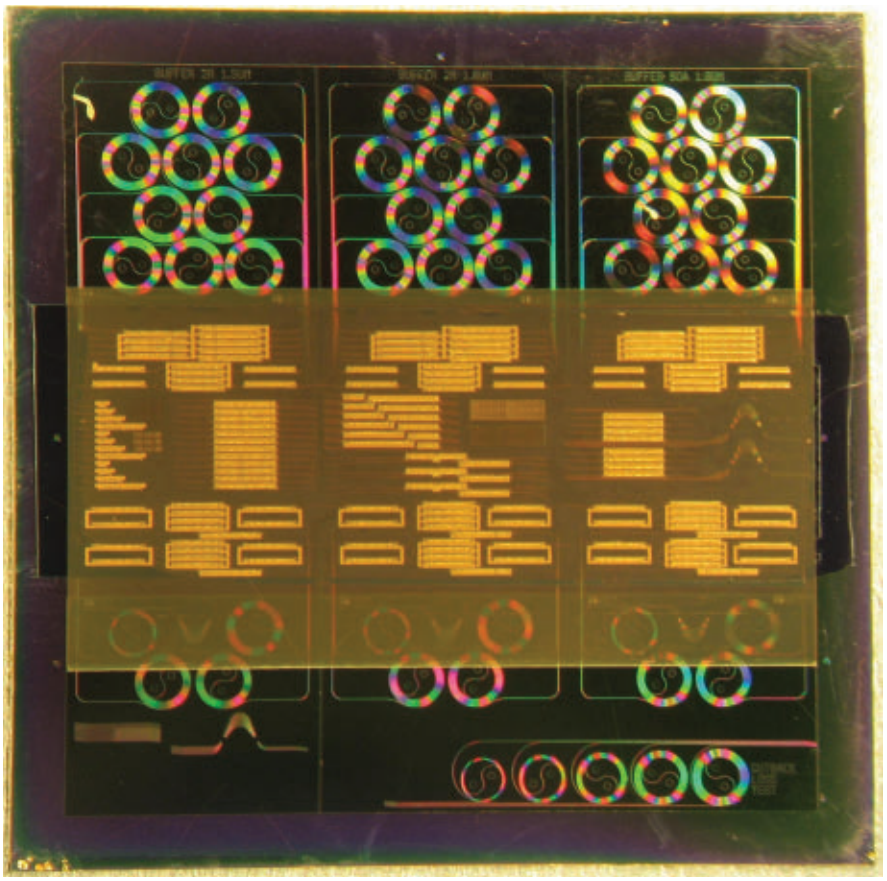
Data transmission challenges also are expected to crop up for chip-to-chip and even subchip distances. Microprocessors, which today may have two or four cores, eventually will have hundreds of cores, all running independently while swapping data back and forth. Estimates are that today 40 percent of the power needed to run a chip is consumed by moving data on and off the device. Higher data rates and more cores will drive this number higher, unless something is done.

Ray Beausoleil, a physicist at Hewlett-Packard's research labs in Palo Alto, Calif., noted that photonics can solve this problem. "Using light allows you to spend much less energy to send a signal from a transmitter to a receiver. It also allows you to significantly increase the number of connections that you have by using wavelength division multiplexing."

The work by Beausoleil and others at HP Labs is aimed at driving down the cost in dollars and the energy of computer interconnects. On the money side, the connections have to be essentially free. As for the energy expense, that too has to be almost nothing. The goal is to get as close as possible to 100 fJ per bit transmitted, roughly 10 times better than the current best research results.

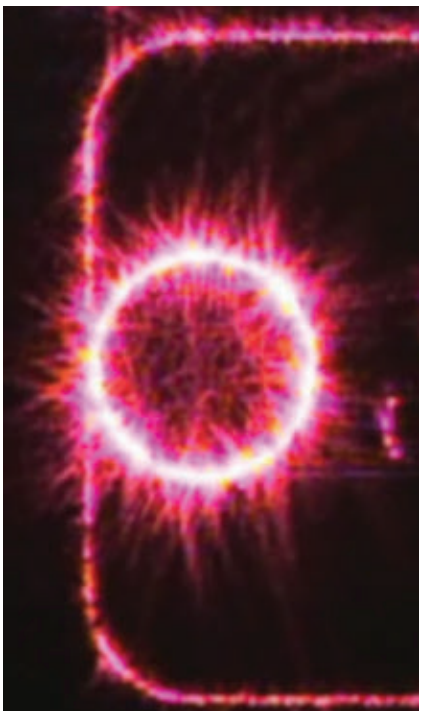
Beausoleil, Bowers and others recently published a paper on a compact hybrid silicon microring resonator laser, the type of device that could act as an on-chip light source. It's a hybrid because it uses a III-V semiconductor material, along with silicon, to generate continuous-wave laser light in a structure with a 12.5-µm radius.

Beausoleil noted a number of challenges in chip-scale silicon photonics. Still to be decided are fundamental questions such as whether to put the light source on



Optical buffers built in silicon, such as this chip, could be used as building blocks for silicon photonic circuits. The rings seen here function as long delay lines. Courtesy of John Bowers, University of California, Santa Barbara.

the chip or to bring it in. He added, though, that the new technology may be able to piggyback on trends in the electronics industry.



Shown here is a U-shape waveguide that glows because the light is tuned to the resonant frequency of the ring in the center. In practice, this structure would act as a modulator by injecting charge into the silicon, thereby tuning the ring's frequency as needed to allow light to pass, or to stop it from doing so. Courtesy of Hewlett-Packard.

Currently, chips are two-dimensional, but interconnect needs are forcing the industry into the third dimension. In the future, chips essentially will be stacked atop one another. As a result, memory and logic functions may be on separate layers. A photonic networking layer could be implemented on top of that, allowing on-chip optical routing.

That's a solution being investigated by Yurii Vlasov, manager of silicon integrated nanophotonics at IBM in Yorktown Heights, N.Y. He noted that implementing such a layer creates numerous hurdles. For example, a running chip generates heat, causing a temperature rise of as much as 30 °C. That rise isn't uniform or stable, Vlasov said. Instead, there are hot spots, which move around as circuitry switches on and off.

Designing optical components to handle such heat swings will be a challenge, especially given that the devices must be compact, inexpensive, low in power usage and CMOS-compatible. Nonetheless, suitable switches, modulators, wavelength division multiplexing filters and detectors have been demonstrated, at least in a laboratory.

Although Vlasov doesn't expect on-chip silicon photonics to appear soon, the day also isn't that far off, he said. "We have all the building blocks. It is now a question of putting it all together."

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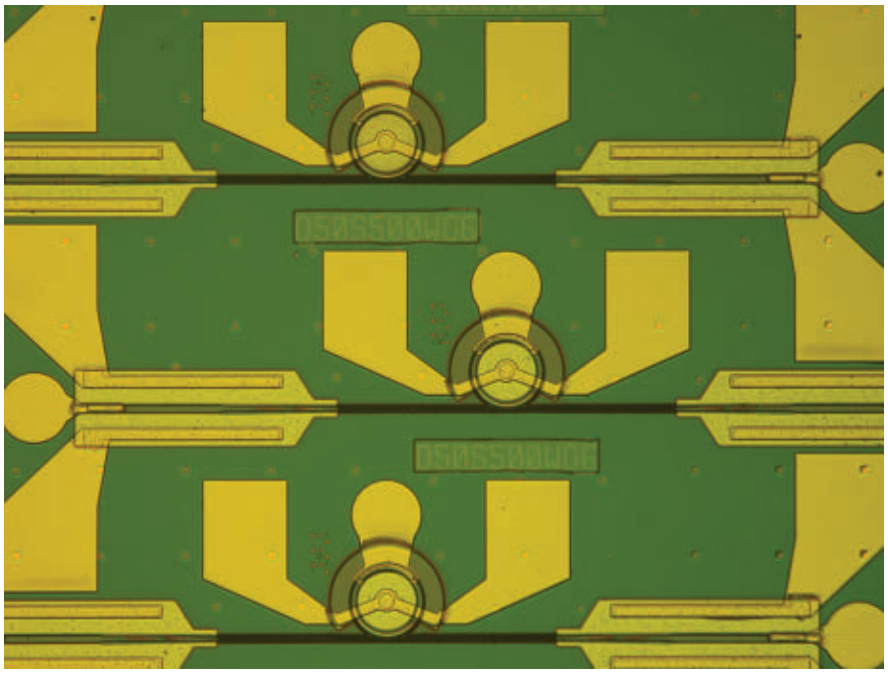

A hybrid silicon ring laser, like the three shown here, could be used as an on-chip light source in future photonic circuits. The 12.5-μm-radius rings in the image consist of a III-V compound semiconductor. Waveguides – the black lines running below the rings – connect two integrated photodetectors. Courtesy of Di Liang, University of California, Santa Barbara.

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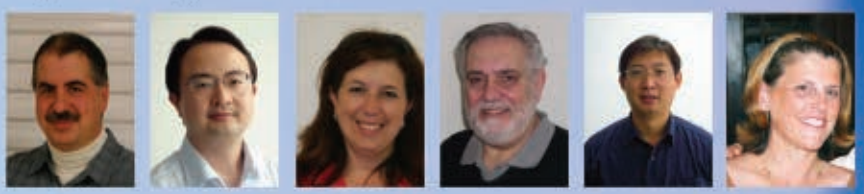

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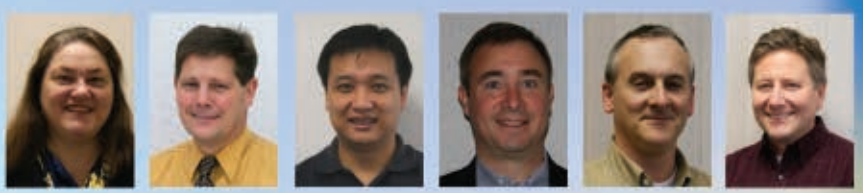

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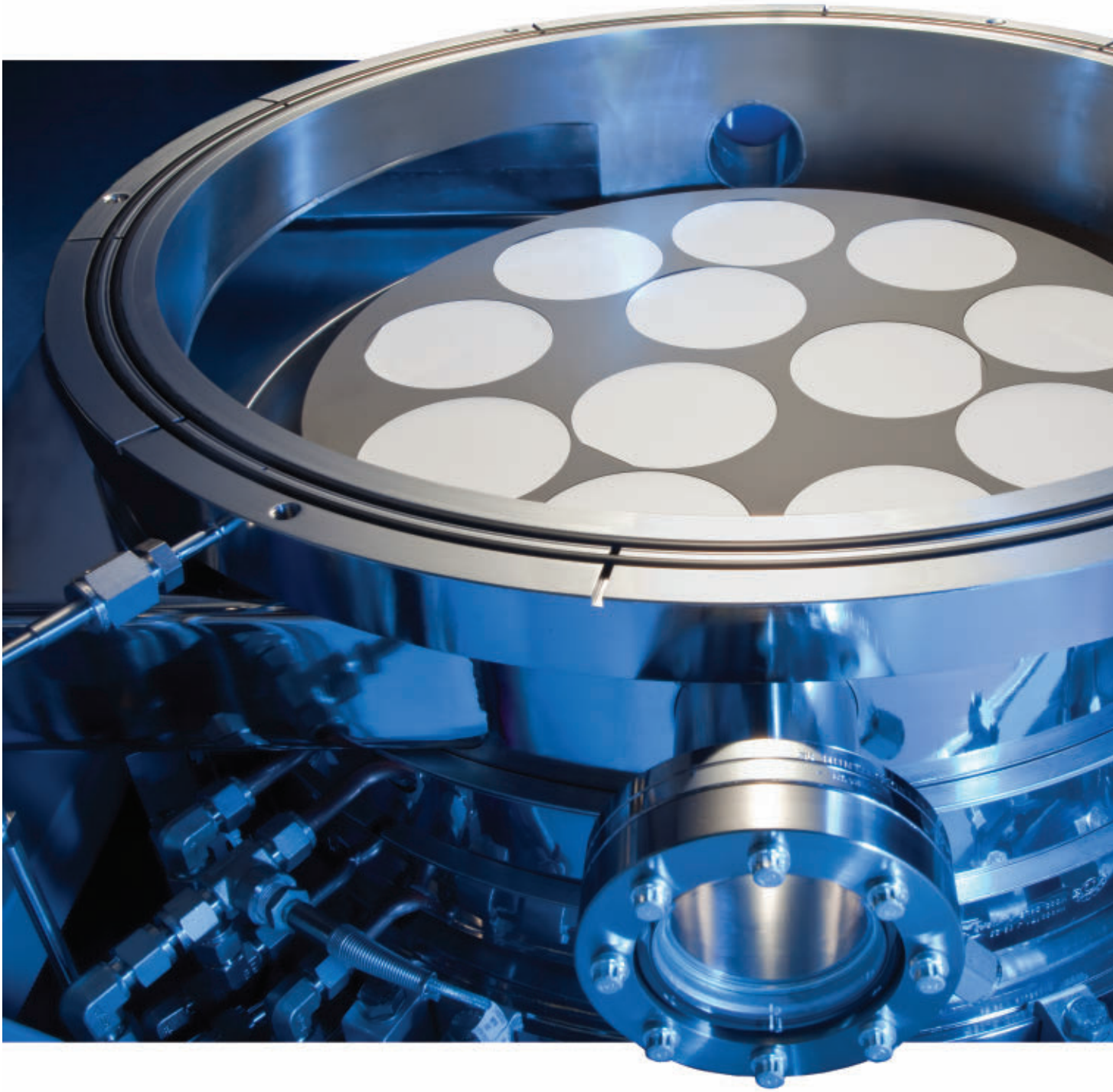


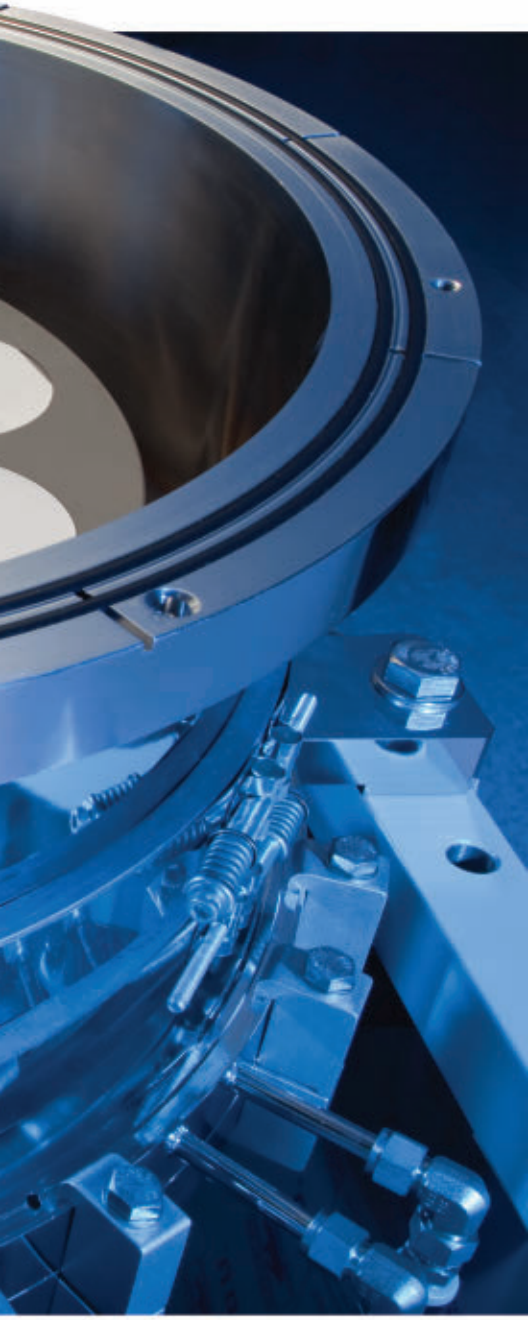
# MOCVD SYSTEMS MEET LED BACKLIGHT DEMAND

BY ANNE L. FISCHER, CONTRIBUTING EDITOR

**EXPLOSIVE GROWTH** in the backlighting market for televisions, displays, handheld devices and more is creating a ripple effect throughout the LED industry. LEDs are sought after for backlighting because of their proven performance, low power consumption, slim form factors, variety of colors and because, unlike fluorescents, they contain no mercury.

According to the September 2009 *Quarterly LED & CCFL Backlight Report* by DisplaySearch of Austin, Texas, shipments of LED backlight panels grew 116 percent from first- to second-quarter 2009. In a subsequent report, DisplaySearch forecast that fluorescent lighting for notebook PCs, monitors and TV displays would drop to 44 percent in 2011, while LEDs would hold 56 percent of that market.

Although Samsung dominated the LED TV market in 2009, according to Displaybank of Bundang, South Korea,



THIS MOCVD MANUFACTURING SYSTEM ACCOMMODATES WAFER SIZES OF UP TO 8 INCHES. PHOTOS COURTESY OF VEECO.

announcements at the Consumer & Electronics Show in Las Vegas in January indicate that LED backlit TVs are proliferating and are being marketed not only by many leading manufacturers but also by some who are sidestepping from other lines. ViewSonic, Westinghouse and Haier are just a few of the many who were showing LED-backlit TVs.

The good news for LED manufacturers is that they are going to be kept extremely busy into the foreseeable future. Even better news is that many TV makers, such as Samsung, LG and Sharp, are making their own LEDs using metallorganic chemical vapor deposition (MOCVD) process systems.

## LED MANUFACTURING

At its core, LED manufacturing is the same as that for producing compound semiconductors: It uses epitaxy, a process in which very thin layers of material are deposited or grown on a substrate. The layers are crystalline structures, often consisting of very different elemental materials, such as gallium, arsenic, indium, phosphorus, nitrogen, silicon, germanium, antimony, aluminum and beryllium.

The common technologies used to deposit or grow these layers are MOCVD and molecular beam epitaxy. MOCVD provides the lowest cost and highest throughput of the two processes and is more commonly used by leading LED manufacturers for everything from traffic signals, car taillights, billboards and signage to TV backlighting and general illumination.

Shipments of LED backlight panels grew 116% from first- to second-quarter 2009.

Paul Semenza, an analyst at DisplaySearch, said that MOCVD is the preferred method for LED manufacturing. Orders for this equipment are going through the roof, he said.

MOCVD is used in growing epiwafers of III-V compounds. It uses metallorganic compounds such as trimethyl gallium or trimethyl aluminum as precursors for the material in thin films. The process transports the precursors via a carrier gas to a hot zone within a growth chamber. Thin films are produced when the precursors react or dissociate with another compound. The resulting LED is produced by changing the composition of the deposited materials and doping the epilayers with specific elemental materials to change their electrical properties.

Two leading manufacturers of MOCVD equipment are Aixtron AG of Aachen, Germany, and Veeco Instruments Inc. of Plainview, N.Y. James T. Jenson, vice president of marketing for the LED business unit at Veeco, said that the greatest concern for LED manufacturers is economics.

"We've looked at LED manufacturing costs from the substrate coming into the LED line in the factory through the epi step and chip processing, all the way through final packaging." By increasing the yield and improving the process and tool architecture, he estimates that costs can be reduced fourfold from 2009 to 2013.

A few considerations that go into achieving the overall cost reduction include increasing automation, using a larger wafer size and improving the processes to ensure a higher throughput of very high quality LEDs. Although Semenza noted that one advantage of MOCVD is greater throughput and larger wafer size, the leading equipment manufacturers want to lower manufacturing costs while boosting output even further.

Jenson said that Veeco examines the cost of the epitaxial process on a square-centimeter basis, which requires looking at the labor that goes into using the epi tool. "The MOCVD process is a lot more labor-intensive than traditional semiconductor manufacturing. By lowering the epi cost while improving yield, you've improved everything. In other words, there is a multiplier to the cost benefit that occurs on the downstream processing when the epi step is improved."

Manufacturers also are paying close attention to the growth rate because speeding up the rate will improve process time. There are various ways of doing this, including tailoring gas-flow dynamics, adjusting chemistry concentrations and optimizing the temperature environment. The catch is not to compromise the end result for the sake of faster output.

Automation also is helping to improve process time. By using loaders on the reactors, the number of wafers in a batch or the speed at which they are loaded can be increased. And by automating the loading process, common human error is eliminated. Veeco has a tool that automatically moves the wafers in and out of the reactor, a hands-free operation that eliminates the need to open the reactor by hand, release its vacuum pressure and lower the temperature. By maintaining the reactor under vacuum and at the proper temperature during wafer loading and unloading, productivity remains high.

WITH UNIFORM CHEMICAL FLOW OF CRITICAL IMPORTANCE, THIS SYSTEM USES A PATENT-PENDING TECHNOLOGY THAT ENSURES A CONSISTENT FLOW PATTERN OF ALKYL AND HYDRIDE ACROSS ALL WAFERS.

NEW LED-BACKLIT TVS ANNOUNCED AT THE CONSUMER & ELECTRONICS SHOW IN LAS VEGAS IN JANUARY, INCLUDING THIS VIEWSONIC LED HDTV, SHOW THAT THE TECHNOLOGY IS CATCHING ON. COURTESY OF VIEWSONIC.

## LEDS FOR BACKLIGHTING

LEDs come in a variety of flavors for a variety of applications. Those for general illumination are color-tuned to emit bright whites. Signal lights used in automotive applications are manufactured in specific colors and sizes. LEDs used for notebook computer backlighting are very small and use low to medium power. They usually are on the order of 0.3 × 0.3 mm on a side and can be mounted on the edges or behind a display. When lit, a diffuser plate and optics control the light so that it appears uniform behind the display.

For backlighting, LEDs offer additional advantages: Their small size allows for extremely thin displays, and they can be turned on and off as needed, enabling "local dimming." For example, when an area on a TV screen is supposed to be dark, a screen lit with fluorescents would have to shut off a whole series of tubes, whereas an LED backlit display can simply turn off the LEDs behind that dark area. This improves the contrast ratio and is a benefit that is seeping into marketing campaigns for some of the leading TV ads.

One challenge, however, is in ensuring the consistency of film thickness. The whole process can take from six to 11 hours, a period during which many things can happen. Temperature control is critical, especially when it must be changed for a specific period. Being able to do it precisely affects the final outcome. Controlling the gas entering the chamber also is critical because each wafer must receive the same gas or chemical process to ensure consistency of the end product. Thus, both temperature and gas flow must remain constant throughout the process – and from run to run.

We are now seeing MOCVD systems with state-of-the-art reactor technology for high-volume production with process control. With LED manufacturing at an all-time high, demand for these systems is strong and growing. In addition, MOCVD process systems are used in space-based solar and concentrated photovoltaics – two areas that also are seeing unprecedented demand.

Semenza said that, with only a handful of manufacturers of MOCVD equipment, "the market is certainly ripe for new entrants."

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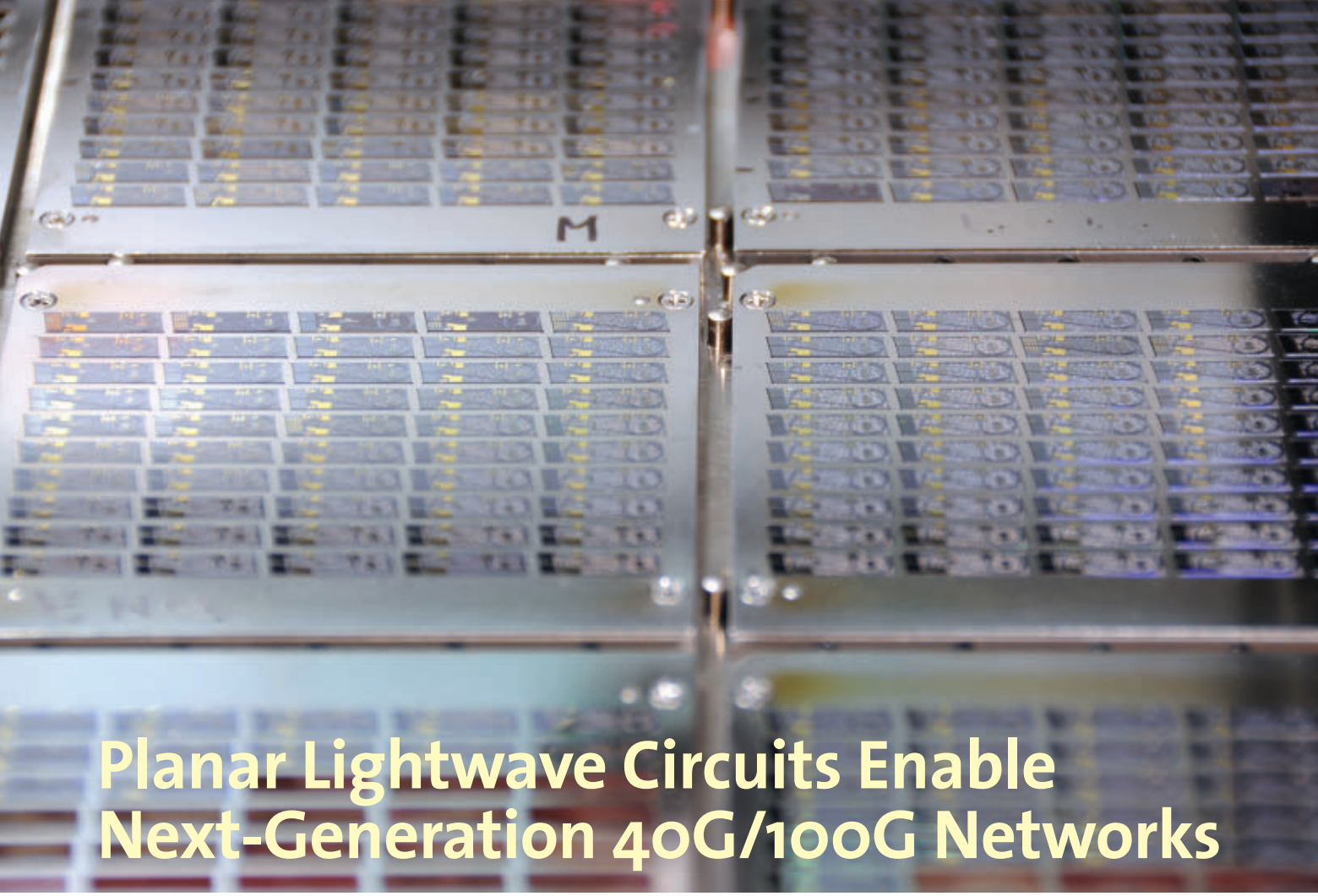


# Planar Lightwave Circuits Enable Next-Generation 40G/100G Networks

BY DR. ASHOK BALAKRISHNAN
ENABLENCE TECHNOLOGIES INC.

THE AVAILABILITY OF BANDWIDTH-INTENSIVE SERVICES SUCH AS FIBER-TO-THE-HOME, ALONG WITH BANDWIDTH REQUIREMENTS IN THE COMMERCIAL SECTOR, HAS CREATED A GROWING DEMAND FOR THE INTRODUCTION OF NEW 40G/100G OPTICAL NETWORKS.

Many new systems rely on advanced modulation formats such as differential phase shift keying and differential quadrature phase shift keying to complement traditional architectures such as dense wavelength division multiplexing. Each method presents substantial optical, mechanical and electronic complexity. Although traditional bulk-optic assemblies can achieve the required complexity in relatively low volumes in some cases, they have considerable problems meeting the additional requirements of volume manufacturability, compactness, ruggedness and low cost.

Advanced planar lightwave circuits (PLCs) can achieve the desired level of sophistication in a small, rugged package. These optical chips, similar in many ways to their electronic counterparts, are fabricated using wafer-level processing techniques, and they use optical waveguides to route photons the same way that metal traces are used to route electrons in an electronic chip.

Typical PLC modules for 40G/100G applications require the following subcomponents: a fiber interface, a wavelength filter or combiners, precise phase-delayed optical interferometers, polarization control and polarization-based splitting/com-

(Above) High-volume assembly of planar lightwave circuits (PLCs) includes automated alignment and bonding of lasers, photodetectors and other active components. Photos by Predrag Bosnjak, courtesy of Enablence Technologies Inc.

bining, optical isolators, laser sources and detectors.

Over the past several decades, PLCs have established themselves as an ideal way to create wavelength filters and stable interferometric structures. They are mass-producible, using the same general techniques as those in the semiconductor industry.

### PLC construction

A packaged PLC device consists of a planar chip with passive optical filters and a fiber pigtail. With standard etching and metallization techniques, the planar chip also can serve as a platform for active elements. Recently, successful hybridization methods were introduced onto the PLC platform that efficiently couple lasers and detectors to waveguides using passive automation.

**PLCs can achieve a desired level of sophistication in a small, rugged package.**

In a bulk optic assembly, lasers are coupled to fibers using one or more bulk-optic lens assembly. In that configuration, changes in mechanical positioning can occur because of temperature drift or stress, which leads to variations of the optical signal. In contrast, lasers can be soldered directly in front of a mode-matched optical waveguide on a PLC. In this configuration, there is little mechanical stress and no distance over which thermal drift can accumulate. Tracking error can be held to less than 0.2 dB quite easily, over a 120 °C range.

Optical receivers are fabricated by integrating photodiodes onto the PLC chip itself. In a bulk optic device, a lens is used to focus the incoming light into the narrow aperture of the photodetector. In a PLC, the detector chip can be placed within a few microns of the waveguide carrying the light, enabling the use of narrow-aperture (low capacitance) photodiodes without the need for active alignment.

Between the high-speed photodetector and the external electronics, there is usually a transimpedance amplifier (TIA). The PLC platform allows these TIAs to be mounted onto the optical chip platform, directly adjacent to the photodetector, ensuring optimal signal integrity at high data rates.

### Increasing bandwidth

In wavelength division multiplexing systems, data is created as pulses where the signal level is turned on or off to indicate ones and zeros. This method of modulation, sometimes called on/off keying (OOK) suffers from fiber nonlinearity and signal-to-noise problems at high data rates of 40 G per channel. To increase bandwidth, multiple wavelengths are used to pack more signals onto the same optical fiber. In this regime, PLCs have already proved advantageous from a cost and size standpoint, especially for systems with four or more wavelength channels.

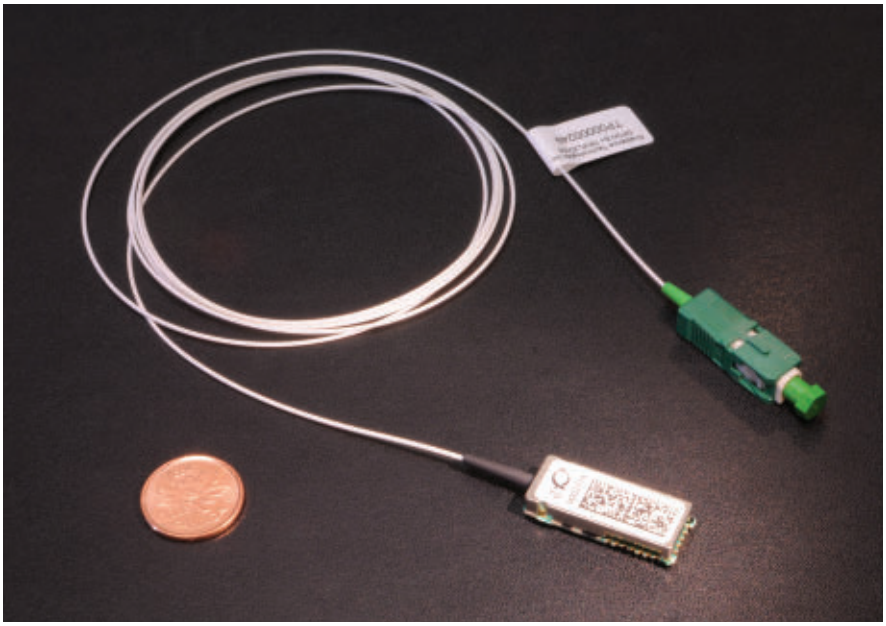
To reach higher per-channel bandwidths, sophisticated 40G/100G architectures are being developed that make use of phase-based multiplexing. This is called phase shift keying (PSK).

Differential PSK (DPSK) consists of a single stream of data at a defined bit rate. Through an optical delay line interferometer, data bits are interfered with preceding bits to create an intensity-keyed signal. This interference-based demodulation technique improves signal to noise and, for a variety of reasons, reduces fiber nonlinearity effects.

Because PLCs are manufactured using processes similar to those used in electronic wafers, they afford the possibility of stable delay lines that can be fabricated with photolithographic precision. Polarization effects in the network can be corrected using polarization diversity strategies implemented on the optical chip itself.

Phase shift keying capacity can be increased further using differential quadrature PSK (DQPSK). With this method, information is coded into two quadratures of optical phase, leading to a fourfold increase in the effective data rate. An optical wave can be subdivided into a set of constituent waves that do not mutually interfere.

Although an OOK pulse can represent only two states (0 or 1), a DQPSK pulse can represent four possible states (00, 01,



Compact PLC-based transceiver module includes a wavelength division multiplexing filter, a laser, multiple detectors, an amplifier and other subcomponents all integrated onto the PLC chip.

10 or 11). DQPSK starts with the bandwidth advantages of DPSK, then multiplies the bandwidth by accessing different quadratures (or phases) of light. The optical quadratures must be implemented on the scale of the wavelength of light itself and involve a phase difference equivalent to a few hundred nanometers, which can be extremely difficult to control using anything less than photolithographic precision.

To correctly demodulate a DQPSK signal, two delay lines similar to the ones used in DPSK are needed, but these must be delayed between themselves in phase by only one optical quadrature. This secondary delay must be held to a precision of tens of nanometers. The photolithographic precision of a PLC circuit is ideally suited to DQPSK.

Finally, TIAs, electrical traces (possibly impedance matched), decoupling capacitors and an assortment of small electronic components can be bonded close to the optical circuit – indeed, even immediately above optical waveguides and filters – leading to a high degree of compactness and signal integrity.

## Improving functionality

A typical hybrid PLC device consists of small optoelectronic chips and subcomponents integrated onto a larger optical chip, which typically comprises the optical filtering elements and other passive structures. This hybridized subassembly is then placed in a planar package, wire-bonded, pigtailed, lidded and tested for final use.

All of the processes involved in the manufacturing of such a component, from optical fabrication to final assembly, are suited to automated bonding and testing methods. The semiconductor and electronic chip industries have developed pick-and-place and flip-chip bonding processes that are well suited to PLC manufacturing. Wire bonding and postpackaging can be carried over from the electronics industry with little modification.

As customers demand more bandwidth, volume requirements will increase. And as is often the case, costs will continue to decrease despite the added functionality. Meanwhile, with so much deployment under way, ruggedness and reliability become mandatory requirements for any optical component.

Increasing system functionality imposes size restrictions on all components, but collapsing that functionality onto a single integrated optical chip presents an opportunity for meeting the needs of new 40G/100G systems, both now and as their requirements continue to evolve.

Hybrid PLCs represent an ideal choice for low-cost, rugged, compact optoelectronic components for a high-volume market.

## Meet the author

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ARRA

# The Year in Stimulus Funding:

## The impact of the American Recovery and Reinvestment Act on biomedical research

BY GARY BOAS, CONTRIBUTING EDITOR

*A little more than a year has passed since the American Recovery and Reinvestment Act (ARRA) was signed into law. In the May 2009 issue of* BioPhotonics, *we examined the potential impact of ARRA on the biomedical research community: The stimulus package set aside an additional $10.4 billion for the National Institutes of Health (NIH), effectively increasing its budget last year by 34 percent (though the funds will be disbursed over two years). Now, 10 months later, we look at how ARRA has benefited the community thus far, and at some of the challenges faced by the NIH since the act was introduced.*

Dr. Francis S. Collins had, as they say, his work cut out for him. In early August 2009, the former head of the Human Genome Project was sworn in as the 16th director of the NIH and thus was charged with overseeing what President Obama would later call "the single largest boost to biomedical research in history." The American Recovery and Reinvestment Act had allotted $10.4 billion for the NIH, with the twin goals of creating jobs and spurring innovation in biomedical research. It fell to Collins and his staff to disburse this additional funding and to figure out the best way to move forward and continue the work begun under the act.

In addition to funding previously submitted grants that did not make the initial cut, ARRA offered a variety of new opportunities, including the Challenge Grants, which were designed to support areas of biomedical and behavioral research that would benefit from significant jump-start financing. As of Sept. 30, the final day of the 2009 fiscal year, the NIH had disbursed $5 billion in ARRA money to more than 12,000 grants in both of these categories. In an interview conducted on Dec. 30, Collins reported that this money had created or saved 50,000 jobs, providing a much-needed shot in the arm for the biomedical research community and returning $2.25 on the dollar in goods and services.

The NIH has developed a Web site listing the studies funded by the Recovery Act and including a number of "ARRA Stories" (http://recovery.nih.gov/story.php). Among the latter is that of Oregon Health & Science University in Portland. As of Oct. 16, it had attracted $51.5 million in federal stimulus funding and created 116 full- and part-time jobs, with further hiring expected. These included study coordinators, research assistants, lab technicians and scientists in a variety of research areas.

The optics community has benefited as well. Irving Bigio of Boston University had previously submitted a grant application to the NIH to develop instrumentation that uses elastic scattering spectroscopy to perform real-time quantitative monitoring of programmed cell death in viable cell cultures. The proposal had received a good score, but not quite within the pay line. After the ARRA was signed into law, however, Bigio was told it

The National Institutes of Health has disbursed much of the $10.4 billion it was allotted in the American Recovery and Reinvestment Act, both by funding new grant applications and by revisiting previously submitted proposals. Shown here is a view of the NIH campus looking north. The Claude D. Pepper Building (upper right) provides office space for most NIH directors and their immediate staff. Images courtesy of the NIH.

would be funded. This saved one job, "potentially two," he said. It allowed him to maintain a post-doc whose contract would have been up otherwise, and it furthermore paid for a graduate student he might not otherwise have been able to support.

## A bumpy ride

The road has not been entirely smooth for the NIH. The Challenge Grants, the most high profile of the new funding opportunities, elicited more than 20,000 applications, leaving the institutes scrambling to find reviewers – 15,000 of them – and leading some to question the efficacy of the grants in helping the economy. In a July 7, 2009, letter to *Science*, a researcher from the University of South Alabama College of Medicine in Mobile wrote, "I am one of the 21,000 applicants for the NIH Challenge Grant, which will fund roughly 200 grants at a success rate of 1 percent. This unprecedented low rate makes me wonder whether this feeding frenzy is actually stimulating the American recovery." (When all was said and done, 3 to 4 percent of the proposals were funded.)

Bigio suggests that the ARRA money might have been used to greater effect by funding additional previously submitted grants, many of which are still worthy. "All of those grants had gone through a rigorous review process – in fact, much more rigorous than for the Challenge Grants," he said.

In an interview published in the Oct. 9, 2009, issue of *Science*, Collins was asked whether he would rethink the Challenge Grant competition if given the opportunity to do it over again. "I wasn't here then, but I don't hear that from others," he replied. "I would say this is a great problem to have. What it showed was this pent-up demand that had been building over five years of flat budgets."

A broad range of research projects, including a number of optics-related studies, have benefited from ARRA dollars.

Much of that demand is still there, of course. Collins noted that 2011 could be a "pretty tough year" in terms of success rates because of a possible lag in the NIH's budgets, but also because many of the Challenge Grant applications that were not funded will be resubmitted as traditional R01 grant applications. Still, the American Recovery and Reinvestment Act helped to advance a great deal of research that would not have been funded otherwise, while creating jobs and putting money back into the economy. The challenge now is to ensure that this work continues.

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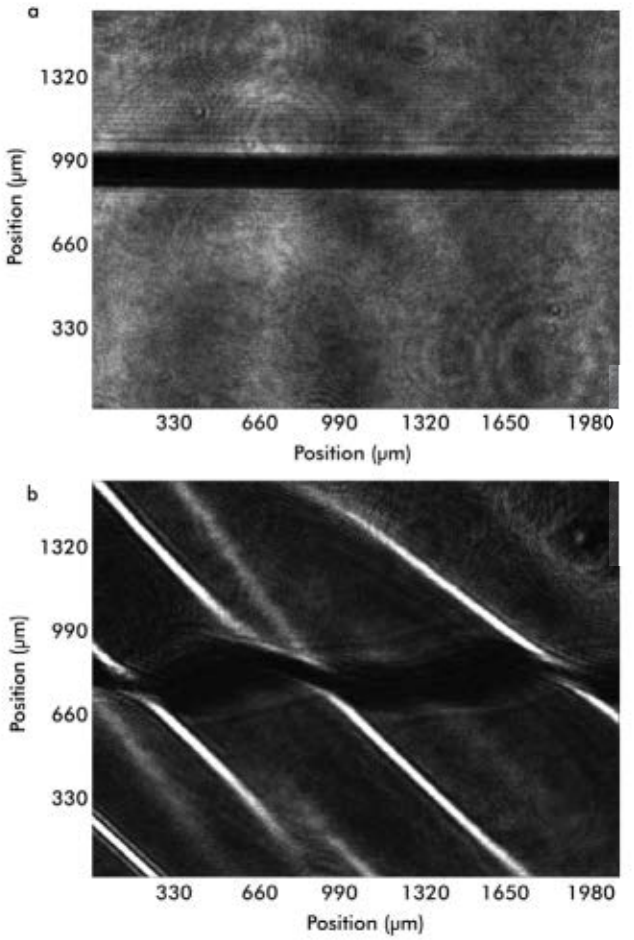
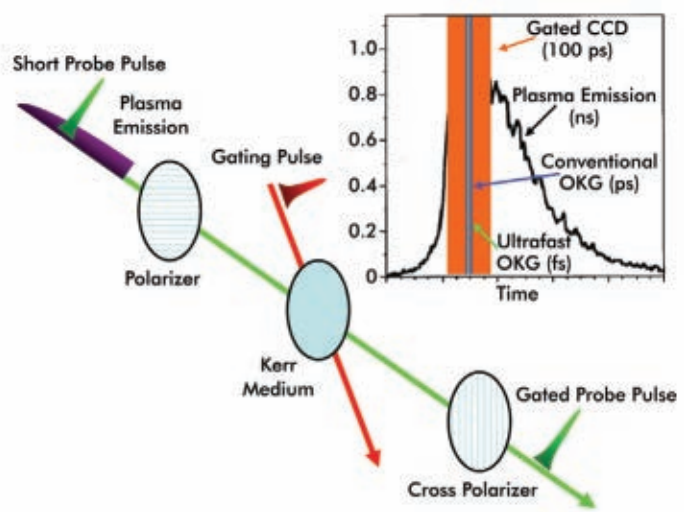



Not all materials are equal candidates for use as optical Kerr gates. Zinc oxide works fairly well (a), although it absorbs pulse probes around 400 nm. Lead-bismuth glass (b) produced striations in the image, which excludes it for future consideration. Reprinted with permission of *Applied Physics Letters*.




Using an optical Kerr gate is the key to ultrafast imaging of laser-induced plasma, according to researchers at Rutherford Appleton Laboratory and at Imperial College London. The CCD used for imaging is placed behind crossed polarizers; aiming intense gating pulses at the nonlinear Kerr medium alternates its birefringent state, permitting a quick shuttering effect. Courtesy of Dan Symes, Rutherford Appleton Laboratory.

# Specialized "shutters" capture superquick PHENOMENA

BY LYNN SAVAGE, FEATURES EDITOR

Remember when "faster than a speeding bullet" was exciting news? At about 2700 mph, the quickest ammo is moving turtle-slow when compared with the rates needed to study physical phenomena at the level of molecules, atoms or even photons themselves.

Researchers around the globe are studying the fundamental processes of the universe, from how biological cells talk to each other to how light interacts with matter. Discovering how the world works at the furthest outskirts of physical reality promises to improve how people interact with it. Ultimately, better medical, industrial and communications technologies – to name a few – are churned out because of novel investigations of ultrafast phenomena.

## Focusing on plasma

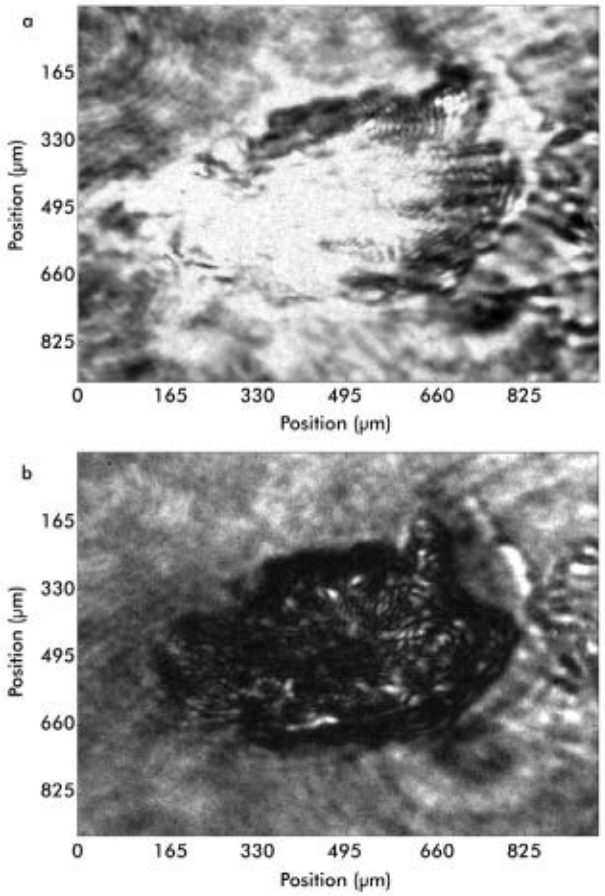
Point a high-powered laser at glass, metal or any other material, and you will burn away the substance, "instantaneously" ionizing the material. In the process, you will generate plasma, a gaseous blend of ionized particles. Studying the spectra of plasma provides information about its temperature and density as well as about the strength of the laser's harmonics. Backlighting plasma with a second laser or x-ray source also provides the opportunity to measure its electron density, which, in turn, enables imaging of related ionization fronts and shock waves.

As with basic photography, getting high-resolution images of even fast-moving plasma interactions requires similarly speedy shutter speeds. Unfortunately, no mechanical shutter comes close to being able to achieve the necessary pace.

Electro-optical gates are used as high-speed shutters because they remove the slow mechanical parts from the process. One type, called an optical Kerr gate, comprises a pair of crossed polarizers sandwiching a nonlinear medium. Struck with a high-intensity laser pulse, the nonlinear medium changes polarity briefly, "opening" long enough to allow the probe light through.

Although the Kerr gating effect has been used in spectroscopy, biomedical imaging and other applications, researchers at Rutherford Appleton Laboratory (RAL) in Chilton, UK, and at Imperial College London now have applied it to plasma imaging.

"A current hot topic in high-intensity laser interactions is the capability to accelerate electrons to gigaelectron (GeV) volt energies in a few millimeters of gas," said RAL's Dan Symes. According to Symes, lead author of a paper published in the Jan. 4, 2010, issue




Shown are shadowgraphic images of a 100-μm-thick glass target shot with a high-energy laser both without (a) and with (b) the use of an optical Kerr gate. Reprinted with permission of *Applied Physics Letters*.

of *Applied Physics Letters*, this acceleration occurs in a wake field behind the laser pulse. "The Kerr gated system would allow us to measure properties of this wake field on [a sub-10-fs] timescale."

Symes and his colleagues tried several candidate materials to act as the Kerr medium, including fused silica, Schott's NSF-66 glass, lead-bismuth glass and zinc oxide. Each had widely disparate results. The fused silica did well because its nonlinear response was about 1 fs, Symes said. Although the group coaxed gate times of about 100 fs, it still sees room for improvement.

"The crucial property of the material is that its nonlinear response must be effectively instantaneous," he said. "In that case, the gating time is limited by the laser pulse duration rather than the material."

Their next step is to improve the dynamic range and to accurately measure the temporal resolution of the system. Optimizing these properties will result in a system that is orders of magnitude better than conventional gated or streak cameras, Symes said.

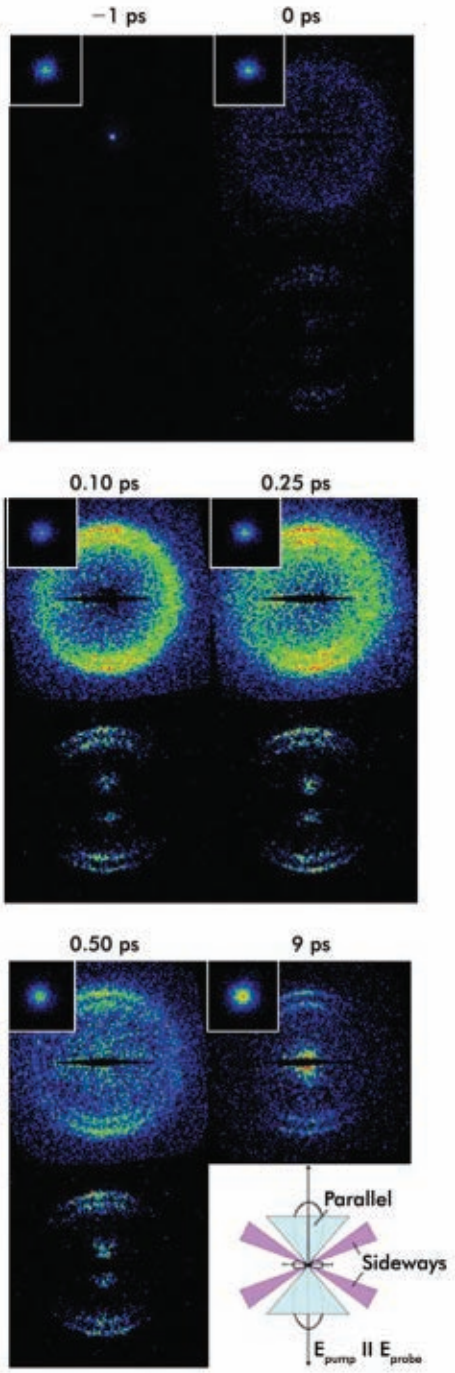
## Supercool imaging

Many high-resolution molecular spectroscopy studies require extremely low sample temperatures. However, many important molecules cannot be prepared with conventional cooling techniques. This catch-22 can be resolved by placing the molecule under investigation in superfluidic nanometer-scale droplets of helium, which can cool substances to 0.4 K yet have only a weak effect on the physical properties of the atoms and molecules that they host.

Furthermore, according to Oliver Gessner of the Ultrafast X-Ray Science Laboratory at Lawrence Berkeley National Laboratory in Berkeley, Calif., helium nanodroplets have been suggested as possible aides in single-shot imaging applications performed at places such as the Linac Coherent Light Source in Menlo Park, Calif.

"Here, the idea is to slow down Coulomb explosion effects in systems that are being exposed to novel ultraintense x-ray laser sources," Gessner said. Such damage mechanisms are the result of ultrafast charging processes in matter that is

subject to intense laser radiation. Slowing these charge build-up processes by embedding molecules in helium nanodroplets is expected to slow the motion of atoms during the exposure time, thus enabling sharper images of microscopic samples in the same way that it is easier to get a crisp photograph of a tortoise than of a hare at full speed.




Photoelectron images show electronically excited helium nanodroplets (top row) and helium atoms (bottom row). The timescale across the top indicates the pump-probe delay used during imaging. Reprinted with permission of the American Chemical Society.

To visualize the electronic dynamics of helium nanoparticles, he and his colleagues excited helium nanodroplets with 25-fs pulses of extreme-ultraviolet (EUV) radiation produced in a high-order harmonic-generation scheme using a 785-nm driving laser made by Kapteyn-Murnane Laboratories Inc. of Boulder, Colo. Using this ultrafast EUV light source, they excited helium nanodroplets to about 23.8 eV with a single photon. The excitation energy is above the ionization potential of helium nanodroplets, which is about 23.0 eV, but below the ionization potential of single helium atoms, 24.6 eV.

Following each pump pulse, the researchers sent a probe pulse of 1.58 eV. They recorded photoelectrons emitted from the helium clusters with a Dalstar 1M30P CCD camera made by Dalsa Corp. of Billerica, Mass. The pulse-probe scheme provided snapshots of the electronic dynamics in the nanodroplets with femtosecond resolution starting from the moment of excitation up to hundreds of picoseconds later.

"Femtosecond time-resolved photoelectron imaging of helium nanodroplets enables us to simultaneously follow the electronic and nuclear dynamics of electronically excited states of matter in real time," Gessner said.

The indirect photoemission process initiated by the pump pulses generates ultraslow electrons from the helium clusters. The low-energy photoemission is particularly interesting because it is the result of a convoluted relaxation scheme inside the nanodroplets, Gessner explained. "Nobody knows where the energy actually goes and which internal dynamics are associated with this energy redistribution mechanism."

Gessner's group, which reported its findings in the Jan. 28, 2010, issue of the *Journal of Physical Chemistry A*, wants to push the technique further into the realm of soft x-rays. Ultimately moving toward this higher photon energy regime, Gessner said, would let them visualize well-localized core electrons of atoms with a more sophisticated electronic structure than helium, thus gaining atomic specificity and insight into charge-carrier dynamics in photovoltaic devices and transition states in chemical reactions.

Continuing efforts by the teams led by Symes and by Gessner – as well as ultrafast research being performed at other labs – appear certain to run rings around lethargic ammunition.

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## 1 ☐ My principal job function is: (Please insert one letter only.)

Engineering- and Science-Related

A research & development
B design
C application
D manufacturing or production
E measurement (testing, quality control or safety)
F other engineering or science function (please specify) _____

Management- or Business-Related

G corporate
H engineering/technical
J manufacturing or production
K purchasing
L other management function (please specify) _____

Other

M consultant
N educator
P other functions (please specify) _____

## 2 ☐ Please indicate the primary end product or service of your company at this location. (Please insert one letter/number only.)

A aerospace/aviation systems
B agriculture, food, forestry & mining
C analytical, test or measurement instrumentation
D automotive or transportation
E cable TV/video/broadcasting
F cameras, detectors, sensors & electro-optical components
G chemical or pharmaceutical products
H communications equipment or services (incl. telcos, RBOC & other carriers)
J computer displays, peripherals, office & business equipment
K consumer electronics & appliances
L electronics, semiconductors & IC
M environmental monitoring
N fiber optic components or systems
P hospital/medical university or office
Q industrial control systems & robotics
R laboratory, government
S laboratory, industrial
T lasers/laser systems
U manufacturing equipment, machinery or metal products
V medical & biotechnology equipment
W military equipment
X navigation & guidance systems or equipment
Y optical components, materials or systems
Z plastics, polymers, rubber
1 printing, publishing, graphic arts
2 university/institution/college
3 utilities, energy, petroleum & coal
4 government personnel not classified elsewhere
5 industrial company or commercial user incorporating photonic products not classified elsewhere
6 other _____

**Principal Product or Service** _____

## 3 Which of the following publications do you read regularly? (Please check all that apply.)

A ☐ Advanced Imaging
H ☐ Laser Focus World
K ☐ Lightwave
M ☐ NASA Tech Briefs
N ☐ Nature
P ☐ OLE
R ☐ Physics Today
S ☐ Science
T ☐ Semiconductor International
V ☐ Vision Systems Design
X ☐ None of the above

## 4 ☐ The number of employees at this location is: (Please insert one letter only.)

A 1-10
B 11-25
C 26-50
D 51-100
E 101-500
F 501-1000
G 1001-5000
H over 5000

## 5 Which of the following technologies/sciences do you and/or your organization work with? (Please check all that apply.)

**A.**
A ☐ aerospace/aviation
C ☐ astronomy
D ☐ automotive
E ☐ biotechnology
G ☐ chemistry, chemical engineering
J ☐ chromatography
L ☐ communications
N ☐ computer engineering
P ☐ displays
R ☐ environmental monitoring/sensing
T ☐ forensic science
V ☐ holography
W ☐ lighting/illumination
X ☐ imaging
Z ☐ inspection/identification

**B.**
A ☐ machine vision
C ☐ materials processing/production
E ☐ materials research
G ☐ medical/biomedical
J ☐ microscopy
L ☐ military/tactical
N ☐ nondestructive testing
P ☐ optical character recognition
R ☐ optical computing/data storage
T ☐ photonic component mfg.
V ☐ process control
X ☐ quality control
Z ☐ remote sensing/lidar

**C.**
A ☐ reprographics/printing
C ☐ robotics
E ☐ semiconductor processing
G ☐ simulation/modeling
J ☐ signal processing
L ☐ spectroscopy
N ☐ test & measurement
P ☐ ultrafast/time-resolution studies
R ☐ other _____

## 6 Which of the following products do you buy, use, recommend and/or specify? (Please check all that apply.)

**A. Optical Components & Software**
A ☐ coatings
C ☐ filters & beamsplitters
E ☐ gratings
G ☐ infrared optics
J ☐ laser optics
L ☐ lenses
N ☐ mirrors & reflectors
P ☐ optical design software
R ☐ polarizing optics
T ☐ prisms
V ☐ ultraviolet optics
X ☐ windows & domes

**B. Lasers**
A ☐ semiconductor, diode
C ☐ solid-state, diode-pumped
E ☐ solid-state, Nd:YAG
G ☐ solid-state, Ti:sapphire
J ☐ solid-state, tunable
L ☐ solid-state, VCSELs
M ☐ fiber lasers
N ☐ gas lasers, $CO_2$
P ☐ gas lasers, excimer
R ☐ gas lasers, HeNe
T ☐ gas lasers, ion
V ☐ gas lasers, other
X ☐ dye
Z ☐ other lasers _____

**C. Laser Systems**
A ☐ biometric/forensic
C ☐ biotechnology
E ☐ communications
G ☐ industrial (cutting/welding/marking)
J ☐ entertainment
L ☐ environmental monitoring
N ☐ holography
P ☐ materials processing
R ☐ medical
T ☐ military
V ☐ remote sensing
X ☐ reprographics (printing/graphic arts)
Z ☐ spectroscopy & photochemical analysis

**D. Fiber Optics**
A ☐ cables
C ☐ communications lasers
E ☐ connectors or couplers
G ☐ detectors or receivers
H ☐ fiber
K ☐ gratings
M ☐ lightguides
N ☐ network components
O ☐ optical amplifiers
Q ☐ optical switches
S ☐ splicing & polishing equipment
U ☐ test equipment
W ☐ transmitters
Y ☐ WDM or DWDM
Z ☐ other fiber optic components _____

**E. Cameras**
A ☐ CCD or CID
C ☐ CMOS
E ☐ high speed
G ☐ infrared
J ☐ line scan
L ☐ other camera _____

**F. Detectors/Sensors**
A ☐ CCD or CID
C ☐ CMOS
E ☐ detector arrays
G ☐ infrared
J ☐ photodiodes
L ☐ photomultipliers
N ☐ semiconductor

**G. Imaging Equipment & Software**
A ☐ frame grabbers
C ☐ image intensifiers
E ☐ imaging software
G ☐ infrared imagers
J ☐ illumination equipment
L ☐ vision systems
N ☐ x-ray imaging

**H. Manufacturing Equipment for Photonic Components**
A ☐ assembly or packaging equipment
C ☐ cleanroom equipment
E ☐ coating equipment
G ☐ cooling & cryogenic equipment
J ☐ diamond machining equipment
L ☐ grinding & polishing equipment
N ☐ optical design software
P ☐ photonics test equipment
R ☐ vacuum equipment
T ☐ other manufacturing equipment _____

**J. Positioning/Vibration Isolation Equipment**
A ☐ benches, rails & slides
C ☐ micropositioners
E ☐ mounts for photonic components
G ☐ positioning equipment
J ☐ position-sensing equip.
L ☐ stepper motors & drivers
N ☐ tables, optical
P ☐ vibration-isolation equipment

**K. LEDs and Displays**
A ☐ CRTs
C ☐ flat panel
E ☐ LCDs
G ☐ LEDs
J ☐ light valves
L ☐ OLEDs
N ☐ plasma

**L. Test & Analysis Equipment**
A ☐ interferometers
C ☐ microscopes, optical
E ☐ microscopes, other
G ☐ monochromators
J ☐ optics testing equipment
L ☐ power/energy meters/wavelength meters
N ☐ radiometers/photometers
P ☐ spectroscopy equipment
R ☐ spectrum analyzers
T ☐ telescopes

**M. Electronics & Signal-Analysis Equipment**
A ☐ amplifiers
C ☐ oscilloscopes
E ☐ power supplies
G ☐ pulse & signal generators
J ☐ signal analyzers
L ☐ time-delay generators

**N. Laser Accessories**
A ☐ beam analysis
C ☐ flashlamps
E ☐ laser chillers
G ☐ laser dyes, gases or rods
J ☐ laser power & energy meters
L ☐ laser power supplies
N ☐ laser safety
P ☐ laser scanners

**P. Light Sources**
A ☐ arc sources
C ☐ flashlamps
E ☐ infrared
G ☐ LEDs
J ☐ ultraviolet

**Q. Materials & Chemicals**
A ☐ cements, adhesives & epoxies
C ☐ coating materials
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# Solar Tech Industry Rises in East Asia

BY CAREN B. LES
NEWS EDITOR

The People's Republic of China is home to one-third of the world's solar manufacturing capacity, according to a study by the Breakthrough Institute of Oakland, Calif., and the Information Technology and Innovation Foundation of Washington, organizations that track American policy and technology trends. Titled *Rising Tigers, Sleeping Giant* and published in November 2009, the report compares public investments by the US and key Asian countries in clean energy technologies such as solar, wind and nuclear power. It notes that, over the next five years, the governments of China, Japan and South Korea plan to invest a total of $509 billion in domestic clean technology, while the US government will likely invest $172 billion over the period.

Dongguan Quoncion Solar Energy Lighting Co. Ltd. of Dongguan City in Guangdong Province, China, produces photovoltaic (PV) monocrystalline and multicrystalline modules from 1 to 300 W. The company is planning to construct a solar-power industrial park in JiangXi Province and is enlarging its factory in Henan Province this year, according to Sue Zhong, the company's sales manager.

"The year 2009 was an important one for the solar market in China," Zhong said. She noted that China's solar feed-in tariff support system, launched by the government, is helping to propel the domestic PV industry. The system, which has attracted worldwide attention to the solar industry, has provided China with new opportunities for growth. Zhong commented that the global financial downturn led to a decline in the solar feed-in tariff support systems in the main European market, but that the refund system was on the rise in other countries.

## Connecting to the grid

Feed-in tariffs, also known as serial refund systems, are policies that typically guarantee renewable electricity generators a long-term performance-based payment at a premium price and interconnection to the grid (i.e., the right to "feed in" electricity). The practice is explained in the white paper *Advancing a Sustainable Solar Future: SEMI PV Group Policy Principles and Recommended Best Practices for Solar Feed-in Tariffs*, published in 2009 by the SEMI trade association. Basically, under such a tariff, a regional or national electric utility is obligated to buy electricity generated from renewable sources from all eligible participants.

PV Group noted that approximately 80 percent of the world's PV demand has come from markets supported by feed-in tariffs. SEMI supports the development of feed-in tariffs around the world as an effective means to ensure sustained growth for the PV industry, and its white paper notes that recent feed-in tariff policy development activity in China, India, Japan and Taiwan has set the stage for possible significant PV market growth during the next few years.

Ross Young, senior vice president of photovoltaics and displays at IMS Research in Wellingborough, UK, a market research firm that follows the electronics industry, predicts that 2010 will be tremendous for the solar industry. He writes in his article titled *PV Market Enjoys Strong Rebound in Q3 '09* that numerous factors will be catalysts, including lower prices, impending changes to tariffs and growth in subsidy efforts. He noted that in China, the regulatory and approval processes are in place to implement the country's rooftop, power plant and feed-in tariff programs, a situation that should result in rapid growth. In Japan, feed-in tariffs are expected to be introduced, although the subsidies for residential and nonresidential PV technology have already led to significant growth. In South Korea, a 32 percent increase to a market cap of 132 MW should lead to a strong year, according to Ross.

"Solar energy is undoubtedly a market with a huge growth potential in China. At present, the technology level and know-how in China are still behind that of the Western countries," said Lixin Ren, managing director at Semikron (Hong Kong) Co. Ltd., an international power semiconductor manufacturer. He added that Semikron puts strong emphasis on the solar energy market and aims to bring high-end, innovative and reliable technology to the solar inverter market in China, while at the same time providing individualized service to customers.

## Growth and innovation

Satcon Technology Corp., a Boston-based provider of utility-scale power solutions for the renewable energy market, has delivered 23 MW of its PowerGate Plus 500-kW solar PV inverters to GCL Solar Limited for its 20-MW Jiming Hill Xunzhou solar plant and its 3-MW Yancheng Guoneng rooftop installation. These two installations – technological breakthroughs in project construction and technology innovation – demonstrate China's increasing demand for utility-scale renewable power production and its commitment to large-scale solar innovation, said Gu Huamin, general manager of GCL Solar.

In January 2010, Yingli Green Energy Holding Company Ltd., a vertically integrated PV product manufacturer based in Baoding, China, announced that the Ministry of Science and Technology in China has approved its application to be the first national-level laboratory in the field of PV technology development, at its base plant. The State Key Laboratory will aim to drive the Chinese development of world-class PV technology in China, said the company, which will have priority rights to commercialize technologies developed in the laboratory. Yingli Green Energy sells its PV modules to systems integrators and distributors in various markets around the world.

In Japan, Showa Shell Sekiyu KK and its subsidiary Showa Shell Solar KK, based in Tokyo, are expected to start construction next year on a 900-MW copper indium gallium selenide factory in Miyazaki; Sharp Corp., based in Osaka, plans to ramp up its 480-MW thin-film line in Sakai by March 2010, producing triple-junction a-Si modules at 10 percent

efficiency, according to the *Q4 '09 Quarterly PV Cell Capacity Database & Trends Report* from DisplaySearch, based in Austin, Texas.

Overall in the industry, solar cell capacity growth is expected to slow somewhat in 2010 and 2011 as demand starts catching up to capacity, according to DisplaySearch. The report notes that the 2009 solar cell capacity rankings for manufacturers First Solar Inc. of Tempe, Ariz.; Suntech Power of Wuxi, China; Sharp Corp.; and Q-Cells SE of Bitterfeld-Wolfen, Germany, were 1092, 950, 870 and 836 MW, respectively.

## Development and challenges

Published in September 2009, a report titled *China PV Market Development* from GTM Research, a Greentech Media company based in Cambridge, Mass., states that since 2002, China's solar cell and module manufacturers have exported more than 95 percent of their products to countries such as Germany, Spain, Italy and the US, enabling the country to become a top global solar cell producer. In 2008, in response to the worldwide economic crisis, China scaled back this export capacity and considered national solar incentives to support the solar manufacturing industry.

"Ultimately, the Chinese power sector wants solar electricity generation costs to approach those of wind and, later, coal. As evidenced with its policies in the wind sector, the Chinese government pushes for high amounts of installed capacity, with the long-term goal of bringing down high capital costs. Newly installed solar PV capacity will face challenges such as a lack of standard interconnection procedure across grid regions and general lack of experience on the side of developers. The development model supports domestic manufacturers and domestic economic growth," according to the report from GTM Research.

## Concentrating solar power

Based in Pasadena, Calif., eSolar, a global supplier of concentrating solar power plants, and China Shandong Penglai Electric Power Equipment Manufacturing Co. Ltd., a privately owned company based in Penglai, Shandong, China, announced in January 2010 a master licensing agreement to build at least 2 GW of solar thermal power plants in China over the next 10 years. The plants will be collocated with biomass electricity generation facilities to work in tandem with the solar power plants. In total, the companies say the plants will eliminate 15 tons of carbon dioxide emissions annually.

The deal represents the country's first foray into concentrating solar power. The technology uses mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it to heat. The thermal energy is then used to produce electricity via a steam turbine or heat engine driving a generator.

## PV manufacturing equipment

The world market for PV manufacturing equipment is projected to exceed $9 billion in 2013, according to IMS Research. The company added that Asia, and in particular China, is expected to be a key growth driver in the PV manufacturing equipment market and to account for more than half of the revenues in that sector through to 2013. Equipment suppliers are expected to take advantage of the region's lower labor costs and, because equipment users are increasingly based in Asia, shipping costs will be reduced.

As noted in *The China Post*, Taiwan Semiconductor Manufacturing Co. in Taipei announced in December 2009 that it will pay about 6.2 billion NT for a 17 percent stake in Motech Industries Inc., a large solar cell manufacturer also based in Taipei.

Taiwan's Environmental Protection Administration is also looking into the possibility of building "photonic greenhouses" as part of an effort to promote the development of renewable energy. It is suggested that the greenhouses, which would use thin-film solar cell panels installed on the roofs of facilities, could possibly provide power for local regions and be used to raise cash crops such as orchids.

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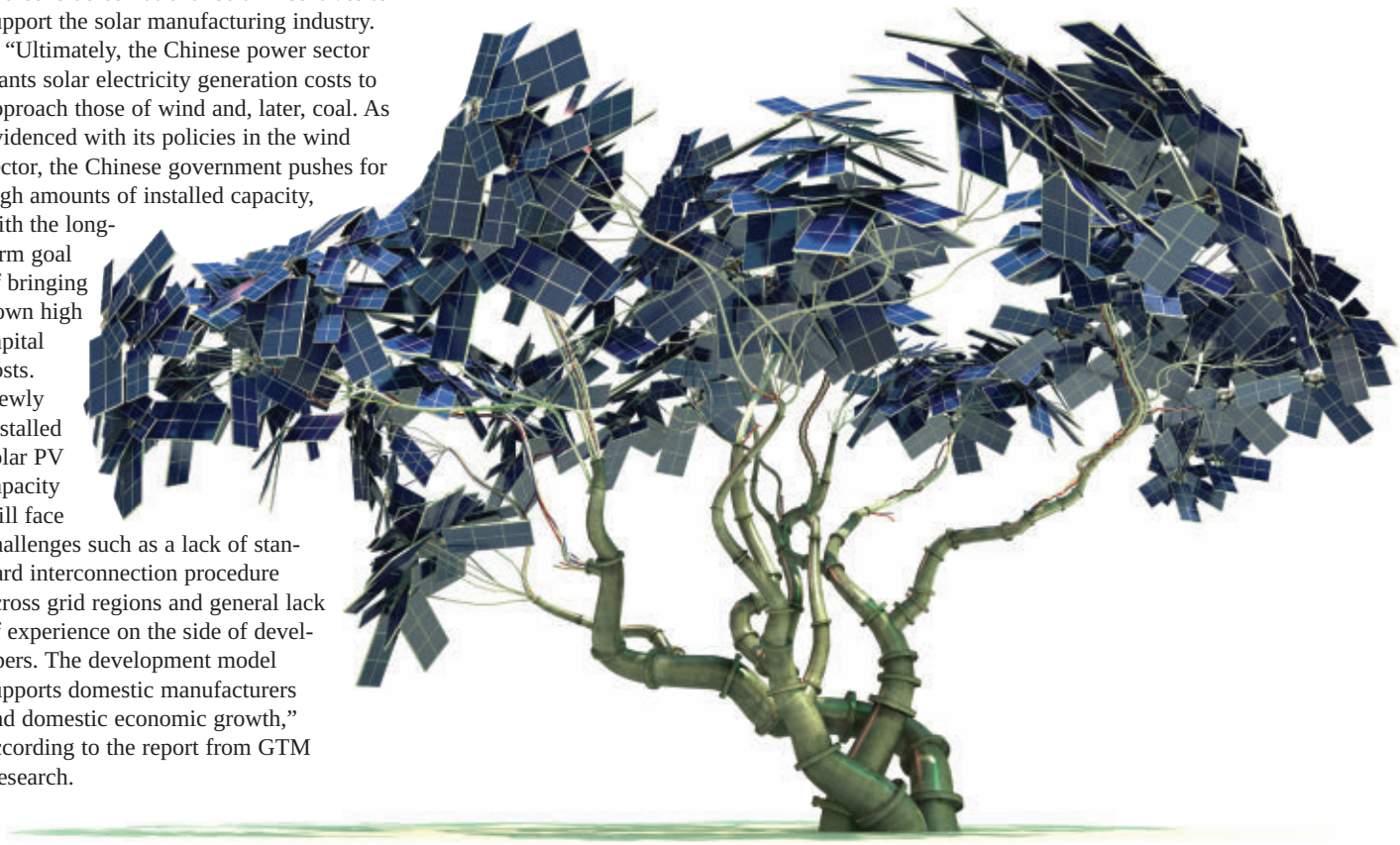

# China a Leader in Solar Revolution

BY GARY BOAS
CONTRIBUTING EDITOR

Not for nothing is it called the Sleeping Giant. A variety of new markets and manufacturing possibilities are emerging in China, creating new opportunities for many in the optics and photonics communities. Chief among these, perhaps, is solar energy. China is positioning itself as an important – if not *the* important – player in this area. In the past few years, it has become a major producer of solar products, even as changing demographics make it one of the largest markets for renewable energy.

On one level, this may come as a bit of a surprise. China has never been known as a paragon of environmental friendliness. News of the country's remarkable economic growth in recent decades has been tempered by images of coal plants spewing smoke into the air and blanketing the countryside with a cloud of pollutants, and by reports of the Yellow River nearly overflowing with waste.

More than anything, the recent push to develop renewable energy sources in China is a response to surging energy demand. In a Jan. 10, 2010, column, Thomas L. Friedman of the *New York Times* noted that the nation is "in the midst of the biggest migration of people from the countryside to urban centers in the history of mankind." He added that China is determined to meet the skyrocketing demand with "cleaner, homegrown sources so that its future economy will be less vulnerable to supply shocks, and so it doesn't pollute itself to death." Solar has emerged as one of the more desirable of these sources; in the past year, governments at the national, provincial and local levels have been seeking to attract solar companies by offering a number of subsidies, including free land and generous support for R&D efforts.

China has been particularly aggressive in courting US-based companies. Since September, First Solar of Tempe, Ariz., eSolar of Pasadena, Calif., and Applied Materials of Santa Clara, Calif., have inked deals to build plants or open R&D facilities in China. The former two companies have announced plans to partner with China in developing 2-GW plants in the Mongolian desert in northern China. When completed, these will rank among the largest solar power plants in the world.

Bill Gross, CEO of eSolar, noted how much more assertive China has been than the US. The company applied for a US Department of Energy (DoE) loan for a 92-MW project in New Mexico, he told Friedman, and in less time than it took the DoE to complete stage one of the application review, China had approved the 2-GW project and was awaiting the beginning of construction.

Applied Materials, which produces the equipment used to make solar panels, opened an R&D center in the central Chinese city of Xi'an late last year, and in

January the company relocated its chief technology officer to China. The move was "a natural extension of our desire to be close to where our customers are," said Cathy Boone, senior director of global marketing and government relations with Applied Materials' solar products group. "China is a huge manufacturing market for solar panels, so this plants us right in the heart of the customer base."

At the same time, the Chinese government has been very strong in instituting policies encouraging domestic demand for renewable sources of energy – thus creating an ecosystem with companies "from up and down the value chain," Boone said.

Applied Materials of Santa Clara, Calif., recently opened an R&D center in Xi'an, China, where the company has extensive ties with universities nearby. The facility has an entire floor dedicated to training rooms and classrooms, so it will serve as a learning center as well, said a company representative. China now constitutes a sizable portion of the solar panel manufacturing market.

### Coming to America

Even as US companies are working to set up shop in China, many Chinese companies are trying to establish a presence in the US. On Nov. 16, 2009, Suntech Power Holdings announced in Beijing its plans to build the company's first plant in the US. The facility, which will be located in Phoenix and begin production by October of this year, will have a 30-MW capacity, with enough flexibility to increase output to 200 MW.

Building a plant in the US will help Suntech lower delivery time and costs, and it will serve other goals as well. It will help to allay US lawmakers' fears of China's cornering the market on solar and other green manufacturing jobs. In addition, it could help the company – and possibly other Chinese solar providers – to combat protectionist policies in the US. Following Honda's example in the auto industry in the 1980s, Suntech has suggested that its executives in the US join the two major industry groups, in part to discourage the groups from blocking its efforts in the American market.

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# Green is good for Asian laser makers

HSINCHU, Taiwan; and FUJIAN and SHANGHAI, China – For Asian laser diode makers, green seems to be the dominant hue. It shows up in emerging and recovering markets, as a look at just a few companies reveals.

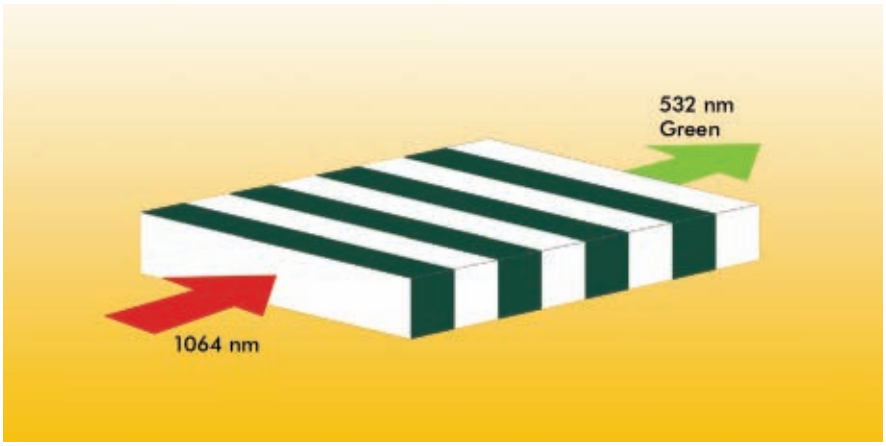
At HC Photonics Corp. in Hsinchu, for example, green is the color – for now. That may change in the future, however, said Karin Wu, the company's marketing and sales director.

The firm's green focus is a result of the emergence of picoprojectors – handheld or pocket-size ones suitable for use in cell phones, notebooks, netbooks and the like. Picoprojectors could be a new mass market, with tens of millions of units worth hundreds of millions of dollars shipping. There were a number of picoprojector announcements from companies such as Syndiant Inc. in Taiwan and Foryou Multimedia Electronics Co. Ltd. of Huizhou, China, at the recent Consumer Electronics Show.

There is a problem with current technology, which employs LEDs as a light source, Wu said. "The image is not big enough, bright enough or always focused. That's the reason people are trying to adopt laser-backed picoprojectors."

Doing that requires red, green and blue laser diodes. However, there are no commercially available green semiconductor laser diodes that meet required specifications.

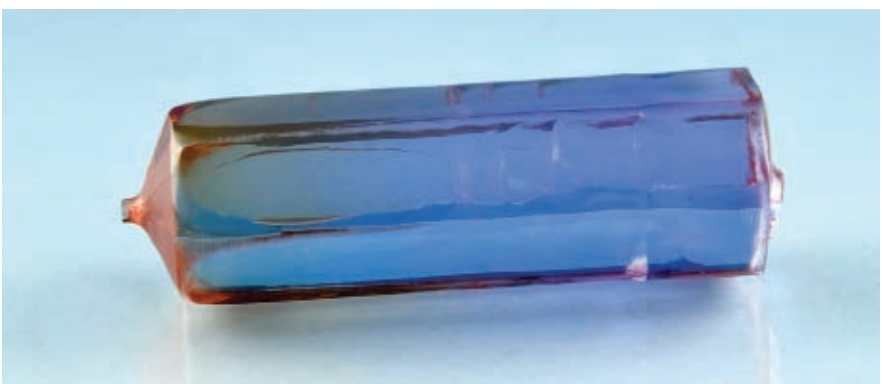
That's where HC Photonics comes in. The 10-year-old company, which does business throughout Asia and the rest of the world, specializes in periodically poled nonlinear technology. It uses a lithium niobium implementation that enables conversion of 1064-nm to 512-nm light. Thus, picoprojector makers could use it with readily available near-infrared sources to generate green light.




HC Photonics Corp. gets the green light needed for picoprojectors from frequency-doubling an infrared input. Courtesy of HC Photonics.

Wu noted that picoprojectors are in an early stage and that the company's sales are not yet large. However, as long as there are no suitable green semiconductor laser diodes available, HC Photonics could be well positioned to take advantage of growth in this market, she said. "Our solution is competitive."

According to Man Li, the general manager's assistant at Daheng Optics in Beijing, demand is increasing and the market for optics and laser-related products is expanding. The new year looks to be a good one, although the company does not have a laser-related product announcement at this time.



An improved crystal-growing method allows Castech Crystals Inc. to manufacture larger Nd:$YVO_4$ crystals. Courtesy of Castech.

## A different focus

Laser crystal maker Fujian Castech Crystals Inc. reported developing a new crystal growing technique. The company put the method to use in manufacturing a new Nd:$YVO_4$ product, creating a crystal greater than 60 mm long, of excellent inner quality, and with low bulk absorption. The material emits in the infrared.

Castech frequency-doubles this output by using it in conjunction with other materials. The result is a diode-pumped microchip laser crystal, which the company claims is highly efficient and could be used as a green light source in a picoprojector.

In speaking about a different kind of green, Castech marketing manager Tanny Tan noted that the recent Photonics West trade show indicated that the market is in better shape than it was last year. Opportunities and customer interest seem to be increasing.

However, that may be due in part to a change in emphasis at Castech. "This year we put more attention to precision optics," Tan said.

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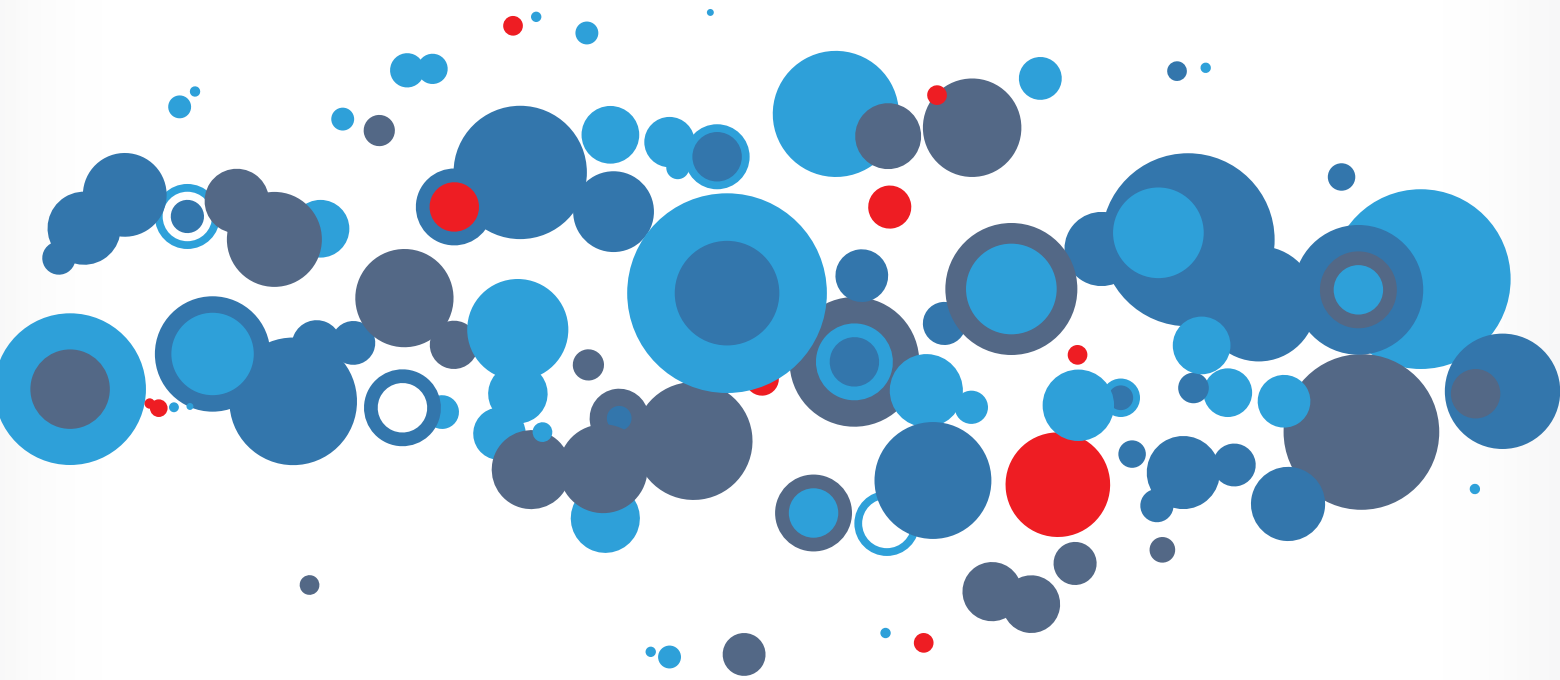

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# Pragmatic attitude drives machine vision forward

This printing inspection system is just one of the products on offer at the China Daheng Group Inc. Beijing Image Vision Technology Branch. Images courtesy of the China Daheng Group Inc. Beijing Image Vision Technology Branch.

The product families offered by the China Daheng Group Inc. Beijing Image Vision Technology Branch include CCD cameras with 1394 and GigE interfaces, CMOS cameras with 1394 and USB interfaces, analog frame grabbers and smart cameras for intelligent transportation systems applications.


The China Daheng Group partners with some of the best-known machine vision companies in the world.

SHANGHAI, China – All eyes will be on China from March 31 to April 2 for the China International Machine Vision Exhibition 2010, which will be held at the Shanghai Exhibition Center. The event coincides with the China International Motion Control and Sensor Exhibition 2010 and is expected to gather some of the biggest players in the machine vision industry.

"The exhibition provides a platform for customers to learn about the latest technology in machine vision and to find the right product to fit their application. It also gives machine vision companies in China a chance to communicate with each other," said DeShan Duan, senior engineer of machine vision at the China Daheng Group Inc. Beijing Image Vision Technology Branch in Beijing. "As one of the largest machine vision companies in China, we must attend."

The machine vision market in China is growing fast, with more and more opportunities for manufacturers of sensors, lenses, filters and cameras. Although most of the specialized products still come out of the US, Europe and Japan, China offers much lower labor costs, which means that it enjoys the lion's share in terms of manufacturing.

"The machine vision industry in China is a little backward compared with Japan and some of the more advanced countries in the world, but it is growing fast," Duan said. "The China Daheng Group was one of the first companies to enter the Chinese machine vision industry. We have the ability to design and produce industrial digital cameras and frame grabbers that are more suitable for the Chinese market."

Machine vision technology can be used in almost every industry, with the automotive, electronics and semiconductor markets at the top of the list. The initial setup for Chinese machine vision companies was to cooperate with foreign specialists to provide machine vision components to end users or systems integrators. But this has started to change as more Chinese companies find themselves better able to cater to local markets.

"The cost of components from other countries is high, and the products are not always the right fit for our markets," Duan said. "This led some Chinese machine vision companies to start to develop these components themselves."

As for what's in store for machine vision

The China Daheng Group Inc. Beijing Image Vision Technology Branch (Imavision) exhibits at the China International Machine Vision Exhibition 2009.

in Asia, it seems that a business that supports manufacturing will most likely continue to enjoy strong growth. According to Duan, events such as the China International Machine Vision Exhibition 2010 should be seen by individual machine vision companies in China as an opportunity to strengthen the industry as a whole.

"I think that the machine vision industry in one country is not just a competitor against others; every company should cooperate with each other so that they can play to their respective advantages," he said. "Everybody in the industry should know that getting a good image is the first and most important step in the entire machine vision system. For this we must learn more about the optical properties of the sensor inside the camera, lenses, filters and illuminations."

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# LED backlight applications growing

TAIPEI, Taiwan – LED applications in consumer products including cell phones, automobiles, displays, lighting and signals totaled more than $4.8 billion in 2009, according to a market report by PIDA, the Photonics Industry & Technology Development Association, a nonprofit organization that works to promote and grow Taiwan's optoelectronics industry.

And PIDA predicts that LED backlight applications will expand in 2010 from cell phones to large-format LCDs. As a result, the association expects a surge in LED consumption, which would lead to global expansion in LED production.

The LED epitaxy wafer and chip industry suffered a 30 percent decline in the first two quarters of 2009, compared with the same quarters in 2008, but demand for medium-to-large LED backlight panels boosted revenues in the last two quarters, so that the epitaxy wafer and chip industry saw overall negative growth of 3 percent compared with 2008.

The total revenue for Taiwan's LED industry, including packaging, was $2.733 billion in 2009; this represents a 19 percent growth, which PIDA attributes to government policies and strong global demands.

PIDA predicts that the growth trend will continue in 2010, estimating LED chip production in Taiwan to break $1.068 billion, with packing production value reaching $1.665 billion. The global LED chip market value is expected to reach $3.2 billion in 2010, and it is anticipated that the packaging market will hit $8.23 billion.

In early June 2010, PIDA will hold the Photonics Festival in Taiwan, an industry event showcasing new developments and offerings from Taiwan's LED industry. Concurrent with the festival will be Display Taiwan, an exposition devoted to flat panel displays.

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# spotlight

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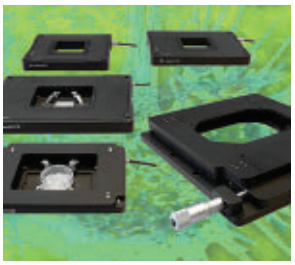

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## Color Smart Camera

Dalsa Corp. has announced a color version of its BOA integrated smart camera for color inspection applications in the automotive, food, packaging and pharmaceutical industries. It can be used for sorting, counting, positioning of robotic handlers and verification of color hue, and for identification of parts or assembly features. The iNspect Express software interface enables operators to rapidly prototype and deploy vision systems, and it is available with an emulator for off-line application development and debugging. The RoHS- and CE-compliant camera supports Modbus and Ethernet/IP communication protocols, operates from 0 to 45 °C, has a ⅓-in. CCD sensor and produces 640 × 480-pixel resolution. Its 44 × 44 × 44-mm form factor enables use in space-limited conditions, and the IP67-rated housing allows deployment in harsh wash-down environments.

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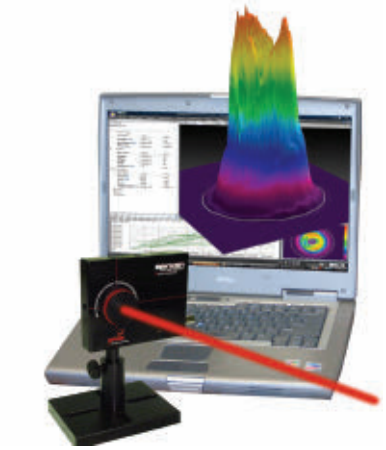
**Lumera Laser**
**info@lumera-laser.de**



## Laser Beam Analysis System

Ophir-Spiricon LLC has added the BeamGage Professional to its family of next-generation laser beam analysis systems. It features the BeamMaker beam simulator, automatic camera control, comprehensive beam analysis algorithms, partitioning of the camera output for separate analysis of multiple beams, a .NET automation interface and camera sharing. Based on the proprietary and patented UltraCal baseline correction algorithm, the system provides results that guarantee that the data baseline is accurate to 1/10 of a digital count on a pixel-by-pixel basis. It includes more than 55 measurement choices, including Centroid X and Y, ellipticity, eccentricity and peak fluence. Running on Microsoft Vista or Windows 7, it operates in 32-bit mode and offers enhanced 3-D graphics for improved data rendering. The software supports cameras with FireWire and USB interfaces that cover the 190- to 3000-nm wavelength range.

**Ophir-Spiricon**
**sales@ophir-spiricon.com**

## Uniform AR Coatings on Ball Lenses

Deposition Sciences Inc. offers durable antireflection (AR)-coated ball lenses in diameters from 200 µm to 10 mm. The IsoSphere lenses are created using a proprietary low-pressure chemical vapor deposition process that provides uniform coating over the entire surface of the sphere. The company's multilayer coating capability provides dual- and broadband coatings (1310/1550-nm dual band). The dual-band coatings allow one lens to be used for either wavelength. A choice of lens materials, with indices from 1.44 to 2.15 at 1550 nm, minimizes cost and provides freedom in the optical design. Featuring hard, scratch-resistant coatings, the lenses offer a mechanically simple optical solution for coupling and collimating applications. They also are used in fiber-to-fiber, diode-to-fiber and fiber-to-detector coupling when access to the beam is required.

**Deposition Sciences**
**solutions@depsci.com**

## Laser Oscillator

Fusion M1, introduced by Femtolasers Produktions GmbH, is an ultracompact Ti:sapphire laser oscillator with mode-locked average output power of >1 W, pulse duration of <12 fs, pulse energy of >13 nJ, and peak power of >1 MW, both at 75 MHz. Proprietary and patented dispersive mirror technology provides broadband intracavity group delay dispersion compensation. The oscillator integrates a pump module with a low-loss cavity design. Features include Femtolock repetition rate stabilization, bandwidth tunability and custom center wavelength control. Applications include seeding of amplifier chains, materials processing, coherent terahertz generation, time-resolved spectroscopy and multiphoton processes.

**Femtolasers Produktions**
**info@femtolasers.com**

## Piezomotor Rotary Stage


A 15-mm direct-driven high-speed rotary stage based on proprietary PILine piezomotor drive technology has been introduced by PI (Physik Instrumente) LP. The MM-660 operates at 720°/s and achieves resolution to 8 arc-sec. Its self-locking ceramic drive holds the position steady at rest, with no energy consumption or heat generation. The directly coupled precision optical encoder provides phase lag-free, backlash-free feedback to the servo controller. The compact design with minimized mass and inertia provides high-precision bidirectional speed and position control, and high-speed motion contouring.

**PI**
**photonics@pi-usa.us**

## Erratum

*The "Bright Ideas" product announcement for the Nickel-Alloy IN718 (January, pp. 107-108) contained incorrect company contact information. EOS GmbH can be contacted about the product at info@eos.info.*

### Metal Material

EOS GmbH has introduced the NickelAlloy IN718, a metal material for its EOSINT M 270 laser sintering systems. A heat-resistant superalloy, it corresponds to the Inconel 718 alloy. It is a precipitation-hardening nickel-chromium alloy characterized with good tensile, fatigue, creep and rupture strength at temperatures of up to 700 °C. It is corrosion-resistant, has suitable cryogenic properties and can be used in many high-temperature applications. The main target for this material is the aerospace industry. The company has developed process parameters that enable part building and ensure that the relevant industrial standards for this material type are met. These include heat treatment in accordance with AMS 5662 and 5664 standards as well as tensile and stress-rupture properties at elevated temperatures.

**EOS**
**info@eos.info**

### STED Microscopy

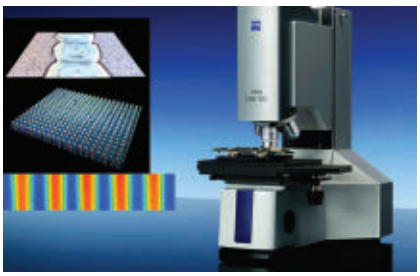
Mobius Photonics Inc. has announced upgraded fiber lasers that produce visible light with a 20-MHz pulse repetition rate. The G1+ series, tailored for stimulated emission depletion (STED) microscopy experiments, has been designed to improve imaging speed over

prior setups that used the company's 1-MHz lasers. Based on a pulsed master oscillator and fiber power amplifier architecture, the lasers provide diffraction-limited operation over a range of user-adjustable settings. Available in 1064-, 532- and 355-nm wavelengths, they produce maximum average output power of 30, 18 and 10 W, respectively, and deliver a $TEM_{00}$ beam with M2 <1.3. Emission linewidth is <0.5 nm, and power drift is <±3%.
**Mobius Photonics**
**info@mobiusphotonics.com**

## Industrial Laser

Spectra-Physics, a Newport Corp. brand, has announced an addition to its Pulseo family of Q-switched diode-pumped solid-state industrial lasers. The rugged and reliable Pulseo 355-10 provides 10 W of 355-nm output at 90 kHz with a short pulse width of <23 ns. Applications include crystalline silicon photovoltaic solar cell manufacturing processes such as wafer scribing and dicing, drilling and marking. The high-power industrial laser is also suitable for use in microelectronics applications, such as via hole drilling, flex circuit cutting, flat panel manufacturing, indium tin oxide patterning, LED substrate scribing, silicon wafer dicing/scribing and low-K dielectric scribing. The laser delivers high peak power and high repetition rates that, combined with the short pulse width, reduce undesired thermal effects and result in higher throughput with less damage to the parts.
**Spectra-Physics**
**tim.edwards@spectra-physics.com**

## Microscope Upgrade



Carl Zeiss MicroImaging Inc. has expanded the functions on its Axio CSM 700 confocal light microscope to enable materials scientists to measure the 3-D topography over large sample areas. A motorized scanning stage with 150 ×

## BRIGHT IDEAS

150-mm travel is suitable for materials research and quality inspection. Scanning stage control is integrated into the software to allow large sample areas to be captured in a mosaic fashion. A stitching algorithm assures that no transitions are perceived between the single images in the final mosaic image. The microscope provides noncontact measurement of roughness on soft surfaces. Topographical measurements can be performed at >100 fps. Additional benefits include reliable detection of height information with step heights from 20 nm up to the millimeter range. The software provides numerous analysis options, and a newly programmed filter facilitates image processing.
**Carl Zeiss MicroImaging**
**ksalerno@zeiss.com**

### Multiplexer

Agilent Technologies Inc. has announced the N4876A 2:1, a multiplexer that extends the generator data rate of the J-Bert N4903B and Par-Bert 81250A up to 28 Gb/s and enables accurate characterization of next-generation serial interfaces. The device doubles the pattern generator data rate by multiplexing two generator channels. It performs accurate characterization by providing good output signal performance, transition times of <20 ps and intrinsic jitter of <1 ps rms. A small front-end box located close to the device under test enables short signal cables.
**Agilent Technologies**
**janet_smith@agilent.com**

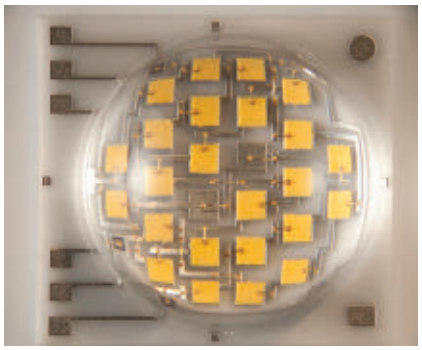
### Raman Microscope

The Nomadic multiwavelength Raman microscope has been unveiled by BaySpec Inc. Equipped with 532-, 785- and 1064-nm excitation sources, it

provides molecular fingerprint information on every point of the sample. The dedicated spectrographs and detectors for each wavelength ensure optimal spectral coverage, resolution and sensitivity. The 532-nm excitation produces high sensitivity, the 1064-nm suppresses fluorescence, and the 785-nm balances the two. The research-grade optical microscope delivers micron-scale spatial resolution and accommodates samples in solid, powder, liquid and gel forms.

**BaySpec**
**sales@bayspec.com**

## Multichip LED



The multichip XLamp MPL EasyWhite LED manufactured by Cree Inc. is suitable for directional lighting applications, including PAR- or BR-style lightbulbs. The company says that the device can deliver the required light output for a 3000-K, 75-W BR-30 lightbulb, while consuming 78% less energy. The LEDs are offered in 2700-, 3000-, 3500- and 4000-K color temperatures. They produce up to 1500 lm at 250 mA and have a compact 12 × 13-mm footprint. They meet the efficacy and lumen-output requirements for integral LED lamps as defined by Energy Star.

**Cree**
**info@cree.com**

## Lens Measurement Instrument

Optikos Corp. has introduced the LensCheck lens measurement instrument for production and prototype lens qualification. It features high-resolution USB motorized stages, 12-bit real-time video output and integrated glass scale encoders, providing accurate and efficient measurements in a compact, portable system. Coupled with proprietary and patented

## b BRIGHT IDEAS

VideoMTF image analysis software, the system enables real-time modulation transfer function (MTF) testing, measurement and analysis. Features include a 50-mm clear-aperture refractive collimator, an eight-position manual target and filter wheels, and a self-centering lens holder. Besides on/off-axis MTF, it also measures effective focal length and *f* number, back focal length, astigmatism, field curvature, distortion, transmission and relative illumination.
**Optikos**
**sales@optikos.com**

### Light-Measurement System

For spectroradiometric analysis of LEDs, lamps, flat panel displays, solar radiation and other radiant sources, Ocean Optics Inc. has released the Jaz-ULM-200. Jaz is a family of stackable components that share common electronics and communications and are configurable for various applications. Included is a CCD array spectrometer and a microprocessor with an onboard display. Users can capture, process and store full spectra without a PC. The irradiance measurement software, stored on an SD card, collects full spectral irradiance information from the selected light source, and the data is post-processed to yield intensity parameters, including W/cm², lumens, lux and photosynthetically active radiation. An included Ethernet module stores data and enables users to connect to the Jaz unit via the Internet for remote measurements. A rechargeable lithium-ion battery module provides portability, and a mounting fixture enables orienting the Jaz stack horizontally for hands-free operation.
**Ocean Optics**
**info@oceanoptics.com**

### Bright-Field Objectives


The MPLAPON line of plan apochromatic objectives has been unveiled by Olympus Europa Holding GmbH for use in industrial imaging applications. The devices provide good chromatic aberration correction over a broad wavelength range for materials imaging. Available in 50× and 100× magnifications, they

provide good bright-field imaging, including differential interference contrast. They have numerical apertures of 0.95 and are compatible with active autofocusing units. They also are suitable for inspecting minute areas in industrial imaging samples, such as semiconductor patterns. Their high resolution enables individual imaging and observation of points separated by only 0.35 μm. The company's wavefront aberration control process quantitatively measures small aberrations and eliminates them to yield objectives with strehl ratios of at least 95%.
**Olympus Europa**
**microscopy@olympus.com**

## UV Light Source

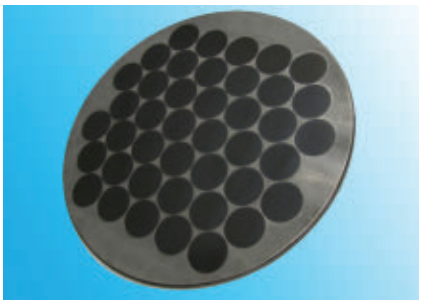
The Lightningcure LC-L3, a UV spot light source introduced by Hamamatsu Corp., features nine UV LEDs that emit at 365 or 385 nm, depending upon the model. It delivers intensity of 250 mW/cm$^2$ at 365 nm and 325 mW/cm$^2$ at 385 nm, and uniform light level output throughout the LEDs' 20,000-h lifetime. On/off switching and light-level adjustment can be controlled on each LED, enabling creation of tailored irradiation profiles. Up to 16 steps can be input into a program. The light source is suitable for UV adhesive curing, UV ink drying, semiconductor and liquid crystal exposure, and high-resolution optical microscopes. The unit monitors the temperature inside the head to control and maintain light intensity at a constant level, eliminating the need for daily light-level checks.
**Hamamatsu**
**usa@hamamatsu.com**

## Thermal Imaging Lenses


LightPath Technologies Inc. has introduced athermalized *f*/1.0, 10.63-mm-focal-length long-wave infrared lens assemblies for thermal imaging using 8- to 12-μm infrared signatures. Designed for uncooled infrared sensors, the lenses are the primary optics for thermal im-

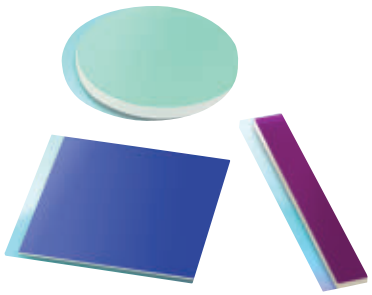
agers in homeland security, firefighting, predictive maintenance and drivers' vision enhancement systems in automobiles. The assemblies integrate proprietary Black Diamond molded chalcogenide infrared lenses that are a lower-cost substitute for high-volume diamond-turned germanium and zinc selenide optics. The material properties of the Black Diamond glasses provide natural athermalization for temperature stability from 25 to 75 °C. The design yields a 52° field of view when paired with a 10-mm sensor with a 25-µm pixel pitch.
**LightPath Technologies**
**info@lightpath.com**

## Wafer Carriers



Chemical vapor deposition silicon carbide wafer carriers for high-temperature metallorganic chemical vapor deposition processing have been unveiled by Morgan Technical Ceramics. They increase the yield for manufacturers of high-brightness LEDs using GaN deposition. The carriers are 99.999+% pure and exhibit high thermal conductivity and thermal shock resistance. The solid monolithic material achieves theoretical density, generating minimal particulates and exhibiting high corrosion and erosion resistance. It can vary opacity and electrical conductivity without introducing metallic impurities. The carriers are ~431.8 mm in diameter and hold up to 40 wafers measuring between 50.8 and 101.6 mm. They transmit heat efficiently, with high thermal conductivity.
**Morgan Technical Ceramics**
**lorraine.henry@morganplc.com**

## Colored-Glass Alternative Filters



A line of colored-glass alternative filters that exhibit durability and wavelength stability in any environment has been introduced by Newport Corp. Available are 34 long-wave-pass thin-film filters in four standard sizes, suitable for applications where steep transitions from blocking to high transmission are required. RoHS-compliant, they provide low autofluorescence and typical transmission of 90%. Proprietary and patented Stabilife coating technology produces thin-film coating that can withstand harsh environmental conditions. Spectral temperature sensitivity is <0.0015 nm/°C, coating operating temperature is from −100 to 400 °C, and typical filter thickness is 1.1 mm.
**Newport**
**ken.pihl@newport.com**

## Laser Diode Series

Alfalight Inc.'s 808C single-emitter laser diodes have a center wavelength at 808 ±3 nm and 3.5 W of output power. Operating current is 4.1 A, forward voltage is 1.7 V, threshold current is 0.7 A, and spectral width is 2 nm FWHM. Fiber core diameter is 105 µm, fiber length is 1.5 m, and numerical aperture is 0.15. Housed in a six-pin uncooled package, the laser diodes integrate proprietary wavelength stabilization tech-

nology that produces 0.07 nm/°C stability and eliminates the need for precise temperature control for solid-state laser pumping and other spectrum-sensitive applications. Power conversion efficiency is 51%, typical, and slope efficiency is minimum 1 and typical 1.05 W/A.
**Alfalight**
**sales@alfalight.com**

## Luminescence Sensors

The DK50-UV series luminescence sensors has been released by Pepperl+Fuchs Inc. for error checking, sorting, measuring and positioning materials that blend into a background or that are invisible. The compact sensors detect inks,

pigments, dyes, coatings and adhesives, even on irregular backgrounds, and have a sensing range of 600 mm. They feature up to four automatic teach modes and one manual one, a graphical eight-segment LED display that indicates luminescent signal strength, an output mode toggle for quick adjustments and an integral timer that enables slower controllers to react to sensor output. Applications include verifying the presence of tamperproof seals, aligning bottle sleeves to labels, sensing labels on cartons, measuring the amount of glue on a carton flap and confirming the presence of a packing slip in a carton.
**Pepperl+Fuchs**
**sales@us.pepperl-fuchs.com**

## Compact Laser Packages

TeraXion Inc. has introduced compact versions of its distributed-feedback PS-LM and narrow-linewidth PS-NLL PureSpectrum specialized semiconductor laser modules. The company says that the new package is more than six times smaller and five times lighter and that it consumes two times less power than the original PS-NLL version. Developed for integration into OEM instrumentation, it measures 20 × 64 × 90 mm and operates over a temperature range from −5 to 55 °C. Both lasers offer a side mode suppression ratio of >30 dB, a polarization extinction ratio of >17 dB and frequency modulation amplitude of ±2.5 GHz. Applications include lidar and remote sensing, coherent sensors in oil and gas operation, perimeter and submarine detection for security, test and measurement, and coherent optical time-domain reflectometry.
**TeraXion**
**info@teraxion.com**

## Kinematic Mirror Mount

Thorlabs has released Polaris, an ultrastable kinematic mirror mount for 25.4-mm-diameter optics. Fabricated from heat-treated stainless steel that minimizes temperature-dependent hysteresis, it incorporates a matched 100-tracks-per-in. actuator and bushing pairs that minimize drift and backlash, and it has ball contacts with sapphire seats at all contact points. It provides the stability necessary for use in alignment-sensitive applications and is designed for long-term use in multiple setups. A flat-spring mechanism secures the optic in place, regardless of the ambient temperature, eliminating the need to glue the optic into position. The optics can be easily swapped in and out of the mount, which is equipped with an M4 counterbore for post mounting.
**Thorlabs**
**techsupport@thorlabs.com**

## Zoom Lenses

Resolve Optics Ltd. supplies OEM quantities of zoom lenses for specific applications that cannot be served by off-the-shelf types, such as high-definition and large-image formats, operation in the UV or IR region, and compact designs. Features include compactness, high resolution and focus tracking throughout the zoom range. Custom lenses can be developed in motorized or nonmotorized formats and in materials to suit a wide variety of applications, including nuclear fuel inspection, high-definition lenses for broadcast TV, miniature zoom lenses for head-up displays and pipeline inspection, and IR zoom lenses for machine vision.
**Resolve Optics**
**sales@resolveoptics.com**

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# HAPPENINGS

## PAPERS

**Metamaterials 2010 (September 13-18) Karlsruhe, Germany**
**Deadline:** submissions, March 29
Papers are sought for oral and poster presentation at the Metamaterials 2010: Fourth International Congress on Advanced Electromagnetic Materials in Microwaves and Optics. Topics to be considered include photonic crystals, optical metamaterials and applications, and superlenses, hyperlenses and other near-field imaging optics. Papers will be selected based on originality, content and quality. Contact Stefan Linden, contact@congress2010.metamorphose-vi.org; www.metamorphose-vi.org.

**ICONO/LAT 2010 (August 23-27) Kazan, Russia**
**Deadline:** abstracts and summaries, April 14 (noon GMT)
Researchers are invited to submit papers for the collocated meetings International Conference on Coherent and Nonlinear Optics (ICONO) and Lasers, Applications and Technologies (LAT). Among the program topics are nonlinear optics in condensed matter, gases and plasmas; nonlinear space-time dynamics, instabilities and patterns; and high-peak-power lasers and high-intensity laser-matter interactions. Contact ICONO/LAT Organizing Committee, Zavoisky Physical-Technical Institute, +7 843 272 05 03; iconolat10@kfti.knc.ru; congress.phys.msu.ru/iconolat10.

**SPIE Laser Damage (September 27-29) Boulder, Colorado**
**Deadline:** abstracts, April 16
Submissions are encouraged for the 42nd Annual Symposium on Optical Materials for High-Power Lasers. Laser-induced damage issues in multilayer thin-film, photonic bandgap materials, and high-power fiber and ultrafast lasers will be discussed. Related issues, including measurement protocols, fundamental mechanisms and contamination of optical components, also will be addressed. Contact SPIE, +1 (360) 676-3290; spie@spie.org; spie.org/ldcall.

## MAY

**CLEO/QELS 2010: Laser Science to Photonic Applications (May 16-21)** San Jose, Calif. Includes PhotonXpo. Contact Optical Society of America, +1 (202) 416-1907; custserv@osa.org; www.cleoconference.org.

**Sensor + Test 2010: The Measurement Fair (May 18-20)** Nuremberg, Germany. Contact AMA Service GmbH, +49 5033 9639 0; fax: +49 5033 1056; www.sensor-test.de.

**2010 IEEE International Communications Conference (May 23-27)** Cape Town, South Africa. Contact Heather Ann Sweeney, +1 (212) 705-8938; h.sweeney@comsoc.org.

**SID: 2010 International Symposium, Seminar and Exhibition for the Electronic Display Industry (May 23-28)** Seattle. Contact Mark Goldfarb, +1 (212) 460-8090, Ext. 202; mark@sid.org; www.sid.org.

**10th International Conference of the European Society for Precision Engineering & Nanotechnology (EUSPEN) (May 31-June 4)** Delft, the Netherlands. Contact Debbie Nyman, +44 1234 754 154; debbie-nyman@euspen.eu.

## JUNE

**Photonics North 2010 (June 1-3)** Niagara Falls, Ontario, Canada. Collocated with Photovoltaics Canada First National Scientific Conference. Contact Mélanie Lemay, +1 (418) 522-8182; melanie.lemay@conferium.com; www.photonicsnorth.com.

**EIPBN: 54th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication (June 1-4**) Anchorage, Alaska. Contact Marty Feldman, +1 (225) 578-5489; feldman@ece.lsu.edu; www.eipbn.org.

**Optical Interference Coatings (June 6-11)** Tucson, Ariz. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/oic.

**Sensors Expo & Conference (June 7-9)** Rosemont, Ill. Contact Questex Media Group Inc., +1 (617) 219-8300; www.sensorsexpo.com.

**Imaging and Applied Optics (June 7-10)** Tucson, Ariz. Collocated topical meetings and tabletop exhibits: Applied Industrial Optics: Spectroscopy, Imaging and Metrology; Digital Image Processing and Analysis; Imaging Systems; Optical Remote Sensing of the Environment; Optics for Solar Energy; and Photonics Metamaterials and Plasmonics. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

**Automatica 2010: International Trade Fair for Automation and Mechatronics (June 7-11)** Munich, Germany. Collocated with the International Symposium on Robotics 2010. Contact Messe München GmbH, +49 89 9 49 2 01 21/22; info@automatica-munich.com; www.automatica-munich.com.

**LASYS 2010 (June 8-10)** Stuttgart, Germany. Includes a short course titled "Basics on Lasers and Laser Material Processing." Contact Messe Stuttgart International, +49 711 258 9550; fax: +49 711 258 9440; www.messe-stuttgart.de.

**EuroLED 2010 (June 9-10)** West Midlands, UK. Contact Eve Gaut, +44 121 250 3515; eveg@astonsciencepark.co.uk; www.euroled.org.uk.

**Photonics Festival in Taiwan: Opto Taiwan, LED Lighting Taiwan, Solar Taiwan, Optics Taiwan; concurrent exposition: Display Taiwan 2010 (June 9-11)** Taipei, Taiwan. Contact Pamela Hsiao, +1 866 2 235 140 26, Ext. 805; exhibit@mail.pida.org.tw; www.optotaiwan.com.

**Optical Fabrication and Testing (June 13-16)** Jackson Hole, Wyo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/oft.

**International Optical Design Conference (June 13-17)** Jackson Hole, Wyo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/iodc.

**Optatec 2010: The International Trade Fair for Future Optical Technologies, Components, Systems & Manufacturing (June 15-18)** Frankfurt, Germany. Contact P.E. Schall GmbH & Co. KG, +49 7025 9206 0; Fax: +49 7025 9206 620; www.optatec-messe.com.

**Advanced Photonics: OSA Optics & Photonics Congress (June 21-24)** Karlsruhe, Germany. Collocated with Access Networks and In-House Communications; Bragg Gratings, Photosensitivity and Poling in Glass Waveguides; Nonlinear Photonics; Optical Sensors; and Signal Processing in Photonic Communications. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

**Renewable Energy: OSA Optics & Photonics Congress (June 21-24)** Karlsruhe, Germany. Collocated with Solid-State and Organic Lighting; and Optical Nanostructures for Photovoltaics. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/topicals.

**Nanotech Conference & Expo 2010 (June 21-25)** Anaheim, Calif. Collocated with Clean Technology Conference & Expo; Microtech Conference & Expo; BioNanotech Conference & Expo; and TechConnect Summit & Expo. Contact Sarah Wenning, +1 (925) 353-5004; Fax: +1 (925) 886-8461; www.techconnectworld.com.

**SPIE Astronomical Telescopes and Instrumentation 2010 (June 27-July 2)** San Diego. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

**Laser Optics 2010 (June 28-July 2)** St. Petersburg, Russia. Contact Program and Organizing Committee, Institute for Laser Physics of Vavilov SOI Corp., +7 812 328 5734; conf2010@laseroptics.ru; www.laseroptics.ru.

## JULY

**17th International Conference on Ultrafast Phenomena (July 18-23)** Snowmass Village, Colo. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/up.

**Integrated Photonics Research, Silicon, and Nanophotonics (July 25-29)** Monterey/Santa Cruz, Calif. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/ipr.

**Photonics in Switching (July 25-29)** Monterey/Santa Cruz, Calif. Contact OSA, +1 (202) 223-8130; info@osa.org; www.osa.org/ps.

## HAPPENINGS

### AUGUST

**SPIE Optics + Photonics: Optical Engineering + Applications (Aug. 1-5)** San Diego. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; spie.org.

**International Conference on Coherent and Nonlinear Optics (ICONO)/Lasers, Applications and Technologies (LAT) (Aug. 23-27)** Kazan, Russia. Contact ICONO/LAT Organizing Committee, +7 843 272 05 03; iconolat10@kfti.knc.ru; congress.phys.msu.ru/iconolat10.

### SEPTEMBER

**EWOFS 2010: European Workshop on Optical Fibre Sensors (Sept. 8-10)** Porto, Portugal. Contact INESC Porto, University of Porto, +351 220 402 301; ewofs@inescporto.pt; www.ewofs.org.

**Metamaterials 2010: Fourth International Congress on Advanced Electromagnetic Materials in Microwaves and Optics (Sept. 13-18)** Karlsruhe, Germany. Contact S. Linden, Congress Secretary, +49 7247 82 2861; congress2010.metamorphose-vi.org.

**MNE 2010: 36th International Conference on Micro and Nano Engineering (Sept. 19-22)** Genoa, Italy. Contact Corso F.M. Perrone, +39 010 659 8773; secretariat@mne2010.org; www.mne2010.org.

## Asia Photonics

# OCT provides new tool for art historians

Scientists in Poland have described how optical coherence tomography (OCT) – a technique most often used in medical imaging – can be used to reveal the forgery of an artist's signature or changes in inscriptions on 100-year-old paintings.

Piotr Targowski of the Institute of Physics at Nicolaus Copernicus University in Torun, Poland, notes that easel paintings prepared according to traditional techniques consist of multiple layers. The artist, for instance, first applies a glue sizing over the canvas to ensure proper adhesion of later layers. Those layers may include an outline of the painting, the painting itself, layers of semitransparent glazes and, finally, a transparent varnish.

Understanding the stratigraphy – or the order, thickness, composition and origin – of an artwork is important for proper attribution of the piece, for detection of possible forgeries or reproductions, and for planning conservation efforts.

Art conservators and other experts resort to a variety of technologies to see below the surface of a painting and to detect changes, including forged signatures. However, many techniques require removal of samples from a painting, thus damaging artistic treasures no matter how tiny the removed portion. In addition, many analytical techniques are not sensitive enough to detect finer details.

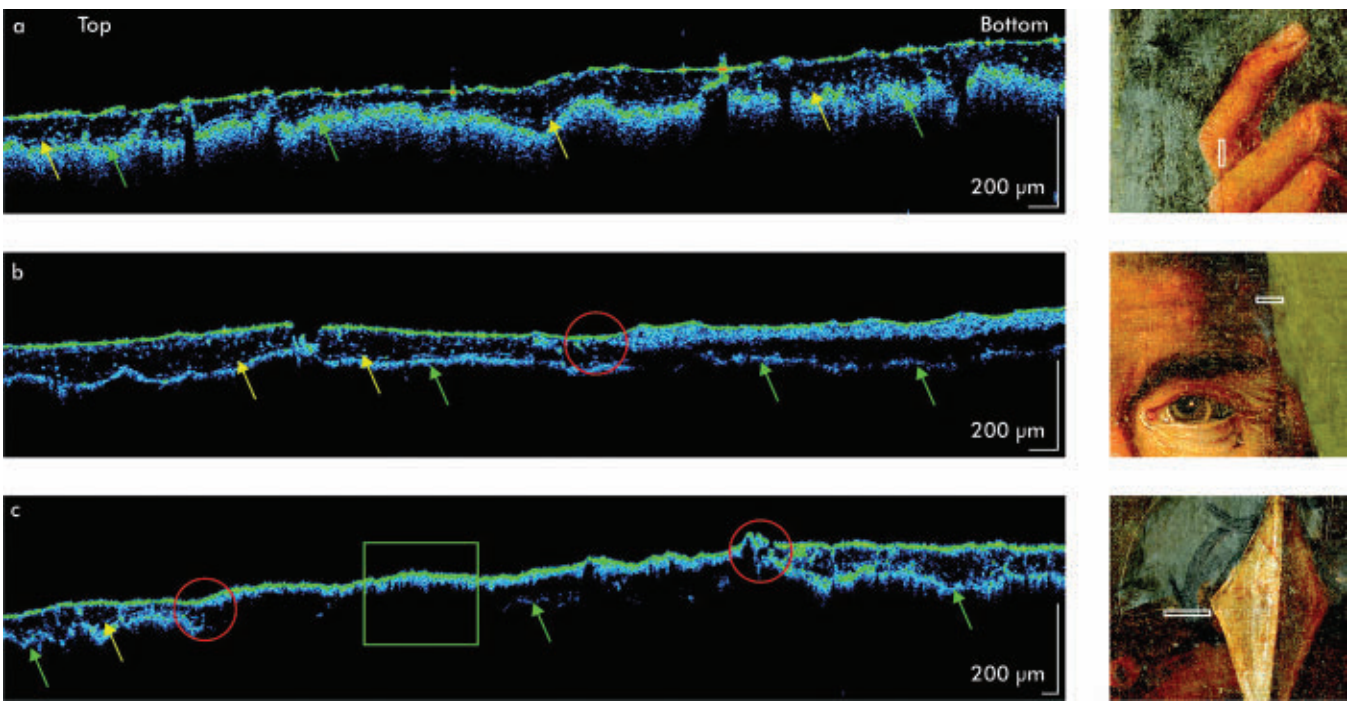

Shown is "Saint Leonard of Porto Maurizio," an 84 × 121-cm oil-on-canvas picture that hangs in the Franciscan Church of St. Bonaventure in Pako, Poland. Circles mark the regions in which the tomograms were acquired. Rectangles mark the regions of the inscriptions investigated. Figure numbers refer to the original paper in *Accounts of Chemical Research;* 4a-4c are shown top to bottom in the image below. Photo by Magdalena Iwanicka is used with permission.

Targowski and his colleagues describe how OCT, which is commonly used to produce three-dimensional images of the layers of the retina, overcomes those difficulties. OCT has been used by art conservators to study varnishes and underdrawings, but the work by Targowski's group is the first known effort to use it to extrapolate historical information,

The group used OCT to analyze two oil paintings from the 18th and 19th centuries. In one, "Saint Leonard of Porto Maurizio," OCT revealed evidence that the inscription "St. Leonard" was added approximately 50 years after completion of the painting. In the other, "Portrait of an Unknown Woman," OCT found evidence of possible forgery of the artist's signature.

The group reported its work in the Dec. 31, 2009, issue of *Accounts of Chemical Research*.

lynn.savage@photonics.com




OCT tomograms from "Saint Leonard of Porto Maurizio": (a) multilayer varnish (image width, 7 mm); (b) semitransparent overpainting (image width, 7 mm); (c) opaque overpainting (image width, 12.3 mm). Yellow arrows indicate the surface of the primary varnish layer; green arrows indicate the primary opaque paint layer; circles show boundaries between original and overpainted areas; the rectangle indicates a region in which the overpainting is completely opaque. The bars indicate real distances in media of refractive index of 1.5.



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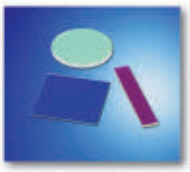
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