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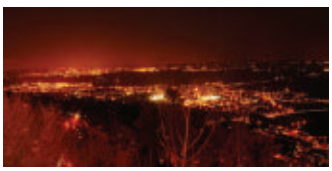
t TABLE OF CONTENTS


NEWS & ANALYSIS

16 | TECH NEWS
Making nanotubes respond to rainbows
A closer look at our ancestor, Lucy
Holographic disc can store 100 DVDs
Detecting melamine in food
Fingerprint tech gets tested
Schott Solar opens in Albuquerque
To the moon and back, many times a minute
Unscrambling holograms gains high-res images
Special effects captured in a whole new light

28 | FASTTRACK
Business and Markets
Image sensor market: Looking forward to better times
Changing spaces: Women in STEM moving to acadene

35 | GREENLIGHT
by Anne L. Fischer, Senior Editor
Solar from space
Concentration boosts photovoltaics' potential
Lighting up lives
Battling outdoor light

72 | SLICES FROM THE BREADBOARD
It's All About Patents
by Amanda D. Francoeur, News Editor
Patented genes impede cancer diagnosis

16

DEPARTMENTS

10 | EDITORIAL
12 | LETTERS
73 | BRIGHT IDEAS
82 | HAPPENINGS
84 | PEREGRINATIONS
A slice of everyday life

THE COVER

A feature article beginning on page 58 examines ways in which near-IR and Raman instrumentation is improving chemical analysis, including the production line safety monitoring of food and drugs. This month's cover was designed by Art Director Lisa N. Comstock.

PHOTONICS: The technology of generating and harnessing light and other forms of radiant energy whose quantum unit is the photon. The range of applications of photonics extends from energy generation to detection to communications and information processing.

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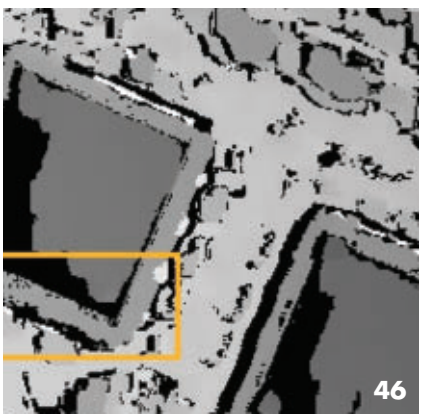
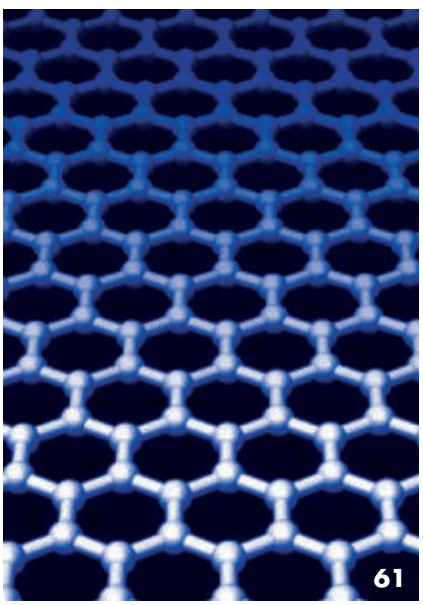
FEATURES





42 | **OPTICAL POWER METERS: VERSATILE AND ECONOMICAL**
by Dr. Jay Y. Jeong, Newport Corp.
Complex experiments, safety and environmental requirements demand optimum, low-cost optical devices.

44 | **COMMERCIALIZING THE NOBEL-WINNING DISCOVERY OF THE BOSE-EINSTEIN CONDENSATE**
by John Cowley for ColdQuanta Inc.
Bose-Einstein technology reduces production time and cost for "ultracold" matter experiments.

46 | **SEEING CLEARLY: THE LATEST IN MACHINE VISION SOFTWARE**
by Dr. Lutz Kreutzer, MVTec Software GmbH
3-D vision, large-image processing, bar and data codes, and an integrated development environment make up Halcon 9.0.

54 | **A WAVE PLATE FOR EVERY APPLICATION**
by William Barbarow, Meadowlark Optics Inc.
Matching the material to the intended use leads to success.

56 | **INTO THE PHOTON DETECTOR'S TOOL KIT**
by Wayne Seemungal, Amplification Technologies Inc.
Solid-state photomultipliers compare well with traditional devices.

58 | **PROFITING FROM TELECOM INVESTMENTS**
by Eric Bergles and William Yang, BaySpec Inc.
Taking advantage of the NIR first overtone and Raman's spectral fingerprints.

61 | **AVOIDING FAILURE**
by Hank Hogan, Contributing Editor
Advanced metrology finds tiniest defects in semiconductor materials.

66 | **AUSTRALIAN AGENDA: NO GREAT BARRIERS?**
by Caren B. Les, News Editor
University of Sydney in New South Wales offers a master of photonics program.

70 | **GETTING BY WITH THE HELP OF YOUR FRIENDS AT SPIE AND OSA**
by David L. Shenkenberg, Features Editor
Professional societies offer a slew of financial, educational and economic benefits to their members.

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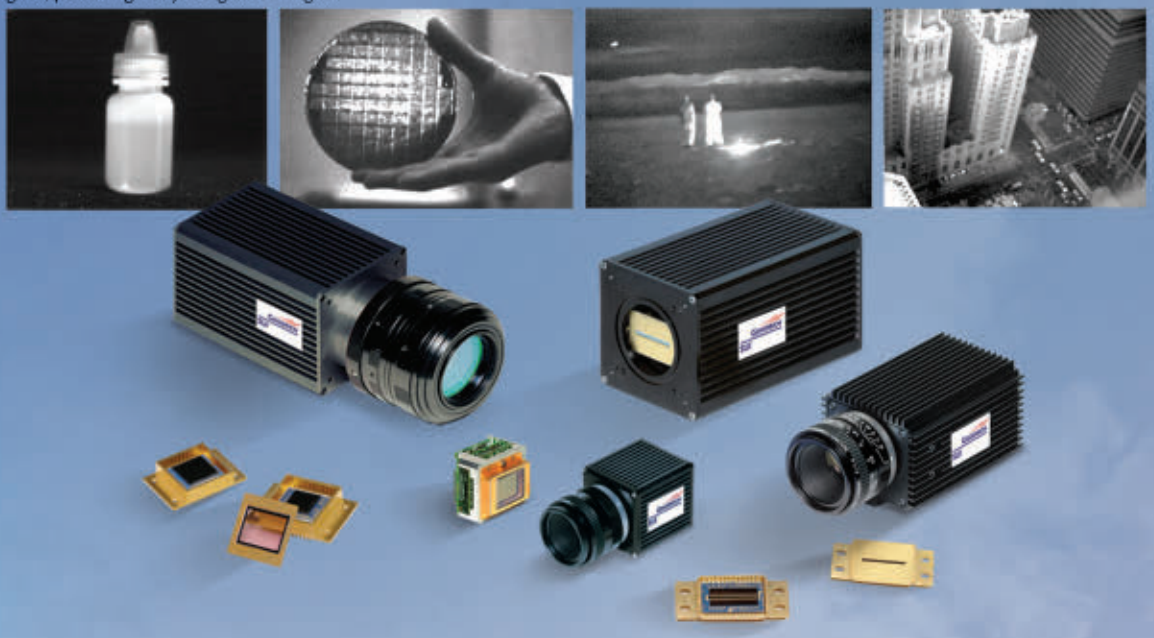

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Anticipating the 2009 Prism Awards

By the time most of you read this, Photonics Media and SPIE will be in the midst of planning the 2009 Prism Awards for Photonics Innovation – the second year of what we consider to be the industry's most prestigious awards for advances in photonics products and technology.

As they were last year, the 2009 awards will be presented during SPIE's Photonics West, only this time the ceremony will be held at San Francisco's Moscone Center from Jan. 23-28, 2010. Nine winners will be honored for excellence in the following categories:

- Analytical Test and Measurement
- Detectors, Sensing and Imaging
- Optics
- Lasers
- Other Light Sources
- Photonics Systems
- Photonics Processes
- Sustainable/Green Technology
- Life Sciences

Back in the fall of 2008, we had an independent panel of 23 judges who are regarded as experts in their fields. Each one painstakingly reviewed and analyzed the applications, assigning rankings compiled according to a list of criteria. During that time, the organizers took every precaution necessary to sensitively address the many details involved in creating awards and, to that end, we believe that we have developed a competition that is distinct from all others.

Science and technology awards exist in a number of areas, but in an industry like ours, where invention, instinct and knowledge have engendered a strong global market, we have been confident in taking on the challenge of determining and honoring the winners. We understood from the first that collaboration between a strong society and a strong media partner would very effectively select and call attention to the best of the best.

More than 300 industry professionals attended our first awards celebration in January this year. We expect that even more in 2010 will witness the winners sporting the crystal prism awards that signify their accomplishments.

If you were with us last year, we would be pleased to welcome you back. If you are a newcomer, please join us as by entering the competition today. You can find more information at photonicsprismaward.com. The application deadline is Sept. 22, 2009.

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A satisfied reader

I can finally share my hard copy of *Photonics Spectra* with family and friends from different disciplines. From the Letters forum to feature articles, the applicability of science and technology to everyday realities is being highlighted in your new format and approach to articles. An example is the superb, clearly written sidepiece by Lynn Savage titled, "Nanoparticles leading the way to light-driven computers" (May, p. 53).

If all the highly educated could explain intricacies as well as was done in this gem, we'd have a much better informed public in the US and around the world. Ultimately, an educated public leads to a more enlightened, supportive taxpayer and is a huge benefit to science funding and human progress.

Thank you for a *Photonics Spectra* that we now look forward to receiving monthly.

Thomas Peter von Bahr
Pacific NorthWest Group
Lopez Island, Wash.

Food safety

I enjoyed reading "Food Safety Just Got Smarter" in the April 2009 issue, about the smart bar-code incorporating thermochromic pigments developed by Sira Technologies Inc. Your readers may be interested to know that this topic has been studied for at least 35 years and that the barriers to acceptance have not all been technical in nature.

As early as 1972, I was involved with a group working on thermochromic freeze-thaw indicator inks for frozen food packaging at Syva Research Institute in Palo Alto, Calif. I later worked independently at Battelle Memorial Institute in Columbus, Ohio. At both organizations, candidate compounds were developed that met the technical requirements for undergoing an irreversible color change when their temperature was raised above 32 °F for more than a few minutes.

The problem with commercialization of the materials at that time was that the frozen food industry was decidedly not interested in adopting any kind of freeze-thaw indicator labeling – no one wanted to get caught shipping or selling food that had been allowed to thaw and then been refrozen.

I hope the technology developed by Sira Technologies and described in your article will face a "warmer" reception in the industry this time around.

Robert E. Schwerzel, PhD, President
Technology Guidance Services LLC
Johns Creek, Ga.

Where was Hungary?

I read News Editor Caren Les' article "Czeching out photonics from Prague to Kiev" in the May issue and, because it dealt with Eastern Europe, was surprised to find no mention of Hungary. I wonder why you omitted Hungary (and Poland)?

Does it mean that photonics in Hungary is so much less than in Slovakia or Romania? I know Boris Vedlin from Optotek d.o.o. in Slovenia very well; for example, I know that company's fine progress in optics, but I also know several companies here in Hungary that have fine results in the market – both in Europe and in the USA.

There are thousands of employees in Hungary working for multinational corporations, assembling well-known products for Carl Zeiss, General Electric Co., Schmidt & Bender, Karl Kaps GmbH & Co. KG, etc.

Dr. István G. Szabó
ügyvezető/managing director
Optika Mérnökiroda Kft.
Optics Engineering Ltd.
Budapest, Hungary

Editor's response:
While I did contact representatives in the Hungarian and Polish photonics communities, unfortunately, I received no replies from them.

Stimulus concern

I have but one concern about the Stimulus Package, and that is where it is coming from. Because the businesses that are expected to be providing the revenue for it are suffering a major decline at this time, it is very likely that the US Treasury will be printing a lot of the money being used, decreasing the value of the dollar. This will have bad effects in the future, no matter how nice it seems for the research and development field.

As taxes are raised on companies and high-income makers – those that normally plow their wealth back into the economy to help expand their businesses – they will be forced to spend less on developing and marketing the widgets created from the Stimulus Package funding.

It would serve our country well to read "The Forgotten Man" by Amity Shlaes before we get too excited about the Stimulus Package and other plans the Obama Administration and Congress have in store for us. President Obama is doing similar things that President Franklin D. Roosevelt did, as if he did not study the history of the Great Depression. So it is being repeated.

Jim Davidson
Baton Rouge, La.

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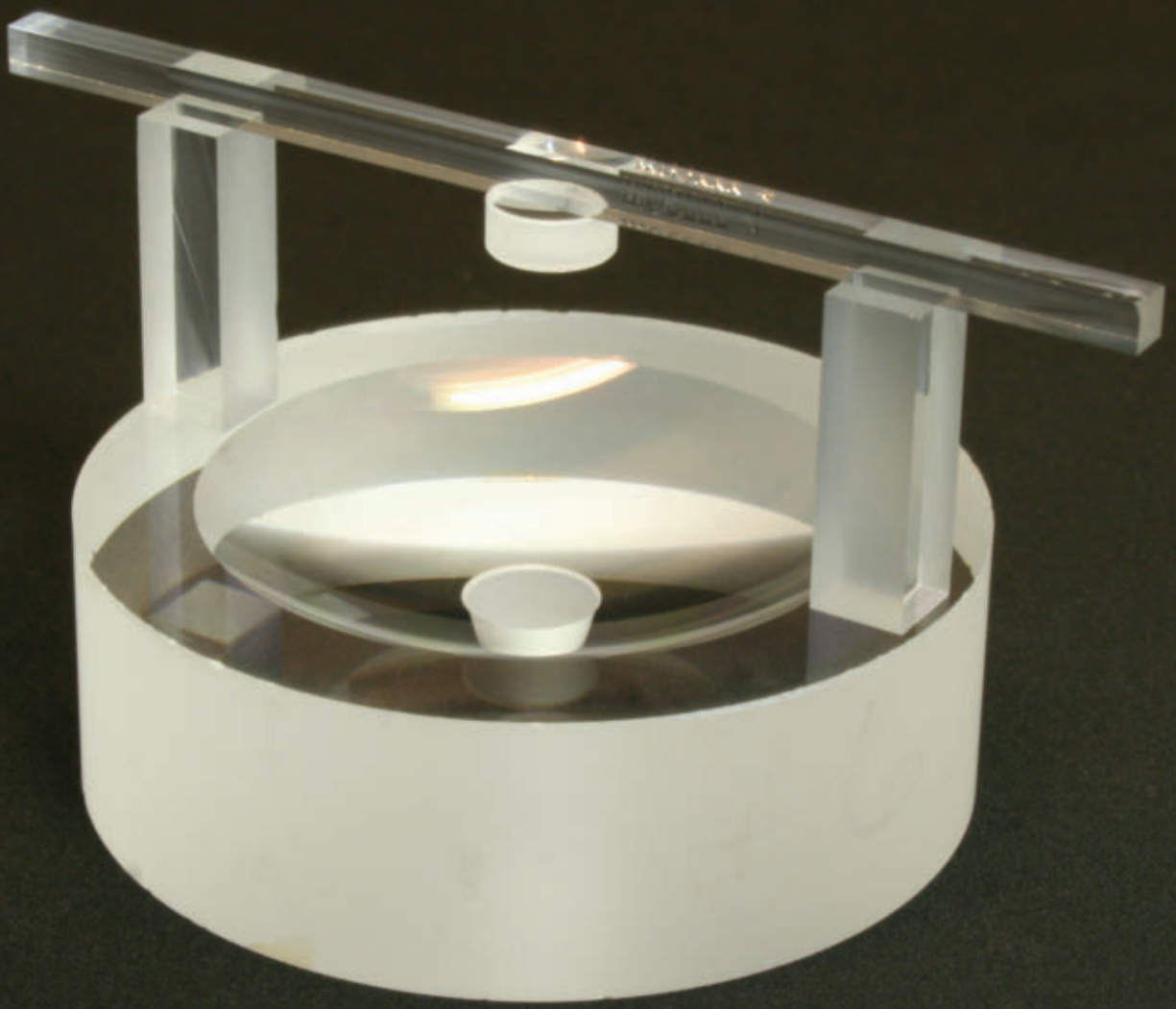

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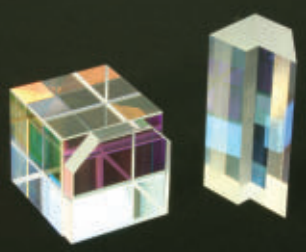

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Online

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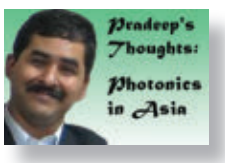
Visit *Photonics.com* for reporting on what's timely and of interest to the photonics community – news, technology, advances, research, company changes and profiles, new products, feature articles and major industry events.

Plus, for an interactive look at the photonics industry check out our live Photonics Media twitter feed.



Pradeep's Thoughts
New: a regular column by blogger Pradeep Chakraborty detailing the photonics industry in Asia. Pradeep is a semicon/telecom consultant at PC Mediaworks.

WEB EXCLUSIVES:

Thermal Signatures Determine Time of Death
During decomposition, microorganisms emit different thermal signatures, which can be detected by thermographic imaging. Thermography detects infrared radiation in the electromagnetic spectrum and, when used on decomposing bodies, the thermal growth signatures of microorganisms can be detected.

Check out a sample of the new digital version of *Photonics Spectra* magazine at www.photonics.com/DigitalSample. It's a whole new way to stay informed about the global photonics industry.

Plus all the latest news, products and industry information you need each day.

Coming in August …

'Virtual Fence' Planned Along US-Mexico Border
Boeing and the Homeland Security Department are building a "virtual fence" using sensors, cameras and communications equipment to detect drug smugglers and illegal imigrants along the nearly 2000-mile border between the US and Mexico.

Trends in Laser Diodes
Laser diodes have recently seen advances involving today's standard semiconductor laser diodes and steps toward tomorrow's plastic laser diodes.

Replicating Photosynthesis
For generations, scientists have tried to replicate the way plants convert the sun's rays into life-giving energy – photosynthesis – but just how close are these efforts to providing the most efficient known solar energy utilization?

The *CSI* Effect
TV shows such as *CSI* have brought awareness to the field of forensics, inspired students to enroll in forensics courses and even led some to become crime scene investigators themselves.

Women in Science Faculty Positions
A new report from the National Research Council found, for example, that women at research-intensive universities who apply for faculty positions in math, science and engineering are as or more likely than men to be interviewed and hired. However, women are still underrepresented in the applicant pool for these positions.

GreenLight will include stories on making hydrogen from the sun and water, lasers in the solar industry, understanding weather and climate change using CT scans of clouds, pasteurization using sunlight, and the hot solar thermal market in Europe.

Plus all the regular features you look for month after month.

You can't afford to miss this issue.

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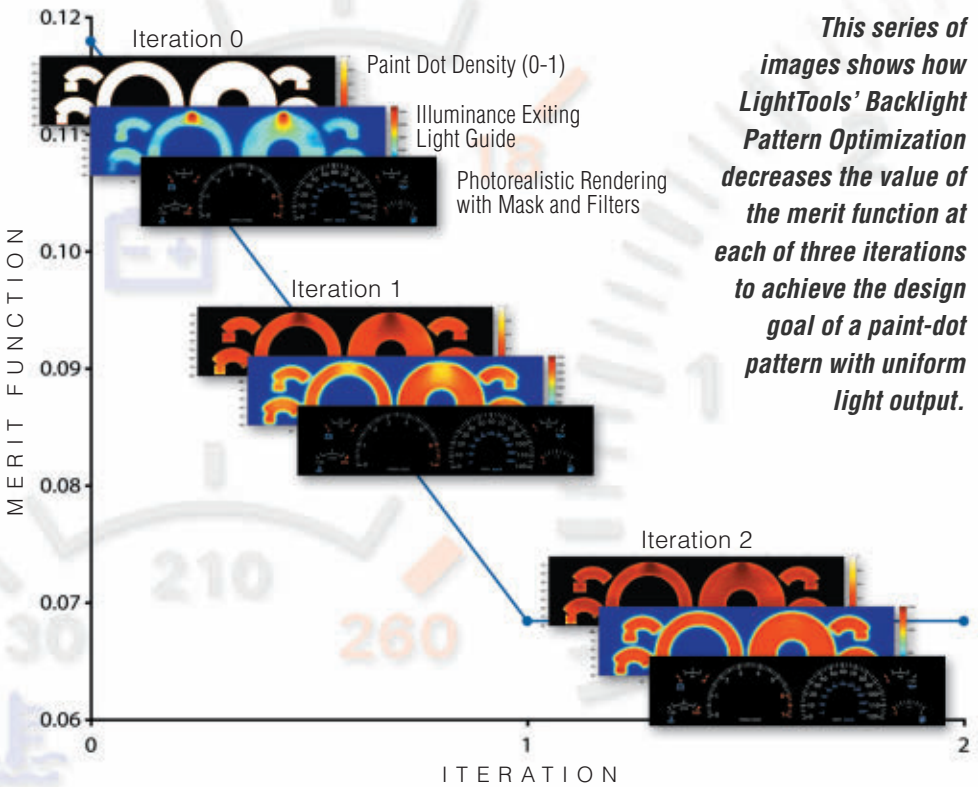

This series of images shows how LightTools' Backlight Pattern Optimization decreases the value of the merit function at each of three iterations to achieve the design goal of a paint-dot pattern with uniform light output.

Final Result : Iteration 2

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Making nanotubes respond to rainbows

LIVERMORE, Calif. – Taking their cue from the eye, researchers have constructed a carbon nanotube that responds to all the colors of the rainbow. With some changes and more work, they could even have a nanometer-size photovoltaic device.

The eye detects light through a photon-induced isomerization of a molecule. In its work, the group from Sandia National Laboratories attached azobenzene chromophores to a single-walled nanotube, with the chromophores serving as photoabsorbers and the nanotube as an electronic readout.

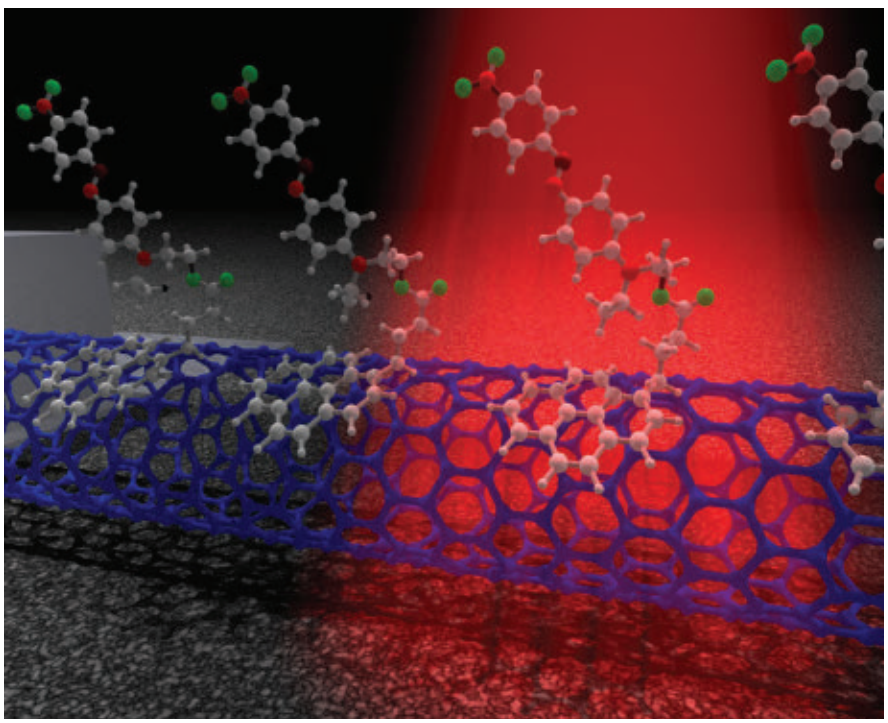
In some ways, the approach improves upon nature – at least as far as potentially maximizing photoabsorption. As Sandia chemist Andrew L. Vance noted, "In the eye, the light actually has to pass through the sensor to get to the molecule being isomerized. We have the sensor behind the molecule."

In the study, which was described in a *Nano Letters* paper in February, the investigators used 0.8- to 2.0-nm-diameter single-walled carbon nanotubes from CheapTubes Inc. of Brattleboro, Vt. They deposited these on silicon wafers that had an array of electron sources and drains. As a result, many of the source-drain gaps were bridged by a single nanotube, creating a field-effect transistor.

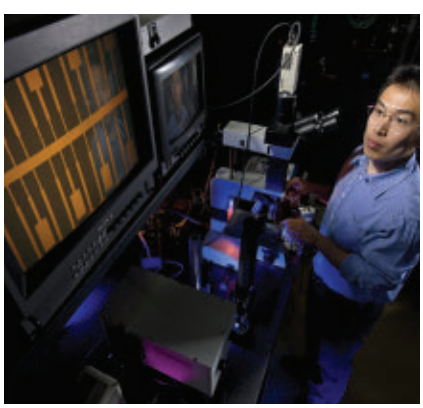
They then prepared chromophores and attached them to the nanotubes. When light of the right wavelength struck the chromophore, it changed the molecule's structure and dipole moment. Because the nanotubes in the experiment were in field-effect transistors, the effect of that small molecular change was not insignificant.

"The transistor has an amplification effect, so we have a large signal response," said postdoctoral researcher and lead author Xinjian Zhou.

Zhou also developed the instrumentation used in the research. He modified a Zeiss optical microscope, taking the light from a xenon arc lamp and feeding it through an Acton monochromator to produce a 3-nm-bandwidth source that could be focused down to a 35-µm spot. This enabled illumination of a single device with light anywhere in the visible spectrum.



Shown is a representation of chromophores attaching to a transistor made from a single carbon nanotube. The resulting device acts as a photodetector with a response similar to the chromophores' spectral response.



Sandia researcher Xinjian Zhou measures the electronic and optical properties of carbon nanotube devices in a probe station. The monitor shows the electrode layout on the device wafer; the nanotubes are positioned in the small horizontal gaps. Photo by Randy Wong. Photos courtesy of Sandia National Laboratories.

By functionalizing the nanotubes with different chromophores, the researchers created photodetectors that responded to different parts of the spectrum. In their study, they used disperse red 1, disperse orange 3 and nitrophenyl azophenol. They obtained response curves from the functionalized nanotubes that correlated with the absorption spectra of the respective molecules.

The current devices work well enough to study fundamental properties of chromophore-nanotube hybrids. In the future, the group would like to improve the sensitivity of the device. This could be done by having multiple layers of chromophores attached to the nanotubes or by having more than one nanotube running between the source/drain on each transistor. Applications of these improved devices could include single-molecule detection.

It might even be feasible to create a photovoltaic device, which would require fabricating a *p-n* semiconductor junction. That would take more research, but such a device is a possibility. It could even have multiple configurations, Vance said. "Depending on how the chromophores are applied, you could use it as a transistor, or you could set it up as a *p-n* junction."

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A closer look at our ancestor

AUSTIN, Texas – Discovered in 1974, the 3.2-million-year-old bones of the fossil Lucy could give us more insight into our origins. Lucy's remains, which are the oldest and most complete adult erect-walking skeleton ever found, consist of around 80 separate bones. The fossil has been studied extensively, but questions about the way she walked and stood, and about whether she climbed trees, have gone unanswered. On her current tour of the US, Lucy took some time out from her busy museum schedule to be imaged.

A group of researchers at the University of Texas received permission from the government of Ethiopia, which owns the skeleton, to scan the fossil in 3-D using x-ray computed tomography (CT). Previous scans of the remains were completed using early-generation CT systems that could not visualize important details of the structure. Using a MicroXCT scanner from Xradia Inc. of Concord, Calif., and an Actis scanner from Bio-Imaging Research Inc. (now part of Varian Medical Systems Inc. of Palo Alto, Calif.), the investigators spent 10 days imaging every element of the fossil.

The bones were examined before and after imaging to make certain that no damage had been done. In addition to taking images of each element as a whole, the scanners enabled investigators to view close-ups of larger portions such as the jaw bone, which allowed them to look more closely at the teeth embedded therein. The images are currently being analyzed, with the hope that the detailed architecture of the bones in Lucy's arms and legs will reveal important information about her lifestyle and the adaptations she made to her environment.

Although none of the CT images has been released yet, the researchers said that their digital images of Lucy would eventually be accessible from any classroom or research center. According to John Kappelman, an investigator and professor of anthropology, once the scientists have finished their analysis, the Authority for Research and Conservation of Cultural Heritage in Ethiopia will make the data available to other investigators.

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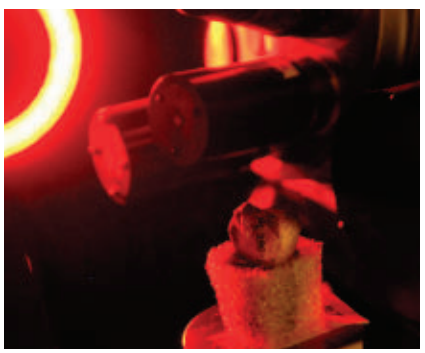
Skeletal elements of the ancient fossil Lucy are assembled for display. Image courtesy of the Houston Museum of Natural Science.

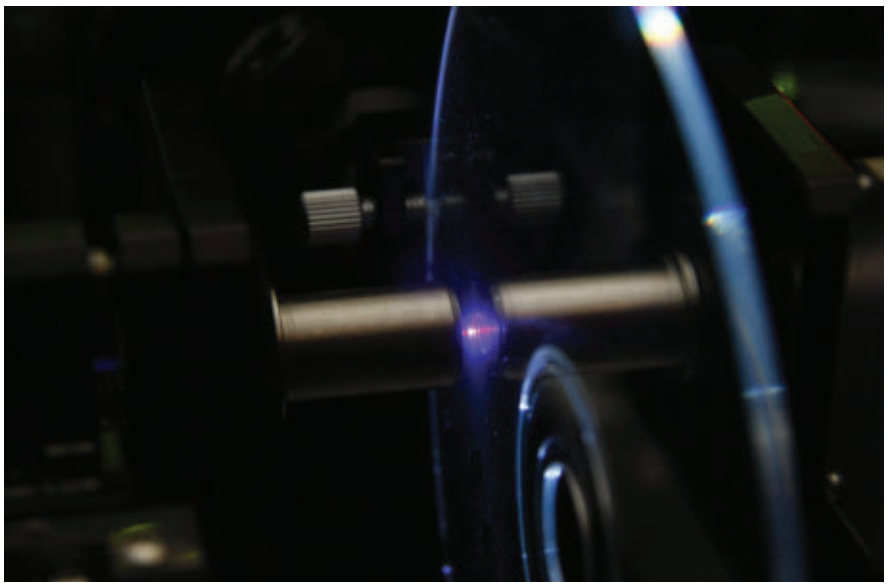


Several of Lucy's skeletal elements, including the right distal radius (arm bone), were scanned with an ultrahigh-resolution Xradia MicroXCT scanner in the High-Resolution X-ray CT Facility at the University of Texas at Austin. Custom-built foam mounts were constructed to safely hold the specimens in the scanner. Photo by Marsha Miller, courtesy of University of Texas at Austin.

Holographic disc can store 100 DVDs

NISKAYUNA, N.Y. – GE Global Research, the technology development unit of General Electric, has created a disc that is the size of a standard DVD yet can hold the equivalent of 100 DVDs' worth of information.

The disc contains holograms similar to those you might find on credit cards. Not only can holograms be pictures, as in this example, but they can also be markings. When a holographic disc is being read inside a DVD or Blu-ray optical drive, a laser beam alights on the disc and bends according to the characteristics of the holographic markings.



Overlapping blue lasers record holograms in a GE microholographic disc. Courtesy of GE.

What the GE team has done is to make simple marks that are very small and that are incorporated into the whole disc, not just etched onto the surface. The team found that marks with diameters of 1 µm exhibited almost 1 percent reflectivity. When used with DVD or Blu-ray optics, this reflectivity is consistent with a storage capacity of 500 GB of data, which is equivalent to 100 DVDs or 20 Blu-ray discs.

"Now almost everyone has heard of the 'format war' that continues to exist between the two next-generation optical storage formats: Blu-ray Disc and HD-DVD," wrote Brian Lawrence, the leader of the holographic storage program at GE, on a corporate blog. "Regardless of which one ultimately wins, these technologies are mature, and the industry is starting to shift focus to the next format."

GE initially will be focusing on the commercial archival industry, followed by the consumer market. "The day when you can store your entire high-definition movie collection on one disc and support high-resolution formats like 3-D television is closer than you think," Lawrence said.

The researchers achieved an important milestone in the laboratory, and they are working on their next goal: storing more than 1 TB, or 1000 GB, of data on a disc. However, to make money off this discovery, they need to incorporate the technology into products that can be mass-produced affordably.

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Recording with nanorods

GE's holographic technology could face competition from a method being developed at Swinburne University of Technology in Melbourne, Australia, under the leadership of professor Min Gu. The Swinburne method could store the equivalent of 2000 DVDs, or 10 terabytes of information, on a single disc.

The researchers used gold nanorods as their storage material. Accordingly, they patterned the nanorods on a surface. In the future, they will pattern the nanorods on an actual disc.

Gold nanorods are known to be sensitive to polarization and to emit various colors of light when hit with a laser, allowing the researchers to exploit these two properties or "dimensions." In the past, the length, width and height of stacks of such recording materials, or the three spatial dimensions, have been varied. This is why the researchers are calling this technology five-dimensional. They plan to test various nanorods in the future. The researchers believe that the technology will be commercially available within five to 10 years. (See "Australian Agenda: No Great Barriers?" on page 66.)

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Detecting melamine in food

WEST LAFAYETTE, Ind. – Researchers at Purdue University are using infrared lasers and light spectroscopy methods to rapidly detect tiny amounts of melamine in baby formula. The technique is performed with equipment that's readily available to health officials and businesses and could go far in detecting the cancer-causing chemical in a variety of food products.

Melamine is a synthetic chemical that's used in cleaning products, in the production of resins such as those used in plastic plates, and in fertilizers and pesticides. According to the Centers for Disease Control and Prevention in Atlanta, exposures

to high levels of melamine – or exposure to lower doses combined with other chemicals – has caused urinary tract and kidney problems in animals, and long-term exposure can cause cancer. The US doesn't allow melamine to be used as a food ingredient, but in China it has shown up in pet food, infant formula, dairy products, candy and more. It likely was used to increase the protein content of the food, according to a Dec. 25, 2008, article in the *New England Journal of Medicine*.

After the discovery of pet food contaminated with melamine (along with cyanuric acid, a related compound), a liquid chromatography/triple-quadrupole tandem mass spectrometry detection method became widely available. This technique can detect down to 250 parts per billion, although sample preparation and cleanup are difficult, and detection time can take up to three hours. A rapid detection method was recently developed by R. Graham Cooks, a professor of chemistry at Purdue University, using a low-temperature plasma probe with tandem mass spectrometry, but drawbacks include the lack of available equipment and the question about whether it's exportable for international use.

A new approach

A group of students at Purdue, working in a food science laboratory that houses near- and mid-IR spectrometers, found another rapid detection method. However, finding an alternative to the liquid chromatography methods was not their original purpose. "We had a new software program, and I gave them the exercise so they could learn to use the software while working on a relevant industrial problem," said Lisa Mauer, an associate professor of food science at Purdue. The near-IR setup included a multiple-purpose analyzer from Bruker Optics of Billerica, Mass. Spectra were collected in the mid-IR region using a Fourier transform-IR spectrometer from Thermo Scientific of Madison, Wis.

They applied two sampling techniques: diffuse reflectance spectroscopy and multibounce attenuated total reflectance. The near-IR instrument had a sample loading wheel, so it was fully automated and very simple, according to Mauer. By reflecting IR laser beams off unadulterated samples of powdered infant formula and toward a detector, they calculated how much of the energy was absorbed by the sample, creating an absorbance spectrum unique to that sample. The spectra were analyzed using the new lab software from Bruker Optics. They then collected the same data for pure melamine and compared the two. Because the melamine structure is very different from the formula's, they were able to detect down to 1 part per million (ppm) of melamine. US federal guidelines allow for 1 ppm in formula and 2.5 ppm in other products.

The method developed at Purdue is fast and accurate. As reported in the *Journal of Agricultural and Food Chemistry*, the factorization analysis differentiated unadulterated formula from samples with 1 ppm of melamine with no misclassifications. The near-IR method took two minutes, while the mid-IR method took five.

Although this new technique is capable of detecting down to the critical 1 ppm level and yields rapid feedback, the current challenge is that the partial least-squares analysis and factorization models are not matrix-independent. New calibration models are needed so that different brands or formulations can be analyzed. Because the study was conducted as a lab training exercise, "It's not something the students will continue on," Mauer noted. However, each student has an individual project as well, so even lower detection methods might emerge from Purdue's department of food science.

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Fingerprint tech gets tested

GAITHERSBURG, Md. – The characteristics that help to differentiate one set of fingerprints from another were first defined in 1892 by Sir Francis Galton. In the decades since, fingerprint identification has become a staple of forensic investigations.

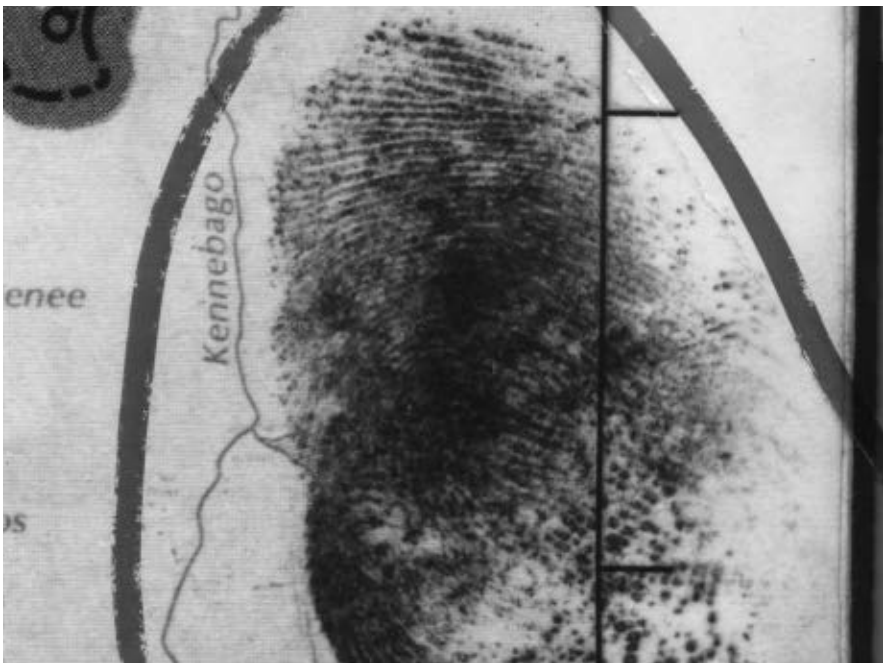
Originally, it was a time-consuming process that required manual comparison of a latent print with dozens or hundreds of prints previously taken from suspects, with no guarantee of finding a match.

In recent years, however, computers have been used to determine potential matches between latent prints and those in crime databases. Human assistance still is needed to mark important features of latent prints before they are entered into the computer because, typically, prints are incomplete or are smudged or located on a textured surface. Without this input, the machines have difficulty matching the prints to their potential mates effectively. Every image requires this manual processing, so the time that technicians can spend on more difficult prints is drastically reduced.

Many companies and universities are trying to ease the workload of fingerprint technicians by developing algorithms and programs to automate the majority of the work. Before these new technologies can be considered for forensic investigations, they must be independently tested and evaluated to help potential users find the best program for their application.

This is where the National Institute of Standards and Technology (NIST) comes in. For the past two years, researchers at the institute have been working on the first two phases of the Evaluation of Latent Fingerprint Technology (ELFT) program. Beginning in 2007, investigators invited companies and universities to submit their feature-identification algorithms – whether commercially available or still in development – for examination in a study that would determine their strengths and weaknesses as well as provide a baseline for the industry. For Phase II of the program, which began in 2008, eight organizations provided technology for testing.

These eight software systems were tested with 835 latent fingerprints, all of which were compared with two galleries, or databases, of 10-print records – fingerprint sets taken by police. The first gallery contained 5000 records (50,000 fingerprints) and the second, 10,000 (100,000 fingerprints). All 835 prints had matches in both galleries. Each system processed the 10-print records and latent print images without human assistance, identifying the important features of each.



At left, a latent fingerprint – such as this one pulled from a nail file – can be the key to solving a mystery. Automated feature extraction could make the process of identifying such prints faster and easier. Above, this latent print, imaged at 39.37 pixels per millimeter, is similar to those NIST used to test automated feature identification technologies under its ELFT program. Images courtesy of NIST.

Once the features had been identified, each algorithm compared the latent prints against the galleries, finding possible matches and ranking the top 50 potential matches from most to least likely. Each system was then scored on accuracy (how often it suggested a correct match and how high the match was ranked). The tests enabled the researchers to investigate factors that could affect the performance of the technology. The criteria included gallery size, image resolution, finger position and the availability of a supplementary region of interest – the area of a smudged print most likely to provide useful minutiae.

The investigators determined that half the prototypes tested found fingerprint matches about 80 percent of the time, while one was more than 95 percent accurate. There was a slight decrease in the identification rate when the gallery size was increased from 5000 to 10,000 records. The resolution of the images was not a statistically significant factor, and selecting a region of interest proved to be of limited use with some algorithms. The higher the quality of the image and the more features the algorithm could truly detect, the better the identification rate.

Although these programs are still being tested and improved, their potential is clear. By reducing the amount of tedious, routine precomputer work required for fingerprint matching, these algorithms have the potential to enhance the quality and speed of print identification.

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Schott Solar opens in Albuquerque

ALBUQUERQUE, N.M. – Schott Solar, the first facility in the world to produce both concentrated solar power receivers and photovoltaic (PV) modules, was inaugurated May 11 in Albuquerque. The company's flagship North American plant represents the first solar manufacturing facility to open after the American Recovery and Reinvestment Act of 2009 was signed into law in February.

New Mexico Gov. Bill Richardson (left) and Dr. Udo Ungeheuer of Schott AG sign the first CSP receiver to roll off the assembly line at the new Albuquerque plant. (Photos: Melinda Rose, Photonics Media)

Attending the ceremony at Schott Solar's $100 million, 200,000-sq-ft facility were company executives from the US and Germany, and state, local and national officials, including New Mexico Gov. Bill Richardson, US Rep. Martin Heinrich and Speaker of the New Mexico House of Representatives Ben Lujan. The grand opening began with a performance by the Dineh Tah Navajo Dancers.

"This is one of the most significant economic development projects in state history," Richardson said of the plant, which expects to employ 350 as it ramps up production over the summer. Estimates are that the potential economic value of the plant to New Mexico will top $1 billion by 2020, he said.

Dr. Udo Ungeheuer, chairman of the board of management at Schott AG, said

Schott Solar's PV modules.

the site has the potential to employ up to 1500 by 2012 or 2014, a substantial number of jobs in a state with a population of only 2 million.

Even though the plant just opened, Schott continues to prepare land near its PV and concentrated solar power (CSP) receiver production facilities for future expansion to 800,000 sq ft.

"The US has the potential to become a solar superpower," Ungeheuer said, pointing out that Germany, where Schott AG is located, has the solar energy equivalent of Alaska yet is a leader in producing and using solar power.

Schott Solar in Albuquerque begins with two CSP receiver lines, with a capacity of 400 MW; future expansion will double that to four lines. The first phase on the PV side has an annual capacity of up to 85 MW of PV 225-W polycrystalline modules, sold under the Schott Solar Poly 225 name. The size and durability of the modules make them well-suited to applications such as commercial buildings and schools, the company said.

Researchers at Fraunhofer Institute in Germany have calculated that the sun sends enough energy to Earth in one hour to cover the entire planet's energy needs for a full year. President Barack Obama has said that he wants to double the nation's renewable energy portfolio in three years.

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To the moon and back, many times a minute

FORT DAVIS, Texas – The moon is spiraling away at 3.8 cm, or about an inch and a half, a year. But don't worry. Given that it sits at a distance of about 385,000 km, or just under 240,000 miles, there will be no noticeable change in its appearance for a long, long time.

Detecting that slight lunar movement has been possible because of photonics technologies and the only Apollo experiment still running. For almost 40 years, scientists have periodically pinged the moon with a laser beam, measuring how long light takes to make the round trip.

The answer, for the curious, is about 2.5 s, varying because the moon's elliptical orbit results in a constantly changing distance. From precise measurements of that number, researchers have confirmed not only a key tenet of Einstein's theory of relativity, but have shown that the force of gravity is very stable and have discovered that the moon probably has a liquid core.

The last is a consequence of an early and unexpected finding, said Peter J. Shelus, project manager and principal investigator for the McDonald Observatory and Center for Space Research Laser

Ranging Program at the University of Texas at Austin, a job he has held for almost four decades.

"The rotation of the moon is a lot more complicated than originally thought," he said, adding that, once it was better understood, scientists got a bonus from the lunar laser ranging experiment. "It's a probe into the interior of the moon."

The finding involving relativity arises because the experiments have confirmed that gravitational and inertial mass are equivalent, at least to current accuracy levels. That proves that Albert Einstein's formulation of relativity is correct.

Measuring the distance from Earth to the moon is dependent upon retroreflectors left on the surface by Apollo astronauts and by two Russian robot vehicles. Researchers on Earth hit the reflectors with a laser pulse, a feat that has been likened to successfully targeting a moving dime with a rifle at a distance of 3 km.

For almost 20 years from the late 1960s, astronomers measured the Earth-to-moon distance by beaming a laser from the 2.7-m McDonald Observatory Smith Telescope to retroreflectors placed on the moon. Courtesy of McDonald Observatory.

The retroreflectors send the pulse back to Earth. Usually only one or, at most, a few photons make it back to be collected and detected to provide the total trip time. That and the speed of light yield the distance to the moon to an accuracy of a few centimeters or better, depending on the equipment.

Today, the McDonald measurements are done on a dedicated system, one that also does ranging to orbiting artificial satellites. This setup enables cost sharing and avoids the scheduling conflicts of a larger system. The drawback is a lower data rate because of smaller collecting optics.

Besides McDonald, two other sites collect lunar laser ranging data, one in New Mexico and the other in France. The latter has been off-line for years while undergoing an upgrade, and the former has scheduling constraints.

As for how long the experiments can go on, Shelus noted that the retroreflectors should be observable for years to come. The science itself, he added, gets better with each additional year of observations.

Given all that, there is no technical reason not to continue the lunar distance measurements for another two score years or more, he said. "They can go on as long as there is financial support – and the interest – to do so."

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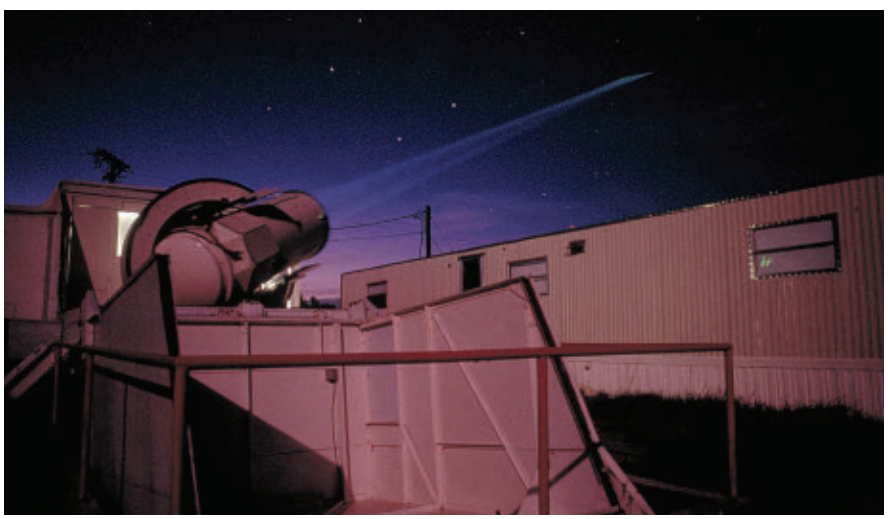

Earth-moon measurements are now preformed with a dedicated telescope, the McDonald Laser Ranging Station. Photo by Kathryn Gessas, McDonald Observatory.

Unscrambling holograms gains high-res images

PRINCETON, N.J. – There's a catch-22 to cameras. Either they have high resolution and a narrow field of view, or they have a wide field of view at a loss of resolution.

One reason why resolution is poor is that many light rays never make it to the detector because they are too weak or they go off to the side instead of straight through the lens. Some cameras have been rigged to scan very close to objects to capture more of these light rays. Then these images can be pieced together to get a wide field of view.

This means putting a camera really close to an object and taking a bunch of pictures. This course of action is not always wise or feasible, especially when that subject is dangerous, hostile or otherwise hard to reach.

In the case of a microscope and camera setup, putting the objective really close to the sample can damage both the sample and the objective if the objective inadvertently touches the sample. Moreover, taking bits of images at different time points and stitching them together is no good if the experiment is time-sensitive.

What if high resolution and a wide field of view could be obtained all at once without the objective's being so close to the object? That's what assistant professor Jason Fleischer of Princeton University is wondering. He and grad students Christopher Barsi and Wenjie Wan decided to project a hologram of an object under study because this can be done relatively far away from the object.

The researchers not only created a hologram but also used an unusual material to do it: a crystal of strontium barium niobate. This material mixes the light nonlinearly, which results in a scrambled hologram.

At this point, an ordinary person might suppose that the hologram is worthless because it's all mixed up, but the researchers realized that it contains more light rays than an ordinary lens can pick up. All they

Jason Fleischer, an assistant professor at Princeton University, adjusts the green laser setup that was used to create holograms. Courtesy of Frank Wojciechowski.

have to do is unscramble the hologram.

In a way, these light rays can be thought of as optical information and the hologram as a message. The researchers decoded the message mathematically.

There are some more details. The researchers fired a green laser through a chart and then through the crystal to create the hologram. They determined the amplitude and phase of the light field and input those variables into Schrödinger's equation to unscramble the image. The setup also involved a reference laser beam that helped them determine the amplitude and phase. This experiment is detailed in the April issue of *Nature Photonics*.

At this point, the work is preliminary, and it could go down several different paths. The principle of encoding and decoding the image could be used for data encryption or for tomography. The method also improve microscopy or lithography. Or it could simply help them understand how weird materials like strontium barium niobate mix up light.

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Special effects captured in a whole new light

CAMBRIDGE, Mass. – Imagine an imaging system that doesn't require a camera or reflective markers but instead uses small photosensors and solid-state projectors that transmit near-infrared light to capture movement. The technique could improve the way special effects are rendered in movies, providing filmmakers with an easier, more adaptable and less expensive on-set motion capture system.

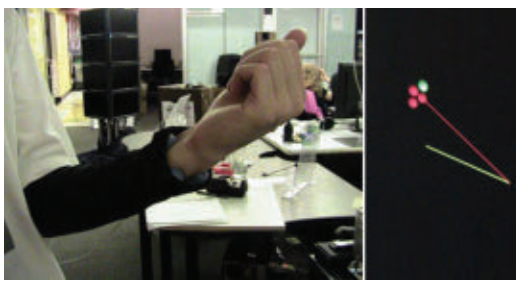
Ramesh Raskar, an associate professor of media arts and sciences at MIT, and Dennis R. Miaw, a graduate student, created the technique they call "second skin."

"The system is better than traditional camera-based motion capture because the markers are imperceptible and you get a unique ID per marker," Raskar said. "Plus the actors can work in natural conditions, i.e., under studio lights and stage costumes. This makes it possible to finally achieve 'on-set' motion capture, a holy grail in this business."

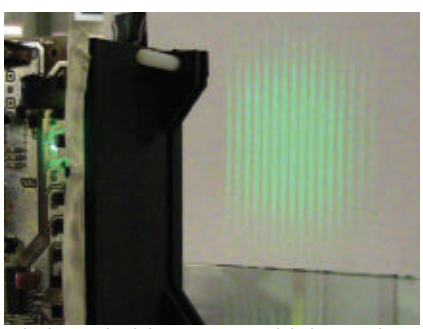
~~Lights, camera~~ … action!

Small optical tags with photosensors are worn underneath the subject's clothing, making the tags more discreet than conventional markers. The sensors compute location, orientation and incident ambient illumination – when the lighting matches all of the elements placed in the scene at the time the image is captured – for surface reflectance. The data is stored by a flash memory microcontroller, also hidden under clothes, that sends the information wirelessly via a radio-frequency channel to a computer.

An unlimited number of tags can be integrated within the system because "the tags receive light from the projectors, and the tags themselves determine their own location based on the light sequences they receive," Miaw said. With reflecting markers, it's hard for cameras to differentiate each one individually, which can repeatedly result in reacquisition problems.



Photosensors are embedded into a sleeve to track movement of a subject's arm and wrist, while vibrating sensors (blue devices around the wrist) are incorporated to correct the subject's position (left). A software program depicts the arm's actual location (red line) and its ideal position (yellow line) (right). The dots correspond to the vibrating sensors, and the green dot indicates vibration that tells the subject how he should reposition his arm. The technique is useful for tracking and correcting motions in tai chi exercises and, in the future, it could advance physical therapy methods.



A high-speed solid-state projector labels space by emitting near-infrared patterns of light at 870 nm. Imperceptible photosensors hidden underneath a subject's clothes receive a distinct pattern from the sequence and, by doing so, determine their own location. The projectors encase an LED and passive binary film that transmit the patterns of light.

High-speed solid-state projectors, or beamers, include LEDs and passive binary films, or masks, set in front of them for use as transmitters. The beamers label space surrounding the tags by creating zones, and they can be mounted anywhere on set or placed outside, as long as the tags are in the beamers' line of sight and at least 1 to 8 m away.

Every projector emits eight different near-infrared patterns at 870 nm, and the photosensors receive their own distinctive pattern, which they decode into a binary signal to indicate their position. "A photodetector that is sitting somewhere in the space will receive a unique light pattern corresponding to that 3-D point in space," Miaw said. "If that photodetector moves to a different spot, it will receive a different unique pattern that corresponds to the new location." At the same time, each sensor records the patterns approximately 500 times a second, and 10 projectors can acquire a frame within 800 ms.

The system uses time division multiplexing – transferring two signals within one communication channel with separate time slots of fixed length – set at 455 kHz. The beamers have their own time slot where the patterns remain on for 33 ms at a time followed by a 33-ms delay. According to Miaw, the delay is to ensure that the tags do not confuse patterns from a start bit that's emitted at 100 ms in length at the beginning of the sequence, which may hinder synchronization.

The technique results in easier and faster production time and management, and it eliminates the need to change settings. "This system is also extremely inexpensive, with hardware costs on the order of tens to hundreds of dollars, as opposed to tens of thousands of dollars for most conventional camera-based systems," Miaw said.

Second skin not only advances special effects for movies, but it also can be used in tai chi training and, possibly in the future, injury rehabilitation and sports training.

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THE PULSE OF THE INDUSTRY

Image sensor market: Looking forward to better times

PORTLAND, Maine — After a short downturn, the worldwide image sensor market, which consists of more than 11 billion devices with a market value of more than $7.5 billion, is expected to pick up steam by 2012 and to exhibit robust growth rates by 2014, according to a report from Pira International of Leatherhead, UK, which provides information and organizes events for a range of industries, including electronics, displays and lighting.

Published in May 2009, the report, titled *The Future of Image Sensors*, offers a quantitative view of market sizes and forecasts to 2014 based on primary and secondary research. It is designed for end users; business planners and analysts; manufacturers of image sensors and modules; and wafer and equipment suppliers, packagers and designers. Additional information on the company and the report can be found at www.intertechpira.com.

In 2008, the base year of the report, the total market for image sensors was $7.9 billion, but because of the downturn in the main areas of demand for the devices, the value is expected to fall to $6.3 billion. According to the company's extrapolation, by 2015-16, the image sensor market likely will regain the total market value of the 2007-08 period.

The image sensor markets in the Asia-Pacific and North American regions probably will be the first to recover from the economic downturn, said Charles E. Spear, head of US publishing at IntertechPira in Portland, Maine. He added that he expected 2- to 5-megapixel sensors to continue to dominate the market through 2014.

Applications ahead

The market has been adversely affected by the sectors of its principal applications – computers, mobile communications and consumer markets – all of which have been hit hard by the economic slowdown. The image sensor manufacturing industry is experiencing a period of lower activity because the demand for many systems and components has fallen, according to the report.

The evolution of the image sensor market is shown in billions of dollars from 2000 through 2008 and projected from 2009 through 2016. Courtesy of Pira International Ltd.

The mobile communications sector will remain the most important application area for the devices, and the extent to which it thrives will have a great impact on the device business and on its supply chain, the report states.

The telecommunications and data communications industries could double in size over the next five years by tapping into new geographical markets. Competition for these application markets is expected to intensify once the downturn is over. Telecommunications and other sectors such as the consumer and automotive markets are likely to expand, but the pressure will be on device makers to keep prices lower. Continuing depression in the total market value is likely to continue in 2009.

Other applications areas expected to drive the growth of image sensors include security and surveillance, and vehicle driver aids, the latter of which will grow only when the car market picks up.

The demand for image sensors also may increase with the expansion of personal battery-operated equipment for the information and entertainment market, such as digital cameras, high-definition camcorders, game consoles, music and movie players, and two-way interactive entertainment; for example, the shift to more online capability in television sets may result in next-generation models with embedded cameras for Internet video telephony or interactive participation in games and discussions.

Another growing application area for image sensors is the military, which continues to develop smart technology as it increases its reliance on intelligence gathering. While emphasizing lower costs, the military is evolving fully automated vehicles and more accurate weapons based on high-performance devices.

Market expansion is key

Variations of existing devices will be launched over the next five years, and only those with the best combination of performance and pricing are expected to succeed. The report notes that companies can either promote products based on existing image sensors, such as cameras, camera phones and computer notebooks, or they can try to convince existing end users of the importance of replacing image sensor-based products with next-generation versions.

Expanding the market is the next challenge, according to the report. Companies will need to initiate a second generation of devices that will feature higher levels of sophistication and performance. A third generation of devices based on polymeric thin films or on nanoscale structures also could be developed. New companies may enter the market as a result of diversification.

The product's position in its lifecycle and the competitive nature of the market can affect how it will perform in the market, according to the report; for example, it suggests that the market for CCD sensors is mature and that the number of units shipped may not recover as well in comparison with that of CMOS sensors.

By 2014, providers with the most competitive components and subsystems for the telecommunications industry are likely to be the most successful – but this prediction is a relatively uncertain one and is based on the timing of the introduction of next-generation personal telecommunications and multimedia systems.

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VCSEL contract awarded

MERCERVILLE, N.J. – Princeton Optronics Inc., a privately held company that develops and manufactures vertical-cavity surface-emitting lasers (VCSELs) and low-noise solid-state lasers, has been awarded a Phase II Small Business Innovation Research contract by the US Navy. The two-year, $750,000 grant, which follows the completion of a Phase I contract received last year, will fund the company's research into developing blue laser arrays by frequency doubling of high-power external-cavity VCSEL arrays.

The company's goal is to create pulsed blue lasers with energy of >10 mJ per pulse and a short pulse duration for use in the Navy's light detection and ranging applications. Because of seawater's blue-wavelength transmission band, the lasers will enable longer-range transmission than other wavelengths. VCSEL technology permits the creation of lasers that are much smaller and lighter, weighing only a few pounds, compared with the 100 lb typical with existing solid-state lasers.

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Changing spaces

SEATTLE – PhD-level women with established private sector careers in the sciences, technology, engineering and mathematics (STEM) who want to explore the possibility of a career in the academic world are invited to workshops designed to help them make the transition.

Funded by a grant from the National Science Foundation, the On-Ramps into Academia series of workshops is being offered at the University of Washington, beginning in October 2009 with the first of three annual programs. They are targeted to women scientists and engineers with doctorates who have been working in the private sector for at least three years. The two-day workshops will feature a panel of women who have made the transition, as well as offer opportunities to network and form a supportive community.

The On-Ramps series will look outside the academic world to identify a new pool of women faculty in the STEM disciplines because women are largely underrepresented in these academic areas. The goal to achieve some measure of gender parity in the academic halls of science and engineering is important for many reasons, said principal investigator Eve Riskin, who is a professor of electrical engineering, the associate dean for academic affairs in the college of engineering and director of the ADVANCE Center for Institutional Change at the University of Washington. More women faculty in the STEM disciplines will eventually lead to a friendlier environment for women students, and overall, this eventual sea change will likely lead to a greater number of women in the engineering field – which will be good for everyone, she said. Greater diversity will lead to a greater pool of effective design ideas and solutions for all of us, she added.

Research freedom

Freedom to be your own boss, to do what you love and to do your own research are among the reasons why a woman might want to consider a job in the academic world, Riskin said, adding that job security and tenure were also compelling incentives.

She said that there tends to be a perception that the academic world is not family-friendly but that in reality it is very flexible: Professors can generally make their own hours and set their own schedules, possibly enabling a better balance of work and family life.

The main challenges that women face when transitioning from a career in industry to an academic professorship include the lack of recent publications and the proprietary nature of their work, Riskin said. Applicants from industry look quite different to the academic world, and academic employers have to be convinced that industrial research skills can be transferred in a positive way toward the education of college students. She said that academic personnel should be interested in hearing

about a job candidate's activities in patents, intellectual property, project leadership and in professional societies.

Practical tools

The On-Ramps into Academia workshops will provide practical tools to help private sector career women make the switch to teaching and academic research. Among the topics to be covered will be networking, the job application process, interviewing and start-up negotiations. Women will get help in learning how to teach effectively and in working with graduate and undergraduate students. They will also be educated in how to leverage their industrial position to bring funding into their academic program. They will get information on why the academic world would want them, how to obtain grant funding, how to transfer nonacademic experience into classroom practices, how to create a balance between work and personal life, and on what level to enter academic life – whether as an assistant, associate or full professor, for example.

Transitioning in photonics

Lih Y. Lin, a professor in the electrical engineering department at the University of Washington, is an example of a woman in the photonics community who successfully made the transition from industry to academia. Lin and her group investigated turning quantum dots into waveguides that channel laser light through photonic cir-

Canada's first 10-kW fiber laser

OXFORD, Mass. – Canada just got its first 10-kW fiber laser.

IPG Photonics Corp. recently delivered the laser to the Centre spécialisé de technologie physique du Québec inc. in La Pocatière, Québec.

The most powerful of its kind in Canada, the new laser will be dedicated to applied research, development and technology transfer aimed at manufacturing companies.

Fiber lasers enable end users to increase productivity and decrease operating costs by delivering better performance, reliability and usability at a lower total cost of ownership compared with conventional lasers, said Bill Shiner, vice president of industrial markets at IPG.

"[Our] industrial fiber lasers have a reputation for providing high power, reliability, efficiency and ruggedness in a compact package at a low cost," said Randy Paura, the company's Canadian regional manager and processing consultant. "While scaled up in power … to 50 kW, the industrial laser power sources provide the same simplicity of operation, providing high reliability of performance with their high-life-span diode pumps.

"What starts in the fiber, stays in the fiber until delivered to the focus optics for materials processing."

Founded in 1990, the company pioneered the development and commercialization of optical fiber-based lasers for a wide range of uses, including materials processing, advanced applications, telecommunications and medical applications.

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cuitry. Their work is described in the article "Nanoparticles leading the way to light-driven computers," which was published in *Photonics Spectra* (May 2009, p. 53).

Lin received her PhD in electrical engineering from the University of California, Los Angeles, in 1996 and was employed at AT&T Labs-Research as senior technical staff member and at Tellium Inc. as director of optical technologies. She said she was attracted to academic life for the research freedom that it offers, as well for the interaction with students and the flexibility in scheduling. She mentioned that, within the academic environment, a woman with children should be sure to have a strong and supportive social network and resources for help, and that she should manage her time well.

Women who are interested in attending the free workshops are invited to visit www.engr.washington.edu/onramp for additional information and an online application form. Applications received by June 30 for this year's workshop will be given priority, but applications may be considered after that day if spaces are still available.

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Novotech Adds Product Novotech Inc. of Acton, Mass., a infrared-grade germanium and silicon provider, has added the Optipro SX 150, a precision optical grinding machine with computer numerical control to its arsenal of fabrication tools. The tool from OptiPro Systems of Ontario, NY, enables curve generation of blanks to tight tolerances as well as generation of concave and convex aspheric blanks. The five-axis system manufactures complex nonstandard blank and window shapes and performs multistep deterministic grinding of spherical surfaces with precision edging and beveling.

Frontier Development Brookhaven National Laboratory of Upton, N.Y., has been selected by the US Department of Energy (DoE) to be home to one of the 46 new Energy Frontier Research Centers. The centers will pursue advanced scientific research on energy and are being established at universities, national laboratories, nonprofit organizations and private firms across the US. The DOE plans to fund each center at $2 million to $5 million per year for an initial five-year period.

New Name SmartSpark Energy Systems of Austin, Texas, has changed its name to better reflect its focus on the solar market with microinverter and monitoring solutions. Its new identity, SolarBridge Technologies Inc., demonstrates the company's mission to reduce the levelized cost of energy for solar installations.

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Software Purchase Siemens AG of Munich, Germany, has expanded its industrial portfolio by purchasing Elan Software Systems SA of Toulouse, France, a supplier of software for manufacturing execution systems in the pharmaceutical and biotechnology industries. The purchase price was not disclosed.

Distribution Agreement Signed Mouser Electronics Inc. of Mansfield, Texas, and Osram Opto Semiconductors of Sunnyvale, Calif., have signed a distribution agreement. Mouser initially will stock the latter's high-powered, midpowered and standard LEDs as well as infrared and sensor products.

Looking for UXOs The US Army has offered a contract to Curtiss-Wright Controls Inc. of Charlotte, N.C., under which the company will supply its ground-penetrating radar technology for use in the detection of unexploded ordnances (UXOs) in overseas operations. Under terms of the agreement, the company will provide the military with its step-frequency B3231 antenna and its GeoScope processing solutions. The contract is expected to last for one year.

Semiconductor Distribution AMS Technologies AG of Martinsried, Germany, has entered into an exclusive distribution agreement with C3 Semiconductors LLC of San Diego. The contract will allow the German company to sell the latter's semiconductor products throughout Europe.

Biofuels Office Wilks Enterprise Inc. of South Norwalk, Conn., has opened a West Coast office in Boulder Creek, Calif. The office will focus mainly on expanding applications and products for the biofuels industry. The company currently offers a mid-IR analyzer and a mid-IR spectrometer for use in that field.

Lighting Application Support In Sunnyvale, Calif., Bridgelux Inc. has launched a lighting services group. The company, a supplier of LED-based light sources, has created the group to support customers in developing application-specific optical, electrical, thermal and mechanical designs to simplify the adoption of solid-state lighting technology.

Photonics in Asia SPIE has announced the launch of the Optics and Photonics Society of Singapore, which has roots in the former Singapore chapter of SPIE. The society aims to promote greater interaction between the optics and photonics communities in Singapore, in both academia and industry, and it retains strong ties to SPIE.

Licensing Nanotechnology Reactive NanoTechnologies Inc. of Hunt Valley, Md., has signed a licensing agreement with Thermal Conductive Bonding Inc. of San Jose, Calif. The latter company will gain the use of its partner's patented NanoFoil and NanoBond technologies, which it will use in factories in California, Germany and Korea.

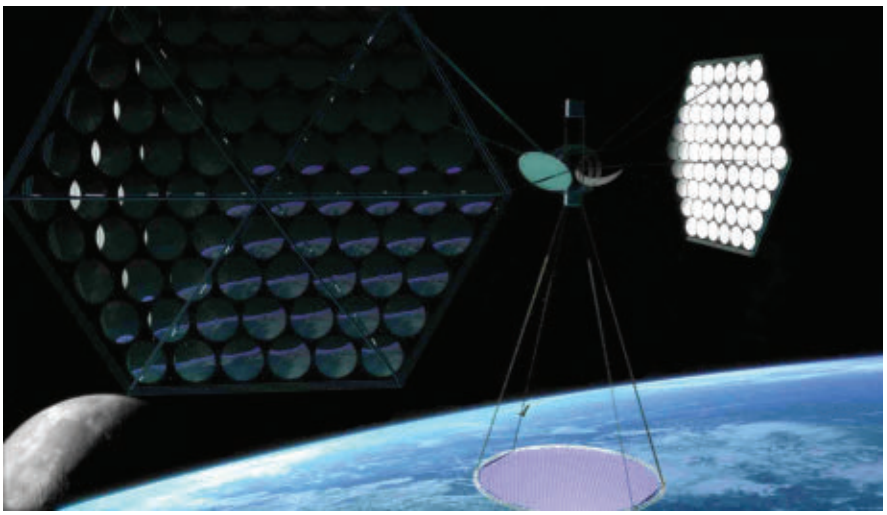
Expanding Camera Company Allied Vision Technologies GmbH of Ahrensburg, Germany, has expanded its office space in Newburyport, Mass. The camera manufacturer said that the increase in floor space was the result of its acquisition of Prosilica Inc., which took place last July.

New Company The Optoelectronics Co. Ltd., based in Henham, UK, has been created by the founders of Photonic Products Ltd. The new company specializes in the distribution of optoelectronic devices and will initially offer VIS/IR vertical-cavity surface-emitting lasers and GaAs pin photodiodes.

Solid-State Lighting Funding QD Vision of Watertown, Mass., a developer of nanotechnology-based products for lighting and displays, has been awarded more than $700,000 in funding by the DoE. The award will fund research into developing a cost-competitive solution to the extraction efficiency of organic LEDs with a stable color rendering index for use in solid-state lighting.

Solar from space

BY ANNE L. FISCHER
SENIOR EDITOR



The concept of gathering the sun's energy in outer space and beaming it to Earth is getting closer to reality. Courtesy of Mafic Studios Inc.

The sun shines 24/7 in outer space, so it is not surprising that solar power seekers worldwide are setting up shop out there – or at least taking steps in that direction.

Solar power drawn from space-based satellites is not a new concept. It was presented in the journal *Science* in 1968 and patented by Dr. Peter E. Glaser in 1973. During the energy crisis of the 1970s, the US Department of Energy studied space-based power, proving that, although technically feasible, it was economically impractical and less efficient than other forms of energy.

In the 1990s, NASA revived the concept with the "Fresh Look" study and, by 2007, with a revived focus on renewable energy sources, many groups – both government and industry – had stepped up the studies and the investment. Over the course of three decades, the US government and NASA have collectively invested about $80 million in the study of space-based solar.

The most common approach to space-based solar power generation would place satellites into geostationary orbit – a 24-hour revolution synchronized with the Earth's rotation – at an altitude of 22,500 miles. The satellite would be equipped with photovoltaic solar panels that would collect sunlight and, using solid-state power amplifiers, would convert the solar power to 2.45- or 5.8-GHz microwaves that would be beamed to a receiver on Earth. The receiver, called a rectenna, would convert microwave energy into electricity, which would be sent to a local power grid.

John C. Mankins, who formerly managed NASA's space solar power studies and who now owns Managed Energy Technologies of Ashburn, Va., said that this is no small undertaking. Speaking with Jeff Young on National Public Radio's "Living on Earth" program, he said that the transmitter would measure about a half mile across, or the equivalent of approximately 20 international space stations. The beam would be about a half mile wide in space and would spread to about four miles wide when received on Earth.

"You'd certainly want to take the right precautions, keep the energy density, the amount of power that's in a square meter of the beam low enough to be safe," he told Young.

Not without challenges

As with the development of all forms of solar power, a huge challenge is generating power cheaply, reliably and safely. Generating it in space adds variables, including finding materials that can withstand high temperatures, placing huge satellite transmitters into space and placing receivers on Earth, and ensuring that the beams sent to Earth are not harmful to humans or to the environment.

Research and development costs aside, the biggest ticket item is expected to be the cost of launching the satellites. Space Energy AG of Switzerland has made great strides toward developing its solar-from-space concept, and its business plan allocates about $125 million just to hoist its satellite into space.

The beam of microwave energy would measure a mile or two across and would pass through the atmosphere easily. Some energy would be lost, although exactly how much is not yet known, and skeptics could raise disaster-ridden questions: What if the beam strays? Could birds or humans be harmed? Would the beam affect weather or cause other changes to the environment?

Generating power in space adds variables, including finding materials that can withstand high temperatures, placing huge satellite transmitters into space and placing receivers on Earth, and ensuring that the beams sent to Earth are not harmful to humans or the environment.

Dr. James Logan, former chief of medical operations at NASA's Johnson Space Center, has studied these issues and has answers to many of the questions: If the beam strayed, for example, it could be defocused. If birds passed through the beam, they would feel some warmth, but microwave radiation is nonionizing and

Solar-powered space station

The International Space Station is a great example of solar power at work. The largest spacecraft ever in orbit, it has a wingspan of approximately 361 ft. and a length of 262 ft. It weighs 1 million pounds and orbits at an altitude of approximately 220 nautical miles. Six astronauts currently are conducting experiments in its six laboratories.

The space station is powered by four power modules with two solar arrays on each. The eight arrays produce around 120 kW of usable electricity – enough to run about 42 average-size homes. The arrays play a critical role, supplying power to such things as the systems that provide or control the air the astronauts breathe, food storage and temperature controls.

Each wing uses 32,800 solar cells manufactured by Spectrolab Inc. of Sylmar, Calif., a Boeing Corp. company. The fourth set of solar arrays was attached in March by two space-walking astronauts, with the assistance of a robotic arm that held the $300 million, 14-ton power module. With the power supplied by the fourth wing, the space station now provides living quarters for six astronauts, double the number prior to the new installation. The astronauts also have enough power for life support and for taking on additional scientific studies.

Designed in the 1990s, the solar cells are silicon-based. Spectrolab President David Lillington describes the cells as being the largest produced at the time, measuring just over 60 cm^2. He said that the cells can turn about 14.5 percent of the solar spectrum into electricity. Uniquely designed, the front contacts to the solar cells wrap through to the back side via small holes drilled through the cells.

The space station provides an ideal environment for evaluating new solar cell technologies and materials through NASA's Materials International Space Station Experiment test bed. In addition, much can be learned about the effects of atomic oxygen, Lillington said.

Solar cells in space are not without their tormentors. Space debris can take them out quickly. Carter Reznick, a Boeing engineer, said that, because working on or replacing the cells is not a simple process, the station is equipped with far more of them than necessary. A cell's power drops off over time, but constant monitoring via sensors has shown that all 82 circuits are working and that there has been no measurable drop thus far.

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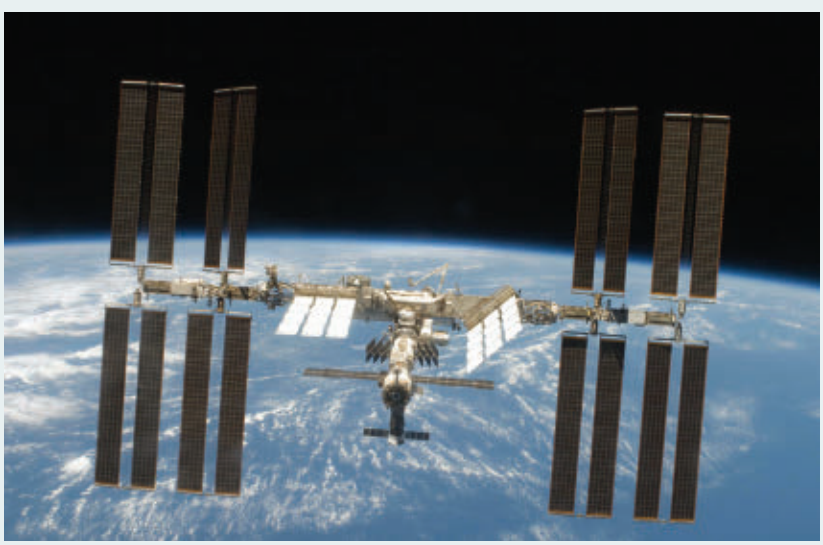

The International Space Station is powered by four solar arrays that produce about 120 kW of electricity. Courtesy of Boeing Corp.

cannot make a charged particle that would damage DNA or biomolecules.

Signing up

Pacific Gas and Electric Co. (PG&E) of San Francisco recently signed a supply agreement with Solaren Corp. of Manhattan Beach, Calif., for 200 MW of electricity generated in space and transmitted by microwave beam to a receiving station in Fresno County, Calif. The contract calls for the power to begin to flow in 2016.

In an interview posted on PG&E's Next100 Web site, Solaren CEO Gary Spirnak said he is confident that, by using proven technology and designs, and through extensive testing, the company will be able to deliver on the contract.

Others also are working to commercialize space-based solar power. Space Energy is developing solar satellites, and the Japanese Aerospace Exploration Agency (JAXA) plans to have a 1-GW satellite in orbit by 2030 but has not decided whether it will beam microwave or laser beams back to Earth. In conjunction with Mitsubishi Electric and Electronics USA of Cypress, Calif., it is working on the concept of a space solar power system composed of multiple satellites orbiting in formation.

Another group, sponsored by The Discovery Channel, conducted land-based tests last year, sending a microwave beam from solar collectors on a mountaintop in Maui, Hawaii. The beam was transmitted about 90 miles, or the equivalent of the distance it would have to penetrate from space. The transmission was successful but sent only about 20 W with a limited setup.

Turning talk into action

No one country owns outer space, so it makes sense to work on an international level to resolve many of the hurdles. A global dialogue has been taking place in many forms. For example, in September, the International Symposium on Space-Based Solar Energy will take place in Toronto, sponsored by SPACE Canada in cooperation with the International Academy of Astronautics. A lot of the talk will be focused on perhaps the greatest hurdles for space-based solar: regulatory and licensing issues around frequency allocations, orbital slots and liability. Nonetheless, with promises such as that made by Solaren, space-based solar may be moving into the sphere of reality.

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Concentration boosts photovoltaics' potential

Solar farms with concentrating solar technologies have the potential to contribute greatly to the world's growing energy needs. As efficiencies in photovoltaic (PV) cells increase and silicon availability decreases, attention is turning toward concentrating the sun's energy using multijunction cells.

A variety of concentrating photovoltaic (CPV) designs exist, but generally they consist of a system of reflective optics – either mirrors or Fresnel lenses – that concentrate the sun onto PV cells. Tracking systems keep the solar arrays precisely facing the sunlight throughout the day.

Multijunction cells have achieved the highest efficiencies of all types of PV cells, and labs around the world continue to leapfrog each other in announcing higher and higher numbers. For example, Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, recently announced an efficiency of 41.1 percent using GaInP/GaInAs/Ge on a germanium substrate. Compare that with 27.6 percent for a silicon-based solar cell. Multijunction cell efficiencies will approach 50 percent by 2015, with an overall system efficiency of up to 30 percent, according to a study done by the University of Jaén in Spain in conjunction with the professional society CPV Today which is based in London.

Show me the money

Cost is still a factor with any form of solar. According to the report "Achieving Grid Parity" from CPV Today, the costs of CPV are expected to drop 62 percent by 2015 and could reach grid parity by 2011. But first the systems have to be installed, and a major impediment to that is financing.

Obtaining financing is a double-edged sword. There are not many CPV installations, and those that are up and running are still relatively new compared with other forms of solar. According to Reese Tisdale, research director at Emerging Energy Research in Cambridge, Mass., "Banks are risk-averse." When presented with a menu that includes concentrating solar power (CSP), CPV and then silicon-based PV that's been operating for 25 years, banks are going to look at what's proven and operationally viable. With so little CPV installed, it's hard to prove its long-term viability; yet, with financing, CPV could take off and become competitive at the utility scale. According to analysts at GreenTech Media Inc. and the Prometheus Institute for Sustainable Development, both in Cambridge, Mass., this could happen within the next decade. Tisdale noted that for CPV to take off at this point, "They just need to get over the hump and get it installed."

Concentrating PV is best suited for ground-based installations in the sunniest of locations, such as this site in Spain. Photo courtesy of Guascor Foton.

Location, location, location

Only the sunniest areas are best for planting CPV, as the design concentrates normal direct solar irradiation. The US government's National Renewable Energy Lab has studied the best areas for renewable energy resources and recently updated its list. Location is critical to CPV. In addition to sunny conditions, the climate must offer a "direct beam resource," or a straight shot at the sun. This is one reason that some of the largest installations are in Spain and Greece.

Multiple CPV installations are under construction now in Greece, where SolFocus of Mountain View, Calif., is partnering with Samaras Group, a consultancy based in Greece, to provide a total of 1.6 MW of electricity.

Pushing ahead

It's unfortunate that CPV installations are few and far between, because of the many advantages of this renewable energy resource. Key drivers include proven technology, modularity of systems, minimal use of water and potential high efficiency, according to the recent report "CPV: Searching for the Sun" from Emerging Energy Research. CPV has yet to be embraced by the large utilities that – right now – prefer concentrated solar thermal and flat panel PV.

According to Keith Emery, device performance team leader at the National Renewable Energy Lab in Golden, Colo., utilities don't quite get CPV and are more likely to go with a CSP plant, which produces steam that drives an engine to produce electricity – a method with which they're more familiar. Thermal also appears to offer more storage capability than the PV approach, although in practical use, storage is not much of an issue with CPV because the power is used when it's generated. Tisdale pointed out that storage is an issue on a case by case basis. Some utilities demand it, while others are content covering peak demand.

A further challenge is the lack of standards and approvals. The International Electrotechnical Commission does have performance, qualification and safety standards; however, so far few modules have received its stamp of approval.

CPV is not alone in dealing with technical, cost and regulatory issues, in addition to switching mindsets. Some see CPV in competition with other renewable energy sources, but by resolving the various issues with each, they'll all take part in contributing to the world's energy needs.

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Lighting up lives

Solar lanterns are doing more than just bringing light to the poor in India. They also have improved the standard of living for those who formerly relied on kerosene lamps, a recent study asserts.

Govindasamy Agoramoorthy, a professor at Tajen University, and Minna J. Hsu, from National Sun Yat-sen University, both in Taiwan, studied the effects of solar lanterns in 25 villages in the Dahod District of Gujarat State, India. They focused on people helped through the NM Sadguru Water and Development Foundation, a local organization that sells lanterns on an installment basis, and they looked at changes in quality of life, energy use and household savings.

Many nonprofit groups supply solar lanterns to rural households in India (see "Lighting Up the Underdeveloped World," *Photonics Spectra*, November 2008, p. 35), but Agoramoorthy said that the foundation's philosophy is not to offer things for free but, instead, for social workers to help the poor upgrade their living standards. Although 70 percent of the villages in the study were connected to the power grid, they did not receive power in the early morning or evening. Women in rural households were interviewed both before and after purchasing the lanterns, and the study found that, with the lanterns, women could perform routine household chores at any time, students' study hours increased, and school performance improved.

The lanterns save about 100 liters of kerosene per year and reduce electrical use. The study estimates a total savings of USD 91.55 in energy costs per year, a significant figure considering that annual income in that area ranges from $150 to $250.

Solar advantage

The sun shines an estimated 250 to 300 days a year in India, making it an attractive location for producing electricity. With the country's growing economy, its energy use will double by 2020, according to the International Energy Agency's *World Energy Outlook 2007*.

India's renewable energy industry is estimated at $500 million, with a growth rate of 15 percent that includes solar, wind, hydro and other alternative energies. The government hopes to produce 10,000 MW of renewable energy by 2012, a goal that has the dual advantage of launching a leading solar energy market and of providing dependable and clean energy in both rural and urban areas.

Solar lantern use, which is growing at a rate of about 40 percent a year, is providing the people of India with a glimpse of all that is possible when they harness the sun.

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Solar-powered lanterns are improving the lives of people in impoverished areas of India. Courtesy of Vimal Electronics.

Battling outdoor light

Skyglow over Worcester, UK, is caused by lights shining above the horizon. Photo courtesy of C.J. Baddiley.

The battle against light pollution recently had a mathematical model added to its arsenal. Developed by Chris Baddiley, the scientific adviser to the British Astronomical Association's Campaign for Dark Skies, the algorithm calculates how much illumination from streetlights is reflected by surrounding surfaces.

Called the skyglow model, it determines how light scattering is affected by the atmosphere, taking into account the wavelength, angle and viewing distance of light. In constructing the model, Baddiley found that the white light typically used in contemporary light sources, which often use blue and green wavelengths, produces greater reflectivity and scattering than previous light source models, which used more yellow and orange; switching to sources with longer wavelengths, he noted, could significantly cut light pollution.

The skyglow model, which took seven years to develop, could be used to improve the design of streetlights, cutting glare by a factor of three to five, Baddiley said. These findings have been published by the Institution of Lighting Engineers and incorporated into the standards of the UK Highways Agency.

The movement toward reducing light pollution is effecting change throughout the world. Slovenia, for example, enacted a decree against outdoor light pollution in 2007.

The association Dark Sky Slovenia recently released a study of streetlighting on two roads, comparing conditions in 2007 before lighting reform with conditions in 2008. Using fully shielded luminaires and switching 250-W bulbs for 150-W bulbs with improved optics reduced glare and illuminated the road more evenly. In addition, energy consumption was decreased by 40 percent.

For more on light pollution, see "Light pollution: the good, the bad and the just-too-bright" (p. 39) and "Looking for light in all the wrong places" (p. 42) in the March 2009 issue.

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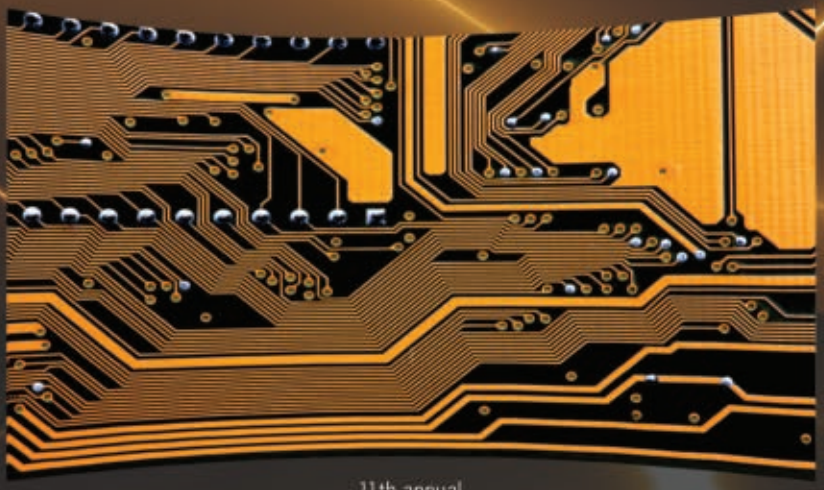

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Optical Power Meters: Versatile and Economical

BY DR. JAY Y. JEONG, NEWPORT CORP.

Increasingly complex experiments, safety and environmental requirements, and pressure for more performance at lower cost require lab instruments to be ever more powerful, with more functions squeezed into a single box – and they have to be economical, too. Optical power meters are no exception, and today's state-of-the-art meters can handle much more than just optical power measurement. Frequency measurement, various display and charting options, statistical data, data collection, simple mathematical functions and reduced energy consumption are just some of the functions that can be performed with these meters.

An optical power meter measures photon energy in the form of current or voltage from detection devices such as photodiodes, thermopiles or pyroelectric detectors. Three major components can be considered: the (detector) interface, the analog board and the digital board. Figure 1 shows a simple electrical-block diagram that indicates the signal flow. Even though the optical power meter cannot be fully discussed without an account of an optical detector, this article will focus only on the meters.

The analog board

Depending on the type, the detector produces either current or voltage analog signal. There are a number of different types of optical detectors in use, such as semiconductor-based detectors, thermopile detectors, pyroelectric detectors and photomultiplier tubes. An optical power meter should be able to handle as many different types of detectors as possible to achieve maximum flexibility. Operational principles vary between detectors – some generate current signals, while others generate voltage signals, and some require pulsed input signals – so it is a great challenge to incorporate these different signal paths into one design.

Another challenge is maintaining a huge dynamic range, as one user may measure subpicowatt power from a fluorescence sample while another may be measuring kilowatt power from a materials-processing laser. Certain photodiode detectors currently available on the market – those with an integrated attenuator design – can measure an impressive 12 decades of optical signal range, and the meter should ensure accuracy throughout the entire range.

To cover such a broad signal range with high resolution, an optical meter employs multiple transimpedance amplifiers. The key challenge in the analog board design to achieve the highest possible resolution is to reduce the noise from the circuitry. Reduced noise allows the power meter to resolve down to the noise-equivalent power level of a given detector type, typically in the picowatt level. It is not only that the component-to-component path in the printed circuit board assembly layout ensures low-noise design, but also that each component must be carefully chosen to achieve the best possible noise performance. Exhaustive dynamic modeling as well as mathematical and circuitry simulations have been performed to turn this design goal into reality. The overall design should ensure not only the best noise spec in the power meter class but also product-to-product repeatability in manufacturing.

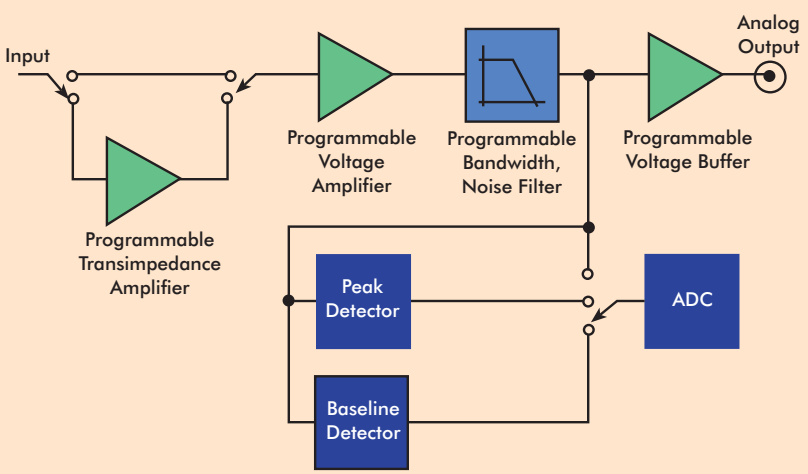

Figure 1. This is a signal flow diagram for an optical power meter.

The digital board

The next step is to digitize the analog signal for postprocessing. In addition to low-noise analog design, a powerful processor and an advanced digital board design allow a previously unthinkable level of sensitivity. For instance, Newport's 1936-C series power meter can achieve 11 fW minimum detectable power.

Another drastic improvement from older-generation designs is an order-of-magnitude faster sampling repetition rate. For example, the Newport 1936-C series power meter achieved an impressive 250-kHz. The fast sampling rate of the digital board enables capturing an entire pulse form with well-resolved signal rise and fall, generated by a pyroelectric detector, an important class of optical detectors used for pulsed lasers. This eliminates the

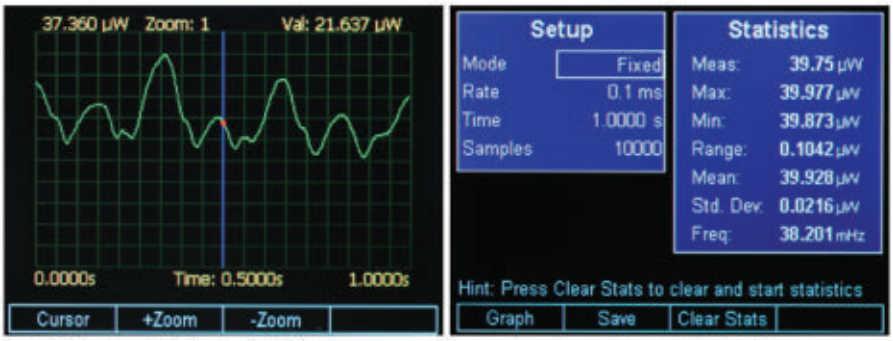

Figure 2. A fast sampling rate allows quick verification of whether the input signal is what was expected and whether it is free of noise.

Figure 3. Advanced optical power meters feature a number of graphical display options.

need for a capacitance circuit to hold the signal level at its peak, which is required for pulse energy measurements in power meters with conventional designs. Such a physical circuitry design cannot accommodate various types of pyroelectric materials that have different rise time characteristics.

Traditionally, an optical power meter was not intended to measure fast events: A power meter would measure the average optical power, and then a photodiode connected to an oscilloscope would check the noise level, signal modulation or pulsing. The fast sampling rate improves the resolution of data collection in the time scale, and thus the user can verify whether the input optical signal fluctuates, either graphically or by checking the statistics (Figure 2). This is a great advantage, as it is easy to pick up noise from the environment or any component in the experimental setup, due to the ever-increasing complexity and sensitivity necessary for advanced experiments. A power meter alone can potentially be used to find and eliminate noise sources that interfere with the desired signal.

The graphical user interface

Arguably, the area where a power meter has improved most significantly over time is the graphical user interface (GUI). Up until only a few years ago, an optical power meter did little more than provide a value for an input optical signal. Current state-of-the-art optical meters, however, are equipped with processors with significant computing power and are powered by commercially available, powerful operating systems. In a way, optical power meters are small computers. Some of the advanced GUI and graphical features boasted by leading optical meter manufacturers are quite stunning. Figure 3 shows some of the graphical displays available in Newport's line of optical power meters.

Advanced functions

In addition, there have been numerous other improvements in the general functionality of power meters. One of the most heavily used functions can be filtering, if the filtering function is available (See Figure 1). Users often want to place a filter in the output reading to rule out any unwanted fluctuations from the measurements. Some products include either an analog low-pass filter circuit or a digital averaging capability. Newport's advanced optical power meters feature four stages of both the analog and the digital filters, with a total of 256 possible filtering combinations.

Also worth noting is the adoption of software techniques for compensation of slow thermopile detector rise time. The rise and fall times of thermopile detectors are on the order of 1 to 10 seconds, depending on the design and the thermal absorption materials. The conventional design uses circuitry to physically speed up the response of the detector. Typically a trimming potentiometer, or trim-pot, is adjusted to achieve the quickest rise time of the signal without creating a significant overshoot or an oscillation. The optimal value is different for each type of thermal detector. Newer designs employed by many newer models instead rely on software algorithms to predict the final, steady-state value of the detector based on the known natural rise time.

Finally, the race to reduce electrical power consumption during manufacturing should not go unnoticed. There now is industry-wide recognition of "green" manufacturing practices. The latest Newport optical power meters are now available with a standby mode, similar to that found on a laptop, for power saving while the instrument is not in use and for avoiding the warm-up time before initial use at the beginning of the day.

Doing more for less

The optical power measurement market is very competitive, and technological advancement has sped up significantly. Many new optical meters introduced recently come with a high-visibility, high-resolution color screen, an excellent man-machine interface and wireless capabilities, and they offer more functions at great prices.

Current economic conditions put even more pressure on manufacturers to drive costs further down while implementing more functionality. This will, however, benefit users, allowing them to improve their own productivity.

Meet the author

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Commercializing the Nobel-Winning Discovery of the Bose-Einstein Condensate

BY JOHN COWLEY FOR COLDQUANTA INC.

A Bose-Einstein condensate is a new state of matter that may have been overlooked in your introductory science classes. It is a small cloud of atoms in a high vacuum that behaves as a single atom after being magnetically trapped and cooled to a millionth of a degree above absolute zero. In 1925, this phenomenon was predicted by Satyendra Nath Bose and Albert Einstein.

In 1995, a Bose-Einstein was actually produced, for which Eric Cornell and Carl Wieman, both of the University of Colorado at Boulder, and Wolfgang Ketterle of MIT in Cambridge received the 2001 Nobel Prize in physics. Now, in a movement to produce commercially useful applications, Bose-Einstein condensates are moving out of pure researchers' laboratories and into mainstream development facilities.

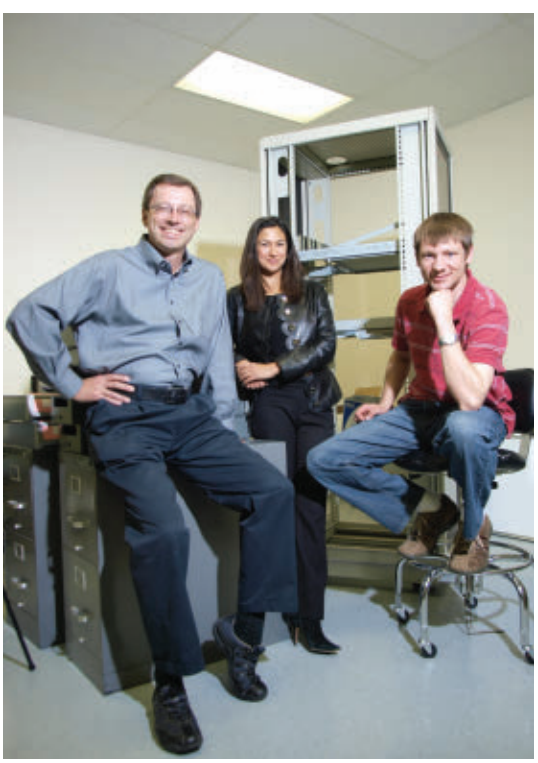
Simplifying the process

A start-up company, ColdQuanta Inc. of Boulder, Colo., is making it easier for interested groups to experiment with Bose-Einstein condensates. It has begun to deliver the RuBECi, a briefcase-size device containing the basic components and environment for creating Bose-Einstein condensates.

The RuBECi was developed at the University of Colorado by a team of scientists and engineers led by Dr. Dana Anderson, who founded ColdQuanta along with Rainer Kunz. Their product reduces the specialized expertise needed to work with "ultracold matter," helping to spark commercialization of Bose-Einstein condensates. The company's goal is "to cut developers' setup time by months or years – and to cut their costs by hundreds of thousands of dollars," said Kunz, ColdQuanta's president and CEO.

The RuBECi is a 25-cm-long, brass-and-glass sealed chamber that is optimized for creating Bose-Einstein condensates of rubidium atoms. It includes a rubidium source within its seal. The seal supports the necessary vacuum of 10^{-9} torr – about a trillionth of an atmosphere – without additional evacuation. A built-in ion pump facilitates the vacuum by removing unwanted ions. The RuBECi's glass compartments allow laser beams to enter to manipulate the atoms.

A key feature of the RuBECi is an atom chip integrated into the glass chamber. Like a small computer chip, it has a microscopic pattern of conductors formed by standard lithography and electroplating.



Pictured are ColdQuanta personnel (from left to right) CEO Rainer Kunz, executive assistant Seema Isabel Hess and senior scientist Dr. K. Jeramy Hughes. Courtesy of Mark Manger.

Powered from outside the chamber, the chip produces currents and fields within the chamber to control the Bose-Einstein condensate cloud and to drive experiments. A Bose-Einstein condensate cloud positioned within 25 to 100 µm of the chip's inside surface becomes a sensitive detector of field disturbances.

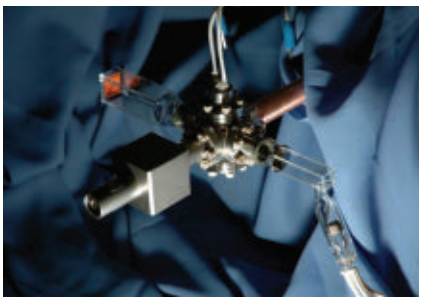
User-supplied external equipment transforms the RuBECi into a working laboratory. Cooling lasers impinging from outside stifle the atoms' energetic motions and coax them into a trap created by external magnets. Evaporative cooling inside the chamber – releasing the highest-energy atoms – also reduces cloud temperature. Within seconds, the assembly can cool a cloud of 100,000 atoms to the required millionth of a degree.

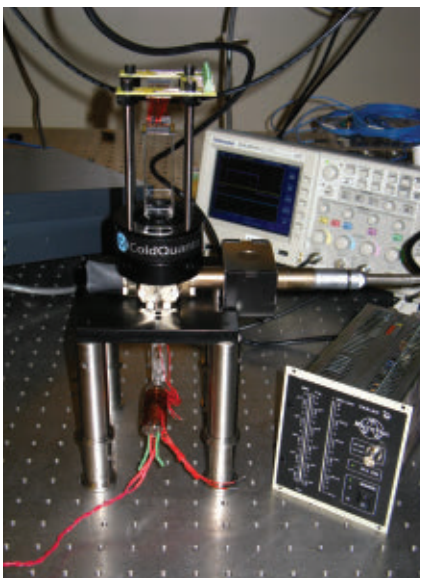
Promoting new discoveries

Proponents of Bose-Einstein condensate research compare its untapped potential with that of lasers before laboratory-size equipment became miniaturized for thousands of uses. Likewise, easier access to Bose-Einstein condensates is expected to lead to many applications.

Bose-Einstein condensates respond to weak magnetic fields by changing shape. Laser mappings of the clouds' distortions reveal details of nearby current flows, which could help designers of computer chips better understand the fields within their devices.

The device could be a sensitive magnetometer not only for local fields but also for wider-area radio-frequency fields. After spin-polarization by lasers, the atoms in a Bose-Einstein condensate change polarization in response to specific radio-frequency magnetic disturbances. This modification is revealed by probe lasers. Similar methods could detect weak nuclear mag-





The RuBECi is a device that allows researchers to re-create the Bose-Einstein condensate in the lab just as the Nobelists did at UC Boulder. At top is the naked apparatus, and below is the device hooked up to other equipment needed for its operation. Courtesy of ColdQuanta.

netic resonance signals, possibly shrinking medical magnetic resonance imaging equipment. They could also detect telltale radio-frequency signals from certain explosives.

In 2000, Lene Vestergaard Hau and her colleagues at Harvard stopped a light pulse by using a Bose-Einstein condensate. More precisely, they stopped the "group velocity" of a passing light pulse by using specially tuned lasers to alter the response of a Bose-Einstein condensate of sodium atoms. Their ability to manipulate light in this way could find applications in optical communications and data processing. Some researchers are thinking of ways to store whole images – briefly – in Bose-Einstein condensates.

Their wavelike properties give rise to additional applications. For example, when set up to perform as atomic interferometers, the phase difference between divided pairs of Bose-Einstein condensates traveling different paths can reveal motion extremely accurately.

Bose-Einstein condensate-based atomic interferometers can measure rotational motion, as laser-based gyroscopes currently do with light beams. Bose-Einstein condensate interferometers offer orders of magnitude more sensitivity than the lasers.

Using interferometry techniques similar to the rotation sensor, Bose-Einstein condensates can measure accelerations with great precision. In their role as accelerometers, they can provide sensitive measurements of gravitational variations, which could aid in geological pursuits such as detecting oil, gas and mineral deposits.

In summary, the RuBECi will make it easier for mainstream researchers and commercial innovators to create products for these and yet-to-be-imagined applications such as quantum computing.

Meet the author

John Cowley is a retired aerospace engineer and freelance writer living in Boulder, Colo.

Seeing Clearly: The Latest in Machine Vision Software

BY DR. LUTZ KREUTZER
MVTEC SOFTWARE GMBH

Imaging and machine vision are multipurpose technologies widely used in industry, science, medicine and surveillance. More and more, vision applications are requiring improved production processes and the capacity to address quality issues.

Faster algorithms and better use of current hardware, such as multicore computers, are key for imaging software. Also needed are new matching technologies designed to robustly and reliably find objects or workpieces, even in images with strong perspective distortions.

Moreover, 3-D vision methods and processing of extremely large images are increasing in importance. Advanced methods allow for identification, such as reading of the bar and data codes increasingly used in speed and tolerance.

An example of machine vision software that fulfills all these requirements is Halcon 9.0 by MVTec Software GmbH.

Image preprocessing: GPU or frame grabber?

There has been much discussion about the possibility of outsourcing image preprocessing to the computer's GPU. But for practical use, this does not make sense. Indeed, on GPUs, processing steps can occur at high speeds, but no currently available hardware enables sufficiently fast data transfer. Thus, every application is decelerated by the twice-slow transfer times, so GPU image preprocessing should not be the first option.

But on a frame grabber, free computing capacity can be used without additional data transfer, so the software must enable image preprocessing in real time. The software also must focus primarily on increasing the speed of the algorithms.

Halcon 9.0 provides a Visual Applets interface that enables image preprocessing in real time with frame grabbers by Silicon Software.

With the rollout of the first multicore machines, MVTec developers began to think about an automatic operator parallelization (AOP) to process images. Halcon was well prepared when, a few years ago, the first multicore processors came on the market. The well-established AOP was part of this technology.

Now a standard

Multicore processors now have become standard for PC hardware, and modern machine vision software makes optimal use of them. With version 9.0, AOP again sped up by 20 percent. The software automatically

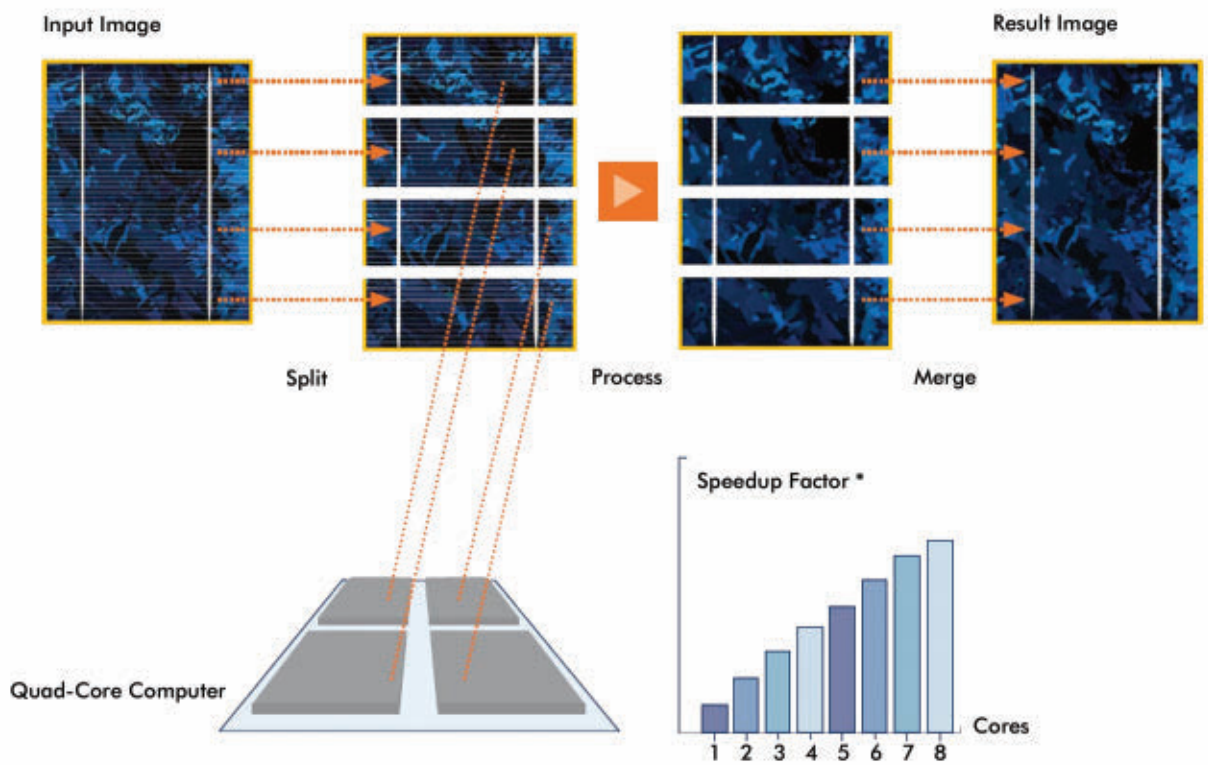


Figure 1. When executing an operator on a quad-core computer, Halcon automatically splits the image into four parts, which are then processed in parallel by four threads executing the operator. *1/1.96/2.90/3.79/4.51/5.48/6.34/6.93 of the operator median – image with mask size 13 × 13 on a 2 Quad-Core Intel Xeon E5345, 2.33 Ghz, image size 1280 × 1024. Note that the reachable speedup generally depends on the used Halcon operator and the image size. Images courtesy of MVTec Software GmbH.

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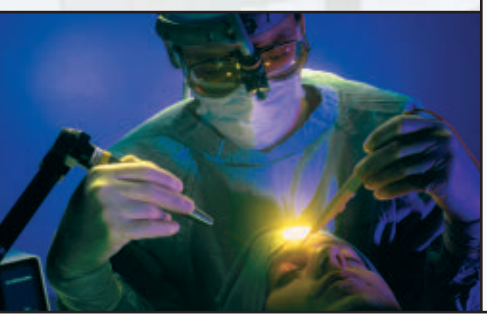

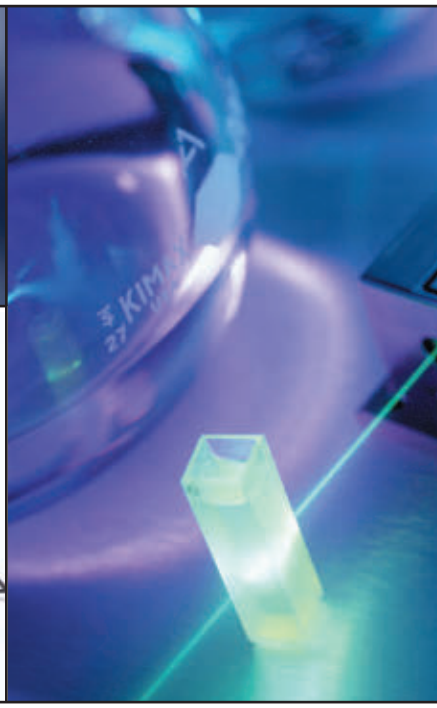

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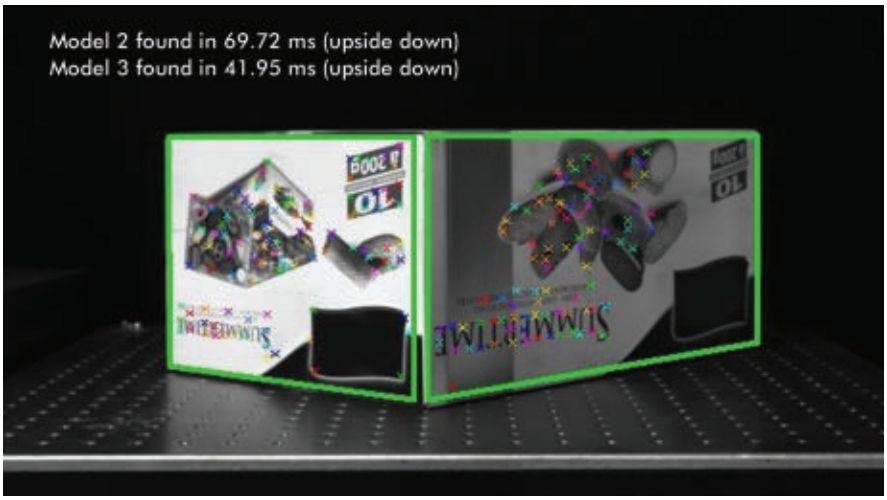

Figure 2. Halcon's descriptor-based matching detects perspective-distorted areas. Interest points are detected where gray values are clearly differentiated from neighboring areas, such as brightness, curvature, corners and spots.

finds the number of available cores. The image then is split into subimages, which are automatically delivered to a corresponding number of threads. After processing, the data are merged to achieve the complete results. As the number of processors increases, so does the speed (Figure 1).

To meet these requirements, it is necessary to parallelize not only filters but also operators and methods important for a vast number of industrial applications. This includes methods for matching, 3-D matching, subpixel extraction and fast Fourier transform.

Another advantage is the ability to preselect a region of interest as a free form in an image of any orientation. If the software can process only a preselected area of the image, there is a dramatic reduction in processing time. This benefit increases if the software can process arrays of images in parallel as well as arrays of regions caused by segmentation – e.g., optical character recognition or blob analysis – and arrays of subpixel-accurate outlines, as Halcon does.

However, parallelization makes sense only if enough memory throughput is

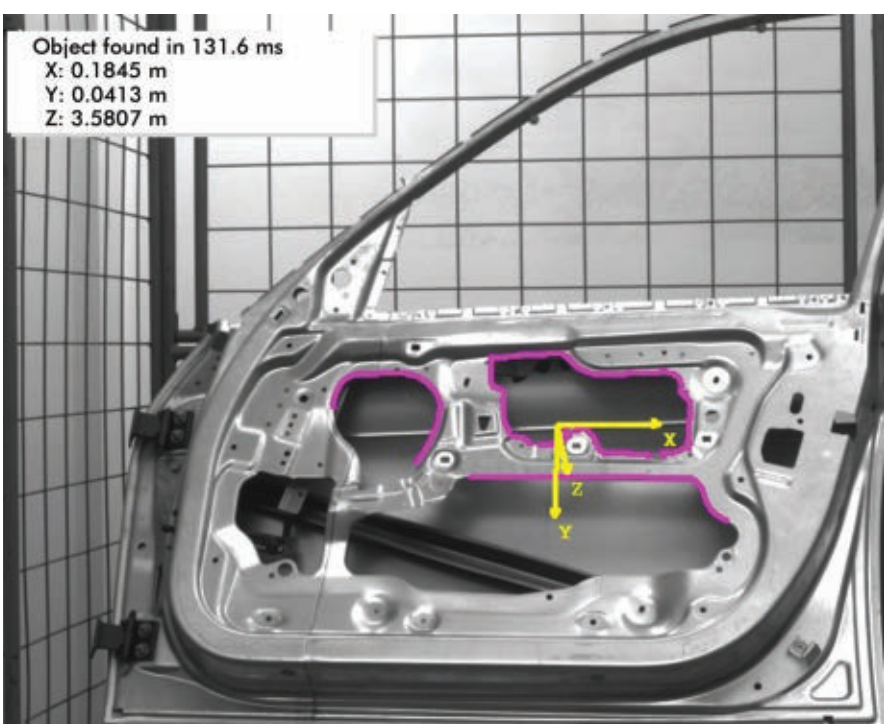

Figure 3. Halcon's perspective-deformable matching recognizes perspective-distorted objects – such as a car door – with distinct edge- and area-accented elements.

available; thus, the performance depends on the hardware. Halcon automatically identifies the hardware environment, deciding which algorithms will parallelize and which will not, and avoiding unnecessary overhead.

Multichannel images such as color images are becoming increasingly important, and software can parallelize them with an unlimited number of channels.

Comprehensive 3-D vision

In the field of robotics, machine vision is growing more and more important – particularly comprehensive 3-D vision, an umbrella term for a collection of technologies used to determine the orientation, or pose, of a given object or to reconstruct its shape. Halcon provides the following technologies for 3-D vision:

With 3-D camera calibration, the relationship between camera, object and, if required, robot is established. The calibration should work for area- as well as for line-scan cameras. So-called internal and external camera parameters map the image coordinates to world coordinates, and robot control becomes easier. Calibration is essential for highly accurate and flexible measurements.

3-D matching enables recognizing and determining the pose of arbitrary objects with a single camera. The object is represented by its computer-aided design model. Multiple 2-D views matched to the object's image can detect its position and orientation using Halcon's shape-based matching technology extended to 3-D.

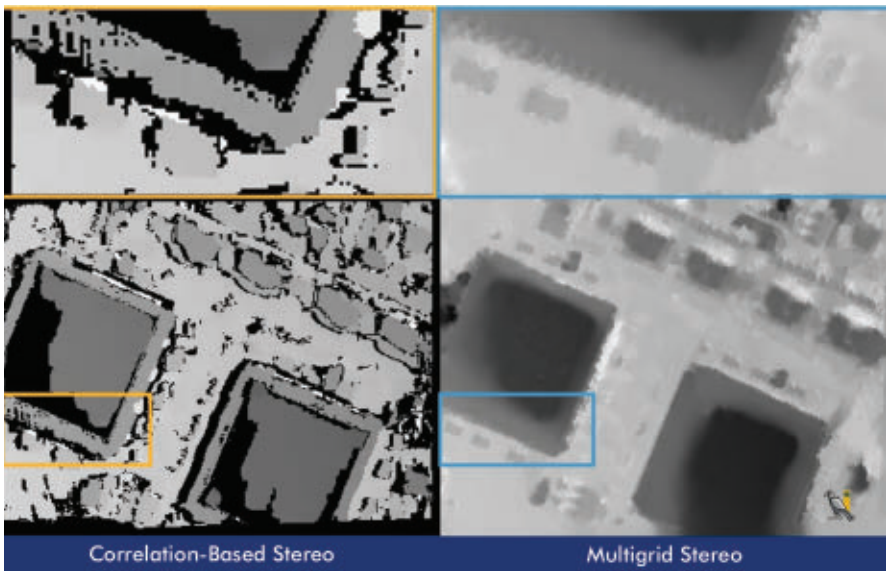

Figure 4. With multigrid stereo, the disadvantages of conventional correlation-based stereo methods are eliminated. After multigrid stereo processing, the areas without information appear as proper edges and structures.

It was only a matter of time until industry requested perspective matching – matching perspective-distorted objects with only one camera. This technique can be based on the detection of interest points where gray values are clearly differentiated from neighboring areas – brightness, curvature, corners, spots. Planar objects such as prints with texture can be located quickly in any pose and tilt (Figure 2). Another method of perspective matching recognizes perspective-distorted objects by shape-based technology. Workpieces and objects with distinct edge- and area-accented elements – such as a car door – can be identified by this method with accuracy, reliability and robustness (Figure 3).

An object within a perspective-distorted image can be more quickly and easily determined with a single camera if the object has significant circles or rectangles; e.g., using the known size of the circle or rectangle to calculate the object's distance and tilt angle with respect to the calibrated camera.

With binocular stereo, the 3-D coordinates of visible points on an object's surface can be determined by calculating the disparity of different points of view based on a two-camera setup. During stereo pro-

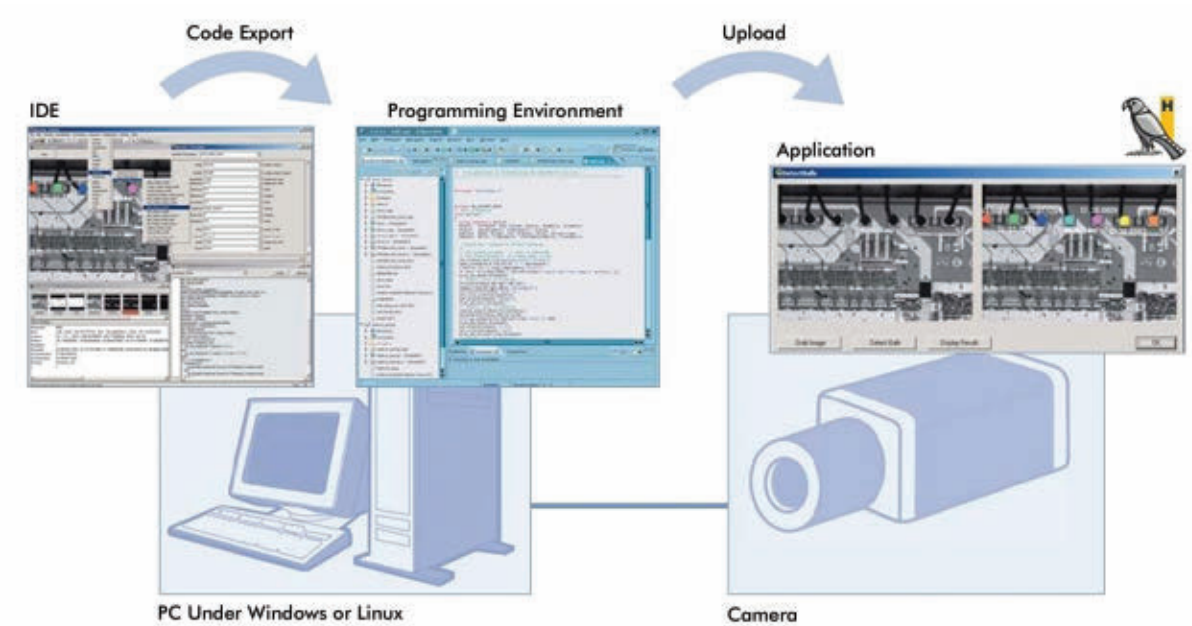

Figure 5. Halcon's embedded software library allows development of software on a PC and, afterward, uploading of the application to the embedded system.

cessing, the problem often is that complete areas do not have any texture. To close this information gap, MVTec developed the multigrid stereo, which eliminates the disadvantages of the conventional stereo method. After processing by multigrid stereo, the areas without information (Figure 4, left, dark areas) appear as proper edges and structures (right). Thus, multigrid stereo can bridge texture gaps in stereo images and deliver highly accurate results.

The depth-from-focus method is especially suitable for very small objects. With the height adjustment of the camera, the 3-D conditions of the object can be determined by extracting distance information and calculating the focus of all pixels in an image. Photometric stereo acquires multiple images with illumination from different orientations. In this case, the depth information is reconstructed by using the reflectance features of the object.

In the case of objects without any texture, the sheet-of-light method is suitable. This means measuring an elevation profile of the object by reconstructing the projected line of laser light on the object, generating a 2½-D model.

Bar and data codes

Bar-code reading has been ubiquitous for a long time, and data-code reading is a growing technology worldwide. Ideally, a data code consists of a dot print area composing the actual code, and a frame for orientation and pose identification of the code, called the finder pattern. In practice, important parts can be overprinted, not printed, defocused or damaged by transport and other mechanical influences. For most data-code readers, such a defective code often is not readable. But Halcon enables the reading of such damaged codes, even if the whole finder pattern is missing. The software reads ECC200, QR and PDF417 of each size with elements even smaller than 2 × 2 pixels.

It is important for bar codes to be read in any orientation. Today's newest software can read a bar distance of only 1.5 pixels.

Processing large images

Software that can process images of more than 32 × 32 k – long anticipated by the industry – is finally here. The size of images is not limited, which is especially interesting for the high-resolution line-scan cameras that are deployed in print and electronic industries for print and component inspection. If this technology is combined with fast parallel processing, real-time processing will be achieved without outsourcing image preprocessing, even with a large amount of data. Thus, programming is significantly easier and faster, and the application can run trouble-free.

IDE with high usability

Machine vision software packages must be comprehensive not only in technology but also in usability. Moreover, they must provide an integrated development environment (IDE) to significantly speed up programming. Halcon's IDE allows the user to quickly implement an application, improving time to market.

Beyond rapid application development, a machine vision IDE should directly export the application code to C++, C, C# or Visual Basic. Thus, a machine vision application can be directly included in a control program. The IDE also enables the running and integration of external procedures created by the programmer as separate files or programmed by different developers. External procedures are supported by password protection.

Halcon's IDE runs under Windows, Linux and Unix and provides a development interface, a text editor, a compiler or interpreter, a linker, a debugger and a source formatter.

Embedded software for sensors, smart cameras

In recent years, vision sensors and smart cameras have conquered the market. For noncomplex applications, these devices are a good alternative to a PC-camera setup. Halcon's architecture is flexible enough to run on special platforms and portable to various microprocessors/digital signal processors, operating systems and compilers.

Halcon has an embedded software library to provide the full and comprehensive power of machine vision on embedded systems. It allows developing the software part of a machine vision application on a standard platform, greatly easing the programming of an embedded system (Figure 5).

Meet the author

Dr. Lutz Kreutzer is the manager of PR and marketing at MVTec Software GmbH in Munich, Germany.

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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
E ☐ crystals
G ☐ grinding & polishing materials
J ☐ transmissive materials, IR
L ☐ transmissive materials, UV
N ☐ transmissive materials, visible

R. Computers & Software
A ☐ computer hardware (PCs, servers, workstations, mainframes)
C ☐ data acquisition
E ☐ scientific/engineering software

S. Nanophotonics
A ☐ microscopes
C ☐ nanophotonic devices
E ☐ nanophotonic materials
G ☐ quantum dots

T. A ☐ Other _____

X. ☐ None of the above (6A-6S inclusive)

7

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A Wave Plate for Every Application

Matching the material to the intended use leads to success.

BY WILLIAM BARBAROW
MEADOWLARK OPTICS INC.

The applications for wave plates are many and varied. They can find use in areas such as power attenuation of a laser and optical isolation. In biomedical applications, wave plates are used to determine the polarization of body fluids in microscopes and to correct for unwanted phase shifts. They are also used in astronomy, in the semiconductor industry and in aerospace. In short, almost every application that requires polarized light uses a wave plate to control polarization. The materials used for them are determined by the application. These options include a wide array of birefringent crystalline materials, total internal reflection retarders, polymer retarders and liquid crystals.

How a wave plate works

A wave plate produces a phase shift between the two orthogonal polarizations of a light wave. This is done via birefringence, or when the index of refraction along the slow axis differs from that along the fast axis. Common wave-plate retardances include quarter- and half-wave plates. The quarter-wave plate turns linearly polarized light into circularly polarized light with the input light at a 45° angle between the fast and slow axes. The half-wave plate is a polarization rotator as it flips the polarization direction around the fast axis of the retarder. These are manufactured from various materials, depending on the application, with costs ranging from tens to thousands of dollars.

Key specifications include the wavelength, retardance accuracy, dimensions and the order of the retarder (which affects other specifications). A true zero-order retarder has the retardance specified with no additional waves. True zero-order wave plates have increased bandwidth and acceptance angle and good thermal performance. Because of the thinness of the retarder material, they are laminated between glass windows to increase robustness. A multiple-order retarder is more sensitive to changes in the incident angle, wavelength and temperature. A compound zero-order retarder is one that is manufactured from two multiple-order wave plates that are positioned together with their axes crossed to get an overall retardance of less than one wave. Compound zero-order retarders have a lower sensitivity to changes in temperature and wavelength than multiple-order retarders but have smaller acceptance angles.

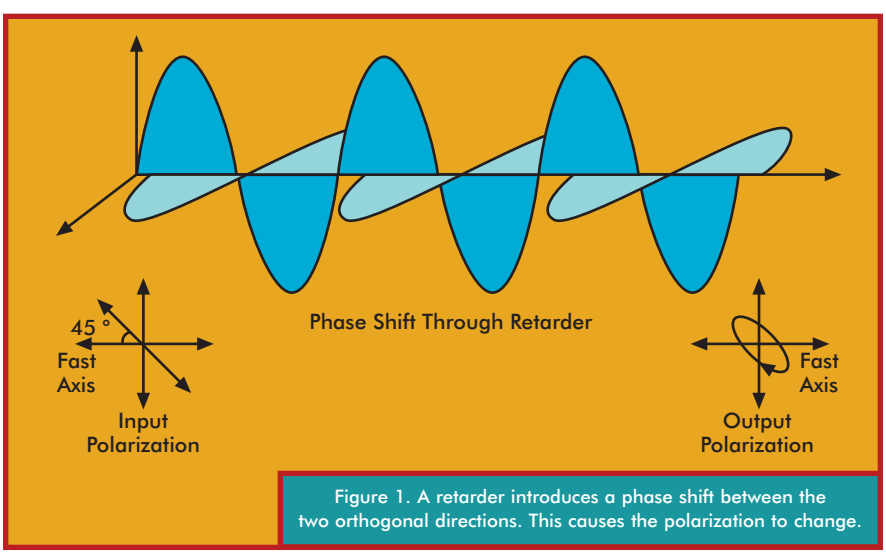


Figure 1. A retarder introduces a phase shift between the two orthogonal directions. This causes the polarization to change.

Wave plate materials

Quartz is the most commonly used retarder material. It is easy to find and manufacture, is inexpensive and operates from 180 to 2300 nm. Quartz retarders are fabricated with the optic axis in the surface plane and then polished to the desired thickness and retardance. Quartz has good surface quality and a high laser damage threshold – more than 1 MW. To maximize transmission, most quartz retarders are antireflection-coated. Three different constructions of quartz retarders impact their bandwidth, their off-axis and their thermal performance. Multiple-order retarders have considerable temperature, off-axis and wavelength variations. True zero-order retarders improve on all of these specifications, while compound zero-order quartz wave plates have a larger bandwidth and better thermal stability but a worse field of view. For applications over a large wavelength range, a bicrystalline achromat can be manufactured out of quartz and another crystal, such as magnesium fluoride, to get a 300-nm bandwidth, but it has a limited field of view. This can be corrected by combining quartz with a negative birefringent material, such as sapphire.

Mica, which is used over the 400- to 2000-nm range and is transparent to 6 µm, can be cleaved to the correct thickness for the desired retardance. Mica retarders are used for low-power imaging applications; however, spatial uniformity problems can sometimes result. The long-term outlook on the supply of optical-grade mica, a naturally occurring birefringent crystal, is uncertain. This makes large parts with large clear apertures expensive and hard to obtain.

Magnesium fluoride is used with quartz to manufacture bicrystalline achromatic retarders that operate from the ultraviolet to the infrared. It is also used as the sole wave plate material for ultraviolet re-

tarders down to 121 nm and for mid-infrared retarders from 3 to 7 µm, because it has higher transmission than quartz.

Sapphire has a negative birefringence, as the index of refraction of the extraordinary axis is less than that of the ordinary axis. This makes sapphire useful for bicrystalline achromatic retarders with a large field of view. Its main advantage, when used by itself, is that it has a higher laser damage threshold with low absorption. However, sapphire is more expensive than quartz and magnesium fluoride, and polishing it is usually a long process.

Fresnel rhombs are achromatic retarders that use total internal reflection to induce retardation and prisms that are parallelepiped. Each time light hits a prism wall and is reflected, a one-eighth phase shift is produced. Therefore, two reflections in a single rhomb cause a quarter wave of retardance, and four reflections in a double rhomb cause a half wave of retardance. Common materials include BK-7 glass, FK5, fused silica and calcium fluoride. Fresnel rhombs are used from the ultraviolet to 2000 nm, with a retardance accuracy of 1 or 2 percent, and are found at prices comparable to those of bicrystalline achromatic retarders.

Polymer pros and cons

Birefringent polymer is "tuned" to the retardance at the operating wavelength, making custom retardances easy to manufacture. The polymer is true zero order, with an excellent field of view and thermal performance in the visible and near-infrared. However, polymer is susceptible to ultraviolet damage and has a lower laser damage threshold than crystalline retarders. By stacking polymer, one can manufacture achromatic retarders that work over a couple hundred nanometers with retardance accuracy of less than 1 percent. Other polymer stacks can be used for retarders made with large acceptance angles – up to 30° – and for dual-wavelength retarders that allow the user to have two retardances at different wavelengths hundreds of nanometers apart.

Sometimes active retarders are required. Liquid crystals require a drive voltage to change the retardance for the visible and near-infrared. Nematic liquid crystals have response times in the tens of milliseconds and are manufactured in sizes as large as several inches in diameter and as small as about 10 mm. Recently, developments have led to polymer-stabilized nematic liquid crystals with a response time of around 100 µs.

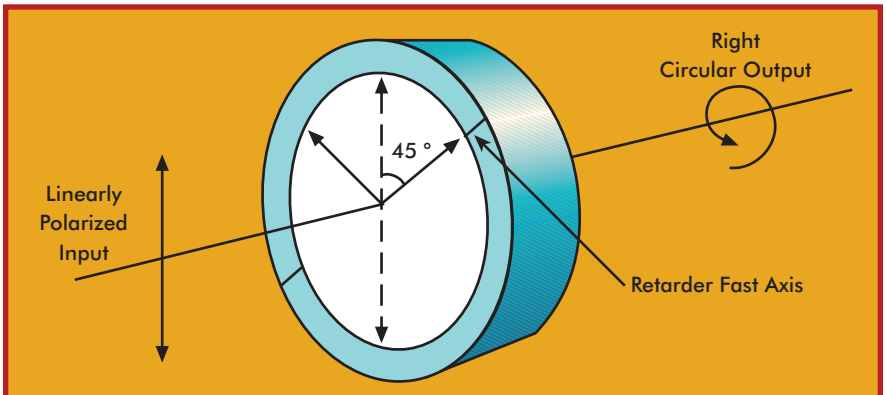


Figure 2. A quarter-wave plate converts linearly polarized input light into circularly polarized light when the input light is 45° to the fast axis.

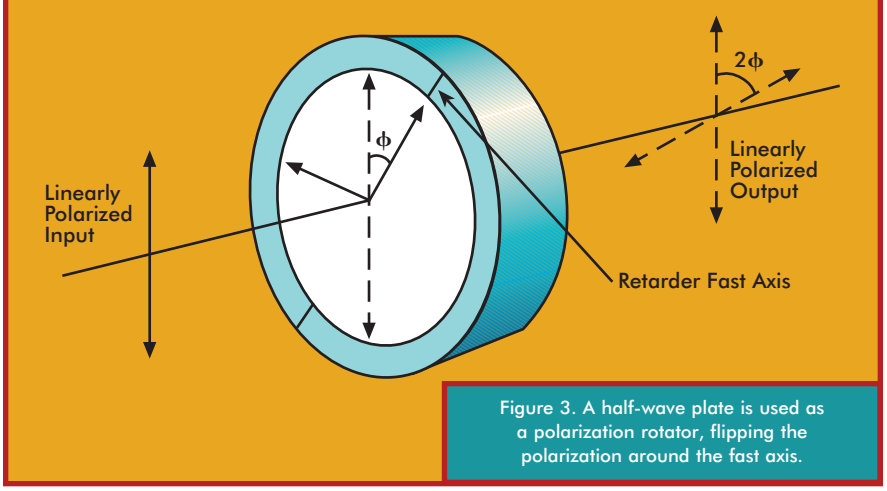


Figure 3. A half-wave plate is used as a polarization rotator, flipping the polarization around the fast axis.

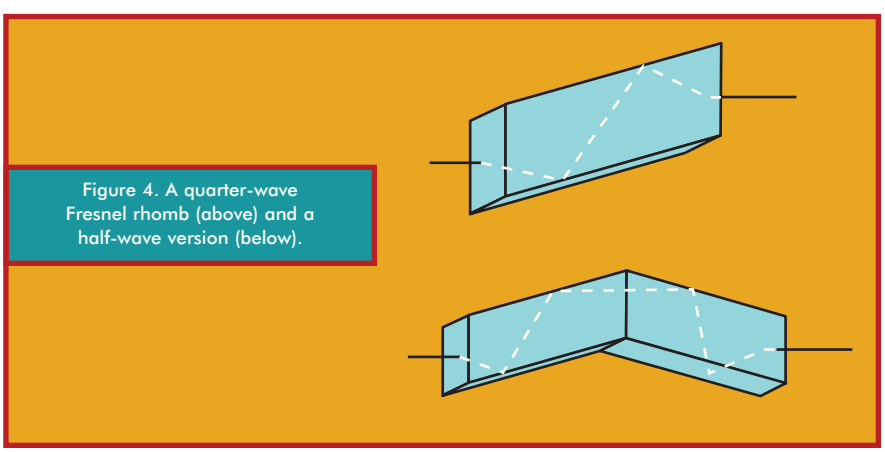


Figure 4. A quarter-wave Fresnel rhomb (above) and a half-wave version (below).

Wave plates manipulate the polarization of light and control it for numerous applications that are in use today. Because retarders are made from many different materials, it is easy to become confused as to which wave plate will work best for your application. The best material depends on the various wavelengths, applications and other optical specifications. By identifying the specifications most crucial for your application, you can determine the wave plate that is optimal for controlling the polarization.

Meet the author

William Barbarow is a sales engineer at Meadowlark Optics in Frederick, Colo.; e-mail: wbarbarow@meadowlark.com.

Into the photon detector's tool kit

Solid-state photomultipliers compare well with traditional devices.

BY WAYNE SEEMUNGAL
AMPLIFICATION TECHNOLOGIES INC.

Vacuum tube technology has always preceded its solid-state counterpart. The most familiar example of the former is the transistor, considered the greatest invention of the 20th century. Other examples are cathode-ray and electronic amplifier tubes. Advances in materials technology have allowed all of these to be replaced by solid-state alternatives.

The photomultiplier tube (PMT) is one of the last types of vacuum tube technologies still in use. Traditional vacuum tube photomultipliers are hard to match for sheer noiseless amplification of photoelectrons (160 dB). In some ways, they have superior features when compared with other detectors: High frequency response, low timing jitter and a single detector can cover up to 10 in. in diameter.

A new solid-state technology, dubbed silicon photomultipliers – although the technology can be implemented in many other materials systems – has finally arrived, matching the performance of photomultiplier tubes and even surpassing it in some cases.

The choice of silicon versus traditional PMT can be a function of the specific application requirements. This article will explore uses for various types of photon detection technologies and share developments in solid-state. It also will give the reader an understanding of which technology is most appropriate based on application needs.

According to *Wikipedia*, the first patent for a vacuum-based amplifier was filed in Canada by Julius Lilienfeld in 1925. This was for a field-effect transistor. Twenty years later, in search of higher frequency amplifiers needed for radar, workers at Bell Labs developed the first semiconductor transistors. The first vacuum tube photomultipliers date to early 1934, capitalizing on the photoelectric effect for which Albert Einstein received the 1921 Nobel Prize in physics. Within two years, the device was perfected; it has changed little since. It is only recently that a solid-state replacement has become possible.

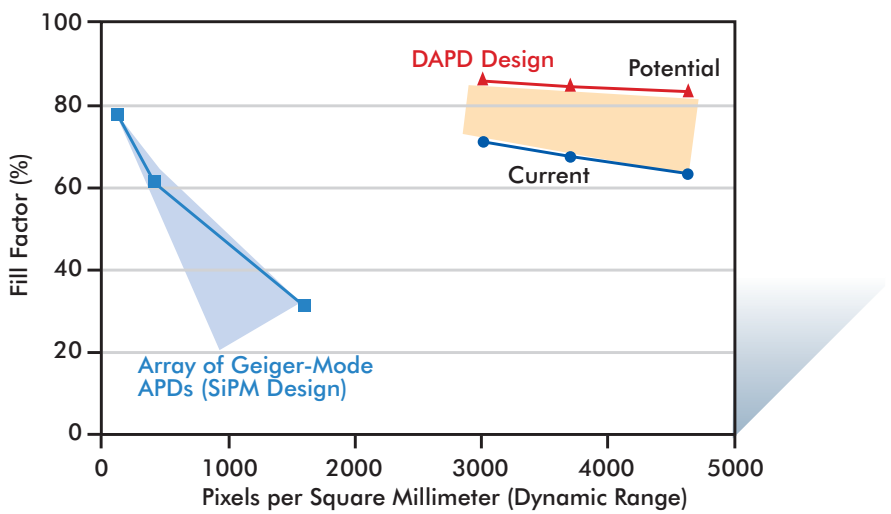


Figure 1. The design of a discrete amplification photon detector permits trade-offs among various parameters to optimize it for specific applications.

Vacuum tube technology has certain obvious shortcomings. For one, dynode multiplication necessitates a large package. Operation at high voltage requires large power consumption. Monolithic arrays are very difficult, with low yields on photocathode quantum efficiency and uniformity, and are limited in size. Then there is the issue of maintaining a vacuum.

In today's world, the buzzwords are "leaner, greener, faster and smarter," or LGFS. These can be applied to all technologies, not just automobiles. For photodetectors, only semiconductors hold such promise. The semiconductor photomultiplier was invented by scientists at Amplification Technologies Inc. about 10 years ago. The original design has spawned an entire new class of photodetector devices based on controlled Geiger-mode avalanche operation.

Breaking new ground

Avalanche photodiodes (APDs) with limited gain have been a standard technology for many years, but achieving controlled, high-gain electron amplification by operating in the Geiger regime was a significant challenge that has now been solved. These devices hold the promise of replacing vacuum tube PMTs and even doped-glass electron multipliers, such as microchannel plates, in many applications. They fit the LGFS profile: They consume far less power, operating at one-tenth the voltage of PMTs; there are no compounds used in fabrication that pose a danger to the environment upon disposal; and they are adaptable to a variety of applications, as any size array format is possible on a semiconductor wafer.

The latter extends the range of capabilities of these devices beyond replacement for single-channel PMTs. Consider extending the detection capability of CCD cameras down to the single-photon level, without deep cooling of back-thinned arrays

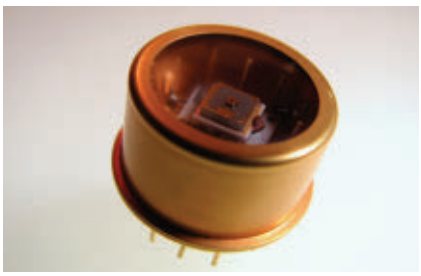
(room temperature operation). Or consider high-resolution night vision arrays with high sensitivity, without the downside of image intensifiers.

Traditional silicon photomultiplier technology is based on arrays of Geiger-mode APDs. Several manufacturers have products based on this technology, but the technology still is not considered mature; i.e., several device designs exist.

The traditional structure has a limitation in having a trade-off with photon detection efficiency. Also, the basic design is not flexible, not allowing customization for specific applications. The current design from Amplification Technologies – dubbed DAPD, or discrete amplification photon detector – consists of specially designed discrete amplification elements. These include a multichannel threshold avalanche amplifier and a reader for the amplified charge packets.

The design allows trade-off among various parameters to optimize a device for a specific application (Figure 1). The detectors perform analog detection of short pulses – down to single-photon levels – over a wide spectral range. Recently, the technology has been implemented in InGaAs, extending the spectral sensitivity to the near-infrared. The electron multiplication process is a binary amplification in separate channels that is nearly noiseless. The measured excess noise factor for these devices is typically less than 1.05 at room temperature, better than the best cryogenically cooled single-photon detector.

Important advantages of discrete-amplification technology are its wide operating voltage range, and its voltage and thermal stability. The discrete-amplification device can be operated up to 10 V above the breakdown voltage. The measured results show that the operating voltage variation is less than 30 mV/°C, and the gain variation, less than 0.5%/°C. These performance benefits enable the development of large detector arrays that would use a single reverse bias, with array elements having only minor variations of basic parameters at the same voltage.



	Spectral Range	Rise Time	Gain	Timing Resolution	In 0.15-mT B Field	Voltage
PMT - XP2020	Visible	1.5 ns	10×10^7	1.5 ns	½ Gain	2000 V
DAPD	Visible to Near-IR	0.5 ns	10×10^6	0.5 ns	No Effect	50 V

Data shows how the best photomultiplier tube (PMT) compares with standard SiPM technology.

Another advantage of semiconductor devices is their insensitivity to magnetic fields, which is a major problem for photomultiplier tubes. This is very important in large physics experiments and for future medical applications that hope to fuse images from PET and MRI or CT and MRI.

The age of silicon

So it appears that the time has come where a solid-state technology to replace vacuum tube photomultipliers is a reality. This is not to say that light-detecting photomultipliers will disappear. On the contrary, the technologies will coexist because there are applications where it may be impossible or impractical to use anything but a photomultiplier tube; for example, neutrino detectors must cover large real estate to capture just one of these elusive particles. Only thousands of photomultipliers with 10-in. photocathodes are a practical choice.

Some large physics experiments, however, would be better served by silicon photomultipliers, and beta testing has already begun. The flexibility of the semiconductor technology, however, gives it a much broader application because it can be used not only for light detection across the entire electromagnetic spectrum but also for ion and charged-molecule detection, such as in mass spectroscopy. Undoubtedly, people will find unique applications for this technology that may not be obvious at the present time.

Fast response time of a photodetector is important for many applications, especially those involving measurements within a narrow time gate. Discrete-amplification technology provides very fast response as well as a high gain-bandwidth product, a prerequisite for the high-speed detection of low-level signals. The response time of a single-electron-response pulse as an output of a 1-mm active-area-diameter DAPD is approximately 1.4 ns full width half-maximum (FWHM) at the gain level of 2.8×10^5. The timing resolution of the detected pulses, evaluated as the transit time spread (jitter) distribution at FWHM, is less than 300 ps (Figure 2).

Meet the author:

Wayne Seemungal is business development manager of Amplification Technologies Inc. in Brooklyn, N.Y.; e-mail: wayne@amplification-technologies.com.

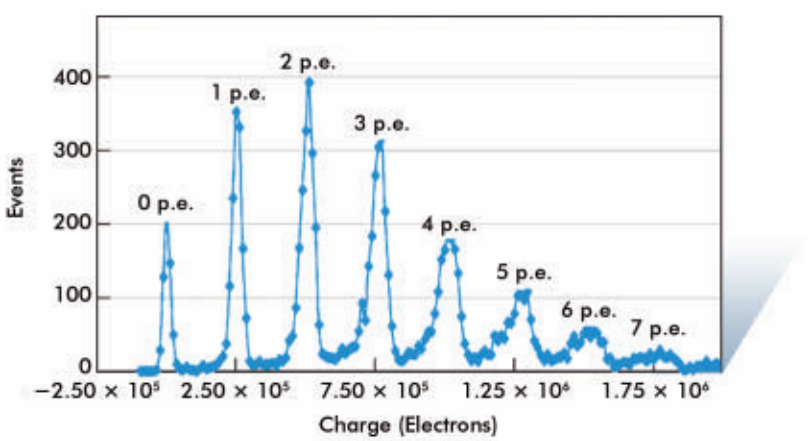


Figure 2. Discrete-amplification technology provides fast response times as well as high gain-bandwidth. p.e. = photoelectrons

Profiting from telecom investments:

Taking advantage of the NIR First Overtone and Raman's Spectral Fingerprints

BY ERIC BERGLES AND WILLIAM YANG,
BAYSPEC INC.

Instrumentation professionals have long recognized great potential for near-infrared/Raman spectroscopic analyzers in application areas ranging from lab analysis to portable field monitors. Until now, however, near-IR and Raman process analytical instruments were too big, too expensive, too fragile and so sophisticated that they required highly trained operators for "real world" use. But recent advances in high-volume telecom device manufacturing have painted a new picture.

Applications for near-IR and Raman instrumentation are far-reaching, promising to improve the efficiency of in-/at-line process monitoring on production lines and the safety of food and drugs, while at the same time enhancing quality control at each step of the product life cycle.

At work on the border

Government customs officials currently use handheld near-IR/Raman instruments at border points of entry to identify unknown substances quickly and with low cost of ownership. Pharmaceutical manufacturers are deploying near-IR/Raman instruments on production lines to monitor blending/drying conditions, fulfilling the promise of process automation technology initiated by the FDA earlier this decade.

Fourier transform infrared (FTIR) spectrometers were developed for commercial use in the 1960s but tended to be used only in research labs because of their high cost and complexity of operation. Gradually, technology advancements in computers and instruments reduced the cost and enhanced their capabilities, making FTIR the industry standard for organic compound identification work in modern analytical laboratories.

As sampling moves from the laboratory to the production line and points of entry, however, FTIR becomes impractical because of the size, complexity and cost of these systems.

Dispersive infrared instruments are sometimes called grating or scanning spectrometers. A dispersive infrared instrument also has a source and mirrors. The source energy is sent through both a sample and a reference path, through a chopper to moderate the energy reaching the detector, and directed to a diffraction or transmission grating (Figure 1). The grating, similar to a prism, separates the wavelengths of light in the spectral range and directs each one through a slit to the detector. Each wavelength is measured one at a time, with the slit monitoring the spectral bandwidth and the grating moving to select the wavelength being measured. The X-axis of a dispersive infrared spectrum is typically nanometers, which can be converted to the wave numbers by dividing by 10 and taking the reciprocal. An external source of wavelength calibration is used, eliminating the need for high-precision laser wavelengths to reference in the system.

Spectral information

An understanding of near-infrared spectral information serves two purposes. It enables the prediction of where a particular chemical species should absorb and provides an assessment of near-infrared's ability to perform an application.

The near-infrared region can be broken into four sections:

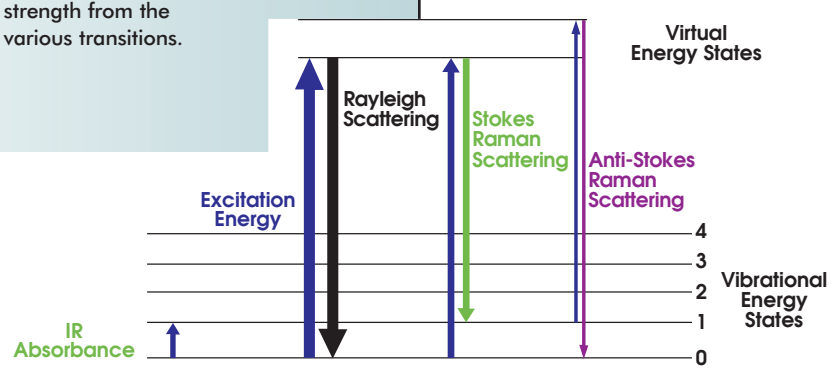
1) Transflectance: 800 to 1100 nm. Most suited to transflectance through a thick sample, such as seeds, slurries, liquids and

Why Raman?

The transition of Raman spectroscopy from a technically demanding research technique to a useful practical method of chemical analysis started in the late 1990s because of the development of and more general access to various lasers, thin-film coatings, holographic optical components, semiconductor detector/optoelectronics and small, fast computers. The development of the optical telecommunications industry in the past 10 years has not only accelerated the transition but also revolutionized the Raman instrumentation. Today, Raman instruments are becoming ubiquitous analytical tools.

The beauty of Raman is that it uses optical wavelengths but can obtain vibrational spectroscopic information of molecules – the spectral fingerprint – that was previously achievable only by long-infrared spectroscopic techniques. It has the best of both worlds.

The energy-level diagram below shows the states involved in the Raman signal. Line thickness is roughly proportional to the signal strength from the various transitions.



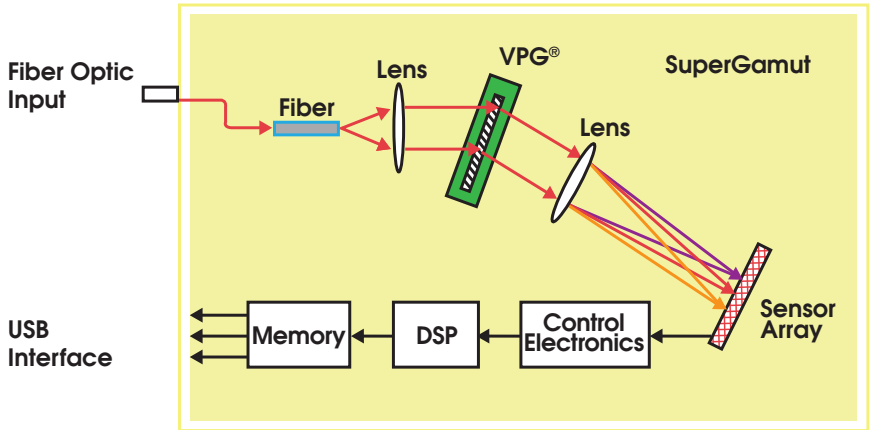


Figure 1: A schematic diagram of a NIR dispersive transmission spectrometer. Images courtesy of BaySpec Inc.

pastes, the absorption bands result from third overtones of the fundamental stretch bonds in the mid-infrared region.

2) Transmission: 1100 to 1800 nm. This section can be used for transmission through liquids and films as well as for diffuse reflectance measurements off samples with high water content. The absorption bands result from the first and second overtones of the fundamental stretch bonds in the mid-infrared region.

3) Reflectance: 1800 to 2500 nm. This section is predominantly used for making diffuse reflectance measurements off ground or solid materials. The absorption bands result from combination bands; e.g., C-H stretch and bend combination bands.

4) Raman: This technique looks at the fundamental molecular vibrations through an inelastic scattering process. It generates the so-called "spectral fingerprint" effect.

The transflectance region is of particular interest in food analysis because it is suitable for measuring high moisture- and high fat-content products such as meat, dairy products, jams and conserves, dough and batters. Sample cells with longer path lengths can be used to collect the near-infrared spectra. Typically, a 10- to 20-mm path can be used, making sampling easier and enabling viscous and nonhomogeneous samples to be scanned without further processing.

A major advantage of measuring in transflectance as compared with reflectance is that the spectra represent the variation in components throughout the entire sample, not just the surface. In reflectance, the first 1 mm contributes as much as 99 percent of the spectrum. Uneven distribution of components (in the sample, egg, drying at the surface, or separation of a water or oil layer at a glass window) results in reflectance spectra that do not represent the entire sample.

The advantages of using transmission spectroscopy, however, are evident in that the intensity of near-infrared bands is approximately an order of magnitude higher than the transflectance region, allowing for relatively long path lengths. The reflectance region also provides an additional 10× improvement over the transmission region.

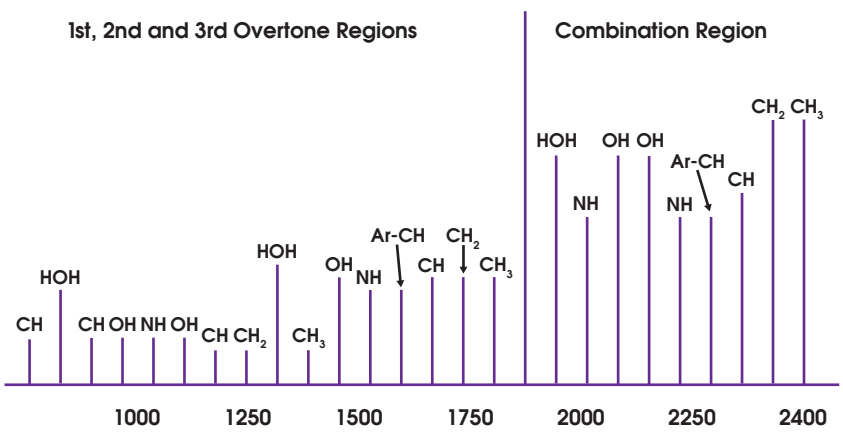
The performance of near-infrared greatly depends on the ability to control and acquire data from the instrument and to calibrate and analyze it. Optical path length is a key parameter of the near-infrared instru-

Why Near-Infrared?

The near-infrared spectral region – 800 to 2500 nm – is the "overtone and combination" region of the mid-infrared (see chart below). Near-infrared spectra contain absorbance bands mainly the result of three chemical bonds; i.e., C-H (fats, oil, hydrocarbons), O-H (water, alcohol) and N-H (protein). Other chemical bonds may exhibit overtone bands in that region; however, they generally are too weak to be considered for use in analysis of complex mixtures such as those mentioned above. Near-infrared is ideal for the quantitative determination of oils, protein and moisture. In addition, high scatter coefficients allow for excellent diffuse reflectance spectra of solids.

The sensitivity and directivity of any spectroscopic measurements depend on band intensities. Short wavelengths, such as the visible region – 400 to 800 nm – are what spectroscopists call "third overtones," which have considerably weaker band intensities – 103 less – when compared with the second overtone region – 800 to 1100 nm. This is even weaker – another 103 – compared with the first overtone region – 1500 to 1800 nm. Overtones in the short wavelength region of 400 to 1100 nm of various molecular stretches also diminish the spectral fingerprint effects, which render no spectral discrimination, making it harder to identify molecular information. So it is advantageous to use near-infrared instead of visible or infrared.

Near-infrared spectra do not have the resolution of the mid-infrared spectra but can usually be collected off or through materials without sample preparation. They also are suitable for measuring high and low water-content materials. And, whereas mid-infrared is mainly a qualitative technique, near-infrared is mainly a quanttative one.



These are the overtone and combination spectral regions.

Components and Instrumentation Advantages

Near-infrared offers other practical considerations when compared with other wavelength ranges, including:

* Sampling cells can be made from glass; mid-infrared requires sodium chloride or potassium bromide (expensive preparation devices and rigorous sample preparations).
* Relatively little sample preparation.
* Path lengths up to 10 to 20 mm may be used because of low molar absorptivity and high-energy throughput in this region.
* Commercial availability of light sources.
* Compatibility with fiber optic cables for portable quality control analyses.

ment, which has been thoroughly discussed in univariate quantitative analysis in the presence of photometric errors. Although multiple wavelengths can provide more chemical information, it is difficult to determine a single path length that is suitable for each wavelength region. Therefore, availability of full near-infrared wavelength ranges is necessary.

Vibrational modes that are inactive in mid-infrared absorbance are active for Raman scattering, and vice versa. The bands are about as narrow and distinctive as mid-infrared absorbance bands. For this reason, it is extremely useful for elucidating molecular structure from first principals and from library spectra, in the same way as mid-infrared spectroscopy. However, bands tend to be weak and subject to interference by fluorescence from the sample. New availability of surface-enhanced Raman spectroscopy substrates and nanoparticles – especially the newly developed dispersive 1064-nm Raman instruments – solves these issues.

At left is BaySpec's SuperGamut near-infrared spectrometer engine.

Portable near-IR/Raman instruments

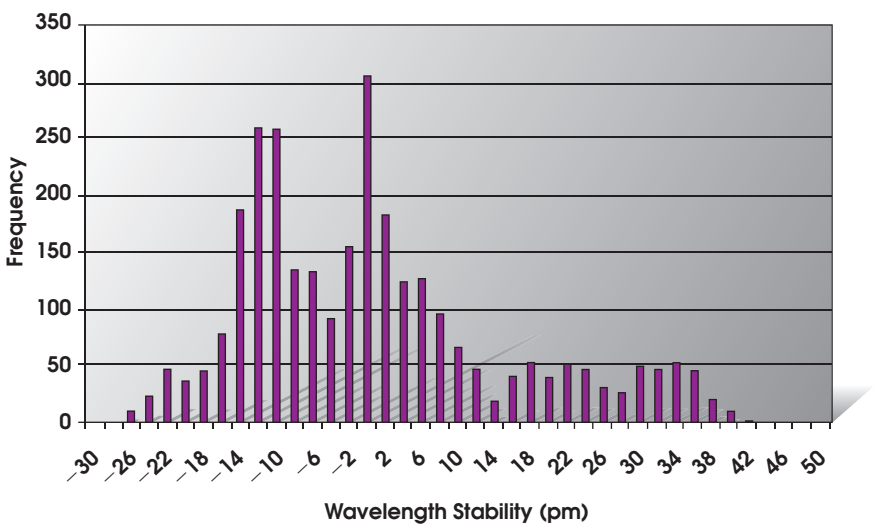
Today's state-of-the-art near-infrared/Raman spectral engines borrow largely from the massive investments made in telecom-grade components over the past 10 years. These include transmission holographic volume phase gratings, linear array image sensors, miniature lasers and light sources, and solid-state computer chips. Collectively, these are now assembled into ultracompact, no-moving-parts, low-power-consumption, hermetic, reliability-tested spectral engines that can run on batteries in a handheld form factor.

There are four parameters that describe the capability of a spectrometer: spectral range, spectral bandwidth, spectral sampling, and signal-to-noise ratio (S/N). Spectral range is important to cover enough diagnostic spectral absorption to solve a desired problem.

A spectrometer must measure the spectrum with enough precision to record details in the spectrum. The S/N required to solve a particular problem will depend on the strength of the spectral features under study because the S/N is dependent on the detector sensitivity, the spectral bandwidth and the intensity of the light reflected or emitted from the surface being measured. A few spectral features are quite strong, and a signal-to-noise of only about 10 will be adequate to identify them; others are weak, and an S/N of several hundred (or higher) often is needed. In addition, device-device repeatability is now effective with manufacturing lot-lot consistencies learned from higher volumes.

Today's spectral engines are designed to meet real-world challenges for best-in-class performance, long-term reliability, compact size and ultralow-power consumption at affordable prices. Near-infrared/Raman spectrometers use telecom reliability-tested components and feature no moving parts for long-term reliability and lifetime calibration in the field.

This new type of affordable, accurate and rugged spectral device is helping to fulfill the promise of near-infrared/Raman spectroscopy.



The SuperGamut has sub-50-pm repeatability.

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Avoiding failure:
Advanced metrology finds tiniest defects in semiconductor materials

BY HANK HOGAN, CONTRIBUTING EDITOR

Chip features are small, and the defects that make them fail, even smaller. What is more, inspecting chips must be done on an assembly line, where throughput is crucial. Add to that layers of reflective and other obscuring films, and you have a recipe for a real challenge.

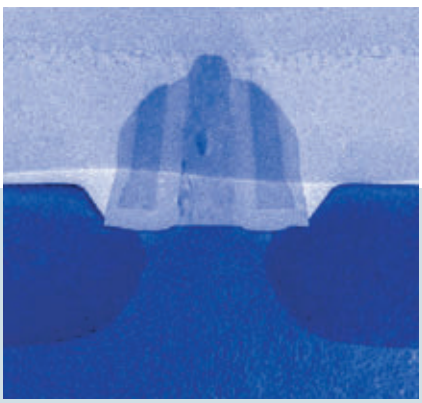
There is one other factor that must be considered. Because of technological advances, chip inspectors must hit a moving target, and their aim must be not on today's technology or even tomorrow's, but on that of the day after.

As Dilip Patel, defect metrology program manager at the International Sematech Manufacturing Initiative (ISMI), a chip manufacturing consortium in Austin, Texas, noted, "In general, you need metrology before any other technology."

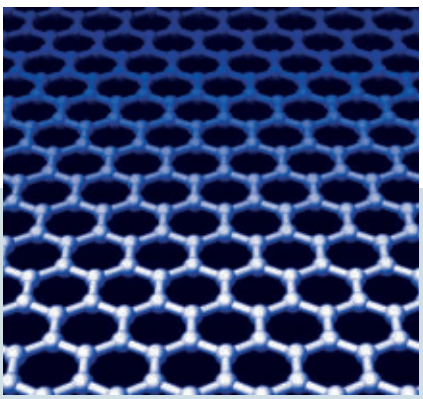
Whereas today's state-of-the-art semiconductors have minimum feature sizes in the 50-nm range, researchers already are worrying about defects two or three process nodes ahead. They are struggling to come up with reliable methods to detect defects with dimensions below 10 nm. Consequently, industry and academic researchers are seeking new ways – and new wavelengths – to inspect semiconductors. A survey shows some successes and outlines what remains to be done.

The inspection challenge can be broken down into three phases: spotting point defects, measuring the thickness of films and determining critical dimensions, which are measurements of the sizes of important circuit pattern features.

Given the dozens of processing steps a chip goes through during fabrication and the need to sample a meaningful percentage of the hundreds of chips on a wafer, inspection speed is paramount. Much of today's chip checks are done using optical tools, in part for historical reasons and in part because such an approach offers the required throughput.



Advances in semiconductor manufacturing require that chips in production be inspected for new parameters such as strain, which could be done using x-ray diffraction of Raman spectroscopy. This image shows strained silicon, used to boost performance. Courtesy of ISMI and Intel.



New semiconductor materials, such as the graphene shown here, will require new inspection metrology techniques. Candidates include x-ray diffraction, spectroscopic ellipsometry, and spectroscopic and x-ray reflectometry. Courtesy of Thomas Szkopek, McGill University.

Detecting invisible defects

With regard to the first inspection category, some tools operate with light in the ultraviolet to blue regions of the spectrum, or about 250 to 450 nm. The rule of thumb is that a killer defect can be as small as half the feature size of the circuitry. Because today's state-of-the-art processes are at the 45-nm node, that means the tools are being used to spot something that is a little over 20 nm in size.

That is well below the classical resolution limit; thus, the defects cannot be resolved into discrete objects. But the situation isn't anything new.

"Defects have been unresolved for more than five years and closer to a decade," said Greg Kirk, vice president of technology for the optical patterned wafer inspection line of products at KLA-Tencor Corp. in Milpitas, Calif. The company makes a variety of chip inspection tools.

In describing the situation, Kirk said, "The defect shows up as a point-spread-functionlike dot. You've got to figure which dot is a defect and which is noise."

The concept behind these optical inspection techniques is fairly straightforward: Hit the chip with light, make the defect interact with the light and collect the resulting signal for analysis. Over the years, KLA-Tencor has found that contrast is more important than resolution, and that images that look poor to the eye actually may be the best for defect detection. Thus, a longer wavelength – say around 450 nm – may yield better results than one in the ultraviolet.

Getting to that point, however, can require painstaking simulation work, with the various film layers and circuit geometry being used as parameters. Added to that must be factors such as line edge roughness, which can contribute to scatter and noise.

What will be needed in the future, Kirk said, are more powerful broadband light sources and more sensitive and speedy detectors. He noted that the company's road map calls for sensors with data rates higher than 6.4 gigapixels per second, something not available today. On the optics front, it needs a broadband response with a wide field of view and a high numerical aperture in different illumination and collection sectors of the spectrum, he said. "That is key to collecting the signal we want and rejecting the noise we don't."

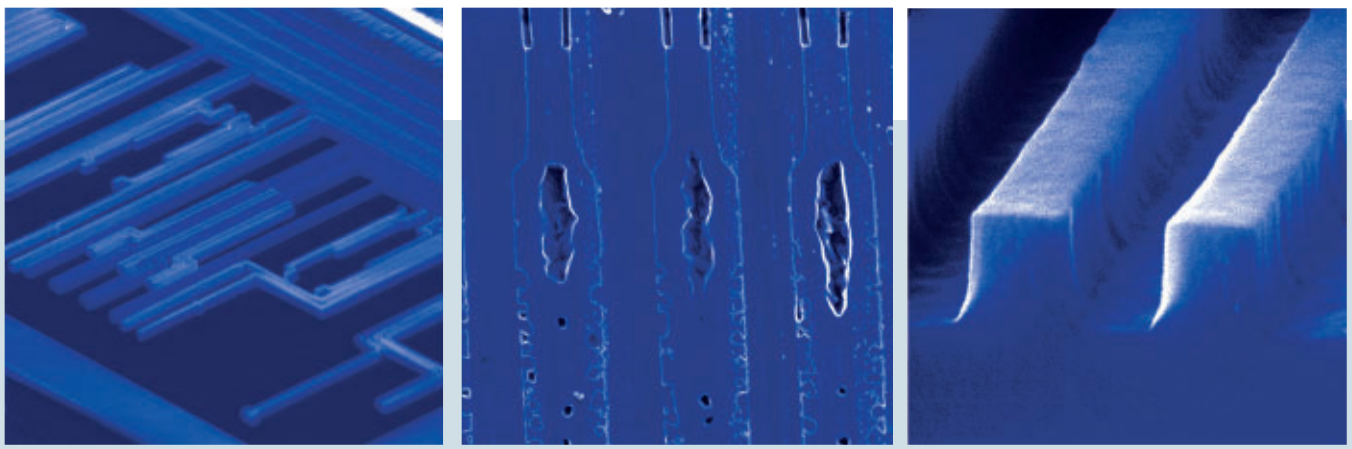
Nonoptical contenders

For its part, ISMI is working with vendors and researchers to facilitate the development of new inspection technologies. Doing so requires the creation of test structures that mimic the proposed stack of films that will make up tomorrow's chips. Investigators then must create an array of defects of the right size and composition so that the inspection technology can be tested.

ISMI's Patel noted that various approaches exist today that can do the job at larger defect sizes or at lower throughput. "The issue is to get smaller resolution and at the same time higher throughput."

The consortium is working with FEI Co. of Hillsboro, Ore., maker of scanning electron microscopes, to improve that technology. Another area of investigation involves the helium-ion microscope supplied by Carl Zeiss SMT of Oberkochen, Germany.

As the name implies, the microscope uses a beam of helium ions. Because these ions weigh 8000 or so times what an electron does, they have a de Broglie wavelength that is about 300 times smaller. As a result, the beam suffers correspondingly less diffraction and can achieve a smaller spot size. It also can be used to characterize materials on the nanoscale, offering the prospect of enabling defect detection and classification in one tool.



Detecting defects in semiconductor chips may require the use of novel nonoptical methods as feature sizes shrink. Seen here are images obtained with a helium-ion microscope, a new inspection technology. Courtesy of Carl Zeiss.

Going to great lengths

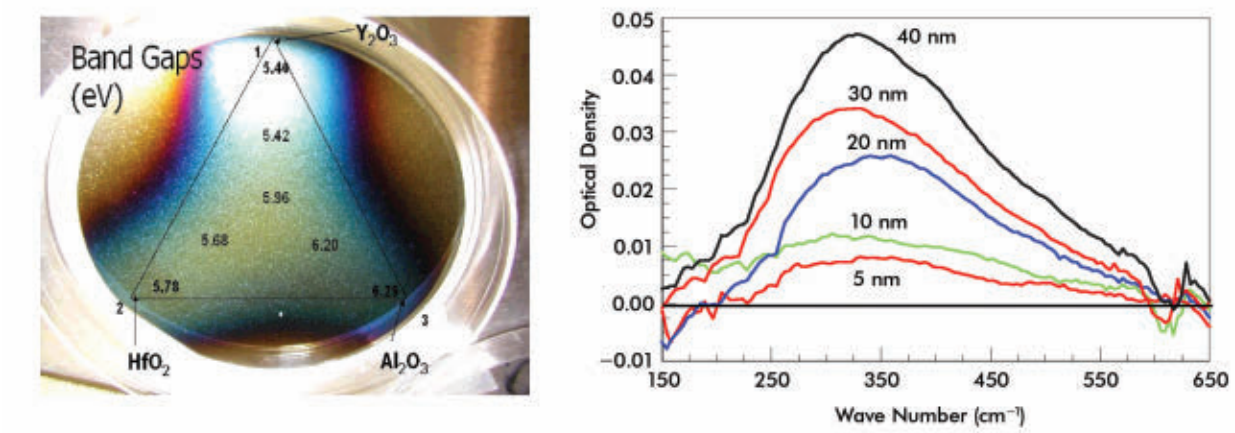
Although nonphotonic methods are being pursued actively, don't count out optical techniques. A case in point comes from research that appeared in the May 1, 2009, issue of *Optics Letters*. Lead author Edwin J. Heilweil, a chemist at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., said that the work began with the hope of imaging wafers for defects.

In its investigation, the NIST group modified a commercial IR detector, adding a beamsplitter and changing the sensor so that the device detected terahertz waves. Located between IR radiation and microwaves, terahertz waves can be used for a type of spectroscopy known to be very sensitive to crystal and molecular structures.

However, these wavelengths are 15 to 300 µm, roughly 1000 times the 50-nm-or-less thickness of the metal-oxide films being used in leading-edge semiconductors. Nonetheless, when the researchers looked at samples, they saw a large signal, one that changed when the crystalline phase of the film did. The technique yielded a useful signal from films as thin as 5 nm.

By way of explanation, Heilweil pointed to film vibration modes, or phonons. "These phonon modes in these types of materials are spread around the film, and they act like an antenna in a way."

The phonon modes effectively increase the interaction cross section of the film, making a thin film yield the signal strength equivalent to a much thicker one.



Terahertz measurements (left) of metal-oxide films reveal details on films as thin as 5 nm. On the right is a visible image of a mixed-oxide combinatorial library grown from yttrium, aluminum and hafnium targets. Courtesy of Edwin J. Heilweil, National Institute of Standards and Technology.

Before the technique can be used in production, more research and development must be done, particularly with regard to increasing the detected spectral bandwidth and spatial resolution. Heilweil believes that the use of the right laser as the light source can solve those problems.

Once bandwidth is sufficient, the method holds promise as an in-line film monitor because it can detect microscopic changes in the crystalline structure during deposition of titanium and hafnium and other metal-oxide films. The first two are in some of the latest semiconductors and are expected to be used much more extensively in next-generation devices.

Measuring the future

The NIST work illustrates that unusual wavelengths may prove unexpectedly useful, but new wavelengths also may present new problems. A case in point can be seen in thin-film metrology, which measures various film aspects.

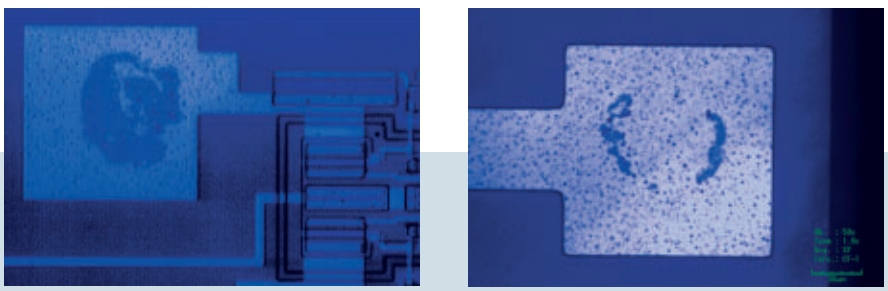
Victor Vartanian, ISMI's films metrology manager, noted that the industry faces some challenges because of transistor performance degradation that began when feature sizes went below 130 nm. Above that size, transistors gained in performance by going smaller; below, their performance suffered as they went smaller.

Regaining that lost performance has been possible through novel transistor engineering, but that, in turn, has made it necessary to measure the strain and other previously nonessential parameters in films. These measurements must be made on films that are sometimes only tens of nanometers thick.

This requirement has been met by the use of deep-UV or vacuum-UV. Consequently, there has been a need for different sources, detectors and optics. However, such energetic photons can raise new questions, Vartanian said. "What types of damage might you be doing to thin dielectric surfaces, and are you accounting for these effects?"

These questions could become more acute. One issue with x-ray and UV inspection has been the lack of high fluence sources. Increasing throughput can require brighter sources, but those same sources could adversely affect the films being inspected. Balancing throughput and yield could take considerable research and development.

The final aspect of chip inspection – critical dimensions – has long been meas-



Near-IR inspection can detect details and defects not visible otherwise, particularly since silicon is transparent to near-IR. The image on the right is from a standard microscope equipped with near-IR, while the one on the left is from a high-resolution laser confocal microscope. Courtesy of Olympus America.

ured via an optical technique called scatterometry. In it, light of a wavelength well above the feature size is scattered off chip structures, and the size of those features is then deduced from the scattering profile.

Solving the scattering problem with a two-dimensional model of the actual shape was sufficient in the past, said ISMI critical dimension project manager Benjamin Bunday, but now the 3-D shape of the structure must be taken into account. That change has meant that 15 or so parameters must go into the solution, instead of the five used previously. Some of the new ones involve the slope of the walls or the roughness of the edges of the features.

Of course, scatterometry has its limits. Investigators at NIST and ISMI have attempted to determine these, and their results indicate problems ahead, Bunday said. "With optical scatterometry, about the 22-nm node or the 18-nm node, you might see some issues. That's when things will get interesting."

However, he added, "Don't say that's set in stone. Suppliers will probably rally to the cause, as they have in the past, and find a way to make things work."

In case they don't, researchers are looking into an x-ray version of scatterometry. Putting it into production, however, requires an improvement of three orders of magnitude in source brightness and detector performance.

Going up

Another factor in the inspection challenge arises because the future of chips is looking up – literally. The latest twist is stacking chips atop one another in a 3-D structure. This is being done because of an ongoing need to route ever-faster signals around ever-larger chips through ever-smaller metal traces. Exploiting the third dimension gets around those problems, upping the performance and density of future chips.

However, it does add a new aspect – again literally – to the inspection challenge. The through-silicon vias that connect one stacked circuit to another stretch through the substrate, a distance that can run hundreds of microns for a full-size wafer and some fraction of that for a thinned one. Yet the vias themselves measure only, at most, a few tens of microns across. Thus, the aspect ratio – the depth divided by the width – can run as high as 15:1. It isn't enough for the via just to reach the other side; the slope and shape of the walls also are important.

The inspection and stacking are done after the chips are largely finished. This means that a lot of money has been invested in them, and it is difficult to see through all of the film layers.

One possible solution being investigated is the use of near-IR, using wavelengths out to as much as 1700 nm, and an indium gallium arsenide camera as a detector. Olympus America Inc. of Center Valley, Pa., manufactures a microscope with near-IR imaging capabilities that could be used for this. With the near-IR approach, the alignment of the chips could be checked before the 3-D structure was finalized.

Linda Sikel, a product manager for Olympus America, noted that the key is being able to use wavelength, optics, sensors and image-forming techniques to make the job easier. Such optimization also is important for virtually any other optical inspection of semiconductors.

As for applying the right light to this particular inspection task, Sikel said, "What's extremely valuable is the ability to see through the silicon."

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Australian Agenda

No Great Barriers?

BY CAREN B. LES
NEWS EDITOR

With the launch of the Institute of Photonics and Optical Science (IPOS) in April 2009, scientists at the University of Sydney in New South Wales, Australia, now can draw on the research and teaching expertise of the university's schools of physics, mathematics, chemistry, and electrical and information engineering, as well as from its electron microscope unit.

The institute's new master of photonics program, which is scheduled to begin operation next year, already is experiencing good levels of interest, according to professor Simon Fleming, IPOS deputy director and head of business development. The university has an international reputation for teaching at the undergraduate and postgraduate levels and has drawn together teaching staff and world-leading researchers from the various disciplines within IPOS to create an exciting and current master's program, he said. The goal is to build up teaching activities to reach the same level of success as the school's research operations.

To keep in line with the core concept of IPOS, which is that photonics is becoming important across so many areas, the new institute plans to diversify its activities and funding over the next five years or so, particularly across application areas and funding sources, Fleming said. The hope is that this strategy will increase the institute's impact and relevance and mitigate the risks of being linked too strongly to one application area.

Fleming said that the institute's goal also is to construct a building to house state-of-the-art cleanrooms and other infrastructure necessary to undertake initiatives in the areas of nanophotonics and nanoscience.

High-impact projects at IPOS

With Danish and Chinese collaborators, researchers at IPOS demonstrated optical switching of signals at close to 1 terabit per second, said Fleming, adding that their approach was based on a scheme known as four-wave mixing in a highly nonlinear chalcogenide glass waveguide. He noted that this record-breaking result generated international media attention and shows enormous potential for ultrahigh-speed signal processing for terabit-per-second communications.

An example of green photonics – a photonic chip capable of low-power optical switching – has been developed at the institute. Fleming said that this breakthrough is critical because the exorbitant energy demands currently placed on the electronic information routers are estimated to reach a crisis point by 2013. The key factor behind this discovery, he added, is that the material used in the photonic integrated circuit is well-proven and available. It is a high-refractive-index version of the glass in typical optical fiber, which, when combined with the novel device design, enables operations to be performed with more than a million times less power than previously required in glass circuits.

Researchers at IPOS have pioneered microstructured polymer optical fiber that allows them to make and study structures that would be difficult to make in silica and to which they incorporate material additives such as dyes, quantum dots and metal inclusions. Fleming said that a particularly interesting fiber is a graded-index multimode type fabricated from a single material – with the grading provided by distribution of airholes – which has a large core and a high bandwidth and which could be produced extremely economically for fiber-to-the-home (FTTH) or fiber-in-the-home (FITH) applications.

A new device, called a "photonic lantern," has been developed that has applications in the field of astrophotonics, he said. In astronomy, multimode fibers are used to gather optical signals. However, most photonic signal processing devices are single mode. To enable the use of single-mode devices in conjunction with multimode fibers, a taper in the photonic lantern allows a multimode fiber to pass through and to split into a large number of single-mode fibers. This device has demonstrated superb results, he said, adding that it allows fiber Bragg gratings to be used to filter a large number of interfering signals in multimode fiber across a very broad spectral range, providing high signal clarity.

The Australian photonics market and the global financial crisis

Because Australia represents a small part of the world's economy – about 1 or 2 percent – its photonics companies must be "born global" to achieve a sufficient market for their products, said Fleming, adding that, in this respect, Australian companies seem to be as exposed to the financial crisis as any other country's, despite a somewhat healthier local economy.

He suggested that the photonics companies in Australia actually may be faring somewhat better. Although the world may be buying less, those buying decisions are more influenced by cost, he said. In Australia, the traditional low cost of even highly skilled labor has been coupled with currency movements that have made its manufactured photonics components even more competitive.

National Broadband Network

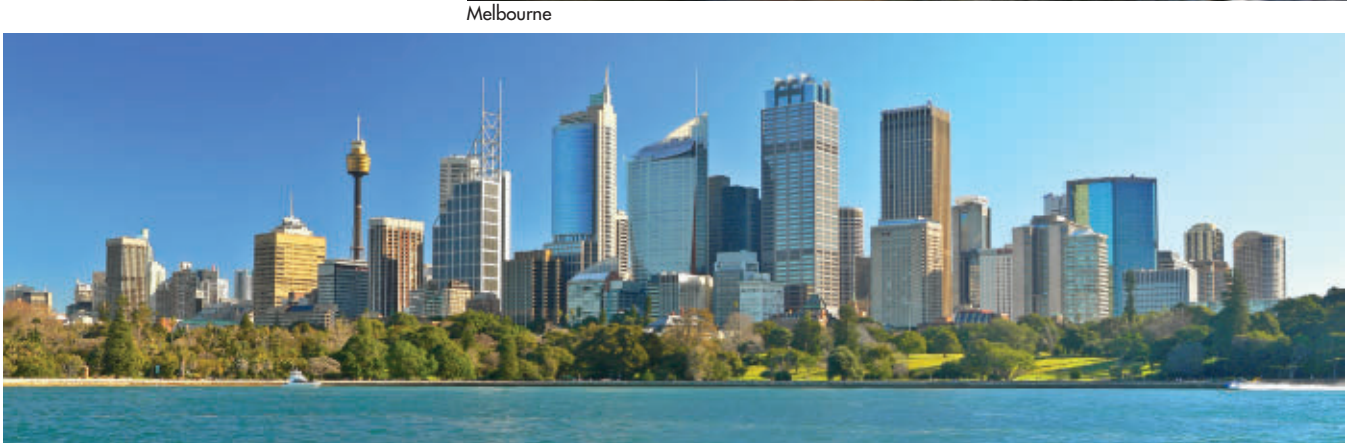
There are a few important areas that stand out from these broad trends, Fleming said.

The Australian government recently announced that, over eight years, it will establish a company that will invest up to $43 billion to build and operate the National Broadband Network, a project that will serve to deliver superfast broadband to the country's homes and workplaces.

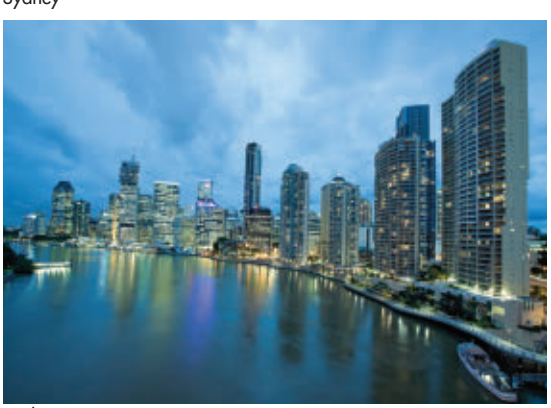
One main goal of the network, which will be built in partnership with the private sector, will be to connect 90 percent of all Australian homes, schools and workplaces with broadband services via optical fiber with speeds up to 100 megabits per second – 100 times faster than those currently used by many households and businesses. The network will provide fiber optic transmission links connecting cities, major regional centers and rural towns. Other goals include connecting all other premises in Australia with next-generation wireless and satellite technologies that will deliver broadband speeds of 12 megabits per second.

Envisioned as a major nation-building program, the project is expected to help drive Australia's productivity, improve the delivery of education and health services, and connect big cities and regional centers. One of its aims is to directly support up to 25,000 local jobs a year, on average, over the life of the project.

Melbourne



Sydney



Brisbane

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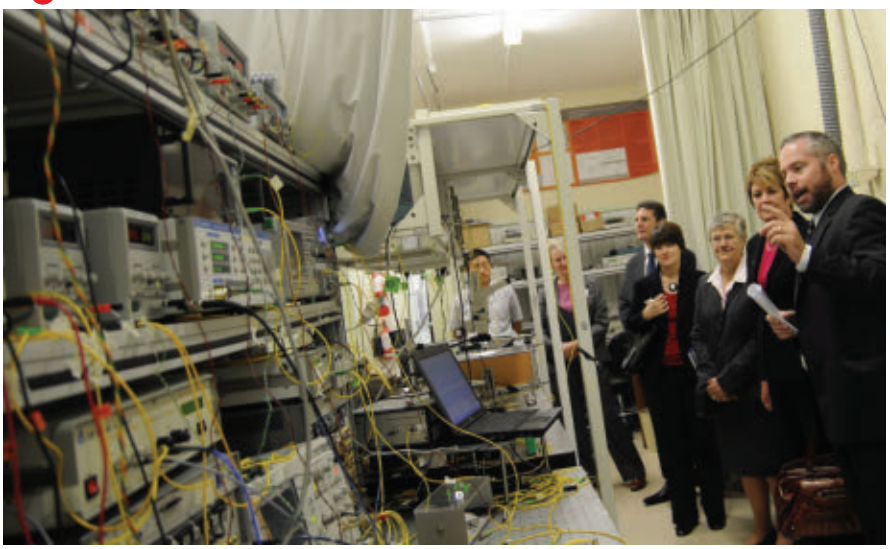

Professor Ben Eggleton, director of IPOS, a newly launched photonics center at the University of Sydney, is shown in the terabit-per-second laboratory explaining progress in recent research to Sen. Anne McEwen of South Australia. Courtesy of IPOS.

Fleming said that, although few details are known about the network's implementation, the project is expected to represent a huge change in the domestic market for photonic equipment and fiber.

There also are steadily developing opportunities, primarily in the domestic market, for photonics outside telecommunications that do not yet appear to be perturbed by the economic downturn, said Fleming, adding that small companies are addressing applications in the health monitoring, medical, power, security and defense sectors.

Astronomy initiatives

Domestic opportunities for the Australian photonics market also may arise from some important initiatives in astronomy and space science announced in the recent national budget, Fleming said.

For example, in its 2009-10 budget, the government announced that it will invest $160.5 million in its space science and astronomy programs between 2012 and 2013.

The investment is expected to improve the country's chances for hosting an extremely large and powerful telescope, the Square Kilometre Array (SKA). Western Australia is one of two possible hosts for the $3 billion international project, which will be designed to probe the universe for earthlike planets and to observe first objects and examine the mysteries of dark energy. A supercomputer will be required to process the data collected by the telescope. The project is expected to have a significant economic impact on the host country. Of the $160.5 million, $80 million will be spent to establish a high-performance computing and science center in Perth for the SKA.

Solar cell technology

Solar cell technology is expected to grow significantly in Australia over the next few years, in the opinion of Min Gu, professor (chairman) of optoelectronics and director of the Centre for Micro-Photonics at Swinburne University of Technology in Hawthorn, Victoria, Australia. He does not believe that there will be a significant change in the Australian photonics market as a result of the global economic downturn.

Gu said that the major goals for the center are to develop innovative nanophotonics devices for all-optical information technology, to advance optoelectronic imaging methods for biological studies and industrial applications, and to understand mechanisms for light interaction with biological materials. Projects involving nanoplasmonic solar cells, nonlinear optical endoscopy and multidimensional optical data storage are in progress at the center.

Swinburne and Suntech Power, based in China, are collaborating to create a new generation of solar cells, according to a June 2009 press release from the university. Their aim is to develop solar cells that are twice as efficient and half as expensive as the existing technology. Based on the development of nanoplasmonic solar cells, the technology will allow for the efficient collection of solar energy in a wider color range than with other cells currently in development. Gu will lead the research and development effort at Swinburne, and Suntech Power will manage the manufacturing and other commercialization aspects. It is expected that the cells will be ready for manufacture within five years.

Also, researchers at the Centre for Micro-Photonics have demonstrated a five-dimensional optical recording technique using the polarization of light and its wavelength as two dimensions in addition to the three spatial dimensions. The method, which consists of using a substrate of gold nanorods immersed in polymer, has the potential to increase storage capacities by several orders of magnitude. The report on this research appears in the May 21, 2009, issue of *Nature*.

Breaking broadband barriers

The outlook in Australia is positive, particularly because the government has announced that it will facilitate the rollout of funding for the National Broadband Network, according to Rodney Stuart Tucker, research director at the Australian Research Council (ARC) Special Research Centre for Ultra-Broadband Information Networks (CUBIN), which is based at the University of Melbourne in Victoria. Tucker said the rollout will be the largest single infrastructure initiative in Australia's history and will provide an enormous boost to the optoelectronics industry.

He said that lightwave technology, especially fiber-to-the-premises, is expected to grow significantly in Australia over the next few years, and that the biggest challenges facing the photonics industry there are likely to be associated with network design, equipment supply and shortages of skilled labor.

Research in extended-reach passive optical networks for rural and remote areas also is in progress at the university, Tucker said. This project was covered in the May 2009 issue of *Photonics Spectra* ("Passive optical networks, higher power lasers keys to broadband services in rural areas," p.24). A collaborative project on the social benefits of broadband also is under way and will involve researchers from medicine, education and other areas, he said.

With assistance from equipment vendors, CUBIN is establishing a fiber-to-the-home test bed aimed at providing a comprehensive facility for evaluating equipment and services for the National Broadband Network. "In addition to enabling cross-vendor interoperability tests, this facility will provide opportunities for researchers and service providers to test

new applications for 100-Mb/s services," Tucker said.

In collaboration with NICTA, Australia's Information and Communications Technology (ICT) Centre of Excellence, CUBIN is home to a major research program in coded orthogonal frequency division multiplexing (COFDM) for very high bit rate communications. Using COFDM, researchers at NICTA and CUBIN recently demonstrated the transmission of data at 1 terabit per second over 600 km. A spinoff company of NICTA, Monitoring Division Inc. of East Melbourne, is developing sophisticated performance-monitoring equipment for high-capacity optical trunk transmission systems.

Tucker said that a major part of CUBIN's research is focused on "green" aspects of photonics. His group has developed a comprehensive energy model of the Internet that has helped identify the greenhouse impact of the Internet.

"If we exclude data centers and end-user equipment such as personal computers, the Internet uses about 0.5 percent of all electricity," Tucker said. The photonics component of the Internet uses only a small part of this 0.5 percent. The photonics transmission part of the Internet is very efficient, he noted. His group also is investigating the potential carbon footprint of increased penetration of photonic switching in the network.

Although 2008 was the final year that CUBIN received core funding from ARC, the center will continue to pursue its ongoing research programs until at least 2011, according to its annual report. In 2009, research will progress in areas such as the greening of the Internet, alternative optical network architectures to overcome the limits of growth, and optical fiber transmission systems in both core and access networks.

Research at CUBIN is conducted by staff members at the university, research fellows and students associated with the center, and by academic visitors and collaborators from around the world.

Locally made optics

Francis Lord Optics, a division of Avtronics (Australia) Pty. Ltd., manufactures a wide range of precision optics, including prisms, lenses, mirrors, laser windows and reference flats. The company works with a diverse selection of glasses and can achieve tolerances of up to ⅒ of a wavelength of light, according to Glenn Davis, a representative of the business, which is based in Gladesville, New South Wales.

Davis said that the company has a close association with Australia's Commonwealth Scientific and Industrial Research Organization as well as with many universities, both domestic and foreign. It has fabricated optics for the Australian military, the Anglo-Australian Telescope and a variety of privately owned companies, he added.

In the wake of the economic downturn, the company has risen to the challenge and broken into new arenas that it normally would not have considered, including optics for the art world and for the architectural lighting industry, and it has increased its involvement in research and development.

"We are continually looking for and at ideas where optics can be used as an alternative medium," Davis said, adding that he hopes there will continue to be a need for Australian-made optical products, despite the attraction to get things made cheaper overseas.

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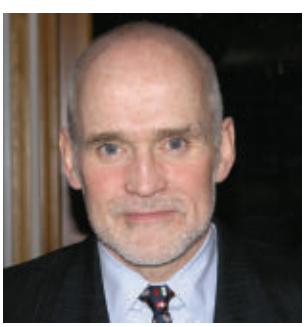

Eugene Arthurs, CEO of SPIE (top), and Liz Rogan, executive director of OSA.

Getting By with the Help of Your Friends at SPIE and OSA

BY DAVID L. SHENKENBERG
FEATURES EDITOR

Optical scientists and engineers have a lot to celebrate as Galileo's telescope turns 400 this year and the laser turns 50 years old next year. The Optical Society of America (OSA) is serving as a partner in LaserFest, a series of events taking place in 2010 that are designed to inform the public and Washington thought leaders about the benefits of the venerated device.

This is just one example of what a professional society provides its members. Most scientists and engineers know about the benefits of poster sessions and oral presentations, the one-on-one interaction with questions answered in real time, but doubtlessly some may be unaware of the other perks of membership besides receiving information, influencing the field, and social and cultural enrichment.

For example, OSA coordinates visits between members and legislators and between members and embassies. It lobbies world leaders to support the field of optics, primarily in the form of funding R&D, and bestows the Advocate of Optics award on those leaders who follow through on their funding promises.

The 15,000 individual and 200 corporate members of OSA can subscribe to *Optics and Photonics News*, OSA journals, *Physics Today*, both in print and online, and have access to free career services and the WORKinOPTICS database, grants, award fellowships, an online research library and Optics InfoBase. OSA provides about $1 million per year in total grants funding.

"Through the OSA Foundation and other efforts by OSA, we're able to help scientists who otherwise would not be able to afford to travel to meetings or have access to the latest journal articles," said Liz Rogan, OSA executive director – the equivalent of CEO.

Membership in SPIE has its privileges, as well. SPIE provides $380,000 each year in grants and scholarships on a competitive basis and another $40,000 as student and travel grants to its meetings, which take place all over the world.

The CEO of SPIE, Eugene Arthurs, said, "Our tax status as a 501(c)(3) not-for-profit limits the amount of lobbying we can do, but we do significant work at trying to inform decision makers in the US and EU on the importance of the work our members do."

"To me, my three decades of membership as someone briefly in academia but mostly in industry were extraordinarily fulfilling and, in bottom-line terms, yielded rewards much richer and more real than Madoff-type ROIs."
– Eugene Arthurs, CEO of SPIE

Educational opportunities

There is a widespread belief in the field of education that interest in science must begin at a young age. Toward this goal, the National Science Foundation (NSF)-funded Hands-On Optics program was organized by SPIE, OSA and the National Optical Astronomy Observatory. This program brings the excitement of optics to underserved communities in the US.

The local and student organizations of OSA use tools such as the Optics Discovery Kit and Hands-On Optics modules to bring optics into the classroom. The organization has a partnership with the Girl Scouts of the USA.

Arthurs emphasized that scientists have valuable knowledge. Many careers of people who majored in liberal arts or business are frustrated by an inability to understand technology, and mastery of a vital area of science is increasingly rare, he noted, adding that the importance of scientists as advisors is underscored by the actions of the current US presidential administration.

At conferences, short courses help people within the field explore new areas, and meetings and journals encourage cross-disciplinary learning.

For many people, lectures by Nobelists are a particular highlight. In the words of Arthurs, "Two Nobel laureates who impacted me substantially in recent days were the late Richard Smalley, who after winning his prize tried so hard to inspire scientists to work on the major problems facing humanity, and NASA's John Mather, currently chief scientist on the James Webb Space Telescope, who donated a large chunk of his prize to fund a graduate student scholarship."

SPIE's 2009 Defense, Security and Sensing meeting featured speakers from industry and government, including Norm Augustine, former CEO of Lockheed Martin, and Jay M. Cohen, Under Secretary for Science and Technology in the Department of Homeland Security.

The OSA-sponsored CLEO 2009 event hosted Edward Moses, principal associate director for the National Ignition Facility and Photon Science Directorate at Lawrence Livermore National Laboratory. Nobel laureate and US Secretary Steven Chu made remarks at the 2009 annual OSA leadership reception.

At the helm

The leader of SPIE is a president elected by its members. However, the organization also requires extensive business management. Consider that there are 17,000 individual members and more than 500 corporate members. On top of that, some 40,000 people attend SPIE events each year, with 80,000 technical authors and 18,000 speakers. Therefore, there is a need for a CEO to control the business aspect of the organization.

Arthurs was himself a member before being selected via a search committee. "To me, my three decades of membership as someone briefly in academia but mostly in industry were extraordinarily fulfilling and, in bottom-line terms, yielded rewards much richer and more real than Madoff-type ROIs," he said.

He credits his leadership acumen to his father and to his long experience in corporate management, yet he notes that not all productive scientists and engineers enjoy management and should not covet it. They should find an environment that recognizes a broad spectrum of contributions.

Prior to becoming the executive director of OSA, Liz Rogan served as chief operating officer and chief financial officer of the organization. She had this to say, "Leading an organization really takes a combination of things to be successful, including business-savvy, big-picture thinking, and the ability to inspire and drive new developments. Both Rogan and Arthurs cited the customer service of the organizations as a driving force in their success.

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Patented genes impede cancer diagnosis

What if you requested a genetic test to check your risk of having a hereditary form of cancer but were turned down by the company that has a monopoly on that test?

Genae Girard of Austin, Texas, faced that dilemma when she was diagnosed with breast cancer in 2006. Concerned that her genes might put her at risk for ovarian cancer as well, she underwent genetic testing, which turned up positive. Before making the irreversible decision to have her ovaries removed, however, Girard decided to seek a second opinion.

At that point, the situation became complicated. Myriad Genetics, a Salt Lake City biopharmaceutical company, owns the patents not only for the *BRCA1* and *BRCA2* genes – biomarkers for breast and ovarian cancer – but also for the related genetic testing. The company charges $3,000 for the testing and does not accept all types of insurance. In seeking a second opinion, Girard encountered a huge financial hurdle.

Fighting back

In alliance with other outraged cancer patients, genetic researchers and various medical organizations, including professional societies representing more than 100,000 pathologists, Girard filed a Section 1983 action against Myriad as well as the directors of the University of Utah Research Foundation and the US Patent and Trademark Office.

The lawsuit, which was organized by the American Civil Liberties Union and filed in federal court, alleges a breach of constitutional rights, patent law and lawful medical practice. The litigants claim that Myriad's patents related to the *BRCA* gene violate the First Amendment and Article I, section 8, clause 8 of the Constitution: "Because human genes are products of nature, laws of nature and/or natural phenomena, and abstract ideas or basic human knowledge or thought, the challenged claims are invalid under Article I, section 8 of the Constitution and 35 U.S.C. Section 101."

Myriad maintains that it isolated and purified the DNA, creating something that does not exist in nature. Yet, argue its opponents, the patented product still corresponds to an actual gene sequence; the patented method simply removes genes from their natural location – the body and cell that contain them – but the end result is still the product of a natural phenomenon.

Genes have been patented for decades. Today more than 50,000 patents related to DNA have been issued by the US Patent and Trademark Office and, according to the DNA Patent Database, more than 70,000 additional applications have been filed. Twenty percent of the human genome is represented in current patents, which means that public access to thousands of individual genes is at issue. From the beginning, controversy has swirled around the patenting of genes, but this lawsuit is considered a landmark case.

Uncertain outcomes

Genetic testing is a complex procedure that can yield uncertain results. Many feel that, if testing were more accessible and affordable for patients, they would be more likely to seek second opinions, and diagnoses would become more accurate. Moreover, making genetic material more available would advance research and medicine more quickly. A company's DNA patent can make it illegal for another business to perform testing on the same genes.

A panel of government experts has looked into this litigation and determined that no critical problems related to research or medical care are necessarily the outcome of gene patents. Therefore, whether the case will favor the plaintiffs is still unknown; if it is successful, however, the decision could accelerate the generation of new treatments.

Amanda D. Francoeur
amanda.francoeur@laurin.com

Aperio Awarded CBIR Patent

Aperio Technologies Inc. of Vista, Calif., a digital pathology provider for the health care and life sciences industry, has announced that it has been issued patent No. 7,502,519 from the US Patent and Trademark Office, covering its systems and methods for image pattern recognition using vector quantization (VQ). It is the company's second patent on the use of VQ for these applications.

Izon Patents Resizable Nanopores

Izon Science Ltd. of Christchurch, New Zealand, presented its patented resizable nanopore technology for rapid nanoparticle detection and analysis at Biodetection Technologies 2009 in Baltimore last month. The nanopores can be adjusted dynamically in real time to enable optimization of the aperture size for the particle set of interest. The technology is used in virology applications.

Brookhaven Applies for Nonprovisional Patent

A physicist at the US Department of Energy's Brookhaven National Laboratory in Upton, N.Y., has developed a simpler, less-expensive gantry design for delivering tumor-killing particle beams. The company that manages the lab for the energy department, Brookhaven Science Associates, has applied for a US nonprovisional patent on the design, which is now available for licensing and commercial development.

Mobius Receives Power Control Patent

US Patent No. 7,529,281, titled "Light source with precisely controlled wavelength-converted average power," has been awarded to Mobius Photonics Inc. of Santa Clara, Calif., a commercial fiber-based laser source provider for the visible and ultraviolet regions. The innovation protected by the patent enables the company to control wavelength-converted pulse energy and average power, achieved through control of the wavelength conversion efficiency. It is useful in fiber master oscillator power amplifier systems where the IR fundamental wavelength is converted to green or UV wavelengths.

SOLID-STATE LASER

Cobolt AB has announced that its Cobolt Fandango 515-nm diode-pumped solid-state laser is now available with up to 100 mW of continuous-wave output power. Suitable for use in confocal microscopy, high-speed plate reading and single-molecule analysis, it also is an alternative to bulky argon gas lasers. Built into a hermetically sealed package measuring 50 × 50 mm, it uses proprietary HTCure technology for robustness. The single-longitudinal-mode laser produces noise of <0.3% rms and delivers a spectral linewidth of <30 MHz and beam quality of M^2 <1.1. It can withstand 60-g mechanical shocks and can be exposed to temperatures >100 °C.
Cobolt
info@cobolt.se

LARGE-FORMAT LENSES

Custom large-format lenses are available from Resolve Optics Ltd. for use in current and future megapixel line- and area-scan sensors and cameras. They provide high center-to-edge resolution, low distortion and application-specific *f* number performance. The diffraction-limited types have high contrast, a large depth of field and a wide field of view for close-up imaging. The custom lenses are suitable for use in scientific and machine vision applications.
Resolve Optics
sales@resolveoptics.com

OPTICAL ENCODER SYSTEM

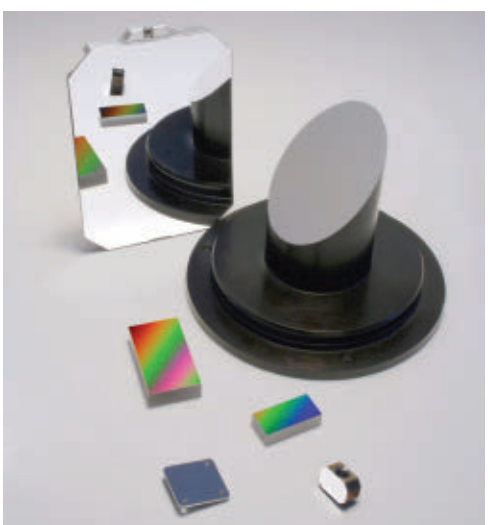
The Resolute optical encoder system unveiled by Renishaw Inc. produces 27-bit resolution at 36,000 rpm and 1-nm resolution at up to 100 m/s for linear and angle encoding applications. It uses a single-track optical scale and acquires absolute position immediately upon switch-on, eliminating the need for reference returns. Its optics read a fine-pitch 30-µm scale, resulting in low noise levels with jitter of <10 nm rms. The single track combines the absolute position and embedded phase information into a single code, eliminating the de-phasing problems associated with dual-track scales. The IP64-sealed read head enables wipe-clean recovery for reliability. Its temperature sensor measures heat buildup and signals an alarm if the temperature rises above 80 °C.
Renishaw
usa@renishaw.com

REPLICATION PROCESS

Opco Laboratory Inc.'s Replication Process reproduces complex optics with high quality and repeatability. It transfers the profile of a precision optical surface from a master and creates a duplicate on a range of substrates, including glass, silicon carbide and ceramic, and metals such as beryllium, aluminum, titanium and stainless steel. The replicated optics are less expensive and often lighter than the master. The process produces a variety of ruled and holographic diffraction gratings, reflective and transmission holographic optical elements, dual-wavelength gratings, and plano and conic sections. Surface accuracy and radii are certified to customer specifications using an interferometric measuring system or a profilometer.
Opco Laboratory
info@opcolab.com

LED LAMP

Cree Inc. has introduced the LRP-38 LED lamp, a narrow-beam PAR38 spotlight designed for use in display and retail installations. Based on proprietary TrueWhite technology, the lamp generates a color rendering index of 92 at a color temperature of 2700 K. The tightly focused beam delivers center beam candlepower of 4000 with a 20° beam angle. The UL-listed light replaces 50- to 90-W halogen PAR38 bulbs in many applications. Input power is 12 W, resulting in minimum efficacy of 42 lm/W. Lamp life is up to 50,000 h.
Cree
info@cree.com



LED FIBER OPTIC ILLUMINATOR

The LED fiber optic illuminator released by PerkinElmer Inc. comprises high-intensity and high-power white LEDs, patent-pending optics that precisely couple light into 3- to 10-mm fiber optic bundles, a heat sink and fan, linear light intensity control and an AC power supply. An energy-efficient and maintenance-free alternative to halogen and metal-halide fiber optic illuminators, it is suitable for use in medical endoscopy, microscopy and machine vision applications. The LED light does not change over time or when the light is dimmed. Typical output is 390 lm, typical correlated color temperature is 5500 K, and input power is 80 W.
PerkinElmer
productinfo@perkinelmer.com

VISION SYSTEM

Cognex Corp. has expanded its In-Sight 5000 series with the In-Sight 5604 line-scan vision system, which operates at 22 fps and builds 2-megapixel-resolution images using a 1024-pixel-wide imager and up to 2048 lines. The 14 × 14-µm pixel size results in good light sensitivity at microsecond exposure rates. The 1-GHz digital signal processor performs rapid vision analysis, and the built-in Ethernet interface connects to the automation control system via the suite of Cognex Connect factory floor protocols. The camera accepts standard C- and CS-mount lenses, enables 360° product inspection and is supplied with In-Sight Explorer software.
Cognex
john.lewis@cognex.com

PROBE KIT

Agilent Technologies Inc. has introduced a probe kit for making differential time-domain reflectometry (TDR) and time-domain transition (TDT) measurements. The N1021B is an 18-GHz kit that connects printed circuit boards to the 54754A differential TDR/TDT module in the 86100C Infiniium DCA-J wideband oscilloscope mainframe. The optional 86100C-202 impedance and S-parameter software characterizes differential impedances in the time and frequency domains. The probe's thumbwheel enables one-hand pitch adjustments. Hardened tips ensure many touchdowns, and the chamfered design makes good contact, even on small pads or traces.
Agilent Technologies
janet_smith@agilent.com

CO_2 LASER

The firestar v30 manufactured by Synrad Inc. is a 30-W CO_2 laser built for use in rugged industrial environments. The air-cooled device is suitable for OEM marking and engraving systems. Its resonator technology produces a circular beam with typical M^2 quality of <1.1 in both the near and far fields, and it features a small-diameter bore and high gas fill pressure for rise/fall times of 80 to 90 µs. Long-term power stability is better than ±3%. The laser can be operated from 0 to 100% duty cycle, with power adjusted via a pulse width modulation control.
Synrad
synrad@synrad.com

CMOS CAMERAS

The Falcon 4M60 and 4M30 color CMOS cameras with global shutter have been launched by Dalsa. Operating at 60 and 30 fps, respectively, they deliver 4-megapixel resolution and are suitable for electronics and semiconductor inspection. Features include individual color gain and offset, white balancing, vertical windowing, flat-field correction, exposure control, gain and offset adjustment, and good antiblooming. The

RoHS-compliant cameras are fully programmable with a base or medium Camera Link interface that enables 10-m data transmission. Dynamic range is 56 dB, operating temperature is from 0 to 50 °C, and power dissipation is <10 W.
Dalsa
sales.americas@dalsa.com

SCANNING LENSES

Edmund Optics Inc. has announced an expanded line of *f*-Theta telecentric scanning lenses that ensure a linear relationship between the input scan angle and the focal position on a flat plane. The 355-nm fused silica lenses have a short focal length, providing users with a small spot size to improve system resolution. The company says that fused silica provides better optical transmission than N-BK7 glass, especially in the UV and near-UV wavelengths. Applications include laser marking, 3-D prototyping, and semiconductor and solar panel processing.
Edmund Optics
medmund@edmundoptics.com

IMAGING SYSTEM

The CV-5000 series, manufactured by Keyence Corp. of America for use in machine vision applications, has a 5-megapixel camera that transfers 2432 × 2050-pixel images in 61.2 ms. Up to four cameras can transfer images simultaneously for high-definition inspection of up to 20 million pixels. The system also enables 14 other camera types, all in color and monochrome, to be used in this simultaneous imaging process. Up to four lighting control units can be attached, each with two lighting terminals, enabling the system to automatically dim and strobe up to eight lights at the same time. Built-in statistical functions allow the user to view inspection results in real time.
Keyence
keyencepr@keyence.com

SPF MEASUREMENT

To support its UV-2000S transmittance analyzer for quality assurance and UVA protection factor analysis in the development and testing of sunscreen, Labsphere Inc. has released version 1.2 of the software. The analyzer and software perform in vitro, Boot Star, COLIPA, FDA and user-defined sun protection factor (SPF) measure-

ments. The software carries out reference channel saturation checks of the sample if the substrate or plate is highly absorbing. It is available on a subscription basis so that users will be updated as new standards and regulations are added.
Labsphere
labsphere@labsphere.com

VIBRATION ISOLATORS

Newport Corp.'s S-2000 Stabilizer series pneumatic vibration isolators use a proprietary and patented self-centering pendulum design, a laminar flow damping system and precision autoleveling valves. Features include enhanced leveling indicators, recessed lifting channels and a low magnetic permeability design. Load capacity is 2000 lb. The devices are suitable for isolating optical tables, large inspection equipment, heavy machinery and large-area subfloors. Six heights, ranging from 16 to 28 in., are available. Vertical resonant frequency is 1 Hz, and vertical isolation efficiency is 98% at 10 Hz. Horizontal isolation begins at 2.5 Hz and reaches 95% efficiency at 10 Hz.
Newport
newproduct@newport.com

WAVELENGTH PHOTODIODES

The ODD-470W selective-wavelength photodiodes released by Opto Diode Corp. have a spectral bandwidth of 100 nm and operate between 380 and 540 nm, with peak sensitivity response at 470 nm. They produce low dark current, have no optical filters and are suitable for use in color sensors, fluorescence detection and medical diagnostic applications. The hermetically sealed standard TO-46 can facilitates installation into any existing or new system. Storage and operating temperatures range from −30 to 85 °C, and lead soldering temperature is 260 °C.
Opto Diode
sales@optodiode.com

WHITE LED

Osram Opto Semiconductors Inc.'s Advanced Power TopLED Plus is an optimized white LED designed for architectural and retail lighting and for applications that require bright light in a limited space. Luminous efficiency is up to 90 lm/W and luminous flux, up to 27 lm (100 mA/5700 K). Available in various white tones ranging from 2700 to 6500 K, the LED has a typical beam angle of 140° and homogeneous white color from every viewing angle. It is specified for a connected load of up to 0.5 W. Heat

is dissipated via gull-wing connections to the lead frame and the printed circuit board.
Osram Opto Semiconductors
support@osram-os.com

PIEZO STAGES

The PI nano XY and PI nano XYZ piezo scanning stages launched by PI (Physik Instrumente) LP are optimized for integration into high-resolution microscopes. They feature a 20-mm profile, a large aperture, a piezoresistive integrated sensor and travel ranges of up to 200 × 200 × 200 µm with subnanometer closed-loop resolution. Typical linearity is ±0.1%, maximum payload is 500 g, typical repeatability is <5 nm, and operating temperature is from 20 to 30 °C. Long lifetime is ensured by the integrated ceramic-encapsulated PICMA piezo actuators. Applications include 3-D imaging, laser technology, mask/wafer positioning and interferometry.
PI
photonics@pi-usa.us

SOLAR TESTING

Atlas Material Testing Technology has introduced technology for ultra-accelerated solar exposure testing. The outdoor testing device provides approximately 63 years of south Florida UV-radiation exposure in one year, tracking the sun while concentrating reflected sunlight on test specimens mounted in a target area. The technology exposes various types of materials to ultrahigh-UV irradiances, maintains high fidelity to the natural solar UV spectrum and maintains specimens at acceptable exposure temperatures. Using multiple focusing mirrors arranged on the curve of a 10-m sphere concentrates the UV energy on a target area ~10 × 10 cm.
Atlas Material Testing Technology
info@atlas-mts.com

LC CONNECTOR

Slimpack, reconfigurable LC connectors released by Alliance Fiber Optic Products Inc. for small-form-factor applications, enables users to reconfigure the channels in the field by releasing the rear cover and switching the ferrules, and to change polarity without having to re-terminate. The devices are available in single- and multimode versions, with rear bodies and boots of 2-, 2.4- or 3-mm cable jackets. Applications

include local area networks, fast Ethernet, optical transport and optical access networks.
Alliance Fiber Optic Products
sales@afop.com

THERMAL CAMERA CORE

Flir Systems Inc. has announced the Tau uncooled long-wave thermal camera core with a 25-µm focal plane array detector and proprietary digital detail enhancement image processing algorithms. It is suitable for use in handheld thermal cameras, unmanned vehicle vision systems, firefighting imagers and thermal weapon sights. The family of cameras comprises three configurations and seven available lens options. Weighing 70 g, the cameras consume <1 W. The graphical user interface and software development kit enable users to control a variety of camera functions, to select an analog video format and to configure a digital interface.
Flir Systems
sales@flir.com

OPTICS MEASUREMENT

IB/E Optics has released the OptiBench tool for measuring aberrations in optics, such as radial and asymmetrical distortions, telecentricity errors, field curvature, illumination density, chromatic aberrations and modulation transfer function. The quality of the imaging optics can be determined and recorded automatically, and online corrections to fine-tune a lens can be made. Paraxial data such as focal length and magnification can be detected, as can the location of the optical axis, and the autofocus function enables reproducible statements on working and imaging distances of the optics under test.
IB/E Optics
ibe@ibe-optics.com

NO-POLISH CONNECTORS

The No Polish LC connector for multi- and single-mode fiber applications and the No Polish Connector LC/APC for single-mode fiber applications have been introduced by the 3M Communication Markets Div. Using a one-piece preassembled design, they both enable fast on-site installation of 250- and 900-µm terminations. The LC model is tested for fiber-to-the-premises and premises applications for indoor and outdoor locations and is available in SM, in 62.5 and 50 µm, and in 50-µm laser optimized multimode fiber for 10-Gb applications. The LC/APC version is available with a standard flat-splice configuration or with a keyed angle splice for backreflection of less than −60 dB.
3M Communication
cahornharris1@mmm.com

MEASUREMENT HEAD

The OMH-67452B is an optical power and wavelength measurement head for ILX Lightwave Corp.'s OMM-6810B optical power and wavelength meter. It is water-cooled to provide continuous measurement up to 30 W from high-power laser diodes, including single emitters and fiber lasers. The calibrated head provides NIST-traceable power accuracy of ±5% and wavelength accuracy of ±1 nm from 800 to

1100 nm. A fiber exit port connects to an optical spectrum analyzer or other instrument to make spectral measurements. The device uses integrating spheres and photodetector technology to provide instantaneous measurements.
ILX Lightwave
sales@ilxlightwave.com

LASER SOFTWARE

Cincinnati Inc.'s Scheduler software identifies excess capacity on stand-alone laser cutting systems and automatically nests parts for best materials usage and job turnaround. It uses a database of all active parts files and prioritizes nesting by part-due date. The software takes user-entered information, including order requirements, part numbers, due dates and quantities, and generates a job schedule in calendar format. It uses a color-coding system to group jobs with similar lens/nozzle setups to facilitate unattended operation.
Cincinnati
info@e-ci.com

DPSS YAG LASER

Lee Laser Inc. has introduced an 800-W continuous-wave diode-pumped solid-state (DPSS) Nd:YAG laser that delivers Q-switched performance with >600-W average output power at a 10-kHz pulse rate. Pulse width is <70 ns, and pulse instability is <8% peak to peak. Operating at 1064 nm, the laser is suitable for use in deep marking and engraving, cutting of hard materials such as tungsten carbide and polycrystalline diamond, flat panel display manufacture and laser patterning for LCD manufacture. Power consumption is 10 kW.
Lee Laser
salesdept@leelaser.com

SPECTROGRAPHS

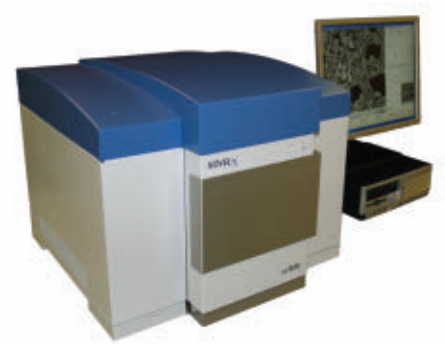
Specim, Spectral Imaging Ltd., has expanded its ImSpector Enhanced series imaging spectrographs with Raman versions that combine high light throughput, distortion-free performance and a polarization-free optical design. They are available for wavelengths ranging from 500 to 1000 nm for use with various types of excitation lasers. The small-footprint devices can be integrated with an area monochrome camera to form a spectral imaging system that captures line images of a target and that disperses each line image pixel into the spectrum.
Specim
ana.aranda@specim.fi

LASER MARKERS

The LMF series fiber laser markers manufactured by Miyachi Unitek Corp. mark text, bar codes and graphics "on the fly" on continuous production lines. Available are 10- and 20-W versions that produce Q-switched frequencies of 2 to 500 kHz and that feature a PC, a touch

screen, stand-alone or pendant operation, an intuitive and customizable marking interface, integrated rotary and X-Y-Z motion, LAN connectivity, and an in-line camera option to view the mark and provide a nonintrusive code verification or read capability. The markers are compact, air-cooled and robust.
Miyachi Unitek
info@muc.miyachi.com

FIELD-EMISSION SEM



Novelx Inc. has introduced mySEM, a compact field emission scanning electron microscope (SEM) suitable for imaging and characterizing nanoscale objects and materials. The instrument's compact design is optimized for low-voltage operation and delivers <10-nm resolution at 1 kV. The microscope provides up to 65,000× magnification and does not require coating of nonconductive samples. It is suitable for imaging of sensitive samples, biomaterials and thin films. Users can select an operating voltage between 0.5 and 2 kV. The multichannel detector detects both secondary and backscatter electrons to provide information about samples.
Novelx
info@novelx.com

POWER SUPPLIES

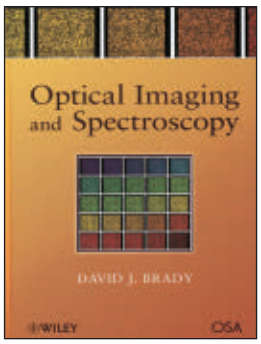
UltraVolt Inc. is offering several families of standard-product, microsize and micropower high-voltage power supplies. The miniature and lightweight models offer low ripple, tight line and load regulation, programmable output and output current-limit protection. Some models perform voltage monitoring to 10 ppm. Applications include avalanche photodiodes, photomultiplier tubes, microchannel plates, image intensifiers, electrostatic chucks, scanning electron microscopes and mass spectrometers. Output voltage ranges from 0 to 100 V through 0 to 8 kV at 100 mW to 6 W of output power, with output currents from 30 μA to 6 mA.
UltraVolt
csd@ultravolt.com

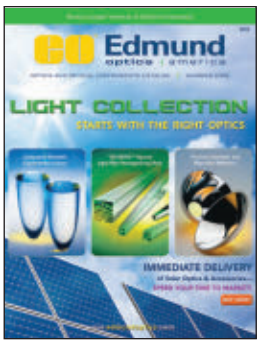
HIGH-TRANSMISSION FILTERS

Sperian Eye & Face Protection Inc. is offering a high-transmission diode and YAG filter for its laser safety eyewear. Filter 162 has an outer diameter >6 from 800 to 820 nm and from 920 to 1064 nm, with visible light transmittance of 56%. It is available in the company's Milan and GPT XC laser eyewear, both of which have antifog and antiscratch coatings. The GPT XC features custom adjustments and patented multimaterial technology for added comfort. The filter also is available in the Encore over-the-glass spectacle for people who wear prescription eyewear.
Sperian
laserinfo@sperianprotection.com

VCSEL ARRAY

Princeton Optronics Inc. has released 40-W continuous-wave 808-nm (PCW-CA1-40-W0808) and 976-nm (PCW-CA1-40-W0976) backreflection-immune vertical-cavity surface-emitting lasers (VCSELs). The devices comprise a 2-D planar VCSEL array mounted on a high-thermal-conductivity submount with a copper base. They have a spectral width of ~0.8 nm, a thermally stable emission wavelength (0.06 nm/K) and low beam divergence with a numerical aperture of ~0.14. Not subject to catastrophic optical damage, they also can be operated in quasi-continuous-wave and short-pulsed (<20 ns) modes. They are suitable for use in solid-state laser pumping and medical applications.
Princeton Optronics
sales@princetonoptronics.com





OPTICS WEB SITE

JML Optical Industries Inc. has launched an e-commerce Web site to provide information on its optical manufacturing and coating capabilities. Visitors to the portal can find technical information on more than 4000 stock optical products and order them online. They also can make online requests for custom optical systems and components as well as for design and coating services. The site features a lens finder function, a downloadable test plate list and an enhanced optical calculator.
JML Optical Industries
www.jmloptical.com

SOLAR OPTICS

The *Light Collection* catalog from optical components provider Edmund Optics Inc. features 12 product lines that address the production, inspection and deployment of photovoltaic solutions. The company's collection of solar optics includes compound parabolic concentrators, precision ellipsoidal and parabolic reflectors, and Techspec tapered light pipe homogenizing rods. The company also offers sensors and cameras, and lenses suitable for solar cell and panel manufacturing inspection.
Edmund Optics
sales@edmundoptics.com

SENSOR SYSTEM DESIGN

Designed to serve as a reference for optical sensor system design, the 528-page volume *Optical Imaging and Spectroscopy* covers areas such as coded aperture and tomographic imaging; strategies for coherence measurement in imaging system design; geometric, wave and statistical models of optical fields; the basic function of modern optical detectors and focal plane arrays; and sampling and transformations in optical systems, including wavelets and generalized sampling techniques essential to digital system analysis. David J. Brady; John Wiley & Sons Inc., Hoboken, N.J., Optical Society of America, Washington, 2009; $110.
John Wiley & Sons
consumers@wiley.com

DC-AC INVERTERS

A manufacturer of DC-AC inverters for powering cold cathode fluorescent lamp-backlit LCDs, Endicott Research Group (ERG) Inc. has introduced its online LCD Module-to-ERG Part Number Cross-Reference Guide. Available on the company's Web site, the tool is designed to help users match OEM LCD panels with inverters to provide optimal cold cathode fluorescent lamp performance. Users can search by ERG inverter part number or by the panel manufacturer's model number.
Endicott Research Group
www.ergpower.com

LASER OPTICS

Laser Research Optics, a division of Meller Optics Inc., has updated its Web site. Featuring CO_2 laser optics for original equipment manufacturers and users of medical and industrial laser systems, the portal presents windows, metal mirrors, focusing lenses, beamsplitters and beam combiners, total and partial reflectors, and zero phase shift and partial retardation reflectors. It offers optics for lasers from 25 W to several kilowatts and includes product sections based on manufacturers' model and part numbers, with cross-referencing to Laser Research Optics.
Laser Research Optics
www.laserresearchoptics.net

SOLAR TECH SITE

Schott Solar has launched a redesigned Web site to showcase its solar technology products and their applications in a more user-friendly format. The informational and solution-oriented site has been optimized to more clearly present the company's capabilities. The home page features a 360° image of the possible applications of the company's technology, among them, photovoltaic rooftop installations and large utility-scale power production plants.
Schott Solar
www.us.schottsolar.com

PHOTONICS LETTERS

The Photonics Society of Poland has introduced an electronic journal titled *Photonics Letters of Poland*, which is published in cooperation with SPIE. Launched on March 31, the quarterly publication publishes peer-reviewed letters on optics, optoelectronics and photonics, focusing on aspects such as fundamental and applied research, physics, materials, components, devices, circuits, systems, design, construction, manufacturing and metrology.
Photonics Society of Poland
www.photonics.pl

VIDEO GALLERY

A supplier of high-speed and high-resolution imaging systems, Specialised Imaging Ltd. has expanded its online video gallery to demonstrate the growing range of applications for its products. Video files from customers around the world show ultrahigh-speed applications such as detonics, crack propagation, aeroballistic studies, plasma injection, sports science, automotive lean-burn technology development and space probe flight characterization.
Specialised Imaging
www.specialised-imaging.com

LASER SAFETY

The Laser Institute of America has released the 2009 version of its DVD *Mastering Light – An Introduction to Laser Safety and Hazards*. The upgraded resource is designed for laser safety officers who are responsible for training new employees and keeping their teams updated on current safety issues and practices. With a playing time of about 20 minutes, it fulfills the ANSI Z136.1 *Safe Use of Lasers* and the Occupational Safety and Health Administration's training requirements for employees working with or around Class 3B or 4 lasers and laser systems.
LIA
pubs@laserinstitute.org

EXCIMER LASERS

A 52-page catalog from Coherent Inc. presents the company's excimer lasers and related products. It provides specifications, selection guides and an application matrix for more than 40 excimer laser products, including the ExciStar XS, Xantos XS and BraggStar Industrial lines. The lasers cover the range from 157 to 351 nm, with pulse energies from 1 mJ to more than 1 J and have applications in marking, materials processing, surface treatment, medical procedures, and measurement and metrology. The VarioLas UV materials processing systems and GeoLasPro UV optical systems also are detailed.
Coherent
ralph.delmdahl@coherent.com

MOTION SYSTEMS

Steinmeyer Inc. has released a 100-page catalog on its precision linear and rotary motion systems, which are manufactured by its Feinmess Dresden GmbH division. The publication is divided into six product sections, detailing plug-and-play systems; motion controllers; and linear, micro, rotary, goniometer, lifting and compact X-Y stages. It features an expanded applications section, with examples of how the products are used in markets such as the medical, scientific and semiconductor sectors.
Steinmeyer
jskaltsas@steinmeyer.com

HAPPENINGS

PAPERS

RadTech UV & EB 2010 (May 24-26) Baltimore
Deadline: abstracts, July 31
RadTech, the Association for UV and EB Curing Technology, invites papers for the RadTech UV & EB Technology Expo and Conference 2010, which will cover developments in the UV and electron beam (EB) curing industry. Applications to be considered include photovoltaics, and optics and optical fibers. Contact Mickey Fortune, RadTech, +1 (240) 643-0517; mickey@radtech.org; www.radtech2010.com.

Comsol Conference 2009 Boston (Oct. 8-10) Newton, Mass.
Deadline: abstracts, August 7
Comsol Inc. encourages submissions for its fifth annual North American conference on multiphysics modeling and simulation. Technical papers are sought on the innovative application of Comsol Multiphysics software in areas such as optics, photonics, quantum mechanics, and bioscience and bioengineering. Contact Yeswanth Rao, Comsol Inc., + 1 (781) 273-3322; yeswanth.rao@comsol.com; www.comsol.com.

Pittcon 2010 (February 28-March 5) Orlando, Fla.
Deadline: abstracts, August 14
Abstracts for oral or poster presentation are encouraged for Pittcon 2010 Conference & Expo, which focuses on scientific innovations, novel applications and improved techniques from representatives in the fields of analytical chemistry and the life sciences. Symposia will cover areas such as sensors, nanotechnology and biospectroscopy. Contact The Pittsburgh Conference, +1 (412) 825-3220; program@pittcon.org; www.pittcon.org.

AUGUST

SPIE Optics and Photonics 2009 (Aug. 2-6) San Diego. Includes the conferences Nano-Science + Engineering; Solar Energy + Technology; Photonic Devices + Applications; and Optical Engineering + Applications. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

NIWeek 09: Worldwide Graphical System Design Conference (Aug. 4-6) Austin, Texas. Contact National Instruments, +1 (888) 564-9335; niweek@ni.com; www.ni.com.

POEM 2009: Photonics and Optoelectronics Meetings (Aug. 8-10) Wuhan, China. Contact Xiaochun Xiao, Wuhan National Laboratory for Optoelectronics, +86 27 8779 2227; poem@mail.hust.edu.cn; poem.meeting163.com.

CALCON Technical Conference: Characterization and Radiometric Calibration for Remote Sensing (Aug. 24-27) Logan, Utah. Contact Stephanie Halton, Utah State University, +1 (435) 797-4656; stephanie.halton@usurf.usu.edu; www.spacedynamics.org.

CLEO/Pacific Rim 2009: Eighth Pacific Rim Conference on Lasers and Electro-Optics (Aug. 30-Sept. 3) Shanghai, China. Contact Ronghui Qu, Shanghai Institute of Optics and Fine Mechanics, CAS, +86 21 6991 8005; cleopr2009@siom.ac.cn; www.siom.cn/cleo.

SPIE Europe Security + Defence and SPIE Europe Remote Sensing (Aug. 31-Sept. 3) Berlin. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

SEPTEMBER

China International Optoelectronic Exposition 2009 (Sept. 6-9) Shenzhen, China. Contact Nancy He, CIOE, +86 755 8629 0819; nancy@cioe.cn; www.opto-china.com.

InterOpto'09 (Sept. 9-11) Chiba, Japan. Contact InterOpto Secretariat, Optoelectronic Industry & Technology Development Association (OITDA), +81 3 5225 6431; interopt@oitda.or.jp; www.oitda.or.jp.

SPRC 2009 Symposium (Sept. 14-16) Stanford, Calif. Contact Stanford Photonics Research Center, +1 (650) 723-5627; photonics@stanford.edu;www.photonics.stanford.edu.

Eurodisplay 2009 (Sept. 14-17) Rome. 23rd International Display Research Conference. Contact J. Kimmel, Nokia Research Center, +358 7180 35484; jyrki.kimmel@nokia.com; www.eurodisplay.org.

SPIE Photomask (Sept. 14-17) Monterey, Calif. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

ECOC 2009 (Sept. 20-24) Vienna, Austria. 35th European Conference and Exhibition on Optical Communication. Contact Hatice Altintas, VDE Conference Services, +49 69 63 08 477; ecoc2009@ove.at; www.ecoc2009.at.

SPIE Laser Damage (Sept. 21-23) Boulder, Colo. Contact SPIE, +1 (360) 676-3290; customerservice@spie.org; www.spie.org.

ISOT 2009: International Symposium on Optomechatronic Technologies (Sept. 21-23) Istanbul, Turkey. Contact Bogaziçi University, +212 359 54 00; isot09@boun.edu.tr; www.optomechatronics.org.

IRMMW-THz 2009: 34th International Conference on Infrared, Millimeter and Terahertz Waves (Sept. 21-25) Busan, South Korea. Contact irmmwthz2009@gmail.com; www.irmmw-thz2009.org.

Diskcon USA 2009 (Sept. 23-24) Santa Clara, Calif. Contact Trudy Gressley, IDEMA, International Disk Drive Equipment and Materials Association, +1 (408) 719-0082; tgressley@idema.org; www.idema.org.

2009 FTTH Conference & Expo (Sept. 27-Oct. 1) Houston. Contact Legend Conference Planning, +1 (613) 226-9988, Ext. 1; infoftth@legendconferences.com; www.ftthconference.com.

OLEDs World Summit 2009 (Sept. 29-Oct. 1) San Francisco. Contact Brian Santos, IntertechPira, +1 (207) 781-9618; brian.santos@pira-nternational.com; www.intertechpira.com.

OCTOBER

ISOM'09: International Symposium on Optical Memory (Oct. 4-8) Nagasaki, Japan. Contact Secretariat, secretary@isom.jp; www.isom.jp.

OFS-20: 20th International Conference on Optical Fiber Sensors 2009 (Oct. 5-9) Edinburgh, UK. Contact Jenny Bremner, OFS-20 Secretariat, Institute of Physics, +44 20 7470 4908; ofs20@iop.org; www.ofs20.org.

OPTO 2009 (Oct. 6-8) Paris. Contact Nadège Venet, GL Events, +33 1 44 31 82 57; nadege.venet@gl-events.com; www.forum4s.com.

SEMICON Europa 2009 (Oct. 6-8) Dresden, Germany. Contact Kelli Torres, SEMI Global Headquarters, +1 (408) 943-6979; ktorres@semi.org; www.semiconeuropa.org.

Frontiers in Optics 2009/ Laser Science XXV (Oct. 11-15) San Jose, Calif. Collocated with the Fall OSA Optics & Photonics Congress, which includes the meetings Advances in Optical Materials (AIOM); Adaptive Optics: Methods, Analysis and Applications (AO); Computational Optical Sensing and Imaging (COSI); Femtosecond Laser Microfabrication (LM); and Signal Recovery and Synthesis (SRS). Contact The Optical Society, +1 (202) 416-1907; custserv@osa.org; www.frontiersinoptics.com.

Image Sensors 2009 (Oct. 12-14) San Diego. Contact Derek Mitchell, IntertechPira, +1 (207) 781-9615; derek.mitchell@pira-international.com; www.intertechpira.com.

Photonex 2009 (Oct. 14-15) Coventry, UK. Contact Laurence Devereux, Xmark Media Ltd., +44 1372 750 555; ld@photonex.org; www.photonex.org.

LEDs 2009 (Oct. 20-22) San Diego. Contact Brian Santos, IntertechPira, +1 (207) 781-9618; brian.santos@pira-international.com.

ADVERTISER INDEX a

a
4D Technology Corporation....22
Ade Inc....80
Applied Scientific Instrumentation....77

b
Bristol Instruments Inc. 76

c
Cargille Laboratories....80
Coherent Inc. 47
Cooke Corporation, The....CV2
CVI Melles Griot 17, 19

d
Deposition Sciences Inc. 63
Directed Energy, Inc. 69

e
Edmund Optics....CV4
Electro-Optics Technology, Inc. 74
Esco Products, Inc. 40
Expo Indus 64

h
Hamamatsu 29
HVM Technology 38

i
Image Science Ltd. 30
Intertech USA 41
ISP Optics....65

l
Lake Shore Cryotronics, Inc. 76
Lambda Research Corporation....24
Lee Laser, Inc. 8
Leybold Optics GmbH....10
Lightmachinery, Inc. 50, 79
Lightworks Optics Inc. 37

m
Mad City Labs 80
Master Bond, Inc....75
Meadowlark Optics....12
Media Cybernetics 45

n
National Reconnaissance Office....11
nm Laser Products, Inc. 78
Northrop Grumman 25

o
Optical Research Associates 15

p
Picoquant GmbH 14
Power Technology, Inc. CV3
Precision Photonics....13
Prior Scientific Inc. 48

r
Research Electro-Optics 21
Rocky Mountain Instrument 23
Rolyn Optics Co. 34
Ross Optical Industries 6

s
Sacher Lasertechnik GmbH....77
SEMI....33
Sensors Unlimited, Inc.
Part of Goodrich Corporation....7
Stanford Research
Systems, Inc. 3, 9
StellarNet Inc. 71
Sutter Instrument 74

t
Tec5....32
Tohkai Sangyo Co., Ltd. 79
Toptica Photonics Inc. 31, 39

v
Vortran Laser
Technology, Inc. 75

w
WALA Laser-2009....62

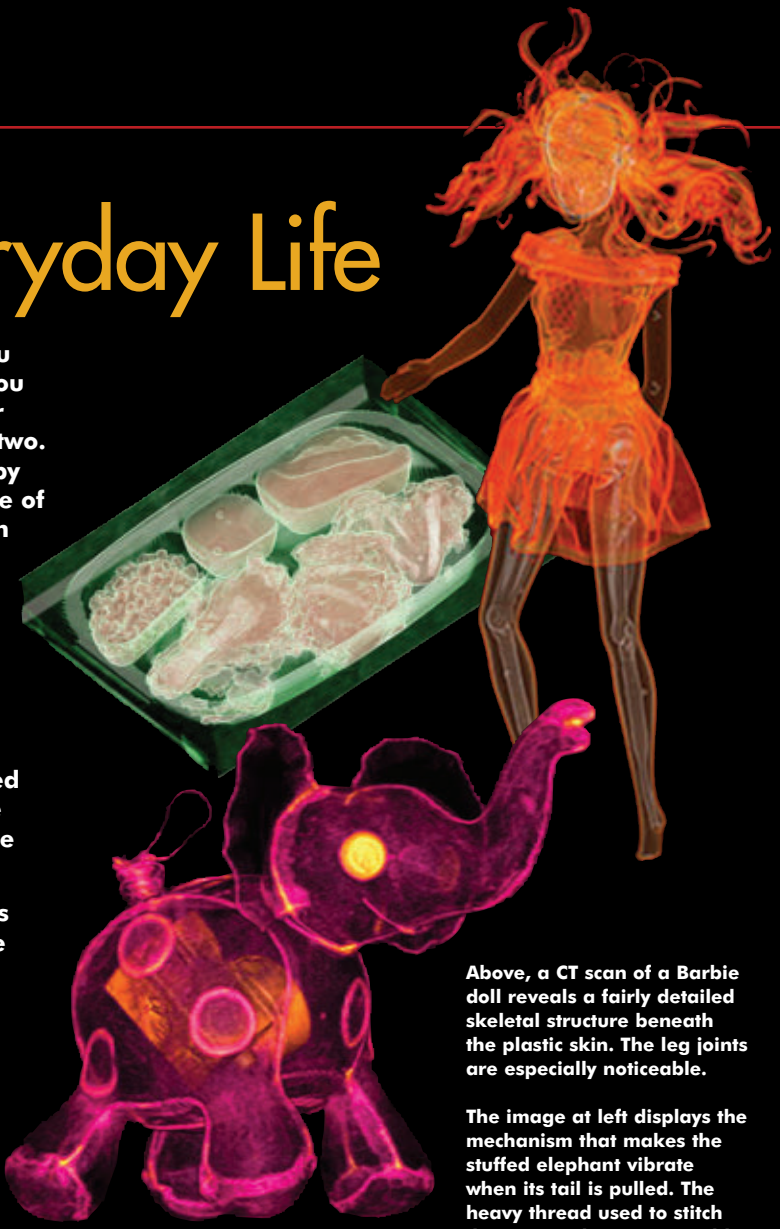
A Slice of Everyday Life

How would you balance your interests if you were an artist-turned-medical-student? You could forego your first love to pursue your new dream, or you could compartmentalize the two. However, you could also choose the path taken by Satre Stuelke of New York and combine your love of art with medical imaging technology, creating an innovative way of looking at common items.

Using a four-slice research CT scanner from GE and a free image software program called Osirix, Stuelke images objects that have some hidden structure within them. The images are generally produced using a slice thickness and interval of 0.625 mm and a speed of 1.25 mm per rotation. The colors in each scan are assigned depending on the density of the materials in the object, and then the image is processed in Adobe Photoshop to correct the contrast and balance.

Through this art, Stuelke hopes to lead viewers to question why and how they identify with these common objects that now appear so different, as well as their own preconceived notions about the safety and usage of medical imaging and radiation. He feels that "using radiation to 'photograph' things which we have connection to, even affection for, is compelling and gorgeous on the one hand, and simultaneously alarming on the other." He encourages visitors to his Web site to submit their own ideas about items to be imaged.

Rebecca C. Jernigan
rebecca.jernigan@laurin.com

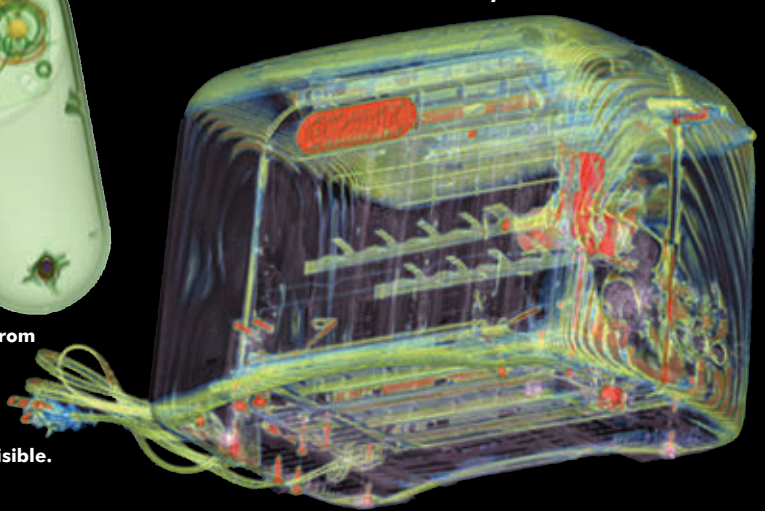


Above, a CT scan of a Barbie doll reveals a fairly detailed skeletal structure beneath the plastic skin. The leg joints are especially noticeable.

The image at left displays the mechanism that makes the stuffed elephant vibrate when its tail is pulled. The heavy thread used to stitch the eyes and seams is visible; the diffuse, fluffy contents are the toy's stuffing.

Pieces of chicken, mashed potatoes, corn and a brownie can be seen inside the box of a frozen dinner, top left. Even the chicken bones are easily identifiable.

Above, the detailed electronic mechanism of a wireless remote from a Playstation 3 game system is shown in this scan. The circuit board can be seen, as well as the surface knobs and buttons.



In the CT scan to the right, the inner workings of a toaster are revealed. The electrical cord and heating elements are clearly visible. All images courtesy of Satre Stuelke, radiologyart.com

Unique Applications... "Custom" Solutions.

You might have noticed that Power Technology, Inc. uses the phrase "putting the 'custom' back in customer" in tandem with our company logo. That phrase is not only an integral part of our corporate identity, but is an undeniable factor of our almost 40 years of success within the photonics industry. With wavelengths ranging from 370 – 1600nm, output powers from 1mW – 7W, and both CW and pulsed power offerings, thousands of laser solutions are made available to our customers. Let Power Technology, Inc. produce a custom laser solution for your unique application.

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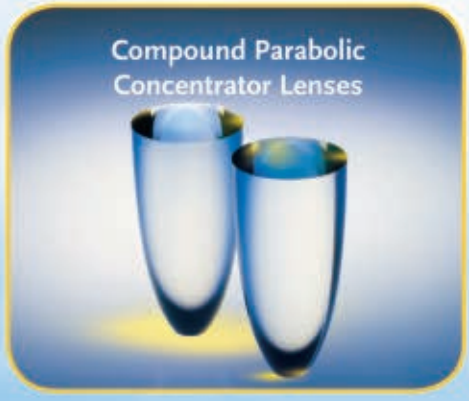
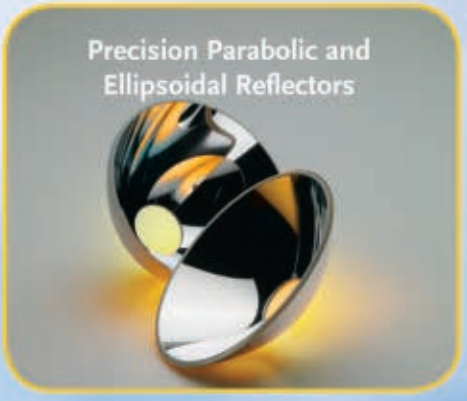
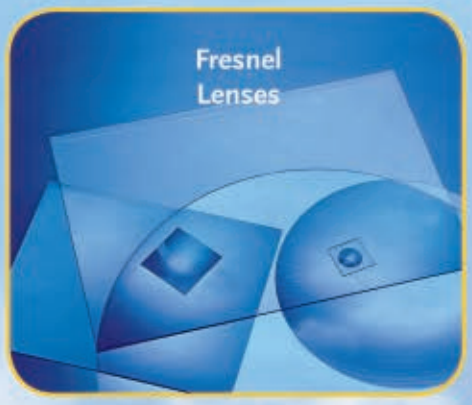
www.PowerTechnology.com
Email: sales@PowerTechnology.com

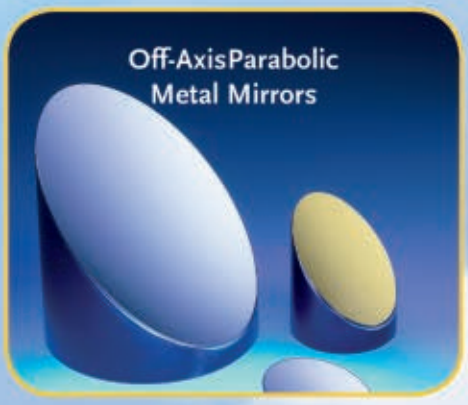
LIGHT COLLECTION

STARTS WITH THE RIGHT OPTICS









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