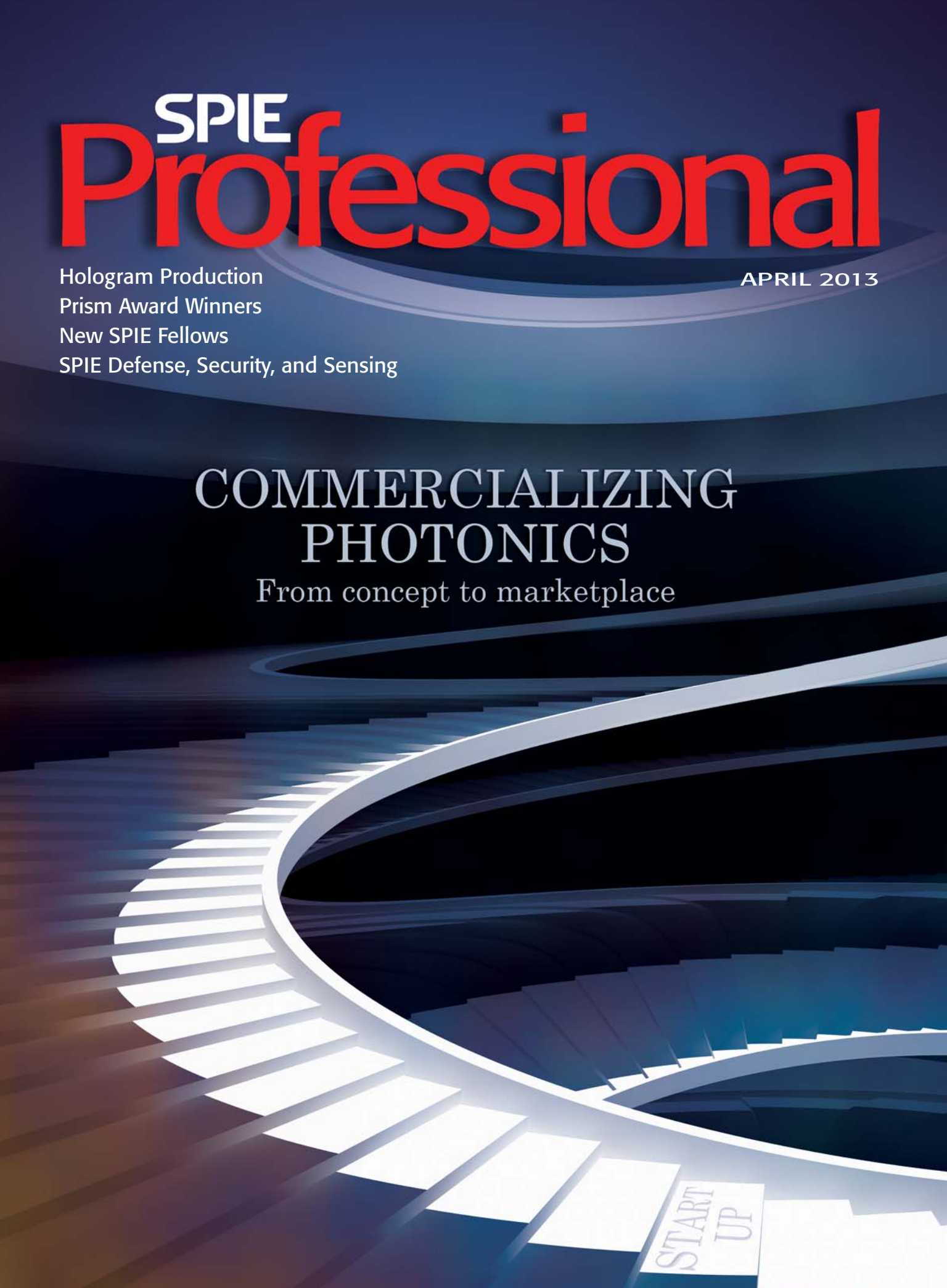
SPIE Professional

APRIL 2013

Hologram Production
Prism Award Winners
New SPIE Fellows
SPIE Defense, Security, and Sensing

COMMERCIALIZING PHOTONICS

From concept to marketplace

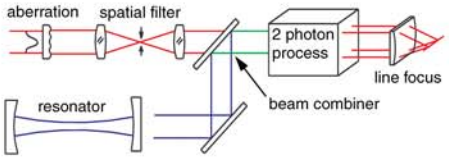


GLAD

Laser and Physical Optics Design Software

Full diffraction analysis

GLAD is the state-of-the-art in laser and physical optics analysis. GLAD can model almost any type of laser or physical optics system with a complete end-to-end 3D diffraction analysis.



GLAD uses a general description of intensity and phase to perform full diffraction propagation through the most complex systems including detailed treatment of laser gain, nonlinear optics, stable or unstable resonators, diffractive optics, waveguides, fibers and coupling, fiber lasers, photolithography, excimers, optical integrators, etc.

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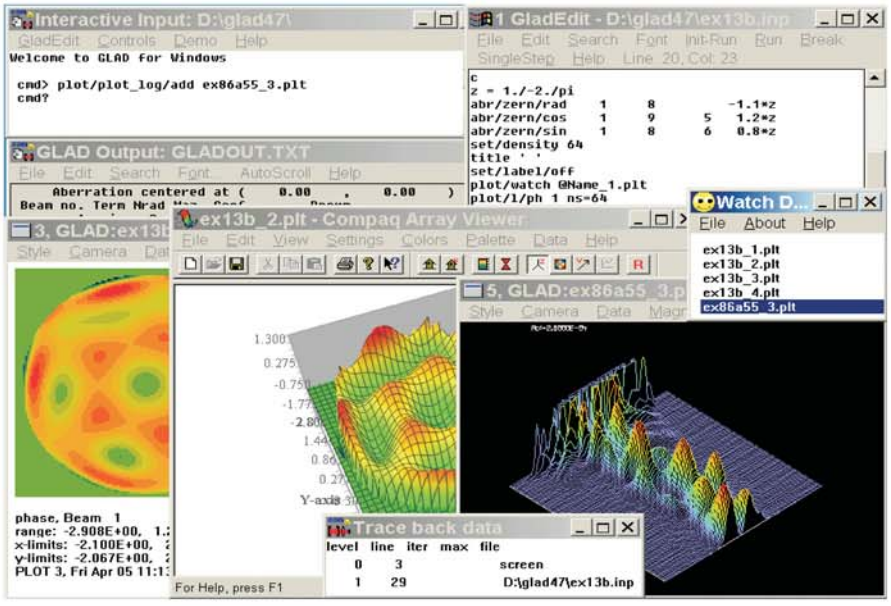
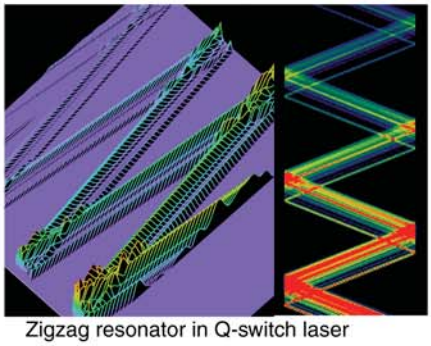
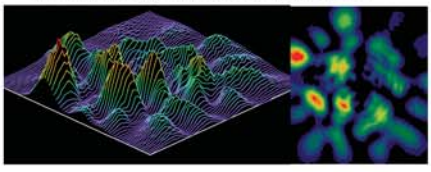
Features:

- Complex, multiple laser systems
- Laser gain models
- Q-switch lasers
- Nonlinear optics
- Interferometry
- Diode pumped lasers
- Stable, unstable, ring resonators
- Lens and mirror arrays
- Binary optics and gratings
- 3D waveguides and fibers

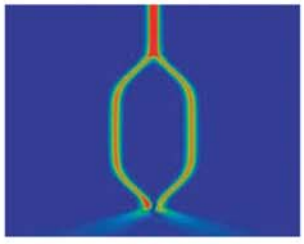




Zigzag resonator in Q-switch laser showing amplification from top to bottom and self-interference at side mirrors.



Transient Q-switch laser mode at 2ns



Photonic switch in the *off* position

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SPIE Professional
Volume 8, Number 2 (ISSN 1817-4035)

features




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SPIE Professional
The Member Magazine of SPIE
spie.org/spieprofessional

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Volume 8, Number 2
SPIE Professional (ISSN 1817-4035) is published quarterly by SPIE, 1000 20th St., Bellingham, WA 98225-6705 USA.

South University of Science and Technology, Shenzhen, China
Faculty position in Electronic Engineering





The Department of Electronic Engineering at the South University of Science and Technology invites applications for faculty positions at all ranks of tenured and tenure-track faculty members in all areas of electrical and electronic engineering. In particular, we are in high demand of applicants in the area of microelectronics, including IC design and Device Process/Technology, Micro/Nano-Electro-Mechanical Systems, Photonic Integrated Circuits, 3D Integration and Packaging, Testing and Reliabilities, Thin Film Transistors and Displays etc. Applicants should have a PhD with demonstrated strength in research and a commitment to teaching. Successful candidates are expected to pursue an active research program, to teach both graduate and undergraduate courses, and to supervise graduate students.

South University of Science and Technology, officially established in April 2012, is a research-intensive public institution funded by the municipal of Shenzhen, a growing international metropolitan neighboring Hong Kong. The University is accredited by the Ministry of Education, China and is a pioneer in higher education reform in China. **The teaching language at the University is English or Putonghua.** The choice is made by the instructor.

The University offers internationally competitive salaries, fringe benefits including medical/dental insurance, retirement and housing subsidies.

Applications including full curriculum vitae, list of publications, statement of research, and names of five referees addressed to Professor Yu Hong Yu, and should be sent by email to **ecesearch@sustc.edu.cn** as well as **hiring@sustc.edu.cn.**

Additional information is available at **http://www.sustc.edu.cn** and **http://english.sina.com/china/2012/0902/502496.html.**

Marketplace of optics and photonics ideas

Every year in San Francisco, SPIE holds its biggest event: Photonics West. This year the dates were 2-8 February. Four symposia, BiOS, LASE, MEMS-MOEMS, and OPTO, as well as the Green Photonics virtual symposium, are held, and the exhibits fill the north and south halls of the gigantic Moscone Center.

The scale of this event is mind-boggling to someone in optics: more than 20,000 registered attendees and more than 1230 exhibiting companies from countries around the world, among which the United States, China, Germany, and Canada have the highest representation. It takes hours to walk the aisles but the exhibition is a lot of fun. The air is electric (photonic?) in this marketplace of optics products and ideas. We hope every exhibitor had a successful show and visitors found what they were looking for.

The technical conferences are also strong. BiOS attracted more than 2000 papers this year, with an impressive growth curve. The Hot Topics session, which was held Saturday night so that doctors and others in the medical community can perform their normal responsibilities during the work week, highlighted fascinating advances in robotic surgery and optogenetics in which neurons can be turned off or on in response to photons.

Innovators rewarded

I had the pleasure of awarding the Britton Chance Biomedical Optics Award to James Fujimoto of MIT and the SPIE 2012 Directors' Award to Rox Anderson of Massachusetts General Hospital. These two organized the Hot Topics session. Also, a new award, the Biophotonics Technology Innovator Award, which targets achievements across disciplines and may include elements of basic research, technology development, and clinical translation, was presented to Aydogan Ozcan from UCLA.

At Photonics West, we take the opportunity to recognize many of the innovators in our field at the fabulous Prism Awards for Photonics Innovation (sponsored jointly with Photonics Media).

Innovation sometimes starts with a drawing on the back of an envelope or a cocktail napkin, or one or two people brainstorming, but if the conditions are right, it can soon spark the start of a business and creation of a team to design and realize a product.

The Prism Awards honor teams who create great products in categories such as biomedicine, green photonics, and laser manufacturing. This year saw 10 winners at this exciting event. (See page 8.)

Also at Photonics West, we recognized 29 new Fellows of the Society (of 69 elected for 2013). I hope if you know a strong candidate for this top technical achievement you will send in a nomination (due by 15 September to fellows@spie.org).

See the list of new fellows on page 16.

I also hosted the BiOS Student Lunch with the Experts at which we honored several SPIE scholarship winners. In 2012, SPIE awarded over $353,000 in scholarships to 140 outstanding students. It is such a pleasure to meet the newest generation of scientists and engineers who are entering our community, and I hope those of you I met will continue to be active in the Society and stick with us in the future!

It is a great honor for me to represent the Society at such an extraordinary event which showcases the wonders of our field in both exhibits and in technical symposia. I was happy to see some of you at my personal favorite event, SPIE Advanced Lithography, in February, and I look forward to meeting you at Optics and Optoelectronics in Prague in April. Please come and introduce yourself and let me know your ideas for making SPIE a better home for all of us. ■

William Harwold

William H. Arnold
2013 SPIE President

See you in Prague?

SPIE Optics + Optoelectronics, 15-18 April in Prague, will be the setting for 17 conferences to address new metamaterials, quantum optics, high-power lasers, and related topics and the awarding of prestigious prizes from the International Commission for Optics (ICO).

Providers of the latest laser systems and a broad range of optics and optoelectronic devices will be in the exhibition hall at the Clarion Congress Hotel 16-17 April.

On 18 April, the U.S. National Science Foundation will host a workshop on "U.S.—Czech Frontiers in Photonics."

The ICO has endorsed the meeting and will officially award the 2011 Galileo Galilei Award to Jan Peřina of the Czech Republic, honorary chairman of SPIE Optics + Optoelectronics since 2007, on Tuesday, 16 April. The ICO recognized Peřina for his research results in quantum optics and coherence related to non-classical states that were "obtained under difficult circumstances."

More information: www.spie.org/EOO

Photonics initiative

A National Photonics Initiative (NPI) is being developed to increase collaboration and coordination among U.S. industry, government, and academia and to identify and advance areas of photonics critical to maintaining competitiveness and national security.

Recommendations on how to maintain national leadership in optics and photonics will be released by cooperating societies in April, just eight months after a National Research Council report advanced the idea.

"Photonics is a critical enabler for our high-tech economy," says SPIE Fellow and past SPIE President Paul McManamon, a co-chair of the committee that wrote the report, "Optics & Photonics: Essential Technologies for Our Nation."

"The Internet, MRIs and CAT scans, and space-mission spinoffs such as optical blood diagnostic instruments and infrared cameras that indicate hot spots in a fire are just a few examples of photonics-enabled applications," McManamon says. "We need the National Photonics Initiative" for future development of the technology.

The industry-driven recommendations were developed by working groups and are focused on defense and security, energy, healthcare, communications, and manufacturing.

SPIE will have more information on the NPI at opticsandphotonics.org.

Lion Lights: A bright solution

Photonics For a Better World

Among the innovators, inventers, and scientists who presented at a recent TED conference was a 13-year-old Maasai boy who had spent much of his young life defending his family's livestock from lions.

Richard Turere of Kitengela, Kenya, just south of Nairobi, says he grew up hating lions. "They used to come at night and feed on our cattle when we were sleeping," he tells interviewers.

Turere's family lives on the edge of Nairobi National Park, which has the world's largest density of lions.

At the age of nine, Turere was given the responsibility of looking after his family's herd of cattle. These valuable animals — the family's source of meat and milk — were too often taken down by the lions.

By age 11, Turere decided to find a way to protect his family's livestock, which also included goats and sheep, from falling prey to the roaming lions. At first he tried building fires, but the lions learned to skirt around them and remain in the shadows – still able to hunt vulnerable animals.

Turere soon noticed that while the lions didn't seem to fear the stationary fires, they were afraid of moving lights; they wouldn't come near the stockade if someone walked around with a flashlight. After a few weeks of contemplation and experimentation, he came up with an innovative, simple, and low-cost system to keep the predators at bay.

With little to no access to technical information, Turere put together an automated lighting system using LED bulbs from broken flashlights and a car battery powered by a solar panel that also powers the family's television. These "Lion Lights" are designed to flash intermittently, tricking lions into thinking someone is walking around with a flashlight.

This solution has been so successful that several families have asked for Lion Lights and so far, 75 such systems have been rigged up around Kenya.

Saving tourism, too

Tourism is a key in helping support the national economy in Kenya and thousands of tourists visit Nairobi National Park every year to see wildlife — especially lions. But these predators are detrimental to the Maasai tribes around the park, and entire prides of lions have been killed in retaliation for attacks on livestock. In less than a decade, the lion population in Kenya has dropped from 15,000 to 2000. Lion Lights have provided a solution that benefits the tourist industry and park inhabitants.

"This is a solution that was invented by somebody in the community," said Paula Kahumbu, executive director of the Kenya Land Conservation Trust and chairman of the Friends of Nairobi National Park. "Therefore, the support for it is very high," she said in a CNN interview.

Kahumbu and her team were so impressed with Turere's invention that they helped him get a scholarship at Brookhouse International School, one of Kenya's top educational institutions, where he is now a student.

"A year ago, I was a boy in a savannah grassland," Turere said in his closing remarks at the TED conference in California. "I saw planes fly over and said I'd be inside one day. I had a chance to come by plane for the first time for TED. My dream is to become an aircraft engineer and pilot when I grow up."

The audience responded with a standing ovation. ■

–Karen Thomas, SPIE Staff

Photonics for a Better World

Read more articles and blog posts celebrating the many ways that photonics are applied in creating a better world:

- spie.org/betterworld
- PhotonicsforaBetterWorld.org

Instant prescription eyewear

The Centre for Vision in the Developing World (UK) is working to bring "instant prescription eyewear" to millions of people in the developing world who have no access to vision correction services.

At a luncheon for nearly 200 SPIE Fellows at SPIE Photonics West in February, Joshua Silver, the organization's CEO, discussed and demonstrated several adaptive optics technologies that could allow people to adjust their eyeglasses to correct their own refractive error.

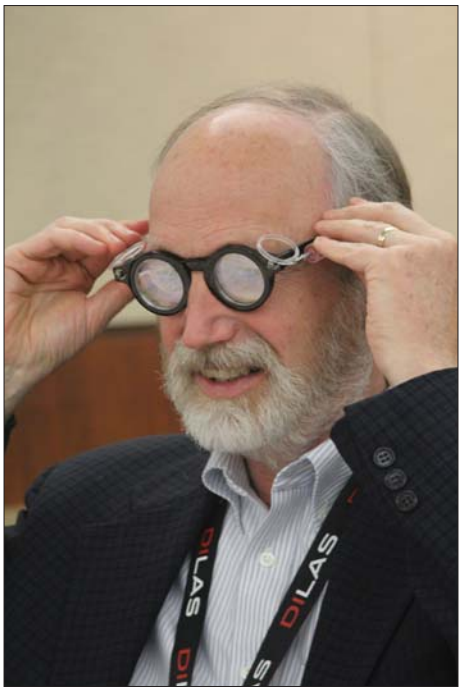
Using electrowetting, electroactive, and fluid-filled lens technology in inexpensive eyeglass frames, people can turn a dial on the eyepiece to correct their refractive error.

Adjustable glasses can be used with all refraction techniques, including the process of self-refraction, which is particularly useful for populations where there are too few eyecare professionals to meet the needs of the people. Silver estimates that only 10% of the population in the developing world has access to vision correction.

The techniques and clinical trials for the lenses with variable refractive power are still in their infancy, Silver said, but they are already in use by 50,000 people in 20 countries.

Silver, a physics professor at University of Oxford, became interested in adaptive optics in the mid-1980s. After considering the way our eye-brain adaptive optical system works, Silver tried the self-refraction procedure on himself, creating several adaptive lens eyeglasses and conducting research on his idea.

Silver acknowledges that the adaptive lenses being used today aren't stylish, but he expects more fashionable frames to be developed in the future. ■



SPIE Fellow James Leger wears a pair of adjustable glasses.

The Prism Awards for Photonics Innovation recognizes some of the best new photonic products on the world market.

Since the first competition in 2008, the Prism Awards program has received applications from more than 35 countries across the globe.

A record number of applications were received for the 2013 competition.

PRISM AWARDS 2013

PRESENTED BY
SPIE & PHOTONICS MEDIA

Winning technologies in the 2013 Prism Awards for Photonics Innovation include an early-stage diagnostic tool for skin cancers, a portable device to test for toxins in water and food, and a versatile laser capable of meeting multiple industrial needs.

Winners of the 2013 Prism Awards were announced in February at SPIE Photonics West in San Francisco. Recipients included SPIE corporate members OEwaves, a winner in last year's awards; Princeton Instruments; Heidelberg Instruments; and Continuum.

Prizes for Raman tools

Spectroscopy technologies were featured heavily as Raman tools won two awards, for LEOSPHERE (France) and Verisante Technology (Canada).

Verisante was recognized in the "Life Science and Biophotonics" category for the Aura system, a hand-held Raman probe which distinguishes between benign and malignant skin lesions using a 785nm excitation source.

As skin cancer rates are increasing in many countries, research groups around the world have been working to apply Raman spectroscopy to the detection of different cancers. "But none have gone to the commercialization stage before now," says Verisante CEO Thomas Braun.

Tie in green photonics

Two companies tied for the "Green Photonics" category — recognizing solutions that generate or conserve energy, reduce pollution, and yield sustainable outputs.

LEOSPHERE (France) won for the R-MAN510 dual-polarization Raman lidar system — designed for accurate and real-time classification of aerosols. Its network-mode operation enables the easy identification of volcanic ash for enhanced air traffic security.

The ChromaID device from Visualant (USA) tests virtually any material, liquid, gas, aerosol, or color using spectral pattern-matching technology. Using this technology, doctors could check skin lesions with a smartphone, police officers could determine if a substance is an illegal drug, and passports and import products could be authenticated based on their color signatures.

"There's a whole host of medical, agricultural, and environmental diagnostic capabilities we haven't thought of yet," said Ron Erickson, Visualant founder and CEO. "We're working with a technology that has unlimited potential."

Pointing out the increasing interest in green technologies, Erickson noted that the Fortune 500 are increasingly looking at their core business through a sustainability lens.

"The business consultant Deloitte reports 49% of CFOs see sustainability as a key driver of future financial performance," Erickson said.

Photonics for positive change

SPIE Executive Director Eugene Arthurs noted how photonics technologies in all categories are gaining importance in everyday life.

"This year's Prism winners serve as inspiring examples of the many ways ubiquitous photonics technologies touch and improve our lives — diagnosing and treating disease, ensuring food hygiene and water purity, maintaining safety in our communities — as well as improving research capabilities to address those and other challenges," Arthurs said.

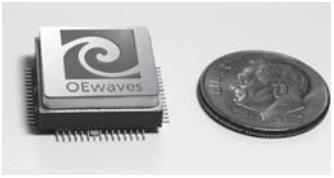
"While the Prism Awards provide well-deserved recognition for these innovative companies, they also serve to underscore the powerful role of photonics R&D in effecting positive change in the world."

A panel of leading industry experts, academics, and venture capitalists determined the winners in nine categories. Winners in their respective categories were:

Defense and Security

OEwaves (USA)

Micro-Opto-Electronic-Oscillator (μOEO)



This optical microresonator offers low phase noise, low vibration, and acceleration sensitivity for signal sources required in both high-frequency and high-performance applications. At the heart of the μOEO is a whispering-gallery-mode optical microresonator with a postage-stamp-sized (~ 1 mm) footprint that generates signals in the microwave and millimeter wave frequencies used by the military. Based on optical properties of ultrahigh-quality-factor microresonators, the μOEO enables significant performance improvements in airborne radar and signal intelligence systems in operating environments on miniature military platforms such as UAVs.

Detectors, Sensing, Imaging, and Cameras

Princeton Instruments (USA)

IsoPlane SCT Spectrograph

With its novel optical design, the IsoPlane gives researchers the ability to utilize the full spatial extent of their detector without loss of spectral or spatial resolution. Historically, only the center of the focal plane of an imaging spectrograph was corrected for aberrations, leaving the edges of the focal plane highly distorted from astigmatism and other higher-order aberrations. The IsoPlane achieves a near-perfect dispersed image of the instrument's entrance slit or any extended source placed at the slit plane, such as an optical-fiber array. The IsoPlane's number of resolvable optical fiber channels is on the order of 100, a factor of 10 times greater than what was previously possible for similar aperture ratio spectrographs.

Green Photonics (TIE)

Visualant (USA)

ChromaID

The ChromaID tests virtually any material, liquid, gas, aerosol, or color using spectral pattern-matching (SPM) technology to record and analyze invisible chromatic identifiers. Patterns of a light-spectrum signature are collected from the structured light transmission of 36 LEDs, and processing software matches the reflected pattern against a database in the cloud. A Bluetooth interface allows the ChromaID to communicate with smartphones for field testing of water, food, biofuel, and commercial fuel, or to be configured for integration into systems for continuous sensing applications. SPM technology can be used in environmental testing as well as in medical, security, manufacturing, and agricultural applications.

LEOSPHERE (France)

R-MAN510

The R-MAN510, with its Raman and dual-polarized channels, combines the full performances of sophisticated research lidar with the compactness and low maintenance requirements of cloud ceilometers. This eye-safe, networkable instrument provides real-time detection and classification of atmospheric structures and hazards, such as ash from volcanic eruptions or dust, biomass particles, or soot. The R-MAN510 emits in the UV (355 nm) with a low-energy and low-maintenance diode-pumped tripled Nd:YAG laser and its algorithm identifies four types of clouds and five types of aerosols. The system's Raman inelastic, 387 nm backscattered signal provides self-calibration for the instrument, so ancillary measurements or presuppositions about particle type are not required.

Industrial Lasers

TeraDiode (USA)

TeraBlade 2kW High Brightness Direct Diode Laser

This high-brightness laser emitter allows direct diode lasers to cut and weld steel in industrial applications. With its wavelength beam-combining technology, the TeraBlade combines the output of any number of laser emitters, of any type, wavelength, or power, into a single, incoherent laser beam while retaining the brightness of the original emitters. The result is a great improvement in brightness compared to a single source. This technology can be applied to any laser wavelength and has been demonstrated from 450 nm to 9 µm and in lasers where the sources in the cavity were more than an octave apart, at 760 nm, 1500 nm, and 1600 nm.

Life Sciences and Biophotonics

Verisante Technology (Canada)

Aura

The Aura™ is a novel Raman spectroscopy device designed to aid in the early detection of all forms of skin cancer including melanoma, basal- and squamous-cell carcinoma. The near-infrared, in vivo system provides valuable information by identifying spectral changes associated with the biochemistry of skin-cancer cells in less than a second, providing immediate results. Unlike other optical devices for skin cancer detection, Aura does not use visual characteristics to assess skin lesions; it scans the biochemical constituents of the skin based on molecular vibrations. Aura's underlying technology has also shown promise in the early detection of other cancers including lung, cervical, and colon cancer.

Manufacturing

Heidelberg Instruments (Germany)

MicroPG501 Direct-Write Lithography System

The µPG501 is a desktop maskless aligner lithography tool able to write small patterns into photoresists without using a photomask — allowing the user to go directly from design to imaging on the substrate. The system can write structures down to 1 µm at a speed of 50 mm^2 / min. The integrated exposure wizard (GUI) guides the operator through the complete procedure: Load the substrate, select the design, and start the exposure. The µPG 501 was designed to fit into even the smallest R&D laboratories and requires only a power connection and an air pressure supply to operate.

Optics and Optical Components

TAG Optics (USA)

TAG Lens 2.0

The TAG Lens 2.0 is a tunable gradient index of refraction (GRIN) device, exhibiting aspherical wavefronts with low spherical aberrations for emerging applications in industrial or biomedical imaging, laser microprocessing, and metrology. The fundamental principle behind the TAG Lens 2.0 is that sound traveling through a liquid causes small, coordinated density fluctuations at well-defined locations. Because a material's index of refraction is related to its density, these changes can be controlled to produce the desired optical effect. The result is an ultrahigh-speed device capable of extending the depth of field of conventional optics or providing user-specified focal lengths.

Scientific Lasers

Continuum (USA)

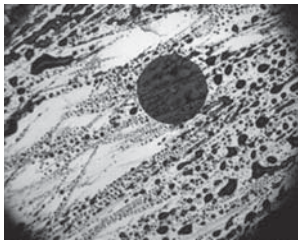
Horizon OPO

The Horizon OPO is a research tool designed to transform the way spectroscopists work: Instead of using multiple devices to conduct research, scientists can have one all-encompassing tool allowing them to take their experiment through the entire spectrum. The Horizon OPO is a unique oscillator with a sophisticated cavity design and optimized optical configuration that exhibits an efficiency of greater than 40%. It provides narrow linewidth, excellent beam quality, and a gap-free tuning range from 192 nm to 2750 nm (vacuum UV). With its wider tuning range, the Horizon OPO opens possibilities for new applications. Direct-drive digital motors ensure linear and fine-controlled scanning and eliminate backlash for precise and accurate bidirectional scanning.

Test, Measurement, Metrology

Linden Photonics (USA)

Lindex Optics Cleaners



The Van der Waals force allows a gecko's feet to stick to slick walls with the aid of tiny microhairs. Harnessing the power of nature, Lindex fiber-optics cleaners employ this force to make contaminants such as carbon and oils stick to their highly absorptive fiber optics cleaning tool at a molecular level. This innovative, carbon nanotube-based cleaning material offers an improvement over cotton- and foam-based materials, helping to eliminate cross-contamination and the need for post-cleaning inspections. The cleaner is made from a dry adhesive material that can be used with or without solvents.

Sizing a New Market

Thorough research and planning of potential markets and products is the other "lab" work for product managers.

By **Lynore M. Abbott**

You want a market with that?

Technology companies sometimes will go off and invent new products that no one wants because someone said, "I figured out how to make this."

But companies should first ask themselves: "Is there a market for it?"

Why don't we first work on our current operations and improve our delivery time?

In the meantime, the marketing department or a consultant can help size the market to see if there's a need and if it's worth pursuing.

A good VP of engineering understands that spending two weeks in the lab building things might feel like progress, but it doesn't make sense if you haven't first fully researched the market opportunities.

In every organization there is a shortage of resources: personnel, skills, time, and money. As professionals, we owe it to ourselves and our employers to make the best use of those resources.

Product managers must choose which products to develop and bring to market; engineering managers must prioritize research and development activities; sales managers must choose whether to expand geographically or within a targeted market segment.

We all know that we need to do this, yet sometimes we don't. We get distracted by the tactics, the newness of the technology, or the difficulties in trying to get the data to make a decision. Or we build something in the lab because it is fun or feels like we are doing something – before fully researching the market space or really thinking about it. The resources are not focused.

> "Two weeks in the lab will save you two hours in the library."

As one of my graduate school advisers facetiously reminded us daily: "Two weeks in the lab will save you two hours in the library." Granted, in those days, researching the literature was very time-intensive because you had to physically go to the library, find the journals on the shelf, copy the papers, and find out that no one had worked the issue before.

Sizing a new potential market that does not exist is daunting. However, research and planning will nearly always pay off in the end.

Recently, I have had the pleasure of working with several companies trying to pick markets and products.

These are the three top lessons that kept repeating (or were we re-discovering?) as we analyzed and tried to choose where to focus.

Follow the money

One of the best places to start is to determine which product or market is most profitable. This is particularly important if the sales channels or pricing are radically different between available choices.

For example, I recently helped a company, ProCog (ProCog.com), work through a software product launch plan. Essentially, the development time for an enterprise product was the same as for a single-end-user product. However, the sales channels are radically different.

Sales people would be required to close sales on the enterprise solution, and the single-end-user product would be self-serve (i.e., downloaded off their website) without much human intervention.

The decision was particularly hard because the company's primary experience was with sales of end-user products and it had almost no experience with enterprise sales. The price of the product for each market was also considerably different.

We built a simple profit and loss (P&L) statement for each of the two products, estimating how many accounts needed to be booked each day to hit the revenue targets for profitability. The number of closed accounts (sales) determined the number of sales professionals, which was the biggest variable cost in the model.

We did not stop at margin; we also included the sales, marketing, and general administration expenses. You may find out that the product is too expensive to support because it requires too much sales effort and so on.

I particularly like modeling how many items need to be manufactured and sold and at what price. If it turns out that your plan only works if you sell twice as many items as 100% of current demand, then I would suggest you probably have not identified a good market.

This is an easy step that is often overlooked. It is a great sanity check for production, for staffing your sales team, and for sizing the market. See tables on next page for some of these modeling examples.

Calculate risk; take one

Another company, Nitride Solutions (NitrideSolutions.com), has a product that can serve four different applications.

The product could 1) displace existing technology in the deep-UV LED market where the current solutions are not adequate and have many yield problems; 2) displace existing technology in the ultraviolet to visible LED market as the E-O (Electrical to Optical Efficiency) conversions are better; 3) enable key components for power electronics equipment; or 4) enable new laser lines for UV laser diodes.

The discriminating variable in this example is risk. Option 1 is the least risky because there is an apparent need with no good solution.

Option 2 is risky because there is an incumbent technology that might engage in a price war.

Option 3 is fairly risky because the entire plan depends upon the end customer developing his products for markets (which may not exist either).

Option 4 is the most risky because no one in the company has worked in that industry. In other words, they don't know what they don't know.

In this case, I recommended a staggered approach, starting with the existing applications and working to displace the incumbent (silicon substrate) technology. Later, when the company is established and has a good track record of delivering product into a market it knows and understands, Nitride Solutions could hire knowledgeable people from the laser-diode market to develop new products and sales channels. (A different team, with different strengths and connections, would actually do option 4 before option 3.)

Pricing and Revenue Model	2013	2014	2015	2016
Revenue required, per business plan	$7,500,000	$10,000,000	$15,000,000	$25,000,000
Average Sale Price (ASP*)	$ 7,500	$ 7,875	$ 8,269	$ 8,682

* ASP includes annual re-pricing and 20% average attrition (churn) rate

Customer Model	2013	2014	2015	2016
Total customers required (Revenue / ASP)	1,000	1,270	1,814	2,879
Continuing customers (Previous year number, less 20% churn)	NA	800	1,016	1,451
New customers needed	1,000	470	798	1,428

Sales Support Model	2013	2014	2015	2016
Employees required for new customer bookings via outbound callers	2	1	2	3
Employees required to upsell existing customers to next product	NA	2	2	3
Total sales employees required	**2**	**3**	**4**	**6**

How big is the hill to climb? When you need to choose a market, determine staffing requirements, or just to know whether your plan is even feasible, start with a spreadsheet or two.

The fiber-laser adoption path is a great example of the newer technology (being more power efficient and/or having better beam quality) gradually, and then more quickly, displacing flash-pumped and diode-pumped laser lines. As the laser industry gained more experience, new applications were developed that are only possible with the fiber-laser capabilities.

Play the game you got

That brings us to the third theme, play to your strengths.

"Play the game you got." My father-in-law said this to my husband one day on the golf course after my husband had one of the worst slices imaginable.

So my husband bravely lined up 45 degrees from the fairway and gave the ball a great whack. It flew out and over a lake, took a right hand turn, and landed neatly in the middle of the fairway. He was lucky, but the situation reminds us that it is best to practice and improve at the driving range – not in the heat of battle.

In his 2011 book, *Toward Entrepreneurship: Establishing a Successful Technology Business*, Milton Chang says the same thing: "Start with what you know."

When Newport Corp. was started, the founders knew about accessories for laser research, so they started making opto-mechanical components for the laser-research applications they were personally familiar with. The company was built from there.

If you can name the customers and even the person you would sell the product to, then you

Continued on page 14 ▶

Sizing a New Market

◀ *Continued from page 13*

are close to the market. If you cannot name the companies that are your targets, then you are probably not close enough to the market.

If your team is made up of forward-looking infrared-component designers, you should start in the infrared world. You have an advantage when competing with people who work in the UV and visible parts of the spectrum because you know things they do not. The reverse holds true for them; they have experience with all the nasty things UV light does to materials over time.

If you stick to what you know, you can evaluate the risks better and develop a more profitable plan. It is easier to evaluate the plan's profitability and it will be easier to identify and, therefore, mitigate the risks. It will be more fun because you know the who, what, and why of what you are developing, marketing, and selling.

Examine what you are working on. Is it busy work "in the lab" or is it execution of a researched plan?

You'll find that planning and fully evaluating your choices before you start your lab work isn't wasted time, but will save you time and money while increasing your chances for success.

– SPIE member Lynore M. Abbott has more than 20 years' experience developing and launching new products, penetrating new markets, and building international teams for companies such as CVI Laser, Southampton Photonics, and Polaroid. She recently formed Logical Marketing (LogicalM.com) to facilitate small-company access to big-company processes and success. She holds an SB in material science and engineering from the Massachusetts Institute of Technology; an Executive MBA from University of New Mexico; and an MS in polymer science and engineering from University of Massachusetts, Amherst. She is an active member of the SPIE Corporate and Exhibitor Committee and the board of the New Mexico Optics Industry Association. ■

Optics training

OP-TEC
National Center for Optics and Photonics Education

OP-TEC, the National Center for Optics and Photonics Education, is a consortium of colleges and industry groups working to increase the supply of well-educated photonics technicians by building and strengthening the capacity and quality of photonics education in U.S. two-year colleges.

Funded by the National Science Foundation, OP-TEC empowers community and technical colleges to meet the urgent need for new technicians and the retraining of workers in optics and photonics.

SPIE is a partner and supporter of OP-TEC.

New skill standard set for precision-optics technicians

The National Center for Optics and Photonics Education (OP-TEC) in the United States has released the second edition of the National Precision Optics Skill Standards for Technicians. The standard provides the community with an updated listing of what technicians working in the precision-optics industry should know and be able to do.

Technicians produce, test, and handle optical components used in lasers and sophisticated electro-optical systems for defense, homeland security, aerospace, biomedical equipment, remote sensing, alternate energy production, and nanotechnology. Precision-optics technicians also integrate optical components into electro-optical systems and maintain electro-optical systems.

The skill standard, developed by OP-TEC in collaboration with precision-optics industry professionals and academic representatives, has received endorsements from the American Precision Optics Manufacturers Association (APOMA), Colorado Photonics Industry Association, New Mexico Optics Industry Association, and the Rochester and Florida Photonics Clusters.

"The U.S. needs more highly trained and skilled technicians than ever," said SPIE Fellow Jay Kumler, president of APOMA.

The standard is not only a valuable resource for employers; it provides a means by which employers communicate to educators their requirements regarding the content of the courses and programs that will produce their future employees.

The second edition standard will provide educators and employer advisory committees a solid foundation for generating courses and programs that will enable U.S. two-year colleges (and their feeder high schools) to produce these globally competitive workers.

For more information and to download a copy of the standards: www.op-tec.org. ■

Image courtesy of Sydor Optics.

SPIE 2013 election

SPIE members will be asked this year to vote on a slate of officers to serve the Society for 2014.

Members will select four new directors and vote on candidates for vice president and secretary/treasurer during an election that begins 29 June.


Lieberman


Mendoza-Santoyo


Lula

The candidates for vice president are:

- Robert Lieberman, Intelligent Optical Systems (USA)
- Fernando Mendoza-Santoyo, Centro de Investigaciones en Optica (Mexico)

The candidate for secretary/treasurer is Brian Lula, PI (Physik Instrumente) (USA)

For director:

- Michael Descour, Sandia National Labs (USA)
- Michael Eismann, Air Force Research Lab (USA)
- Asher Friesem, Weizmann Institute of Science (Israel)
- James Grote, Air Force Research Lab (USA)
- Martin Leahy, National University of Ireland Galway (Ireland)
- Anita Mahadevan-Jansen, Vanderbilt University (USA)
- Sergio Restaino, Naval Research Lab (USA)
- Jim McNally, Applied Technology Associates (USA)


Descour


Eismann


Friesem


Grote


Leahy


Mahadevan-Jansen


Restaino


McNally

SPIE directors serve three-year terms and officers serve for one year.

SPIE Fellow H. Philip Stahl, NASA Marshall Space Flight Center (USA), president-elect for 2013, will be seated as president in January 2014, and SPIE Fellow Toyohiko Yatagai, serving as vice president for 2013, will become president-elect in 2014.

The new officers will be announced at the SPIE annual general meeting in San Diego, CA (USA), 27 August.

For more information about leadership and governance at SPIE: www.spie.org/leadership. ■

New SPIE Fellows

SPIE has promoted 69 new Fellows of the Society this year to recognize the significant scientific and technical contributions of each in optics, photonics, and imaging as well as their service to SPIE.

This year's honorees include the first SPIE members elected from Iceland and South Africa.

"The SPIE Fellow award is given only for the highest technical achievement in optics and photonics, and friends and colleagues of the recipients should be aware of the special nature of this honor," says SPIE President William Arnold. "All of us congratulate these extraordinary people for their accomplishments."

SPIE Fellow Cheng-Chung Lee of National Central University (Taiwan), chair of the 2012 SPIE Fellows Committee, also extended the committee's congratulations and encouraged nominations of deserving candidates for next year's awards. Nominations for promotions in 2014 are due 15 September.

For more information and to see a complete list of SPIE Fellows: www.spie.org/fellows.

Enjoying a social chat at the Fellows luncheon at Photonics West were (left to right): Warren Grundfest (UCLA), Ephraim Suhir (Consultant), Robert A. Fisher (RA Fisher Associates), and E. Fred Schubert (Rensselaer Polytechnic Institute). Twenty-nine new SPIE Fellows were honored at SPIE Photonics West and three recently promoted Fellows received their Fellow plaques at IS&T SPIE Electronic Imaging in February. New Fellows are recognized at a conference of their choosing during the year.

Call for SPIE Fellow Nominations

The SPIE Fellows Committee will accept nominations for the next class of SPIE Fellows through 15 September.

Nominees will be evaluated on their technical accomplishments in optics, photonics, and imaging, including publications and patents; service to the general optics community in the form of volunteer work at science fairs, service as an editor or technical reviewer, etc.; and service to SPIE.

Nominations of members working in industry are encouraged.

Nomination materials for candidates who are not elected the first time they are nominated are automatically considered in the next two years.

More information:
www.spie.org/fellows

Jón Atli Benediktsson
University of Iceland (Iceland)

Aleksey Bolotnikov
Brookhaven National Lab (USA)

Yan Borodovsky
Intel Corp. (USA)

Liliana Braescu
Universitatea de Vest din Timişoara (Romania)

Shoou-Jinn Chang
National Cheng Kung University (Taiwan)

Antao Chen
University of Washington (USA)

Wood-Hi Cheng
National Sun Yat-sen University (Taiwan)

James Churnside
National Oceanic and Atmospheric Administration (USA)

Alain Diebold
University at Albany (USA)

Zhe Feng
National Taiwan University (Taiwan)

Maurizio Ferrari
Istituto di Fotonica e Nanotecnologie (Italy)

Robert Fiete
ITT Exelis Geospatial Systems (USA)

Andrew Forbes
Council for Scientific and Industrial Research (South Africa)

Venu Govindaraju
University at Buffalo (USA)

Bo Gu
Consultant (USA)

Christoph Hitzenberger
Medizinische Universität Wien (Austria)

Hong Hua
University of Arizona (USA)

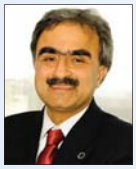
Bormin Huang
University of Wisconsin-Madison (USA)

Vladimir Ilchenko
OEwaves (USA)

Eddie Jacobs
University of Memphis (USA)

Faquir Jain
University of Connecticut (USA)

Jin Kang
Johns Hopkins University (USA)



Raman Kashyap
École Polytechnique de Montréal (Canada)

Sean Kirkpatrick
Michigan Technological University (USA)

Bernard Kress
Consultant (USA)

Sridhar Krishnaswamy
Northwestern University (USA)

Franko Kueppers
University of Arizona (USA)

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◀ Continued from page 17

Hao-Chung Kuo
National Chiao Tung University (Taiwan)

Kafai Lai
IBM Corp. (USA)

Edmund Lam
University of Hong Kong (China)

Luke Lester
University of New Mexico (USA)

Raúl Martín-Palma
Universidad Autónoma de Madrid (Spain)

Dennis Matthews
University of California Davis Medical Center (USA)

James McNally
Applied Technology Associates (USA)

Anna Mignani
Istituto di Fisica Applicata Nello Carrara (Italy)

Juan Carlos Miñano
Universidad Politécnica de Madrid (Spain)

Vladimir Mitin
University at Buffalo (USA)

Haldun Ozaktas
İhsan Doğramacı Bilkent University (Turkey)

Aydogan Ozcan
University of California Los Angeles (USA)

Miles Padgett
University of Glasgow (UK)

Keith Paulsen
Dartmouth College (USA)

Qibing Pei
University of California Los Angeles (USA)

Gang-Ding Peng
University of New South Wales (Australia)

Stephen Pompea
National Optical Astronomy Observatory (USA)

Kevin Priddy
Air Force Research Laboratory (USA)

Nimmi Ramanujam
Duke University (USA)

Rajeshuni Ramesham
Jet Propulsion Laboratory (USA)

Bryan Rice
SEMATECH North (USA)

Martin Richardson
CREOL University of Central Florida (USA)

David Sampson
University of Western Australia (Australia)

Ifor Samuel
University of St Andrews (UK)

Jasbinder Sanghera
U.S. Naval Research Laboratory (USA)

Tae Seong
Korea University (Korea)

Gaurav Sharma
University of Rochester (USA)

Lu-Ping Shi
A*STAR - Data Storage Institute (Singapore)

Sivalingam Sivananthan
University of Illinois at Chicago (USA)

SPIE President William Arnold (ASML) and Advanced Lithography Chair Harry Levinson (GLOBALFOUNDRIES) recognized five of 69 newly promoted SPIE Fellows for 2013 during SPIE Advanced Lithography in February. Among those new Fellows honored for their contributions to the lithography community were Martin Richardson (CREOL, University of Central Florida), pictured left with Arnold, Yan Borodovsky (Intel Corp.), Alain Diebold (University at Albany, New York), Kafai Lai (IBM Corp.), and Bryan Rice (SEMATECH North).

Ephraim Suhir
Consultant (USA)

Carmen Vázquez-García
Universidad Carlos III de Madrid (Spain)

Warren Warren
Duke University (USA)

Dacheng Tao
University of Technology Sydney (Australia)

Alex Vitkin
Ontario Cancer Institute Princess Margaret Hospital (Canada)

Brian Wong
Beckman Laser Institute and Medical Clinic (USA)

Thomas Thundat
University of Alberta (Canada)

Ruikang Wang
University of Washington (USA)

Qiwen Zhan
University of Dayton (USA)

Jie Tian
Institute of Automation (China)

David Ting
Jet Propulsion Laboratory (USA)

Rick Trebino
Georgia Institute of Technology (USA)

Andreas Tünnermann
Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany)

SPIE Professional

Call for Articles

SPIE Professional is accepting article proposals from members.

Future issues of the open-access magazine will cover career and industry topics as well as advances in optics, sustainable energy, high-power lasers, and more.

Do you know of a researcher, engineer, or entrepreneur who is making the world a better place?

Please submit your idea as a short outline or abstract to:

spieprofessional@spie.org

Commercialization Basics

SPIE member David Krohn shares mistakes and successes in commercializing photonics technologies.

This issue of *SPIE Professional* has a special focus on entrepreneurs who are transferring photonics technologies into commercial products and services.

In this article and excerpt, serial entrepreneur David Krohn shares more than three decades of experience commercializing photonics technologies.

See other articles in this issue about photonics entrepreneurship, including coverage of the SPIE Startup Challenge and the story of RefleXion Medical, a seed-stage medical technology company developing an innovative radiation therapy system.

Donna Connor Photography

On the day David Krohn became CEO of his first photonics company in 1979, his former boss at Exxon Research took him aside and gave him some advice.

"No matter how smart you are, you're not smart enough," the boss told him. "No matter how good you are, you are not good enough. Hire people that are better than you and smarter than you, and ride the wave."

Krohn says he has learned that and much more about photonics entrepreneurship since co-founding EOTech, and that first lesson was perhaps the most important.

"I've learned over the years not to be threatened by people, to get out of their way," Krohn says. "My job is to be at the front of the boat and to block all the things that come at them so they can do their job. That's the lesson I've learned.

"I've made a lot of mistakes, but I've learned a lot more from mistakes than successes."

In the interest of sparing other potential photonics entrepreneurs the pain of making the same mistakes he made in helping 115 companies commercialize photonics technologies over the last 34 years, Krohn has published a new book with SPIE Press, *Commercialization Basics for the Photonics Industry*.

The 178-page book (www.spie.org/Krohn) covers fundraising strategies and government contracts, marketing and manufacturing basics, and the all-important recruitment process for anyone considering starting his/her own photonics business.

> "A strong business team is the most important ingredient in the success of the business."

People most important

"A strong business team is the most important ingredient in the success of the business," Krohn writes in the book.

The number one tip from a man who has written business plans for more than 60 startups and who was an angel investor for 11? "Money is the engine," Krohn says. "Whatever you think you're going to need, it will probably be a factor of four higher."

Krohn also says that the biggest mistake most new businesses make – and it can be a fatal mistake – is to do a poor job of marketing or manufacturing the technology. Most inventors with a cool idea think that people will "rip the walls off the building to get at the better mousetrap," Krohn says. But they may not fully understand the market dynamics or problems in manufacturing.

As an example, he cites the solar energy company Solyndra, which went bankrupt in 2011 after receiving millions in U.S. government loan guarantees. "Solyndra was positioned to fail from Day One," Krohn says, because the expense of manufacturing its innovative solar rooftop system was twice the cost of what manufacturers, especially in China, were selling solar panels for on the market.

Krohn is managing partner of Light Wave Venture Consulting, where he helps startups in the fields of fiber optics, sensors, lasers, telecommunications, and biophotonics recruit employees, raise money, and write business plans. He was CEO of EOTec until that business was acquired by 3M in 1987. He later served as global new business director for photonics at 3M. He was also general manager of the 3M Specialty Optical Fiber business that included the Bragg Grating Technologies business acquired from UTC.

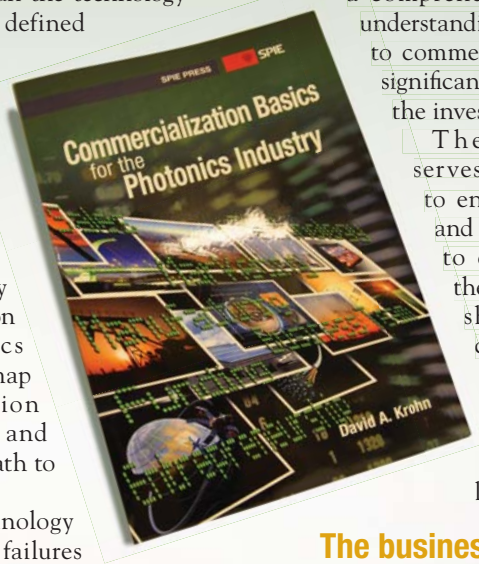
He is an SPIE member and has an MS from Case Western Reserve University and a PhD from Lehigh University.

Read excerpts from Krohn's book on commercializing photonics in the next pages, and see our February 2013 interview with him at www.spie.org/Krohnvideo. ■

— EXCERPTS FROM —

Commercialization Basics for the Photonics Industry

The goal of commercialization is to transform good technology into meaningful products that can fulfill customer needs while remaining cost effective. Specifically, can the technology be the basis for meeting a defined customer need? Can it be reproduced consistently, and can it be manufactured cost-effectively?



Most entrepreneurs have expertise in one or more of the critical areas of commercialization, but may lack key elements necessary for success. Commercialization Basics for the Photonics Industry serves as a roadmap for the commercialization process, helping identify and address roadblocks on the path to commercialization.

Assuming that the technology is sound, 75% of business failures are caused either by poor market understanding or the inability to manufacture quality products in a timely manner. Therefore, good reproducible technology is only one of several critical elements required for successful commercialization.

Marketing and manufacturing are additional elements that are not only required, but required early in the product-development cycle. Several other elements are important to the implementation process, including funding, sales, manufacturing engineering, and the team itself.

In many ways commercialization is like a political campaign: the engine is often the funding that drives the product toward a successful conclusion. Sometimes the market input will drive the technology. Often, as technology evolves, market input is needed early in the evolution process to adjust to market needs. Funding allows the technology to be developed, the market input to be generated, and the sales and manufacturing structure to be devised and implemented. Many companies start on a shoestring budget with little or no initial funding.

We hear of fantastic successes when these companies rise to great heights from very humble beginnings. However, the vast number of companies that fall by the wayside is often played down. The takeaway here is that thinking about commercialization very early during the process of product formation significantly increases the probability of successful market entry, where a key element of success is getting the proper funding. Having a comprehensive plan and an understanding and commitment to commercialization concepts significantly reduces the risk for the investor.

The business plan serves both as a vehicle to encourage investment and as a roadmap for how to direct and manage the company. The plan should clearly and concisely provide a view of the company's mission, goals, as well as what makes it different and likely to succeed.

The business team

A strong business team is the most important ingredient in the success of the business. A good team can win with limited resources. A weak team will likely lose with unlimited resources.

Commercialization is the responsibility of all key employees. Cross-functional teams are required to make a smooth transition from concept to product. Product development, marketing, manufacturing engineering, manufacturing, sales, as well as general management, all have to work in concert to move successfully from concept to market.

If the development group merely throws the prototype over the wall and the manufacturing team scrambles to productize something that fulfills a customer need, they will meet with a low probability of success.

It is very important to recognize that the structure of the team will need to change as the business moves through the various stages of growth.

Stages and sources of funding

Raising funds for the business will always be a challenge. Most entrepreneurs will tell you that whatever amount you project as your financial needs, in almost all cases, this amount is an understatement.

There are potentially

Continued on page 22 ▶

Top concepts

SPIE member David Krohn explains in his new book that technology startups typically set aside 10%-20% of projected annual budgets for product development.

However, "In small startups, that number may be closer to 90%," he says.

"It is essential to focus this development effort on selecting the right products to maximize market opportunities."

Careful selection of development activities eliminates limited-potential products early in the commercialization process and provides for better utilization of available resources.

The takeaway concepts for successful commercialization of technology include:

- Don't live in a technology vacuum.
- Identify a problem or need first, then provide a technical solution, not the other way around.
- Understand the business side of technology (marketing, sales, and manufacturing).
- Ensure that commercialization is a team effort.

Learn more about the book at www.spie.org/Krohn, and see our interview with the author at www.spie.org/Krohnvideo.

Commercialization Basics

◀ *Continued from page 21*

several stages of funding needs and multiple sources, including angels, venture capital firms, business loans, government contracts, and strategic industrial investors.

In the startup phase, funding needs are limited. The anticipated needs are in the range of $50,000 to $750,000. The funds are used to show proof of concept through prototype production and alpha sites to get preliminary feedback on performance. At this stage, spending should be lean. Overfunding at this early stage can lead to wasting resources by running with a product before it is ready. It can also lead to valuation problems that can negatively impact future funding rounds.

In the development stage, the funding is usually around $500,000 to $3 million. In some instances it may approach $5 million. In this stage, the funds are needed for product development, pilot manufacturing, market development, beta-site testing, and product introduction.

Once products have been qualified and accepted, the company enters the expansion phase. The funding needs are typically $2 million or more, depending on the need for capital equipment and the ramp-rate for expansion.

The growth stage is signified by a steep ramp rate where all aspects of the company are growing, including manufacturing, manufacturing engineering, marketing and sales organization with an emphasis on customer support, and new and advanced product development. The funding level could be $5 million or more.

Not all successful companies experience all of the stages. Sometimes very promising companies or companies that are very strategic to another company may be acquired at an earlier stage. ■

Government cash is good—but only if it solves multiple problems

One of David Krohn's top tips for photonics entrepreneurs is to ensure that there is a problem or need for a new technology or product.

"Technology in search of a problem is not focused," Krohn says.

"I like opportunities that are more diversified," Krohn says of his work with Light Wave Venture Consulting.

Entrepreneurs should strive for one technical platform that can serve multiple markets. He advises new entrepreneurs to pick an engineering problem "that can move to multiple development markets."

Similarly, Krohn advises innovators to be careful about government funding, which has its benefits and drawbacks.

The main benefit of government grants is they are a significant source of needed cash. "But most people don't realize that government funding has a long gestation period," he says and are intended for "one-off" technologies that are focused on a specific government need.

"Make sure you are taking something that is supplementing your research," he says, and fits in with an overall business case.

New Books from SPIE

Laser Beam Quality Metrics
T. Sean Ross

This text guides you through the subtleties of laser beam quality analysis and requirements synthesis, arming you with the tools to understand beam quality specifications and to write custom specifications that are traceable to the intended application.

Vol. TT96
SPIE Member $47 / Nonmember $55

Multimodality Breast Imaging: Diagnosis and Treatment
E. Y. K. Ng, U. Rajendra Acharya, Rangaraj M. Rangayyan, Jasjit S. Suri *(Editors)*

This book covers breast cancer detection, diagnosis, and treatment using different imaging modalities such as mammography, magnetic resonance imaging, computed tomography, positron emission tomography, ultrasonography, infrared imaging, and other modalities. The information and methodologies presented will be useful to researchers, doctors, teachers, and students in biomedical sciences, medical imaging, and engineering.

Vol. PM227
SPIE Member $114 / Nonmember $134

In Press

Field Guide to Physical Optics
Daniel G. Smith
Vol. FG17
SPIE Member $36 / Nonmember $42

Stray Light Analysis and Control
Eric C. Fest
Vol. PM229
SPIE Member $47 / Nonmember $55

Electro-Optical System Analysis and Design: A Radiometry Perspective
Cornelius J. Willers
Vol. PM236
SPIE Member $78 / Nonmember $92

The Proper Care of Optics: Cleaning, Handling, Storage, and Shipping
Robert Schalck
Vol. PM233
SPIE Member $34 / Nonmember $40

Chemical Vapor Deposited Zinc Sulfide
John S. McCloy, Randal W. Tustison
Vol. PM237
SPIE Member $56 / Nonmember $66

Read details and sample pages | SPIE PRESS

www.spie.org/books

From bench to marketplace

SPIE Professional has a special focus on entrepreneurs who are succeeding at transferring photonics technologies into commercial products and services.

This issue of the magazine offers perspectives on photonics commercialization from various places on the entrepreneurial spectrum — from those at entrepreneurship's early stages to one entrepreneur with enough experience to write a primer on the subject.

In this article, two 34-year-old optics and photonics professionals who have yet to begin manufacturing their radiation-therapy system offer the story of their company's beginnings and their hopes for the future.

See other articles in this issue about photonics entrepreneurship, including coverage of the SPIE Startup Challenge and David A. Krohn's new book, *Commercialization Basics for the Photonics Industry*.

Birth of a startup

Building a machine to fight cancer:
A perspective from the founders of RefleXion Medical.

Sam Mazin and Akshay Nanduri, both 34, are cofounders of RefleXion Medical, a seed-stage medical technology company based in Silicon Valley. RefleXion is developing an innovative radiation-therapy system with the potential to revolutionize cancer care by treating metastatic disease with highly precise and focused radiation.

In this article, they offer their views as founders of a life-sciences startup and detail the opportunities and challenges encountered in the pre-revenue stage of commercializing a photonics technology for medicine.

Problem: breath and tumor motion

After completing his PhD in electrical engineering at Stanford University (USA), Mazin started a postdoc position focused on medical imaging in the Radiological Sciences Lab, also at Stanford. While attending a 2007 talk on campus by a professor from the Radiation Oncology department, Mazin was introduced to radiotherapy — the modality of treating cancer with radiation.

Mazin learned that the biggest challenge in the field was determining the exact location of cancer in the body during treatment and that this problem was exacerbated by tumor motion caused by patient breathing.

With his strong training in medical imaging (and an issued patent for a novel X-ray CT system developed as part of his PhD work), Mazin quickly understood the limitations of current radiotherapy systems, which rely on anatomic imaging like X-ray, computed tomography (CT), ultrasound, or magnetic resonance imaging (MRI) to visualize a tumor and infer its motion. Mazin also thought about positron emission tomography (PET), a form of biological imaging and the gold standard in noninvasive cancer detection and staging.

"Why couldn't PET, the most powerful imaging modality for cancer visualization, be used at the *time of treatment*?" he wondered. "If cancer signaled its location back to the therapy machine, the motion problem would be solved."

Mazin realized that the key challenge was to overcome PET's fundamentally slow image-acquisition time. After some more thinking, a light bulb flicked on.

In PET, a radiotracer administered to the patient causes cancer to emit a pair of photons forming a so-called 'line of response.'

"Instead of waiting for the thousands of lines that are detected and used to reconstruct an image, I imagined sitting at one of the endpoints of a 'line of response' with a baseball bat and smashing that photon right back to where it came from," he thought. "In practice, a therapeutic radiation beamlet would be delivered right back to the source of the photon pair emission along the same linear path.

"If this process is repeated for most of the detected photon pairs, the therapeutic radiation dose would accumulate as the PET image is forming!"

Startup business plan

Becoming increasingly fixated on the idea, Mazin devised a practical design of a hardware system implementing this concept (RefleXion now has an issued patent for the innovation.). He also started developing a business plan, which was jumpstarted in the summer of 2008 by participating in Stanford Ignite, a four-week crash course in business for entrepreneurs without business backgrounds.

After completing the program, Mazin began looking for a cofounder. "I needed someone I could trust, who had succeeded at an early-stage startup, and whose skills would complement my training," Mazin says. And Nanduri, one of his closest friends from high school and from his undergraduate engineering days at University of Waterloo (Canada), met all of these criteria.

Indeed, after Nanduri completed his undergraduate degree in computer engineering in 2001, he had joined a venture-backed startup in Canada as its first employee. Nanduri eventually became the director of software development at SlipStream Data, leading a software team of 10 engineers, and played a crucial role in the company's acquisition in 2006 by Research in Motion, the pioneering smartphone giant and maker of the BlackBerry.

Moreover, Nanduri was rounding out his startup experience with formal business training at Massachusetts Institute of Technology (MIT). Mazin successfully recruited Nanduri, and RefleXion was incorporated in California on 17 March 2009.

Fellowship jumpstarts funding

In contrast to the workings of most biotechnologies and medical devices, the performance of image-guided radiotherapy technologies can be predicted by physics software simulations and imaging experiments. The next crucial milestone in RefleXion's execution plan was proving that its core technology worked through these software simulations.

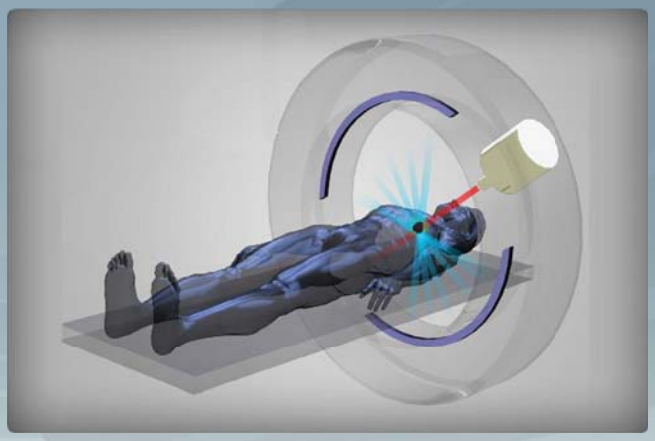
Startup capital was needed to begin this important work. In a stroke of good fortune, Mazin was accepted to the 2009 Ewing Marion Kauffman Foundation (USA) Postdoctoral Entrepreneurship program, designed to help scientists commercialize innovative technology. The program gave Mazin the freedom (and a year's funding) to focus 100% of his postdoc time on the company.

With the Kauffman fellowship serving as RefleXion's first funding and Nanduri completing his MBA at MIT's Sloan School of Management, Nanduri moved to Palo Alto in 2009 and the two cofounders began weeks of all-night coding sessions.

Using a refurbished personal computer in Mazin's living room and open-source software packages (for physics simulations and for an integrated development environment), Nanduri and Mazin created a complete physics software simulation framework that modeled key aspects of their proposed system.

Their efforts consisted of more than 30,000 lines of C++ code and played a crucial role in raising a seed-round of funding from former industry executives and clinicians in late 2010.

This work was also instrumental in obtaining a Small Business Innovation Research grant from the U.S. National Cancer Institute in 2011 to carry out the first PET imaging experiments in collaboration with the Stanford Cancer Institute.



Concept of RefleXion system.

Low-key marketing approach

Generating 'buzz' for medical technology is a delicate process where overly aggressive claims can backfire by upsetting the U.S. Food and Drug Administration (FDA) and alienating clinicians. Mazin and Nanduri decided on a grassroots approach, where credibility with the medical-physics and radiation-oncology communities would be earned through concrete data and results.

In July 2010, the initial physics software simulations were submitted to the American Association of Physicists in Medicine (AAPM) annual meeting in Philadelphia, where they showed how radiation would track a moving PET-active target.

At a 2012 AAPM meeting, more than 100 physicists and R&D industry executives attended RefleXion's oral presentation on a retrospective patient-feasibility study in collaboration with Stanford and the Georgia Institute of Technology (Georgia Tech).

To date, RefleXion has participated in nine scientific and medical conferences, and through these has cultivated key relationships with leading physicists, oncologists, and industry executives.

Continued on page 26 ▶

Donna Connor Photography

Akshay Nanduri, left, and Sam Mazin say the key lessons from starting their medtech company are to surround the founding team with experienced clinicians and advisers and to stay capital-efficient as long as possible while producing predictive results that reduce project risk.

Next steps for RefleXion

With support from a business and scientific advisers, engaged seed investors, the National Cancer Institute, and key partnerships, RefleXion is poised to execute its vision for dramatically improving cancer treatment with its biologically guided radiation-therapy system.

RefleXion's patented technology uses signals emitted from the tumor itself to guide the treatment beam.

"Personalized radiotherapy has long been desired as a tool for clinicians to improve efficacy," says John C. Ford, a seed investor in RefleXion and former senior vice president and senior scientist at Varian Medical Systems.

RefleXion anticipates closing a major round of institutional funding in 2013 that will result in an expansion of the R&D team to 12 engineers (mechanical, electrical, and software) and physicists.

When that is completed, the next step will be the development of the first hardware system that will bring biological information into the treatment room for the first time.

Birth of a startup

◀ *Continued from page 25*

"We are a scrappy startup inspired by many of our innovative predecessors who have brought new technologies to market in a cost-effective manner," Nanduri says of the company's marketing strategy. "RefleXion's 'booth' at these shows has historically been a small table commandeered outside the exhibit hall. Clinicians huddle around a laptop and get excited about our results and experiments, which is reassuring and fits our current budget."

The gray hair factor

Unlike Internet startups, new companies in the life sciences can be penalized for having a young founding team. To address this, RefleXion decided to recruit a respected group of scientific and business advisers, not only to gain credibility but also to answer key clinical questions and solidify their business/execution plan.

This "gray hair" factor became increasingly important as RefleXion pursued institutional funding from venture capitalists. Through the Kauffman Foundation, they recruited Jay Watkins, a highly experienced med-tech entrepreneur, executive, and venture capitalist, to join their Board of Directors.

"Jay Watkins and our business advisers have made numerous introductions to leading venture capital firms, helped us hone our business plan and investors' pitch, and continue to be a highly-valued strategic sounding board," Mazin says. "They are also playing a key role in pulling together our first round of institutional financing."

The company has also recruited key thought leaders from radiation oncology, radiology, and molecular imaging to join the Scientific Advisory Board. Through these relationships, RefleXion has formed important research collaborations with Stanford, the University of Chicago, the MD Anderson Cancer Center, and Georgia Tech.

Investors become advisers

A common financing path for startups is to raise seed capital from friends and family. These entrepreneurs, however, believed in a different approach and decided to exclusively target individuals and organizations who would add value on top of their money.

Former industry executives, leading clinicians, entrepreneurs in medical imaging, and even a free-standing cancer center were targeted and ultimately invested in RefleXion based on promising scientific simulation results and the potential of the core technology.

RefleXion is now reaping the rewards from that decision with its seed investors constituting a second set of advisers who actively contribute to the success of the company.

Moreover, the seed-round fundraising strategy sends a strong signal to the market as well as future/prospective investors that RefleXion's biologically guided radiation-therapy system is a big opportunity in cancer care.

A little help from friends

Throughout its four years of life, RefleXion has forged key partnerships with academic institutions, research entities, and companies that have been instrumental in solidifying the company's position in intellectual property, R&D tool/efficiency, and clinician acceptance.

For example, the University of Chicago granted RefleXion an exclusive license on critical complementary IP in 2011, and the National Research Council of Canada provides a key Monte Carlo software package. CliQr, a venture-backed Silicon Valley startup that builds cloud-computing software and services, works closely with the young company on improving the execution time of simulations; and a leading diagnostic imaging-system player recently donated a radiotherapy treatment-planning workstation for research purposes.

RefleXion has also benefited significantly from connections with Stanford (Ignite, BASES business plan competition) and MIT (the MIT $100K business plan competition, MIT Venture Mentoring Service, and the Sloan alumni network).

"In a cash-constrained climate, it is critical to search relentlessly for organizations, institutions, and people that believe in your mission and are aligned with your company's goals," Nanduri says. "This can lead to partnerships and relationships that create significant value in a cost-effective manner."

–Sam Mazin is president and cofounder of RefleXion Medical and inventor of the company's core technology. He has a BASc in computer engineering from University of Waterloo (Canada) and a PhD in electrical engineering from Stanford University (USA). He has presented several papers at SPIE Medical Imaging and received the cum laude poster award at Medical Imaging 2007 for "A Fast 3D Reconstruction Algorithm for Inverse-Geometry CT Based on an Exact PET Rebinning Algorithm."

–Akshay Nanduri is RefleXion's cofounder and vice president of business development. He has more than 10 years of experience in software engineering, product management, and technology commercialization and led RefleXion to the semifinals of the MIT Business Plan Competition in 2009. His MASc and BASc degrees in computer engineering are from University of Waterloo, and his MBA is from MIT. ■

STARTUP challenge

The founders of a one-year-old company that is developing a rapid 3D surface-inspection system for aircraft rivets took home the $10,000 first-place prize at the SPIE Startup Challenge in February.

Arun Chhabra, a former digital light processing (DLP) manager at Texas Instruments and now CEO of 8tree, and SPIE member Erik Klaas, 8tree CTO, won the top prize for their fastCHECK system, which can rapidly and accurately inspect the external rivets on an airplane to ensure they are perfectly flush with the plane.

The 8tree system can speed the manufacturing, quality assurance, and maintenance of aircraft with real-time scanning and analysis by addressing a chronic problem in the airline industry of fasteners that don't meet specifications.

The founders impressed a panel of judges with their plan to replace the established 2D inspection techniques with 8tree's patent-pending 3D measuring modality. Chhabra's winning pitch described the portable fastCHECK system as a combination of a high-performance 3D optical scanner with augmented-reality techniques.

Now in its third year, the SPIE Startup Challenge at Photonics West expanded the prizes this year through sponsorship from JENOPTIK and additional support from TRUMPF, Open Photonics, Knobbe Martens, and University of California, Davis, where the three top winners and an additional seven finalists will receive sponsorship to attend the Entrepreneurship Academies. The UC Davis academies offer help to beginning entrepreneurs who can refine their business case, analyze the market more fully, and develop a network of connections to help drive their new business.

2nd, 3rd place for biophotonics startups

The $5,000 prize for second place went to SPIE member Ryan Denomme, founder of Nicoya Lifesciences, which has created the Nicoya HeartDoc, a device for the home that can measure brain natriuretic peptide (BNP), a biomarker indicator of heart failure. The device uses a disposable cartridge to measure BNP levels and transmits the information via smartphone to a physician for review.

Denomme notes that the BNP analysis device is designed to capitalize on a $2 billion global market opportunity. He says people with chronic heart failure have a 50% rate of being hospitalized for recurrence within six months of diagnosis, so an in-home diagnostic device could reduce that rate.

Frank Palmer, CEO of ColdSteel Laser, won the $2,500 third prize for his "Remote image-guided endoscopic surgery (RIGES) platform." The RIGES device uses transmissive optics to steer a surgical CO_2 laser within the tight confines of a patient's body. Palmer hopes his technology will result in faster surgeries, fewer surgical complications, shorter hospital stays, and more surgeons who can perform minimally invasive laser surgery on patients with early-stage cancers.

Judges for the final round of pitches at the 2013 SPIE Startup Challenge were SPIE Fellows Jay Kumler, president of JENOPTIK Optical Systems, and Adam Wax of Duke University; SPIE Senior Member Jason Eichenholz of Open Photonics; Patricia Glaza, a principal at Arsenal Venture Partners; and Bruce Itchkawitz, a partner in Knobbe Martens.

Videos of the winning pitches at the SPIE Startup Challenge are available online at: www.spie.org/2013startup. ■

–Reported by Christina CC Willis and Goldie Goldstein.

SPIE Startup Challenge prize winners, from left: Arun Chhabra of 8tree, Ryan Denomme of Nicoya Lifesciences, and Frank Palmer, CEO of ColdSteel Laser.

Hologram Production

European team finds techniques for mass production of computer-generated holograms.

By **Christophe Gorecki** and **Ignacio Moreno**

More than four decades after the first computer-generated holograms (CGHs) were introduced by Adolf Lohmann and his coworkers[1], CGHs continue to play an important role in modern optics for generating specific optical functions. The CGHs can transform incident light beams into arbitrary wavefronts. This is possible because we can now create micro- and nano-size structures, designed to generate specific diffraction patterns.

CHGs are used for interferometric testing, wavefront shaping, pulse shaping of femtosecond lasers, and for highly efficient coupling of light onto optical fibers. Security is another big application for CGHs because they can authenticate products and prevent counterfeiting and falsification.

Numerous studies have been conducted to improve the hologram fabrication process and design, resulting in advances such as powerful numerical calculation techniques to efficiently calculate complex diffractive structures. Scientists have also developed cost-effective fabrication processes and effective tools for the quality evaluation of the fabricated elements.

Creating CGHs requires precise generation of the microstructures. Many different technologies have been demonstrated over a variety of substrates, including spatial light modulators (SLMs) capable of reproducing programmable CGHs.

Despite the progress, fabrication of these optical micro-structures remains a technically complex process[2]. Manufacturing technologies adapted from the semiconductor industry, such as laser or e-beam lithography, have been demonstrated to be the most competitive ones. Such modern lithography techniques can expose large substrates to create diffractive patterns with high enough resolution and accuracy to efficiently reproduce CGHs.

Research teams at the Institut FEMTO, from Université de Franche-Comté (France), and the Departamento de Ciencia de Materiales, Óptica y Tecnología Electrónica, from Universidad Miguel Hernández (Spain), have been collaborating on solutions to this problem. Our 2010 paper, "Low cost production of computer-generated holograms: From design to optical evaluation," which received the 2012 EOS Prize from the European Optical Society, describes some useful techniques for the mass production of CGHs.

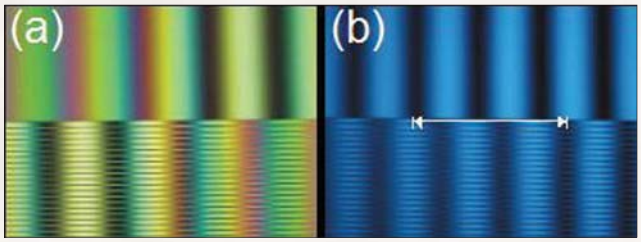


Fig. 1. Microscope images of the binary diffraction grating captured with the interferometric objective for broadband illumination and monochromatic illumination at 488 nm.

Our teams applied standard silicon micromachining techniques to fabricate CGHs and developed characterization techniques for their optical inspection[3]. These techniques represent a useful guide for the production and inspection of CGH at a relatively low cost.

Master substrate on silicon

In spite of its relatively poor optical properties, silicon offers very attractive possibilities as a substrate for CGHs in combination with high-quality materials. In addition, the inclusion of micromachining steps is an accessible mass-production method that minimizes fabrication complexity, component turnaround time, and cost.

CGHs with a continuous phase profile (kinoforms) provide higher diffraction efficiencies. However, elements with multiple phase levels usually require a multistep fabrication process, with the consequent disadvantage in terms of time and the strict requirements on multimask alignment and etching accuracy.

Therefore, binary-phase holograms would be better in terms of fabrication simplicity and reduced cost.

We developed binary-phase CGHs by selectively etching a SiO_2 layer grown onto a silicon substrate. Although reflections on Si cause important losses that affect the overall diffraction efficiency, these are excellent candidates to be used as master CGHs for replication onto other types of substrates[4]. This can be done directly with polymer or onto Ni molds by electroplating as inserts for mass production replication tools, such as hot embossing or micro-injection molding.

The phase difference between the two levels of binary CGHs is the key parameter to achieve a good diffraction efficiency. The optimal diffraction efficiency is obtained when this phase

difference is of π radians (modulo 2π). In other words, the optical path difference between the two levels must be λ/2, with λ being the wavelength of the CGH.

Inspection of production process

The development of inspection tools to easily characterize this phase shift is obviously important for quality control of CGH production processes.

We applied various optical inspection tools such as spectral ellipsometry to measure the reflection coefficients and derive efficiency. Interference microscopy is another useful technique to measure depth changes as shifts in the interference fringes[5].

We used a Nikon LV100-Pol microscope to directly visualize the phase shift between the two levels of the fabricated holograms. Figure 1 on previous page illustrates this, here applied to a binary diffraction grating fabricated onto the same wafer with the same conditions as the CGH. Fig. 1(a) shows the image captured with broadband illumination and a 20x Mirau-type interference objective.

The microscope platform tilt is adjusted to obtain parallel interference fringes perpendicular to the border between the uniform region and the grating region. The uniform region corresponds to the area where SiO_2 was not removed. A shift in the polychromatic interferogram on the top of the image is clear in comparison with the one on the bottom, which corresponds to the area where SiO_2 is not removed. This lateral shift is greater than two fringes and is clearly visible for the whole broadband spectrum.

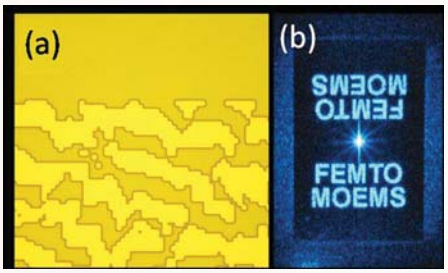


Fig. 2. Detail of a fabricated CGH and its optical reconstruction with a laser beam of 488 nm.

Figure 1(b) shows the corresponding image when a blue interference narrowband filter centered at 488 nm is introduced in the microscope. The blue image shows a shift of approximately 2.5 fringes, denoting a phase shift of 5π radians, thus providing a good diffraction efficiency for this hologram illuminated with this wavelength.

Excellent reconstruction of patterns

The application of powerful numerical tools such as iterative inverse Fourier transform algorithms (IFTA) permits us to calculate phase patterns that very efficiently reproduce a desired pattern.

In this case, the target pattern is the text FEMTO-MOEMS. Figure 2(a) above shows a detail of the developed CGH, while Fig. 2(b) shows the experimental — and excellent — reconstruction

Continued on page 31 ▶

BiOS Hot Topics

from optogenetics to tissue imaging

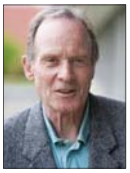
Speakers at this year's BiOS Hot Topics session at SPIE Photonics West discussed the challenge of integrating optics and photonics technologies into clinical practice and provided updates on applications such as surgical robotics and tissue imaging for diagnosing and treating stroke, cancer, and other conditions.

Hundreds of people packed into a room at the Moscone Center in San Francisco to hear eight speakers in a session moderated by SPIE member Sergio Fantini of Tufts University.

Many of the speakers' presentations from Hot Topics and Photonics West plenary sessions are available in multimedia format at www.spie.org/PW13presents.

The next BiOS Hot Topics session will be held 1 February 2014 during SPIE Photonics West.

Bamberg on optogenetics



Bamberg

Ernst Bamberg of Max Planck Institute fur Biophysik (Germany) led off with a talk on optogenetics, a field that uses light to signal functional changes in the activity of individual neurons in living tissue. The cells of the neurons express a protein, channelrhodopsin, which acts to light gate ion channels.

The absence or presence of light (or light of specific wavelengths) can inhibit nerve cells from firing. This capability can be used to map the motor functionality of the brain or to control functionality of other cells. Bamberg showed how this technique can be used to activate cells in the optic nerve for those without sight or to stop and start a beating heart in a small animal.

Sorger on robotic surgery

Sorger

Jonathan Sorger of Intuitive Surgical (USA) discussed the benefits and challenges of robotic surgery and the desire to combine diagnosis, tissue characterization, and treatment into the clinical workflow. Robotics are minimally invasive and reduce bleeding, chance of infection, and length of hospital stay.

Robotic systems also provide a stable platform for imaging modalities used by the surgeons during procedures, Sorger explained. However, the surgical environment presents many challenges to this instrumentation, such as motion of the subject and the need for high positional accuracy.

Choi on imaging hemodynamics

Choi

SPIE member Bernard Choi of the Beckman Laser Institute (USA) spoke of the need for a real-time image guidance technique that identifies blood-flow changes during procedures such as laser treatments to reduce port-wine stain of the skin. He discussed speckle imaging techniques for that procedure as well as in neurosurgery, where blood flow needs to be monitored during clamping, cutting, and re-sectioning of blood vessels.

Choi presented approaches using the speckle produced by structured illumination to map scattered and absorbed light in such a way as to produce a more absolute scale of blood flow and help reduce the uncertainty associated with current practice.

Bio-inspired camera lens

A bio-inspired design for a simple digital camera system was the topic of one of the first talks presented at SPIE Photonics West in February.

In "Digital cameras in bio-inspired designs: from humans to flies," SPIE member John Rogers of University of Illinois at Urbana-Champaign explored methods of producing curved optical detector arrays with a thin silicon substrate and a pre-stretched elastomer base.

Proceedings from SPIE Photonics West can be viewed in the SPIE Digital Library (SPIEDigitalLibrary.org).

Flow cytometry and high-speed OCT


Zharov

SPIE member Vladimir Zharov of University of Arkansas for Medical Sciences (USA) explored ways of monitoring the characteristics of a patient's blood as it passes through the veins. His approach uses magnetic nanoparticles targeted to attach to specific cells in the blood.

A strong magnet near a surface vessel would attract these particles to the vessel edge where they could be sampled by non-invasive techniques using lasers and the spectral response of the plasmonic nanoparticles. This could provide diagnostics, destroy cancer stem cells and/or infected cells, and provide therapy for the disease.


Potsaid

Ben Potsaid of Massachusetts Institute of Technology (USA) noted that optical coherence tomography (OCT) is a powerful technique for volumetric scanning through material like living tissue and for mapping the layers of cells within that tissue. However, in order to produce an image, the laser source needs to be swept across the sample in 2D fashion, and the data must be gathered quickly to create an image.

Initial implementations of OCT used time-domain techniques that limited data collection to 400 samples/second. The next advancement came with spectral domain OCT and improved the rate to 26,000 samples/second. Potsaid discussed a swept-source technique using a MEMs tunable vertical cavity surface-emitting laser (VCSEL) which improves speed by a factor of 50. The MEMS element is modulated at 600kHz over a range of only 1 micron.

Oron on tissue photoactivation


Oron

Dan Oron of Weizmann Institute of Science (Israel) discussed how to overcome a broad area of response from laser illumination of tissue that scatters light in front of and beyond the focus region. Oron discussed using two-photon techniques where only the region of interest contains the two-photon response; diffuse light is too weak in other regions.

Temporal focusing uses multiple pulses and changes the duration of the individual pulses so that their overlap at a specific location is limited in time. This combination of spatial and temporal focusing provides improved sensitivity which facilitates much longer depths of penetration in tissue. This technique was used to photoactively stimulate a single neuron through 200 microns of nerve tissue.

Fink and Culver on imaging


Fink

Mathias Fink of ESPCI, CNRS (France) explained his multiwave approach to elasticity, or shear-wave, imaging for cancer detection.

Acoustic imaging uses a phased array of ultrasound sources to focus a compression wave through the tissue. Fink showed how a time-reversal analysis technique of data from an array of receivers produces a reconstruction of the transversed medium and an image of internal subject. The time-reversal analysis is made possible because the speed of sound in most soft medium is fairly uniform.

The technique allows for faster scan times and more detail, both of which lead to improved specificity for detection of tissue density changes from cancer.


Culver

Joe Culver of Washington University in St. Louis (USA) described how diffuse optical imaging of scattered light is being investigated to produce a more portable brain-monitoring system.

Functional magnetic resonance imaging (fMRI) is currently used to map brain activity by employing tasked-based testing while the subject is in the MRI instrument. But this is not transportable to the operating environment.

The new technique uses correlations among multiple detector signals to map regions of brain activity. Pilot studies are underway in operating rooms and prenatal care units where resolution, field of view, and wearability of the instrument are being investigated.

Read more highlights from BiOS and other symposia at Photonics West 2013 online at spie.org/pwnews. ■

Hologram Production

◀ ***Continued from page 29***

of the text obtained by Fourier transforming the optical wavefront simply by diffraction in the Fraunhofer regime.

Additional terms, or orders, are also observed in the diffraction pattern, like the zero order (DC) peak present on axis, and the inverted reconstruction corresponding to the negative first order. ■

–SPIE Fellow Christophe Gorecki serves on the SPIE Board of Directors and is director of research at FEMTO-ST Institut National Centre for Scientific Research (CNRS) and Université de Franche-Comté (France). His PhD in optics and signal processing is from Université de Franche-Comté.

–SPIE Senior Member Ignacio Moreno is a professor of optics at the Universidad Miguel Hernández in Elche (Spain). He has a BS and PhD in physics from the Autonomous University of Barcelona (Spain).

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R&D Highlights

EDITOR'S RECOMMENDATION

Phase-based OCT sheds light on glaucoma

Glaucoma, a leading cause of irreversible blindness, results from an aqueous outflow abnormality. Abnormal intraocular pressure in glaucoma results from changes in the mechanical properties of the trabecular meshwork, a tissue that controls both aqueous outflow and intraocular pressure (IOP). No technology has previously been available to assess the properties of the trabecular tissues that control aqueous outflow.

At University of Washington (UW), Murray Johnstone, a glaucoma specialist and clinical professor with the Eye Institute, took the problem to SPIE Fellow Ruikang Wang, a professor in the Department of Bioengineering. Working with a team of researchers, Johnstone and Wang developed a new conceptual framework based on examining the way the tissue moves, a motion-based optical coherence tomography (OCT) to monitor dynamic tissue movement with sensitivity at the sub-nanometer scale.

As recently reported in the *Journal of Biomedical Optics*, the group developed a phase-sensitive OCT (PhS-OCT) specifically tailored to measure tiny trabecular meshwork movements in response to pulsatile changes of IOP. The group demonstrated the feasibility of the PhS-OCT in ex vivo primate eyes subjected to experimentally induced pulsatile pressure-gradient changes (3mm Hg). The pulse amplitudes and frequency mimicked typical in vivo intraocular pressure oscillations resulting from cardiac-pulse-induced changes of intraocular vascular volume.

The UW researchers found that the detected trabecular meshwork movement was highly synchronous with the ocular pulse, experiencing tissue displacement amplitudes of ≤4μm.

Aqueous humor flows through the trabecular meshwork into a venous sinus called Schlemm's canal. The PhS-OCT was able to measure synchronous pulse-dependent trabecular meshwork velocities, displacement, and strain rate (with ~20 nm sensitivity) while simultaneously using spectral domain OCT to measure Schlemm's canal volume changes. Analysis of the data indicates that pulse-induced trabecular meshwork excursions into the canal are enough to account for all of aqueous outflow.

Dynamic motion of the trabecular meshwork has previously been unrecognized. This new non-invasive technology provides both quantitative measurements of movement and insights into trabecular tissue biomechanics.

Early glaucoma detection

Clinically, this new ability to detect outflow system properties holds the promise of permitting both earlier abnormality detection and recognition of progressive outflow system malfunction that reduces its ability to maintain IOP homeostasis. Such information should permit better-informed and timelier decisions in glaucoma management.

With the technology, Johnstone finds that it is possible to watch the internal motion of the meshwork as the pressure-induced wave propagates outward to the external wall of Schlemm's canal. Johnstone sees this new technology as a breakthrough in glaucoma management which is currently limited to treating IOP and based on remarkably limited knowledge of the IOP profile over time in individual patients.

"We measure intraocular pressure maybe three to four times a year, each time for about 3 seconds," he says. "That's about 12 seconds per year, and we miss out on what's going on in the other 31 million seconds."

In addition, Johnstone points out there are issues with how the pressure is measured with the eye looking straight ahead with no movements (the normal frequent eye movements and blinking increase IOP ~30% from baseline).

We also measure IOP during the daytime, whereas pressures often rise 20%-30% at night. Current IOP measurements do not capture these diurnal fluctuations, which are important in determining the real IOP profile and also whether medication is working.

With this new technology, practitioners can measure the mechanical properties of the meshwork and see if movement abnormalities are reducing the trabecular meshwork ability to maintain the IOP profile within a normal range.

"Also, if we see reduced trabecular movement over time, we're in a position to say this person is getting into further trouble with maintaining pressures within a narrow range. We have a new potentially sensitive predictive tool to help decide if preemptive IOP management is appropriate before the patient goes on to further structural and functional damage to the visual system," Johnstone says.

In addition to Johnstone and Wang, coauthors of "Phase-sensitive optical coherence tomography characterization of pulse-induced trabecular meshwork displacement in ex vivo nonhuman primate eyes" include SPIE member Zhongwei Zhi, Peng Li, Roberto Reif, Tueng Shen, and Elizabeth Martin.

Source: *Journal of Biomedical Optics* **17(7)**, 076026 (2012); doi:10.1117/1.JBO.17.7.076026. ■

– *Lihong Wang, editor of* Journal of Biomedical Optics.

EDITOR'S RECOMMENDATION

Dyakonov-like wave a new avenue for optical sensing applications

A surface wave has to not only satisfy the laws of electromagnetics in two distinct mediums but also boundary conditions. Hence, the propagation of a surface wave is easily disturbed by a change of constitution of either of the two partnering mediums.

This renders surface-wave propagation attractive for optical sensing of stimuli such as infiltrant matter, quasistatic magnetic fields, and temperature changes.

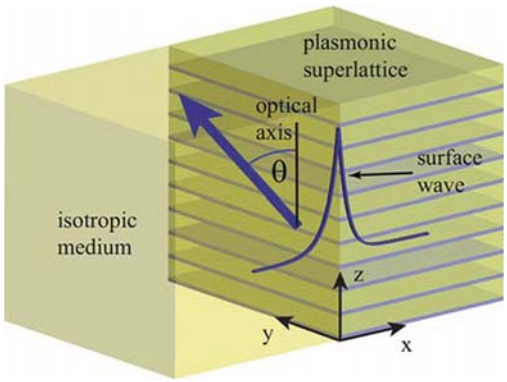
Among surface waves of different categories, the surface plasmon-polariton (SPP) wave guided by a metal/dielectric interface is extensively used for optical sensing. During the 1980s, another surface wave was theoretically predicted. It came to be called the Dyakonov wave.

Its propagation is guided by the interface of two homogeneous dielectric materials of which at least one must be anisotropic. As dissipation in both partnering mediums is extremely small, the Dyakonov wave should propagate over very long distances. It should also be excitable using the prism-coupled configuration commonly used to excite SPP waves.

The Dyakonov wave can propagate only in a very restricted range of directions along the interface. The angular existence domain rarely exceeds a degree in width, which seriously impeded experimental verification of the existence of the wave. Only in 2009 was it actually observed.

Now Juan Miret et al. have theoretically shown a way to widen the angular existence domain to several tens of degrees in their paper entitled, "Substantial enlargement of angular existence range for Dyakonov-like surface waves at semi-infinite metal-dielectric superlattice," published in the *Journal of Nanophotonics* in November 2012.

The widening is achievable by replacing the anisotropic partnering medium by a metal-dielectric superlattice with the volume fraction of the metal not exceeding 0.1. The superlattice is periodic in a direction lying wholly in the interface plane.



A schematic setup under study consists of a semi-infinite Ag-GaAs superlattice (x>0) and an isotropic cover (x<0), either N-BAK1 or P-SF68 (SCHOTT).

The incorporation of a metal in one of the partnering mediums would naturally reduce the propagation length, but the widening of the angular existence domain may compensate by making these surface waves robust for optical sensing applications.

A new avenue for experimental research beckons SPIE members and other researchers.

Coauthors in the research are Carlos J. Zapata-Rodriguez, Zoran Jakšić, Slobodan Vuković, and Milivoj R. Belić.

Source: *Journal of Nanophotonics* **6**, 063525 (2012); doi:10.1117/1.JNP.6.063525. ■

– *Akhlesh Lakhtakia, editor of* Journal of Nanophotonics.

Special sections focus on nano-bio

Papers related to the February 2013 SPIE conference on Nano-Bio Sensing, Imaging, & Spectroscopy are being solicited for special sections in two photonics journals.

The *Journal of Nanophotonics* is seeking manuscripts by 1 June for a special section on nanobiophotonics and related techniques based on the conference in South Korea. This special section is devoted to advances in the techniques and theory of nanobiosensing, nanobioimaging, and nanobiospectroscopy.

The call for papers is open to anyone who wishes to submit a relevant paper, even those who did not attend the conference.

Guest editor is SPIE member Mun Seok Jeong of the Gwangju Institute of Science and Technology (South Korea).

Other papers related to the NBSIS conference are expected to be published in a special section of the *Journal of Biomedical Optics*.

Light-emitting nanoprobes detect tumors

A group of Taiwan researchers has reported that zinc oxide (ZnO) nanorods bonded to antibodies may be useful as nanoprobes for sensing cancer cells during tumor resection.

SPIE member Yung-Tsan Chen et al. presented "ZnO light-emitting nanoprobes for tumor detection" at the Nanoscale Imaging, Sensing, and Actuation for Biomedical Applications conference at BiOS in February.

The researchers say the detection of purple light from epidermal growth factor receptor (EGFR) cells connected to ZnO nanorods may make real-time identification of cancer cells during surgery easier than with the traditional fluorescence methods. The cancer cells can be excised more precisely with the help of purple light emission, they added.

Their paper can be found in the SPIE Digital Library at: http://dx.doi.org/10.1117/12.2004511

IS&T/SPIE Electronic Imaging

SCIENCE AND TECHNOLOGY

Electronic Imaging moves in 2014 to San Francisco

Next year's IS&T/SPIE Electronic Imaging Science and Technology moves from Burlingame, CA, to San Francisco.

The symposium will be held 2-6 February 2014 at the Hilton San Francisco Union Square.

More than 1000 international experts in 3D imaging, digital photography, multimedia processing, mobile displays, computer vision, and related fields gathered in Burlingame, CA, in February to present their latest findings on the 25th anniversary of IS&T/SPIE Electronic Imaging Science and Technology.

The symposium featured more than 700 presentations in 23 conferences on the latest advances in image processing and applications for popular consumer products, with many technologies on display and several interactive special events. Among those events was a presentation on the cameras and other technologies that captured the 2012 human "space dive" from the Red Bull Stratos Project.

Plenary speaker Sabine Süsstrunk of Ecole Polytechnique Federale de Lausanne (Switzerland), who received the Electronic Imaging Scientist of the Year Award, gave an overview of how signal processing can augment photo effects to highlight so-called intangible qualities. She demonstrated how the same image can have different effects based on the "spirit" you want to capture, e.g.,"sunset," "snow," or even "strawberries."

University of Washington professor Steven Seitz's plenary talk, "A Trillion Photos," presented his group's efforts to utilize the world's collection of 2D photographs to create 3D models of historic sites. Watch the SPIE Newsroom video interview for more on his project: www.spie.org/Seitz.

Awards for 3D films

In the Stereoscopic Displays and Applications (SD&A) conference, a packed audience and three judges viewed 42 films at the annual 3D Theater session.

Two Best of Show prizes were awarded.

"Ninety Three Million Miles" from Site-Eye Time-Lapse Films, directed by Brian McClave and Gavin Peacock (UK), received the Best of Show award for 3D live action. "Nuts & Robbers" from ToonBox Entertainment (Canada) and Redrover Co. (South Korea) won for 3D CGI.

Judges at the 3D Theater session were:

- Jason Goodman, stereographer on "The Amazing Spider-Man"
- Eric Kurland, president of the Los Angeles 3-D Club and stereographer on the Oscar-nominated "The Longest Daycare" starring Maggie Simpson
- SPIE Fellow Lenny Lipton, founder of StereoGraphics Corp. and former CTO of RealD

The prize for the best use of 3D during the technical presentations at the SD&A conference was awarded to Jim DeFilippis for his keynote presentation "Coverage of the London 2012 Olympic Games in 3D."

The prize for the best demonstration at the SD&A conference went to John Toeppen and Jason Buchheim for their "Giga-Pixel Immersive Stereoscopic Panoramas."

For more event news from IS&T/SPIE Electronic Imaging: www.spie.org/news2013EI. ■

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Forum and course on export controls

An expert in international trade law will lead an open forum and teach a course on International Traffic in Arms Regulations (ITAR) at SPIE Defense, Security, and Sensing on Wednesday 1 May.

Kerry T. Scarlott of Goulston & Storrs will address the requirements of the law covering all manufacturers, exporters, and brokers of defense articles, services, or related technical data.

Discussion at the open forum will center on critical export control issues confronting the optics and photonics industry and key techniques for increasing defense-related business.

Scarlott will address the top 10 myths about export controls, including the notion that registering a company with the State Department constitutes a compliance certification.

For those wanting more in-depth information, Scarlott will also teach a course on complying with ITAR.

To view or register for this or other courses, go to www.spie.org/dsscourse.

SPIE Defense, Security, and Sensing

The annual technical event, 29 April through 3 May.

SPIE Defense, Security, and Sensing (DSS) returns to Baltimore, MD, 29 April with a continued focus on advancing technologies for sensing and security challenges and strengthening innovative teaching methods for the next generation of photonics researchers.

The exhibition at the Baltimore Convention Center will include 500 suppliers, along with a student demonstration of an aerospace reconnaissance system that was part of a high-school space-science research program. A special demonstration showcase will feature the "Virtusphere," flight simulators, unmanned aerial vehicles, and other interactive technologies.

DSS runs through 3 May, with the free exhibition occurring from 30 April to 2 May. Retired Maj. Gen. Ken Israel of the U.S. Air Force is chair of the event.

New conferences on optical space communications, flexible electronics, and next-generation analysis will join established conferences in topics such as infrared systems; lidar; radar; display technologies; unmanned systems and robotics; cyber protection; biometric technology for human identification; sensor data analysis; and energy harvesting and storage.

More than 2300 presentations are expected to be made during the week in 55 conferences covering non-classified advances in robotics, IR detectors, chemical sensors, high-speed imaging systems, ocean sensing, displays, and related topics. SPIE is also offering 50 courses onsite, an educators' workshop, a two-day Job Fair, and several other special events.

Virtusphere will demonstrate its VR training platform at SPIE Defense, Security, and Sensing.

Arati Prabhakar, director of the U.S. Defense Advanced Research Projects Agency (DARPA) and a long-time leader in research and high-tech fields, is the plenary speaker for Monday, 29 April.

Prabhakar

The Kineto Tracking Mounts on the MARS system can telescopically track and image aircraft, rockets, spacecraft, and other objects.

Technology demonstrations

A special showcase at the exhibition, "New Technology Demos and Displays," will include the Virtusphere, a virtual-reality locomotion simulator for military, law enforcement, firefighting, and other training for hazardous environments. Inside the 10-foot hollow sphere, a user wears a wireless, head-mounted display and can walk, jump, roll, crawl, or run over virtually unlimited distances without encountering real-world obstacles.

Other technologies for demonstration and display include laser propulsion, high-performance imaging, flight simulators, and the Mobile Aerospace Reconnaissance System (MARS).

The MARS system has several Kineto Tracking Mounts (KTMs) used to telescopically track and image aircraft, rockets, orbiting spacecraft, and hypersonic test vehicles. MARS' telescopes provide high-resolution visible, infrared, and spectral imaging, and can be configured for manned or unmanned operation.

The demonstration is also a showcase of sorts for inspiring young people to consider careers in science, technology, engineering and math (STEM). At the exhibition, two students, former members of a high-school photonics research program, will demonstrate a fully powered MARS KTM.

Continued on page 38 ▶

Industry sessions

Challenges of processing "big data" will be the subject of several special events during the weeklong SPIE Defense, Security, and Sensing symposium in Baltimore 29 April through 3 May.

Technical and industry events include three panel discussions on aspects of information fusion.

Srikanta Kumar, Chee-Yee Chong, and Ivan Kadar will moderate a panel discussion on Monday 29 April on processing big data, specifically as applied to information fusion.

Jerome J. Braun will moderate a discussion on information fusion and robotics, 1 May, and Shiloh L. Dockstader will moderate a discussion on Thursday on Synergistic Data Fusion through Multi-Sensing Enablement.

A workshop on early-stage IR technology commercialization on Wednesday morning is also part of a large industry program. Joseph X. Montemarano will moderate a panel from U.S. government laboratories, venture capital community, and industry.

For more information: www.spie.org/dss.

SPIE Defense, Security, and Sensing

◀ *Continued from page 37*

"These two are wonderful examples of how providing students with high-level opportunities in photonics can be life-changing," says Ron Dantowitz of the Clay Center Observatory (USA), which sponsors the high-school space-science program. "Obviously, experiences such as these enhance the possibility of their continuing in various STEM fields."

The free DSS exhibition features 500 vendors showing the latest innovations in optics, lasers, sensors, image processing, spectroscopy, infrared systems, and optoelectronic components.

Microscopy for educators

Also for science educators at DSS, SPIE Fellow Michael Postek and Mary Satterfield of the National Institute of Standards and Technology (USA) and Robert Gordon of Hitachi High Technologies America (USA) will lead a workshop on using microscopy in the teaching of science and technology.

"Microscopy for STEM Educators" will feature examples of successful programs implementing microscopy in STEM education to foster student interest and excitement. A hands-on session with tabletop scanning electron microscopes will be held at the end of the presentations and the attendees will operate the instruments.

Lifetime achievement for Long


Long

In honor of her many contributions to the defense sector, Letitia Long will receive the Defense, Security, and Sensing Lifetime Achievement Award 1 May.

Long cracked the glass ceiling for combat support when she became the first female director of the National Geospatial-Intelligence Agency (NGA) in 2010. Before that, Long served as deputy director of the Defense Intelligence Agency (DIA) and was the deputy undersecretary of Defense for Intelligence (Policy, Requirements, and Resources). Long also served in senior posts at Naval Intelligence and Intelligence Community Affairs at the Central Intelligence Agency.

Security sensor challenges

In one of several special industry and technical sessions, three U.S. national security leaders will discuss emerging sensor needs and challenges that must be overcome to provide security in the 21st Century.

Panelists on Wednesday, 1 May will address long-term breakthrough sensing challenges as well as nearer-term cost, size, and weight improvements to enable new mission capabilities.

Brigitte Berman and Yiannis Karavas will demonstrate the Mobile Aerospace Reconnaissance System at the Baltimore Convention Center.

Panelists are Stefanie Tompkins, deputy director of the Strategic Technology Office, DARPA; Peter Highnam, director of the Intelligence Advanced Research Projects Activity (IARPA); and Walter F. Jones, executive director of the Office of Naval Research.

Symposium co-chair David Whelan of Boeing Defense, Space and Security (USA) will serve as moderator.

Career development events

Networking events will include a panel discussion on getting hired in 2013 and beyond and a student "Lunch with the Experts."

Robert Kester, CTO of Rebellion Photonics, will make a presentation at a reception for early career professionals on Tuesday, 30 April.

Rebellion Photonics, begun at Rice University in 2009, commercialized a unique snap-shot hyperspectral video platform used in biological research, UAV markets, and for leak imaging in the oil and gas industry. The camera won a 2012 R&D 100 Award, and co-founder Allison Lami Sawyer was named one of "30 Under 30" entrepreneurs for 2012 in *Inc. Magazine*.

Papers from DSS will be published in the SPIE Digital Library as soon as manuscripts are approved by conference chairs.

For more information: www.spie.org/dss. ■

–Karen Thomas, SPIE staff.

Photonics in Europe's Future

SPIE sponsors several events in Europe this spring for photonics researchers and industry representatives.

SPIE Optics + Optoelectronics in Prague, 15-18 April, will include a two-day exhibition and the added attraction of presentations on the future ELI Beamlines Facility, to be built in Prague.

Talks on nanoplasmonic antennas, silicon photonics, and the U.S. National Ignition Facility (NIF) will be part of the plenary session Monday, 15 April. Speakers are:

- Roel Baets, Ghent University (Belgium)
- Mikael Kaell, the Bionanophotonics Research Division at Chalmers University of Technology (Sweden)
- Ed Moses, NIF (USA)

SPIE Microtechnologies, 24-26 April in Grenoble, France, will feature plenary talks on each day of the event. Speakers are Carol Featherston of Cardiff University (UK), Santiago Marco of University of Barcelona (Spain), and Markus Winkler from Fraunhofer Institute for Physical Measurement Techniques (Germany).

Two other meetings will be held as part of the World of Photonics Congress in Munich.

SPIE Optical Metrology, 13-16 May, will feature Wim M.J. Coene of ASML Research (Netherlands) as the plenary speaker discussing challenges in optical metrology for photolithography. An SPIE Student Chapter Leadership Workshop is also scheduled for 12 May. Students interested in attending the workshop should RSVP to students@spie.org.

The OSA/SPIE European Conferences on Biomedical Optics will be held 12-16 May. ■

PHOTONICS21

The Photonics21 annual meeting, 29-30 April in Brussels, will provide the latest information on Horizon 2020, Europe's €80 billion research and innovation program for the period 2014-20. Photonics21 President Michael Mertin and Neelie Kroes, vice president of the European Commission, are scheduled to give keynote talks.

Other highlights include presentation of the Student Innovation Award; discussion of the Photonics Public Private Partnership that the European technology platform is developing; and publication of the photonics strategic roadmap.

Information: ow.ly/iLeHt/

Advertiser Index

Optics+ Optoelectronics 15 - 18 April spie.org/oo2013	**Defense Security+Sensing** 29 April - 3 May spie.org/dss2013	**SPIE/SIOM Pacific Rim Laser Damage** 19 - 22 May spie.org/pld2013
SeTBio Sensing Technologies for Biomaterial, Food, and Agriculture 23 - 26 April spie.org/setbio2013	**SPIE/OSA European Conferences on Biomedical Optics** 12 - 16 May spie.org/ecbo2013	**Optics+ Photonics** 25 - 29 August spie.org/op2013
Microtechnologies 24 - 26 April spie.org/mt2013	**Optical Metrology** 13 - 16 May spie.org/om2013	

Abstract and Application Due Dates

Check your monthly SPIE Member E-News for Web links to the items below.

- 1 April — SPIE Alumni Advantage competition ends
  Abstracts for SPIE Remote Sensing; SPIE Security + Defence; and SPIE Optifab
- 2 April — Nominations for SPIE Senior Member
- 15 April — Abstracts for SPIE Laser Damage
- 31 May — Applications for SPIE Education Outreach grant

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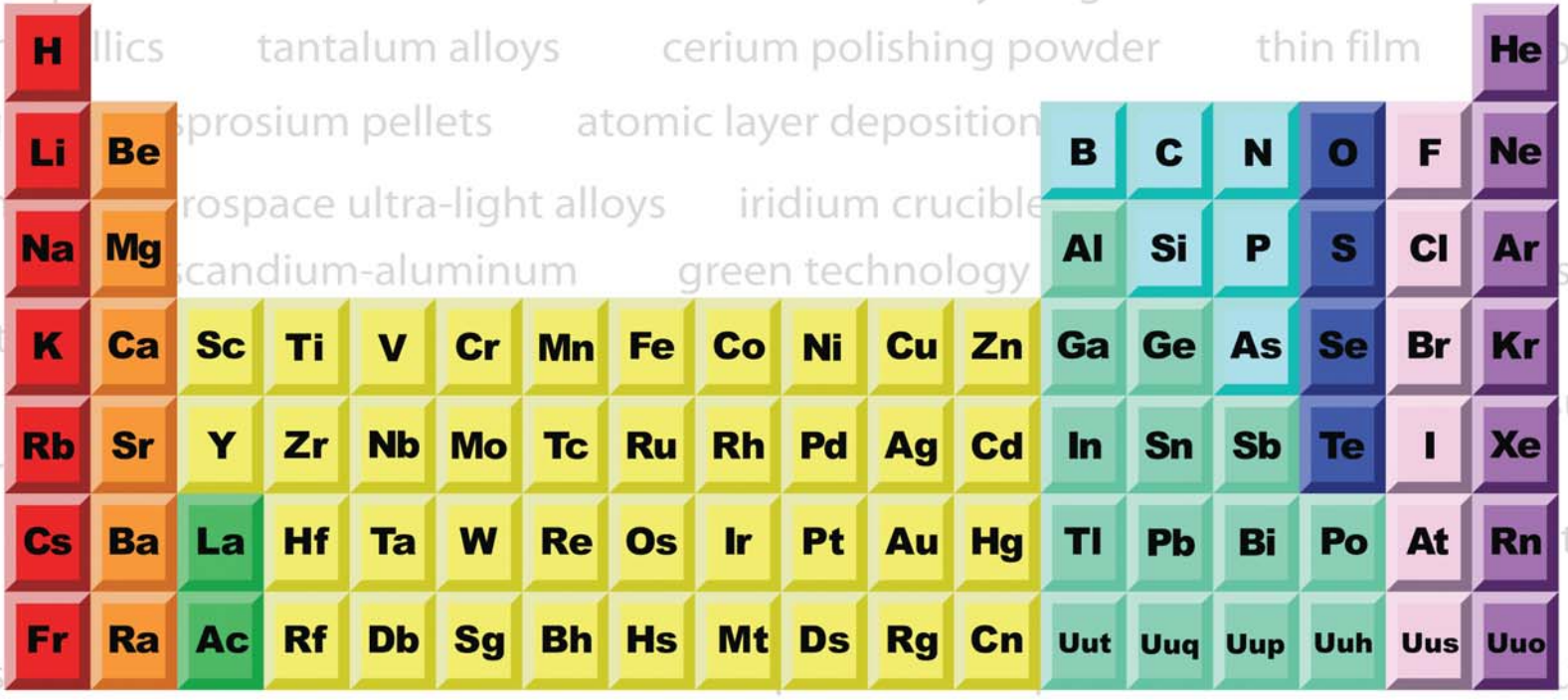

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