TUESDAY EDITION

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PHOTONICS WEST. SHOW DAILY

"Ultra" holography meets Fabergé eggs
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Canada report urges strategic focus

A new report by the Canadian Photonic Industry Consortium (CPIC), unveiled at Photonics West, is calling for the optics and photonics community in the country to focus its efforts on a "few key sectors," to be decided by a strategic panel of experts from academia and industry.

Entitled *Light Technologies: A Strategic Economic Asset*, the report states that Canada invests about C$150 million in photonics research and development centers and universities annually, employing around 1000 researchers. "However, the research is often untargeted and translation of the outcomes into commercial success must be increased," it says.

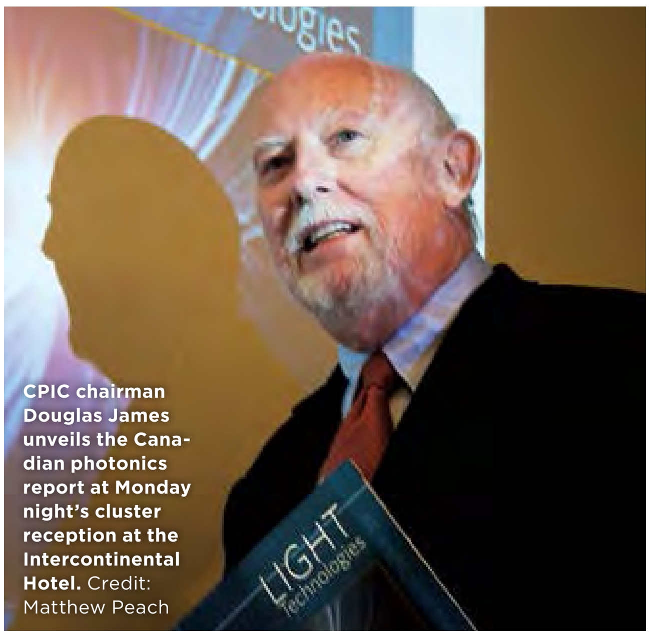
Among five recommendations in the report – which range from calls for more engagement with educators and end users, to an expansion of the existing cluster model in Canada – is recognition that technology flow and transfer between the academic and industrial sectors is "inadequate".

"We recommend establishing programs that encourage stronger participation and leadership from industrial and university partners," states CPIC.

CPIC executive director Robert Corriveau told *Show Daily*: "We need to develop a better strategic view about photonics in Canada. This report is the first step to initiate the process. We needed to document the situation to identify the way ahead."

Corriveau added that one surprising finding was the strong appetite for photonics technologies among potential end-users. "Some were already aware of the benefits of using photonics, but needed better links with photonic companies," he said.

According to CPIC the approximately 400 photonics companies based in Canada employ more than 25,000 people and collectively



CPIC chairman Douglas James unveils the Canadian photonics report at Monday night's cluster reception at the Intercontinental Hotel. Credit: Matthew Peach

generate close to C$4.6 billion annually. "Most of these companies are sub-system or system-level integrators of photonics components," it added. "Imports of photonic goods reached C$6.4 billion in 2015, indicating the increased potential for today's Canadian domestic photonics industry."

Pointing out that Canada's investment in photonics is "broad-brush and relatively unfocused", CPIC would like to see a photonics strategy group established. Its role would be to focus investment on a few key sectors judged to be of global significance during the next ten years, and where Canada has the photonics skills to make a difference.

"During the past 20 years, Canadian industry has evolved from not knowing what photonics was, to realizing that photonics pervades all aspects of our society," CPIC says. "Consequently, the Canadian photonics sector has reached a tipping-point: it can maintain the *status quo* or pursue all opportunities to play an important role in the future of both Canadian and global photonics development and manufacture."

While the country already has some strong cluster activity, CPIC points out that it is somewhat unbalanced. "The Quebec cluster is very active, while those in Ontario and the western provinces need to strengthen," it reports.

Like other parts of the world, the Canadian photonics sector comprises a small number of large companies or company divisions, but the core is firmly rooted in small and medium-sized enterprises and start-ups.

Among those at the Moscone this week are fiber laser firm MPB Communications, Vancouver-based Crosslight Software, and the Montreal high-performance CCD specialist Nüvü Caméras.

MIKE HATCHER

DON'T MISS THESE EVENTS TODAY

PLENARY SESSION
NANO/BIOPHOTONICS
10:30-11:30 AM
ROOM 3002, WEST
Halina Rubinsztein-Dunlop
(Univ. of Queensland)

INDUSTRY EVENTS

SPIE Job Fair
(10 AM-5 PM, South Exhibit Hall)

Silicon Photonics and PIC panel
(1:30-3 PM, Room 103, South)

Patent filing workshop
(1:30-3 PM, Room 102, South)

Non-financial reporting session
(3-4:30 PM, Room 102, South)

Financing photonics businesses panel
(3:30-5 PM, Room 103, South)

See the technical program and exhibition guide for more details on daily events. Conference registration may be required. Industry events are open to all registration categories, except where noted.

IN THIS ISSUE

Optical microscopy, translational research take center stage at BiOS Hot Topics

The popular BiOS Hot Topics sessions are known for showcasing cutting-edge biomedical optics technology and research, and this year's event, held Saturday evening in a cavernous West Hall venue filled nearly to capacity, was no exception. Surprisingly, the star of the night turned out to be one of the old guard — optical microscopy — but with a few new twists.

Hot Topics is a unique platform that allows the well-known as well as the up-and-coming to share their latest research advances — albeit in a neat and tidy 10-minute package. The result is that, in about two hours, "you really get a sense of the state-of-the-art," noted co-chair Sergio Fantini of Tufts University.

In addition to giving visibility to new ideas, Hot Topics gives the biomedical optics community "snapshots" from a number of subareas in biomedical optics.

In recent years Hot Topics has seen a growing emphasis on translational research and clinical applications that use optical technologies to address ongoing challenges in diagnosing and treating cancer, heart disease, and other critical medical conditions.

"I've been coming to this meeting for a long enough time that I can see the progress being made," said BiOS co-chair R. Rox Anderson. "It is all about helping people, and we are seeing real applications emerging."

The evening kicked off with a tribute by David Boas, winner of the 2016 Britton Chance Biomedical Optics award, to his long-time mentor. Boas and Chance worked together for more than 20 years, starting when Boas was pursuing his PhD at the University of Pennsylvania and continuing after he moved on to Harvard and Massachusetts General Hospital. They also shared a passion for sailing, Boas noted.

Lee Rosen, a scientific review officer at the National Institutes of Health (NIH) who lost his battle with leukemia in 2015, was also honored. Behrouz Shabestari of the NIH's National Institute of Biomedical Imaging and Bioengineering praised Rosen for his unparalleled support of biomedical optics and imaging research projects over nearly three decades. He was known for going out of his way to recruit the most appropriate reviewers and for helping grant applicants better understand the review process.

First to take the stage at the Hot Topics session, Melissa Skala, assistant professor of biomedical engineering at Vanderbilt, discussed her group's work using quantitative microscopy and tumor organoids to streamline drug development and treatment planning for pancreatic cancer.

"Pancreatic cancer is one of the most lethal cancers; only 8% of those diagnosed survive five years," she said. "And because each tumor is unique, we have to use trial and error to determine the proper treatment regimen. There is an opportunity here to bring new tools to combat this problem at a new level."

Tumor organoids are three-dimensional cultures, grown from actual tumors, that closely replicate key properties of those tumors. They could pave the way for individualized treatment approaches that optimize clinical outcomes in cancer patients.

"In my lab, we are interested in grabbing a tumor and understanding it at the patient level," Skala said. "New drug development is equally important, and we need a high-throughput technique to speed this process."

Aaron Aguirre, assistant professor at Massachusetts General Hospital, discussed how microscopy techniques can be used to assess a beating heart at subcellular resolution in small animal models. The goal is to better understand what happens to heart cells following a myocardial infarction and thus prevent subsequent heart failure in these patients.

"As a cardiologist, I take care of many patients who have heart attacks, which are responsible for 1 in 7 deaths in the US annually," Aguirre said. "We can respond with drugs and other treatments, but many patients still go on to have heart failure. We need to understand how heart cells are injured and how we can intervene to defer death."

Researchers and clinicians lack the ability to image and quantify cells *in vivo* and observe cellular physiology in its natural environment, he added. This is where new types of microscopy, such as intravital imaging and prospective sequential segmented microscopy (PSSM), come in.

"We have achieved motion-artifact-free imaging of a beating heart at microscopic resolution by applying new image-processing algorithms (PSSM) and a highly effective tissue stabilizer to intravital microscopy," he said. "We want to use these methods to further study phenomena in this environment and improve drug delivery and patient morbidity."

David Sampson of the University of Western Australia gave an overview of "microscope in a needle" technology for surgical interventions. By putting a microscope inside a standard hypodermic needle to enable 3D scanning, surgeons should be able to locate very small tumor elements, avoiding the need for further surgery.

"We've been applying these probes to basic physiology problems, but we want to find human applications as well, particularly in breast cancer," he said. "We've demonstrated that we can distinguish between tumor and adipose tissue, but you can't tell just by looking at the scattering signature the difference between benign and cancer cells."

So they are now exploring polarization-sensitive OCT in a needle to add fluorescence to the mix. For example, optical coherence elastography in a needle uses the capacity of OCT in the axial direction to measure very small deformations of tissue with sub-nanometer sensitivity and to differentiate adipose and tumor tissue. Other groups are experimenting ,with this approach in ophthalmology, cardiology, and cell mechanics and also developing ultra-high-resolution elastography, Sampson noted.

SPIE President Robert Lieberman, David Boas and Bruce Tromberg. Credit: Courtney Rambo

Photoacoustic imaging pioneer Paul Beard of University College London discussed advances coming out of his lab and elsewhere. One of the challenges in detecting photoacoustic signals is that they are extremely weak due to optical and acoustic attenuation, Beard noted. His group is using resonant polymer optical cavities to better detect these signals.

"The advantage is it has the potential to offer very high sensitivity and broadband uniform frequency response, and the optical element is less than 50 microns in size," he noted.

They have created a number of instruments based on this technology, such as a small-animal scanner that uses planar arrays and an optical parametric oscillator (OPO) excitation laser system that maps the photoacoustic field in 2D and reconstructs the image in 3D. They have also used this system for in vivo imaging of label-free tumor vascular-targeted therapy.

Meanwhile, advances in adaptive optics are enabling *in vivo* imaging of retinal structures to see "invisible" cells, measure retinal function and understand what cells in the retina are really doing.

Jennifer Hunter of the University of Rochester and the Advanced Retinal Imaging Alliance said the goal is to use adaptive optics to visualize "through the eye to look at structures in the back of the eye, such as individual rods and cones and retinal pigment epithelial cells in retinal or ganglion cells, which are difficult to see because they are transparent."

For example, *in vivo* two-photon ophthalmoscopy can image many retinal structures by tapping into fluorescence from inner retinal cells, enabling researchers to see transparent cells such as photoreceptors, the outer nuclear layer, and ganglions without dyes. Likewise, multi-offset detector imaging reveals ganglion cells, while two-photon fluorescence imaging can measure retinoid kinetics and track fluorescence intensity in the eye over time. And in mouse retina studies, wavefront sensorless adaptive optics was used to see small vessels and nerve fiber bundles, which could help clinicians see improvements in vascular quality following surgical correction.

On a more technical note, Eric Potma of the University of California, Irvine used basic physics to explain how optical microscopy techniques such as second-harmonic generation, sum-frequency generation, and coherent anti-Stokes Raman spectroscopy can be "boosted" to increase the number of photons that can be collected. The key is to stimulate the optical process by introducing beams of the same color as the input source and then use the resulting intrinsic parametric processes and dissipative pathways to create quantum interference.

Finally, Heather Franklin, co-founder of Blaze BioScience, discussed the company's ongoing efforts to develop and commercialize a novel contrast agent for targeted fluorescence image-guide surgery. (See related story in Wednesday's issue.)

KATHY KINCADE

A banquet of opportunities

Photonics technologies will continue to outperform global economic norms, writes SPIE CEO Eugene Arthurs.

Welcome to Photonics West 2016 and to the always welcoming San Francisco. I was once a faithful reader of Herb Caen's insightful columns in the *Chronicle*, and love his quote "One day if I go to heaven...I'll look around and say, 'It ain't bad, but it ain't San Francisco'."

We are at a time when modest GDP growth is expected for most of the developed world. Forecasters seem to have learned about the "new normal," and even though forecasts are draped with caveats about geopolitical turmoil and concern about how China's large economy will adjust, the consensus for ongoing slow but solid recovery from the "Great Recession", perhaps with a higher noise-to-signal ratio than we like, has a feeling of credibility.

Challenging demographics and market volatility

Precedent is no longer so useful for economic forecasting as we are in a new era, with challenging population-growth demographics and globally mobile capital. We've seen one serious market fluctuation already in 2016, and there will be more. The doomsayers who fill my email trash with predictions of a crash will eventually be correct of course, but I think they will have to wait for their "I told you so" moment, and be wrong in the meantime. Those with longer integration times will sleep better than those who allow themselves to be swept with hourly, daily, or weekly market numbers. Volatility aside, the world will move forward as human potential grows. And I expect that photonics technologies will continue to outperform global economic norms.

During 2015, the International Year of Light and Light-based Technologies (IYL), my perspective was stimulated by visits to large new photonics centers and by learning of new photonics programs around the world. Clearly, how much we may outstrip GDP or other economic measures is in our hands. The potential and power of photonics offers a banquet of opportunities. Turning these into results will require our creativity, energy, and talent. Putting useful products in the hands of the end user should be our goal – whether a physician, an engineer in advanced manufacturing, any of us who enjoys communication or entertainment, or who endeavors to satisfy the insatiable human curiosity.

For the US, the compromise Omnibus Bill signed in December 2015 includes a fillip for science. Photonics pervades scientific R&D. That's great in the short term for those who serve the R&D market, and innovation will eventually result from some of the research spending, with both social and economic benefits. I still believe global attention must be directed towards developing and supporting an efficient innovation infrastructure beyond the important R&D investment.

I have long been frustrated that so much of what the photonics community has done to change the world is rarely acknowledged. Now I realize that being taken for granted is a key measure of success in technology. The availability of light on demand, personal computational and communications power found only in science fiction a decade ago, the ability to take a selfie and share it immediately with someone on the other side of the planet, pictures of the surface of Pluto and the comet 67P/Churyumov-Gerasimenko, and imaging modalities that allow a doctor to quickly diagnose an ailment and optimize a personalized road to recovery are extraordinary successes of science turned into products or tools...and all are taken for granted by today's youth.

> "We have too long lived the Biblical expression 'hiding our light under a bushel'."

To enlighten the public about the many aspects of light around us, SPECTARIS, the German Hightech Industry Association and industry sponsors, have published a book with 50 infographics on basic concepts and applications of photonic technologies. SPIE has collaborated with them on an English-language version; *Photonics: Technical applications of light – infographics* is available as a free download from SPIE (spie.org/membership) and in print at the SPIE booth in the exhibition hall at Photonics West.

(l-r) Sir Peter Knight, Wilson Sibbett and SPIE chief executive Eugene Arthurs at the Institute of Photonics 20th Anniversary celebrations held at the University of Strathclyde in Glasgow last November.
Photo: MATTHEW PEACH.

IYL energy conserved

At this Photonics West, look for the pointers to a future where your personal smart device is even more loaded with nanophotonic diagnostics, quantum-enhanced GPS, and links to immense data sources and to an internet of things way beyond our primitive vision of today.

The IYL was a major theme for Photonics West 2015. Though strictly speaking the IYL may be over, I am delighted to see that the energy from this most successful ever United Nations "year of" goes on.

One of the great benefits was that many of us were jarred out of our routine worldview. The ferment of ideas and of creativity, and the exposure to different perspectives on light in life broadened our thinking. The effort to communicate the pervasive and crucial role of light in our civilization to decision-makers throughout the world and to the public was a small step forward and a heady learning experience. Read some of the year's legacy in a commemorative selection of IYL blog entries at http://spie.org/about-spie/international-year-of-light.

As a community, we need to sustain and improve the articulation of our successes and increase the visibility of what we do if the developments described at Photonics West and other events in our field are to realize their social and economic benefits. We have too long lived the Biblical expression "hiding our light under a bushel." This has been costly, not just for our community of light, but for humanity. Being taken for granted may be success; we want to make sure it does not mean being ignored when it comes to funding and investment.

Convert ideas into impact

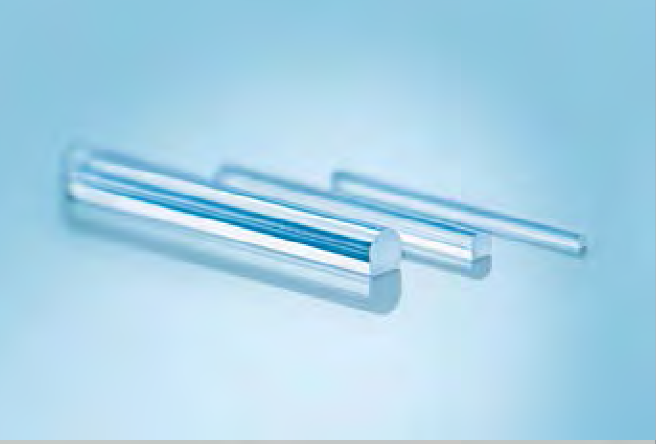
We are in an uncertain world where too many remain in denial about what observed climate changes mean for further destabilizing our species. The Paris Agreement is only a hopeful beginning. It must not be taken as a *fait accompli*.

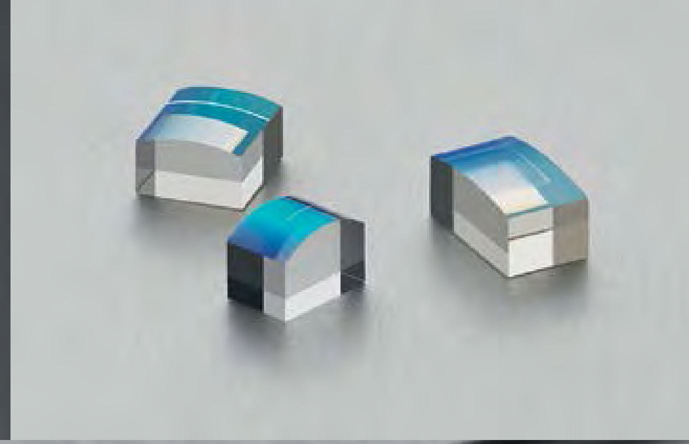
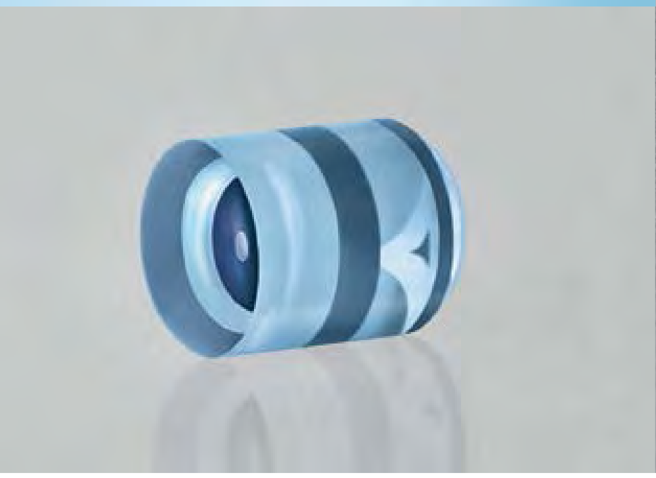
Fortunately the work in our field offers multiple paths of hope for both energy generation and reduced energy use. Now, global political will and action is needed to deploy the potential of our science and technology to improve the human lot, for the many who endure miserable circumstances today, and for the entire human race over the decades to come.

As for all the benefits of photonics, meaningful outcomes require conversion of ideas into impact. Thank you to all who have taken the science off the pages and turned it into products and tools with which to build the future.

Enjoy Photonics West. Take advantage of it for your future prosperity.

Have fun in San Francisco. As another Herb, Herbert Mye, said "It is a good thing the early settlers landed on the east coast...if they'd landed in San Francisco, the rest of the country would still be uninhabited."

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AIM Photonics looks to boost US competitiveness worldwide

Government/academia/industry collaboration aims to create a new manufacturing platform for integrated photonics.

The US photonics industry got a major boost in 2015 with the launch of a first-of-its-kind government/academia/industry collaboration designed to put American manufacturing at the forefront of what many believe will be the next big thing in consumer electronics, telecom/datacom, defense, and biomedical devices: integrated photonics.

The American Institute for Manufacturing Integrated Photonics (AIM Photonics), awarded in July 2015 by the Department of Defense (DoD) to a consortium of 124 companies, nonprofits, and universities, was formed in response to President Barack Obama's 2014 announcement of integrated photonics as a major component of the National Network of Manufacturing Innovation (NNMI) program. AIM Photonics is the sixth of nine public-private NNMI partnerships intended to boost manufacturing and innovation and create new job opportunities in the country.

With a total investment of more than $610 million (including $110 million from the DoD over five years and $500 million in non-federal contributions and investment from industry participants), AIM Photonics is the largest public-private commitment to date for a manufacturing institute in the US. The primary AIM Photonics team, led by State University of New York (SUNY) Polytechnic Institute in New York, includes faculty from the Massachusetts Institute of Technology (MIT), University of California Santa Barbara (UCSB), University of Arizona (UA), and University of Rochester (UR). Industry partners include Intel, HP, IBM, Cisco, Infinera, Corning, Mentor Graphics, Synopsys, Cadence, GE, United Technologies, Raytheon, Lockheed Martin, and Northrop Grumman.

> "If we are still alive in year six, then there is no question we are having commercial impact."
> TOM KOCH, DEAN OF THE COLLEGE OF OPTICAL SCIENCES AT UA.

"In a nutshell, it is all about the fierceness of international competition and a sense of opportunity, and both of these things suggest it is a good time to make this kind of investment," said Tom Koch, dean of the College of Optical Sciences at UA and chair of AIM Photonics' Technical Review Board. "Some really interesting advances in optics and photonics technologies have emerged in recent years, and they are continuing to leverage more and more the huge investments that go into microelectronics manufacturing."

Rod Alferness, dean of UCSB's College of Engineering – and now also head of government and industry outreach at AIM Photonics. Photo: UCSB.

John Bowers, professor of electrical and computer engineering and materials at UCSB. Photo: UCSB.

It took many years and multiple lobbying efforts to realize a photonics-specific NNMI. One of the key turning points came in August 2012 when the National Research Council (NRC) of the National Academies released its report "Optics and Photonics, Essential Technologies for Our Nation." That report assessed the current state of optics, photonics, and optical engineering in the US, prioritized research grand-challenge questions to fill technological gaps, and recommended actions to support global leadership in photonics-driven industry. It also led to the creation of the National Photonics Initiative (NPI), designed to raise general awareness of photonics and its role in our everyday lives; increase coordination among industry, government, and academia; and drive US funding and investment.

"Too often the breakthrough research gets done at universities in the US and then ends up getting made outside the US," said John Bowers, professor of electrical and computer engineering and materials at UCSB, which is overseeing the West Coast hub of AIM Photonics. "So that's what the NPI and AIM Photonics are trying to fix. We want to use American ingenuity and inventions to benefit American industry."

Why integrated photonics?

The decision to focus on photonic integrated circuits (PICs) — in which optical systems are miniaturized and fabricated on semiconductor chips that can route and process information with reduced size and power — also had its roots in the 2012 NRC report.

"In that report, one of the top five bullets was integrated photonics," said Rod Alferness, dean of UCSB's College of Engineering and head of government and industry outreach for AIM Photonics. "We realized the ability to integrate together multiple functions and devices to get larger functionality was going to be critical to the continued advancement and application of optics in a number of areas. We also believed it would be critically important to provide the interconnect technologies inside of large data centers, and that large

continued on page 09

AIM Photonics continued from page 07

data centers would be at the heart of economic growth."

Integrated photonics is "an unbelievable game changer," said Tom Battley, executive director of the Rochester Regional Photonics Cluster and New York Photonics, a key player in the efforts that helped make AIM Photonics a reality. "It's like going from buggy whips to motorized cars. It's going to radically transform our lives, without question."

Since the program was unveiled in mid-2015, the AIM Photonics Leadership Council and Technical Working Groups have been busy getting the ball rolling. They have set up four Manufacturing Centers of Excellence (MCEs): Electronics & Photonics Design Automation; Multi-Project Wafer & Assembly; Inline Control & Test; and Test, Assembly & Packaging. They also identified four key technology manufacturing areas (KTMAs): Very High Speed Digital Data and Communication Links; Analog and RF Communications; Integrated Photonic Sensors; and PIC Array Technologies.

> "It is really about building a complete ecosystem for this industry."
> ROD ALFERNESS, HEAD OF GOVERNMENT AND INDUSTRY OUTREACH AT AIM PHOTONICS.

"We are developing a roadmap for the photonics industry that looks at these different areas and says where are we now and where do we need to be in five to ten years," Bowers said. "Our goal is to integrate everything together onto a chip and to manufacture them in high volume. If we can do that, we end up with far cheaper packaging and far fewer interfaces."

PIC foundry infrastructure

One of AIM Photonics' overarching goals is to establish a national foundry infrastructure that will enable broader access to PIC technology and design and manufacturing resources for companies of all sizes.

"The idea is to build something that is modeled after the Fraunhofer program in Germany, which is serving the local German economy by providing a path, especially for smaller companies, that have a demand for, say, very small production runs for research that they couldn't afford because they can't afford the infrastructure," said Michael Liehr, AIM Photonics CEO and SUNY Poly executive vice president of Innovation and Technology. Yesterday Liehr gave an OPTO plenary talk at Photonics West, entitled "Merging photonics with nanoelectronics" (see pages 1-3).

Each AIM Photonics partner brings its own unique expertise to the effort. SUNY Poly, for example, is well known for its fabrication capabilities, while MIT and UCSB are national leaders in silicon photonics and integrating lasers into silicon. Rochester Institute of Technology (RIT), UR, UA, and Columbia University will contribute packaging, assembly, and test solutions for PICs, while all partners will pursue applications advances.

On the industry side, Intel and HP both have very advanced photonics platforms, Bowers noted, while Infinera has developed some of the most complex PICs currently available.

"The role of photonics in so many aspects of our lives has become increasingly difficult to ignore when you begin to realize how dependent we are on the Internet, our smart phones, displays...so many things that are optical," Koch said. "[At the UA College of Optical Sciences] we're now getting engaged by all the IT companies because they realize that the human interface into smart systems involves a lot of optics. We even signed a deal with Uber a couple of months ago because they realize that their cars, interfacing with the world, require a lot of optics."

The AIM Photonics team is already looking at ways to address the design, packaging, and assembly challenges that must be resolved before PIC technology is ready for broad-based commercialization and volume manufacturing. AIM Photonics believes its collaborative approach is just what the industry needs at this point. The goal is to put in place an end-to-end photonics "ecosystem:" domestic foundry access; integrated design tools; automated packaging, assembly and testing; workforce development; and a standardized platform to make it easier to scale the technology across multiple markets for companies of all sizes.

"If you look at the model for AIM Photonics, it is really about building a complete ecosystem for this industry," Alferness said. "It's about leveraging federal dollars to do that, but also leveraging cost-share dollars from companies that will become members of the institute in order to share technology and build up this ecosystem.

"The more companies we have with a broad set of skills and capabilities, the more powerful the institute will become and the better the value proposition. We believe that is especially true for the small- to medium-sized enterprises. The ecosystem becomes complete because they have the opportunity to make integrated photonics devices without having to invest in all of the infrastructure," he added.

Priority areas

One project area AIM Photonics is making a priority involves using complementary metal-oxide semiconductor (CMOS) processing to move photonics onto silicon – to eliminate the data bottleneck that advanced silicon chips are facing during the next decade. Thus high-port-count switches have been chosen as one of the institute's first projects. Another area of interest is 3D stacking of electronics with optics.

"The ability to co-manufacture these as a single-chip sub-assembly on a wafer scale rather than chip-by-chip is an example of one of the most game-changing capabilities of PICs," Koch said. "It will take a few years to see it emerge in commercial solutions. But when it does, it will be very powerful."

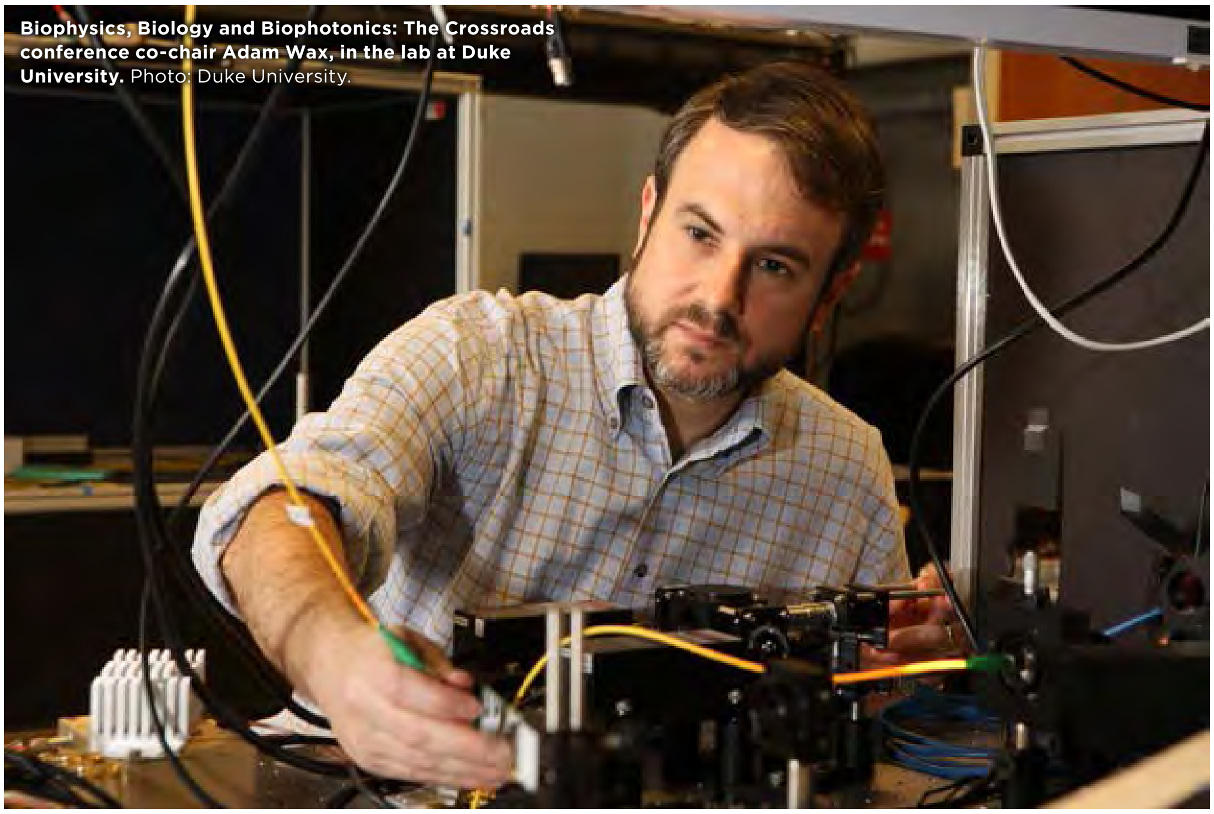
The real test of success will be whether AIM Photonics, which officially opened January 9, can become self-sustaining, and what kind of commercial value it can bring to its members in the process, Koch emphasized.

"The big milestone for us is we know we need to be self-sufficient in five years, and the only way you do that is by bringing value," he said. "If the companies that are benefitting from what we offer cannot see a pathway to commercial advantage from what we are doing within five years, then we are in a tough position.

"So that is our mandate: if we are still alive in year six, then there is no question we are having commercial impact."

For more details about AIM Photonics, including its structure, projects, goals, and membership requirements, go to www.aimPhotonics.com. To see slides from a November 2015 webinar, visit http://bit.ly/1PlBNk4.

KATHY KINCADE



Biophysics, Biology and Biophotonics: The Crossroads conference co-chair Adam Wax, in the lab at Duke University. Photo: Duke University.

Two new BiOS conferences address problem areas in biophotonics

Twin challenges of big data and interdisciplinary communication have motivated the latest extensions to the growing symposium program.

Two new conferences debuted at BiOS this year are addressing the challenges that come with massive amounts of biomedical data and with members of the research and engineering communities who don't always take note of each other's work.

One conference, "Biophysics, Biology and Biophotonics: The Crossroads," has its sights set on bridging the communications gap between the biological research and engineering communities, where optical techniques that address clinical and pre-clinical needs in biomedicine and biophysics are developed.

Nearly 30 papers were presented at this conference over the weekend, on topics ranging from optical trapping and macromolecular crowding to light-sheet imaging, label-free nanoscale sensing, and physiological imaging techniques that study metabolism and blood supply.

Of course optical technologies – most obviously in the form of microscopes – have long played a role in biological research and, more recently, clinical diagnostics. From multiphoton microscopy and fluorescence lifetime imaging to optical coherence tomography and photoacoustic imaging, these tools have fueled the remarkable growth that the biophotonics field has experienced over the past two decades.

And yet, surprisingly — given this success, both clinically and commercially — biologists and optical engineers do not collaborate or communicate as often or as effectively as one might expect.

"The idea is for this conference to serve as a bridge between the biological community and the engineering community — two communities that typically don't talk to each other," said Vadim Backman, conference co-chair and professor of biomedical engineering at Northwestern University. "There are lots of people in these two fields who collaborate, but frequently we don't see effective dialogue because we talk different languages.

"Optical techniques measure an optical signal, not a biological response," he said. "Then you try to come up with a diagnostic algorithm based on that. But the question is: what does it mean biologically? And this question is critical because unless it is answered, most of the optical diagnostic techniques will find it difficult to gain wide acceptance."

Optical solutions for biology

Take advances in the quantitative measurement of tissue and its optical properties, for example. While the optics community will get excited about, say, a new method of measurement of the absorption coefficient, the biology community either doesn't hear about it or doesn't care because the biological significance is often not immediately apparent, Backman explains.

"So everybody in the optics community is happy because it's a major breakthrough, but it goes completely unnoticed or unused in biology because biologists don't want to measure the scattering coefficient or absorption coefficient. They want to know what happens with a particular protein or how they can measure the structure as opposed to optical parameters," he said. "Some of these things could be easily converted, but each side needs to know what the other side wants to see."

These challenges prompted Backman, fellow co-chair Adam Wax of Duke University, and others to

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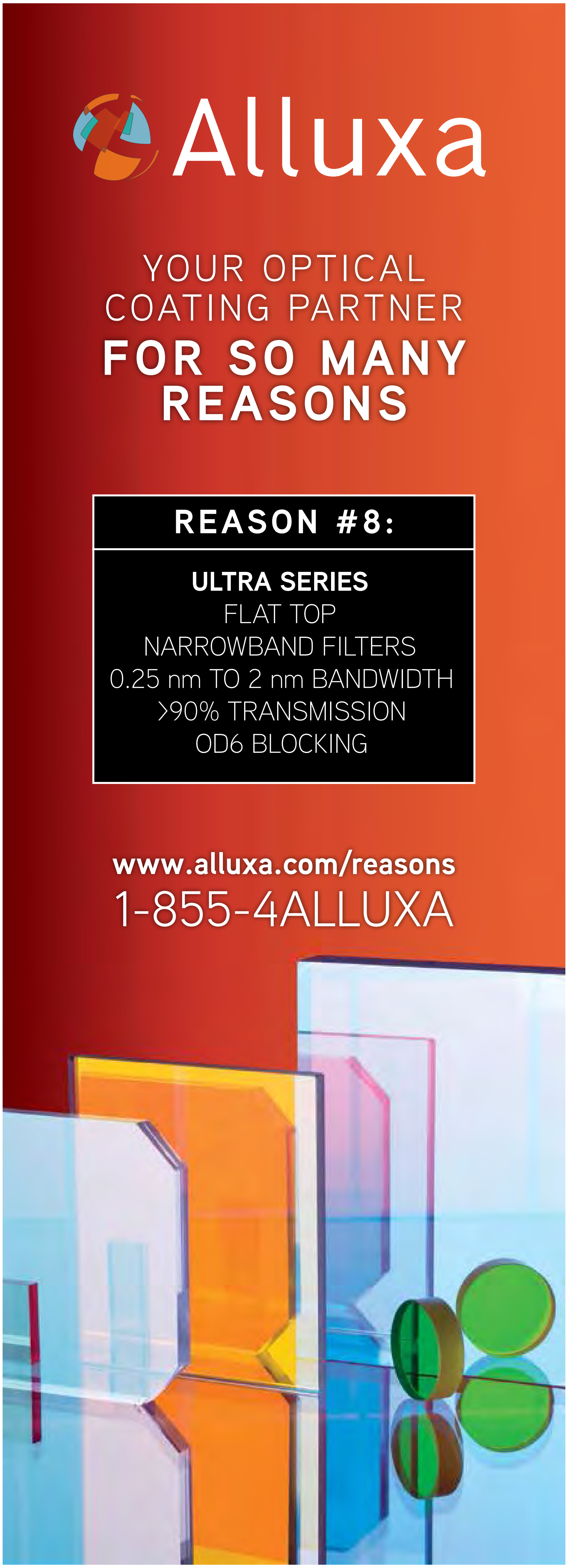
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BiOS conferences continued from page 11

create an opportunity for the two groups to meet and share their expertise at Photonics West. The goal is to give the biology community information about optical technologies that might help them solve existing and emerging biological problems. In turn, this ought to help the engineering community better understand what kinds of clinical and research applications biologists need new solutions for.

"We want to extend the range of the type of presentations and research typically featured at Photonics West by combining biology, biophysics, and biophotonics," Backman said. "There are lots of things that biologists want to see and do that can be addressed using optical technologies that can be developed by optical engineers that go to Photonics West."

However, Backman emphasized that engineers don't always know what the needs are in biology. "And biologists often don't know what the capabilities of the optics technologies are," he added. "What we need is inter- and cross-disciplinary thinking and collaboration."

Unlocking the mysteries of cells

In addition to helping organize and co-chair the conference, Backman is also chairing a section on macromolecular crowding, an emerging area of biology in which nanoscale, super-resolution and label-free imaging techniques are used to characterize the cellular environment in which genes and other molecules exist and interact. Understanding this complex nanoscale environment and the processes that take place within it is already helping biologists unlock the mysteries of diseases such as Alzheimer's, Backman explained.

"We like to talk about genes and the whole function of the cell, but macromolecular crowding regulates at least as much as the genes. If genes regulate everything within the cell, then crowding regulates genes," he said.

"So crowding is an exciting concept in biology because it's almost one of the missing dimensions in our understanding of biology. But it's difficult to investigate because the challenge is how to observe these processes. That is where optics plays a very critical role."

As an example, among the presentations in Backman's session was an invited paper by Igal Szleifer, a professor of medicine and chemical and biological engineering at Northwestern University. Szleifer discussed recent work that incorporates molecular-scale information into a systems-based approach to study the role of macromolecular crowding on different phenomena ranging from protein diffusion to gene transcription.

Response to the new conference from both the biology and engineering communities has been quite positive, Backman noted. He is hoping this leads to an entire new field of interdisciplinary study.

"It is really mind-blowing how different these fields are today," he said. "We don't read their journals and they don't read ours. We don't go to their conferences and they don't come to ours.

"So we are very happy to see the positive response to this conference from both sides. We believe it will enable a convergence of these disciplines and lead to new collaborations in a potentially new field of science or physical biology."

Biophotonics' big data problem

Organizers of another new BiOS conference, "High-Speed Biomedical Imaging: Toward Big Data Instrumentation and Management," are also hoping that a multidisciplinary approach will lead to new research collaborations.

From Raman spectroscopy and fluorescence detection to photoacoustic microscopy and image cytometry, optical instrumentation that enables real-time capture and analysis of biomedical data has become invaluable for applications ranging from cancer detection to drug discovery.

But these high-throughput instruments have also created a new challenge in both laboratory and clinical settings: too much data.

Progressively larger biomedical datasets are required for efficient and accurate data analysis to make better decisions in life science research and clinical diagnosis, but analyzing and managing this data has become a challenge for even the most advanced computers.

This scenario prompted an international group of distinguished scientists to bring together in a single multidisciplinary forum researchers who specialize in real-time optical bioinstrumentation, big-data management, and high-speed signal processing, noted Edmund Lam, conference co-chair and professor in electrical and electronic engineering at the University of Hong Kong (HKU).

"Many of us have been regular attendees to Photonics West," said Lam, who is also director of the imaging systems laboratory and the Photonics and Imaging Technology Cluster at HKU. "And while it has great programs on many aspects of biomedical optics, a dedicated conference that explores the opportunities and challenges accompanying the deluge of biophotonics data — the big data that is a focal point in computational science — would be a great addition."

High-speed imaging strategies

It appears many agree. The conference, which featured eight sessions, attracted more than 50 submitted and invited papers, on topics ranging from light-sheet microscopy and 4D imaging to big-data management, bandwidth limitations and computational algorithms. The sessions were focused on critical aspects of high-speed imaging strategies and the required back-end signal processing techniques that support them, noted Kevin Tsia, conference chair and associate professor in the department of electrical and electronic engineering at HKU.

"While we see a wide spectrum of impressive optical techniques escalating the measurement speed, there is a pressing need to think about the consequences of such innovations," Tsia said. "Many of these techniques share a common problem: the enormous amount of data that is generated. This poses an immediate question: how can we manage the data in terms of compression, processing, and, most important, analysis?"

Tackling these issues is critical for both technology and application development and commercialization, he added. "To make big-data instrumentation commercially successful, one should think not only about the optical front-end that accelerates the measurement speed, but also the clever tricks to acquire, process and analyze the useful data in real time, or at least with minimal latency," said Keisuke Goda, conference chair and professor in the department of chemistry at the University of Tokyo.

"I think there is still some way to go in this regard," Goda said, "and that is why we created this conference: to catalyze new ideas to address this issue."

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Lumentum streamlined in new state of independence

Since last year's Photonics West, JDSU has split into two companies. Six months on, how does independence suit the optical communications and commercial laser unit that has become Lumentum?

In its first quarter of trading as Lumentum, the former communications and commercial optical products (CCOP) division of JDSU, which split in two last August, reported sales figures above Wall Street's expectations. The positive start reflected strength in the company's key applications of telecoms and datacoms, driven partly by record sales of is terrestrial pump lasers, which the company says indicates a strong network build-out trend.

"This strength in telecoms and our overall profits in optical communications products have come in at a multi-year high," said Alex Schoenfelder, the new company's executive responsible for commercial lasers. "On the commercial laser side we saw a sharp increase, quarter over quarter, in fiber laser revenues," he added.

> "We have eliminated two layers of decision-making management."
> ALEX SCHOENFELDER,
> VP OF COMMERCIAL LASERS AT LUMENTUM.

Despite the JDSU split, Schoenfelder says that it has been business as usual from an operational perspective. "Even when this segment was inside JDSU, it had its own culture, which was pushing towards the trajectory we are now developing as an independent company," he said.

Schoenfelder had worked at JDSU for more than 20 years before participating in the formation of Lumentum. "It has been the highlight of my professional career to go through this process," he told *Show Daily*. "With a new support structure, we are now more agile. We have tailored the new business so that an engineer who wants to buy equipment to develop a new system can go through a much more streamlined process to get it quickly."

Lumentum's markets have not changed since it spun out from JDSU; they revolve around telecoms and datacoms networking and various commercial laser verticals. For 2016, Schoenfelder sees a generally positive picture in the key territories of North America, Europe and Asia, with prospects for communications generally looking better than the materials processing sector.

"In telecoms there is growing strength," he said. "We expect to see significant network build-outs in North America and China, for example. These will require the whole breadth of our technologies, especially lasers for 100G transmission systems as well as ROADM (reconfigurable optical add-drop multiplexer) management technologies."

There are also significant growth opportunities as data center customers upgrade their systems to 100G and more this year, although Schoenfelder cautioned: "On the flipside, in the datacoms market there is also a lot of aggressive price competition at sub-100G rates – which is still a significant market – due to the maturing of the technologies that support those speeds and because of lower-priced new market entrants. That market is getting more crowded."

He predicts that for commercial laser markets there will be near-term softness in micro-machining due to falling semiconductor capital equipment spending, which will remain muted this year. That will affect lasers that are used in the processing of semiconductor chips, PCBs and flex-circuits, so there will be some impact on the unit's growth in 2016 compared with 2015.

Schoenfelder expects to see continued strength for kilowatt fiber laser sales as materials processing, metal cutting and welding applications continue to convert from carbon dioxide to fiber technology. At last year's Photonics West exhibition, JDSU had introduced fiber laser systems up to 6kW, with even more powerful systems on the cards for 2016. Speaking ahead of the event, Schoenfelder said: "Our customers and their customers will see a compelling value proposition for making that conversion to industrial fiber lasers."

Lumentum may be freed somewhat from the sheer scale of the former JDSU, but does the more agile operation feel somehow less protected in what, certainly in the case of communications and high-power fiber lasers, are highly competitive markets; more vulnerable to cut-throat pricing? Not so, Schoenfelder replies: "First of all, from a competitive perspective, not much has really changed for us, because Lumentum is still serving the same customers in the same markets, as before. Our customers are seeing the impact of us becoming more nimble and agile. We have actually eliminated two layers of decision-making management, to be able to respond more rapidly to opportunities in the marketplace.

Alex Schoenfelder, VP of the commercial lasers product line at Lumentum. This is the first time that the company, which spun off from parent JDSU last year, has appeared as a separate entity at Photonics West. Photo: Lumentum.

"Of course, Lumentum is smaller than JDSU was but we are still close to a billion-dollar company. And if you look at our markets, a lot of our competitors are similar or smaller than us in terms of revenues. So I am not really worried about this. In fact, our customers are facing a new challenge because Lumentum is now offering a more competitive proposition because we are nimbler."

Against a macro-economic backdrop that has become increasingly cautious – even fearful – in recent weeks, particularly in respect of concerns about the slowing Chinese economy, Lumentum remains optimistic about its own growth prospects. "The wind is already starting to blow pretty strongly into our sail," said Schoenfelder in December. "Regardless of the economic direction and the ranges of predictions for the general economy of China, that country has a need for network build-out; it's just something that China must do."

Considering the switch from gas lasers to fiber lasers in the macro materials processing sector, he believes that conversion rates have still only reached about 30-35% of the potential market, meaning that there is plenty of opportunity to replace the remaining 65% share of industrial carbon dioxide lasers still out there. Schoenfelder added, "From that perspective alone, we expect Lumentum's business to keep growing at a high single digit percentage for 2016, at least."

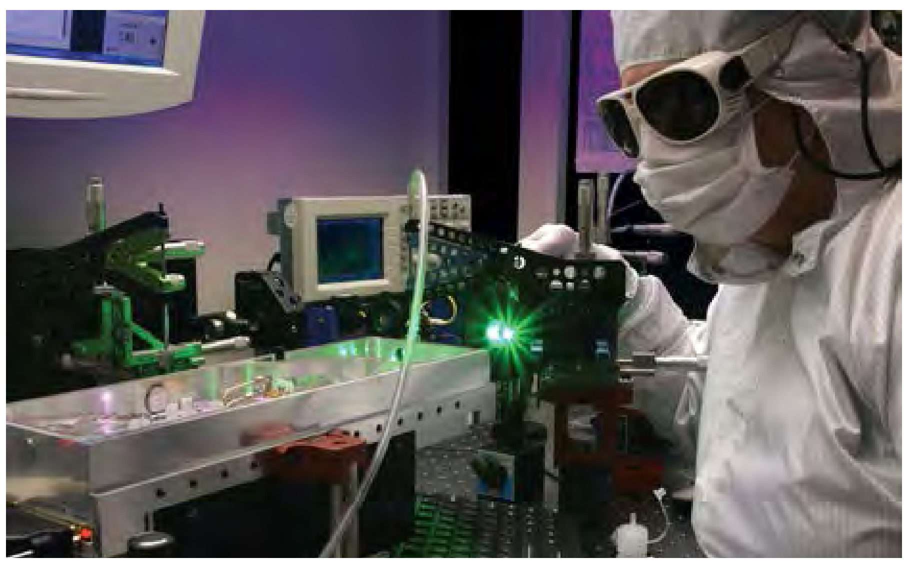
To support this growth, the business will continue to invest in product development for both micro- and macro-machining areas, and particularly for multi-kilowatt fiber lasers, working here mainly with its development partner Amada, one of the largest machine tool makers in the world, with which JDSU has collaborated since 2007.

Besides his long involvement with JDSU and now Lumentum, Schoenfelder is also an enthusiastic veteran of Photonics West: "I attended my first Photonics West show in San Jose, about 25 years ago, it was before I had joined JDSU," he recalls. "I was then working at the Fraunhofer Institute for Applied Solid State Physics in Freiburg, Germany, on gallium arsenide and indium phosphide photonics systems."

He added, "Something I have noticed in recent years is that there are more and more visitors from the investor community attending the show in San Francisco. This is obviously a fast-growing area for photonics investors, which is very interesting for us at Lumentum. Add to this the recent developments such as the US National Photonics Initiative and the International Year of Light during this past year and you can see how photonics technologies are extending their influence in all directions."

See Lumentum at booth #2017.

MATTHEW PEACH



R&D at Lumentum's laser laboratory in Milpitas, California. Photo: Lumentum.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Christopher Pinzone Joins Thorlabs

Christopher Pinzone joined Thorlabs Quantum Electronics (TQE) in Jessup, MD in October 2015 as Director of Epitaxy. One of the pioneers of commercial MOCVD epitaxial wafer growth, Chris' achievements include growing the first room temperature CW laser directly on silicon, bringing CATV analog DFB lasers to market, and developing a new, patented technique for direct wafer bonding of InGaAs to silicon. Pinzone co-founded Ahura Scientific in 2002, a venture-capital-backed startup that developed and produced the world's first handheld Raman and FT-IR spectrometers for rugged field service, culminating in a sale to Thermo Fisher Scientific in 2010.

"We are excited to have Chris' expertise on board," said Peter Heim, Chief Technology Officer at TQE. "He has deep roots in the global epitaxy community that go back to his time at Bell Labs. His leadership will be key to our efforts to provide epitaxial services to both industry and academia."

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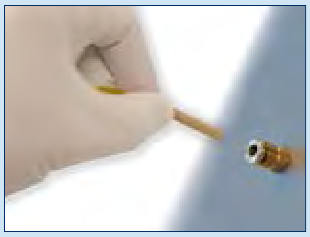

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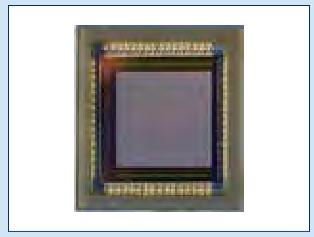

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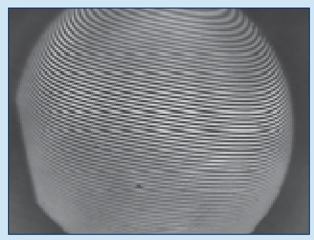
Please see the VFI-2000 at Photonics West 2016 – Arden Photonics booth #5543.



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Multidisciplinary center takes optics to new fields in Arizona

Jennifer Barton tracks the new imaging technology that is setting the pace in biosciences.

In the last five years, imaging has been an arena of breakthroughs that have shaken up science itself, and especially the biosciences. Lasers and sensors get smaller, more reliable, cheaper. Magnetic resonance imaging (MRI) scanners discern body chemistry. Healthcare improves. Agriculture gets more efficient and farmers save water.

Jennifer Barton, interim director of the BIO5 multidisciplinary research center at the University of Arizona. Photo: UA.

Few researchers have been closer to the center of all this action over the last two decades than Jennifer Barton, recently appointed interim director of the BIO5 Institute at the University of Arizona in Tucson, and one of the world's leading experts on optical coherence tomography (OCT).

And when she declared recently, "There has been an explosion in the capabilities of imaging," you can bet she knows the specifics.

For decades, Barton's teaching has spanned optics, electrical and computer engineering and biomedical engineering, while her own research interests in translational biomedical optics have contributed to that explosion in imaging. She has redesigned some of the OCT equipment, allowing the reflected light to generate 3-D images revealing healthy or cancerous tissue.

In particular, Barton has applied OCT to the challenges involved in early detection of ovarian cancer – the topic of her team's Saturday morning presentation at this year's BiOS symposium.

Looking more broadly at imaging, she says, "We have better fiber optics and the ability to handle enormous amounts of data, along with much better tools for analysis." That sums up much of the work on imaging by her world-class team of 200-plus researchers who make up BIO5's research clusters.

Barton came to the research world after six years at McDonnell Douglas Aerospace, where she worked on the International Space Station. Then she opened a new career chapter, returning to the University of Texas at Austin to get a PhD in biomedical engineering. Her first stop was the UA, where she joined and later ran a new interdisciplinary program in biomedical engineering.

A decade later, when the UA looked for someone to develop and lead a new department of biomedical engineering, Barton was the natural choice.

The new department's focus has been on bio-imaging, cardiovascular engineering and nanomedicine. In her own classes, she spells out what biomed engineers are doing to meet challenges like diabetes or cardiovascular disease.

So it's natural that she would now see her current work at BIO5 through the lens of interdisciplinary work on imaging, including expanding capabilities with big data, better lasers, and superior ways of analysis.

"All this has made imaging really integrated into everything people are doing," she says, "from the basic sciences to agriculture to medicine."

Looking at basic sciences, she points to the work of a BIO5 colleague, Carol Barnes, working on understanding how the brain is wired. Barnes, director of the Evelyn F. McKnight Institute at UA and a leader in research on the normal-aging brain, and her team have designed a new microscope with resolution at the level of a neuron. "They can look through the mouse brain, at something about an inch thick; and get a picture of the entire intact brain," Barton says.

"They have developed the ability to examine mouse brain tissue, *ex vivo*, which is normally cloudy with scattered light. Using chemical agents, they can make it transparent," Barton said. The breakthrough is an ability to visualize the entity, not just small parts of it. "They are able to follow all the neurons, rather than just those in one slice. We used to have no idea where all the neurons were going. Now we can look at an entire brain, and see how they connect to each other," Barton said.

That science, Barton says, builds on new capabilities in high-resolution optics and the computing power to handle huge quantities of data to calculate within hours what would previously have taken months.

Moving from study of tissue slices to the entire organ will lead to new insights into the brain's fundamental workings, Barton said.

Detecting ovarian cancer presents major imaging challenges. "The ovary is deep inside the body," Barton explained. "Early cancer cannot be detected with a whole body scan. It's too small. To work, you need optical methods, which have very high resolution and sensitivity."

Barton has received grants from the National Cancer Institute – for identification of the earliest markers of ovarian cancer – and from the Department of Defense to develop a tiny endoscope, on a scale smaller than a millimeter to image the fallopian tubes and ovary. "We are now figuring out how to package it," she said.

Recent advances in fiber-optics technology such as miniature fiber bundles with thousands of micrometer-sized light-transmitting cores, gradient-index fibers that focus light, as well as new materials that are flexible yet strong, are making this work possible. "It was not feasible five or ten years ago," Barton said.

Aside from early detection of ovarian cancer, Barton and her team are presenting papers on the diagnosis and treatment of ailments in the breast and reproductive system at this year's BiOS conferences.

One imaging application that is underappreciated, says Barton, is agriculture. At BIO5, scientists are part of a national effort to help farmers cope with scarce water supplies and the overuse of fertilizers.

"Agriculture has become high tech, with drone technology letting farmers map their fields with multispectral imaging," Barton said, "with data right down to the square meter. Spectra reflected by plant leaves can point to water stress or even indicate what type of nutrients

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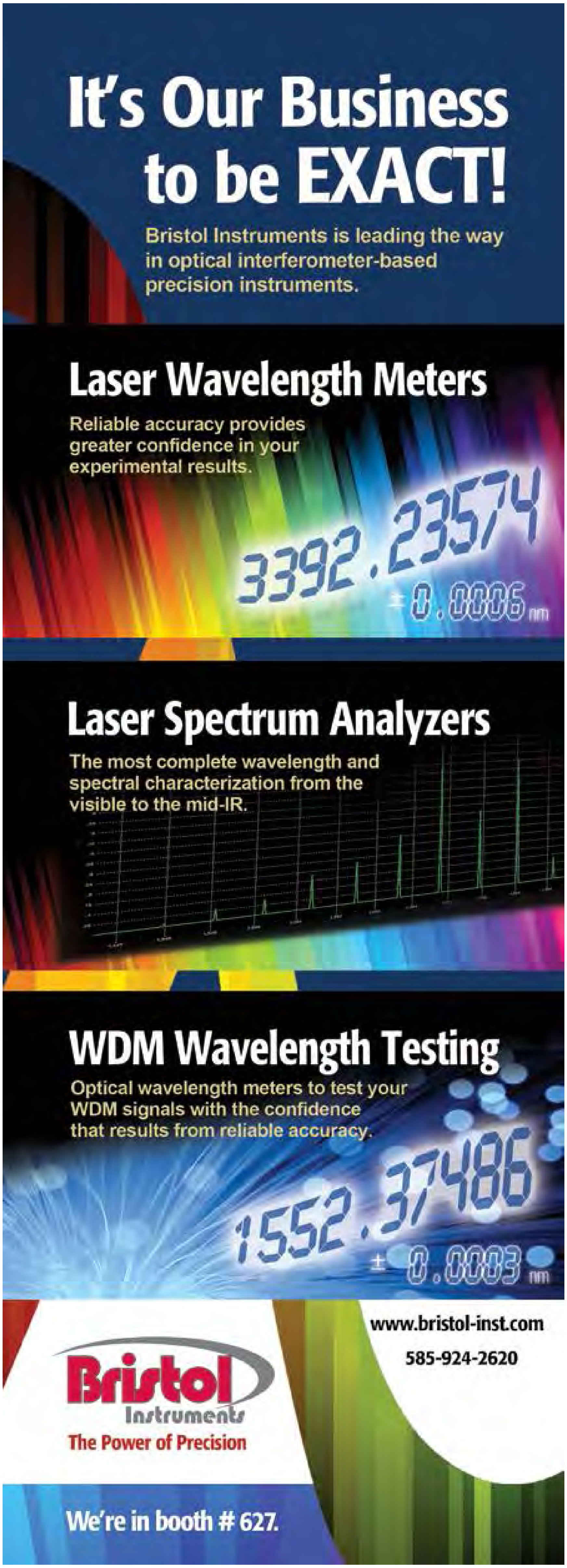
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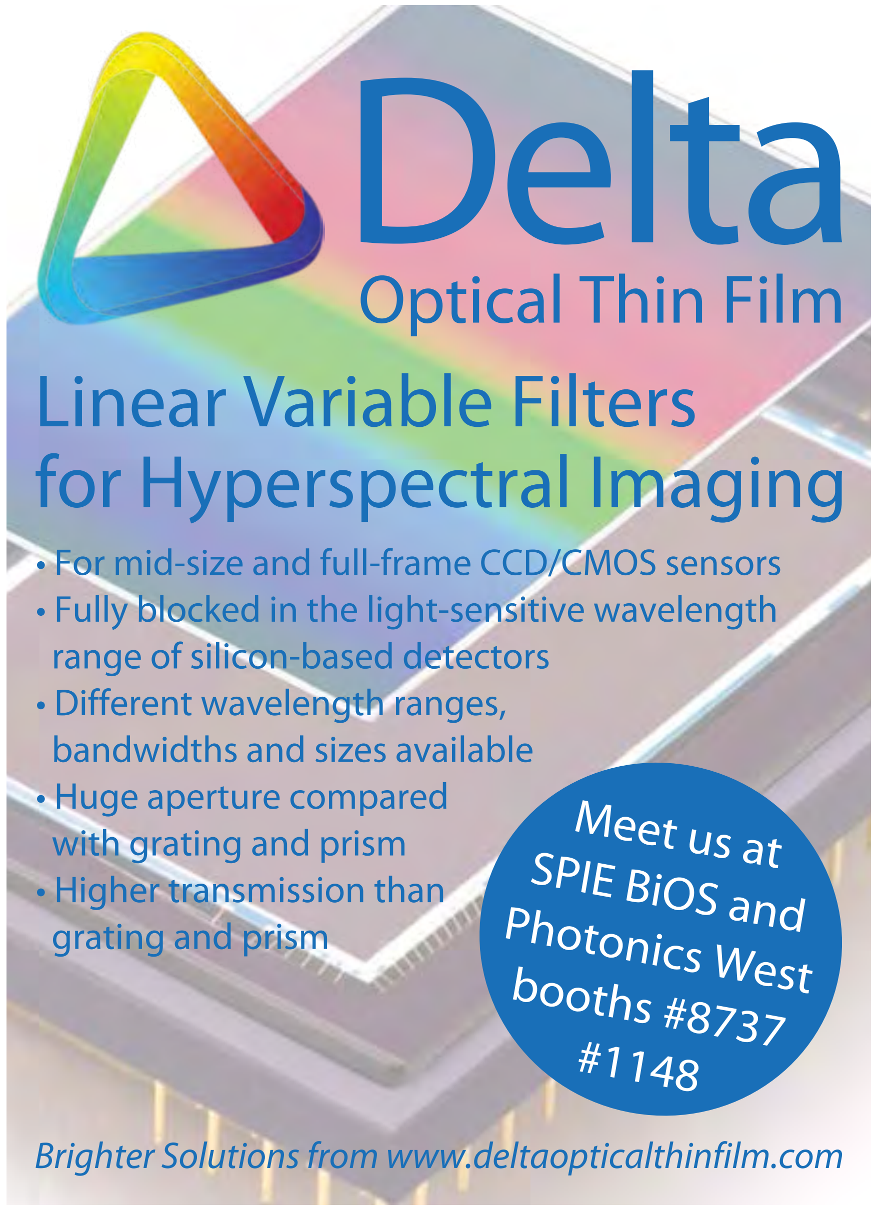
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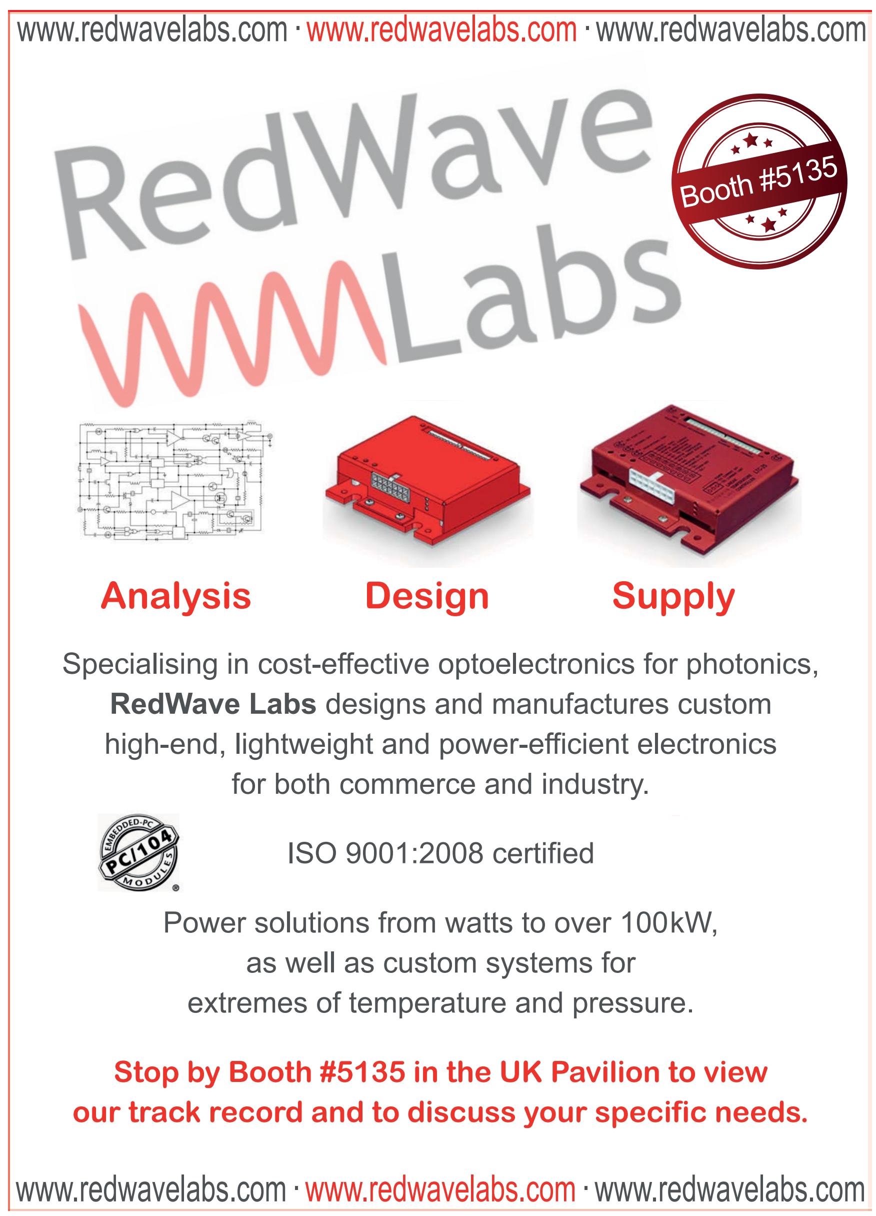
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the plant needs. If it's pale green, it may need nitrogen, and the human eye can tell that. But multispectral imaging can quantify that need, and can see wavelengths of light that the eye cannot see."

This, Barton said, is the age of precision agriculture, in other words "giving the plant exactly what it needs."

The emergence of autonomous technology has been crucial to this development. UAVs equipped with multispectral cameras can acquire and process massive amounts of data, while robots can respond quickly to agricultural needs. Even in the relatively recent past a farmer might only be able to have a plane fly over once or twice a season.

Aside from making farms more productive, precision agriculture can help cope with water restrictions, which, as Barton notes, Californians know about all too well.

"Farmers are being squeezed," she said, "and you can't flood a whole field as in the past and not worry about water use."

In another cancer application for MRI technology, Barton said BIO5 members have found ways to map the pH – or acidity level – of body tissues, a step that might even predict the effectiveness of various therapies and thus match them up with individuals, helping advance personalized medicine in cancer.

The bio-engineers are fine tuning their MRI methods to examine a tumor that has been discovered in a patient but not yet treated. Knowing the pH of the tumor, doctors can monitor the effects of various treatments on both tumors and healthy tissue, and estimate the likely success.

According to BIO5's Mark "Marty" Pagel, UA associate professor of biomedical engineering, tumors produce lactic acid when they are growing. That acid destroys surrounding tissue, and allows the tumor to metastasize elsewhere in the body. "Measuring the pH in a tumor is essential, because some drugs only work at the right pH," said Barton.

One day, she said, the innovative MRI tumor measurement technique may help save lives of women with breast cancer. Pagel's technique, called chemical exchange saturation transfer (CEST) MRI, allows instruments to be sensitive to molecules in the tissue and their environment.

In the new applications, Barton said, MRI techniques are advancing imaging beyond the familiar black and white images that show shapes and sizes. The advances in functional quantitative imaging provide far more detail. "We can know all the kinds of different chemistry that's going on," Barton said, "like the pH of a body part, or detecting a normal organ or a tumor, or the enzyme activity that's going on inside an organ."

Researchers are developing imaging techniques and contrast agents to yield precise, quantitative data about functions and physiology of the body, Barton adds. In short, the science is changing. "As the technology advances, we are developing more capabilities than we could have imagined a decade ago," she said. "These new tools can let you discover new things about how body works, or how the environment functions. We are adopting these techniques and encouraging the imagers to go beyond them, toward even higher resolution, and faster speeds."

What happens at BIO5, Barton says, is unusual. "Scientists are creating feedback loops from one researcher to another. What we do well is accelerate that feedback loop."

"This is not creating imaging technology for technology's sake alone," she said. "It has to have a use. It must enable new discovery, new therapy. We bring people together and everybody's in action to create better health and a better world."

FORD BURKHART

"Ultra" holography applications: from Fabergé eggs to supermassive storage

What do you get if you cross a Fabergé egg with a 3D endoscope? Find out what's in store at one of Photonics West's most diverse conferences, 'Practical Holography XXX'.

When 3D color holograms of Carl Fabergé's jeweled Imperial eggs were unveiled at the 2015 Magic of Light exhibition in St. Petersburg, viewers were stunned.

Long viewed as the 'holy grail' of display holography, holographers worldwide have tried to reproduce these pre-revolutionary Russian treasures since the 1980s. But this display was different.

"People at St Petersburg were so impressed, they just couldn't tell if they were looking at the real thing, an artifact or an image," says Hans Bjelkhagen. "We have found a way to capture light waves, store them and then replay them forever. We've named our images *OptoClones*."

Bjelkhagen, a professor at the UK's Glyndŵr University and proprietor of Hansholo Consulting, is hosting Tuesday evening's Technical Event on Holography as well as the conference, Practical Holography XXX: Materials and Applications, alongside V Michael Bove of the famed Massachusetts Institute of Technology (MIT) Media Lab.

Presenting 'Ultra-realistic imaging and OptoClones' in Session 2 at the conference, the coherent imaging researcher

An *OptoClone* holographic version of the Imperial Coronation Egg, which was made in 1897. Both it and the Bay Tree Egg are owned by the Ukraine-born billionaire Viktor Vekselburg.

had joined forces with optics researchers from Russia-based ITMO University and The Hellenic Institute of Holography (HIH), Greece, to create the breathtaking holograms.

To record an Optoclone, the researchers first developed an imaging method based on the relatively simple Denisyuk single-beam technique.

Here, white light is directed via a mirror and spatial filter onto the object and recording photoplate. Light also reflects from the object onto this photoplate, creating an interference structure that is registered within the recording medium.

However, according to Bjelkhagen two relatively recent optics breakthroughs are key to his team's stunningly clear, high-resolution holograms that combine low noise with high spectral accuracy.

First, the researchers use white laser light from combined RGB, continuous wave, solid state lasers to illuminate both the recording plate and the object. The red diode laser emits at 638 nm, while the green and blue diode-pumped solid-state sources emit at 532 nm and 457 nm respectively.

"These very nice, small solid-state lasers have a long coherence with a very narrow bandwidth," highlights Bjelkhagen. "They emit light from a very narrow diameter to provide super-sharp images."

"Choosing optimum recording laser wavelengths also provides good color rendering [in the hologram]," he explains.

At the same time, a state-of-the-art panchromatic recording plate – comprising a silver-halide emulsion on glass – contributes to the hologram's phenomenal resolution. Photographic film resolution comes in at around 200 lines per millimeter, but Bjelkhagen's holograms hit a high of 10,000 lines/mm.

As the researcher asserts: "To record ultra-realistic images, the emulsion contains light-sensitive silver halide crystals, some four to ten nanometers in size, giving this [high] resolution."

Bjelkhagen is confident OptoClones represent the most realistic-looking 3D image of any object recorded to date, but crystal-clear clarity means images cannot be transmitted and displayed on any current display device, let alone satisfactorily reproduced in printed form.

Thankfully, the hologram recording set-up is housed in a mobile camera that can be shipped from venue to venue, alongside display equipment, to showcase an OptoClone.

Called 'ZZZyclop' and constructed by HIH researchers, the holographic camera was sent to the Fabergé Museum in St Petersburg, Russia, to create the 3D Fabergé egg holograms. Here, placing each egg in a darkened recording tent, HIH chief holographer and scientific director, Andreas Sarakinos, recorded the interference structures of up to two eggs a day.

With patterns in hand, the researchers then turned to a custom illumination device, also developed at HIH, to display the holograms. In the past, illumination systems to display color reflection holograms have relied on halogen spotlights. However, the relatively broadband illumination of these lamps leads to chromatic dispersion and blurring in the final image.

With this in mind, the researchers had combined narrowband red, green and blue LEDs, with peak wavelengths matching those of the lasers used to record the interference structure, into a spotlight. As part of the spotlight, filters and refractive optics were used to combine the different colored LED light beams into a near point-source white light beam with a uniform color cross-section.

"The color just wasn't perfect with halogen lights, and you couldn't get the image sharpness that you do with LEDs," says Bjelkhagen. "The optics also provide an axial mixing of the LED beams, resulting in a homogenous mixing over the full extent of the projected beam."

As the researcher points out, the tiny footprint of each LED die – only 2 mm – is small enough to produce deep, clear holographic images. Critically, for this project, the LED spotlight was incorporated into a free-standing, dedicated display system, to showcase the stunning Fabergé egg holograms.

Holography art for all

During the spring of 2015, HIH's Sarakinos recorded thirteen different Fabergé eggs, producing around sixty-five OptoClones. According to Bjelkhagen, an extensive field of view – typical with Denisyuk holograms – adds to the illusion of observing a real object, rather than an image. And the researcher would now like to display Fabergé egg holograms and more around the world.

Carl Fabergé's jeweled eggs, made before the Russian Revolution, sell for tens of million of dollars each. The Bay Tree and Coronation eggs shown here have been re-created in a holographic form (see left) that is said to have stunned viewers at the Magic of Light exhibition in St. Petersburg last year.

"When you look at these Fabergé egg holograms you can hardly see any difference in color with the real object, so we are now going to work on oil painting reproduction," says Bjelkhagen. "This will be a fantastic technique for perfect reproduction, and we could, for example, show all of Leonardo da Vinci's paintings to the world in an OptoClone exhibition. This is definitely coming up in the future."

Bjelkhagen isn't the only researcher at this year's Photonics West highlighting the importance of holography in the arts. As his co-chair, MIT's Bove, points

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"There's a new generation of research into using holographic techniques for diagnosis as well as for medical education."

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out: "This year we also have researchers looking at the visual language of holography, and in particular digital holography as many art holographers are now working in the digital medium."

Indeed, in Session 2, Maria Isabel Azevedo from De Montfort University in the UK will present holograms captured using holographic and 35 mm cameras, and edited with motion graphics tools and software. In a separate paper another De Montfort professor, Martin Richardson, will discuss the use of floating 3D language in holography.

The same session will feature a team of researchers from Istituto di Scienze applicata e Sistemi Intelligenti and Università degli Studi Suor Orsola Benincasa in Italy, who are set to reveal how they used digital speckle pattern interferometry and thermographic analysis to non-destructively analyze heritage artworks and objects.

As Bove highlights: "Researchers have been analyzing a whole variety of paintings, figurines, sculptures, frescoes and more. Digital speckle analysis is making something of a comeback so I will be very interested to see how digital holography is being used here."

Compressive sensing has also garnered a great deal of interest in optical, infrared and millimeter wave imaging applications, with researchers developing novel sensors and apertures to implement image compression in cameras.

Importantly for holography, the technique can also be used to improve image reconstruction. With this in mind, University of Arizona professor Mark Neifeld and Sehoon Lim, now working on computational imaging with Apple, have developed a volume holographic optical element for compressive imaging.

In Session 3, Applications I, the researchers will describe how they designed this lensless, static system. And as Bove points out: "Compressive sensing is such a hot topic, but researchers haven't really thought about doing this with holographic optical elements so this will be a really interesting example."

In the same session, researchers from Sabanci University in Turkey will showcase their developments in 3D holographic endoscopy. This technique can be used to record 3D large focal depth and high resolution images of internal organs and tissues, making it a powerful tool in medical analysis.

According to the researchers, their 3D optical imaging medical endoscope can be used in the same way as a conventional endoscope, but is capable of producing holograms of objects. As Bove adds: "Holography and medicine have always had an interesting relationship, and there's a new generation of research into using holographic techniques for diagnosis as well as for medical education."

Video holography

For his part, Bove's group will be presenting the latest research on waveguide holography for near-to-eye 3D display. Two years ago the researchers hit the headlines when they unveiled a cheap, monolithic spatial light modulator for high resolution, high performance holographic

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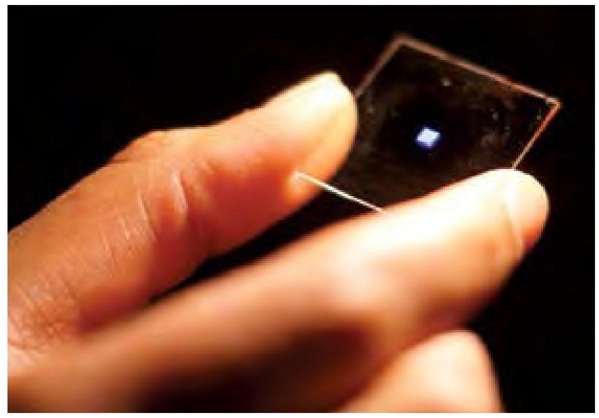

A prototype hologram waveguide for near-to-eye display. Photo: MIT Media Lab.

Andreas Sarakinos, chief holographer at the Hellenic Institute of Holography (HIH) in Greece, stands behind the ZZZyclops camera.

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video displays, sparking excitement over glasses-free holographic 3D television.

But as Bove points out: “To create an image that’s viewable, we still require physical optics, say lenses, mirrors and scanning optics, between the modulator and the viewer, giving us a display with the form factor of a cathode ray tube [monitor].”

Given today’s leaning towards slim screens and growing excitement around wearable displays, Bove and his group are now looking at waveguide holography in a bid to create a transparent flat-panel holographic video display that would not require additional optics.

Inside the “ZZZyclops” holographic camera used to capture the Fabergé egg *OptoClones*, where lasers from Photonics West exhibitor Cobolt provide the key technology.

In waveguide holography, advanced techniques are used to control guided-wave light in integrated optical devices, such as off-plane grating couplers, to generate the interference patterns required for holographic images.

As part of Session 5, Holography I, Bove and colleagues will take a look at the necessary properties of such a near-to-eye 3D display as well as report on recently developed design algorithms and fabrication methods.

“Essentially we could introduce laser illumination from the side of a see-through panel, which would then couple towards the viewer,” says Bove. “The imagery would then appear in front , or behind, the panel as with any transmission hologram.”

The ultimate goal of Bove’s research is to create a holographic flat screen display with motion. As he highlights: “You could imagine having a glass tabletop as a display, wearing it as a visor, or using the windscreen of a vehicle to display images. This has been done in the past with static images but now we are making dynamic holograms.”

Schematic of the *OptoClone* recording set-up used to create the ultra-realistic holograms of the Fabergé eggs.

Clearly, handling the millions of pixels demanded for such an application is no easy task, so Bove and colleagues at MIT Media Lab are also working with Japan-based NHK Broadcasting researchers, to better understand the associated computational and interconnect challenges.

In related work, in Session 1, Materials and Processes, Nobuo Saito and fellow NHK researchers are set to reveal their latest results in holographic storage, which could serve as a method for its ground-breaking 8K ultra-high-definition TV.

“NHK hasn’t spoken about this recently and it’s very interesting as on one hand it’s holography, but it also covers the extremes of non-holography image display,” says Bove.

“This is the point about this conference,” he adds. “It brings together a huge range of interests centered around the technology, for [researchers] united in their love for holography, and their desire to see more of it.”

REBECCA POOL

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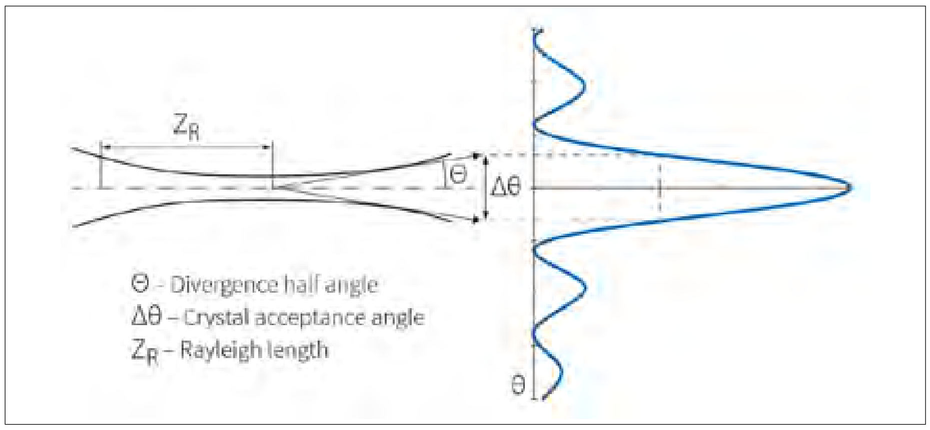
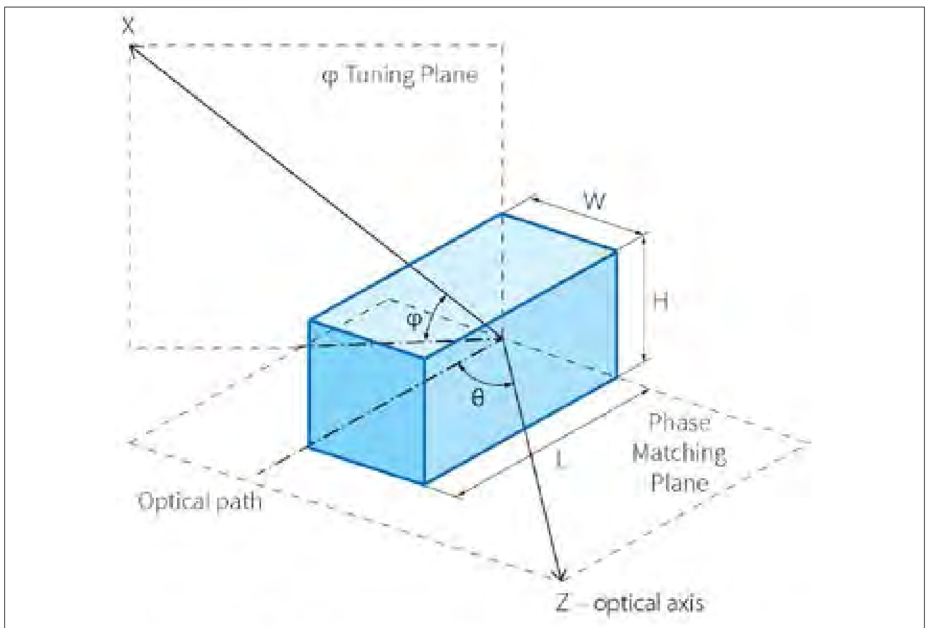
Crystal Optics Engineering

There are many companies in the world providing engineering and development services for custom linear optical systems that are in demand for many applications. Still, lasers or systems together with linear optics require modules, which can generate or switch to desirable wavelengths. For this task engineers need to take advantages of other physical phenomenon, such as population inversion, nonlinearity, Raman scattering, etc., that can usually be exploited with crystals only. Their appearances require rigorous working conditions and limit the wide range of usage, thus, one crystal can fit better for particular applications than the others.

Due to such limited possibilities many material development scientists work on new crystals' research to solve problems or find better ways to operate the required physical phenomena. In the last 30 years a few hundred different crystals or their isomorphs were developed. Some of them are being widely used, others are only applied to very specific areas, while few are completely forgotten. When needing to find the best suitable crystal and its configuration within many of these materials with different mechanical, optical, nonlinear properties and conditions, it would be best to look for Altechna expert's advice and suggested solutions before investing into expensive crystal optics. We provide technical consulting services with no obligations saving you time and resources. Get the most effective solutions for various crystal applications, the needed technical information, and appropriate simulations with optimal optical setup advice from the people who have seen it all.





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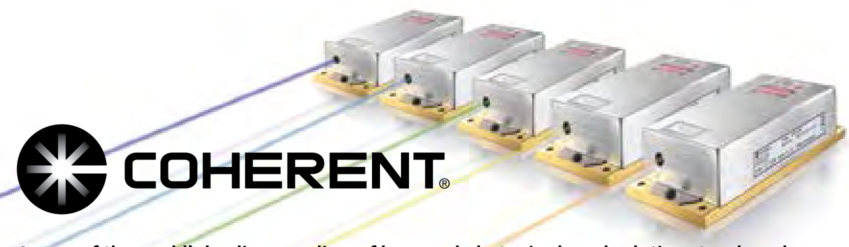

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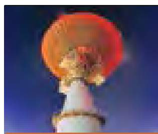

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Sponsored Editorial

Versatile Measurement Systems for Objective Lenses and Camera Modules

TRIOPTICS offers customers maximum versatility with a combined test system for objective lenses as well as for camera modules. The system is based on the ImageMaster® HR technology – the industry standard for testing the image quality of objective lenses. An additional ProCam® object generator converts the ImageMaster® HR into a test system for measuring the image quality of camera modules. The exchange of the object generator is quick and user friendly giving customers the flexibility to use either the ImageMaster® HR or the ProCam® Test R&D functions alternately.

ImageMaster® HR for testing image quality of objective lenses

The ImageMaster® HR is a fully equipped quality test station for medium sized sample lenses. Its modular and upgradeable design enables the measurement of the image quality (MTF) and a wide range of other optical parameters for today and future needs. The instrument is used in R&D labs as well as in quality assurance or in production. The unique vertical setup of the ImageMaster® HR is space saving and ensures the most convenient and accurate positioning of the sample lens mounts. With the collimator on the precise swinging arm an ultra-wide field angle of ± 105° can be measured for infinity conjugate samples. An upgrade for finite testing can easily be adapted to the system with an additional motorized stage and object generator.

ProCam® Test R&D for camera module testing

The ProCam® Test R&D is a versatile measurement device for testing various image quality parameters of camera modules. It does not only feature on-axis but also a wide off-axis angle range of up to ±110°. The computer-controlled test target distance can be freely selected from finite distances to infinity using a focusing collimator. The ProCam® Test R&D can be used for many different types of camera modules. This high flexibility makes the test instrument an ideal solution for comprehensive measurement tasks in R&D environment.

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TRIOPTICS

OPTO plenary explores a whole new playground

Monday's OPTO plenary lectures covered the promise of parity-time symmetry photonics, nonlinear optics, and a new public-private partnership designed to kickstart the US manufacturing infrastructure in integrated photonics.

Xiang Zhang of the University of California, Berkeley opened the plenary session by showing that optical loss could have a positive outcome.

The concept of parity-time symmetry originates from quantum mechanics, Zhang said in his talk on non-Hermitian and parity-time photonics. But when applied to optics, as Zhang showed by comparing the Schrödinger equation to the electromagnetic wave equation derived from Maxwell, it allows for precise manipulations of loss and gain — and new devices.

"If we borrow those concepts from quantum mechanics and apply them to optics, then there's a whole new playground we can explore," Zhang said in an interview.

For example, Zhang has used these techniques to control light at extremely small scales, which is useful for building tiny pixels that operate at precise colors, and thus high-resolution displays or CCDs.

The trick is in manipulating the interactions between optical resonators, which can function as pixels, he explained. Normally, two adjacent resonators are coupled, as if linked with a spring, and they can't maintain their own frequencies without influencing the other. However, by applying the ideas of parity-time symmetry, the researchers can manipulate that coupling — and specifically the spring constant that defines it.

Zhang's team designed the resonators such that the real part of the constant cancels to zero, leaving only the imaginary part, which is what dictates loss and damping in the system. It turns out that doing so allows the individual resonators to preserve their own frequencies, almost like how piano keys are tuned to precise musical notes.

Researchers are using the same methods to design single-mode lasers. Typical laser cavities, he said, have multiple frequencies while a single-mode laser fires at one, distinct frequency. Zhang further showed how these methods can be applied toward nanoscale spectroscopy and spectrum splitting in solar cells.

While nonlinear optics (NLO) is interesting in its own right, it can also serve as a superb platform from which to explore new physical processes and develop photonics applications, said Robert Boyd of the University of Ottawa and the University of Rochester. "It's good physics that leads to good engineering, and you can't get any better than that," Boyd said in his plenary talk.

"If you've read my book, you've had an introduction to nonlinear optics. If you haven't, I've condensed it to one slide," he quipped before launching into a brief overview of NLO.

Linear optics is simple and familiar, such as when a lens bends a light beam. However, an optical device that, for example, doubles or triples the frequency of a beam shows nonlinear behavior. It's this kind of phenomena that Boyd has spent decades exploring, and he was happy to show NLO's immediate relevance by pointing out that it lies at the heart of how the US Laser Interferometer Gravitational Wave Observatory (LIGO) increases its sensitivity to detect gravitational waves. Scientists announced just last week that twin LIGO detectors in the US had observed gravitational waves for the first time, confirming a major prediction of Einstein's 1915 general theory of relativity.

Last year, Boyd's team configured light such that its direction of polarization has the same topology as that of a Mobius strip. In addition to showing that a laser beam can have structure at scales smaller than its wavelength — dispelling preconceived notions — the experiment demonstrated the technological capability to measure the properties of light with extreme precision.



(l to r) Xiang Zhang, University of California, Berkeley; Michael Liehr, AIM Photonics; Robert Boyd, University of Ottawa, University of Rochester. Credit: Adam Resnick

"It's a huge technological advance," he told the *Show Daily*. For example, he explained, light that scatters off a surface would acquire a structure that depends on that of the surface. By measuring the scattered light precisely, researchers could deduce the surface's properties.

Boyd's group has also made the most precise measurement ever of an effect called Fresnel drag, the measured change in the speed of light when photons travel through a material moving with respect to a laboratory reference frame. Using materials that could slow down light by a factor of a million turns out to enhance the Fresnel drag effect. The experimental techniques would allow researchers to measure light velocities extremely accurately, potentially leading to more accurate Doppler velocity meters.

Nonlinear optics may play an even bigger role in the future of communication technology. In most quantum communication systems, light can carry at most one bit of information per photon; the photon is either there or not. But Boyd's team has found a way to pack more bits into a photon.

Using nonlinear optic techniques, the researchers can create photons in quantum states called Laguerre-Gaussian modes. Because a single photon can be in any one of the 27 Laguerre-Gaussian modes — or in any linear combination thereof — it can deliver more than one bit of information.

That means communication systems can send a lot more data. It also turns out that if a photon can be in so many states, such an optical signal is more secure and resilient to loss.

Photonics already underpins much of today's technology, from telecommunication to consumer electronics. In communications, for example, sending data through optical fibers is faster and more energy efficient than transmitting electrons through wires. But to fully exploit the potential of photonics, you're going to need integrated photonics.

"It's an attempt to take the elements of an optical system and miniaturize them such that as many as possible can be put on a wafer as part of a normal wafer-manufacturing process," said Michael Liehr of SUNY Polytechnic Institute, in an interview with the *Show Daily*. That way, manufacturers can produce photonic devices with the same ease and low costs as with silicon-based electronics, enjoying the same rapid progress that's described by Moore's law.

Liehr is also the CEO of the American Institute for Manufacturing of Integrated Photonics (AIM Photonics), a US Department of Defense-funded partnership between the public and private sectors. "We're an entity that's supposed to provide technology and innovation in the manufacturing space," Liehr told the *Show Daily*. "How do I make things cheaper? How do I integrate things better? How can I do it faster?"

In his plenary talk, Liehr gave an overview of how AIM Photonics, just established last summer, will help develop and support the US photonics industry, building the infrastructure needed to catch up with Europe and Asia. He emphasized that the consortium is member-led and focused on manufacturing. He also joked that he should be considered for the Nobel Peace Prize for his past six months of bringing together the wide array of universities, government, and industry members partnering on AIM Photonics.

Integrated photonics encompasses an array of applications, but Liehr said the consortium focuses on a few particular areas: data and communications; LIDAR, which has applications in everything from aerospace to self-driving cars; and new sensors, which Liehr describes as the least well-defined, but perhaps the most significant.

As technology becomes increasingly interconnected, sensing devices will become ubiquitous — but only if they're cheap enough. Integrated photonics will enable gadgets that track and measure pollutants, detect trace materials, and help prevent and diagnose diseases.

See page 7 for more on AIM Photonics.

TIM LAMKINS AND MARCUS WOO

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Wuhan institutes seek international collaborations

The Wuhan Industrial Institute for Optoelectronics (WIIO), the technology transfer wing of the huge research laboratory in the Optics Valley region of China, is hosting a reception on Wednesday night where it will seek to cement new international collaborations and attract new staff.

Taking place 7-9pm in Ballroom B of the InterContinental Hotel, the reception will see WIIO join forces with three other institutions to promote the vast range of expertise that has grown up in Wuhan in recent years. One of the key participants is Qingming Luo, director of Wuhan's Britton Chance Center for Biomedical Photonics and a leading figure in the development of optical technologies for brain imaging.

Luo, also one of the chairs for this year's *Neural Imaging and Sensing* conference within BiOS, told *Show Daily* that the Wuhan laboratories have already spun out dozens of companies looking to commercialize the various technologies being developed in the region. One that he has been closely involved with is OEBio, which produces specialist brain imaging systems using the micro-optical sectioning tomography (MOST) technique based around femtosecond lasers and tissue slicing with a diamond knife.

That equipment is able to produce highly detailed images of neurons and other brain circuitry like individual axons and dendrites, including complete three-dimensional images of a mouse brain. OEBio has already provided ten of its MOST machines to a new "core facility" dedicated to brain imaging in Wuhan, and Luo expects the center to acquire as many as 50 systems in total.

While the economic output of Optics Valley is still led by major players in optical communications like Yangtze Optical Fibre and Cable, Wuhan is targeting emerging technologies including ultrafast lasers, biomedical optics, and silicon photonics and energy to eventually complement the fiber-optic giants. One future spin-off could involve perovskite solar cells, with Wuhan scientists having now developed large-area panels based on the emerging photovoltaic material.

Record-breaking diode module aimed at optoacoustics

Photonics West exhibitor Quantel says it has developed an ultra-compact laser diode module with record-breaking peak power for photoacoustic imaging (PAI) applications. The module, which delivers a peak power of 5 kW in a 40 nanosecond pulse, enables the normally bulky PAI systems to be reduced to a hand-held size.

Olivier Rabot, who described the breakthrough in a busy Monday morning conference session on new sources for PAI systems, said: "Such high peak powers have never been available before in such a small package."

Developed in part thanks to funding for the European "FULLPHASE" research project, the Quantel module produces 4mJ pulses at four different wavelengths: 808 nm, 915 nm, 940 nm and 980 nm. Coupled with the nanosecond pulse duration, that energy level and a repetition rate of up to 10 kHz is needed to generate the kind of power required to create ultrasound in PAI. The technique is advancing rapidly for cancer, cardiovascular and other tissue imaging applications, with this year's BiOS conference on the topic attracting more than 200 paper submissions and packed rooms.

With a diode bar width of only 5 mm, the overall package measures just 5 x 5 cm. It is said to operate at an electrical efficiency of 30%, meaning that a hand-held PAI device based on it would not heat up appreciably. Rabot said that reliability tests on the module were ongoing, with 1400 hours of operation at a repetition rate of 3 kHz completed to date.

Innovations include integrating the diode stack as close as possible to the diode driver board, and slowing the rise and fall time of the diode driver compared with normal. The new patented driver electronics, developed in collaboration with the FULLPHASE partners, are a key part of the high efficiency achieved.

Quantel, which is showing off the record-breaking diode module at this week's exhibition, added that it was pushing the peak power further, and has a 1 mJ, 15 ns pulse version of the module under development.

MIKE HATCHER

TUNABLE LENS SNAPS ZEBRA FISH HEART

Press a long balloon at one end, and the opposite end swells up. That simple principle has been applied to a small fluid-filled lens, instantly giving it a longer focal length and the ability to change shape thousands of times a second – thanks to Swiss optics firm Optotune.

The focus-tunable lenses shown by Optotune in its BiOS demo on Sunday are based on a secret optical fluid, whose shape can be switched by a donut-shaped device similar to the coil in a hi-fi speaker. But instead of creating sound, the electric current moves a membrane outward; that deflects the fluid on the edges, buckling the lens and making it expand or contract as required.

In one application, a US customer is making the tunable lenses for a visual field analyzer, used in ophthalmology. In eyesight testing, it replaces the manually operated, bulky carousel of trial lenses. That allows an optician to dial up any level of eyesight correction, with the lens changing shape to produce the desired focal lengths.

"They could need 50 glass lenses. Big, heavy, expensive equipment, nothing you could wear on your head," said David Leuenberger, sales manager at Optotune. "You'd need to put it on a stand."

The latest Optotune focus-tunable lens, model EL 16-40, appeared last fall and is being aimed at other applications in industry, for example scanning labels on boxes on an assembly line.

"In 12 milliseconds, it can be ready to do a different task," said Leuenberger. "Take an image here, then here, then here. It's called image stacking."

The device can also produce 3D imagery, and Optotune's demo - attracting one of the biggest crowds of the day to the BiOS demo area - included a series of 3D images showing the beating heart of a zebra fish. "Most microscopes provide only 2D images," Leuenberg told the crowd. "But the world is in 3D. And biologists want 3D to image an animal or a whole embryo *in vivo*."

FORD BURKHART

SWIR focus: Xenics' booth at the weekend's BiOS exhibition. Photo: Doug Cody/Bay Area Photography.

Xenics imaging kit eyes optical biopsies

Xenics presented new integrated uses of its short-wave infrared (SWIR) technology at the BiOS exhibition on Saturday, with more to come at Photonics West.

With medical markets demanding equipment that can detect cancer earlier, the Belgian firm's latest technology looks useful for early, non-invasive diagnoses. The Cougar line has been around for three years but is now being integrated into several new spectroscopy applications, offering 640 x 512 image resolution with extremely low noise and high sensitivity.

Erasmus University in the Netherlands has recently assembled an entire new Raman spectroscopy system around the Xenics camera, while other projects in medical research include mid-to-near IR spectroscopy and live tissue imaging, carried out under the MINERVA and INSPECT European research projects.

Under MINERVA, Xenics has developed mid-infrared spectroscopy technology that can be useful in applications from agriculture to medical research. "The goal is to serve a new market for cancer tools," Hervé Copin, CEO of Xenics USA, said.

For the INSPECT project, Xenics is making a customized version of its "Xlin" line-scan SWIR sensor for taking infrared images. It will be integrated into a very compact spectrometer to provide an "optical biopsy," and is linked to a fiber-optic used during surgery.

The compact device can take the place of a large spectrometer - "something you can't move into the surgery environment," Copin said.

The cameras have other potential applications in SWIR imaging such as waste sorting, solar cell inspection, and food sorting.

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