THURSDAY EDITION

THURSDAY, FEBRUARY 2, 2017

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PHOTONICS WEST. SHOW DAILY

2017 Prism Awards : see who won

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Cellino wins Startup Challenge

Dark matter to EUV: LASE talks hit the mark

For more than a quarter of a century, Karsten Danzmann has dedicated his career to developing technology that could expand our understanding of the universe by detecting gravitational waves emanating from exotic objects in space.

On September 14, 2015, the Laser Interferometer Gravitational-wave Observatory (LIGO) finally did just that. For the first time, US LIGO detectors in Livingston, Louisiana, and Hanford, Washington, heard the first "peep" from an event in the distant universe — in this case the collision of two black holes. The event confirmed a major prediction of Albert Einstein's 1915 general theory of relativity and opened a new window into the cosmos.

It was such a major breakthrough that it took several days for the LIGO team to accept that it might actually be real, according to Danzmann, director of the Max Planck Institute for Gravitational Physics, a member of the LIGO Scientific Collaboration. And it was another five months before they made their findings public.

"I've been chasing this for 27 years, and when it finally happened it was unbelievable," said Danzmann, who noted that a second, similar event — the detection of gravitational waves produced by two black holes colliding 1.4 billion light years away — was captured in June 2016 at the same two observatories. "We've been looking at the universe with our eyes for thousands of years, and we know it looks very different depending on whether we look at it with visible light, infrared light, gamma rays, x-rays, ... but we haven't been able to hear it. And suddenly now we can. And we have hope that the dark side of the universe — which makes up 99% of the universe — is now accessible to us."

Karsten Danzmann says when gravity waves were finally detected, "it was unbelievable." Photo: Adam Resnick

During Wednesday's LASE plenary session, Danzmann's enthusiasm was contagious as he described the developments leading up to that historic moment, from the physics and technology to the thousands of people involved worldwide for decades (the first published paper, in *Physics Review Letters*, listed 1004 authors from 133 institutions).

For Danzmann, one of the key turning points came when Advanced LIGO, a $200 million upgrade to LIGO, was unveiled in mid-2015. With the upgrade, which took five years to complete, the observatories are now 10 times more sensitive than their predecessors, thanks to advances in the optical layout, new high-power (165W) stabilized laser systems, advanced mirror suspension, and improved pre-isolation for detecting very low frequencies, according to Danzmann.

"The upgrade to Advanced LIGO was drastic," Danzmann said. "The building is still the same, and the stainless steel of vacuum tubes are the same, but everything else has changed."

Danzmann is equally excited about a more recent development: LISA Pathfinder, a satellite mission launched in December 2015 whose payload includes the first laser interferometer in space.

"On the ground we are listening to the high frequencies of the universe, but if we want to

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DON'T MISS THESE EVENTS TODAY.

INDUSTRY EVENTS

US SCIENCE/TECH BUDGET KEYNOTE
(9:15-9:45 AM, Room 103, South)

PHOTONICS WEST EXHIBITION
(10 AM-4 PM, North & South halls)

PRISM AWARDS FOR PHOTONICS INNOVATION, AWARD WINNERS AT EXHIBITION

EXPORT CONTROL WORKING GROUPS
(10-2:30 PM, Room 102, South)

STARTUP ALLEY
(11 AM-1 PM, South exhibit hall)

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.

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Lidar on the move.
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$10M VC deal sees TetraVue target self-driving cars

Job Fair exhibitor TetraVue says it has just closed a $10 million round of series A equity finance, becoming the latest company targeting autonomous driving to attract investors eyeing the high-profile sector.

Founder Paul Banks, who first set up the San Diego company in 2008, said that he was looking to double the company's currently 20-strong workforce within a year, and was advertising for a series of engineering positions at the Moscone.

TetraVue is developing a high-density time-of-flight imager based around a 2-million-pixel sensor and optics that Banks says simplifies the way in which a scene can be captured and processed – for example distinguishing between a rock and a bag on the road ahead of a car: something that existing sensors struggle to do. "We solve the problem optically," Banks said, adding that the technology's current range of 30 meters will be extended to 200 meters within a year.

Meanwhile, Hamamatsu is demonstrating a new family of silicon photomultipliers, which it says will be to be essential for future autonomous vehicles, on the main show floor.

Attention was focused on its newest detector, which features enhanced detection in the near-IR. "This is ideal for long-range distance measurement," said Jake Li, a marketing engineer with the firm.

See Hamamatsu City feature, page 15

SPIE President-Elect Maryellen Giger with Enas Sakr of Purdue University at the SPIE Women in Optics reception during Photonics West. Photo: Adam Resnick

Panel ponders "global shock" responses

A lively panel discussion Tuesday on dealing with "global shocks" and their implications for photonics saw US policy, "Brexit" and China on the agenda.

Moderator John Dexheimer, a venture capital and private equity analyst, is also a Photonics West regular. He moved straight to Brexit. "There was an interesting survey [from] Silicon Valley Bank a few months ago: 72% of executives said the UK leaving the EU will hurt business, it will be more difficult to find talent, to scale, and they expect to see more mergers and acquisitions."

What did Basil Garabet, CEO of NKT's Photonics Group, think? "At the time of the referendum, I had the view that the British would not vote for something as rash as that. But we [NKT] are small enough to adjust to the situation, to be able to move fast, and we are still actively looking at acquisitions." NKT had acquired UK-based Fianium only three months before the Brexit vote.

Dexheimer asked David Santorum, a project manager in foreign trade and export promotion at German trade group Spectaris, if Brexit might be an opportunity for Germany.

"I was surprised when I learned that Brexit had won the referendum, which I think was the view of people around Germany," Santorum said. "From my lawyer perspective, I think it's hard to believe that there will be a good deal for all parties. UK industry will still be able to sell into Europe but products will get more expensive. Some UK companies, which are large and international, like Vodafone, may decide to relocate into the EU."

Next up was Deepak Kamra, a general partner at Canaan Partners — a $4 billion global investor in emerging growth firms, based in Westport, Connecticut. He gave his thoughts on what new US policies could mean for business development.

"Well, I'm an immigrant. I stole one American job, but I have helped create hundreds of thousands of jobs over the years," he said. "My firm has invested in close to 500 companies, and almost a third of those have an immigrant as a founder. There's a big role played by immigrants [and] I think it's important to maintain that but the situation is changing."

Kamra said that some other countries have put in place constructive mechanisms to encourage immigrants, giving examples such as Canada, China and Chile. He said he recognized that there was now more US government concern about enabling US citizens to obtain high-tech jobs — but reminded the audience that Silicon Valley still often has many positions unfilled due to lack of qualified applicants.

Charles "Chuck" Comey, an M&A and corporate finance partner at Morrison Foerster, a former resident of Beijing and fluent Mandarin speaker, added his take on some of the key issues affecting business with China.

"I was in Beijing and Shanghai two weeks ago and I can say that, notwithstanding all of the geopolitics, the interest in China to invest in, partner with and acquire in the US and Europe has never been higher," he said. "They're not waiting and they're not worrying. They're still very interested in continuing to engage."

LASE talks

continued from page 01

listen to low frequencies, we have to go into space," said Danzmann, who is co-principal investigator on the LISA technology package. "Some of the most interesting things in the universe are supermassive black holes. When galaxies collide, which happens all the time, these supermassive black holes merge and emit a huge signal, and that is what we want to listen to in space."

LDW for hybrid electronics

The second LASE plenary talk featured an overview of the current state-of-the-art in using laser-based direct-write (LDW) methods to print hybrid electronics. The talk was given by Alberto Pique, acting head of the Materials and Sensor Branch of the Materials Science Division at the US Naval Research Laboratory.

"The goal is very simple: can we go from a design to a printed part that is not faithful in a structural sense but in a functional sense?" Pique posited. "To do that, we need a substrate, we need to wire it up, place the devices, then connect the wires and devices. If you do it right, you end up with a functional circuit."

This is where additive manufacturing (AM) comes in. AM is considered a game changer for design and fabrication of 3D parts by reducing the number of steps from concept to part, while direct-write processes make it possible to fabricate custom electronics in less time and at lower cost than other techniques. Combining the two paves the way for more efficient and cost-effective printing of hybrid electronics.

The ability of LDW to deposit functional materials over a wide viscosity range onto many diverse surfaces makes it unique among direct-write processes, Pique noted. For example, when manufacturing inkjet nozzles, "you have to be careful about the material you put on the nozzle and you have to worry about the nature of the fluid. But when you use the LDW forward transfer technique, the nature of material is not that critical."

Advances in lasers, materials, and positioning have spurred the development of LDW in AM, he added. In particular, the availability of high-repetition rate solid-state UV lasers with stable, moderate energies has allowed LDW to deposit materials rapidly in all three dimensions. By comparison, low-rep rate UV lasers with more uniform beam profiles have enabled printing larger area voxels, which also speeds up the LDW process.

"Over the years, we have shown that with LDW we can both add and remove material, and this gives the laser technique an edge (over other direct-write techniques) because you can do two things with the same set up," Pique said. "The same system performs both additive and subtractive processes."

250W EUV light sources

In the final talk, Hakaru Mizoguchi, executive vice president of Gigaphoton, provided an update on the company's efforts to develop high-power EUV light sources for high-volume manufacturing (HVM) lithography. In July 2016, Gigaphoton demonstrated 250W light output at 4% conversion efficiency with a laser-produced plasma (LPP) light source prototype for EUV scanners. Since then, the company has continued to test and refine its EUV light sources, with a goal of eventually reaching 500W, according to Mizoguchi.

KATHY KINCADE

Terahertz systems: ready to roll in paper and pharma

Tuesday's OPTO conference "Towards the industrialization of terahertz technology" showcased two examples of terahertz process monitoring in action, with delegates hearing that the technology has progressed rapidly from a laboratory-focused tool to commercial devices with applications across pharmaceutical testing, manufacturing, and security.

A keynote talk from Dook van Mechelen of Swiss industrial giant ABB Research covered quality control during paper production, while UK firm TeraView's terahertz champion Philip Taday discussed ways to study new forms of tablets produced by the pharmaceuticals company Merck.

"At ABB, we carried out a comprehensive study on a large variety of paper sheets in the industrial environment," said van Mechelen, pointing out that in the last few years terahertz technology has struggled to establish itself in the competitive optical metrology space. In a melodramatic turn, he said that after a "peak of inflated expectations" as long ago as 2005, terahertz systems had started to enter the "trough of disillusionment." But there are some grounds for optimism.

ABB's own production tests ranged from toilet tissue to cardboard, via 100 gsm copy paper. One major challenge is that paper production is fast: something like 120km per hour, with other difficulties such as water splashing, high temperatures, and a cocktail of both liquid and solid chemicals to deal with.

Ending on an upbeat note, he said: "Terahertz technology is definitely ready to be applied. [It] can do it cheaper and better. But its feasibility needs to be shown in factories to create a market pull."

TeraView's Taday then outlined the application of pulsed terahertz imaging to measure the progress of so-called "osmotic tablets." These are a recent pharmaceutical innovation to enable gradual release of drugs — by osmotic pressure — as a tablet dissolves in the stomach.

"Using TeraView's terahertz system, we can measure structural features like tablet film-coat thickness to better understand the push-pull mechanisms," he said.

In recent experiments with Merck, terahertz imaging measured the semi-permeable membrane coating thickness of tablets from different developmental batches. The two companies are now working to understand and model tablet behavior and quality control in tablet production, as film thickness variation significantly affects drug release rates.

MATTHEW PEACH

Japanese team develops tiny micromachining laser

Representatives of the Japanese government's heavily funded "ImPACT Program" are exhibiting at the Moscone Center this week, showcasing the two projects (out of 16 in all) involving novel lasers.

One of the projects is aiming to develop an ultra-compact pulsed solid-state source. The resonator is barely the size of a postage stamp, and designed for integration with robots and drone platforms. Based around a heat-sink comprising alternating layers of millimeter-thin Nd:YAG and sapphire, the source is said to have delivered pulse energies in excess of 20 mJ with a pulse duration of 400 picoseconds.

Future work will involve further reducing the thickness of those alternating layers to just 0.2 millimeters, with commercialization penciled in for around two years from now as micromachining applications are targeted.

In the second laser-related effort, a team led by program manager Takayuki Yagi is working to build a photoacoustic imaging system suitable for applications in medicine and industry. At the weekend's BiOS Expo, Kentaro Miyata from program partner company Megaopto said that the size of the laser system for the photoacoustic imager could be reduced dramatically by selecting specific wavelengths instead of using broadband emission from a Ti:sapphire laser.

Currently being prototyped, the laser system in development uses 756 nm and 797 nm emission tuned for hemoglobin absorption, with applications in vascular imaging and breast cancer screening anticipated around five years from now. Among the big-hitters involved in the program are Canon and Hitachi.

Another Japanese company working on a novel source for photoacoustic imaging during BiOS was PreXion, whose AcousticX system does away with lasers entirely - instead relying on pulsed LEDs combined with a pre-amplifier to boost signal-to-noise performance.

Currently being tested in pre-clinical studies on animals, the full system is expected to sell for around $50,000 — which PreXion says is less than the typical cost of just a solid-state laser and optical parametric oscillator for photoacoustic imaging. Envisaging eventual applications in breast and lymph-node cancer screening, the Tokyo-based firm is working with researchers at Johns Hopkins University and elsewhere, and hopeful of securing US Food & Drug Administration (FDA) regulatory approval for a clinical trial before the end of 2018.

MIKE HATCHER

IPG Photonics is at booth #1623.
Photo: Adam Resnick.

IPG BOUNCES ON BILLION-DOLLAR YEAR

Fiber laser maker IPG Photonics has indicated that its full-year sales for fiscal 2016 are likely to top $1 billion for the first time, sending the company's stock price up 10% in the process.

Estimated at $280 million for the fourth quarter, the sales total beats the prior guidance of between $255 million and $270 million. Added to the $726 million posted for the first nine months of the year, it tips the annual figure just over the billion-dollar mark.

Announcing the preliminary figures on the eve of the Photonics West exhibition, IPG added that a benefit from foreign exchange rates had also helped to boost profits.

IPG's CEO and founder Valentin Gapontsev said in a statement from the Oxford, Massachusetts, firm: "We are extremely pleased to have achieved this landmark revenue level in the quarter that marks our tenth anniversary as a public company."

He added that the approximately 25% year-over-year increase in fourth-quarter revenue compared with the closing three months of 2015 was primarily driven by the continued strong demand for lasers in materials processing applications.

"Geographically, we saw our strongest growth in Asia and Europe," said the CEO. "In terms of products, growth was primarily driven by high-power fiber lasers, QCW lasers, pulsed lasers and amplifiers used in telecommunications applications." The company, which is exhibiting its broad portfolio of lasers this week, will provide a full update of its latest financial year, along with an update on its future strategy on February 14.

On release of the update, IPG's stock price jumped in value by around 10%. Trading at around $115 on January 31, the company now commands a market capitalization in excess of $6 billion.

At its Moscone Center booth, IPG was showing off its six-laser system for digital cinema, with the company saying that its first field units are now under evaluation at cinemas in both Europe and the US. IPG also reported strong interest from the show floor in its mid-infrared fiber lasers, which provide a high-power option for spectroscopy in the "molecular fingerprint" region as well as dental and medical applications, and environmental monitoring.

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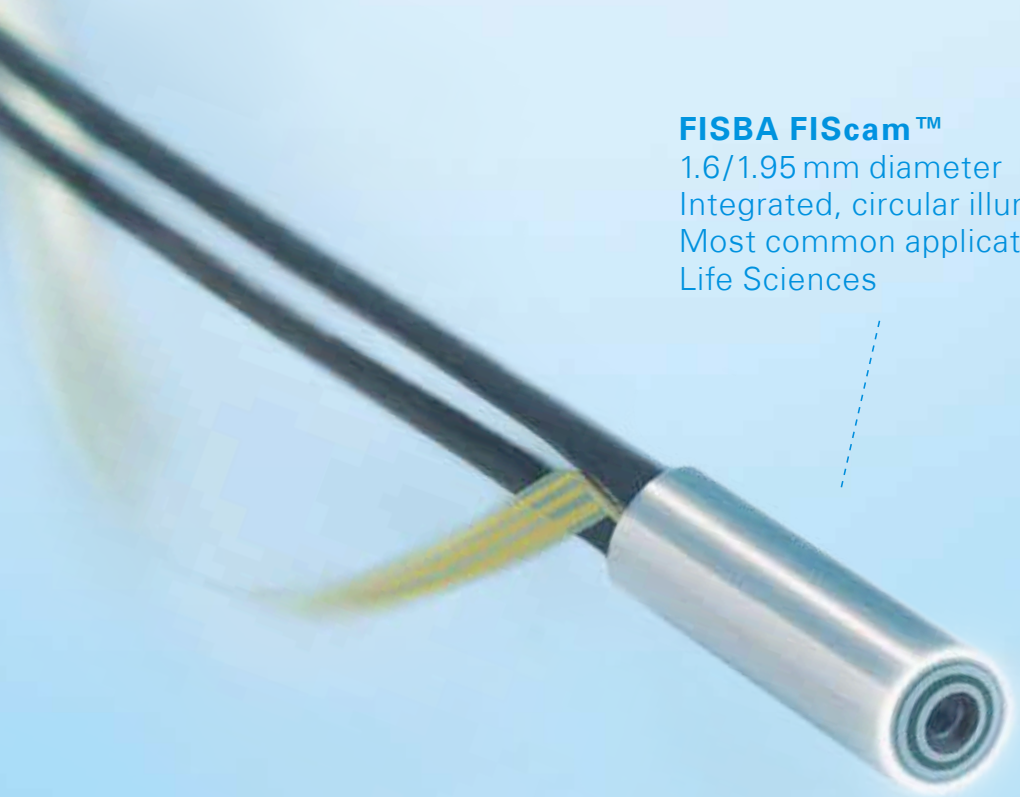

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AIM Photonics sets its sights on an industry revolution

North, south, east, west: the tentacles of the American Institute for Manufacturing Integrated Photonics already criss-cross the US. Where to next, asks Ford Burkhart.

Coast to coast, a new era in integrated photonics manufacturing is shaping up in Year 2 for AIM Photonics, the abbreviated name for the American Institute for Manufacturing Integrated Photonics, where the high-tech agenda ranges from multi-project wafers to self-driving cars.

To the east, top researchers are at work at the AIM Photonics headquarters and research nodes in Rochester, New York, and in Massachusetts. Out west, things are percolating in Santa Barbara, California, and in Tucson, Arizona. Even overseas, the wider photonics industry has been asking how they too might participate in the giant US Department of Defense-sponsored project (no answers yet; AIM is still working on that).

In December, the seven-member New York Photonics Board of Officers, created in 2015, heard AIM Photonics CEO Michael Liehr outline an $81 million funding request draft spending plan for 2017-2018. Then in AIM's "new year" update, some of the details of what is being worked on emerged, with Liehr citing the development of quantum dot lasers on silicon, and lidar sensors for autonomous vehicles and robotics as two key areas. The CEO also welcomed its most recent "Tier 1" member, in no less a form than IBM.

As Washington adjusts to the Trump era, the AIM Photonics team — incorporating industry, government, military and academic sectors — remains optimistic.

"The new administration has really stressed manufacturing technology inside the US," said Frank Tolic, the chief marketing officer for AIM Photonics. "And that is exactly what we are doing. With the recent announcement of the TAP facility, located at ON Semi, in [Rochester's] Eastman Business Park, we're positive that we will continue to focus on manufacturing growth in the years ahead."

And everybody is becoming fluent in a now-familiar language of acronyms: PDK, MPW, SME, and now TAP. For those who aren't, a PDK is a process design kit for silicon photonics, with a release date of January 2017; an MPW is a multi-project wafer, of particular benefit to an SME, a small to medium-sized enterprise. Now with the TAP (test, assembly and packaging) facility selected, things should move forward apace.

AIM Photonics leaders are delighted to see strong international interest in its projects. "The excitement about PDK and MPW is positive," Tolic said. "The fact that they are even asking shows how powerful this is."

AIM Photonics is the largest of about a dozen new US manufacturing institutes proposed by the previous White House administration. Integrated photonics unites optics with electronics to serve a potential multibillion-dollar set of industrial applications. AIM Photonics says it now has 57 signed members, with another 10 expected to sign soon, 60 more in process, and another hundred "in discussion." Last month, Liehr highlighted new recruits from 2016 including the likes of Boeing, Raytheon, Samtec, and Toyota, while Infinera — which has been making integrated photonics chips at its Sunnyvale, California, indium phosphide fab for more than a decade — is perhaps the most significant addition to the list.

Officials said they believe that such a list of stakeholders acting in concert will ensure that a US manufacturing base of technology is growing and playing a critical role, in national security and elsewhere.

Liehr commented: "Considering the significant impact integrated photonics will play in the very near future of communications, as well as day-to-day commutes and our country's national security, it is imperative we have an institute dedicated to securing this manufacturing infrastructure.

"At AIM Photonics we are very pleased with our current accomplishments and excited about the future work. We will

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New York State governor Andrew Cuomo, flanked by the New York State Photonics Board chairman John Maggiore (l) and Empire State Development CEO Howard Zemsky (r) announces the selection of ON Semiconductor's site at the Eastman Business Park in Rochester as the key test, assembly and packaging (TAP) facility for the AIM Photonics project in December.

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NKT Photonics

AIM Photonics continued from page 07

continue to focus on sustainable US integrated photonics manufacturing for many years to come."

Reaching out

The institute is linking outreach for members to its technology thrusts. One example is the work on lidar, similar in principle to radar and of huge and growing interest for autonomous vehicles (read much more about this topic on page 25) and robotics applications. Engineers at Massachusetts Institute of Technology (MIT) and elsewhere within AIM are digging into that, with Toyota signing up as the project's first company partner from the automotive sector.

Park once housed the R&D and cleanroom manufacturing space where Kodak pioneered semiconductor image sensors for digital cameras, imaging satellites, and digital imaging technologies. Now a key part of ON Semi's US manufacturing footprint, the facility will ultimately test, assemble and package photonic chips, combining state-of-the-art performance with the latest fabrication techniques.

The challenge here is a huge one. Attachment of wires, or fibers, to such devices has for decades been done by hand, limiting any potential scale-up and cost reduction. With millions of low-cost chips now needed to support giant servers, the proliferation of data centers, the roll-out of self-driving cars — and plenty more besides —

The ON Semiconductor site in Rochester currently produces high-end image sensors for the likes of NASA, and was originally the location where Kodak developed early CCD technology.

While automotive lidar has thus far required a bulky fruit-basket sized mechanical assembly, as seen most often on the roof of Google's driverless vehicles, and newer designs the size of an ice hockey puck, AIM Photonics plans to shrink all the technology onto a single chip. A focus on manufacturability will speed the emergence of the driverless vehicle, reckons Michael Watts, the AIM Photonics CTO.

Up in New York State, AIM Photonics also has a strong presence at SUNY Polytechnic Institute's Albany NanoTech Complex, which offers a state-of-the-art semiconductor processing facility alongside its 3000 top-tier engineers and researchers. A three-hour drive west in Rochester, the AIM Photonics operation is able to draw on a 100-year history in optics technology development. The ON Semi TAP facility there will leverage the area's workforce, its universities, and industry partners, Tolic said, to make semiconductors more cost-effective. Initial device production is expected there within the next couple of years.

"We are making very good progress 'standing up' the test, assembly and optical packing capability in Rochester," said Ed White, AIM Photonics' corporate outreach executive. "We have selected a site, as well as procuring tools and equipment that will provide the base from which we will develop a manufacturing capability enabling commercialization of innovative new products that advance the state-of-the-art in our key areas of interest."

The ON Semi site at the historic Eastman Business automation is crucial, and it will take a major collective effort to work on that, AIM said.

PDK progress

Over in Massachusetts, a key focus is workforce development, with core management coordinated through MIT. Start dates in 2017 are set for several communications-oriented projects, with industry focus and feasibility studies underway linked to the MPW.

Meanwhile, smaller semiconductor companies, those without a $100 million research budget, are able to access advanced test chip programs on industry-standard 12-inch silicon wafers thanks to AIM Photonics. In Year 1, AIM was testing MPW's through several university institutes, with SUNY Poly driving the program. That work involved MIT and member company Analog Photonics, with a goal of improved semiconductor fabrication. One result was the AIM Photonics PDK.

The electronic-photonic design automation (EPDA) executive for AIM Photonics, Brett Attaway, said, "A few months ago, we released our first process design kit for the AIM silicon photonics technology and subsequently received nine customer chip designs for our first multi-project wafer fabrication run."

He added: "[The] next year is shaping up to be very exciting as we plan on two major PDK releases plus the addition of both interposer and passive-only MPW fab runs for a total of eight MPW runs in 2017. Our vision of being able to offer high-quality solutions for fully integrated

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AIM Photonics continued from page 09

electronic-photonic systems, along with enabling advanced design methodologies, is making significant progress."

In his new year address, Liehr added: "In 2017, participants will be able to create multiple runs from simple passive short loops to full-flow photonic integrated circuits (PICs)."

Members talk of the "I-90 photonics corridor," stretching from Rochester to Boston. In November, nearly 150 experts met at MIT to discuss a roadmap for making chips and photonic sensors, connectors, assembly, testing and systems packaging, and design automation, creating an integrated photonics supply chain for industry and workforce needs.

Workforce planning is also under way at the AIM Photonics Academy, based at MIT. It has a five-year-plan, involving many states, for training tied to integrated photonics manufacturing. Other partners include the University of Arizona, UC Davis, and UC Santa Barbara.

Last November, nearly 150 experts met at MIT to discuss a roadmap to create an integrated photonics supply chain for industry, as well as workforce requirements. Photo: MIT

Also at MIT, academics are working on a major roadmapping project, spelling out training needs five or ten years down the road in areas like automated fiber attachment. Lionel "Kim" Kimerling is executive director of the AIM Academy at MIT, which recently announced that it will receive $800,000 in state funding to assist with workforce development.

The institute is encouraging colleges to follow the model of Monroe Community College in Rochester, which so far is the only US college with a two-year associate's degree dedicated to optics and photonics.

Way out west

AIM Photonics is of course a country-spanning affair. Out in California, UC Santa Barbara represents the West Coast headquarters, under the guidance of the effort's deputy CEO, John Bowers — a pioneer in the field of silicon photonics, and of silicon-integrated lasers in particular.

"UCSB's expertise in epitaxial growth and in designing quantum dot lasers is key in developing next-generation integrated photonic chips," Bowers said. "And we have made significant strides recently with high-quality lasers grown on on-axis (100) silicon without a germanium layer." Work in this area is set to include ultra-low-loss waveguides.

UCSB can offer vital expertise to help meet proliferating demand on data communications at the huge server farms in California and elsewhere, where warehouses accommodate vast racks of equipment moving ever larger volumes of data each second. Photonics offers the best solutions to faster flow, using less power at lower costs. "Shrinking these lasers down to nanometer scale, that's the work of UCSB," Bowers said.

Down south now to the University of Arizona, where Tom Koch, dean of the College of Optical Sciences in Tucson, chairs AIM's Technical Review Board, tasked with reviewing and selecting annual proposals for AIM Photonics projects. Those selections will be carefully integrated with "TWGs," or technical working groups, workforce training and industry roadmapping efforts. Arizona is also working with industry partners on scalability in integrated photonics, and one particular area of Arizona's expertise is process technology for interfacing on PICs using optical I/O (input/output) technology.

Says Koch: "AIM Photonics has made major steps in getting some of the big moving pieces in place, including an open MPW program ... things are coming together nicely in a relatively short time." Pointing out that industry partners — notably Infinera, which began shipping its first PIC devices back in 2005 — are joining the network, Koch added: "This is just how the institute is supposed to work," while Liehr said at the time of Infinera's official joining in October 2016 that the partnership would dramatically expand access to cutting-edge photonics technologies crucial to the success of the institute. "It also adds more photonics industry star-power to our team," Liehr added.

In a December 2016 blog post, the Sunnyvale firm pointed out that although it had only recently joined the AIM Photonics roster officially, it had in fact been involved in the initiative from its inception. Fred Kish, the senior VP of Infinera's optical integrated circuit group, was at the July 2015 inauguration, and said: "We are honored to join AIM in developing and designing the high-performance tools the nation requires to remain competitive." While Infinera has thus far focused on optical networking applications of its PICs, it sees the much wider set of opportunities emerging in areas such as embedded sensors for chemical analysis and life science — perhaps in the form of sophisticated health diagnostics integrated with smart phones — or phased-array antennas that could be used in displays and biomedical imaging.

"Similar to how the development of scalable manufacturing techniques for microelectronics has fueled four decades of US-led economic growth in the semiconductor integrated circuit industry, advances in integrated photonics that are delivering significant improvements in size, performance, cost and reliability are expected to help the US remain competitive in today's global, high-tech economy," stated the firm.

Back to Tolic now, to sum things up. In short, he says, AIM Photonics is taking aim at all manufacturing areas. "From beginning to end, you will have solutions to design, research, manufacturing, assembly, and testing, offering unmatched, capital and time efficient capabilities for photonics-based organizations of all sizes."

At AIM, they like to cite just one example, shrinking that box of lidar hardware — what you see on top of autonomous vehicles — down to chip level. Something that will do for the auto industry what Henry Ford's assembly line did a century ago: in other words, nothing short of a revolution.

FORD BURKHART

Making waves

As the hunt for gravitational waves resumes, Italy's revamped Virgo laser interferometer is set to take its place at the heart of the search.

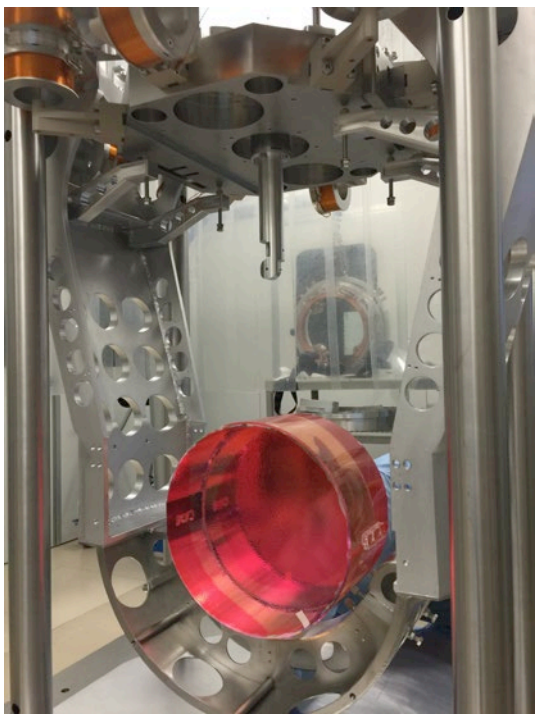
It was a discovery that resonated around the world: shortly before Photonics West 2016 gravitational waves, tiny ripples in the curvature of spacetime itself, had been observed by both of the Laser Interferometer Gravitational Wave Observatory (LIGO) facilities, in Louisiana and Washington.

Nearly three decades after the ambitious, occasionally troubled, big-science project first kicked off — but just days after a lengthy overhaul costing $600 million was completed — that echo of a collision between two black holes 1.3 billion years ago provided the first direct evidence of a phenomenon predicted by Einstein 100 years earlier.

By one calculation, the energy released by that cosmic collision was greater than the combined power of the light radiated by all stars in the observable universe. But on arrival at the Earth's surface it created a fluctuation in spacetime so minuscule that it altered the length of one 4-kilometer arm of a LIGO interferometer by a distance just one-thousandth of the width of a proton.

So, yes, gravitational waves are faint and elusive. Detecting them requires an exceptional laser interferometer — and another one located as far away as realistically possible, since multiple instruments in tandem is the only way to reliably sift gravitational waves from the local "noise" of earth tremors and busy roads.

Each LIGO instrument is built around a 4W, 808nm infrared laser diode. Its emission is turned into a 1064nm beam via a garnet crystal, and then progressively amplified to 200W. If power is important; stability is vital. Intrinsic fluctuations in the beam's frequency and power are mechanically controlled through a series of feedback mechanisms, ultimately reducing these variations by a claimed factor of 100 million before the beam is fit for purpose.



One of Virgo's 42kg mirrors, shown here protected with a pink film and suspended from two fused silica wires attached to its sides. Photo: Virgo Collaboration

When the twin LIGO sites in the US were completed, experiments ran for nine years — and detected precisely nothing. This was not entirely unexpected: the hunt for gravitational waves would require long-term instrumental optimization and a seven-year program of redesign and construction created the updated instrument referred to as Advanced LIGO.

Target mirrors, initially 25 cm across and 10 cm thick, were exchanged for ones measuring 34 cm by 20 cm — and, at 40 kg each, almost four times heavier than their predecessors. Mirror mountings were overhauled, with single-pendulum suspension on metal fibers replaced by a much heftier quadruple-pendulum arrangement using silica, further quashing any motion caused by external and internal forces.

Passive shock absorbers were replaced with an active feedback system, actuators responding immediately to position and motion sensors to further improve seismic isolation.

Thus was Advanced LIGO's desired detection sensitivity of 10^{-19} meters achieved — enough for the successful detection of gravity waves.

Virgo's spring date with LIGO

Now the US installations are about to gain a revitalized European ally. In the Italian countryside near Pisa lies the European Gravitational Observatory, home to another kilometer-scale Michelson interferometer named Virgo.

A program of upgrades and renovations is expected to improve Virgo's sensitivity by a full order of magnitude, and is almost complete. Once operational, Advanced Virgo will work alongside Advanced LIGO to triangulate the origin of incoming gravitational waves — impossible with only the two US interferometers — and point astronomers towards the precise part of the sky to observe the site of interest with more conventional kit.

Speaking in late 2016, Virgo's Fulvio Ricci outlined progress: "The light is circulating in Virgo and we are in the alignment phase, before then working to stabilize and lock the different optical cavities," he said. "We have already locked the Michelson interferometer and the power recycling cavity for a short time, and in that moment kept the whole interferometer output in the middle of the desired fringe, avoiding significant increase of the light power in the interferometer.

"Next we have to better tune the telescopes in front of the quadrant photodiodes used to control the interferometer, and then reduce the frequency noise further by engaging the second stage of the laser frequency stabilization system."

These challenges have been met by developing ways to better estimate the resonance parameters of the cavity and the related forces needed to control them, assisting with the tricky task of locking the interferometer arms.

"Overall, things are going well," Ricci told *Show Daily*. "We are working hard to join LIGO during the spring of 2017."

That timetable should see the three advanced interferometers working together during the second half of LIGO's second observing run, the six-month "O2" work program. But project managers are already looking beyond that — to further possible upgrades facilitating a third work program, and to both Advanced LIGO and Advanced Virgo running at full sensitivity by 2021.

TIM HAYES

Hamamatsu City: a growing hub for applied photonics

Already with a rich high-tech heritage, the Japanese city is becoming a key center for photonics innovation and entrepreneurship — with this year's Hamamatsu Photonics exhibition booth lit with technology from local spin-off Pi Photonics.

Hamamatsu City, long considered one of Japan's premier manufacturing centers for everything from textiles and woodworking to musical instruments and motorcycles, is slowly transforming into a hub for photonics-related R&D.

Located about 260 kilometers (160 miles) southwest of Tokyo in Shizuoka Prefecture, Hamamatsu City has a rich industrial history. From the early 1600s to the 1900s, its success in the production of cotton fabrics led to a thriving textile industry and loom manufacturing business, while its lumber operations paved the way for the manufacture of musical instruments and a resulting woodworking machinery industry. These ventures also created a need for metal working expertise, which evolved over time to include the manufacture of transportation equipment.

Akira Hiruma, Hamamatsu Photonics president and the chairman of GPI, the city's Graduate School for the Creation of New Photonics Industries. Photo: Hamamatsu Photonics

Today, Hamamatsu City offers a number of incentives for manufacturing, engineering, research, industrial design, data centers, and distribution facilities. As a result, it is where several leading Japanese companies, including Suzuki, Yamaha, Roland, Kawai Musical Instruments, and of course Hamamatsu Photonics, maintain their headquarters.

The city's roots in photonics can be indirectly traced back to Kenjiro Takayanagi, a professor at the former Hamamatsu Technical College (now Shizuoka University) and a pioneer in the development of television. In 1926, Takayanagi had the bright idea of using a cathode ray tube to create the first all-electric television receiver. Ever since, the university and its surrounding industrial complex have supported electronics and photonics R&D.

Pre-eminent photonics city

The region's photonics efforts received a major boost in 2013 when four stakeholders — Shizuoka University, the Hamamatsu University School of Medicine, The Graduate School for the Creation of New Photonics Industries (GPI), and Hamamatsu Photonics — penned the document, "Establishing Hamamatsu as a Pre-eminent Photonics City: Photonics Declaration 2013." It sets forth a number of long-term goals designed to establish Hamamatsu City as a center for applied photonics research. Among its stated strategic initiatives:

"To establish Hamamatsu [as] a pre-eminent photonics city that creates innovative photonics science and industries for the world; wherein … fundamental and applied photonics research of the world's highest level is carried out; … photonics products/technologies that the world desires are developed; … [and] venture businesses and small/medium-sized businesses play a leading role in developing applied photonics industries."

The goal, according to Akira Hiruma, president of Hamamatsu Photonics and chairman of GPI, is not to make Hamamatsu City a center for basic photonic devices, but to help companies grow by infusing photonics technologies into existing businesses and new ventures. In particular, he sees photonics as a key enabling technology for small- to medium-sized enterprises (SMEs) interested in developing new applications and products.

"We would like Hamamatsu City, Shizuoka Prefecture, and the Japanese government to recognize the importance of making local SMEs grow and help develop the local ecosystem for local universities and local SMEs," Hiruma said.

Hamamatsu also wants its home city to flourish, added Ken Kaufmann, the firm's vice president of marketing. "We are willing to do things that we feel are important to make the city successful so that the approximately one million people living there will have fulfilling lives," he said. "Photonics is a high-end industry that requires a lot of skill and knowledge, so we think that it will allow new companies to be born, to provide employment for the residents of Hamamatsu City."

Grad school fosters startups

The GPI, also located in Hamamatsu City, has been instrumental in helping many of these new ventures get off the ground. Founded in 2006 with a mission to "educate young startups with photonics technologies and create new photonics industries with students," it features several focused research areas for PhD students, including photonics industry management, photonics for materials processing, optical information and systems, photonics for energy, biophotonics, and medical photonics.

"GPI is focused on fostering entrepreneurs through the cultivation of new fields with photonics," said Yoshiaki Kato, the president of GPI, who notes that 30 venture companies have so far been started by its students. "Students at GPI are concentrated on opening frontiers in photonics by practicing company startups and/or by developing new industrial fields with photonics."

> "In order to create a business ecosystem in this area, we are starting 'Opto-Next Hamamatsu,' a hub for networking the companies, universities, and financial sectors that will maintain close relations with Hamamatsu City and Shizuoka Prefecture and possibly also with overseas activity." Yoshiaki Kato, the president of Hamamatsu City's Graduate School for the Creation of New Photonics Industries.

Kato added, "In order to create a business ecosystem in this area, we are starting 'Opto-Next Hamamatsu,' a hub for networking the companies, universities, and financial sectors that will maintain close relations with Hamamatsu City and Shizuoka Prefecture and possibly also with overseas activities."

One of the school's early students was Takahiro Ikeda, who founded Pi Photonics in 2006 while attending GPI, and remains its CEO today. He developed the company's "HOLOLIGHT" LED lighting technology, which utilizes patented pattern-lighting, with the help of a grant from Hamamatsu City.

"I developed the product in 2007 for applications in safety, entertainment, and architecture," Ikeda said. "Hamamatsu Photonics gave me the opportunity to learn at GPI and to practice the business." Visitors at this year's Photonics West exhibition will see the technology being used to illuminate the Hamamatsu City booth.

This is the third year that Hamamatsu City has had a booth at Photonics West, noted Hitoshi Shimmura, a spokesperson for the city government. The 2017 incarnation features four local ventures: Brookman Technology, Craft Center SAWAKI, Disc Inspection Technology, and Synergy Optosystems (Synos).

"Over the past few years, Hamamatsu has strengthened its presence as one of Japan's leading advanced innovative regions for the cutting-edge activities implemented and advanced by industry," Shimmura said. "In addition, research institutions such as Shizuoka University and Hamamatsu University School of Medicine are doing vigorous R&D activities based on optoelectronic technologies that can be applied to agricultural and medical industries in the city."

Looking ahead, Kaufmann is confident that these efforts will continue to attract SME businesses and entrepreneurs to Hamamatsu City and enable them to create commercially viable businesses that will, in turn, help the city and surrounding regions prosper.

"We believe that photonics is the future — and that future growth in part at Hamamatsu City could be tied to having it become a world-class center for photonics," he said.

KATHY KINCADE

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SPIE. PHOTONICS WEST

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31 January - 2 February 2017

Welcome to the optics.org Product Focus which we have published specifically for Photonics West 2017 in partnership with SPIE and the Photonics West Show Daily.

Here you will find an effective at-a-glance guide to some of the latest products available on the market with booth numbers if available making it easy for you to check out the products for yourself.

All this information and more can be found on the optics.org website. Simply go to **www.optics.org** for all the latest product and application news.

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The 10X HR is the next lens in a new high resolution objective series being rolled out by Navitar in 2017.

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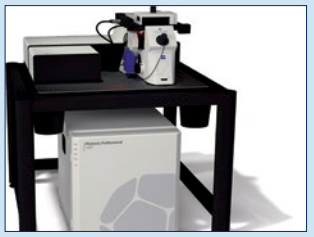

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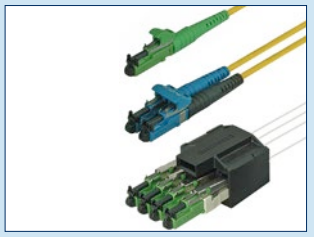

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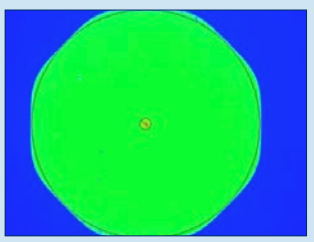

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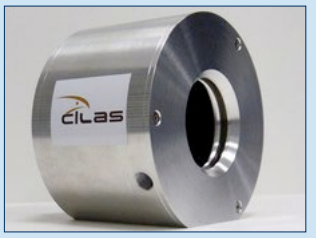

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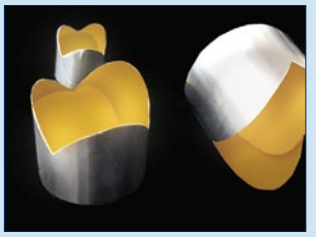

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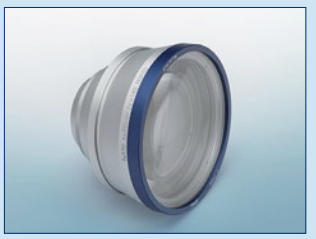

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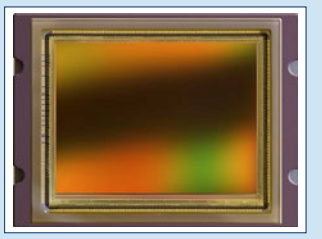

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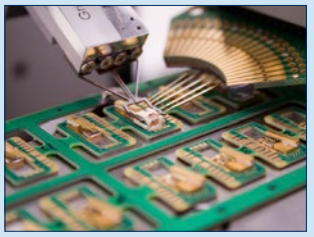

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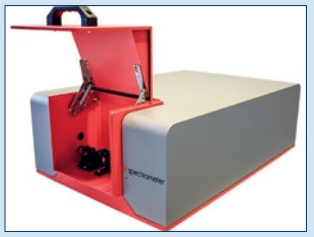

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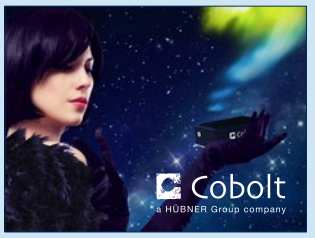

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Osram's Kamper: bold actions needed in choppy waters

The new Photonics21 president has a tough brief: boost European industrial competitiveness amid Brexit and economic stagnation. Aldo Kamper tells *Show Daily* how he's planning to make it happen.

Aldo Kamper, who was elected as the third president of the Photonics21 organization in November 2016. He succeeds Jenoptik CEO Michael Mertin and Martin Goetzler, the former Osram executive who is now CEO of the semiconductor equipment firm Aixtron. Photo: Osram

At a time of dramatic political change on both sides of the Atlantic and beyond — with likely significant consequences for international trade and cooperation — Photonics21, the pan-European member organization, has appointed a new president to guide the continent's industry over the coming two years. Aldo Kamper, whose day job is CEO of Osram Opto Semiconductors, is the new man at the helm. Rubber-stamped by the European group's Board of Stakeholders in November, Kamper progressed from being the sole candidate to immediately succeeding Jenoptik's Michael Mertin, who had been in post for the preceding four years.

After confirming Kamper's appointment, Photonics21 said that Mertin would remain a member of the Board of Stakeholders, although he will be leaving Jenoptik in June 2017. Interestingly, Mertin's predecessor was Martin Goetzler, who was previously the CEO of Osram. By convention, Photonics21 presidents maintain their day jobs while working part-time for the international body.

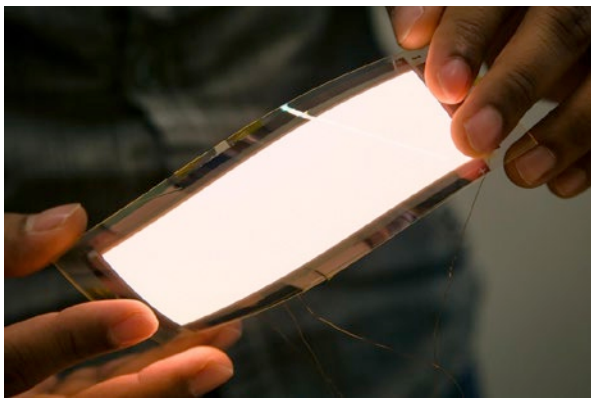
Shortly after taking up the reins, Kamper shared his thoughts on the industry's current trajectory and his vision for Photonics21. Born in Leischendam, Netherlands, in 1970, he has been president and CEO of Osram OS since 2010, after holding a range of senior positions in the company since joining in 1994.

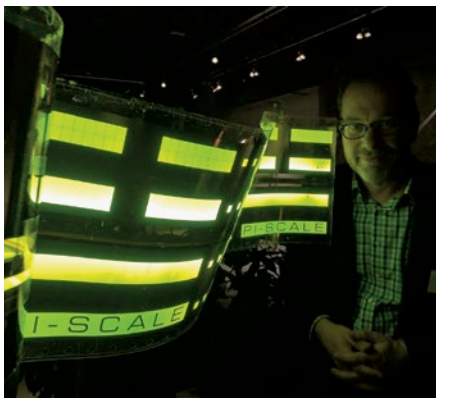
"Being elected as the Photonics21 president for the next two years is a great honor," he says. "[It is] as an overwhelming sign of trust on the part of the Photonics21 Board of Stakeholders, a group that represents hundreds of top-level photonics organizations across Europe. I am convinced that the strength of Photonics21 lies in the trusted partnership within the photonics community as well as with the European Commission — [and] I intend to preserve the unique spirit of Photonics21."

In May last year, Kamper's influential predecessor Mertin outlined his own vision of how the photonics sector should — after his departure — move to meet the diverse needs of European consumers, as well as the wider, international competitive landscape and the European Commission's own expectations of change in society and industry. Mertin said at the time, "Günther Oettinger, the European Commissioner for Economy & Society, shares my view in his Digital Agenda for Europe, which is that in order to generate growth and wealth across Europe, the goal of deriving 20 percent of its GDP from industrial output by 2020 must be achieved."

"I have inherited a well-arranged organization from my predecessor," Kamper says, reiterating the bottom-up nature of Photonics21 and its Public Private Partnership (PPP) funding plan, which are defined by its own boards and members. "We are currently in the process — working with our colleagues from the European Commission — of determining the research priorities for the PPP tenders through to 2020," he adds. "Our focus is on increasing the competitiveness of European photonics by uniting the best minds, most innovative ideas and pioneering technology.

"The PPP is supposed to spend the available funds more wisely, and invest in the most promising photonics growth areas. At Photonics21, our aim is to support technologies in their initial phases and to ensure their production can start as soon as possible. We will review the PPP performance and achievements in accordance with the pre-defined Key Performance Indicators in 2017."





Flexible organic LED (OLED) development at the "PI-SCALE" pilot line, one of three such projects funded under the Photonics21 public-private partnership (PPP) scheme. The other two are "PIX4LIFE," which is focused on photonic integrated circuits (PICs) for life science applications, and "MIRPHAB," whose consortium is working on integrated chemical sensors operating in the "fingerprint" mid-infrared spectrum. The European Commission has invested €35 million in these three projects, intended to boost Europe's industrial competitiveness, out of its total €700 million investment in the PPP over the seven years of the Horizon 2020 budget. The idea is that high-tech SMEs in Europe without their own production sites will use the pilot lines to take their ideas to pilot-level production, and validate products with lead customers for full commercial production. Photos: PI-SCALE/Holst Centre

Prototyping hubs

As Mertin has stressed previously, the challenge for Photonics21 has been to shift its focus more toward industrial deployments and successful market entry. "Europe must increase its market share in the successful invention and production of goods — an area still dominated by the US and Asia," adds Kamper, who says he is ready for the challenge.

"So far, Photonics21 has been highly successful in joining forces at the European level," he said. "Photonics PPP-led research and production projects are currently under way and new ones are in the works. Joint programming actions between the PPP and member state countries are also in progress with the ERA-NET Co-fund actions."

"Our next step will be to improve the collaboration with all regions throughout Europe," Kamper adds. "The idea is to establish photonics innovation hubs in regions that can provide prototyping, demonstration and support services to researchers and SMEs. Regional processes and structures are important to further encourage and enable cutting-edge innovation and to make it easier for companies to speed up their time-to-market. This approach is in line with [commissioner] Oettinger's 'Digitizing European Industry' Initiative.

"We need bold actions to overcome the economic stagnation in Europe and the Photonics PPP is doing its part to make that happen."

Now past its half-way point, Horizon 2020 is of course the EC's first framework program of research to explicitly focus on innovation and associated job creation as well as raw science. So how well does Kamper think photonics is contributing?

"In the photonics PPP about 50 percent of the projects address higher Technology Readiness Levels (TRLs) including prototyping, demonstration and first production activities, to enable promising technologies in their initial phase," he replies. "The photonics industry's participation level has increased from approximately 35 percent in FP7 [the research program that ran from 2007 until 2013] to around 50 percent in the PPP. We regard this as a perfect match for collaborative research and innovation projects and I think we are well on track here."

So will Photonics21 and the PPP simply continue on their current course, or does Kamper have other market objectives in mind? "The photonics industry is already a multi-billion euro industry in Europe," he says. "However, the huge impact of photonics as a key enabling technology on the overall economy makes it utterly indispensable to ensure sustainable growth in Europe.

"A promising field for photonics as a key enabling technology lies within the megatrend of digitization, which will certainly have a tremendous impact on overall growth. This is underlined by many examples: the acquisition of vast amounts of data, the ability to transfer and process "big" data, and new opportunities in consumer electronics as well as information and communication technologies."

Kamper sees that translating to a need to reconsider business models and

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priorities. "The rising tide of digitization will cause fundamental changes in terms of classic global economic structures and business models, in addition to our private lives," he says. "We should not forget a second trend, namely the miniaturization of components and the convergence of optics and electronics. Just think of the connectivity involved in both of them."

Ultimately, those trends offer a huge opportunity that the European photonics industry can work on together. "The most valuable aspect of Photonics21 is that the most innovative companies and research organizations in Europe collaborate for the purpose of determining a joint strategic roadmap for Europe."

Brexit thoughts

With deliberations among Photonics21's work groups now centering on which projects will receive funding in the final couple of years of the Horizon 2020 period, thoughts will inevitably start turning towards the EC's next budget period, which will cover most of the 2020's and be delivered in either a post-Brexit — or at the very least transitional — European landscape.

Although Kamper says that the European Commission will this year initiate preparations for what will represent its 9th Framework Program, covering 2021-2028, he thinks it is "far too early" to speculate about the future of the photonics PPP beyond Horizon 2020. "However, I am positive that the next program will, in part, be aimed at innovation and that photonics, as one of the leading enablers in addressing the megatrend of digitization, will remain a major element of the overall program strategy."

At this point, to say that Brexit represents the elephant in the room is perhaps to underestimate the size of elephants. And with nearly 400 of its members based in the UK — second only to the German contingent — Photonics21 could be affected in a major way, even though the organization has a global outlook and counts, for example, more than 50 members from the US. What does Kamper see unfolding?

"A significant part of our Photonics21 membership and board stems from the UK," he admits. "These are highly valued colleagues who will remain a key part of our community. Even though nobody yet knows what the future will hold in terms of Brexit and its implications, I strongly recommend treating this issue with prudence. In the end, it may turn out to be a model comparable to those found in Switzerland and Norway. Nevertheless, Europe and the UK are stronger when they work together."

The issue is sure to be a major topic at the next annual meeting of Photonics21 and the PPP, the first that Kamper will address as president, taking place just a few weeks after Photonics West. He describes the Brussels gathering as the flagship event for the photonics industry in Europe, with the seat of Europe's political establishment once again set to host more than 350 leading representatives of photonics industry, research, and political institutions.

His hopes for this year's meeting? "We will discuss PPP achievements, demonstrate key projects and [new] pilot-line services to the industry. We will also discuss financing opportunities for innovative photonics companies, which are currently facing challenges in terms of growth — we plan to have productive discussions with the European Investment Bank to find a solution for this situation.

"In terms of the strategy, we will be discussing PPP priorities for the remaining period of the Photonics PPP and beyond. How can we ensure that the PPP enables cutting-edge technology that addresses global megatrends? We will start deliberating on the strategy for the upcoming 5-10 years."

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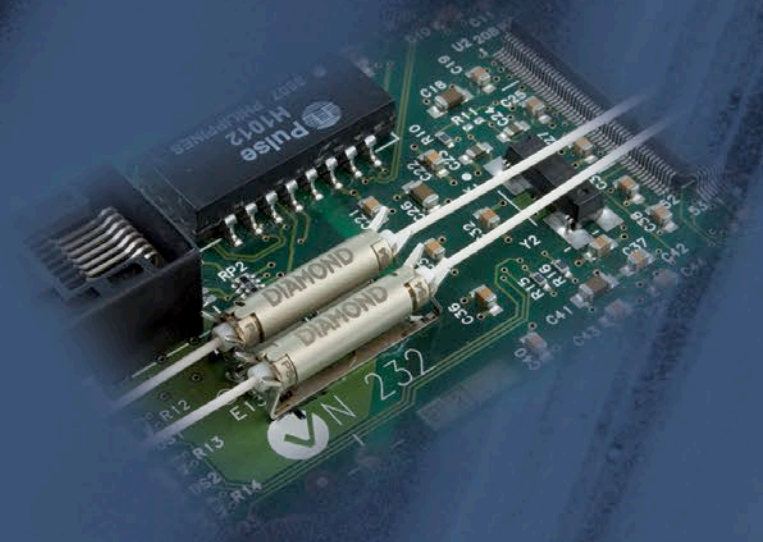

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Lidar in vogue as auto opportunity beckons

BMW says that sensor fusion and artificial intelligence will be the key to autonomous driving — and if cost-performance metrics can be achieved lidar will play a central role.

One of Ford's autonomous vehicles, with four lidar sensors from Velodyne protruding from its roof. Photo: Ford

As car makers around the world persist in the relentless push to develop and commercialize self-driving vehicles, lidar technology occupies a central position as a critical sensor for safe autonomous vehicle operation. A number of companies are now busy working on the cutting-edge photonics technology that makes such systems tick.

After a prolonged period of development and prototyping, there are now clear signs that the incumbent automotive giants, as well as some potential disruptive forces, are beginning to muscle in on the action — and backing up their interest with increasingly substantial investments.

One of the early front runners in the lidar for autonomous vehicles space is Silicon Valley-based outfit Velodyne Lidar, with its range of compact "Puck" sensors — so-called because of their similarity to ice hockey pucks — that boast the impressive ability of producing some 2.2 million data points each second, coupled with a range extending to 200 meters. According to product development manager Wayne Seto, the key focus of Velodyne's activities over the past year has been the development and testing of its novel "Puck Lite" and "Ultra Puck" systems for automobile makers.

Velodyne also received a major boost during August 2016, when Ford Motor Company and the Chinese web services giant Baidu announced plans to accelerate the development and commercialization of autonomous vehicles by leading a $150 million investment in the company.

As Seto explains, the cash will be used to finance a range of technological and business development activities — in particular, mass manufacture of the "auto-grade pucks," along with robotics as part of the overall company expansion. In doing so, the startup hopes the support will also speed up efforts to reduce costs and substantially ramp up production — in the process helping to enable the large-scale deployment of fully autonomous cars.

"The key challenge that Velodyne faces is to scale the development of lidar sensors for high-volume production at a more cost-effective price point, whereby it would allow for mass adoption in vehicles," says Seto.

Scaling up

Little more than a week after Velodyne revealed its investment, rival solid-state lidar company Quanergy Systems — also located in California — revealed that it had secured backing from a range of high-profile global investors. Support came in the form of a $90 million series B funding round backed by Sensata Technologies, Samsung Ventures, Motus Ventures and GP Capital — as well as the top-tier automotive parts supplier Delphi. It means that the Sunnyvale-based outfit has now raised in the region of $150 million — against an estimated company valuation now in excess of $1 billion.

Quanergy CEO Louay Eldada announced similar plans to Velodyne: work alongside the new partners to substantially scale up the production levels of its lidar sensors. And at the recent Consumer Electronics Show (CES) the company confirmed its intention to ramp production later this year, claiming that its solid-state sensors would offer significantly lower cost, higher reliability, superior performance, increased capability, smaller size and lower weight when compared to the traditional mechanical lidar sensors that have become a familiar feature on autonomous test vehicles.

Intel inside: the German car giant BMW says that 40 more test vehicles under development with Intel and Mobileye will take to US and European roads this year, with a fully autonomous launch earmarked for 2021. Fusion of lidar with other sensor technologies is seen as a critical element of the development. Photo: BMW

Global trend

Elsewhere in the US, auto giant GM announced in December 2016 that it plans to start testing its lidar-equipped autonomous vehicles on roads in Michigan — expanding the testing regime into central Detroit within a "matter of months."

Also in December, Montana-based lidar firm Blackmore Sensors and Analytics revealed that it had attracted $3.5 million in series A investment from Next Frontier Capital and Millennium Technology Value Partners. Among other things, the cash will be used to create a miniaturized version of its novel frequency-modulated continuous-wave (FMCW) lidar engine — in another bid to deliver affordable, high-performance lidar sensors to the automotive and surveillance markets.

Although it is perhaps true to say that many of the early trailblazers in the auto lidar sector hail from the US, rapid forward strides in technological innovation are occurring elsewhere. In Europe, Audi and Volvo continue to push the envelope. In Korea, Samsung Electronics unveiled plans to purchase automotive technology company Harman, an $8 billion deal that could well pave the way for the company's entry into the navigation and driver-assist technology sector. Hyundai showcased a concept version of its autonomous Ioniq model at both the Los Angeles Auto Show and CES.

Elsewhere, a consortium of Japanese manufacturers and parts suppliers have revealed plans to design and develop a fleet of autonomous vehicles — with an eye on deploying them in time for the 2020 Olympics in Tokyo — and Chinese companies are already well advanced in plans to construct autonomous trucks, in an effort to kick-start the next generation of logistics technology and to ease congestion and improve commerce across the country's burgeoning urban sprawl.

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Oryx nano-antennas

Another startup targeting the sector is Israel's Oryx Vision, with its "optical nano-antenna" lidar technology for autonomous vehicles. As Rani Wellingstein, CEO at the company, explains, the heart of the invention is an optical sensor that behaves just like a radio antenna — but at the much shorter wavelengths of the optical realm. To do that, the antennas are just a few micrometers in diameter.

Although Wellingstein ranks the creation of such antennas as Oryx's first significant technological achievement, he also points out that the high frequencies involved demand a super-fast photodiode. "Oryx manages that with tunnel junctions, which are made of two metals, separated by a very thin insulator, only a few atoms thick," he says.

According to Wellingstein, although this combination of antennas and tunnel junctions — also known as rectifying antennas or "rectennas" — is a well-known physical concept that many scientists have tried to produce for decades, until now nobody has managed to create a structure that worked for more than a few days.

"Some of our rectennas have been operational for more than three years, and counting," he told *Show Daily*. "Rectennas are a great technology to use as sensors because their link budget is up to a million times better than competing photoelectric detectors," he added.

Each individual Oryx rectenna is manufactured in silicon using a simple thin-film process — with tens of thousands of them combined in arrays to form the depth sensor of the company's infrared lidar.

"As that light travels it bounces off anything that stands in its way and a receiver lens collects the reflected light onto that nano-antenna array," says Wellingstein. "Because the system is coherent, the sensor knows exactly which signals originated from its own laser. When such a match is found in any of the sensor's pixels, the system calculates the time that elapsed since the original signal was transmitted, and determines how far this pixel is from the sensor. That's how a full 3D image of the sensor's field of view is created, at a rate of 30 frames per second."

Although the Oryx sensor technology itself has been working consistently for more than three years, Wellingstein says that the company has only started developing the full system over the past year. Now, following successful proof of the concept in the laboratory, he reveals that the company is building kits for field-testing, and expects to complete a car-mounted prototype during 2017. That has been made possible after the firm closed a $17M series A funding round last October, with Oryx saying that its approach could solve problems with the effects of direct sunlight, which can disrupt some lidar systems.

Wellingstein is confident that the solid-state rectenna technology will perform very well in comparison with existing lidar technology — and believes that it

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This lidar-enabled headlamp at the CES show last month features a compact, solid-state sensor from Quanergy, one of several companies working on the technology. Photo: Quanergy Systems

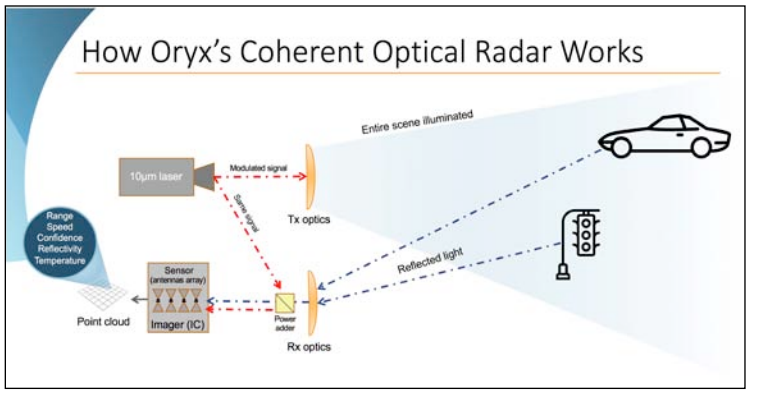
Lidar continued from page 27

could have a number of key advantages when used in autonomous vehicles. Perhaps foremost amongst these advantages is the system's ability to sense depth at an extended long range of 200 meters or more — well beyond the effective 60 meter range of many existing lidar units.

"Their precision — measured in resolution, signal-to-noise ratio and other metrics — will also be higher than any alternative," Wellingstein said. "In addition, they will not be blinded by direct sunlight, a significant lidar weakness, and will be operational in difficult atmospheric conditions, such as dust, rain, snow and fog, another lidar weakness."

Despite his deep confidence in the ultimate potential of the new technology, Wellingstein admits that Oryx still faces a number of key development and commercialization challenges. To begin with, he says, the company faces the perennial challenge of anyone who has tried to introduce groundbreaking technologies to a sector as typically conservative as the automotive industry.

"We need to gain the trust of key participants in the value chain, as developing such systems is a collaborative effort," he adds. "We handle the challenge by working closely with car OEMs and tier-one suppliers. We cooperate with them on defining the exact specifications of our product so that it fits with their own roadmaps."



Aiming to challenge the better-known Quanergy and Velodyne is Oryx Vision. This schematic shows the basics of its "optical nano-antenna" approach. Image: Oryx Vision

'Driving brain'

With Uber wanting to offer its customers the opportunity of hailing a self-driving cab — recent controversies in San Francisco notwithstanding — and target production dates from the likes of Ford and BMW, there are now clear signs that automotive vehicles are moving from the drawing board to reality. With lidar sensors looking like a critical technology for the future autonomous car, this is a sector that looks set to enjoy a prolonged period of rapid growth. Even before the recent capital injections at Velodyne, Quanergy, and elsewhere, one market research report had concluded that the global lidar market would rise beyond the billion-dollar mark by 2020 — but such a figure may soon start to look conservative.

Velodyne's Seto predicts that a major element of the evolution will be focused on the shift to smaller sensors while maintaining excellent optical, mechanical and electrical performance. In his view, this will be one of the key trends in the use of optical technology for autonomous vehicles throughout 2017 and beyond. "Included in that is to extend the range of the sensors to detect objects at greater distances," he added.

Even before the era of full automation arrives, Wellingstein believes that active optical sensing systems will emerge as key facets of many features of semi-autonomous applications.

"Well before commercial driverless cars hit the roads, ADAS [advanced driver assistance systems] applications will make use of the superior performance delivered by optical sensing systems," he said. "The enhanced information such systems can send to the car's 'driving brain' will allow faster and more accurate decision making."

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Opportunities for wearables and wireless

New Biophotonics Executive Forum debuts at Photonics West

Optics and photonics in the digital healthcare arena took center stage at the new Biophotonics Executive Forum.

Following a biophotonics market update from SPIE, Bruce Tromberg, director of the Beckman Laser Institute and Medical Clinic, led a discussion that provided expert insight into the rapidly developing field of point-of-care diagnostics. Accompanying Tromberg on a panel were Michelle Khine of University of California, Irvine (UCI) and Fluxion Biosciences, Gene Dantsker of Qualcomm Life, Aydogan Ozcan of UC Los Angeles (UCLA), and Brad Rice of Profusa.

Progress in miniaturization of light sources and detectors is enabling advances in point-of-care technologies, Tromberg noted in his remarks. "Improving source and detector technology from a fundamental photonics components perspective is essential" to continued progress, he said. This includes CMOS integration of current board and tabletop systems because CMOS is a "key feature that will drive forward all of these advances in digital health technology," he said.

Digital health platforms have two broad components, a computing and informatics platform and a device component, Tromberg noted. Whereas the computing platform may compensate for signal variation or weakness from the device, high-contrast features that can reliably provide a strong signal-to-noise ratio are preferable and are the focus of much current research.

Connectivity is key to the computing and informatics platform. Dantsker discussed efforts at Qualcomm Life to extend the "Internet of Things" into the realm of healthcare. His company's "medical-grade" cloud-based ecosystem "2Net" enables point-of-care devices to capture, share, and transmit data. The goal is to provide care regardless of the patient's location.

Bright idea: Versalume is developing a range of optical fiber products including wearables, architectural and medical systems. Qing Tan (left) and Mario Paniccia model prototype glowing jackets and Glow headphones. Photo: Matthew Peach

Some healthcare systems are already testing remote patient monitoring to reduce the need for emergency readmission to hospital, Dantsker said. Patients leave the hospital with a connected weight scale, blood pressure cuff, pulse oximeter, and communications hub.

Both Dantsker and Khine, who is starting BioENGINE, an institute to focus on medical wearables at UCI, spoke to the importance of seamless connectivity and installation in the home for widespread adoption of medical-grade wearables. In general, the devices are still relatively bulky, and people will not wear them if they obstruct day-to-day activity, Khine said.

Other barriers to adoption that Khine mentioned include whether insurance will pay for the device and what to do with all the data from continuous monitoring of physiological parameters. From a technology point of view, "we are doing a good job, improving accuracy and miniaturization," she said, but other factors will slow adoption, such as the inherent conservatism of medical service providers.

Looking out longer term, Khine hopes to see wearables as part of a closed-loop system that produces actionable medical information. Existing devices, she says, are not there yet, as they are mostly open loop. Eventually, it should be possible for a point-of-care device to instruct its wearer what to do without necessarily consulting a physician, she said.

Materials a challenge

Tromberg noted the challenges in developing new materials in this arena. They must be isolated from the body so as not to induce a negative reaction, while being integrated enough to sense a specific molecular process.

In this vein, startup Profusa is working with implantable hydrogels sensitized to a specific chemistry. External illumination from an LED excites fluorescence, which is then measured externally, Rice explained. The company is currently testing oxygen and glucose sensors, but the system can work with any chemistry where a fluorescence assay is available, he said. The company envisions a combination sensor and wireless infrastructure with continuous monitoring in which the wearer is alerted to a parameter being out of range.

Ozcan covered a range of devices, mostly based on the image-sensing capability and connectivity of mobile phones. He said the economies of scale inherent in the smart-phone infrastructure and the interface itself are enabling cost-effective biomedical measurements in a mobile format with performance that matches clinical needs.

An active audience-driven discussion followed the panelists' presentations and moved very quickly to questions and concerns about the data produced by these devices: what can be done with the data, how can they be secured, and perhaps most importantly how can we make best use of the data?

Real-time monitoring in daily life of physiological metrics such as blood pressure and blood oximetry levels is on the horizon, but how we make best use of that remains to be seen. Comments from European attendees highlighted the significantly higher levels of concern about data protection in Europe versus the United States.

STEPHEN G. ANDERSON

Promising 2D tunable materials

Tunable 2D materials like graphene and black phosphorous are opening a range of new technological applications, from driverless cars to holographic imaging.

Harry Atwater of the California Institute of Technology reported this week that he and his colleagues have used graphene to make a material with 100% optical absorption, something first proposed five years ago.

"This allows one to move from still-life daguerreotype nanophotonics to the film and television era," Atwater said.

To force the graphene to interact strongly with light, the researchers sliced a monolayer of graphene into thin ribbons only 50 or 100 nm wide. These ribbons allow light to efficiently couple with surface plasmons — the collective excitation of electrons — in the graphene.

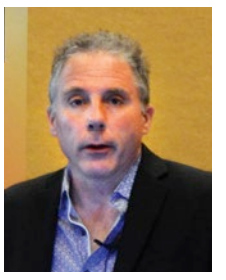
Surrounding the ribbons is gold film that funnels light to the graphene. Underneath is a Salisbury screen, which acts like a mirror that prevents light from escaping through the material, reflecting photons back into the graphene. The researchers designed the structure of this surface so that its impedance matches that of free space, which enables it to absorb all photons that come its way.

"That's quite a dramatic result," Atwater said.

By changing the voltage going through the graphene, the researchers can adjust absorption. The device works in IR wavelengths, so tunability could lead to all sorts of devices for controlling thermal radiation. In essence, Atwater explained, you could turn a black body into a white body with a flick of a switch.

"It's like a coat of paint I can change the color from black to white in the infrared."

Caltech researchers have also used graphene to make a tunable phase modulator, paving the way toward beam-steering devices that can reflect IR beams in any direction without the need for the slower, mechanical mirrors used in conventional beam steerers.



Harry Atwater of Caltech. Photo: Amy Nelson.

IR beam-steering devices would be essential for lidar systems in driverless cars, and Atwater's group has already demonstrated a tunable phased array in the NIR that scans at megahertz frequencies.

His team is also working on controlling polarization of light in graphene; developing devices for 3D holographic images; gauging potential applications for 2D black phosphorous; and developing new photovoltaic cells with sheets of materials such as MoS_2 and WSe_2.

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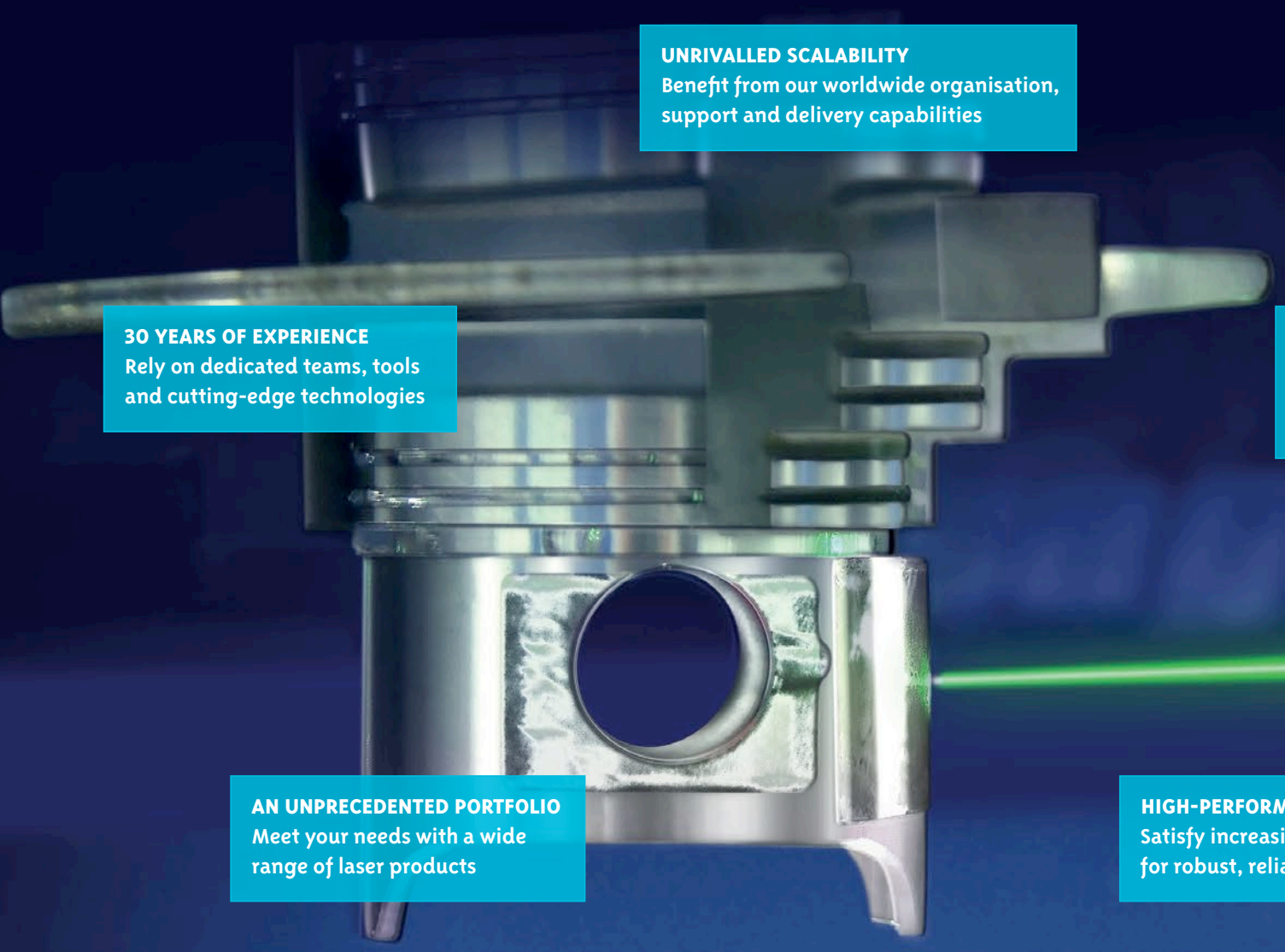

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