THURSDAY
EDITION

SPIE. | optics.org | THURSDAY JANUARY 27, 2022

PHOTONICS WEST SHOW DAILY

PRISM awards: Lighting the path to victory
p. 07

Credit: LightPath Technologies.

A higher power: fiber lasers at the cutting edge

Smooth operator: Alexei Markevitch presents the cut quality achieved by IPG Photonics' high-power fiber lasers. Credit: Joey Cobbs

Metal cutting and welding/brazing account for about half of the $6 billion generated annually in laser sales for materials processing. New tools described at Photonics West reflect technological advancements for metals processing that promise to keep the market strong.

Dahv Kliner from nLight outlined advanced metal processing enabled by fiber lasers with tunable beam quality. He noted that metal processing performance depends on laser beam characteristics: size, shape, and divergence.

The motivation for tunable beam quality is the necessity to optimize beam characteristics for major applications like cutting, welding, and additive manufacturing (AM), Kliner said. Beam size and shape are both critical for precise control of heat deposition into the workpiece.

Kliner said nLight has developed an all-fiber technology to enable rapid tuning of the beam characteristics directly from the laser. Advantages of the new system, he said, include no free-space optics, fast switching in less than 25 ms, more than 20 million beam changes with no change in performance, a versatile platform that includes a wide range of beam specs with different fiber designs and optimized beam sizes and shapes, and power scaling limited only by the silica fiber.

The system has three basic components. First is a feeding fiber with multiple guiding regions. The beam is partitioned among the guiding regions and varying the partitioning enables tuning output beam characteristics. Second is a fiber that enables the beam to be shifted

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THANKS FOR COMING—SEE YOU NEXT YEAR!

SPIE staff are thrilled to be back in San Francisco serving the photonics community at the BiOS and Photonics West exhibitions. Credit: Joey Cobbs

DON'T MISS THESE EVENTS TODAY.

PHOTONICS WEST EXHIBITION
10 AM – 4 PM, Moscone North/South Exhibition Halls

FREE PROFESSIONAL HEADSHOTS
10 AM – 3 PM, Hall F

GOVERNMENT POLICY UPDATE
10:15 – 10:45 AM, Expo Stage, Hall DE

PHOTONICS MARKET UPDATE
10:45 AM – 11:15 AM, Expo Stage, Hall DE

EXECUTIVE INSIGHTS: EMERGING STRONGER FROM A PERIOD OF UNCERTAINTY
1 – 2:30 PM, Expo Stage, Hall DE

PHOTONICS WEST NETWORKING RECEPTION IN THE EXHIBITION
2:30 PM – 3:30 PM, Moscone North/South Exhibition Halls

For the full schedule, see the SPIE Conferences app. Some events require registration.

We very much appreciate all of the support this week from exhibitors, attendees, volunteers, and presenters. There's nothing like coming home to Photonics West.

— Kent Rochford, SPIE CEO

IN THIS ISSUE.

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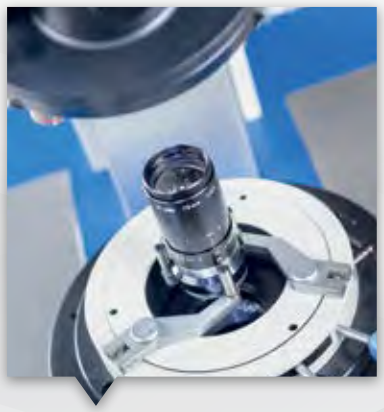

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Testing of image quality

Alignment and testing of camera modules

Engineering – customized device development

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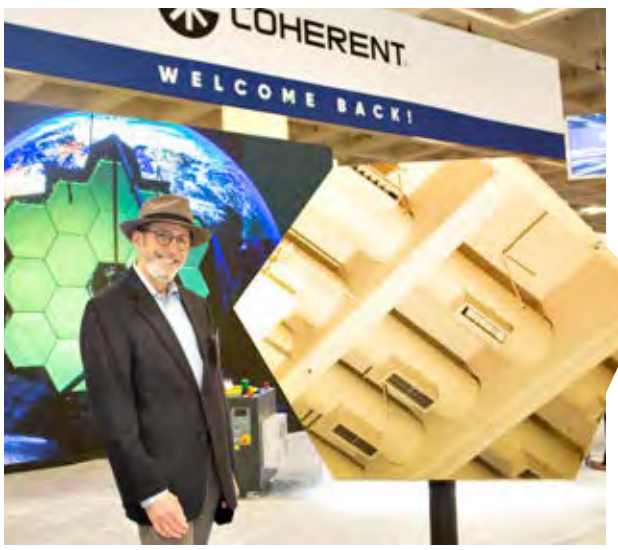
Mirror image: reflections on the Webb telescope's journey



The sky's the limit: Coherent spokesman David Kuntz with the telescope reflector segment. Credit: Joey Cobbs.

At 11 AM PST, on Monday, as we all geared up for Photonics West, the James Webb Space Telescope ("Webb") reached its final orbit around the second Sun-Earth Lagrange point, or L2, almost one million miles from the Earth.

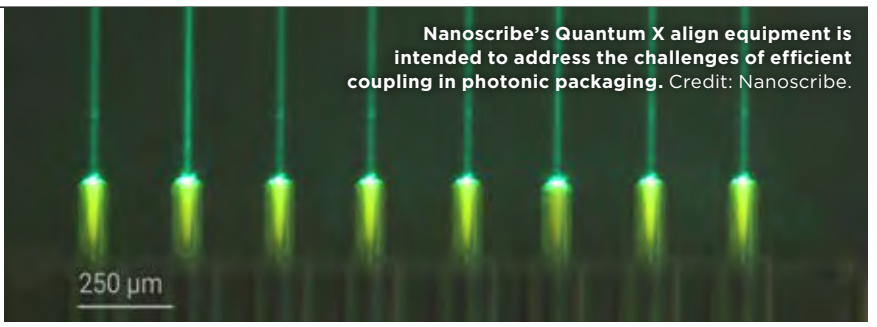
But you don't need to travel any further than the Coherent booth (4805) to see a replica of one of the 18 hexagonal beryllium lightweight mirrors that together form one giant telescope mirror capable of capturing images from distant galaxies.

The mirror has become a magnet for selfie-snappers and Instagrammers capitalizing on the neat coincidence of the space event and what's happening on the show floor. The Webb mirrors made 14 stops across the US during its manufacturing journey, three of them for various processing stages by Coherent.

Coherent Inc. was chosen to smooth and polish each mirror segment until it was nearly perfect. The mirrors were then shipped off for thorough cryogenic testing to determine how extreme cold distorted the mirror's desired final shape.

Once the calculations for adjustments were made, the mirrors were re-polished to 20 nm of surface error. Minute scratches and imperfections were also removed to provide the most accurate image without distortion.

MATTHEW PEACH



Nanoscribe's Quantum X align equipment is intended to address the challenges of efficient coupling in photonic packaging. Credit: Nanoscribe.

Precision 3D printer aims at integrated photonics

Exhibitor Nanoscribe, now part of the BICO Group (previously Cellink) has formally launched its new "Quantum X align" high-precision 3D printer at this year's Photonics West (booth 3114).

The latest equipment from the Karlsruhe firm — headquartered at the Zeiss Innovation Hub at the Karlsruhe Institute of Technology (KIT) — is described as the first-ever microfabrication system within a proven lithographic platform.

"The Quantum X align is the first 3D printer with advanced 3D alignment capabilities that enables the printing of free-form micro-optical elements directly onto optical fibers and photonic chips, setting new standards in the design and fabrication of micro-optical elements," announced Nanoscribe.

Dutch photonics packaging foundry PHIX is among those who will be using the equipment, in a collaboration that will provide on-fiber printing services to the photonic packaging industry. PHIX COO Joost van Kerkhof said: "We are confident in Nanoscribe's new, aligned 3D printing technology for producing lensed fiber arrays and lensed chips with virtually limitless optical designs. This will enable us to further advance integrated photonics packaging."

CEO and co-founder Martin Hermatschweiler, who led the spin-out of Nanoscribe from KIT in 2007, said that the new equipment coupled two-photon polymerization with high-precision alignment, with likely applications in datacom, telecom, and sensing.

"Our goal is to address the challenges of efficient coupling in photonic packaging, and make high-precision 3D printing the technology of choice in integrated photonics," Hermatschweiler added.

MIKE HATCHER

VitreaLab, Quantopticon, and Luminess win at Startup Challenge

On Tuesday, at a ceremony during SPIE Photonics West, VitreaLab, with its laser-lit chip focused on the 2D and 3D display market — a technology which enables more power-efficient displays – was announced the winner of the $10,000 top prize at the 12th annual SPIE Startup Challenge.

With cash prizes all provided by Jenoptik, Quantopticon, a designer of simulation software for quantum photonic hardware manufacturers, received $5,000 for second place. Luminess came in third, winning $2,500, with their versatile platform for safer, more sensitive, and more reliable X-ray medical imaging.

The SPIE Startup Challenge, a pitch competition which showcases new businesses, products, and technologies that address critical needs with photonics, is supported by Founding Partner Jenoptik, Lead Sponsors MKS Instruments, Hamamatsu, Edmund Optics, and Thorlabs, and Strategic Partners Allianse and NextCorps' Luminate.

"I think this was an absolutely fantastic result," said VitreaLab CEO Jonas Zeuner. "It's great to be at the biggest photonics event and at the Startup Challenge."

Quantopticon CEO and Co-founder Mirella Koleva was delighted to be selected as a winner: "It's wonderful to have this opportunity, to receive so much recognition and support from the judges. It really means a lot to me, to us."

IN MEMORIAM: JACK GASKILL

SPIE Past President Jack Gaskill, (pictured, right, with Eugene Arthurs) professor emeritus at the University of Arizona's (UA) Wyant College of Optical Sciences (OSC), passed away 24 January at his home in Tucson. He was 86.

Gaskill joined UA in 1968 as an assistant professor of optical sciences. His career included publishing *Linear Systems, Fourier Transforms, and Optics* in 1978. He was also instrumental in establishing the Industrial Affiliates program at OSC.

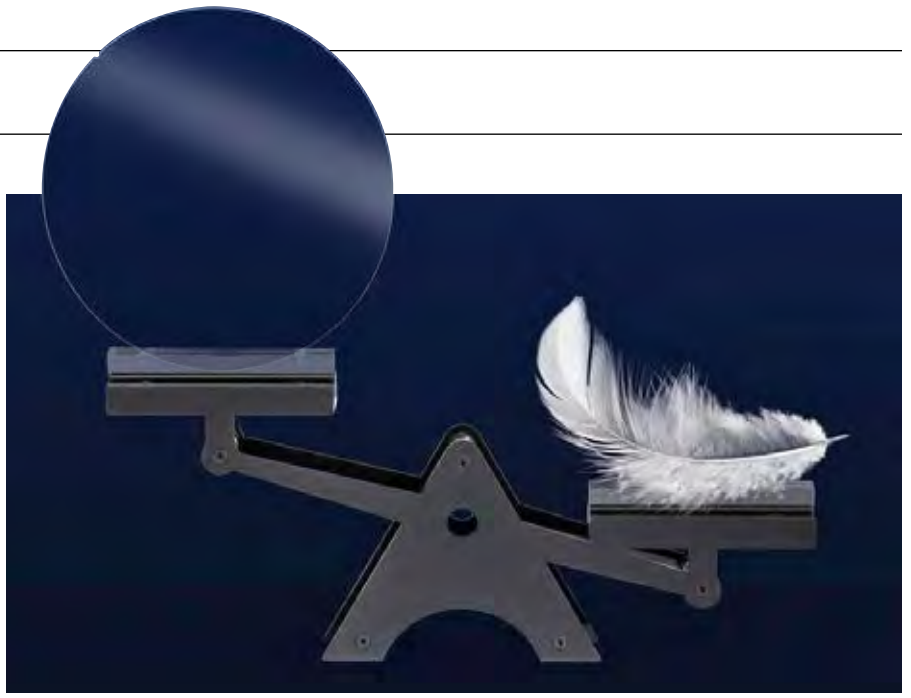
Throughout his career, Gaskill recognized the importance of being involved with professional societies. He became a Fellow of SPIE in 1977 and served as editor of the SPIE journal *Optical Engineering* from 1985 to 1990. He was awarded the SPIE President's Award in 1990, and was elected President of SPIE in 1995, an experience he describes as "one of his best."

In 1999, Jack and his wife, Sandra, commemorated his retirement from OSC by contributing a generous gift for undergraduate student scholarships in optical sciences. Many alumni followed his example, making contributions that endowed the Jack D. Gaskill Undergraduate Scholarship.

In 2015, colleagues, friends, and alumni further honored Jack for his contributions as a professor, adviser, mentor, and administrator by establishing the Jack D. Gaskill Graduate Student (FoTO) Scholarship.

Gaskill was widely known for his limerick-writing skills and his great sense of humor – he almost always began his lectures with a joke – and for his walk-on role in the 1984 film *Revenge of the Nerds*, which was filmed on the UA campus. An optics-advocate to the end, his Arizona license plate proudly read "4YAY."

Schott's high-index AR wafer halves waveguide weight



Schott RealView 1.9 ultra wafers can reduce the weight of AR devices. Credit: Schott.

Glassmaker Schott's lightweight AR device product platform this week made its debut at SPIE AR|VR|MR 2022. The firm says it will help wearable displays "take a step towards a full immersion experience with the highest wearing comfort."

Schott RealView 1.9 lightweight ultra will enable up to 50 percent lighter waveguides. The new grade of ultra-flat wafer topography will give product designers the means to develop thinner waveguides without cutting image quality.

With RealView ultra, the product developers at Schott — known as #glasslovers — have improved the wafer's flatness by up to 60 percent. The company stated, "this achievement enables AR device makers to remove another 30 percent from the scale for a total reduction of 15 g per device."

The RealView 1.9 glass type is not an existing optical glass retrofit for AR use. Its formulation and processing were developed specifically for AR applications. Schott's launch statement concluded, "This represents a major step towards the targeted 70 gram overall device weight and demonstrates our continued commitment to the growing AR industry."

According to Allied Market Research, the global AR/VR smart glasses market size was valued at $8.31 billion in 2019, and is projected to reach $33.16 billion by 2027. In order to grow this market, continued innovation and reduced manufacturing costs are necessary.

MATTHEW PEACH

Fiber lasers

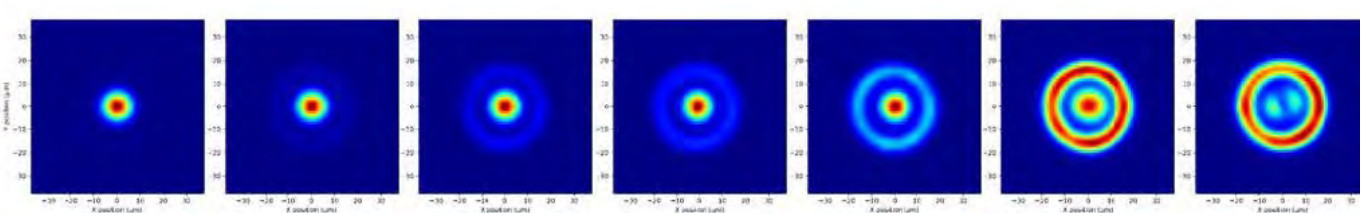
continued from page 01

radially via application of a perturbation, and third, a perturbation mechanism to adjust the beam.

Kliner noted that fiber lasers have replaced CO_2 lasers in most cutting tools because of higher speed, efficiency, reliability, lower maintenance costs, and fiber delivery of the beam to the process head. nLight's CFX tool has proved superior for both thin sheet and thick plate metal cutting, what the company characterizes as "no compromises" cutting performance.

The CFX also delivers in steel welding, Kliner said, reducing material loss from the weld, reducing contamination of the finished part as well as fixtures, shielding nozzles, clamps, and surrounding tooling. He notes that spatter is caused by keyhole instability in the welding process, which the optimized Corona beam helps prevent.

For AM, Kliner said, "a typical part has both fine-scale and large-scale features and so a small beam is needed to generate the small features, but the larger features can be built at a higher rate with larger beam. Actually, the beam size and shape are both critical for precisely controlling the heat deposition across the workpiece."



Beam shapes provided by nLight's AFX™ fiber laser, from a single-mode Gaussian through a 40 μm ring beam and other shapes in between that partition the laser power between the single-mode and ring beams. Credit: Courtesy of nLight.

IPG Photonics' Lurii Markushov introduced his firm's handheld laser welding and cleaning system, LightWELD. He described it as a turnkey system that comes complete with a 1.5 kW air-cooled fiber laser, a laser welding gun, mode chart, IR googles and helmet, welding nozzle tips, and protective glasses.

"We can weld a wide range of materials including stainless steel, mild steel, and aluminum from thicknesses up to four millimeters in one pass," Markushov said.

For safety, the system has a two-trigger system. The first starts the gas flow and the second trigger enables light emission. But nothing will happen if the nozzle is not touching the weld surface. But perhaps the biggest safety feature compared with traditional arc welding, said Markushov, is that no current is flowing through the metal presenting an electrocution risk to the operator.

IPG Photonics' LightWELD system can achieve 100 percent weld consistency using preset programs. Credit: Courtesy of IPG Photonics

What's more, whereas arc welding is a skill acquired with many years practice, a LightWELD operator can achieve 100 percent weld consistency using preset programs after just a day's training. The system, Markushov said, includes a wire feeder that ensures consistent speed and accuracy during the weld process.

The company's newest model, LightWELD XC, welds and cleans and comes with cleaning nozzles for different joint types. The unit is capable of precleaning, such as rust removal, with a non-abrasive, blast-free media process. For post cleaning pickling and passivation on stainless steel, the instrument offers a chemical-free process. The system can also be used on aluminum and to remove galvanized coatings to improve weld quality. Markushov said the system delivers aerospace weld quality results, which means no visual defects, and consistent and smooth weld surface from both sides. X-ray testing confirms the quality, and the metal survives a bend test, meaning there is no cracking on either side of a 180-degree bend. There are no defects on cross sections, and complete fusion between weld metal and base metal.

Markushov said IPG Photonics is expanding their worldwide sales of the system to include targeting of thousands of potential new customers in North America.

WILLIAM SCHULZ

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2022 Prism Awards celebrate innovative photonics technologies

Awards honor technologies and products in 10 categories from quantum, lasers, and biomedical devices to autonomous vehicles and augmented and virtual reality

Last night, following a festive reception, SPIE and media partner Photonics Media recognized the top optics and photonics products released publicly into market with the industry-focused Prism Awards.

Each year, the Prism Awards reflect the latest exciting developments, exponential growth, and rich technical innovations across photonics and photonics-enabled industries. For consideration of this year's awards, SPIE received 120 applications from 18 countries.

The 14th annual ceremony showcased a dynamic range of companies, including many companies exhibiting this week at Photonics West. Finalists who are represented on the exhibit floor include Class 5 Photonics, Direct Machining Control, Emberion, ficonTEC, Labsphere, LightPath Technologies, Litilit, Nanoscribe GmbH & Co., Stuttgart Instruments, TOPTICA, and Zemax. All of the finalists are recognized for applying innovative and creative solutions commercially to critical problems in areas such as augmented and virtual reality, biomedical devices, autonomous vehicles, quantum, and industrial lasers.

Finalists and winners were selected by a panel of international judges that leveraged the knowledge and acumen of leaders from across the technology commercialization and funding sectors. The distinguished judges' roster includes MKS Instruments' Marc Himel, the FDA's Zane Arp, Femtoblanc's Uri Abrams, iFocus' Adi Diner, Berkeley Catalyst Fund's Laura Smoliar, Engender Technologies' Cather Simpson, Nextcorps' Sujatha Ramanujan, Notal Vision's Nishant Mohan, Teledyne Princeton Instruments' Jason McClure, and Chromacity's Shahida Imani.

"We are particularly delighted to be celebrating our Prism Award winners in person this year," said SPIE CEO Kent Rochford. "These scientists, researchers, and engineers — and I am including the finalists as well — are ensuring that key technologies and products are reaching, energizing, and continually growing the photonics market. Their critical, innovative work is impacting lives across the globe."

The winning companies and their products:

Augmented & Virtual Reality
Luxexcel, VisionPlatform™

Autonomous Vehicles
Lumotive, Meta-Lidar™ Platform

Better Sensing
SWIR Vision Systems, Acuros® eSWIR Camera

Biomedical Devices
PlenOptika, QuickSee

Displays
BRELYON, Ultra Reality Display

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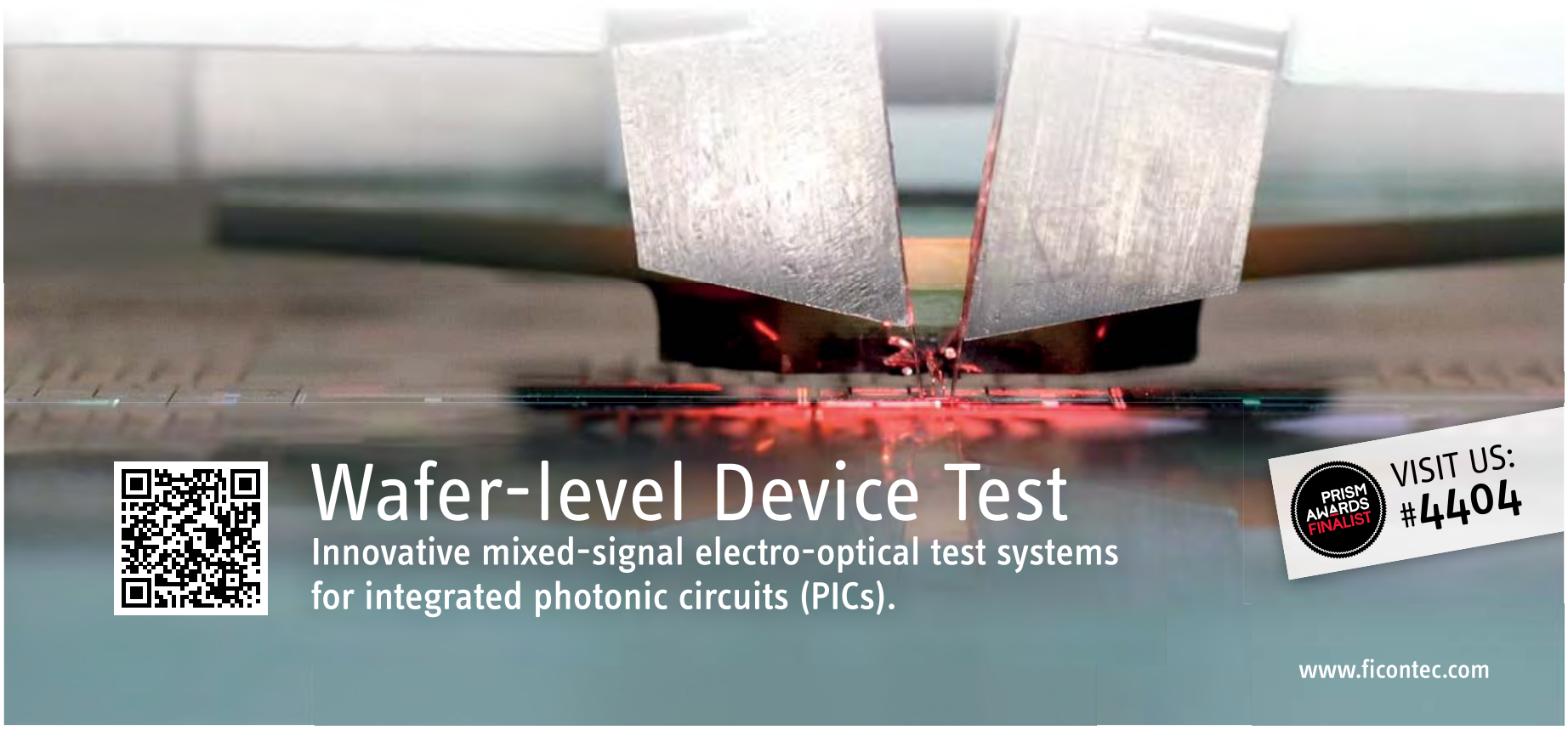

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European Commission pledges €480 million for photonics

New Horizon Europe funding program through 2027 identifies photonics as a technology to invest in, but what are the new challenges and opportunities for collaborations between industry and research groups — and how does the UK fit in, post-Brexit?

Horizon Europe (HE) is the European Commission's latest research framework program (succeeding Horizon 2020) with a budget of €95.5 billion (around $108 billion) to be allocated over the period 2021-27. Photonics has been designated as a strategic technology under the scope of HE, meaning that approved collaborative projects can win funding.

The program facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies while tackling global challenges. It supports creating and better dispersing of excellent knowledge and technologies.

The general aims of HE are: to tackle the impacts of climate change; to help achieve the UN's Sustainable Development Goals; and to boost competitiveness and growth of the European Union and associated countries, including the UK (see below).

The European Commission and Photonics21 — the stakeholder organisation, with members across the continent, which also advises Commission — have entered into a partnership to work together on the further development of this sector. As a key element of HE, the Commission has committed to invest at least €480 million into photonics research and innovation activities in the seven-year course of the program. The Photonics Partnership is one of 49 partnerships selected by the EU Commission in strategic areas ranging from AI to batteries, and clean energy to robotics.

European photonics industry leaders assemble at the Photonics 21 meeting and conference in Brussels, 2018. Credit: VDI Technologiezentrum GmbH.

There are regular Photonics Calls for Proposals (by collaborative research partners seeking funding) published by the European Commission. The first Horizon Europe calls for proposals were launched on the EU Funding and Tenders Portal in June, 2021. The photonics-related Calls are allocated within focused "clusters" — 1. Health; 4. Digital, Industry & Space; and 6. Food & Natural Resources. Further information and new announcements are available on the EC website: ec.europa.eu

Growing sector — despite the pandemic

Markus Wilkens , Secretariat & Head of Operations at Photonics21, explains that Europe's photonics sector growth over recent years has not been dampened by the Covid-19 pandemic: "Europe's photonics industry grew from €76 billion in 2015 to €103 billion in 2019 according to a recent Photonics21 market study conducted by analyst Tematys."

This equates to a growth rate of 7% (CAGR), meaning that Europe's photonics industry grew faster than many other high-tech industries (e.g. the IT industry: 4.5%, medical technology: 4.9%, microelectronics: 4%).

Markus Wilkens , Secretariat & Head of Operations at Phoronics21. "Despite the pandemic, the European photonics industry's propsects are good," he says. Credit: VDI Technologiezentrum GmbH.

"However," he says, "recent market data from German technology industry association Spectaris suggests that, more recently, the coronavirus pandemic has had a rather mild effect on the European Photonics Industry and the prospects are good.

"Photonics was seen by the European Commission as a key technology with which to respond to the corona crises. The pandemic prompted the Commission to open calls for urgently needed research into the coronavirus."

At the time of the pandemic calls, last year, Thierry Breton, the European Commissioner for Internal Market, and responsible for photonics, commented: "We are supporting the health authorities, healthcare professionals and the general public in all member states in tackling the coronavirus crisis. To this end, we are deploying innovative technologies and tools that can quickly be used to prevent, optimally treat, and recover from this pandemic and prepare for its aftermath. These include digital solutions and technologies such as telemedicine, data, AI, robotics, and photonics."

Projects under consideration

So, pandemic aside, what are the emerging areas of interest and technical problems to be solved for the European photonics sector that could become new collaborative projects?

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Horizon Europe

continued from page 09

Wilkens proposes: "Currently, the Photonics21 working group leaders and deputies are in the process of drafting the call priorities for the 2023-24 funding program, which we will then discuss with the EU Commission. More than 1500 experts have been consulted in the past three months, photonics experts as well as experts from other technology areas and end-user markets. The final decision will be made by our Board of Stakeholders in January 2022."

The types of projects coming up can be divided into classical research projects, typically covering Technology Readiness Levels (TRLs) of 2-5 (early- to mid-stage research and feasability assessment), and innovation projects, covering TRLs of 5-7 (prototypes and demonstrators).

Wilkens adds, "Of the topics, according to our new strategy, a large area will be where a core technology is to be advanced, so that several fields of application will benefit at the same time. A typical example would be imaging. This is relevant simultaneously for agriculture, medical technology, automotive engineering and many other fields."

Wilkens believes that photonics, like many other cost-intensive key technologies, must break out of the technology silo. "We want to launch joint calls with other areas in Horizon Europe to accelerate diffusion. For example, the Made in Europe partnership on manufacturing or the Quantum Flagship, specifically for the area of quantum photonic integrated circuits, " he says.

"With the introduction of the Photonics Partnership in the previous framework program (Horizon 2020), we raised the industrial share in projects to about 50%, which we consider a good value for collaborative research projects. At the end of the day, it's about bringing together the industrial and academic sides to come up with truly new innovative ideas. SMEs play a special role here, as they are the lifeblood of the European photonics industry. In the past, they accounted for about half of all industrial participants, a value we expect to reach in this partnership as well."

John Lincoln, CEO of the UK's Photonics Leadership Group. Credit: Courtesy of John Lincoln.

"Only in this way can we identify the common relevant technology topics and needs and later bring them into the partnership calls. In addition, we are able to bring together all relevant experts along the entire value chain, to jointly work on solutions to specific challenges, hopefully also outside of the funded projects."

The Zepler Clean Room complex at the UK's University of Southampton used by the Future Photonics Hub. This facility enables the development of next generation fiber lasers for green manufacturing and silicon photonics technologies that will massively reduce power consumption in data centers. Credit: Zepler / University of Southampton.

Meeting society and market needs

Photonics21 has aligned its seven working groups (Digital Infrastructure, Manufacturing, Health, Climate & Energy, Space & Defense, Agriculture & Food, and Core Photonics) according to the needs of society and what are described as the "future megamarkets".

Wilkens says, "We believe this will allow us to better exploit synergies and prevent us from working in parallel. We have also made some changes to the process. Whereas all working groups used to meet in parallel, we now ask the application groups to meet first and bring the results back to the core technology working group.

UK must 'continue participation' in Horizon Europe

The particular interests of the UK photonics sector, including its continuing relationship with European and other international partnerships, is the focus of the Photonics Leadership Group (PLG), led by its Chief Executive Dr John Lincoln.

The PLG aims to nudge industry, academia, support agencies and government to work together to make photonics "bigger, faster, and stronger." In an interview with *Show Daily*, Lincoln says, "Our latest vision, released in November 2021, is to grow UK photonics to a £50 billion ($68 billion) industry by 2035, at which point 60% of the UK economy will depend on photonics to keep it competitive."

Lincoln stresses that the UK's continued participation in Horizon Europe "will be key to delivering that vision." He adds, "UK photonics organisations have already joined consortia bidding for the first calls to be released from Horizon Europe and we fully anticipate UK photonics companies, research organisations and universities will add significant value to many future consortia."

He also believes that a key part of being associated with Horizon Europe is to be an active member of the community and Photonics 21 itself. "I personally am extremely pleased and grateful to have been elected to the P21 Board of Stakeholders at the election of November, 2021."

Lincoln is joined by Alison McLeod from Photonics Scotland and Richard Pitwon from Resolute Photonics, who are both also committed to European collaboration.

He adds, "It is great to see the new Photonics 21 Working Groups up and running again, defining the program for 2023/2024, and great to see UK participants joining their peers from across Europe in shaping future research and innovation direction and priorities."

Post-Brexit, the UK-EU Trade and Cooperation Agreement (TCA) included provisions for the UK to continue participating in certain EU programs, such as HE and

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SPIE Community Support stays strong despite pandemic disruptions

Investment in the optics and photonics community remains core to the Society's mission.

With virtual events replacing most of its conferences and exhibitions in 2021, SPIE was unable to connect with its constituents in person for the majority of the year. But the Society stayed active and engaged though the rich range of its community-support activities. From young students and doctoral candidates, to postgraduates, early-career professionals, and established academics, the global optics and photonics community benefited directly from SPIE recognition and financial support.

"Inherent in the SPIE mission is giving back to our community," notes SPIE CEO Kent Rochford. "It's an integral aspect of our involvement in the global photonics community. We don't ask for money, we don't have a foundation – we fund through our operations. The proof of our commitment lies in our various scholarship, endowment-matching, and education outreach programs. Through our community-support activities, we help to develop and advance international photonics technologies and professionals, helping them to shine a little brighter."

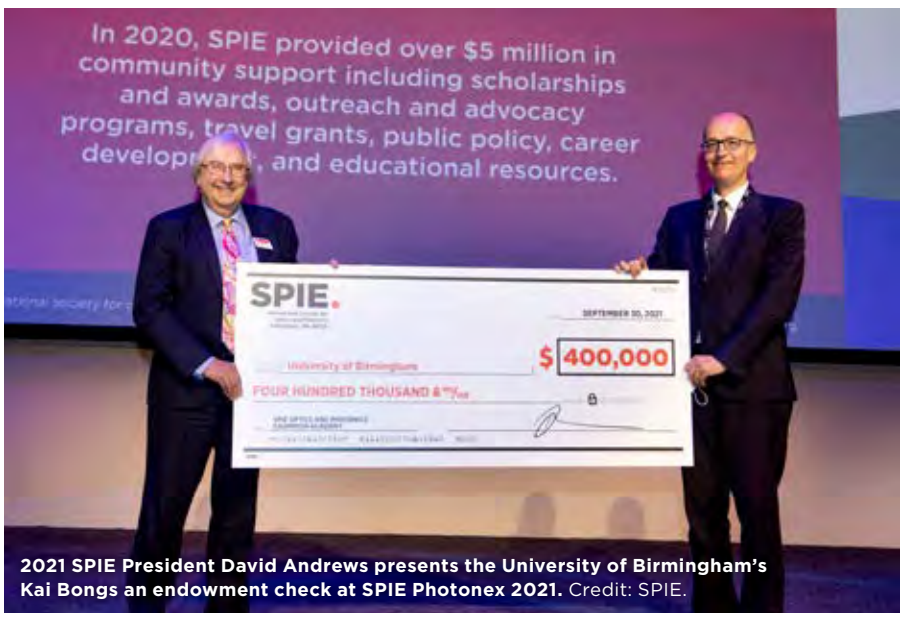
In 2021, the Society continued to grow the endowment-matching program, establishing a $1-million funded SPIE Faculty Fellowship in Optics and Photonics that will support a faculty member at Vanderbilt's School of Engineering, and an $800,000 fund at the University of Birmingham, UK, that will create the SPIE Optics and Photonics Champion Academy. SPIE also announced a partnership with IBM to support quantum optics programs at America's historically black colleges and universities (HBCUs) with the annual $100,000 IBM-SPIE HBCU Faculty Accelerator Award in Quantum Optics and Photonics. The first recipient of that award is Delaware State University professor Renu Tripathi.

> 78 SPIE Optics and Photonics Education Scholarships were disbursed last year for a total of $298,000 in support.

Meanwhile, some of the earlier SPIE endowments are benefiting their initial recipients. The Soileau Family-SPIE Optics and Photonics Undergraduate Scholarship Fund for the University of Central Florida's (UCF) College of Optics and Photonics (CREOL), established in 2020, recently named its latest cohort of recipients: Carlos Granja Angulo; Aiden Nipper; Maya Sosa; Adriana Guevara; and Isabella Pardo. And ICFO, the Barcelona-based Institute of Photonic Sciences, welcomed the 2021 SPIE@ICFO Chair María Yzuel Fellows, part of the $1-million endowed SPIE@ICFO Chair for Diversity in Photonic Sciences established in 2020: Hanna Salamon from Poland, in the research group Quantum Photonics with Solids and Atoms, with her focus on efficient memory compatible quantum light source; Carolina Fajardo from Columbia, part of Medical Optics with her focus on pulsatility assessment of diffuse correlation spectroscopy/time resolved spectroscopy measurements in human subjects; and Maria Paula Ayala from Ecuador, in the Thermal Photonics group, with her focus on tunable thermal emission of VO2.

In addition, 78 SPIE Optics and Photonics Education Scholarships were disbursed last year for a total of $298,000 in support. One recipient was Agata Azzolin a PhD student at Deutsches Elektronen-Synchrotron Research Center (DESY, Germany) whose current research focuses on attosecond spectroscopy on solids and 2D materials. "This scholarship supports me in a life-changing decision. It is not straightforward, leaving your native country to pursue your doctorate and realize your dream – it can be scary. Nonetheless, I felt encouraged by this award: it was a sort of confirmation that I was following the right path."

The SPIE Endowment Matching Program and Education Scholarships represent just two SPIE community-support programs. In addition, named scholarships and fellowships provide wide-ranging opportunities in academics, industry,



2021 SPIE President David Andrews presents the University of Birmingham's Kai Bongs an endowment check at SPIE Photonex 2021. Credit: SPIE.

and government, honoring and benefitting a wealth of aspiring optics and photonics scientists and engineers. Yuka Esashi, for example, is pursuing her work developing novel semiconductor metrology techniques thanks to the 2021 Nick Cobb Memorial Scholarship which recognizes an exemplary graduate student working in the field of lithography for semiconductor manufacturing. "The award strongly motivates me to continue my work on refining and improving our technique of EUV imaging reflectometry," she told SPIE. "And I am looking forward to presenting it at future SPIE conferences."

SPIE Past-President Jim Oschmann and SPIE scholarship winners. Credit: SPIE.

From the SPIE D.J. Lovell Scholarship, the Society's largest and most prestigious scholarship, awarded in 2021 to the University of Cambridge's Simone Eizagirre Barker, and the Michael Kidger Memorial Scholarship in Optical Design – awarded in 2021 to Geoffroi Côté at Université Laval – to the Laser Technology, Engineering and Applications Scholarship and the BACUS Scholarship, SPIE offers a rich range of opportunities for financial support and early-career recognition. "Thanks to the generous support of SPIE, I have been able to continue to push myself toward achieving my academic and professional goals," noted Montana State University's Riley Logan, winner of the 2021 John Kiel Scholarship. "SPIE has been instrumental in both my intellectual growth and progress toward a fulfilling career in optics and photonics."

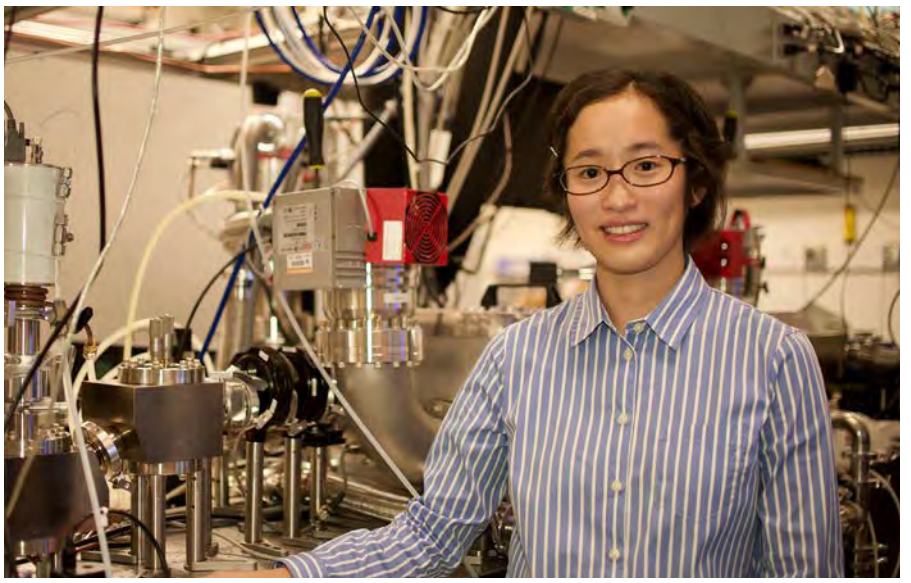
Now SPIE has kicked off the new year in fine form, with announcements of 2022 Nick Cobb Memorial Scholarship winner Yonghwi Kwon and Ivan Kosik, recipient of the $75,000 SPIE-Franz Hillenkamp Postdoctoral Fellowship. And this week the Society announced the latest SPIE Matching Endowment Program partnership, a $1-million fund for the SPIE Graduate Fellowship in Optical Sciences and Engineering at the University of Rochester. With this tenth endowment, SPIE marks nearly $4 million in matching gifts, resulting in more than $10 million in dedicated funds, a remarkable impact from the endowment program alone.

Altogether, the Society provides unmatched support for young scientists and engineers pursuing career goals in optics and photonics. Why do this? Because SPIE is a community-focused Society, operating globally. And integral to the SPIE mission to partner with researchers, educators, and industry to advance light-based research and technologies for the betterment of the human condition, is a commitment to support, nurture, and develop future generations of optical scientists, policymakers, and engineers, ensuring a sustained and healthy optics and photonics community.

And, ideally, that support galvanizes them to give back to the community themselves. As 2021 SPIE Optics and Photonics Education Scholarship recipient Emily Elhacham notes, "receiving such a significant recognition from SPIE has given me more confidence in pursuing my career path and is supporting my efforts in introducing more girls to these fields." It's that approach and commitment to the community, that's known as coming full circle.

DANEET STEFFENS

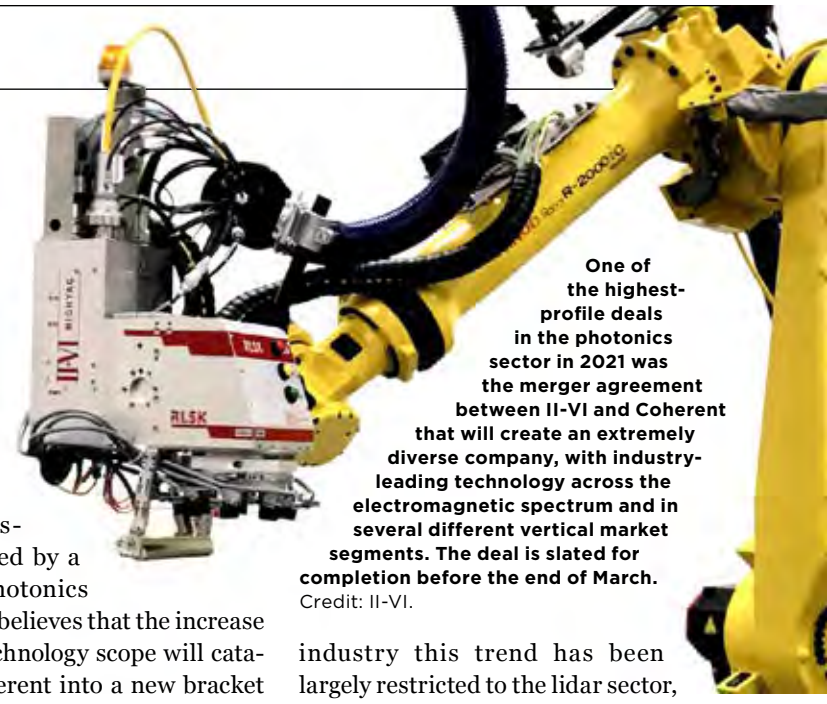
> The award strongly motivates me to continue my work on refining and improving our technique of EUV imaging reflectometry



2021 Nick Cobb Memorial Scholarship winner, Yuka Esashi, next to the phase-sensitive EUV imaging reflectometry beamline. Credit: SPIE.

Strategic buyouts and SPACs dominate industry consolidation

Photonics sector transactions hit $85 billion in 2021, thanks to some high-profile mergers and listings fueled by private equity.



One of the highest-profile deals in the photonics sector in 2021 was the merger agreement between II-VI and Coherent that will create an extremely diverse company, with industry-leading technology across the electromagnetic spectrum and in several different vertical market segments. The deal is slated for completion before the end of March. Credit: II-VI.

With thousands of participants, most of them SMEs, the push and pull of industry fragmentation and consolidation is a perennial topic of interest in the photonics business. And with 2021 characterized by a number of high-profile merger deals — most obviously the protracted battle to acquire Coherent, one of Photonics West's largest exhibitors — you could be forgiven for thinking that last year represented a record level of activity. In fact, that's not quite the case: the latest annual compilation of photonics business transactions by industry analyst Linda Smith of advisory firm Ceres shows that deals in 2021 totaled $85 billion — just short of the $87 billion figure registered in 2019.

Industry analyst Linda Smith of advisory firm Ceres. Credit: Ceres.

"2021 marks the highest total transaction value in history for mergers and acquisitions, [with] global aggregate M&A transaction value up more than 40% over 2019," wrote Smith in the latest round-up. "However, the total transaction value for targets employing photonics technologies is still shy of its 2019 high."

Smith suggests that this discrepancy may be due to an inherently high concentration of strategic deals in the photonics sector, where more than 80% of acquisitions of photonics-enabled targets involved strategic buyers. That contrasts with wider industry: according to management consultants Bain & Company, although strategic M&A activity overall looked set to reach its highest value in six years, it is private equity investment that increasingly dominates the scene.

"Strategic buyers [face] the challenges of slower growth, an abundance of investment capital, advances in digital and mobile technologies, and government intervention with M&A," wrote Smith. "They acquire companies to open new markets, enhance capabilities and implement new business models. We also see more strategic buyers executing vertical integration plays, bringing critical capabilities in-house. In 2021, however, M&A appears to shift back from 'capability' deals to 'scale' deals, as companies seek to strengthen their core business."

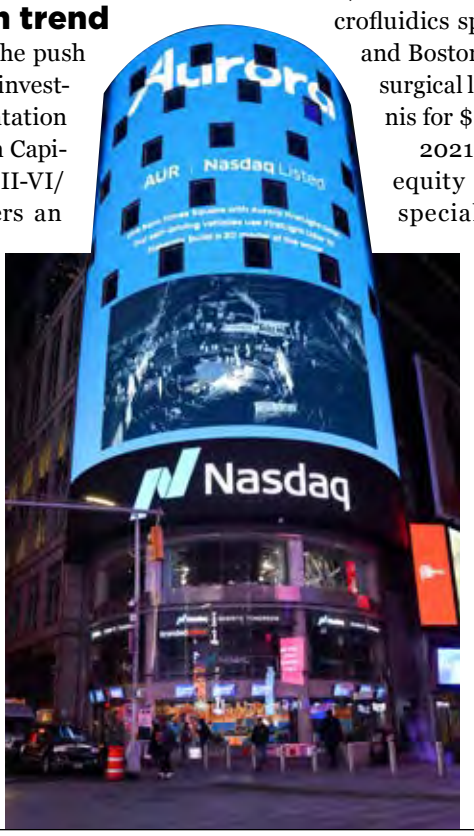
In 2021, a few of those deals stood out, because they involved some of the biggest and best-known brands in the photonics sector — names that would be very familiar to anybody who has visited the Photonics West exhibition in the past few decades.

Last year opened with a flurry as defense-aligned Teledyne Technologies announced plans on January 5 to acquire the thermal imaging giant FLIR Systems for $7.5 billion. Just two weeks later, Lumentum and Coherent revealed their $5.7 billion merger deal. The latter was not to be, however: following a succession of rival bids that turned the sale into an auction, II-VI emerged as the successful bidder with its tabled $7 billion agreement — supported with $2 billion from Bain Capital.

Lumentum's powder did not remain dry for too long, although the near-$1 billion agreement to acquire NeoPhotonics announced in November is significantly smaller than the industry-spanning scope envisaged with its original Coherent plan.

Consolidation trend

So what is driving the push to consolidate? An "investment thesis" presentation document from Bain Capital, in relation to the II-VI/Coherent deal, offers an insight. With combined annual revenues in the region of $4.1 billion, the merged entity would eclipse by some distance the sales of MKS Instruments, Lumentum, and IPG Photonics, elevating II-VI to a size more comparable with leading industrial technology firms such as Agilent, Rockwell Automation, or Teledyne — a scale that has not previously been achieved by a "pure-play" photonics company. Bain believes that the increase in scale and technology scope will catapult II-VI/Coherent into a new bracket — one where stock prices typically command a higher multiple to earnings.



Aurora was one of several lidar firms to raise money via a special-purpose acquisitions company (SPAC) merger deal in 2021. Outside lidar, Rockley Photonics and genomic sequencing equipment firm Quantum-Si have also used SPACs for fundraising. Photo: Aurora.

Looking at some of the other agreements signed in 2021, Smith notes as stand-out developments network testing firm Viavi Solutions' $480 million acquisition of rival Exfo, and Jenoptik's $350 million deal to buy the medical and Swiss Optic divisions of Berliner Glas from semiconductor equipment giant ASML.

Of course, the tentacles of photonics technology spread across all sorts of vertical markets. In life sciences, Smith cites Thermo Fisher Scientific as one the most acquisitive — last year the NYSE-listed firm added four life sciences instrumentation companies and a rapid point-of-care PCR-based testing platform for detecting infectious diseases.

In fact, Smith reports that biophotonics saw more merger activity than any other last year, including deals that saw Quoin Pharmaceuticals merge with time-resolved microscopy firm Cellect Biotechnology to target regenerative medicine, Diasorin buy out optical microfluidics specialist Luminex, and Boston Scientific acquire surgical laser pioneer Lumenis for $1.1 billion.

2021 also saw private equity fuel the value of special-purpose acquisition company (SPAC) deals to new heights. In the photonics industry this trend has been largely restricted to the lidar sector, where SPAC listings by Aurora, Velodyne, Luminar Technologies, Ouster, Aeva, Innoviz, and AEye will soon be joined by Quanergy Systems.

The exceptions are Rockley Photonics and Quantum-Si. Rockley's founder Andrew Rickman enjoyed success in the late 1990s with the flotation of Bookham Technology, and his latest silicon photonics company pivoted from communications to healthcare prior to completing its SPAC deal. Proteomics equipment firm Quantum-Si put its publicly raised capital to work quickly, securing its supply chain and support for scaling commercialization efforts with the acquisition of semiconductor and optoelectronic assembly services provider Majelac Technologies.

Elsewhere, Amphenol Corporation, BICO Group (previously Cellink) and Desktop Metal have all made their presence felt, with moves to snap up fiber-optic interconnect maker Halo Technology Group, precision lithography equipment firm Nanoscribe, and additive manufacturing system vendor ExOne, respectively.

Speaking of snapping up, Snap Inc., the software company behind Snapchat, has made a move into optical hardware with the acquisition of WaveOptics, the UK maker of augmented reality (AR) waveguides based on diffractive optics (and a regular participant at SPIE's AR/VR/MR event, taking place this week at Moscone West).

Summing up the current landscape, Smith observes that although photonics technology deals may not be keeping pace with the wider market for mergers and acquisitions, the strategic activity now being witnessed is significant. "Strategic buyers have the advantage over financial sponsors, such as private equity, in that they can create proprietary deal flow," Smith writes. "However, most M&A deals today are auction processes with stiff competition from financial sponsors, who have more deal-making capability and capacity than strategic buyers — as well as $2.8 trillion of dry powder."

continued on page 21

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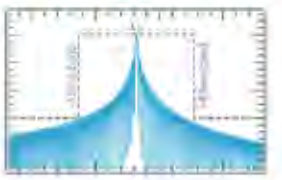

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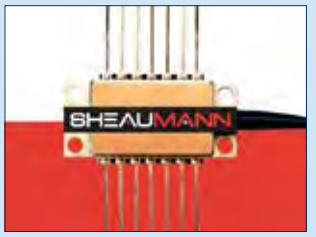

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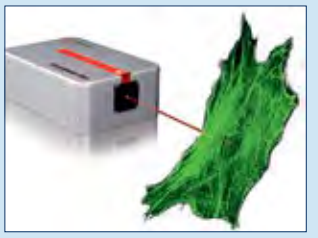

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Webb: risky business will be worth the wait

The James Webb Space Telescope will open up a new view of the universe — all thanks to extraordinary optics and state-of-the-art spectroscopic instruments.

The James Webb Space Telescope, shown here two weeks ahead of launch as it was placed on top of the Ariane 5 rocket that carried it into space. Unfurling of the telescope's sunshield and mirror optics represented two of the riskiest elements of the mission. Credit: ESA/M.Pedoussaut.

Yes it is massively over budget and, yes, it is more than a decade late. But as the Ariane 5 rocket carrying the James Webb Space Telescope (JWST) into space cleared the tower early on Christmas morning, it was impossible not to feel a rush of excitement.

What has become an absurdly complex engineering challenge should by now have arrived at the "L2" Lagrange point, ahead of five months of cooling and instrument commissioning before it finally opens its infrared eyes towards the cosmos. And the early good news is that a perfect launch sequence has left JWST with enough fuel to support science operations for "significantly more" than ten years, NASA reported.

However — and unusually for a space project — JWST's launch did not constitute the riskiest part of the program. "This is just the beginning for the Webb mission," commented Gregory L. Robinson, JWST's program director at NASA, shortly after launch. "Now we will watch Webb's highly anticipated and critical 29 days on the edge. When the spacecraft unfurls in space, Webb will undergo the most difficult and complex deployment sequence ever attempted in space."

Robinson was referring to the fact that JWST has more than 300 "single-point failure" elements — components that do not have a back-up or spare. Most of these were to be found within the month-long deployment phase following launch, and involve highly complex and novel sequences such as unfurling the sunshield that will keep JWST cool, and unfolding some of the 18 gold-coated segments that make up its primary mirror.

Asked ahead of the launch what he thought the most risky part of the mission was, Thomas Zurbuchen, associate administrator for the Science Mission Directorate at NASA, said: "Really, the deployment of the five-part sunshield. Many other parts need to work as well, but this is something that is breaking new ground — and stands out in my mind." That sunshield had already proved problematic, having ripped in a practice deployment in early 2018, and JWST mission controllers will have breathed a huge sigh of relief when its deployment was completed January 4. "We've just wrapped up one of the most challenging steps of our journey to #UnfoldTheUniverse," tweeted NASA shortly after. "With all five layers of sunshield tensioning complete, about 75% of our 344 single-point failures have been retired!"

With its primary and secondary mirrors just deployed at the time of writing, JWST is heading towards L2, ready for the cooling and commissioning phase before "first light", anticipated in June this year. The telescope will now begin moving its 18 primary mirror segments to align the telescope optics, using 126 actuators on the backsides of the segments to

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MIRI: THE COOLEST CAMERA IN SPACE

Operating across the 5-28 micron range, the UK-assembled mid-infrared instrument (MIRI) will open up a new view on the universe with observations at what has, until now, been a largely inaccessible wavelength range. However, one of the key challenges with MIRI is extreme cooling, which is required to reduce system noise to a level that allows sensitive imaging.

JWST's Mid-Infrared Instrument (MIRI), shown here in the giant clean room at NASA's Goddard Space Flight Center after transportation from the Rutherford Appleton Laboratory in the UK back in 2012. Credit: NASA/Chris Gunn.

"By combining expertise from both the US and Europe, we have developed MIRI as a powerful capability for Webb that will enable astronomers from all over the world to answer big questions about how stars, planets, and galaxies form and evolve," said Gillian Wright, co-lead of the MIRI science team and the instrument's European principal investigator at the UK Astronomy Technology Center.

By peering through even thicker clouds of dust than the near-infrared instruments, MIRI will reveal the birthplaces of stars. It will also detect molecules that are common on Earth — like water, carbon dioxide, and methane, and those of rocky minerals like silicates — in cool environments around nearby stars, where planets may form. Near-infrared instruments are better at detecting these molecules as vapor in much hotter environments, while MIRI can see them as ices.

MIRI's ultra-precise mirrors were diamond-turned and coated more than a decade ago, at the Fraunhofer Institute of Applied Optics and Precision Engineering (IOF), in Germany. Stefan Risse, head of the precision optical components and systems department at the Jena facility, pointed out that since their development, freeform reflective optics are now made routinely.

"Using a combination of diamond turning and polishing processes, metal optics can be manufactured with such precision that a surface profile with accuracies in the nanometer range and with roughness in the sub-nanometer range are produced," Risse added.

JWST represented the first space project for Risse's department. "It has now been over 15 years since we delivered the mirrors for MIRI to our client," he recalls. "But research and development projects for space are becoming increasingly difficult due to the enormous requirements and the usually numerous cooperation partners."

IOF director and Photonics West regular Andreas Tünnermann added: "It is a great honor for us to be involved in such a large-scale scientific project. Our contribution is based on expertise that has been built up here in Jena since the institute was founded in 1992. We are now eagerly awaiting the first images that Webb will deliver. They will be views that reach deeper into the universe than ever before."

The critical job of cooling MIRI fell to a team at NASA's Jet Propulsion Laboratory (JPL). Cryocooling specialist Konstantin Penanen said of the effort: "It's relatively easy to cool something down to that temperature on Earth, typically for scientific or industrial applications.

"But those Earth-based systems are very bulky and energy inefficient. For a space observatory, we need a cooler that is physically compact, highly energy efficient, and it has to be highly reliable because we can't go out and repair it. So those are the challenges we faced, and in that respect, I would say the MIRI cryocooler is certainly at the cutting edge."

MIKE HATCHER

Webb telescope continued from page 19

flex each mirror — an alignment that will take months to complete.

Just as the second wing of the primary mirror was being latched into place, Zurbuchen's emotional response was evident: "Webb's successful deployment exemplifies the best of what NASA has to offer," he said. "The willingness to attempt bold and challenging things in the name of discoveries still unknown."

Günther Hasinger, director of science at the European Space Agency (ESA), added: "We are thrilled that the complex telescope unfolding worked successfully. Now we hold our breath for the optics alignment, the instrument commissioning, and finally the fascinating first science results."

While more than capable of generating the kind of iconic imagery captured by its predecessor Hubble, JWST will be a scientific tool primarily, with four instruments to analyze everything from the edge of the known universe to the moons and planets in our own cosmic backyard.

Speaking during an ESA press briefing shortly before launch, Zurbuchen said that the mission's first year will see JWST aimed at Mars to look for signs of historic water, and probing a huge sub-surface ocean on Jupiter's moon Europa.

Hasinger pointed out that JWST is 100 times more sensitive than Hubble, and a "deep-field" captured with the "sharper eyes" of JWST would capture many more celestial objects than is possible with its predecessor. It will also be capable of detecting "first light" in the universe. As he explained, that means JWST should also be able to confirm a recent theory that primordial black holes were formed within a few seconds of the Big Bang. "The first stars were thought to have been formed 300 million years later, but this might have happened sooner if the black hole theory is correct," Hasinger said. "Webb will actually be able to decide that."

'A completely new view of the universe'

Antonella Nota, Webb project scientist at ESA, says that JWST will give us a completely new view of the universe. One key area will be exoplanets. Amazingly, when JWST was first conceived we knew of precisely zero exoplanets — it is only over the past two decades that we have discovered thousands of distant worlds. "JWST will study these exoplanets, and answer the question: is Earth unique?" Nota said. JWST's NIRSpec instrument will look for signs of life on exoplanets, by probing atmospheres for gases like methane, oxygen, water — the building blocks of life — with oxygen-based molecules the primary target."

JWST's 18-segment primary mirror being prepared for final cryogenic testing at NASA's Johnson Space Center in 2017. Subsequent issues with the complex sunshield, logistical delays, and the Covid-19 pandemic pushed the expected launch date back from 2018 to 2021. Credit: NASA/Chris Gunn.

"Webb is a spectroscopic telescope mostly," Nota pointed out. "Of course, it will take a lot of beautiful images, but a lot of the science will be done with spectroscopy. Images tell you what objects look like, but spectra tell you what objects are made of. Infrared is a new regime, [and] the surprises will be amazing." Thanks to photonics technology innovation, NIRSpec will be able to observe hundreds of targets in the same frame.

Arguably the MIRI instrument offers JWST's most transformational capability, giving it "eyes" in a wavelength range that has been simply inaccessible until now. Gillian Wright, European principal investigator for the

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Historic levels of R&D funding flood into certain U.S. Priorities

The U.S. Government's bipartisan infrastructure bill, signed into law on 15 February 2021, provides billions in federal R&D dollars to certain congressional priorities, in addition to the more traditional infrastructure funding of roads and bridges. With even more money and policy changes on the horizon, this could transform many areas of R&D within the United States.

Though the funding provided in the bipartisan infrastructure bill was comparatively minor in the context of the $1.2 trillion bill passed by congress, the funding provided to R&D in the bill is still significant in terms of dollar amounts and will have a big impact on the communities targeted for funding increases.

Specifically, the bill provides $25 billion for large-scale energy technology demonstration projects. The majority of this funding will go through a new Department of Energy (DOE) Office of Clean Energy Demonstrations and will require DOE to rapidly scale up their administration of these projects, especially in the area of carbon mitigation and hydrogen production.

Among this funding it includes $6 billion over 5 years towards carbon capture, utilization, and storage (CCUS) technology demonstrations and R&D, $8 billion over five years towards four hubs producing clean hydrogen, and $2.5 billion across six years for two nuclear reactor demonstrations that are already underway in Wyoming and Washington state.

Additionally, this funding provides $355 million over four years to support energy storage demonstration projects, $3 billion for battery materials processing grants, another $3 billion for battery manufacturing and recycling grants, and $10 billion over five years towards grid reliability and resilience of both the existing grid and innovative approaches toward the US electric grid system. In the area of critical minerals, $140 million is provided for DOE to establish a rare earth demonstration facility and $400 million over four years for grants related to critical minerals mining and recycling research.

DOE has started the process of getting this funding out their doors by gathering input from the community via two requests for information published in the federal register. One seeking "technologies ready to be demonstrated that reduce carbon emissions and remove carbon dioxide from the atmosphere" and another requesting "input on viable hydrogen demonstration and deployment projects." DOE has yet to put out a call for proposals in these areas, but that is expected in the coming months.

Though at the time of writing this article the fate of the reconciliation bill is less than certain, there remains the possibility for another windfall in federal R&D funding more evenly distributed throughout the scientific agencies and community. Based on the bill as it stands today, the National Science Foundation (NSF) would receive $2.5 billion, $1.5 billion of which would be towards a new proposed technology directorate. NASA would receive $1.1 billion, of which $750 million is earmarked for infrastructure and facilities modernization.

Jennifer O'Bryan, Government Affairs Director, SPIE. Credit: SPIE.

The National Institutes of Standards and Technology (NIST) would receive $1.25 billion. $650 million is dedicated to facilities maintenance and upgrades, $260 million is for the Hollings Manufacturing Extension Partnership, and $220 million would support advanced manufacturing research, development, and testbeds. The Department of Energy would receive $5 billion in total for R&D programs, a significant portion going dedicated to their infrastructure needs.

However, negotiations among Senate Democrats, all of which are needed in order the pass the bill via reconciliation rules, took a turn for the worse prior to the holiday break. Though Senate Majority Leader Chuck Schumer vowed to continue this effort, it's unclear at this time if some portions of the bill can be salvaged and passed.

Waiting in the wings is the US Innovation and Competition Act (USICA). This bill not only authorizes billions of dollars toward a new technology directorate at NSF. It provides $52 billion over five years in emergency supplemental funding towards semiconductor research authorized in the CHIPS Act. This bill was passed by the Senate with bipartisan support and has strong support from the Biden administration.

However, a path will need to be cleared for finalizing negotiations with the House of Representatives and passage of a final package. Currently there are many other priorities standing in the way, such as completion of FY22 appropriations and voting rights legislation, on top of possible consideration of a renegotiated reconciliation bill. Timing will be tough as congress will all but crawl to a stand still as we near the mid-term elections. However, with the popular, bipartisan support for this bill, especially the CHIPS funding, it may yet find a way through to making it into law.

**This article was written on 5 January 2022 and does not reflect developments beyond this date.*

JENNIFER O'BRYAN
GOVERNMENT AFFAIRS DIRECTOR, SPIE

Horizon Europe continued from page 11

Copernicus (space). Although the TCA has been in operation since January 2021, UK participation in these programs has yet to be formally signed off.

'Collaboration is key'

Lincoln is keen to see this participation officially confirmed at governmental level: "Collaboration is key, we are 100% behind UK participation in HE as an associate member, welcome the support from across Europe in getting participation ratified as soon as possible and very much look forward to working with our European friends on the next generation of photonics innovation.

So where does he feel that the next opportunities are to be found? "Photonics has such broad impact it is impossible to pick one technology or innovation out for special attention. However the big challenges we must address are clearer. First and foremost is sustainability and achieving Net Zero. Photonics impacts on so many dimensions from power generation to energy efficiency to waste reduction. We must champion these impacts so photonics is clearly a critical part of the solution maximizing the attractiveness of our industry to investors, customers, policy makers, employees and most importantly new recruits."

Dr. John Lincoln chaired the Photonics for Net Zero panel discussion on 26 January 2022 at Photonics West 2022.

Further information about Photonics21 is at www.photonics21.org and the UK Photonics Leadership Group at www.photonicsuk.org.

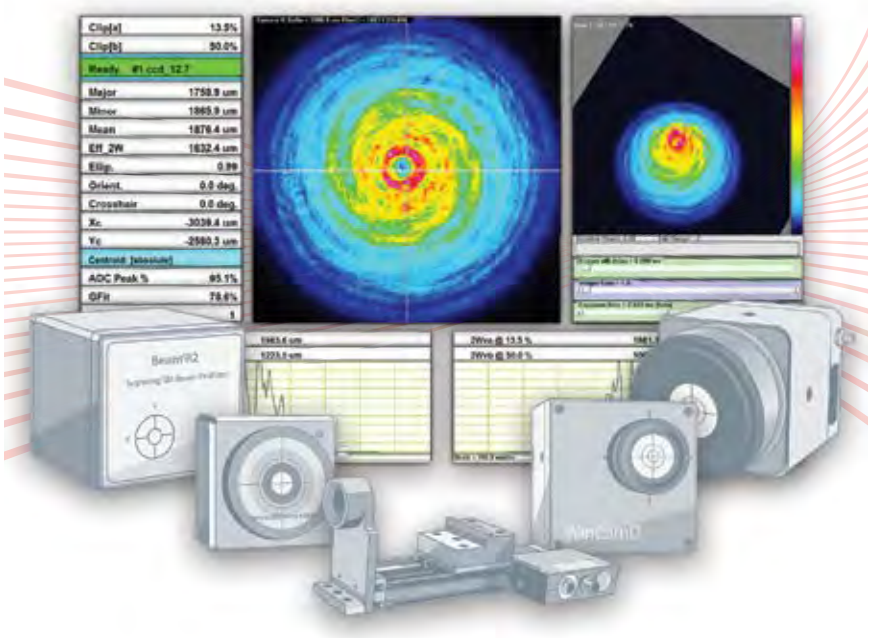
MATTHEW PEACH

Business trends continued from page 14

If financial sponsors do become more attracted to photonics deals in the future, then M&A activity in the sector will likely increase in line with the wider market. "To compete, successful strategic buyers will have to expand their M&A capabilities, and/or instead consider partnerships such as joint ventures or corporate venture capital to expand capabilities and address challenges in talent retention and supply chain," Smith concludes.

MIKE HATCHER

DATARAY



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PASSION IN MOTION ™

Recent cirumstances have contrived to mean that it is with huge disappointment that ALIO Industries will not be able to attend Photonics West in 2022. However, rest assured that after our recent acquisition by Allied Motion Technologies, we are redoubling our efforts on behalf of customers requiring best-in-class motion control solutions.

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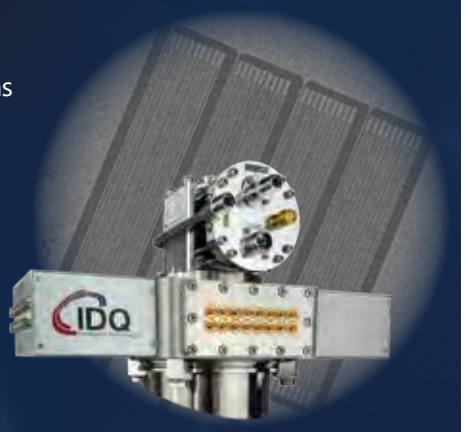

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Webb telescope cont'd from page 20

UK-built MIRI, said: "Technical innovations are part of what helps us to do the science. For MIRI that has brought together optics expertise in Europe with mid-infrared expertise at NASA JPL and the University of Arizona, plus cooling."

In effect, MIRI is one half optical instrument, and one half refrigerator. Mid-infrared wavelengths are incredibly sensitive to heat — meaning that the instrument must be kept even cooler than the rest of JWST. "By adding mid-IR, we can ask questions in more detail," Wright explains. "For example we can see methane in exoplanet atmospheres, [and] we can peer further into the dust. MIRI will give us a unique view, with a sharpness in the mid-IR that we've never seen before."

"It's a different discovery machine to Hubble," added Wright. "[We'll] be able to look in the infrared in more detail than ever before, especially the mid-infrared. With JWST, [there is] huge potential for finding things we haven't even thought about yet."

MIKE HATCHER

A 25-YEAR ODYSSEY: JWST TIMELINE 1996-2021

1996: Next-Generation Space Telescope (NGST) envisaged as an 8-meter diameter observatory with an estimated cost of $500 million and 2007 launch

2002: NGST renamed after Apollo-era NASA chief James E. Webb

2003: TRW wins $800 million prime contract for redesigned 6.5-meter equivalent JWST with launch slated for 2010; Northrop Grumman acquires TRW

August 2004: Axsys contracted by Ball Aerospace to machine beryllium substrates for primary mirror segments

April 2005: Tinsley wins deal to grind and polish JWST's 18 mirror segments

August 2005: Brush Wellman completes mirror blank production

May 2007: novel wavefront sensing and control system approved to align image produced by the mirror segments

April 2009: first mirror segment completes cryogenic tests

April 2011: polished, gold-coated mirror segments arrive at NASA Goddard for testing

July 2011: JWST mission threatened with cancellation after running over budget

September 2011: SPIE urges US authorities to continue JWST mission funding to completion; funding agreement sees new launch date set for October 2018; final mirrors complete coating stage

July 2013: Lockheed Martin delivers NIRCam instrument

April 2014: Airbus-built NIRSpec instrument installed at NASA Goddard

July 2014: Lightweight folding mirror backplane completes static load testing

February 2015: MCT (mercury cadmium telluride) infrared detectors in three of JWST's four scientific instruments replaced after design flaws are found in vibration testing

November 2015: mirror structure assembly begins at NASA Goddard

August 2017: JWST undergoes environmental, thermal, and optical testing in Houston amid Hurricane Harvey

September 2017: logistical delays see launch date pushed back to mid-2019

February 2018: JWST shipped to Redondo Beach facility for final integration

March 2018: launch window pushed back to May 2020 after sunshield tears in practice deployment

June 2018: speaking at SPIE's Astronomical Telescopes and Instrumentation conference in Austin, Texas, JWST manager Lee Feinberg likens the telescope's engineering effort to "climbing Everest"

June 2018: launch delayed to March 2021 as costs escalate to $9.7 billion

July 2020: technical challenges and Covid-19 pandemic delay launch to October 2021

September 2021: launch date reset for December 18, 2021

October 2021: JWST arrives at Pariacabo harbour in French Guiana

December 11, 2021: JWST positioned on top of Ariane 5 rocket (see image)

December 14, 2021: launch date pushed back to December 24 due to a communication issue between the observatory and the launch vehicle system (interface/data loss issue)

December 17, 2021: Tests completed; JWST encapsulated inside launch vehicle

December 25, 2021: Delayed a further day due to bad weather, JWST launches from French Guiana, headed towards Lagrange point 2, 1.5 million kilometers from Earth

December 28, 2021: Pallets containing JWST's mission-critical sunshield are deployed

December 21, 2021: Sunshield fully unfurled

January 4, 2022: Sunshield fully tensioned

January 5, 2022: Secondary mirror deployed

January 7, 2022: Primary mirror deployment begins

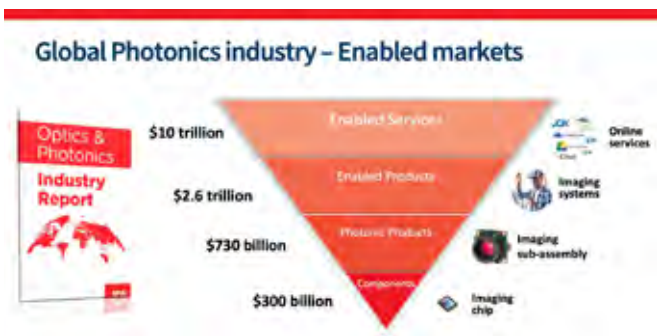
January 8, 2022: JWST mirrors fully deployed

January 21, 2022: JWST due to arrive at L2 point for orbit insertion. Another five months of cooling, instrument calibration, and fine-tuning mirror alignment begins, with JWST scheduled to make its first observations in June 2022

MIKE HATCHER

SPIE updates Core Photonics market report

In 2020, the core components market exceeded $300B for the first time.



SPIE's view of recent market activities: the core photonics markets; enabled markets, and the global picture. Source: SPIE Optics & Photonics Industry Report 2020.

Today at Photonics West, Thursday January 27th, the SPIE industry team is releasing the latest update to its biennial Industry Report. The presentation will focus on the most recent data and trends after a decade of tracking the core photonics components manufacturing business.

SPIE has been providing a benchmark study for quantifying this complex industry since its initial analysis of the photonics components manufacturing industry was unveiled at Photonics West in 2013. This analysis is built on a database built up over several decades and featuring the most comprehensive collection of information and data on companies in the photonics industry. These biennial studies have delivered industry metrics with a robust, consistent, and transparent methodology.

Diverse and dynamic

As diverse and dynamic as ever, the photonics industry continues to exhibit impressive growth. The business comprises a diverse set of products and technologies that underpin nine major market segments ranging from advanced manufacturing to consumer and entertainment. Global revenues from all photonics-enabled businesses and services are now projected to account for more than $2.5 trillion, representing a ~3% share of the >$85 trillion global economy — as measured by global gross domestic product (GDP) — and the prospects are for continued gains across multiple segments. While supply chain issues associated with the pandemic have recently had an impact, companies continue to report record earnings showing the strength and demand of photonics-enabled products and services.

Underlying the end-use market segments enabled by photonics technology is the global photonics components manufacturing industry. Valued at an annual revenue exceeding $300 billion for the first time, this key element of the global photonics industry has experienced sustained growth in revenues, jobs, and companies.

The SPIE Industry Report has tracked, in detail, the core components manufacturing business for a decade and projects an overall compound growth rate (CAGR) approaching 7% through 2020. The number of companies and jobs have also increased at similar rates over this period. These numbers are consistent with other industry reports that continue to show the strength of the global photonics market.

The full report will be presented by SPIE Senior Director of Events and Global Business Development, Andy Brown together with a Public Policy Update from SPIE Director of Government Affairs, Jennifer O'Bryan at 10.15 am, on Thursday January 27th.

ANDREW BROWN
SPIE Senior Director of Events and Global Business Development.

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PHOTONICS MEDIA

SPIE releases Optics and Photonics Global Salary Report

Now in its 12th year, the annual report is based on survey data collected by the Society from the optics and photonics community.

Optics and photonics professionals from around the world report a median annual salary of $78,644 in 2021, a one percent decline from last year's median of $79,380. These findings come from the SPIE 2022 Optics and Photonics Global Salary Report, released for the first time here at SPIE Photonics West. The report is based on survey data from over 3,800 people 90 countries, who shared career information in a short online survey. SPIE delivers the salary report each year, free of charge, as part of its mission as a not-for-profit educational society supporting the science and application of light. This is the twelfth annual survey and report, the largest such study in the optics and photonics community.

Full-time salaries cluster around the median of $78,664, with half of respondents being paid between $44,042 and $134,000. The overall distribution of pay is very wide, with 5th percentile workers earning $9,204 while those at the 95th percentile earn $245,000. Some of the main factors associated with differences in wages include geography, organization, career stage, discipline, and gender.

Workers in Switzerland ($131,052), the United States ($130,000), and Israel ($119,783) enjoy the highest median salaries. Within these countries, private sector workers report higher median wages than their colleagues in academia. In the United States, for example, full-time employees at for-profit companies earned $145,000 while their academic counterparts were paid $104,500 median salaries. At the other end of the wage spectrum, the countries with the lowest median wages are Pakistan at $8,490 and Ukraine at $6,992.

The standout country for wage growth over time is the Peoples Republic of China where median salaries have risen from ¥90,000 in 2011 to ¥250,000 in 2021, an increase of 178%. Over the same timeframe, pay in the United States has grown 23%, from $106,000 to $130,000. Workers paid in euro have enjoyed 10% wage growth, from €47,200 to €52,000 median salaries. In the shorter term, Chinese wages grew 21% from 2020 to 2021, while U.S. pay was flat and euro compensation declined 2%.

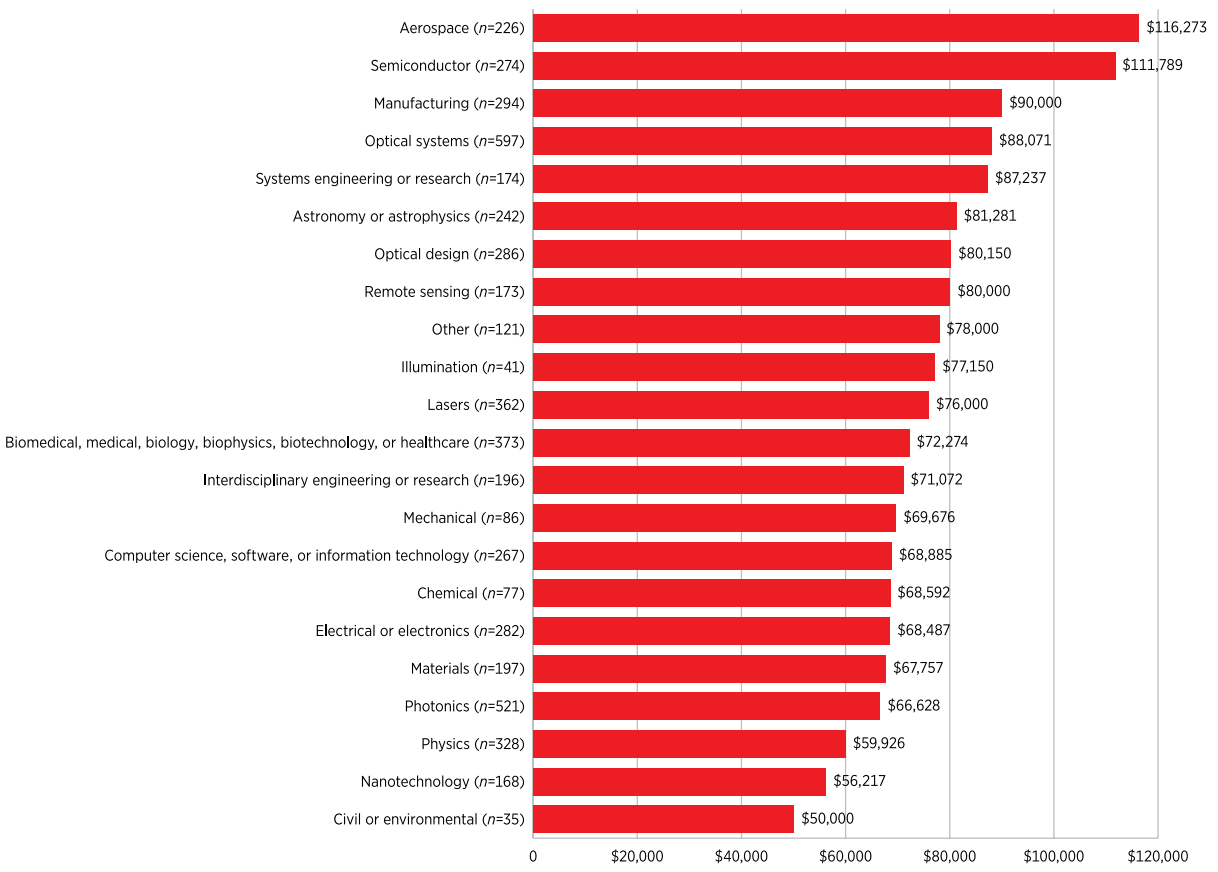
Over the course of their careers, optics and photonics workers receive steadily increasing pay. At academic institutions, new hires were paid $44,708, $51,953 at mid-career, and $150,000 with 30 or more years on the job. At for-profit organizations, starting employees received $54,353, $94,136 at mid-career, and $148,468 after 30 years at work.

Aerospace and semiconductor disciplines enjoy the highest median earnings, at $116,273 and $111,789, respectively. Civil or environmental salaries are the smallest, with a median salary of $50,000. Aerospace has held the top spot for all twelve years that the survey has been conducted. The two most important factors driving salary gaps across disciplines are employment sector and country income level. The highest-paying disciplines have much higher representation at for-profit companies: 69% of semiconductor and 65% of aerospace workers are at for-profits. Country income level has a similar impact on median salaries of optics and photonics disciplines. In aerospace, for example, 89% of workers are in North America or higher-income European countries.

What proportion of your work hours did or do you spend working remotely versus in an office, lab, or other workplace with colleagues?

	100% remote	Mostly remote	About half and half	Mostly workplace	100% workplace
Pre-Covid Pandemic	3%	3%	5%	27%	62%
One year ago	21%	25%	18%	21%	15%
Currently	10%	16%	19%	29%	26%

Median Salary by Primary Discipline



Most full-time workers surveyed (64%) identify as engineers. Within this group, 59% have engineering degrees and are working as engineers, 25% have engineering degrees but are not working as engineers, and 16% work as engineers without having engineering degrees. These subgroups of engineers earn respective median salaries of $90,000, $72,072, and $97,000. The most popular engineering degrees in the optics and photonics community are electrical, accounting for 27% or full-time survey respondents, followed by optical (19%), and mechanical (13%). Electrical and optical engineers are tied, with median salaries of $90,343 while mechanical engineers earned $82,919. In terms of the type of work they do, 41% of survey-takers are engaged in optical engineering, followed by electrical at 11%.

Women make up 21% of the respondents to the survey, 31% of students, 18% of fulltime workers, and 22% of part-time workers. Median salaries are 16% higher overall for men than for women, which is an improvement from a 28% difference in last year's survey. Women earn median salaries of $68,000 versus $79,497 for their male colleagues. The largest wage differences in favor of men are associated with the Middle East, academic organizations, and employment of more than 30 years. Women earn more than men in a variety of subgroups including military/defense and those with 1-5 years of employment.

The COVID-19 pandemic has created a shift to remote work on our community. Prior to the pandemic, only 11% of survey respondents worked half or more of their hours remotely. One year ago, 64% of employees worked remotely half or more of the time, while currently that number has declined to 45%.

The survey asked people what inspired them to pursue optics, photonics, or a related field. The top answer was "The opportunities, excitement, and challenges presented by a growing field," followed by "professors, teachers, or mentors" and "scientific curiosity about light."

To see full results, pick up a report booklet at the following locations: the SPIE Career Center Booth (# 8375 at BiOS Expo and booth #3375 at the Photonics West Exhibition), or the SPIE Information Desk.

ADAM RESNICK

3D sensing: tracking progress on the photonics front line

Show Daily interviewed Pierrick Boulay, senior technology and market analyst at forecasting company Yole Développement, ahead of Wednesday's 3D sensing panel.

Show Daily: What are the latest photonics and optics technologies enabling progress in 3D sensing?

Pierrick Boulay: Fundamental progress is being enabled by certain photonic technologies. On the emitter side, VCSEL arrays for lidar are now using multijunction structures. With the same input current, the output power can be significantly increased. Regarding edge emitting lasers (EELs), manufacturers are developing such lasers with a more limited wavelength deviation (EEL wavelength usually deviates with temperature). On the optics side, AR coatings are being developed to reduce signal loss between the laser emitter and receiver all along the optical path.

Which technologies support autonomous auto technologies?

For autonomous technology in automotive, some of the key topics to be addressed are the challenges OEMs, Tier-1s, and lidar suppliers will have to face: The mounting of lidar and its impact on car design, cleaning solutions, network load, power consumption, and training of AI models for fusion and perception.

Beyond autos, are there other sectors where 3D sensing is seeing significant progress?

For consumers, 3D sensing is increasingly implemented in smartphones, vacuum robots, and payment applications. Regarding other applications, 3D sensing is progressing rapidly in logistics applications, such as warehouse AMR and AGV, delivery robots, and autonomous trucks. Regarding smart infrastructure, applications such as intelligent transport systems, people-flow monitoring, and highway tolling are emerging.

How are the markets evolving, across the spectrum of products?

Two parameters defining 3D sensing in the different markets are the volume of products, and the level of maturity of 3D sensing technology. In the consumer market, the volume of products is now in the range of hundreds of millions of products per year, and after only a few years of development since the introduction of the Face ID by Apple, the technology now seems to be mature, even though some improvements are expected. In industrial applications, the technology is already mature, but the volume of products is in the range of tens of thousands of units per year.

What products or apps are at each end of the price spectrum?

On the low-end side, 3D sensing modules embedded in smartphones, vacuum robots cost only a few dollars. On the high-end side, 3D sensing modules for topographic or aerospace applications are in this price range.

Which companies are some of the main players in 3D sensing?

Notable companies include AEye, with its lidar based on MEMS scanning and fiber laser, which can detect and identify a car at a distance of 1,000 meters. Then Lumotive and Baraja are bringing new solid-state solutions with no moving parts in their lidars. Also worth mentioning, LeddarTech is working more on the data fusion side to develop a scalable solution.

Two parameters defining 3D sensing in the different markets are the volume of products, and the level of maturity of 3D sensing technology.

Describe the changing technology roadmap, from lab to markets.

Today, we clearly see that mechanical scanning lidars are used mainly by automotive players, and this is expected to remain the case for a few years. But in the meantime, solid-state technologies (MEMS-based and flash lidars) are starting to be implemented by a few OEMs. However, other technologies based on FMCW ranging technology are not expected in the automotive industry before 2025.

What are your insights on software and computing needs for lidar?

Even if radars start to become imaging radar, lidars were the first 3D native sensor compared to cameras and radar that were only 2D sensors. Lidar output is a point cloud and brings much more complexity for processing than other sensors. Therefore, the perception software required for lidar should be carefully trained by the supplier. Lidar also brings more autonomy to cars. This means that software is not limited to one sensor but has to be designed at the car level to process data coming from multiple sensors simultaneously.

Pierrick Boulay. Credit: Yole.

What are the important legislative considerations?

Many people speak of autonomous vehicles, and we see some robotic vehicles driving in the US or China. But for automotive, regulations take a long time to be implemented. L3 — meaning "highly automatic driving" — is only possible in Japan today. In L3's driving mode, the driving computer controls a vehicle independently and automatically, with the driver dealing with unexpected situations. No other countries have yet defined the regulations for such a level of autonomy. This will be absolutely necessary for the adoption of high autonomy levels.

FORD BURKHART

NIL Technology debuts metalens camera module

Exhibitor NIL Technology is demonstrating a complete imaging system based around a metalens component at its Photonics West booth (#4539), and says that it will be ready to begin mass production of the metalenses this year.

The Copenhagen, Denmark, company says that the novel camera proves that the innovative optical technology is now ready to be designed into a variety of commercial applications — such as mobile 3D sensing, facial recognition, eye tracking, near-infrared security imaging, driver monitoring systems in cars, and industrial machine vision.

The compact camera module consists of NIL Technology's 1M metalens, a commercial CMOS image sensor from a leading supplier, and an infrared bandpass filter centered around 940 nm. The USB camera is also illuminated by a commercial VCSEL array. The exhibition demo showed a live video feed from the camera module on a large monitor, and included both technical targets and everyday items.

Three of the company's senior representatives are on hand to discuss the metalens technology in technical presentations this week. NIL Technology CEO and co-founder Theodor Nielsen presented details of the latest developments during an invited talk at the SPIE AR|VR|MR event on Sunday. The company's head of optics, Ulrich Quaade, discussed the optical efficiency of metalenses for imaging applications at infrared wavelengths during a presentation on January 26 in the *Photonic and Phononic Properties of Engineered Nanostructures XII* conference.

Close-up of NILT's "1M" metalens component, used inside the camera module being demonstrated at the company's exhibition booth this week in San Francisco. Photo: NIL Technology.

Meanwhile Brian Bilenberg, the firm's executive VP of mastering and also a co-founder, presented a poster at the AR|VR|MR event covering uniformity control of large area diffraction gratings for augmented reality surface relief waveguide masters.

MIKE HATCHER

ficonTEC boosts North American presence

ficonTEC Service, based in Achim, Germany, has announced at Photonics West that it is expanding its sales and service teams in North America, with the establishment of a new facility within the Photonics Incubator housed in CREOL (Center for Research and Education in Optics and Lasers) at the University of Central Florida (UCF).

The new facility also gains a dedicated applications lab to provide both process engineering support to customers, and manufacturing-related photonics R&D.

Over the past three years, ficonTEC has seen record order development for its automated photonic device assembly and test systems, while experiencing shifts in the way business activities can be pursued.

ficonTEC CEO Torsten Vahrenkamp commented, "North America is leading greater adoption of integrated photonics for communications, data centers and 5G, sensors and automotive lidar, and consumer 3D sensing, so we needed a dedicated expansion of our operations.With recruitment already initiated for 2021 and training completed at ficonTEC HQ in Germany, we now have a growing team of field service and application development engineers ready to get the job done."

David Hagan, Pegasus Professor and Dean at CREOL, said, "The benefits in partnering with ficonTEC are clear. It brings a new dimension to CREOL's established photonics R&D groups, to the Florida Photonics Cluster, and to the broader US photonics industry. Equally importantly, it will provide UCF students with an unmatched opportunity to learn the techniques of photonics integration."

MATTHEW PEACH

Deal: David Hagan, Pegasus Professor and Dean at CREOL (l), shakes hands with ficonTEC CEO Torsten Vahrenkamp to seal the agreement for the new joint facility located within UCF/CREOL. Credit: ficonTEC.

EXPLORING THE FRONTIERS OF LED LIGHTING TECHNOLOGY

Some of the future direction and prospects for LED lighting technology were highlighted Wednesday at Photonics West by Lumileds Chief Technology Officer Oleg Shchekin. He cited the 10-fold improvement in luminous efficacy for LEDs over the past 20 years as something of a harbinger of what's to come.

Beyond next level efficacy, Shchekin said, "the truly next step is going to be from color mixing directly." By that he means using four direct colors — red, amber, green, blue — to create white light. He predicts there will no longer be a trade-off between employing the full gamut of colors and efficiency, leading to excellent color quality for most lighting applications.

What's more, while phosphor converted LEDs will remain dominant technology, he said new technology research and development is needed for CM-LEDs, particularly green, yellow, and amber emitting materials. As well, development of "narrow red" and "narrow green" phosphors needs to continue.

Opportunities beyond source luminous efficacy, he said, include using light where it is needed, for example, leveraging digital light source technology emerging in automotive and display fields as well as custom, dynamic light distributions indoors and out.

Another opportunity area, Shchekin said, is human health and wellbeing. This would include technologies like circadian lighting, melanopic tuning with time of day. The challenge, he said, will be maximizing source efficiency through the tuning range.

A Lumileds LED/CMOS hybrid digital light source. Credit: Courtesy of Lumileds.

Healthy daytime indoor lighting, Shchekin noted, requires higher light levels as indoor light levels today are a fraction of what is recommended. "Most of us do not get enough exposure to light indoors," he said, noting that the challenge will be to reduce power consumption at higher lighting levels, and light source concepts to avoid over lighting.

Shchekin also described how digital light sources are transforming automotive headlighting. Beam modulation, configurable arrays, and sensors are delivering lighting packages that are fully automatic and responsive to road conditions, and that can track and identify oncoming traffic to reduce glare as needed, he said.

But digital light sources also hold promise for dynamic indoor spaces, he said, adjustable to many variables like number of people and position, activities, space layout, and time of day. Digital light sources can optimize visual performance and melanopic light dosage, as well as deliver energy savings. "We can deliver the right light, at the right dose, at the right time of day."

Talk of advances in LED technology must include microLEDs, a significant area of development in the industry, Shchekin said. MicroLED displays can reduce energy consumption, deliver greater brightness and high dynamic range. With a wide color gamut, they are self-emissive with no burnout at high brightness, and they are customizable.

MicroLED applications include direct view display, projection/AR display, outdoor signage/display, and automotive. Demonstrated microLED performance indicates that lower power consumption than production OLED technology could be achieved, Shchekin said, along with higher brightness levels for improved visibility in bright, ambient light and for reduced color washout in bright, ambient light.

WILLIAM SCHULZ

Nanoimprint tool for AR waveguide production

Austrian exhibitor EV Group (EVG), which specializes in wafer bonding and lithography equipment for the MEMS, nanotechnology and semiconductor production, says its new "EVG 7300" automated system for nanoimprint lithography and wafer-level optics is now available to order.

Described as the firm's most advanced tool that combines multiple UV-based process capabilities, including NIL, lens molding, and lens stacking in a single platform, it is being aimed at applications in both research and production settings.

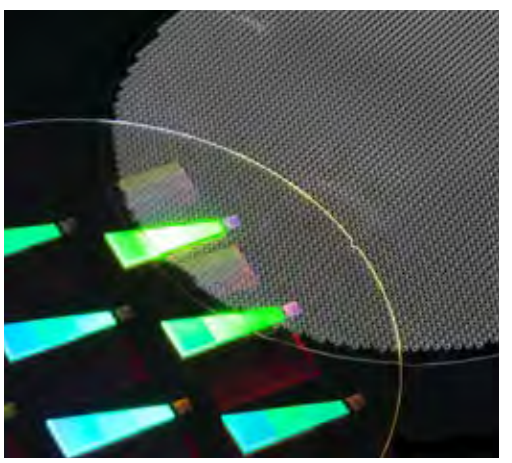
Potential uses could include the manufacture of optical sensors and projectors, automotive lighting optics, waveguides for augmented reality (AR) headsets, biomedical devices, metaoptics, and optoelectronics.

Compatible with wafer sizes up to 300 mm in diameter, the equipment provides high-precision alignment, advanced process control, and high throughput. "The EVG 7300 meets the high-volume manufacturing needs for a variety of free-form and high-precision micro-optical components and devices," states the firm.

Thomas Glinsner, corporate technology director at EVG, claims that the new tool offers the most precise alignment and process parameter control on the market, providing customers with unprecedented flexibility for either research or production requirements. During SPIE AR|VR|MR Glinsner gave an invited talk on the benefits of the system for AR waveguide production.

The EVG 7300 is said to feature industry-leading alignment accuracy down to 300 nm, enabled by a combination of alignment stage improvements, high-accuracy optics, multipoint gap control, and non-contact gap measurement.

MIKE HATCHER



EVG's latest nanoimprint lithography equipment could be used to produce waveguides for AR headsets, metalens optics, and several other micro-optical components. Credit: EV Group.

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