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Fax: +44 (0)1223 213385
Web: www.europascience.com ISSN: 0013-4589

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POSTMASTER: Send address changes to Electro Optics, PO Box 437, Emigsville PA 17318-0437.

Cover image: Economist Enterprise

Editor's Letter

It feels like the world's quantum future is finally moving from 'if' to 'when'. Living in the future tense for years, the complex field has become a throwaway buzzword, promising still theoretical technology is just "five years away". But with outlined government strategies, funding and a new UK cabinet that directly connects scientific innovation to the economy, has that corner finally been turned?

Only time will tell, but our cover star, former Foreign Secretary William Hague, was bullish on the sector's importance, using the Commercialising Quantum Global 2026 stage to deliver a blunt message from him and former Prime Minister Tony Blair: Britain has the science, now it needs the sales.

The call did not land on deaf ears, as (now former) Science Minister Lord Patrick Vallance detailed how the UK government's procurement programme for quantum innovation will ensure the country retains its quantum edge.

The UK won't be the only players in the game, of course. In exclusive interviews, QED-C's Executive Director Celia Merzbacher said "all signs are up and to the right" for the global quantum market and Quantum Computing Inc.'s Chief Revenue Officer Pouya Dianat confirmed that, telling me the company is building a new TFLN foundry in the US to "bring quantum into people's hands".

If this issue has been about how a quantum future could work, next time around we'll be investigating the future of a broken planet, and how photonics can fix it. As I write, yet another record-breaking heatwave is baking most of the Northern Hemisphere. The technologies that fill these pages – from energy-efficient optical networks to cleaner energy production – aren't just scientifically or commercially exciting, they're becoming increasingly urgent.

James Wormald, Editor, Electro Optics

P.S. Nominations for the Photonics100 close on August 14. Vote now at www.electrooptics.com/p100

William Hague: How Britain can become a quantum powerhouse

Can Britain bridge the gap between lab-based quantum expertise and market delivery before international rivals pull away? Former Foreign Secretary William Hague says the Government must act now. **James Wormald** reports

With world-class quantum research taking place within its borders, Britain surely has a genuine opportunity to become a global leader in the emerging sector. But, unless it can find a way to commercialise that early-stage expertise into a world-leading business ecosystem, it risks repeating familiar mistakes and falling behind.

That was the message from ex-MP and former leader of the Conservative Party William Hague, who called for quantum to become part of a new national purpose at the Commercialising Quantum 2026 event held in mid-June at London's Business Design Centre. While artificial intelligence (AI) continues to dominate political debate and public attention, he contends that quantum technologies deserve equal recognition for their long-term economic and strategic importance.

"Quantum is a general-purpose technology with applications as wide and significant as AI," he said. "We know it can be used to sense the physical world with unparalleled precision, revolutionise medical imaging and provide an alternative to satellites for navigation.

"We know that quantum key distribution can lock in more secure communication networks than traditional encryption methods – which will be urgently needed, given that quantum computers will soon be able to break through today's encryption protocols."

But possibly the greatest prize will be in quantum computing, as "replacing the ones and zeros bits of digital machines with atomic qubits will allow more complex equations and modelling," he added.

While significant uncertainty remains over which hardware platform will ultimately dominate, he suggested the destination matters more than the journey. "The future could belong to superconducting, trapped ion, neutral atom or photonic quantum computers. In the end, quantum computing could be dominated by any of these approaches, a mixture of them or by some other approach entirely, (but) whichever kinds succeed, they will have the potential to unlock dramatic scientific progress."

Despite that potential, however, he believes quantum has yet to achieve the recognition it deserves beyond the scientific community. "While AI looms large in the public consciousness, the importance of quantum technologies is underappreciated, and does not always command the attention it deserves among policymakers."

It's that growing concern that led Hague to work with former Prime Minister and one-time sparring partner, Tony Blair, on a series of papers that identify areas of technology and innovation that are key to the UK's economic prosperity and national resilience.

"When I was the leader of the opposition, most of my energies were focused on trying to destroy Tony Blair," said Hague. "That was the least successful part of my life. So, now I have teamed up with him. Now I find there is practically nothing we disagree on!"

The pair's shared conclusion, he said, is clear. "Technology and innovation are the key ingredients, and that's why we've called on the Government and MPs of all parties to make tech leadership our new national purpose. In our quantum paper, Blair and I argue that having a leading quantum sector is critical for Britain's growth and security. We warn that while recent governments have supported, and are supporting, quantum, more interventions are needed around research and development, access to capital and building resilience."

Hague mentioned that although the UK is in an enviable starting position in the sector, ranking "third globally in academic quantum research, and being home to the second highest number of quantum start-ups in the world, Britain still struggles to turn scientific leadership into commercial success".

"We often fall short in converting research into commercial applications. Action is needed to ensure the value of innovation generated by UK quantum research is retained within the country,"

Economist Enterprise

William Hague is co-author, with former Prime Minister Tony Blair, of the New National Purpose paper series, which explores how emerging technologies can strengthen the UK's long-term growth, national resilience and strategic competitiveness

he said. He identified three problem areas in urgent need of attention. "Firstly, R&D," he told the session. "The UK is a leader in long-term foundational research. But we need to do more to target our R&D towards overcoming specific engineering challenges that stand in the way of the commercial deployment of quantum technologies. Progress in key problem areas such as deciding the most efficient paths for qubits to interact or reducing errors in quantum calculations would go a long way towards supporting commercialisation."

The second challenge is scale. "With some notable exceptions, such as the recent £100m investment into OQC, many of Britain's leading quantum companies don't have access to sufficient domestic capital. Oxford Ionics' billion-dollar acquisition was a phenomenal achievement," he said. "It underlines the strength of our ecosystem, but imagine how far our talented quantum companies could go if they had the British or European capital they needed, and could grow into global leaders in their own right."

The third challenge, said Hague, is resilience. "The UK quantum sector lacks the support of a wider ecosystem. Our start-ups are dependent on foreign suppliers for key components, such as cryogenics for cooling quantum computers, for example. So, without the support of a broad and resilient ecosystem, our companies will be forced to move abroad in order to scale. If these three constraints are not overcome, there is a risk that we fall behind again, this time in quantum."

Recent analysis by McKinsey suggests quantum technologies could create as much as $2.7tn in economic value over the next decade, but the commercial opportunity is only one part of the story.

"Tech sovereignty also increasingly matters in today's age of geopolitical upheaval. Most of us will be aware of Teddy Roosevelt's observation that to succeed internationally, a country needs to speak softly and carry a big stick," said Hague. "But, in today's world of technological acceleration, big sticks are no longer sufficient. You also need a deep stack with your big stick!

"While full-stack autonomy would be too difficult to achieve, by doubling down on our areas of expertise and working with allies around the world, we can aim for greater strategic interdependence."

One area where that strategic resilience is becoming increasingly important is cybersecurity. "The day when quantum computers can break classical encryption methods is coming ever closer," he said. "It is expected by the 2030s, (but) anticipating this, Britain's enemies are already stockpiling our encrypted communications to break them open. Too few organisations are taking serious steps to prepare for this eventuality."

Having outlined the challenges, Hague made a number of significant policy suggestions to ensure Britain remains at the forefront of the global quantum race.

"The recipe is similar to other technologies such as AI," he said. "We should make sure the UK has the required talent by ensuring our education and visa systems facilitate access to leading scientists and engineers. We should back pioneering institutions, from universities to research bodies; we should adopt a pro-innovation approach to regulation; and, most importantly, we should ensure that tech start-ups have access to sufficient domestic capital to grow and scale within the UK.

"For the most part, politicians and civil servants are waking up to the importance of AI, but they have not all done so yet with quantum. This is frustrating, given that the global AI market has already concentrated around the US and China, while there is greater scope for Britain to play a significant role in the global quantum market."

As he pointed out, this may be because quantum technology remains a difficult topic to understand.

"There aren't many scientists in Westminster. Ask the average MP about qubits, and they're most likely to think you're talking about ancient measurements," he joked. "Hugh Everett's many worlds theory is particularly challenging, (but) it is gratifying to know that somewhere out there, in some far-flung parallel universe, there is a William Hague who defeated Tony Blair."

"Ministers could offer R&D tax relief or reduced employer NI contributions"

However, there are signs that Westminster is "finally getting to grips with quantum," he said. Welcoming the previous government's National Quantum Strategy and continued investment in quantum research hubs. "All of these announcements (are a sign of) progress," he said. "But, with other countries also investing heavily in quantum, the UK needs to be even more ambitious."

To overcome the three challenges of R&D, scaling and resilience, Hague proposed a range of practical measures to significantly accelerate commercialisation.

"We need to target our R&D towards specific engineering challenges that stand in the way of commercialisation," he said. One option would be a "quantum translational research group, potentially modelled on Finland's Technical Research Centre".

Fiscal incentives could also be used. "Ministers could offer R&D tax relief relating to quantum or reduced employer national insurance contributions for quantum-related hires," he suggested. These would "enhance R&D in commercial uses of quantum and strengthen the market for UK companies".

To help British companies scale, Hague suggested it was important to "ensure leading British quantum companies can access the funding they need," and that "it will be vital to ensure the funding is well spent, with a focus on real-world applications, rather than hitting technical benchmarks".

He also proposed appointing dedicated quantum procurement champions across government departments to identify future applications, support regulatory sandboxes and stimulate early adoption of the technology.

Advanced market commitments, he argued, "have been used to galvanise the creation of new vaccines, and similar advanced market commitments for quantum technologies could galvanise the sector and unlock new use cases".

The final strand of Hague's recommendations was on building "resilience in the sector by ensuring the UK has the necessary supply chain depth". That would require mapping domestic capabilities, identifying strategic gaps and strengthening partnerships with allied nations, while also investing in critical enabling infrastructure. "Given the importance of cooling systems for quantum computers, for example, expanding the domestic capacity of those will be particularly key," he said.

"Each of us knows how important a strong quantum sector is for the UK's future prosperity and security, (but this) isn't always recognised in Westminster or by the wider public. It will be vital that the next government remains as committed to supporting quantum, to help quantum start-ups grow and build a resilient quantum ecosystem with a domestic infrastructure." **EO**

Read our full review of Commercialising Quantum Global 2026 on page 8.

About William Hague: Chancellor of the University of Oxford, Hague served as leader of the Conservative Party (1997-2001) and as UK Foreign Secretary (2010-2014).

Zeiss plans job cuts to counter flat sales

Zeiss

'We are acting from a position of strength before the circumstances force us to act,' said Andreas Pecher

German optics and photonics company Zeiss is preparing a broad cost-reduction programme, including job cuts, after reporting only marginal sales growth in its recent fiscal report. It blamed geopolitical and economic pressures, which it warned are likely to persist.

Although the overall revenue figure of €5.8bn reported in Zeiss' most recent half-year report represents a 1% year-on-year (YoY) increase, the details suggest that the majority of that gain is down to semiconductor manufacturing technologies (SMT). Zeiss' SMT business generated €2.6bn of revenue alone during the period, which represents a 6% YoY increase and accounts for approximately 45% of total sales.

SMT is a key supplier of high-precision optical systems used in semiconductor lithography, including projection optics and the optical components required for advanced chip manufacturing. These systems demand nanometre-scale precision and are a key part of increasingly complex semiconductor devices.

By contrast, Zeiss' Medical Technology unit dropped by 7% in the latest report to €1.2bn, and is one of several of the company's other technology-focused divisions to record a decline, including Industrial Quality & Research, which went down 3% to €1.1bn.

Zeiss CEO Andreas Pecher pointed towards the conflict in the Middle East as one of the major reasons for the slump, suggesting it is putting a "major strain" on markets and reinforcing trade barriers. He said: "In light of (the conflict), Zeiss faces two major challenges. First, declining momentum over several years in the direct-to-market segments; and second, the structures (were) built during years of strong growth, (but) are no longer efficient."

Within the Medical Technology division, Zeiss has already outlined measures targeting annual savings of around €200m by fiscal year 2028/29. These include supply-chain optimisation, the removal of less profitable products from the portfolio and the relocation of some research and development activities to lower-cost locations, as well as workforce reductions.

Announcing the possible job cuts, Zeiss said its plans to strengthen its competitiveness will come through selective "adjustments to (its) cost structure". While the company stated the "nature of the measures will depend on employee dialogue", it does expect those measures to include "job reductions". However, the company says the programme is intended to generate annual savings of several hundred million euros over the next three years.

"As a foundation-owned company, we are responsible for the long-term success of Zeiss, for this and for future generations," said Pecher. "We are acting from a position of strength before the circumstances force us to act."

New PLG General Manager to advise Government on photonics roadmap

PLG

Dr Lewis Hill joins the PLG from the Max Planck Institute for the Science of Light, where he is a Senior Scientist

The Photonics Leadership Group (PLG) has appointed Dr Lewis Hill as General Manager, with effect from 1 September, just as the UK photonics sector prepares for its first Government-led National Photonics Roadmap.

The appointment comes at a time when photonics is receiving increased attention from policymakers because of its role as an enabling technology across multiple sectors. Optical and photonic technologies underpin some of the biggest emerging markets, such as high-speed optical communications, quantum technologies, semiconductor manufacturing, healthcare imaging, sensing, defence systems and artificial intelligence infrastructure. Lasers, optical fibres, photonic integrated circuits, advanced imaging systems and precision optical components are increasingly central to both industrial processes and modern digital technologies.

According to the PLG, photonics contributes more than £18.5bn to the UK economy annually. As the UK Government develops its strategy for the sector, the PLG says there is a growing need to coordinate engagement between industry, academia and government.

Hill joins the PLG from Germany's Max Planck Institute for the Science of Light, where he is a Senior Scientist, following a research career spent in the UK, Germany, France, Canada and New Zealand.

Working alongside the PLG Executive, he will focus on strengthening engagement across the UK photonics community, supporting evidence-informed policymaking and developing collaboration across Europe while maintaining international partnerships.

Alongside his research career, Hill has also held several leadership positions within the photonics community, including Chair of the PLG's Future Photonics Leaders Group, Chair of Optica's Nonlinear Optics Technical Group and an Optica Ambassador. He has also worked with organisations including SPIE to support collaboration between researchers, industry and early-career scientists and engineers.

The PLG says Hill's first engagements will include briefing MPs on the impact of photonics at a meeting of the Parliamentary and Scientific Committee on 8 September, leading a panel discussion on the National Photonics Roadmap at Microelectronics UK in London on 29 September and participating in the PLG AGM and annual dinner before Photonics Means… in Glasgow on 1 October.

"Photonics is becoming increasingly important to the UK's economy and technological future. As the sector grows, so, too, does the importance of bringing together industry, academia and government around shared priorities," said Dr John Lincoln, PLG Chief Executive and Photonics100 honouree. "Lewis brings a proven ability to build connections across our community, convene and engage stakeholders and champion the impact of photonics."

"The UK photonics community possesses an extraordinary combination of world-class scientific talent, innovative companies and entrepreneurial ambition. Our greatest opportunity now is to ensure those strengths work together even more effectively," said Hill.

>> An interview with Hill will appear in the next edition of *UK Photonics Uncovered*, which will be available at Photonics UK and sent to subscribers with the next issue of *Electro Optics*

Thales acquires stake in €3.9bn Exail to boost navigation tech

Thales has announced plans to acquire the Gorgé family's 35.51% stake in Exail Technologies before launching a mandatory tender offer for the remaining shares, a move that would expand its capabilities in photonics, quantum technologies and inertial navigation alongside underwater autonomous systems.

The agreement values Exail at an enterprise value of €3.9bn. Subject to regulatory approvals, the acquisition of the Gorgé family's holding is expected to be completed in the third quarter of 2027, followed by a tender offer for the remaining shares, with completion anticipated by early 2028.

The proposed acquisition would bring together complementary expertise from both companies, including fibre-optic and ring-laser gyroscope technologies.

Combining both gyroscope approaches would enable the company to address a wider range of aerospace, naval and defence navigation applications using two established high-performance inertial sensing technologies.

The companies also expect to combine research and development activities in quantum sensing. Exail develops photonics and quantum technology components that are both supplied to external customers and integrated into its own navigation and maritime robotics products.

Beyond sensing technologies, the acquisition would also strengthen Thales' position in underwater autonomous systems. Exail has developed autonomous mine countermeasure systems alongside surface and underwater drones, and Thales expects the combined portfolio to provide integrated solutions ranging from individual components to complete autonomous platforms. The company also said joint research and development would support future work in autonomous anti-submarine warfare systems by combining AI with unmanned platforms.

Patrice Caine, Chairman and Chief Executive Officer of Thales, said: "Together, thanks to our talents and capabilities, we will strengthen our high-technology industrial base and innovation for our world-class defence and civil customers, while reinforcing Europe's technological sovereignty."

Raphaël Gorgé, CEO of Exail, added: "The Gorgé family is pleased to announce the divestment of its stake in Exail to Thales. Exail's technological development and growth have been exceptional (since the company was created in 2022). By joining Thales, Exail and its teams will enhance (Thales') ability to develop leading sovereign and dual-use technologies for a growing global client base."

Julien Lutt / CAPA Pictures

The proposed acquisition will combine Thales and Exail's expertise in high-performance fibre-optic and ring-laser gyroscope technologies for aerospace and defence systems

Former ministers say UK must invest now to avoid failure in emerging quantum economy

Speakers at the Commercialising Quantum Global 2026 event say industry is quickly moving from ‘if’ to ‘when’, and the UK is on a deadline to build its ecosystem in time

Quantum technologies are beginning to move beyond scientific research and into commercial development. That’s the central theme of Commercialising Quantum Global, the UK’s stand-out quantum sector event from Economist Enterprise, now in its fifth year. But, although the message has been broadly the same for the past five editions, the scope of the presentations, discussions and announcements at the 2026 event seemed to feature a little more ‘when’, and a little less ‘if’.

Rather than focusing on long-term theoretical potential, this year’s programme brought together more than 1,000 delegates to hear 113 speakers talk about where quantum applications such as computing, sensing, communications and cybersecurity are already beginning to demonstrate value, the engineering challenges that remain and how businesses should prepare to adopt them.

Across presentations and the exhibition alike, optical technologies featured prominently as enabling platforms for a sector moving steadily towards commercialisation, while integrated photonics also continued to emerge as a promising route towards new computing architectures.

Sessions explored the convergence of quantum computing, artificial intelligence and high-performance computing, progress in quantum error correction, post-quantum cybersecurity and practical applications in areas including optimisation, materials discovery, navigation and secure communications.

However, delegates were also encouraged to be careful and distinguish genuine technical progress from unrealistic expectations, as the industry’s next advances will depend as much, if not more, on engineering, systems integration and manufacturing breakthroughs as on further scientific ones.

Economist Enterprise

Former Foreign Secretary, Lord William Hague spoke on the topic of ‘Britain’s Quantum Strategy and a New National Purpose: Sovereignty, Scale and Strategic Resilience’

Economist Enterprise

Lord Vallance, the former Minister for Science, Innovation, Research and Nuclear, gave a talk on ‘Backing Science, Building Capability: Delivering the UK’s Quantum Missions’

The UK’s scientific and political leaders had a recurring message: Britain has entered a new phase of its quantum strategy. Rather than focus solely on research excellence, now is the time, argued a lord, a knight and an ex-party leader, to scale the country’s industrial capabilities and keep homegrown intellectual property inside its borders.

Former Foreign Secretary Lord William Hague, (now former) Science Minister Lord Patrick Vallance and Sir Peter Knight each approached the subject from different perspectives, but arrived at a similar conclusion: the UK’s challenge is no longer producing world-class quantum science, but converting that strength into globally competitive business.

Hague said Britain must avoid repeating failures to commercialise breakthrough technologies, warning that stronger domestic investment and supply chains will be essential if UK companies are to scale internationally and retain their intellectual property.

Vallance outlined how Government policy is increasingly shifting towards procurement, adoption and market creation, using programmes such as ProQure to stimulate demand for quantum technologies alongside continued investment in research.

Knight reinforced that message by highlighting the importance of supporting multiple hardware approaches and measuring progress with practical system performance rather than counting qubits.

Collectively, the presentations reflected a broader shift from scientific discovery towards engineering and industrial deployment, with manufacturing capability, standards, software and supply chains now viewed as equally important components of a successful quantum ecosystem.

The programme also recognised that commercialisation depends on more than technology alone. In a session titled ‘Foundations as Kingmakers: How Philanthropy is Shaping the Quantum Era’, Wellcome Leap programme director Shihan Sajeed examined the growing role of philanthropic organisations in supporting early-stage research, developing talent and funding high-risk programmes that complement government investment.

Meanwhile, another example of the outcome-driven agenda was a fireside discussion with Q-CTRL's Lead Solutions Engineer, Niall Moroney. He said that quantum technologies are beginning to deliver practical advantages, including projects involving accelerated materials discovery for clean energy and GPS-independent navigation for defence and aviation, illustrating how both quantum computing and sensing are beginning to move towards operational environments.

Away from the conference theatres, the same themes were mirrored on the exhibition floor, where companies including quantum photonics firms ORCA, Photonic and QCi showcased their progress.

Unlike superconducting or trapped-ion approaches, photonic architectures use light to encode and transmit quantum information, making them well suited to distributed computing and networking over existing optical fibre infrastructure. At the same time, integrated photonics is also enabling emerging electro-optic computing platforms designed to accelerate specialist AI workloads.

One of the most significant announcements came live on stage from ORCA Computing's Richard Murray, who teased news of a major Japanese enterprise customer – in partnership with Toyota Tsusho – ordering its PT-2 photonic quantum computer.

"Installing ORCA's PT-2 quantum system within an enterprise environment in less than one week highlights the maturity of (the technology)," said Murray.

After announcing an investment of more than £25m in a new quantum facility in the UK last year, Canadian company Photonic Inc. used the event to bring its distributed quantum computing architecture that combines silicon spin qubits with native photonic interconnects to a UK audience.

The process allows quantum processors to communicate over existing fibre networks rather than relying on increasingly large monolithic processors, and demonstrates that "commercial-scale quantum computing is within reach", said Photonic CEO Don Mattrick.

Elsewhere during the conference, QCi (Quantum Computing Inc.) announced a framework agreement with Planck Dynamics to deploy its NeuraWave photonic reservoir computing platform for AI applications.

Although distinct from gate-based quantum computing, NeuraWave uses integrated photonics to perform temporal AI and machine-learning tasks with low latency and reduced power consumption, making it suitable for edge computing applications where conventional data-centre infrastructure may be impractical.

"We believe photonic reservoir computing represents an important new computing architecture for AI workloads that must operate at the edge, where data is generated," said Yong Meng Sua, Chief Technology Officer at QCi.

The range of emerging computing technologies enabled by photonics, which includes quantum processors, distributed quantum networks and electro-optic AI accelerators, has never been wider. Although the competing architectures differ, they share one common objective: to improve scalability, connectivity and computational efficiency. And to do it using optical technologies.

Commercialising Quantum Global 2026 reflected a sector entering a more mature phase of development. Yes, scientific advances remain essential, but the emphasis is shifting. The conversation is no longer about proving they work, but about how they can be integrated into sustainable commercial markets. For the UK, that means translating its internationally recognised research base into well-funded companies, robust supply chains and globally competitive products. **EO**

Turn to page 12 to read Celia Merzbacher, Executive Director of the QED-C, give her take on accelerating the commercialisation of quantum.

Photonics Means… 2026 'will bring divided sector together'

Fraunhofer UK's **Simon Andrews** explains why participants loved the 'creative and imaginative' sessions at last year's Photonics Means…, and how the fresh approach to networking will be expanded this October

Photonics100 honouree Simon Andrews, founder of Photonics Means… and Executive Director of Fraunhofer UK Research, says the inaugural event exceeded expectations and established a new format for bringing together industry, academia and policymakers in the UK.

"We did it as an experiment and the feedback was just fabulous," says Andrews. "All the exhibitors were happy and almost all have already signed up to come back."

The event was always conceived as a fixed annual gathering in Glasgow and, rather than touring different regions (as Photonex used to do). Andrews believes the conference now provides a permanent focal point while showcasing photonics clusters from across the UK.

Last year's spotlight was placed on the Torbay photonics cluster. For 2026, Northern Ireland will take centre stage. Northern Ireland Photonics Innovation Cluster (NI-PIC) launched last October, so the Glasgow event – on 1 October – will act as something of an anniversary celebration.

The programme will feature dedicated talks from Northern Irish organisations, alongside tabletop exhibits and networking opportunities designed to foster new partnerships spanning the Irish Sea.

The expansion reflects wider momentum across Britain's photonics sector. Scotland, and Glasgow in particular, has become one of the UK's most important photonics hubs, with strengths spanning quantum technologies, laser systems, sensing, medical devices, space technologies and advanced manufacturing.

The city hosts a concentration of expertise through organisations including the Fraunhofer Centre for Applied Photonics, the Institute of Photonics, the University of Glasgow and a growing network of innovative photonics companies.

Together, these institutions have helped position the region as a significant contributor to the UK's ambitions in quantum technologies and advanced photonics manufacturing.


Fraunhofer

'People have been bumping into me months later saying they really loved the careers or strategy sessions,' says Simon Andrews of last year's Photonics Means… event

A key lesson from the first event was the appetite for a programme that goes beyond traditional academic conference presentations. While technical content remains important, Photonics Means… was deliberately designed to encourage wider conversations around careers, strategy and sector development.

"It's not an academic conference," says Andrews. "The sessions were a bit more creative and imaginative, and participants loved it."

Among the most popular sessions last year were discussions focused on career development and strategic challenges facing the industry.

Feedback continued long after the event itself, with attendees regularly highlighting these sessions as stand-out moments. "People have been bumping into me months later saying they really loved the careers session or the strategy sessions," he adds.

Science communication focus

As a result, organisers are raising their ambitions for 2026. One notable addition will be a science communication session exploring how the photonics community can engage effectively with different stakeholders, from policymakers and investors to the wider public.

The session will be chaired by Scottish broadcaster Kenneth MacDonald, bringing an experienced communications perspective to discussions about the industry's future visibility and influence.

Another new feature will be a dedicated poster session aimed at early-career researchers and students. While organisers initially questioned whether there would be sufficient demand, discussions with younger members of the community convinced them otherwise. Andrews credits a Glasgow University PhD student for helping shape the format after successfully organising poster activities for another Scottish scientific conference.

The addition is intended to create stronger links between industry and academia while ensuring emerging research remains visible within a commercially focused event.

Alongside the formal programme, organisers are also retaining one of the more unconventional elements of the inaugural event: the themed networking reception. Last year's beach party, inspired by the Torbay theme, proved popular. The concept will return this year with a Northern Irish twist – "Northern Ireland's got beaches as well," Andrews notes. "Let's make good use of the silly props again!"

> "We did it as an experiment (but) the feedback was just fabulous"

The event itself will maintain a familiar structure, running from 8am to 6pm.

However, attendees arriving in Glasgow the day before will find an expanded schedule of related activities.

On the afternoon preceding Photonics Means…, The Fraunhofer Centre for Applied Photonics will host its inaugural symposium, which it plans to hold annually. The move creates an additional opportunity for deeper technical engagement while remaining distinct from the exhibition-focused format of the main event.

The timing coincides with another significant milestone for Glasgow's photonics community.

The Institute of Photonics is celebrating its 30th anniversary in 2026 and will hold its own symposium on the same day.

"The Institute of Photonics is our university counterpart here in the technology building," Andrews says.

"They are going to have their own symposium in the morning, and then there'll be a Fraunhofer Centre for Applied Photonics symposium in the afternoon."

Although each event will have a different focus, placing them back-to-back is expected to increase participation across all activities and encourage greater interaction between research organisations, industry representatives and community leaders.

The wider Photonics Leadership Group will also meet during the pre-event programme, further reinforcing the role that Photonics Means… is beginning to play as a focal point for strategic discussions within the UK sector.

For Andrews, the success of the first event has created a challenge as much as an opportunity.

"Year one was an experiment, but it went over and above our expectations," he says. "I've given myself a high bar to beat this year." **EO**

You can register for Photonics Means... at photonicsmeans.com.

Meanwhile, if there's someone you think deserves to join Simon Andrews in the Photonics100, nominations close on Friday, 14 August. **Scan the QR code to nominate now**

How crucial are optical technologies to the stability of the global quantum market?

Ahead of World Quantum Day 2026, QED-C Executive Director and Photonics100 honouree Celia Merzbacher sat down with **James Wormald** to discuss the emerging quantum market and how light-matter interaction, steady algorithm development and strategic cross-border partnerships are accelerating commercial expansion

Electro Optics: Your State of the Global Quantum Industry 2026 report shows strong overall growth in Europe. But how central is photonics to this quantum emergence?

Celia Merzbacher: The quantum behaviour of matter at the atomic and subatomic scale is really about the interaction of light and matter, so almost everything involves light. The detection, the measurement and the manipulation of light are all central to many of these quantum technologies.

DARPA (the US Defense Advanced Research Projects Agency) announced the progression of some of the 20 original companies to the next stage of its Quantum Benchmarking Initiative (QBI), and there are photonics links everywhere. For example, Photonic Inc. is a Canadian company in Stage B that's optically stimulating spin qubits. Quantum Motion is also a spin qubit company from the UK. [DARPA is] funding foreign companies as well as US firms because that's where the innovation is happening.

Atom Computing, based in Colorado, is also on the shortlist. They are looking at neutral atoms interacting with light. There's also Silicon Quantum Computing in Australia. Quantum technology is really emerging everywhere.

Even the companies that are grabbing a lot of the headlines – IBM and Google in particular – which are using superconducting technology that is less dependent on photonics, but which utilise microwaves to control the qubits. There's a lot of progress being made across the board, and that really shows in the data.

EO: Talking about the data, then, quantum technologies have risen steadily again, year-on-year. But what stands out in the past 12 months in terms of quantum breakthroughs?

CM: There is steady progress, yes. A recent report suggested that the number of qubits required to run Shor's algorithm could be orders of magnitude fewer than was originally estimated, so the resource estimations continue to improve.

There are multiple factors driving this trend. One is that the hardware is improving: the quality of qubits is increasing, so they need less correction. The second is the error correction schemes, which are consistently being developed and improved. And the third is the diversity of algorithms: knowing what the use cases are and how we are going to implement them.

Our report goes through 2025, but there have already been multiple announcements this year. For example, the UK committed £2bn to new investments in quantum that's not reflected in our numbers. A paper came out from some Caltech researchers partnering with Google that addressed the "big gorilla in the room" – how to utilise quantum computers to analyse classical data. How do you load classical data into a quantum computer to do what you want with it? Advances such as this may lead to a ChatGPT moment at some point in the future, but, right now, we're making steady progress.

EO: So it's not just that we're steadily moving along the path towards practical quantum applications, but the destination is getting bigger and better as well?

CM: Right, the goalposts are moving in a positive sense. However, the other side of that coin is that classical systems are also getting better. With the advances in AI, people often say to me: "Now we have AI, maybe we don't need quantum any more."

Quantum is still pretty early stage. Rather than thinking about it like an accelerator for doing what we do today with classical computers, what we need is more quantum algorithm "explorers". The hardware is coming, and we need to understand how quantum can manipulate information to allow us to see it in new ways.

Understanding quantum requires an unusual combination of skills, but not everyone has to understand it. Eventually, it will become more of an application that companies can use, but the phase we're in now is where the experimentalists – whether they're academics or are in research institutes, companies or government labs – need to kick the tyres to figure out what we can actually do with this.

EO: Would you say that AI and quantum can work together to improve?

CM: I do think they're very complementary. People often point out that AI has this incredible, voracious appetite for data, but we're running out of new and available data to train the AI models. Some people believe quantum could be the answer, that it can generate synthetic data that mimics the real world because it's inherently statistical rather than deterministic, so it could create artificial data that could actually be useful.

EO: The report suggests the quantum market will double from around $2bn to $4bn between 2025 and 2028, but it also points out that the total amount of

‘Quantum helps us see information in new ways,’ says Celia Merzbacher, Executive Director of the Quantum Economic Development Consortium (QED-C)

public funding to 2025 was $70bn-plus. While steady progress is being made, how long do these well-funded quantum companies have to start repaying some of that investor confidence?

CM: I think this is on top of all these businesses’ minds. They all want to start putting these systems out into the field and making some sales, and there is confidence that this will happen sooner rather than later. What’s interesting is if you look at the data in the report and compare this year’s responses to last year’s, the number of companies who believe their revenue will grow by up to 25% is up compared with last year, so there’s rising confidence that revenues will grow year-on-year. These revenue growth numbers have been steadily around 30% year over year.

And this confidence isn’t just on an individual basis. We also asked companies what they thought would happen in the sector as a whole, and the results showed similar optimism. These companies aren’t thinking they’re the only ones who are going to win big. There’s a general sense that there’s going to be major growth all through the sector.

EO: So, you think concerns of a quantum bubble burst are dying down?

CM: We ask every year, ‘what do you think the likelihood of a quantum winter might be?’ This year, the number thinking it somewhat likely was larger. So, while they are showing a lot of optimism and positivity about their own revenues and that of the sector as a whole, there is still that concern. I don’t know what the basis for that thinking is exactly, because quantum is seen as an important technology for both economic and national security reasons – you see big announcements being made like the one in the UK, for example. So I don’t see governments pulling back from their spending, especially not in the geopolitical environment we’re in. There’s going to be a sort of buffer to cushion against any fluctuations in VC funding that might happen.

Meanwhile, private investment figures were also up substantially in 2025. Investments by large “partial play” companies are harder to measure, but just based on the work being done and the number of people being hired, there’s clearly robust investment.

EO: So, you don’t think recent geopolitical tensions have affected business confidence in quantum as much as other technology sectors?

CM: We’re in the process of doing a separate assessment of quantum supply chains. We know there are global manufacturers and suppliers who want to do business across borders. They want to go where the customers are, and they also want to go where the talent is while observing all the relevant restrictions.

That’s how companies view international boundaries, but governments tend to think a little differently. They’ve got national security interests and responsibilities, so there’s always going to be a difference dependent on where you sit. Overall, though, I wouldn’t say there’s a lack of confidence. If anything, it seems that all signs are up and to the right.

I don’t think global geopolitical tensions have impacted the quantum market that much. The main tension, of course, is with China, both as a military adversary and a business and economic competitor. That

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“People say to me, ‘now we have AI, maybe we don’t need quantum’, but AI has a voracious appetite for data, and we’re running out of it. Quantum could be the answer” makes things complicated, for sure. But, generally, I see more connections across borders than severing of ties, and I hope that continues. We're also interested in seeing what the European Quantum Act has in store, when that comes out, and the US is also talking about renewing its own quantum initiative.

EO: On that point about going where the talent is. Is Europe's talent landscape mature enough to take this expansion? And, if not, what can governments, academic institutions and the private sector collectively do to improve the outlook?

CM: Everyone is trying to develop more qualified quantum workers. That's something I hear from a lot of companies: "I'm headquartered here, but I want operations somewhere else, and I'm trying to decide where I should go."

Often the main reason is not the taxes or cost of doing business – it's access to skilled workers. They go where the people are.

I am passionate about the importance of government-funded university programmes, which create educated people. They go out and take jobs in organisations and that network of people keeps growing.

On the company side, they're looking for very specific sets of skills. So, to make that work, you need to have meaningful relationships between companies and academic institutions.

One example is internship programmes, where students spend summers or breaks at a company. It helps when students go back to the university as well, of course. If they do a short-term internship, they bring that knowledge and experience back with them and their whole group benefits, so it has this sort of amplification.

Figuring out how to give that kind of real-world, hands-on experience is the challenge, and it's something governments should be trying to put in place with educational programmes.

I went to my old undergraduate university a month ago, for what I thought was going to be a one-hour pizza lunch with some students. That one hour turned into three because they were so excited and had so many questions. Their experience is defined by their university, so they were hungry to understand the industry, how they could become qualified and what they needed to do to be ready for a quantum career. We need to tap into that excitement.

> "Advances such as this may lead to a 'Chat-GPT moment' at some point in the future, but, right now, we're making steady progress"

EO: Talking about cross-sector partnerships… what about cross-market partnerships? We're seeing a lot of collaborations and acquisitions between quantum companies and start-ups. How key do you think these are to the advance of the market in general?

CM: Yes, there are a lot of partnerships, including partnerships and acquisitions between companies, as well as partnerships between companies and national laboratories and research organisations. Partnerships and acquisitions between companies are key because, for the acquirer, they fill a technology gap, but they also grant the smaller company access to resources that it wouldn't otherwise get.

This is a sort of natural maturation process that happens with emerging markets. Partnerships between companies and laboratories and research organisations, on the other hand, mainly bring access to capabilities, for example, in testing and evaluation.

Some of the equipment is expensive, so providing access to it with as little friction as possible is also a key advantage.

There's a clear understanding, wherever you are in the world, about the importance of access to test beds and equipment, allowing component makers to see how their equipment will work interoperably with other parts of the system. That's also happening with vertically integrated alliances, where a big company has partnerships with suppliers.

IBM, for example, says quite publicly that it gets around a third of its parts from US suppliers, a third from non-US suppliers and the rest it makes by itself because it's such a challenge right now to find the right supplier. Sometimes this struggle to find potential suppliers is because the markets are still small – it's a chicken-and-egg situation. Hopefully, these partnerships will develop into real, meaningful supply chains for the whole industry.

EO: Finally, what can you tell us about what the near-term future holds for quantum? What will we be discussing at World Quantum Day 2027?

CM: One of the interesting trends is a transition from what we saw a few years ago, when survey respondents predicted we'd be accessing quantum computer systems via the cloud.

However, this year's survey shows quantum computing companies forecasting that, in 2028, access will increasingly be on-prem.

So, over time, maybe not next year but within the next three-to-five years, there's a belief that enterprises will be installing quantum computers on site.

Stay tuned for more on that. EO

Celia Merzbacher was speaking to *Electro Optics* ahead of World Quantum Day 2026. To read more quantum content on how QCi is commercialising quantum PICs with TFLN, head to page 16.

How QCi plans to scale quantum PICs with thin-film lithium niobate

Quantum photonics is moving from experimental lab set-ups to scalable commercial applications. QCi's Chief Revenue Officer, Pouya Dianat (right), tells **James Wormald** why its US foundry investment will pay off with high-value defence contracts

Electro Optics: Tell me about Quantum Computing Inc. What's its role within the quantum photonics landscape?

Pouya Dianat: Quantum Computing Inc. (QCi) is an integrated photonics company providing quantum machines to the world. QCi products are designed to operate at room temperature and low power at an affordable cost. The company's portfolio includes core technology and products for high-performance computing, artificial intelligence (AI), cybersecurity and remote sensing applications.

A major part of our strategy centres on thin-film lithium niobate (TFLN), which we see as a critical material platform for next-generation photonic quantum devices. While we are not yet deploying TFLN-based systems in our product lines, we've made a foundational investment by establishing the first dedicated TFLN photonic device foundry in the US. This gives us end-to-end control over design, fabrication and integration, which is a unique position in the domestic quantum supply chain.

TFLN offers exceptional optical performance, including high-speed modulation, low propagation loss and tight integration with other photonic and electronic components, which makes it ideal for building compact, high-fidelity quantum photonic circuits.

Our foundry positions QCi to transition from discrete or bulk optics to fully integrated quantum photonic chips that are manufacturable, scalable and well suited for both defence and commercial environments.

In short, our role in the quantum photonics landscape is to industrialise the technology and products by moving it out of the lab and into high-performance, scalable systems, powered by vertically integrated TFLN fabrication capability.

EO: What part of QCI's operations are you responsible for, and how does this fit into the company's overall strategy within the market?

PD: I lead QCi's efforts in product strategy, development and commercialisation, ensuring our cutting-edge quantum technologies evolve from innovation to impactful, market-ready solutions.

My role spans revenue-generating functions including product management, sales, marketing, partnerships and customer success to drive growth and adoption across government, commercial and academic sectors.

Ultimately, I focus on bridging product innovation with market viability and enterprise value, turning breakthrough quantum capabilities into real-world applications and bringing quantum into people's hands.

EO: What does success look like? What kind of performance metrics are QCi focused on attaining?

PD: We measure success through a product-driven lens, beginning with customer discovery and validation to ensure our quantum photonics platforms address real-world needs.

Establishing a strong product-market fit is our first priority. We need to understand where our technology delivers the most value across industries such as defence, critical infrastructure and advanced computing.

From there, we track commercialisation metrics including contract acquisition, revenue growth and customer adoption.

On the technical side, we continuously benchmark performance through gate fidelity, latency reduction and system scalability, ensuring our photonic quantum systems meet both market demands and scientific excellence.

EO: How do you identify and prioritise growth opportunities?

PD: We take a hybrid approach, both top-down and bottom-up. From a strategic standpoint, we look at sectors where quantum photonics can solve real bottlenecks such as defence, cybersecurity, pharma and logistics to name a few. At the same time, we engage deeply with end users and ecosystem partners to understand pain points and develop tailored solutions. Our prioritisation matrix factors in addressable market size, regulatory drivers, technical feasibility and time-to-revenue.

EO: QCi recently won a US government contract to supply TFLN PICs… tell me a little bit about why TFLN is so important? How significant is this contract win?

PD: TFLN PICs are the next evolution of photonic integrated circuits. Lithium niobate has long been a foundational material in optics, but the thin-film iteration unlocks much higher electro-optic performance, tighter integration and greater scalability. This makes it ideal for quantum systems where low loss, fast modulation and compactness are essential.

Winning this contract validates our technical leadership in TFLN PICs and represents a major commercial milestone. It's not just about supplying hardware. It's about becoming a trusted quantum photonics provider for national-scale projects, which has far-reaching implications for our credibility and growth.

> “Defence and government are often the early adopters of frontier technologies, quantum included, due to their strategic priorities and budgets”

EO: Are there any specific milestones built into the contract, or any self-applied ones?
PD: Yes, the contract does include structured milestones from assisting with design and prototyping to producing the final design and delivery. Internally, we've set even more aggressive targets around production scalability, integration with quantum control systems and development of modular platforms that can support both quantum computing and secure communications applications.

EO: Do you think government and defence contracts will be quantum's 'in' to the broader commercial market?
PD: Absolutely. Defence and government are often the early adopters of frontier technologies, quantum included, due to their strategic priorities and budgets. These contracts provide a proving ground, both technically and operationally. As performance is demonstrated and costs decrease, we expect many of these innovations to flow into commercial verticals such as finance, energy and transportation. It's a well-trodden path – GPS and the internet (also) started this way.

EO: How important are optical components to your hardware – and what would you like to see more of from suppliers?
PD: Optical components are central to our hardware. Photonic qubits, TFLN modulators, precision couplers – they all determine the fidelity and scalability of our systems. From suppliers, we'd like to see continued innovation in low-loss interconnects, standardisation of quantum-grade components and better integration with existing CMOS processes. Supply chain resilience is also key. As we scale, we need partners that can scale with us.

EO: Looking forward, what should your current and prospective clients be most excited about seeing from quantum photonics over the next five years?
PD: The most exciting development is the shift from experimental set-ups to deployable, application-ready quantum photonic products.

In the next five years, we expect to see breakthroughs in quantum sensing, quantum-secure communications and hybrid classical-quantum computing platforms. Clients should be particularly excited about how quantum photonics can enable real-time decision-making in high-stakes environments from battlefield intelligence to pharmaceutical modelling.

EO: With so much recent quantum investment, how close is the sector to mass ROI gains, and how much time does it have until it bursts? Is this a danger you're concerned with?
PD: The quantum industry is approaching an inflection point. The early hype is giving way to practical applications and measurable ROI, particularly in niche but high-value markets.

That said, there's a risk if the investment narrative stays disconnected from near-term deliverables. We mitigate that by being laser-focused on practical use cases and demonstrable outcomes.

We believe the "burst" risk is mitigated when companies such as QCi deliver real systems that solve today's problems, not just promise tomorrow's revolutions.

It's less about "mass ROI" and more about strategic, high-impact deployments that scale over time. **EO**

Using SOAs and frequency combs can serve to slash data centre energy use

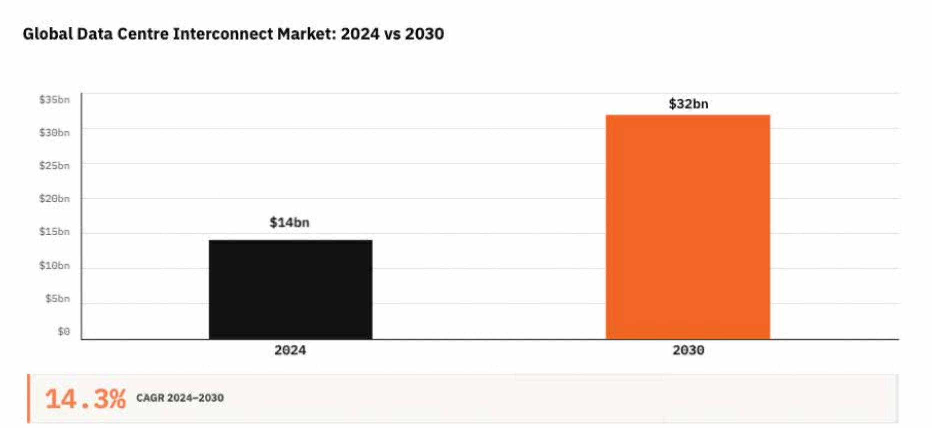
As AI workloads push transceivers past 800G, Photonics100 honouree **Liam Barry** (right) believes semiconductor optical amplifiers and multi-wavelength light sources can scale capacity without power penalty

The modern data centre serves as the engine room for the digital economy, with artificial intelligence (AI) workloads, hyperscale cloud services, 4K/8K streaming and emerging distributed computing paradigms driving an exponential increase in east-west data centre traffic. As Ethernet standards move beyond 800G, the physical layer faces a significant challenge: to dramatically scale capacity while containing energy consumption and maintaining network reliability.

Today's data centres already account for a dominant share of internet traffic, and their energy footprint is rising sharply. Higher per-lane data rates, more complex modulation formats and increasing channel counts through the use of wavelength division multiplexing (WDM), all demand more optical power, tighter link budgets and more complex transceiver architectures. Without innovation at the device level, the energy-per-bit metric risks moving in the wrong direction.

One technology that is re-emerging as a key enabler of energy-efficient scaling is the semiconductor optical amplifier (SOA). Long overshadowed in long-haul systems by the erbium-doped fibre amplifier (EDFA), SOAs are now benefitting from major advances in materials, device physics and integration.

In the context of short-reach data centre interconnects (DCIs), their small footprint, electrical pumping and compatibility with photonic integrated circuits (PICs) make them uniquely attractive. In addition to SOAs, a second key technology is the optical frequency comb, which can replace banks of individual lasers and laser arrays



According to a Research and Markets report, the global data centre interconnect (DCI) market is projected to grow from $14bn in 2024 to $32bn in 2030

with a single, stable source for WDM – simplifying transmitter design, reducing power consumption for thermal management and allowing for higher spectral efficiency.

These device technologies are currently being investigated in two European Innovation Council (EIC) projects, UNICO and M-Engine, where the industry partners (Innolume, Enlightra and Eblana) are focused on integrated device optimisation to enable practical and scalable use in future data centre interconnects.

Why combs are starting to matter

High-capacity data centre links based on WDM technology require multiple laser sources, and, as link capacity increases, we expect to see an increase in channel number. Optical frequency comb sources offer a compelling advantage in these systems as instead of deploying tens of discrete lasers – each requiring individual control and stabilisation – a single multi-wavelength comb can supply many coherent carriers simultaneously.

This consolidation significantly lowers electrical overhead, particularly in hyperscale environments. Thermal management is also simplified with the evenly spaced comb lines reducing the need for wavelength locking and temperature tuning on a per-channel basis, which reduces link efficiency. In addition, as the installation of new fibres in data centres becomes problematic, the spectral efficiency of installed systems may become an issue. The comb sources can enable energy-efficient coherent systems with minimal guard band between wavelengths in future data centre links.

As with the SOAs, integration is another critical factor why frequency combs are starting to matter for data centre interconnects. Microresonator-based Kerr combs using silicon nitride (SiN) ring resonators allow compact, low-loss, on-chip carrier generation. Quantum dot mode-locked lasers enable electrically pumped combs with strong temperature stability and silicon compatibility. Electro-optic combs provide highly tuneable, stable alternatives. Current research and development work into these comb technologies is looking to optimise comb line metrics including power per line, phase/intensity noise and efficiency – with a view to positioning these comb sources as foundational building blocks for scalable, energy-efficient next-generation DCIs.

Why amplification matters again

Intra-data centre links are typically short – tens of metres to a few kilometres – but the move to 100+GBaud signalling and multi-level modulation formats such as PAM-4 and PAM-6 places stringent demands on optical signal-to-noise ratio (OSNR) and receiver sensitivity. In addition, silicon photonics modulators are currently the modulator of choice in many data centre network designs, and these introduce non-negligible insertion loss. Passive WDM multiplexers, demultiplexers, splitters and switches can further erode the power budget.

The traditional response involves pushing laser diodes harder: higher bias currents, higher output powers and tighter thermal management. However, laser reliability declines exponentially with increasing current density. In high-density pluggable modules, thermal constraints are already severe. Simply increasing device length and drive current to reach higher power is not a sustainable scaling path.

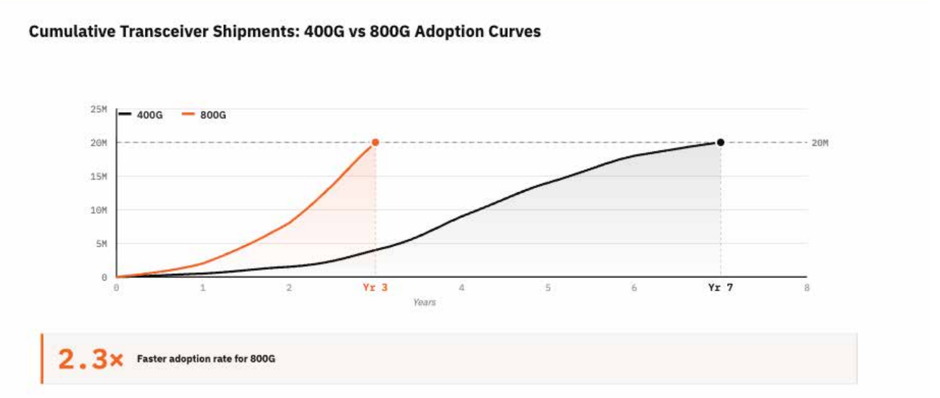
SOAs offer an alternative system architecture, as instead of necessitating each laser to deliver high output power, designers can operate lasers at lower current density and use a shared optical amplifier to provide the required link margin. If a single SOA can simultaneously amplify multiple WDM channels, the energy cost of amplification can be amortised across potentially terabit/s interconnects of data transfer.

While early bulk SOAs were limited by high threshold currents and relatively slow gain recovery times, making them unsuitable for high-speed applications, modern devices based on multiple quantum well (MQW) and quantum dot (QD) active regions can achieve broad gain bandwidth, high saturation output power, low noise figures (around 5-6dB) and fast gain recovery. Crucially for data centre environments, high-power amplifiers have also been demonstrated for uncooled operation. Device design is key for the use of SOAs in data centre links, requiring a careful trade-off between gain, dynamic range and nonlinear distortion, to achieve the performance required for specific applications.

Application 1: High-power sources for parallel fibre

One immediate application of SOAs in DCIs is as part of a high-power optical source feeding parallel fibre architectures. Instead of deploying discrete high-power lasers, a single-mode laser can be integrated with an SOA to create a high-output source, whose power is then passively split across multiple fibres. Experimental results with O-band SOA-integrated sources have shown average relative intensity noise (RIN) levels around –155dB/Hz, suitable for multi-level signalling. Transmission experiments over 1km of single-mode fibre demonstrated robust performance for 100GBaud NRZ-OOK and 100GBaud PAM-4, as well as higher-order formats such as PAM-8 and probabilistically shaped PAM-16.

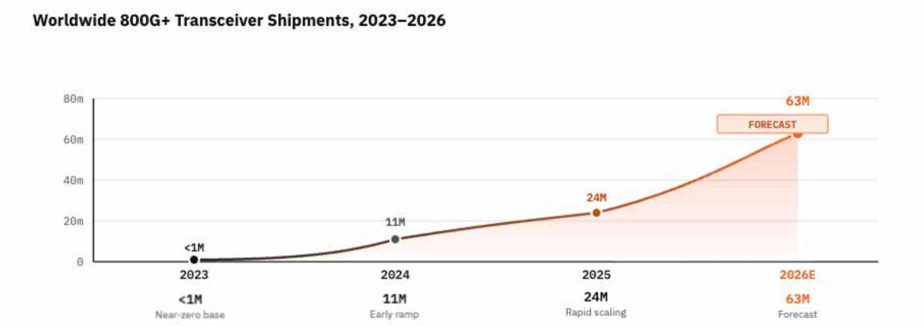
With approximately 100mW output power into fibre, such a source can support multi-terabit aggregate capacities in parallel fibre configurations. For example, 12.8Tbit/s using NRZ-OOK over 128 fibres can be achieved while reaching the HD-FEC threshold, and with a total source power consumption around 4W, this corresponds to device energy efficiencies down to the few >



According to data from market analysts Dell'Oro, 400G took seven years to reach 20m worldwide shipments, whereas 800G hit the same figure in just three years

> "In an era where sustainability and performance are equally critical, comb sources and SOAs are no longer niche"

“A single multi-wavelength comb can supply many coherent carriers simultaneously”



Worldwide 800G+ transceiver shipments grew from less than 1m in 2023 to 24m in 2025, and are projected to reach 63m in 2026, according to combined data from Cignal AI and TrendForce

hundred femtojoules per bit range – highly competitive for intra-DCI applications.

By shifting the burden of high output power from multiple lasers to a single integrated amplifier stage, reliability can be improved while maintaining excellent link performance.

Application 2: Booster amplifiers with comb-based WDM transmitters

As Ethernet standards evolve – such as 800GbE under IEEE 802.3df and the forthcoming 1.6TbE under IEEE P802.3dj – WDM architectures with multiple 100-200G lanes per wavelength are becoming the norm. Here, optical frequency combs can be deployed as the source of multiple optical carriers and the SOA can act as a booster amplifier at the transmitter to offset modulator, multiplexing and switching losses.

In a four-channel demonstration, a single quantum dot SOA amplified 4×128Gbit/s NRZ-OOK signals derived from a quantum dot mode-locked comb source, with spectral spacing of 160GHz between the lines. OSNR remained above 35dB for each modulated line after optical amplification, and all channels achieved BER below the 7% overhead HD-FEC limit. With ~924mW amplifier power consumption for 512Gbit/s aggregate throughput, the booster stage achieved energy consumption of approximately 1.8pJ/bit – again, highly attractive at DCI scale.

When moving this system to a 16-channel case, there is additional signal distortion caused by nonlinearities as the multiple wavelengths pass through the SOA, but we are still able to achieve performance below or close to the HD-FEC level by using more advanced digital signal processing (DSP) techniques such as Volterra nonlinear equalisers. This technique can deliver more than 2Tbit/s aggregate capacity, with the multi-wavelength amplification scenario achieving an amplifier energy efficiency of around 0.36pJ/bit.

Application 3: Pre-amplified receivers

Receiver sensitivity is another critical lever in reducing overall link power. An alternative approach to the standard receiver technologies is to integrate an SOA as a pre-amplifier ahead of a high-speed PIN photodiode. Two potential architectures are possible here for WDM-based interconnects: SOA-filter-PIN, where a single SOA amplifies all WDM channels before demultiplexing; and filter-SOA-PIN, where each channel has a dedicated amplifier.

The first offers superior energy efficiency, as one amplifier is shared, but risks nonlinear distortions in multi-channel operation as for the case of employing a booster amplifier at the WDM transmitter. The second minimises inter-channel effects at the cost of higher component count and power.

In a filter-SOA-PIN configuration, single-lane 108Gbit/s PAM-4 transmission demonstrated that even at modest SOA bias currents (~50mA, ~100mW power consumption), the SOA could provide ~10dB gain and enable BER below FEC thresholds, with amplifier energy efficiency around 1pJ/bit.

This highlights the flexibility of SOA biasing for different link budgets and integration scenarios and the potential to reduce consumption required in transimpedance amplifiers (TIAs) traditionally used after the photodiodes.

Managing nonlinearities with DSP

Unlike EDFAs, SOAs are inherently nonlinear devices. Carrier heating, spectral hole burning and two-photon absorption can give rise to XGM (cross-gain modulation), XPM (cross-phase modulation) and FWM (four-wave mixing). However, in short-reach O-band systems with moderate channel counts, these effects can be contained through careful device design and operating point selection.

Importantly, modern DS P has shifted the balance. High-speed FPGAs and ASICs can implement multi-tap equalisers and nonlinear compensation with manageable power overhead. The combination of quantum well/dot SOA physics – faster gain recovery and higher saturation power – and advanced DSP allows designers to exploit SOA gain while mitigating its drawbacks.

Integration and the road ahead

Perhaps the most compelling argument for SOAs and optical frequency combs in next-generation DCIs is their integrability. Heterogeneous integration of III-V gain material on silicon enables monolithic or hybrid PICs that combine comb sources, modulators, multiplexers and amplifiers on a single platform. This reduces packaging complexity, footprint and cost. As AI clusters scale and data centre architectures evolve toward ever-higher port densities, the ability to integrate comb sources and amplification within compact transceiver modules may be vital additions to ensure capacity and energy efficiency requirements.

Whether implemented via parallel fibres or dense WDM, the physical layer must deliver terabits per second at sub-picojoule energy per bit. The experimental results reviewed here indicate that optical frequency combs and SOAs can meet these requirements across three key roles: high-power multi-wavelength sources, transmitter boosters and receiver pre-amplifiers.

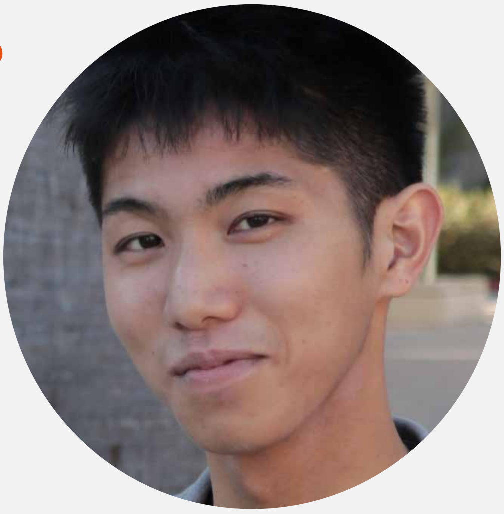
In an era where sustainability and performance are equally critical, comb sources and semiconductor optical amplifiers are no longer niche components.

They are emerging as potentially central building blocks in the quest to build greener, faster and more scalable data centre networks. EO

About the author

Liam Barry was added to the Photonics100 honour roll in 2023. Previously being admitted to the Royal Irish Academy in 2019, Barry holds 10 electro-optics patents and is co-founder of two successful photonics companies, Southern Photonics and Pilot Photonics. He is Professor of Photonic Systems in the School of Electronic Engineering at Dublin City University.

Reprogrammable chips that replace multiple devices with one



Reshaping nonlinear optics on a programmable photonic chip opens paths to new devices, cleaner photon sources and more flexible integrated systems, Dr Ryotatsu Yanagimoto (right) tells **James Wormald**

Electro Optics: Your research looks into the development of single photonic chips that can perform multiple functions. Why does this represent a big advance from the capabilities of existing technologies?

Ryotatsu Yanagimoto: There are things in nonlinear optics that we think of as fixed, but it turns out that many of them are very flexible and dynamic, and that means the actual function can easily change. We're finding we can use nonlinear optics in different ways than we previously thought. But that perspective is quite unusual.

EO: So how did you make this discovery about nonlinear optics being flexible, and that it could be used to solve a problem?

RY: The idea didn't come from a vacuum, it was thanks to a big team effort at Cornell University. Even before I joined the group there was an ongoing project to make a linear programmable photonic device that could control the electric field distribution on a thin-film lithium niobate (TFLN) device. Because of the electro-optic effect, you can modify the linear properties of the device, like the index of refraction, for example. We realised that if you look at the way the device works, then map its mechanism to another physical phenomena in electric field-induced nonlinearity instead of index of refraction, it looked like it might work.

We realised people in biotechnology and biophysics were using photoconductors to control the electric field to basically move around cells. Then we had the idea to use it to control the electric field in the material for programmable photonics. So, it involved a lot of ideas.

EO: Cornell and Stanford were also involved in the research. How was the collaboration set up and how did it work practically?

RY: Both myself and Peter McMahon (corresponding author on the research paper and associate professor at Cornell University) did our PhDs at Stanford, so there was a natural connection there to begin with. Also, NTT Research set up a big inter-institutional collaboration with multiple universities including Cornell and Stanford. We would meet every week to discuss matters surrounding photonics and computation.

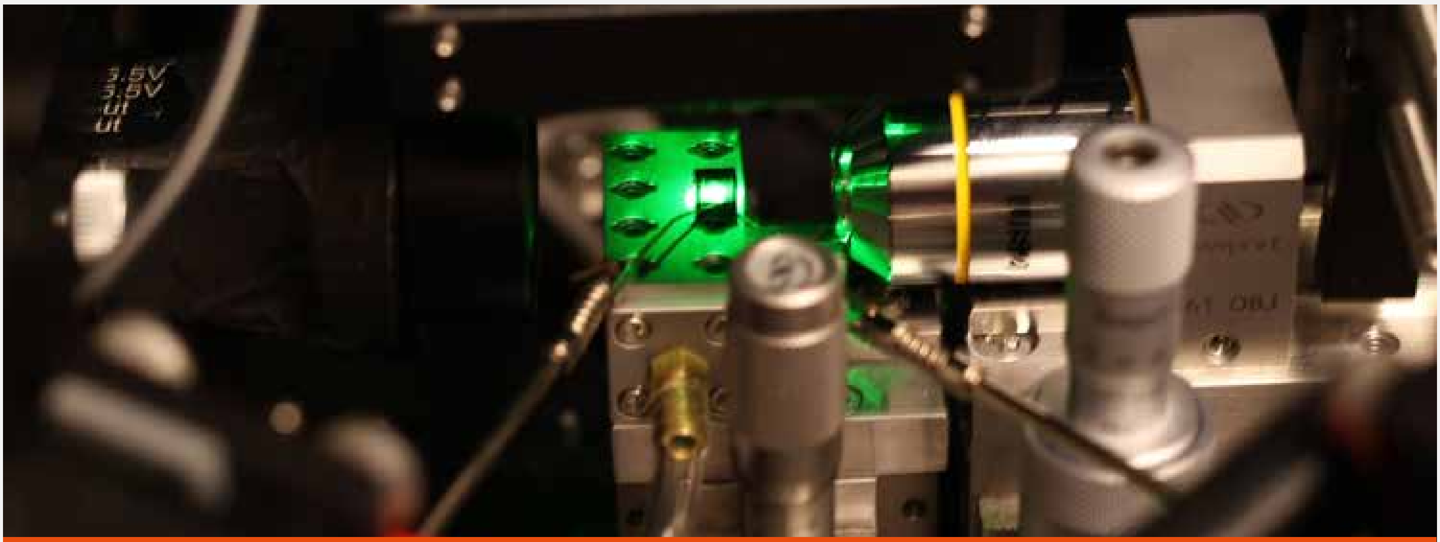
In practice, most of the research was physically completed at Cornell's nano fabrication facility, and NTT sent scientists there to execute the research.

One of the NTT scientists was also affiliated with Stanford, and he brought a lot of knowledge about nonlinear optics, so Stanford really took the role of consultants while Cornell provided the lab space and NTT sent the scientists.

There was also an undergrad at Cornell, Ben Ash, who really pioneered many of the fabrication technologies, so we appreciated collaborating with the talent at Cornell as well.

EO: Are there any trade-offs you had to make regarding the chips' capabilities, and did you identify any performance metrics you wanted to reach before calling it a success?

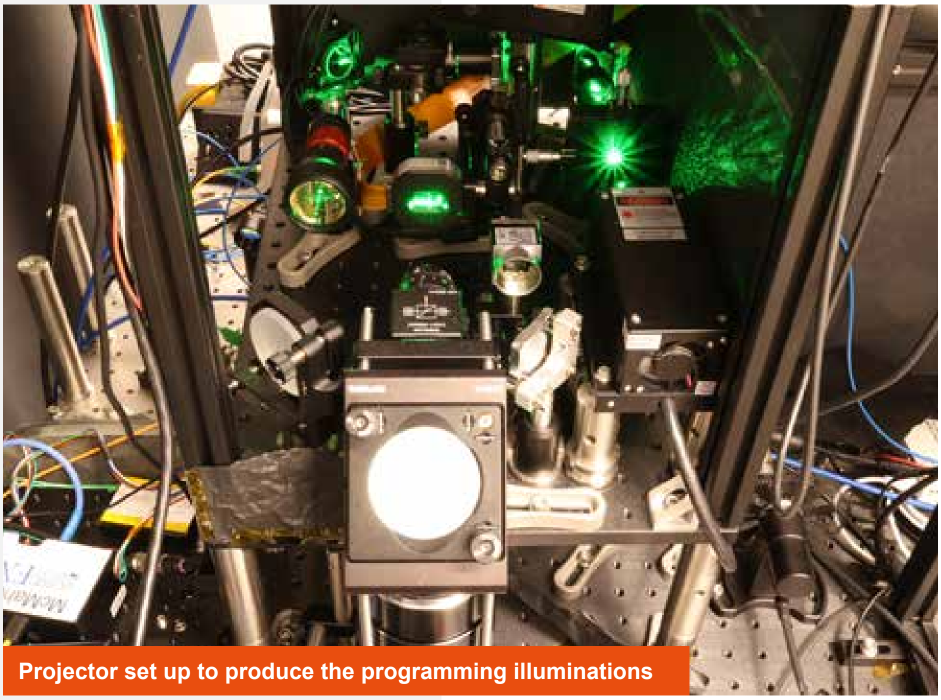
RY: From the beginning, we wanted this to be a proof-of-concept demonstration, so



NTT Research

How a programmable nonlinear photonic waveguide is operated: A combination of the green programming illumination shone on the chip and bias electric field applied through the electrodes programmes the pattern of nonlinearity

NTT Research



Projector set up to produce the programming illuminations

“Many of the things we think of as fixed in nonlinear optics are flexible”

we knew we had to optimise it for flexibility. We needed it to be as programmable as possible, even if it did lose a bit of performance because of it. And by ‘performance’ I mean the conversion efficiency or the nonlinearity of the device. That’s what we care about. The conversion efficiencies were not state-of-the-art, but there should be some middle ground, where you have just the right amount of flexibility without giving up on performance.

EO: So what’s the next step for the research? Will you expand into different areas or look to bring in further collaborators, for example?

RY: We have a lot of follow-up research going on now. One of the threads we have at the moment, for example, is a collaboration with material science people working on intensive material fabrication. Electric-field-induced nonlinearity is a really unconventional way of triggering nonlinearities in a material. It’s only been explored for a few different materials, so we don’t really know the design principles of realising large nonlinearities in this way.

We have a collaboration that plans to test out a lot of materials, then if we see a pattern in which materials show strong nonlinearities, we can understand the physics better. Another route is to fabricate photonic structures. Instead of making it a slab and maximising the flexibility, we can sacrifice flexibility a little, to get better performance.

For example, by making a waveguide that snails around as opposed to a straight one, we can get much more interaction length, and we could also consider integrations with existing photonic technologies with augmented programmability. We are an interdisciplinary group, so collaborating with experts to make photonics platforms is very helpful.

EO: You make it sound very linear, but how likely is it all to go to plan? Are there any challenges you’re expecting to come up against?

RY: It’s really a big uncertainty, actually. One of the most surprising moments during the development was that we originally used a material that’s different from silicon nitride. We used tantalum pentoxide because it is known to have more nonlinearities in conventional use cases. But then when we applied the electric field and saw that the nonlinearity was really, really low, we didn’t understand why. To this day, I still don’t understand. There are a lot of unknowns as this is a new way of doing nonlinear optics, but we believe we have a good chance of finding better performing materials.

Even with silicon nitride’s weak nonlinearity, if you plug in the numbers and make a high-performance (i.e. low-loss) photonic structure and put nonlinearities on top, then estimated performance can be competitive. Making really good silicon photonics hasn’t been our expertise, but it’s an established technique. Because plenty of others know how to make good photonic devices, our path looks less risky.

EO: What will be the quickest or most likely commercial application programmable chips will be used for in the near term?

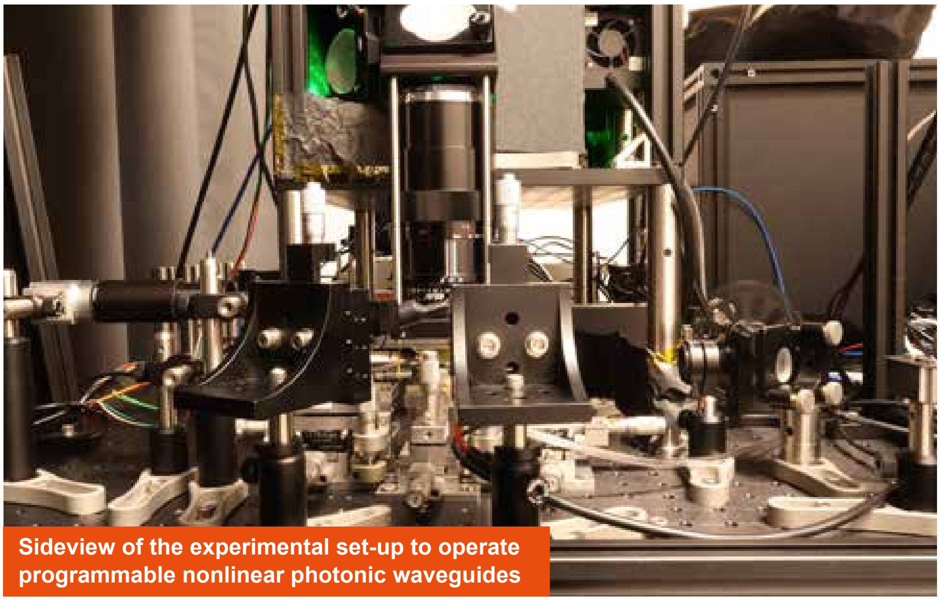
RY: We speculated several application areas in the paper where we thought this could be useful, including quantum frequency converters, entangled light sources and programmable entanglement structures as well as highly tunable integrated light sources. In terms of commercial applications, the closest would be entangled quantum light sources, where the requirement for nonlinearity is actually not that high. What we really want are clean, controllable photon sources. Then on top of that, we can offer programmability in the spatial or spectral domain so you can get desirable entanglement of photons.

Is this going to be useful for quantum networking? The quantum market is still developing, so we’re not sure, but I think that’s where it may appear first. Then, as the device performance develops, further applications such as pulse shapers will come in.

EO: How easy will it be to integrate into existing systems?

RY: It’s actually pretty straightforward. Say you have an existing system that’s composed of waveguides and cladding. If the waveguide comes with cladding on top, we can put a photoconductor directly on top, as long as it’s thick enough. >

NTT Research



Sideview of the experimental set-up to operate programmable nonlinear photonic waveguides

"We're using nonlinear optics in different ways than we originally thought. The function can easily be changed"

> When you put a photoconductor on the top cladding, then it becomes a transparent top electrode. And, as long as the substrate is conductive – which most of the time it is because it's composed of silicon and silicon is conductive enough – then we can augment nonlinearities to any photonic device by applying electric fields through the top and bottom electrodes.

That's a unique feature of the technology. It's relatively easy to integrate with existing systems. We did actually fabricate a one-dimensional channel waveguide using silicon nitride and put nonlinearity on top, and it worked fine. We saw the programmable SHG (second-harmonic generation), for example, and that gave us confidence that we could integrate it with existing technologies.

EO: With any new technology there are questions over reliability and lifetime. Might unknown constraints arise, and how have you tested for them?

RY: We used spectral engineering to test how reliable and how repeatable the process is. We took a waveguide, then an SHG pulse shape was formed in an unconventional shape and used to draw the Cornell logo in the spectrum. Then we repeated that pattern over the course of 10 hours and saw how the output changed.

But it didn't. It basically stayed constant over 10 hours. We also did the experiment over the course of a few months, updating the device every few seconds, and there was no limitation in the number of times we could reprogramme the process.

But it's a fair question. The photoconductor breaching over time is one of the scary things that can happen because we're exciting carriers in the device by shining light on the top. It's a short wavelength light, so it could damage the material. I don't think we've got to the point of being able to say it never happens, but over the course of a few years working on other projects involving nonlinear programmabilities, we can say we've never seen a device that fatigues.

EO: What's your ultimate goal for the research, and what sort of schedule are you looking at?

RY: There are a few areas we're interested in pursuing. One of them is to achieve full integration with existing photonic platforms and to test the most useful applications, which will become more apparent as we demonstrate them over time.

That's what we need to do over the next couple of years to get this past the proof-of-concept stage.

The work has also confirmed that unconventional phenomena (i.e. electric-field-induced nonlinearity) can be useful in nonlinear optics, so, hopefully, it will mean we start to understand those phenomena a little better.

Personally, I'm very interested in where nonlinear optics will go in the next few years. It's been almost 50 years since it was born, and it has been changing constantly since then.

Whenever it seems it has converged to a particular shape, we find something new and it completely changes again.

So, I don't feel like we've quite reached the end of the road yet. And that's what I'm passionate about, continuing to explore the new frontiers of nonlinear optics, thinking of different ways to do it and how they're going to be useful. **EO**

Dr Ryotatsu Yanagimoto is a Research Scientist at NTT Research

NTT Research

Cornell NanoScale Facility (CNF) team: (clockwise from top left) Tatsuhiro Onodera, Research Scientist at NTT Research; Benjamin A Ash, undergraduate student at Cornell; Tianyu Wang, former Postdoctoral Researcher, Cornell, currently Assistant Professor, Boston University; Ryotatsu Yanagimoto, Research Scientist at NTT

A programmable platform for simulating topological matter

Could combining off-the-shelf telecom components with real-time measurement unlock the full potential of quantum matter emulators? **Daniel Duggan** (right) presents his research into feedforward photonics

Topological photonics offers a powerful route to emulate complex quantum systems, but existing platforms often lack flexibility and control. A newly proposed feedforward-enabled architecture aims to overcome these limitations, enabling the tuneable and accessible exploration of topological physics with light.

Condensed matter physics often deals with questions that involve large collections of particles and, as a result, can sound rather abstract: How do the particles work together to create the materials around us? What, for example, makes some materials conduct electricity while others block it entirely?

Researchers from the Technical University of Denmark (DTU) are seeking answers to these questions using a unique approach enabled by photons and feedforward.

For decades, scientists have used theories based on symmetry, local order parameters and band theory to answer these questions. But, in the mid-2000s, researchers discovered something beyond the old picture that would eventually transform how we understand and classify materials: topological insulators.

A topological insulator is a material whose properties are determined not by local details, but by their overall "shape" in a robust, mathematical sense.

Topological insulators behave strangely. For instance, one-dimensional topological insulators can be classified by a number called the winding number, which, essentially, counts how the system "wraps around" a certain mathematical space. If the winding number is zero, the material is ordinary. On the other hand, if it is non-zero, the material can host special states, termed edge states, that can carry energy perfectly, even when the material is disturbed.

This means the surface (or edge if it is just one dimension) of a topological insulator is perfectly conducting, whereas its bulk is insulating. This remarkable stability has made topology one of the most exciting frontiers in physics.

Simple models give surprising behaviour

To understand how such exotic behaviour arises, physicists often use simplified, Lego-like models. One of the most famous is the Su-Schrieffer-Heeger (SSH) model (figure1), which describes a chain of sites connected by alternating links. Dependent on how these links are arranged, the system can switch between a normal insulating phase and a topological phase with robust edge states. Even though this model is extremely simple, it captures the essential ingredients of a topological phase transition.

In the heuristic illustration of the SSH model (figure1), v and w are the coupling strengths of the alternating links. When v > w, the system behaves as a conventional insulator (middle). However, when the relative strengths are reversed and v < w, the system enters a topological phase (bottom).

The bulk sites form paired dimers, while the boundary sites remain uncoupled, preventing hybridisation, i.e. electrons being shared between atoms, giving rise to localised edge states. These edge states are topologically protected and cannot be removed without fundamentally altering the underlying structure of the material (its topology).

While the band structure (figure 2) distinguishes insulating and conducting phases via energies (eigenvalues of the system's Hamiltonian), it does not differentiate between trivial and topological insulators, which share the same symmetries and both exhibit a band gap. This distinction is, instead, captured by the topology of the Hamiltonian in parameter space: the trivial phase has winding number W = 0, whereas the topological phase has W = 1.

At the transition point (v = w), the gap closes, which is a hallmark of a topological phase transition, and the winding number becomes ill-defined. The length of the arrow determines the eigenvalues (energy), while its direction encodes the corresponding eigenstates (wavefunctions). The corresponding probability densities illustrate the bulk–boundary correspondence, with localised edge states appearing only in the topological phase.

Shedding light on topological physics

In recent years, these ideas have been extended from electronic systems to photonic platforms. By designing optical structures such as waveguide arrays and photonic crystals, it has become possible to realise systems in which light exhibits behaviour analogous to electrons in topological materials. This has given rise to the field of topological photonics.

Topological photonics brings two major opportunities: first, it allows the construction of devices with built-in robustness, able to guide light along edges without scattering.

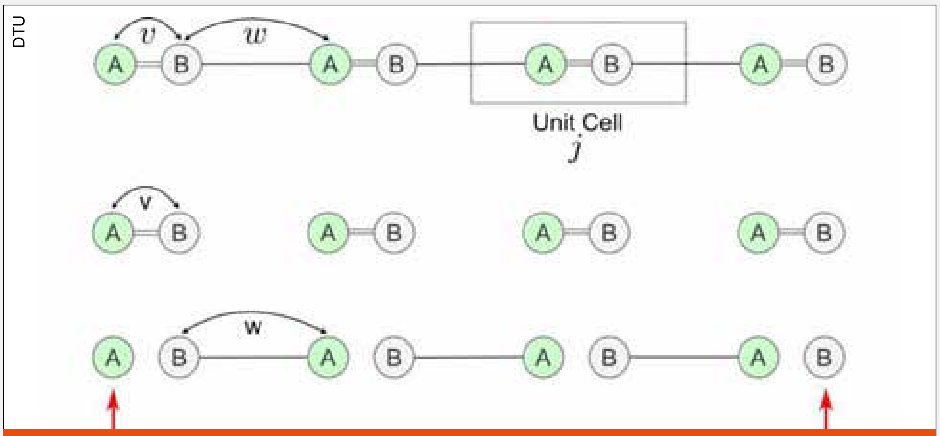


Fig 1: Heuristic illustration of the SSH model

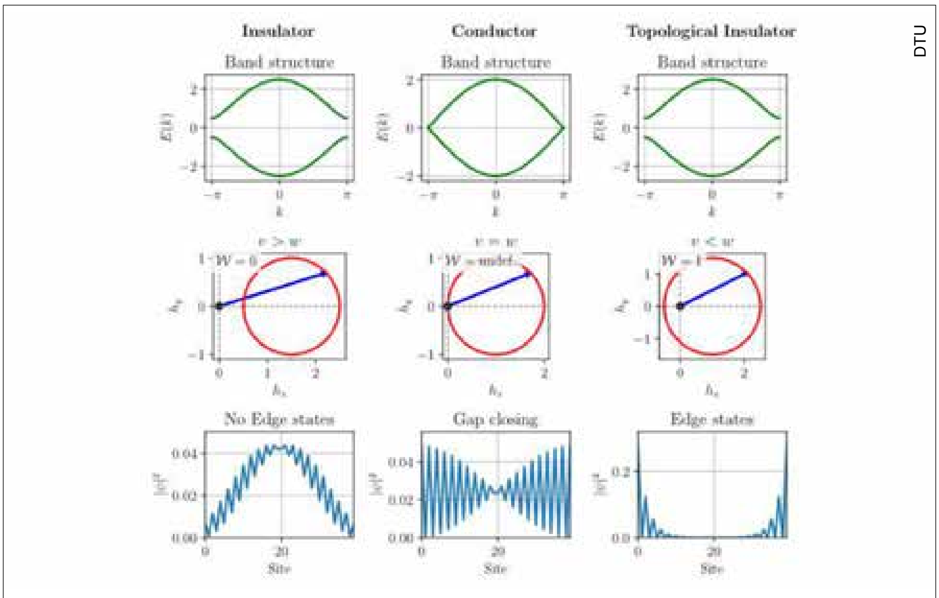


Fig 2: Band structure (top), winding number (middle) and probability densities (bottom) are demonstrated for a (l-r) trivial insulation, a conductor and a topological insulator

"Topological insulators transformed how we understand and classify materials"

Second, it constitutes a promising platform for exploring topological physics, letting researchers emulate models that are difficult or impossible to realise in real materials. Our work focuses on the latter.

Topological photonic systems are attractive candidates for studying topological physics because they offer precise control over coupling strengths, the ability to create complex or higher-dimensional geometries and direct access to spatial and dynamical information. As such, photonic emulators provide a versatile and accessible test-bed for investigating topological phenomena beyond the constraints of solid-state materials. However, current platforms still face a crucial challenge: the coupling form is largely fixed, being completely determined by the optical setup.

Consequently, the same form of coupling repeats over many different modes. The platform thus fails to meet the requirements for studying many key aspects in modern condensed matter physics.

Feedforward leads the way to utopia

To overcome these limitations, we propose a new approach: the Feedforward-Enabled Solid State Emulator (FESS). FESS combines off-the-shelf telecommunications components with real-time measurement and electronic feedforward to create a highly flexible, programmable simulator (figure 3) for topological systems.

In the current form of the FESS system, continuous wave, C-band laser light is injected into a 560m fibre loop. The loop is divided into 24 time slots, like 24 circulating "pulses" of light.

During each round trip, a small fraction of each pulse is measured using heterodyne detection, which gives access to the light's quadratures – essentially its position and momentum in phase space.

All the measured quadrature values are stored in a register and undergo an inner-product calculation with two preprogrammed matrices, Ax and Ap. The resulting two scalars are converted into polar coordinates as modulated displacements, with one scalar driving an intensity modulator and the other a phase modulator.

In this way, Hamiltonian dynamics of the relevant physical system are implemented through measurement-based optical feedforward of the light quadratures.

At the centre of the FESS is an FPGA-based feedforward system. It consists of a 1GHz 12-bit ADC, a 250MHz clock rate FPGA development board and a 250MHz 12-bit DAC.

Ax and Ap together encode the time propagator of the Hamiltonian to be simulated. The full programmability of the FPGA enables imparting arbitrary Hamiltonian dynamics, such as the Haldane or Hofstadter models, into the system without altering the optics. Therefore, different models can be easily implemented by programming the A-matrices appropriately. The system can store 80,000 of these vectors each in a DDR (double data rate) memory, which are then transferred to the calculation fabric via a DMA (direct memory access) engine. The system also contains numerous experimental control signals as well as user-configurable inputs and outputs for precise optical and electronic alignment.

Impact and future opportunities

Successful implementation of the FESS would represent a step towards more flexible and programmable photonic emulators of quantum matter. By combining measurement-based feedforward with a telecommunications-based architecture, it offers a route to engineer and probe topological systems with a level of control that is difficult to achieve in conventional platforms. Our approach could open the door to exploring new topological models, including higher-dimensional structures and structures with dynamically changing Hamiltonians, in a way that is experimentally accessible and highly tunable.

As photonics technology continues to develop, platforms such as FESS may become essential tools for studying quantum matter and building next-generation photonic devices that harness the unique robustness of topological states of light. **EO**

Daniel Duggan is a researcher at the Technical University of Denmark (DTU)

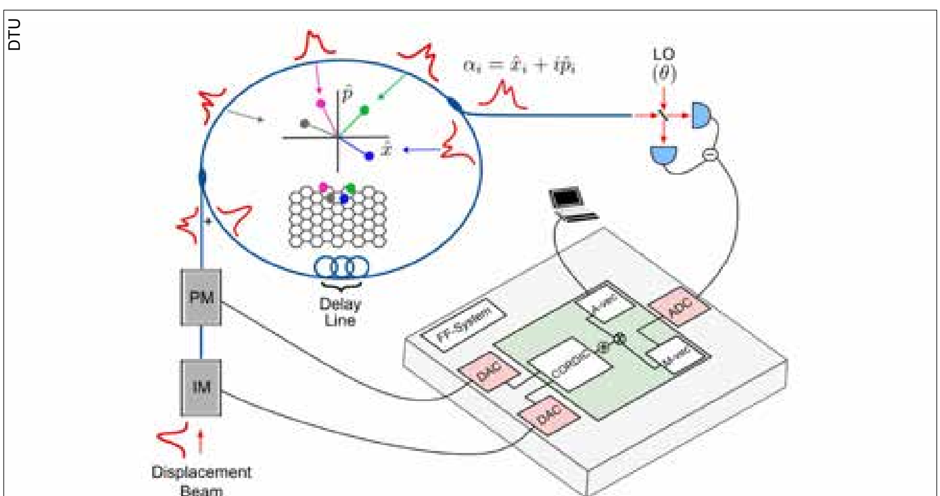


Fig 3: Schematic of the feedforward-enabled solid-state simulator. IM = intensity modulator; PM = phase modulator; LO = local oscillator

'It's not impossible that a SPAD sensor will power your phone camera'

SPAD pioneer Robert Henderson (right) tells **James Wormald** why moving computation under the detector unlocks faster, lower-power imaging, and applications that are well beyond today's cameras

The development of single-photon avalanche diode (SPAD) image sensors in nanometre CMOS technologies was pioneered by Professor Robert Henderson, Chair of Electronic Imaging at the University of Edinburgh, and Scientific Co-Founder of Singular Photonics. It led to the creation of the first time-of-flight sensors in 2013, which are now used in more than a billion smartphones worldwide.

In a discussion with Henderson, he explains that the opportunity is no longer just about SPADs themselves, but about what can now be built underneath them. Thanks to advances in manufacturing, the landscape has changed, making 3D stacked SPAD sensors possible.

"SPAD detectors are now so good, they're close to the quantum limit, and the layer that will now start to make the difference is the layer of electronics that people put beneath them," he says.

This is the key inflection point. The detectors are becoming extraordinarily capable, so the next wave of differentiation will come from the computational layer below – the ability not merely to count photons, but to process their arrival in real time, within the sensor itself.

> "SPADs are close to the quantum limit. The layer that will make the difference is the electronics beneath them"

From photon counting to computational imaging

SPADs are already established in many applications, but Henderson is clear that many current implementations only scratch the surface of what the technology can do.

"There are some beautiful high-resolution image sensors with stacked technology out there," he says. "But they have limited capabilities, often just counting photons. They have not stretched their imagination much further than, 'let's just count; let's just measure the intensity of light'. But there are many, many other things you can do, and that's where I see Singular playing a part."

Once SPAD data is combined with high-speed digital processing under the detector, the sensor can begin to perform much richer forms of computation.

"You can count – indeed, counting will still be an essential part of this," says Henderson. "But you can also time. You can do arithmetic and manipulate the photon information. Then you can do layers of processing, which is about finding features."

Crucially, this is not just about adding more processing for its own sake. It is about rethinking the imaging chain.

"The signal comes in as raw single photons, and we immediately process in digital, and that cuts out all sorts of unnecessary bottlenecks in imaging," says Henderson.

Why processing at the sensor matters

One of the strongest arguments for SPAD-based computational imaging is efficiency. Traditional imaging systems often capture data at the sensor, transfer it elsewhere and only then perform substantial processing. That movement of data costs power, time and design complexity.

"If I keep my image inside the camera and I don't have to send it out over a data link, you'll be saving factors of hundreds in terms of the power to do the computation on the data when it's in situ, rather than pushing it out," says Henderson. "Why does your mobile phone do what it does? It tries to do things in as few components that are as localised to each other as possible, to keep the power as small as possible."

But the implications go beyond power consumption alone. Processing at the sensor can also reduce latency and system overhead. "You can do a lot of that computation in the camera at rates that are much faster," adds Henderson. "If you have to push the data somewhere else, you're going to slow things down as well. You're going to have latency."

This is especially important in applications where speed, compactness and responsiveness matter, from wearable systems to medical devices to future consumer electronics. Henderson believes that SPAD technology should not be seen merely as a better detector, but as the basis of a much broader platform, pointing to the wider ecosystem now emerging around the technology.

"There's not a single major foundry in the world that is not offering SPAD platforms," he says. "And they are increasingly being pushed down in size, which makes it possible to start doing very nice resolution, high-quality images."

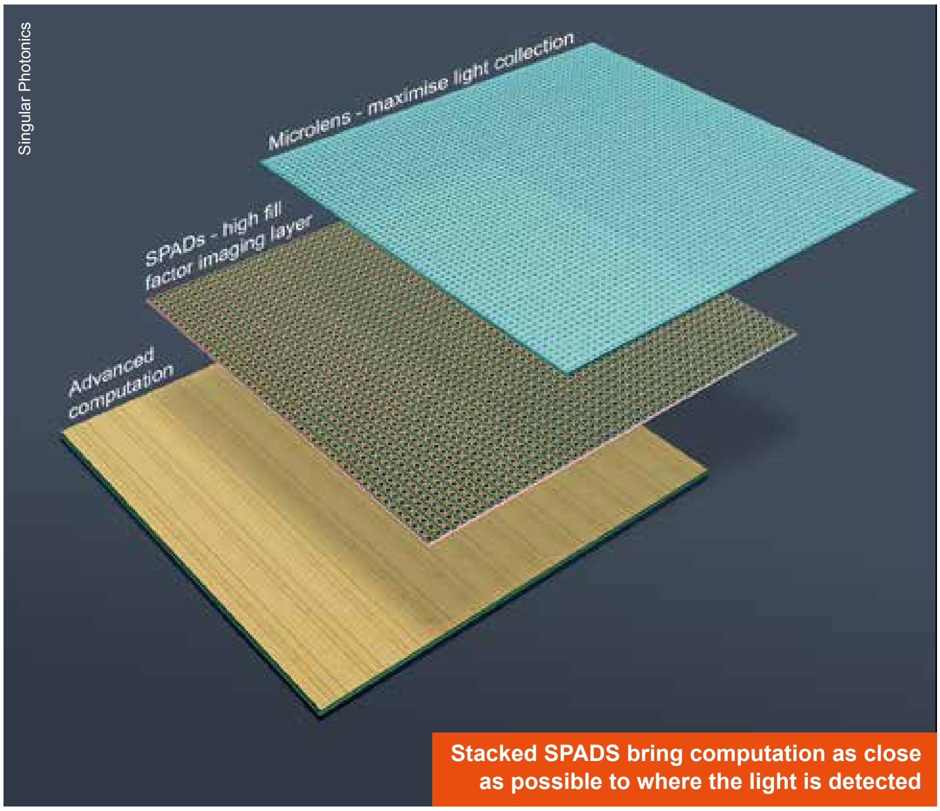
In other words, the foundational infrastructure is arriving. The question is no longer whether SPADs can be used, but how imaginatively they will be used.

The FPGA analogy

Looking to the future, Henderson draws a comparison between the next generation of SPAD sensors and reconfigurable computing platforms such as field-programmable gate arrays (FPGAs) or GPUs.

"I see (a) future (where) we will make the equivalent of an FPGA, but one that can see," says Henderson. "An FPGA is just a reconfigurable computer where you reconnect all your gates and your calculating equipment at runtime. In addition, SPAD systems allow the

"If you have to push the data somewhere else, you're going to slow things down as well. You're going to have latency"



Stacked SPADS bring computation as close as possible to where the light is detected

computation involved in processing images to be conducted in parallel, similar to a GPU, but close to the detector focal plane."

This is a compelling analogy because it suggests a move away from single-purpose sensors toward sensing systems that can be adapted for multiple tasks. "I think the smarter way is to develop a fabric which lets the pattern of processing be defined outside the sensor, offering parallel processing of all the photons that come into your image," he says.

That could allow one sensor architecture to support different use cases including lidar, biomedical sensing, fluorescence lifetime imaging, ultra-fast global shutter imaging and more. However, Henderson acknowledges that not every application will require that flexibility – some markets will still favour highly optimised, application-specific devices.

"If I want a lidar sensor, I will never want that sensor to do anything other than time photons and do that well, at low power," he says. "But there will be many problems where it's not cost-effective to develop a very custom sensor, and you basically want something that's got enough features that can be reprogrammed externally."

The application horizon

In terms of potential application areas that could benefit from on-sensor processing, Henderson highlights three broad areas. First, mainstream consumer imaging, such as the cameras present in every smartphone: "Everybody wants images that are not blurred," he says.

"Everybody wants images which can see in darker and darker scenes."

Second, lidar and depth sensing: "Measuring distance requires you to measure photons on nanosecond timescales." And third, scientific and medical applications: "These markets are perhaps not as big as the others, but there's still plenty of scope for all that computational power to unlock possibilities for those sensors that are just not available today," he adds.

The potential for health-related use cases is especially intriguing, and Henderson points to signatures of light that are too subtle for conventional analogue pixels to capture.

"Some of the cues for health are in signatures of light that are very fast, and only the processing you put under the SPADs can actually capture them," he says.

He also drew a sharp distinction between conventional image sensors and SPAD-based architectures. "Analogue pixels will always be analogue pixels. They measure light as a voltage, and then they send the voltage out," he says.

"There's no extra computation in any of those pixels whatsoever."

That is where SPADs may prove transformative. Not simply because they can detect low levels of light, but because they can make new kinds of sensing practical in small, wearable, real-world systems.

The mobile question

One of the most commercially tantalising possibilities is whether SPADs could eventually reshape smartphone imaging. Henderson is careful not to overstate the case, but he doesn't dismiss it either, noting how widely present SPADs are in phones already, though only in a limited role. "They're in almost every mobile phone, but they're only a very tiny array that measures distance to autofocus your mobile phone," he says.

What has not yet happened is the arrival of SPADs as mainstream image sensors in consumer devices.

"They're not replacing the camera that takes your glorious 10MP image," he says. "So that's not here yet. But it's not impossible that a SPAD sensor will power your mobile phone camera in the future."

A wide open field

For all the enthusiasm around the technology, Henderson is realistic about the competitive environment. Large incumbents are already active in the space, but there is still plenty of room for new entrants that can define the vision of what SPADs should become. "Computational cleverness can be the difference," he says. "There's a key opportunity in this field: stacking and some level of computation. It's just not been done at scale yet – but it will be."

That is perhaps the clearest summary of the opportunity. The manufacturing platform is established and the detectors are ready. "Ultimately, I think sensors always go that way: you push something as close as possible to the source of information," says Henderson.

And that, in essence, is the promise of SPAD technology. Not merely to detect photons more efficiently, but to turn light itself into richer, faster and more actionable information – at the point where it arrives. **EO**

In association with EPIC

Why ultra-compact laser engines are the missing piece of a 15m-unit smart glasses market

Augmented reality has yet to deliver on the promises it has made to consumers. TriLite CEO Mario Spiegl (right) tells EPIC's **Jérémy Pico-Clémente** that its laser beam scanning unit will finally overcome the size and weight barriers that have been holding back wider market adoption

Jérémy Picot-Clémente: What's the background to your appointment as CEO at TriLite Technologies?

Mario Spiegl: After completing a master's in Business and Engineering at the University of Applied Sciences Wiener Neustadt in 2005, I worked as a purchaser for NXP Semiconductors, ending up as Global Sales Manager for Portable Sound Devices.

Then, in 2010, I moved to Knowles Corporation, the global market leader in MEMS microphones, which had acquired NXP's micro-speaker business.

At Knowles, I was promoted to director level as Business Segment Lead for Apple with P&L responsibility.

In 2016, Knowles Electronics' Sound Solutions business was sold to a Chinese private equity fund, and I decided to go with the speaker business because I felt responsible for the team. For the next eight years, I worked for Sound Solutions as Managing Director and General Manager – managing a team of 90 and developing the company's micro-speaker business.

In 2021, Sound Solutions was acquired by Foxconn Interconnect Technology, and I played a central role in the M&A process.

After three years, with the post-merger integration successfully completed, I decided it was the right time to pursue a new challenge. Shortly afterwards, I was contacted by Peter Weigand, then CEO of TriLite, and joined the company in early 2025 as Chief Commercial Officer to lead its global sales and marketing activities. Following Peter's transition into an advisory role in October 2025, I was appointed CEO.

JP-C: How has TriLite developed?

MS: Created in 2011, TriLite Technologies emerged from Austrian research in laser beam scanning, micro-optics and MEMS-based projection systems with the aim of solving a major AR problem – how to make displays small and light enough to fit into normal-looking glasses.

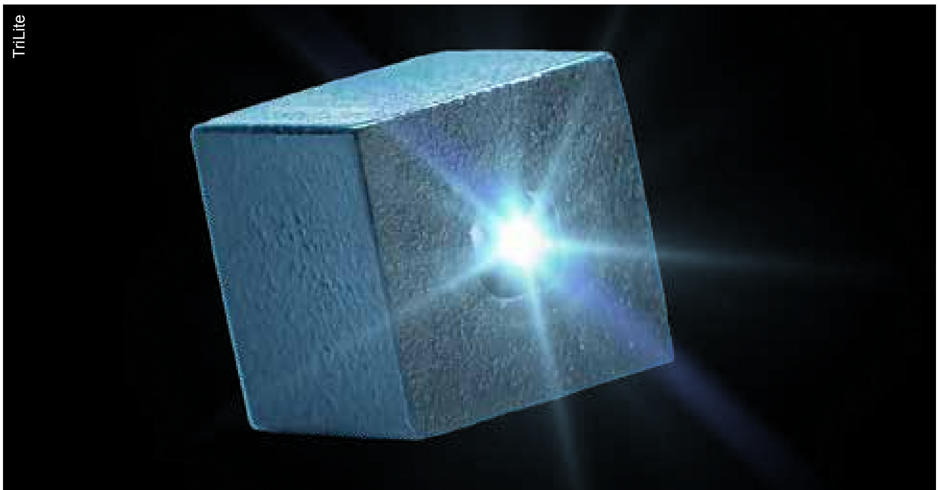
Until 2018, the company focused on R&D of Trixel, its proprietary architecture comprising a micro laser projector and scanning mirror system designed for full-colour, high-resolution AR projection.

In 2019, we entered a scaling phase, increasing visibility and looking for venture capital. We secured funding from strategic investors and public funding organisations and, since 2024, we've moved from pure R&D into industrialisation and production readiness for both consumer AR and automotive applications.

At Display Week 2026, TriLite's ultra-compact laser beam scanning display technology received the Best Prototype

TriLite

Staff at the TriLite headquarters in Vienna, Austria



TriLite's Trixel 3 Cube is an ultra-compact laser beam scanning display engine for consumer augmented reality glasses and automotive projection

"Only laser beam scanning is capable of delivering 50-70° field of view, which gives us a significant advantage"

Award, recognising our continued innovation as we prepare for commercial deployment.

JP-C: What is your main product and how does it stand out from the competition?

MS: For the consumer augmented reality market, our core product is the Trixel 3 Cube. We've reduced its size from 1 to 0.8 cubic cm, while increasing the field of view from 30° to 40°. This product will be available for sampling starting at the end of 2026. Combined with optimised laser waveguides, it should help us secure the design wins we're targeting in the consumer market for AR smart glasses.

What's super important for AR smart glasses is that the light engine is small, bright, delivers good image quality and has very efficient power consumption. We achieve this by firing red, green and blue lasers in nanosecond pulses onto a MEMS mirror. The mirror rotates on two axes at around 20,000Hz and reflects an image in the form of a laser scan pattern rather than traditional raster scanning.

On top of that, we use state-of-the-art semiconductors, MEMS drivers, laser drivers and an image controller.

So, it's a holistic system consisting of hardware, software and semiconductors that only a handful of companies in the world can develop.

JP-C: What were your biggest challenges when you took over at TriLite?

MS: Fundraising is a challenge these days. It requires tremendous effort and preparation. Currently, in Europe, there is some nervousness due to the broader economic situation. We have excellent public funding agencies in Austria and Europe, but venture capital isn't as strong as in some other parts of the world.

That means fundraising has to be approached globally. Our most recent financing round was actually dominated by an investor from Asia. So, fundraising requires diligence, creativity and persistence.

The second challenge has been to define organisational development plans that inspire genuine commitment and engagement from the workforce to carry them forward. I've had to make changes, assign different responsibilities and bring in new people to help transform the company from a technology developer into a product company.

JP-C: What's your perspective on the development of the AR market and TriLite's place within the ecosystem and value chain?

MS: In the past, the AR market overpromised and underdelivered, mainly because some of the enabling technologies such as system-level chips and host platforms simply weren't ready.

Light engines were bulky and as a result, glasses were bulky, heavy and not particularly attractive.

Today, we're in a different situation. The chips are available and AI will help transform AR glasses into genuinely useful devices with features such as navigation, message notifications, instant translation and the ability to take pictures with voice commands instead of pulling out a phone.

Market analysts such as Yole and IDC predict that people may eventually replace traditional prescription glasses with smart glasses. And I'm convinced we will reach the projected 15 million units by 2030.

AR glasses will be mainly differentiated by field of view. Currently, glasses provide around 20-30° field of view.

But to achieve 50-70°, only laser beam scanning will be capable of delivering the required performance, which gives us a significant advantage.

JP-C: How do you see TriLite's future?

MS: Our focus is to continue advancing our display platform while accelerating its path to industrial-scale deployment. That means further improving the performance, miniaturisation and efficiency of our technology while expanding our product portfolio for both consumer AR and automotive applications.

At the same time, we are building the manufacturing ecosystem and strategic partnerships required to bring our technology to high-volume markets.

The recent cooperation with AAC Technologies is an important example of this approach, combining TriLite's innovation with manufacturing scale and global market access.

On the technology side, we continue to invest in future platform generations and new optical architectures that will further improve image quality, brightness and system integration. These innovations will support a wide range of applications, from lightweight AR smart glasses to next-generation automotive projection systems.

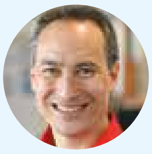
We see strong momentum in both markets. Consumer AR is moving closer to broader adoption, while automotive OEMs increasingly view advanced projection technologies as an important differentiator. Together, these developments position TriLite well for its next phase of growth.

JP-C: What's your advice to the next generation of entrepreneurs?

MS: Firstly, you need to be willing to take responsibility and have a genuine passion for innovation.

Secondly, goals, employees and customers are equally important. If you only care about employees and forget goal orientation, it won't work. You need to challenge and lead the team toward customer satisfaction and results. Too much customer orientation isn't good either. The customer isn't always right – paying late, infringing patents or replacing you with a competitor at the last moment. It's all about balance between these three pillars. **EO**

Mastering photonics is key to Europe's deep tech future



Are European policymakers risking long-term competitiveness by funding deep tech, but neglecting the roots? EPIC Director General **Carlos Lee** looks at why mastering foundational light-based technologies is critical to securing true leadership in the semiconductor, quantum and defence markets

If Europe wants to secure its technological sovereignty and play a relevant role in the global race in technologies such as semiconductors, quantum and defence, it cannot simply invest in end products.

True leadership will come from mastering the deep, foundational technologies that make these advanced systems possible. A critical, yet frequently overlooked, pillar is photonics. A look across today's industrial landscape shows that some of the companies building the future of strategic deep tech did not always originate in those end markets.

They are part of a distinct, highly specialised photonics community that holds the key to Europe's sovereignty.

Technological leadership cannot be bought overnight. Consider the case of ASML and its extreme ultraviolet (EUV) lithography. Simply investing capital into building an EUV machine does not yield immediate results, as seen in China's attempts to develop its own EUV machines. It requires decades of mastering underlying photonics technologies.

Europe's current lithography dominance stands on the shoulders of centuries of continuous photonics innovation. Two of ASML's most critical European suppliers illustrate this perfectly. Zeiss originated as a microscopy company, mastering optics, and Trumpf built its legacy as an industrial laser company.

By nurturing photonics as a core competency, Europe inadvertently built the supply chain that now shapes the entire global semiconductor industry.

Europe is heavily investing in a new generation of critical deep-tech companies such as Black Semiconductor, EPHOS and CamGraPhIC (all members of EPIC). These three have cumulatively raised nearly €500m in public funding and are serving cutting-edge semiconductor and computing markets. However, their roots are not in mainstream silicon; they evolved within the tight-knit photonics community.

> "By nurturing photonics, Europe inadvertently built the supply chain that now shapes the entire global semiconductor industry"

Black Semiconductor integrates graphene onto silicon wafers to enable optical data communication. EPHOS builds glass-based integrated photonic circuits with an architecture specifically designed

>

EPIC

EPIC met European Commissioner Ekaterina Zaharieva – Start-ups, Research and Innovation (fourth from left) as part of its lobbying campaign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As part of its lobbying campaign, EPIC met Henna Virkkunen, European Commission Executive Vice-President, TechSovereignty, Security and Democracy (centre)

"If European policymakers and investors focus their funding exclusively on 'quantum applications', 'defence equipment', or traditional 'semiconductor fabs', they risk undermining long-term competitiveness and innovation"

> for quantum computing, using femtosecond laser writing to inscribe waveguides directly inside glass, creating an integrated photonic circuit. CamGraPhIC develops photonic transceivers, components that convert electrical signals into light signals for ultra-fast telecoms and data centres.

This cross-sector migration is occurring across numerous strategic domains, often driven by the adaptability of photonic technologies to solve problems that electronics alone can no longer address.

The defence sector has taken notice, triggering consolidation. A prime example is the defence giant Thales recently acquiring Exail (also an EPIC member) for a staggering €3.9bn. From ruggedised defence systems to consumer-facing augmented reality displays, photonics companies are consistently pivoting to solve the world's most complex engineering challenges.

The journey from a core photonic technology to a market-dominating product is rarely linear and requires patience. Consider (EPIC member) STMicroelectronics. A decade ago, ST made early moves into optical technologies that did not immediately succeed. But, instead of abandoning the field, it persisted in mastering the core physics of light.

Today, that persistence has made ST a leading optical supplier for Amazon Web Services. It co-developed and now supplies advanced silicon photonics transceivers that enable high-bandwidth connectivity and rapid data throughput inside hyperscale data centres.

What began as a difficult first step in optical technologies has grown into a linchpin of global cloud infrastructure.

The photonics industry needs a distinct identity, separate from semiconductors. It is a misconception to treat photonic integrated circuits (PICs) merely as a subset of the traditional semiconductor industry. The distinction becomes clear when observing where these companies operate, network and showcase their innovations. Key players in the PIC value chain do not primarily identify as semiconductor firms. When asked about their most important industry events, they do not necessarily point to semiconductor exhibitions. Instead, their calendars are anchored around photonics-related events.

For instance, Polariton Technologies, recently acquired by Marvell Technology, could be viewed as a semiconductor company in silicon photonics, yet it remains an active member of EPIC and other photonics associations and has consistently exhibited at photonics events rather than semiconductor ones.

Photonics is an ecosystem with its own identity, research pipelines and supply chains. At the same time, its members have a remarkable ability to pivot and play critical roles in adjacent high-tech markets once those industries reach the point where light-based solutions become essential.

If European policymakers and investors focus their funding exclusively on "quantum applications", "defence equipment", or traditional "semiconductor fabs", they risk undermining long-term competitiveness and innovation.

This would amount to funding the branches while neglecting the roots.

Photonics is the source from which these critical technologies emerge. To build a sovereign Europe capable of leading the next century of technology, Europe must invest in the core foundational technology of photonics and support the unique community that develops it. **EO**

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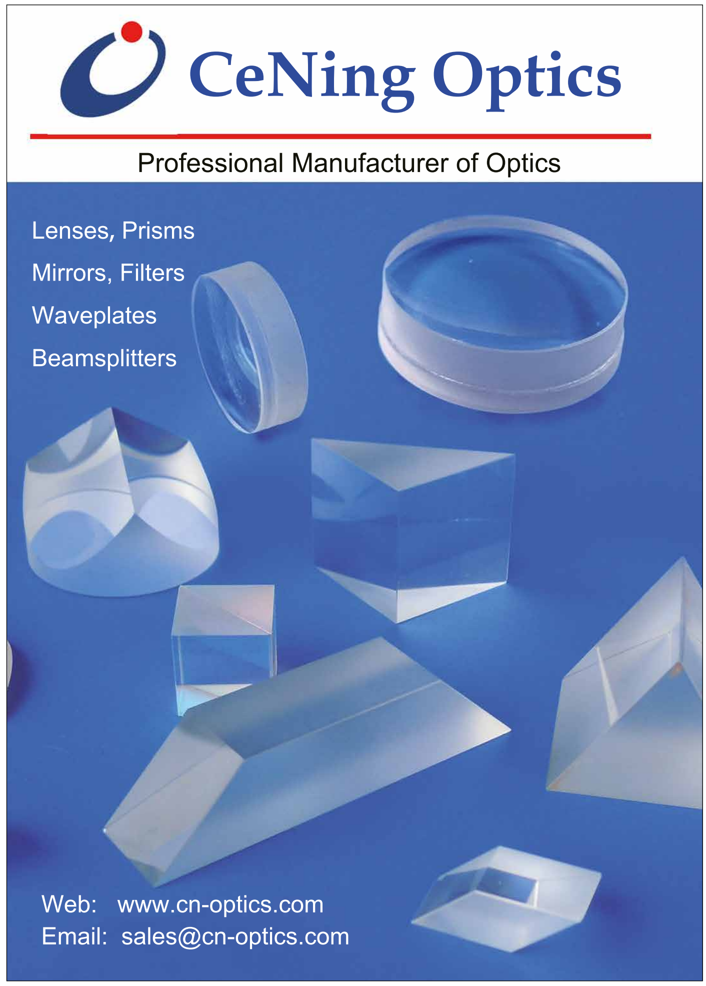

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TOP 10

A curated selection of the most eye-catching photonics products to hit the market in recent weeks

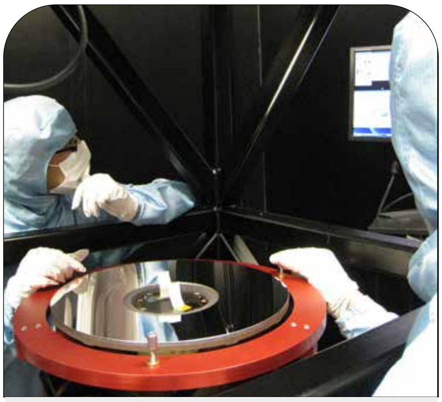
To submit your next new product release for inclusion, please send product details and images to james.wormald@europascience.com

Trioptics
OptiCentric PRO module

The OptiCentric PRO Module from Trioptics is an active alignment system for pancake lenses used in VR headsets. Using dual-head metrology to map lens surfaces in 3D, Trioptics says the device, which can be integrated into existing production lines, achieves sub-micron adjustment with six degrees of freedom and cycle times less than two seconds per measurement.

STMicroelectronics
VL53L9CX dToF lidar

From STMicroelectronics' FlightSense range, VL53L9CX is a direct time-of-flight 3D lidar module that integrates a SPAD array, two VCSELs, metasurface optical elements and processing electronics in a single reflowable package. Features include up to 2,300 zones of resolution, a <5cm to 8.8m range and up to 100Hz frame rate capability.



Optical Surfaces
Optical flats

A range of ultra-high precision optical flats has been released by Optical Surfaces for research establishments and national standards laboratories. Made using stable materials such as Zerodur, Optical Surfaces says the flats are capable of surface accuracies better than $\lambda/20$ peak to valley, and surface roughness less than 10 Angstroms (RMS) on those up to 600mm in diameter, with larger sizes also available up to 1m.

OGP
StarLite S1 video measurement system

StarLite is a semi-automatic, three-axis video measurement system for industrial quality control, which OGP says runs on Measure-X metrology software. It features LED coaxial, substage and SmartRing illumination, as well as the IntelliCentric-S optical system, which combines fixed-lens optics with virtual zoom. The system is designed to support dimensional inspection in shop-floor and quality-control applications.

Find more products also available online at
www.electrooptics.com/products

NoIR
Laser safety eyewear filters

A range of safety filters has been designed specifically by NoIR to offer protection during industrial laser tasks such as cutting, drilling, welding, cleaning and marking across automotive, aerospace and electronics manufacturing. The filters cover multiple wavelengths across IR and near IR, including Nd:YAG 1,064nm, 1,050-1,090nm fibre, diode and CO_2 lasers, and feature optical density levels of OD7+ and OD8+.

Chilas
Atlas 1310 O-band tunable laser

Atlas 1310 is a wavelength-tunable O-band laser from Chilas, aimed at AI infrastructure, data centre interconnects, optical device testing and optical communications. Built on Chilas' hybrid photonic integration platform, the device combines a silicon nitride passive chip with an InP gain chip, and offers 100nm tuning range, intrinsic <10kHz linewidth and ≥13dBm fibre output power.

Leica Geosystems
RTC Series 3D laser scanners

The RTC series of terrestrial 3D laser scanners from Leica Geosystems includes the RTC300, 500 and 700. They are used for surveying in public safety, construction and industrial infrastructure applications and the company says the scanners capture data faster and with 35% more accuracy than the product's nearest competitor. Scan data can be streamed to the cloud in real time, and three performance upgrade tiers are available.

Hübner Photonics
Cobolt 06-HPLD high-power laser diode

Hübner Photonics has added the Cobolt 06-HPLD high-power diode lasers to its Cobolt 06-01 Series. The multimode lasers operate at fixed wavelengths between 405nm and 975nm, delivering up to 1.2W of output power, with direct intensity modulation and multimode fibre pigtailed beam delivery. Aimed at fluorescence microscopy, bioimaging and quantum technology, the lasers use the HTCure packaging technology.

Lasermet
ICS-Magellan laser safety interlock system

ICS-Magellan is an all-in-one laser safety interlock system built on Lasermet's ICS-9 platform. Featuring hardware-only fail-safe interlocks, the system supports up to four independently controlled outputs, achieving Performance Level e under ISO 13849-1. Aimed at multi-laboratory, multi-laser installations, the touchscreen-controlled system is compatible with Lasermet's configurable CALM interface.

Physik Instrumente
H-850.H2IV hexapod

Designed for semiconductor manufacturing, lithography, optical alignment, aerospace testing and synchrotron beamline applications, Physik Instrumente's H-850.H2IV hexapod provides vacuum chambers down to 10^{-6}hPa with sub-micron accuracy, six degrees-of-freedom positioning, up to 80kg load capacity and self-locking holding forces up to 200kg.

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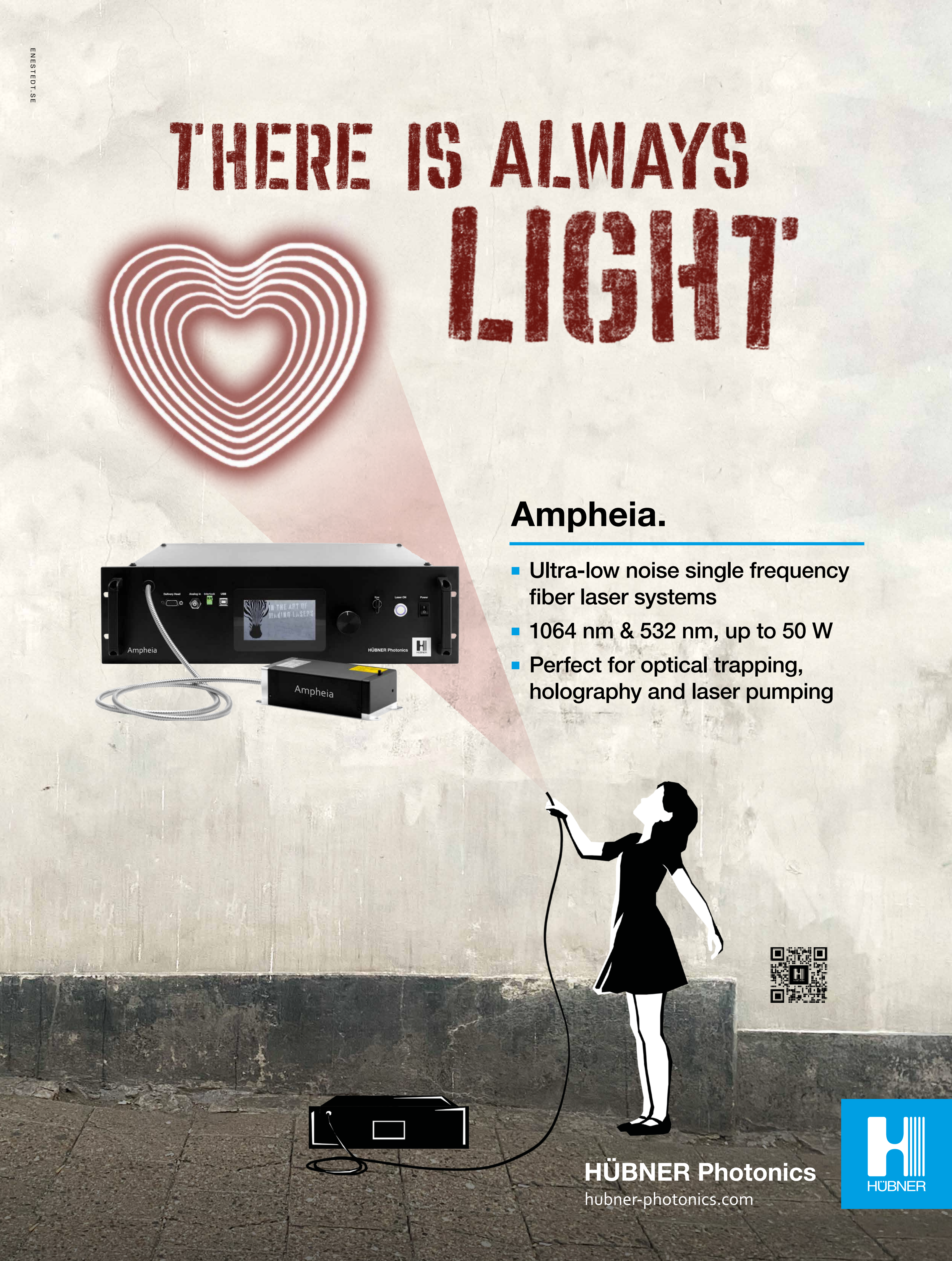
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