2024

SPIE. | optics.org | 20 - 22 August 2024

optics.org OPTICS+ PHOTONICS FOCUS

In this Issue

U.Twente discovers 'new' shapes of photons and novel applications *p3*

Lasers and 2D materials adapted to fight global plastic threat *p.16*

...plus the latest product news

Trumpf and SiMa.ai partner on industrial lasers featuring AI *p.8*

SPIE OPTICS+PHOTONICS 2024

Connecting you with the leading researchers and scientists who contribute to advancements in optical engineering, nanotechnology, quantum science, and organic photonics.

Cover image: Pobytov.

2025 | PLAN TO ATTEND

SPIE. QUANTUM WEST

Colocated with **SPIE Photonics West**

Program: **25–30 January 2025**
Exhibition: **28–29 January 2025**
The Moscone Center
San Francisco, California, USA

Quantum West conferences and business summit will highlight the future of applied quantum technologies and provide a forum that addresses the interests of researchers, engineers, tech companies, investors, and policymakers.

Meet face-to-face with top companies at the free two-day exhibition. These leading companies are providing new capabilities and innovative products to help move your projects forward.

Register today: **www.spie.org/qw**

U.Twente discovers 'new' shapes of photons and novel applications

Including smarter LED lighting, photonic bits of info controlled by quantum circuits, and nano-sensors.

Photo credit: University of Twente.

New shapes of photons promise novel advanced optical technologies.

Researchers from the University of Twente, in the Netherlands, say that they have gained "important insights" into photons, which "behave in an amazingly greater variety than electrons surrounding atoms, while also being much easier to control."

The new insights, described in a paper in Physical Review B promise a range of applications, from smart LED lighting, new photonic bits of information controlled with quantum circuits, to sensitive nano-sensors.

Photonics researchers describe the region of space where a photon is most likely found using "orbitals" – in a similar way that electrons are said to orbit atomic nucleii.

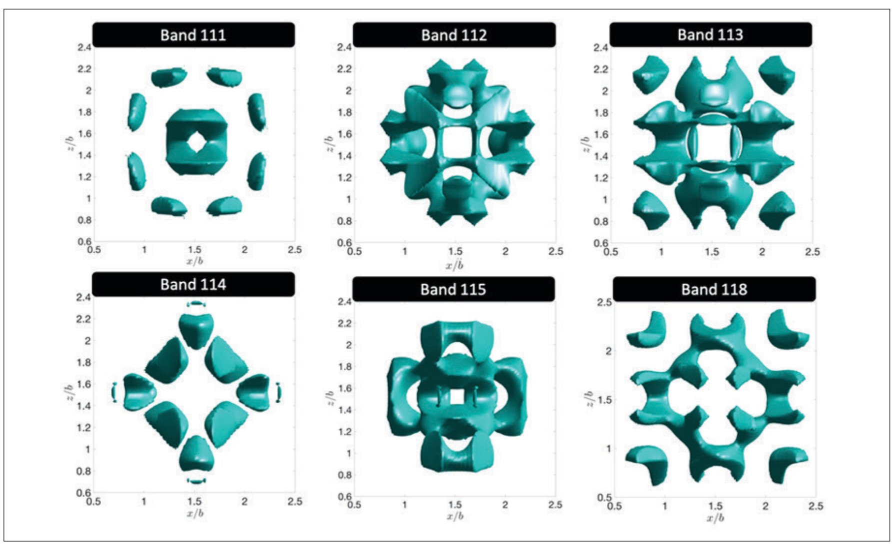
The Twente team studied these photonic orbitals and discovered with careful design of specific materials, they can create and control these orbitals with "a great variety of shapes and symmetries." The results have potential applications in advanced optical technologies and quantum computing.

'Whatever shape'

First author Marek Kozoň explained, "In textbook chemistry, electrons always orbit around the tiny atomic core at the centre of the orbital. So an electron orbital's shape cannot deviate much from a perfect sphere. With photons, the orbitals can have whatever wild shape you design by combining different optical materials in designed spatial arrangements."

The researchers conducted a computational study to understand how photons behave when they are confined in a specific 3D nanostructure consisting of tiny pores: a photonic crystal. These cavities are intentionally designed to have defects, creating a superstructure that isolates the photonic states from the surrounding environment.

Physicists and co-authors Willem L. Vos and Ad Lagendijk commented, "Given the rich toolbox in nanotechnology, it is much easier to design nanostructures with novel photonic orbitals than it is to modify atoms to achieve novel electronic orbitals and chemistry."



Credit: Physical Review B / American Physical Society.

Several photonic orbitals arise within a photonic crystal superlattice.

Advanced optical technologies

Photonic orbitals are important for developing advanced optical technologies, such as efficient lighting, quantum computing, and sensitive photonic sensors. The researchers also studied how these nanostructures enhance the local density of optical states, which is important for applications in cavity quantum electrodynamics.

They found that structures with smaller defects reveal greater enhancement than those with larger defects. This makes them more suitable for integrating quantum dots and creating networks of single photons.

The research work is supported by the NWO-CSER program, project entitled "Understanding the absorption of interfering light for improved solar cell efficiency"; the NWO-JCER program, project "Accurate and Efficient Computation of the Optical Properties of Nanostructures for Improved Photovoltaics"; the NWO-GROOT program, project "Self-Assembled Icosahedral Photonic Quasicrystals with a Band Gap for Visible Light"; the NWO-TTW Perspectief program P15-36 "Free-Form Scattering Optics"; and the MESA+ Institute for Nanotechnology, section Applied Nanophotonics.

https://optics.org/news/15/7/14

Korea's POSTECH develops stretchable, color-tunable photonic devices

Liquid crystal elastomers promise apps in displays, sensing, smart devices, and wearables.

A team at Pohang University of Science and Technology (POSTECH), Korea, led by Prof. Su Seok Choi and Seungmin Nam has developed a novel stretchable photonic device "that can control light wavelengths in all directions".

The work , undertaken in the university's Department of Electrical Engineering, is described in the Nature journal Light: Science & Applications.

Structural colors are produced through the interaction of light with microscopic nanostructures, creating vibrant hues without relying on traditional color mixing methods. Conventional displays and image sensors blend the three primary colors (red, green, and blue), while structural color technology leverages the inherent wavelengths of light, resulting in more vivid and diverse color displays.

The POSTECH announcement says, "This innovative approach is gaining recognition as a promising technology in the nano-optics and photonics industries."

'Free adjustment of pure colors'

Traditional color mixing techniques, which use dyes or luminescent materials, are limited to passive and fixed color representation. In contrast, tunable color technology dynamically controls nanostructures corresponding to specific light wavelengths, allowing for the free adjustment of pure colors.

Previous research has primarily been limited to unidirectional color tuning, typically shifting colors from red to blue. Reversing this shift—from blue to red, which has a longer wavelength—has been a significant challenge.

Current technology only allows adjustments towards shorter wavelengths, making it difficult to achieve diverse color representation in the ideal free wavelength direction. Therefore, a new optical device capable of bidirectional and omnidirectional wavelength adjustment is needed to maximize the utilization of wavelength control technology.

Professor Choi's team addressed these challenges by integrating chiral*1 liquid crystal*2 elastomers (CLCEs) with dielectric elastomer actuators (DEAs). CLCEs are flexible materials capable of structural color changes, while DEAs induce flexible deformation of dielectrics in response to electrical stimuli.

The team optimized the actuator structure to allow both expansion and contraction, combining it with CLCEs, and developed a highly adaptable stretchable device. This device can freely adjust the wavelength position across the visible spectrum, from shorter to longer wavelengths and vice versa.

In their experiments, the researchers demonstrated that their CLCE-based photonic device could control structural colors over a broad range of visible wavelengths (from blue at 450nm to red at 650nm) using electrical stimuli. This represents a significant advancement over previous technologies, which were limited to unidirectional wavelength tuning.

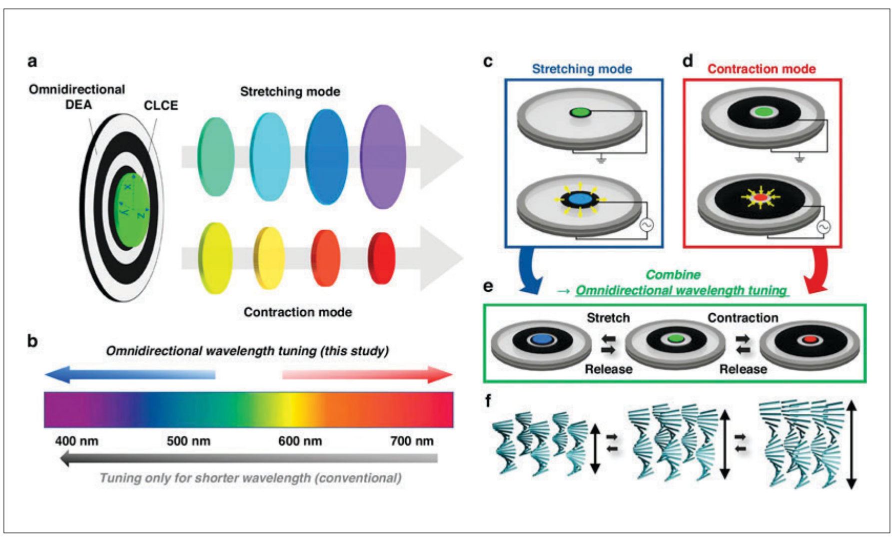
This research not only establishes a foundational technology for advanced photonic devices but also highlights its potential for various industrial applications.

Professor Choi commented, "This technology can be applied in displays, optical sensors, optical camouflage, direct optical analogue encryption, biomimetic sensors, and smart wearable devices, among many other applications involving light, color, and further broadband electromagnetic waves beyond visible band. We aim to expand its application scope through ongoing research.".

The study was supported by the Samsung Research Funding & Incubation Center of Samsung Electronics and the Technology Innovation Program (Flexible Intelligent Variable Information Display) of the Korea Planning & Evaluation Institute of Industrial Technology.

postech.ac.kr/eng

nature.com/articles/s41377-024-01470-w



Source: POSTECH / Nature Light Science & Applications.

Schematic representation of the omnidirectional color wavelength-tunable device. a Schematic representation of the omnidirectional color wavelength-tunable device, consisting of a mechanochromic CLCE and electrically deformable DEA. b Reflection wavelength tuning toward longer and shorter -wavelengths. c-f) Schematic representations showing operations of the DEA in (c) contraction mode, (d) stretching mode, and (e) omnidirectional mode by combining the contraction and stretching modes; (f) helix deformation of the CLCE under each tuning method.

https://optics.org/news/15/6/12

Lithography-free method yields durable antireflective glass

AR performance achieved by nano-structured surface using thermally dewetted silver.

A team of scientists from research center ICFO and photonics materials manufacturer Corning has developed a new method for fabricating anti-reflective (AR) surfaces – achieved through nano-structured surfaces using a lithography-free process.

The method, described in ACS Applied Materials and Interfaces, utilizes thermally dewetted silver as an etching mask to create nanohole structures on glass surfaces, significantly reducing light reflection.

Anti-reflective (AR) surfaces are needed to minimize unwanted reflections, enhancing the efficiency of various optical devices such as laser optics, camera lenses, eyeglasses, touchscreen displays, and solar harvesting systems.

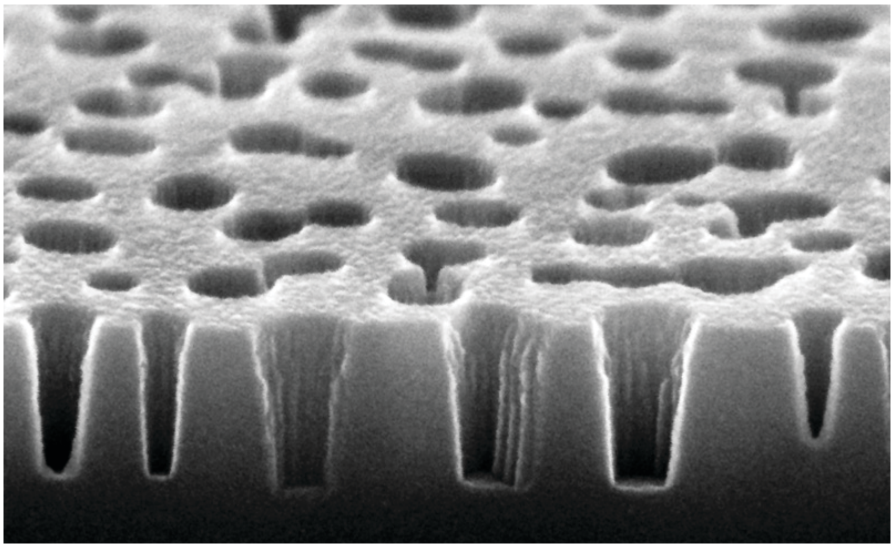


Image: ICFO / Corning.

View of the nanoholes carved on the glass substrate taken with Scanning electron microscope (SEM) showing their depth.

Avoiding complex lithography

In the new study, ICFO researchers Iliyan Karadzhov, Bruno Paulillo, and Juan Rombaut, led by ICREA Professor at ICFO Valerio Pruneri, in collaboration with Corning researchers Karl W. Koch and Prantik Mazumder, describe a simplified method that achieves nanostructured AR surfaces.

This approach uses thermally dewetted thin silver films as etching masks to generate subwavelength nanohole structures on the glass surfaces, characterized by its simplicity and cost-effectiveness by avoiding complex lithography. The results of this study have been recently published in the journal ACS Applied Materials and Interfaces.

The fabrication process involves three main steps. Initially, silver nanoparticles are obtained by quickly thermally annealing an ultra-thin silver film onto a glass substrate. These particles then serve as a base for a secondary etching mask, created by depositing a thin nickel layer over the silver nanoparticles and performing selective chemical wet etching. Finally, this mask is used in a dry etching process to carve nanoholes of varying depths into the glass surface.

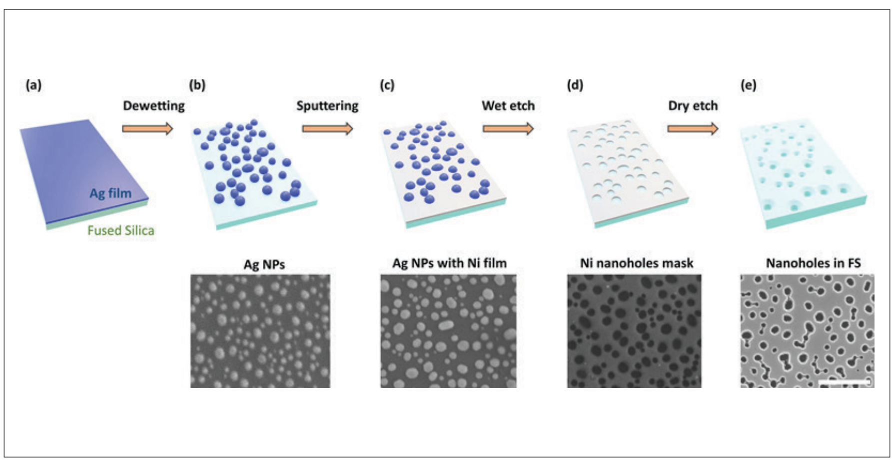
The final arrangement and depth of the nanoholes are determined by the initial thickness of the silver film and the duration of the dry etch process. The team fabricated several samples with varying initial masks and hole depths, testing their performance by measuring both transmittance and reflectance in the visible and near-infrared ranges.

The newly developed AR surfaces exhibited a broadband omnidirectional response that achieves transmittance levels exceeding 99% in both the visible and near-infrared ranges, as well as maintaining high transmittance even at steep angles of incidence (up to 60 degrees).

The samples also demonstrated mechanical robustness and durability in abrasion tests. "One challenge was ensuring that the nanohole structures remained intact during abrasion tests while maintaining high optical performance," said Karl W. Koch, a researcher at Corning Incorporated. "This was overcome by optimizing the nanoholes' geometry and the fabrication process to balance the mechanical and optical properties."

Valerio Pruneri, the leading author of the study and NANO-GLASS project coordinator, concluded, "This new lithography-free method provides new possible solutions to the development of optoelectronic devices that require high transmission and durability."

https://optics.org/news/15/6/10



The main steps of the new ICFO-Corning antireflective surface process.

AI-powered optical detection to thwart counterfeit chips

Researchers from Purdue University have developed a robust optical anticounterfeit method for semiconductor devices.

Credit: DALL-E 3 OpenAI

Artistic rendering of the RAPTOR (Residual, Attention-based Processing of Tapered Optical Response) model against adversarial malicious tampering.

The semiconductor industry has grown into a $500 billion global market over the past 60 years. However, it is grappling with dual challenges: a profound shortage of new chips and a surge of counterfeit chips, introducing substantial risks of malfunction and unwanted surveillance.

In particular, the latter inadvertently gives rise to a $75 billion counterfeit chip market that jeopardizes safety and security across multiple sectors dependent on semiconductor technologies, such as aviation, communications, quantum, artificial intelligence, and personal finance.

Several techniques aimed at affirming semiconductor authenticity have been introduced by previous researchers to detect counterfeit chips, largely leveraging physical security tags baked into the chip functionality or packaging. Central to many of these methods are physical unclonable functions (PUFs), which are unique physical systems that are difficult to replicate either because of economic constraints or inherent physical properties.

Rather than being grounded in cryptographic hardness, PUFs emphasize the economic and technological challenges of duplicating a given system's physical characteristics. Optical PUFs, which capitalize on the distinct optical responses of random media, are especially promising.

Optical PUFs are easy to fabricate and quick to measure, making them ideal for proof-of-concept tampering identification experiments. Nano-scale metallic optical systems have especially been rising in popularity due to their strong scattering response at optical wavelengths, increasing robustness during post-tampering measurements.

However, achieving scalability and maintaining accurate discrimination between adversarial tampering and natural degradation, such as physical aging at higher temperatures, packaging abrasions, and humidity impact, pose significant challenges.

Researchers from Purdue University drew inspiration from the capabilities of deep learning models. As reported in SPIE's Advanced Photonics, they proposed an optical anti-counterfeit detection method for semiconductor devices that is robust under adversarial tampering features such as malicious package abrasions, compromised thermal treatment, and adversarial tearing.

They introduced a novel deep-learning approach dubbed "Residual, Attention-based Processing of Tampered Optical Responses" (RAPTOR), a discriminator that identifies tampering by analyzing gold nanoparticle patterns embedded on chips.

Gold standard

The team first built a 10,000-image dataset of randomly distributed gold nanoparticles by augmenting original images from the dark-field microscope. Next, with nanoparticle pattern pixel regions clustered into local particle patterns, their centers of mass are extracted.

Finally, the Distance matrix PUFs are generated by evaluating all pairwise distances between these nanoparticle patterns. To test anticounterfeit capabilities, tampering behavior in nanoparticle PUFs was simulated, considering both natural changes and malicious adversarial tampering.

RAPTOR, utilizing an attention mechanism, prioritizes nanoparticle correlations across pre-tamper and post-tamper samples before feeding them into a residual, attention-based deep convolutional classifier. RAPTOR demonstrated the highest accuracy, correctly detecting tampering in 97.6 percent of distance matrices under worst-case tampering scenarios, outperforming previous methods (Hausdorff, Procrustes, Average Hausdorff Distance) by 40.6, 37.3, and 6.4 percent, respectively.

This work applied attention mechanisms for deep learning-assisted PUFs authentication. It achieved high verification accuracy under difficult, real-world tampering schema, which opens a

continued on next page

continued from previous page

AI-powered optical detection to thwart counterfeit chips

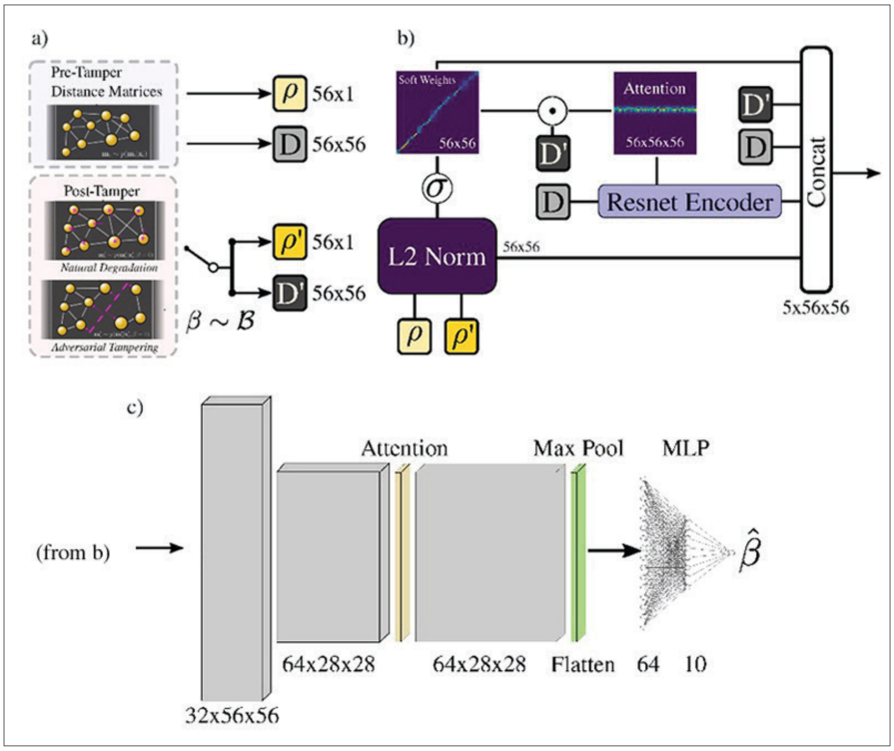
large opportunity for the adoption of deep learning-based anti-counterfeit methods in the semiconductor industry.

Researchers involved in this work are Blake Wilson, Yuheng Chen, Daksh Kumar Singh, Rohan Ojha, Jaxon Pottle, Michael Bezick, Alexandra Boltasseva, Vladimir M. Shalaev, and Alexander V. Kildishev from Purdue University, with the support of U.S. Department of Energy (DOE) Quantum Science Center (QSC), National Science Foundation (NSF), and Purdue's Elmore ECE Emerging Frontiers Center "The Crossroads of Quantum and AI."

purdue.edu

spiedigitallibrary.org

https://optics.org/news/15/7/33



Credit: Wilson et al., doi 10.1117/1.AP6.5.056002

RAPTOR uses an attention mechanism for prioritizing nanoparticle correlations across pre-tamper and post-tamper samples before passing them into a residual, attention-based deep convolutional classifier. a) RAPTOR takes the top 56 nanoparticles in descending order of radii to construct the distance matrices D and D′ and radii ρ and ρ′ from the pre-tamper and post-tamper samples. b) The radii and distance matrices form the query and value embeddings of an attention mechanism. The attention mechanism is then used alongside the raw distance matrices D′ and D, the softweight matrix, and L2 matrix generated from the radii vectors for the classifier. c) The classifier uses GELU activation and attention layers before applying a kernel layer and max pool layer. Then, the output is flattened into a multi-layer perceptron to compute the final classification.

Trumpf and SiMa.ai partner on industrial lasers featuring AI

Firms co-developing smart chips and software to improve welding, cutting and marking.

High-tech and industrial laser systems company Trumpf and SiMa.ai, a developer of machine learning systems-on-chip, have agreed to partner on the development of lasers with artificial intelligence.

The goal is to equip several Trumpf laser systems with AI technology. This will include systems for welding, cutting and marking, as well as powder metal 3D printers.

“AI has high strategic relevance for Trumpf. Our expertise in laser processes and manufacturing helps us to develop smart software for production purposes. SiMa.ai is the ideal partner for this next big step towards intelligent industrial solutions,” said Richard Bannmüller, CTO of Trumpf Laser Technology.

Both companies bring their respective expertise to the collaboration: Trumpf, its laser application expertise, and SiMa.ai, its machine learning system on chip (MLSoC) technology.

‘Increase in performance’

SiMa.ai, headquartered in San Jose, California, with a European office in Stuttgart, Germany, employs aroundy 200 employees. The company says that Edge ML applications that run completely on SiMa.ai’s machine learning system on chip “see a tenfold increase in performance and energy efficiency”. At Trumpf, approximately 90 employees worldwide are working on AI, primarily in product development.

“The rapid acceleration of AI innovation is reshaping how humans can leverage emerging technology,” said Harald Kröger, Head of Sales and President of Automotive Business at SiMa.ai. “Our powerful MLSoC and flexible software alongside Trumpf’s highest level of process understanding is enabling AI solutions that drive the industry forward.”

He added, “In combination with Trumpf’s software, SiMa.ai’s one software-centric platform for all edge AI adjusts to any framework, network, model, sensor, or modality, making it possible to reach the next level of AI-assisted laser technology.”

The joint collaboration intends to accelerate complex material processing. The powerful, compact and energy-efficient AI chips will be integrated directly into the laser systems.

The AI-optimized sensor technology can monitor the quality of the laser welding process in real time and evaluate more than 3,000 images per second. In electric car production, for example, the real-time quality inspection during laser welding with the help of AI is expected to replace separate and complex testing procedures.

Moreover, battery manufacturers will be able to increase the quality of their production in real time and reduce the reject rate which could ultimately lower the price of electric cars for consumers.

https://optics.org/news/15/7/27

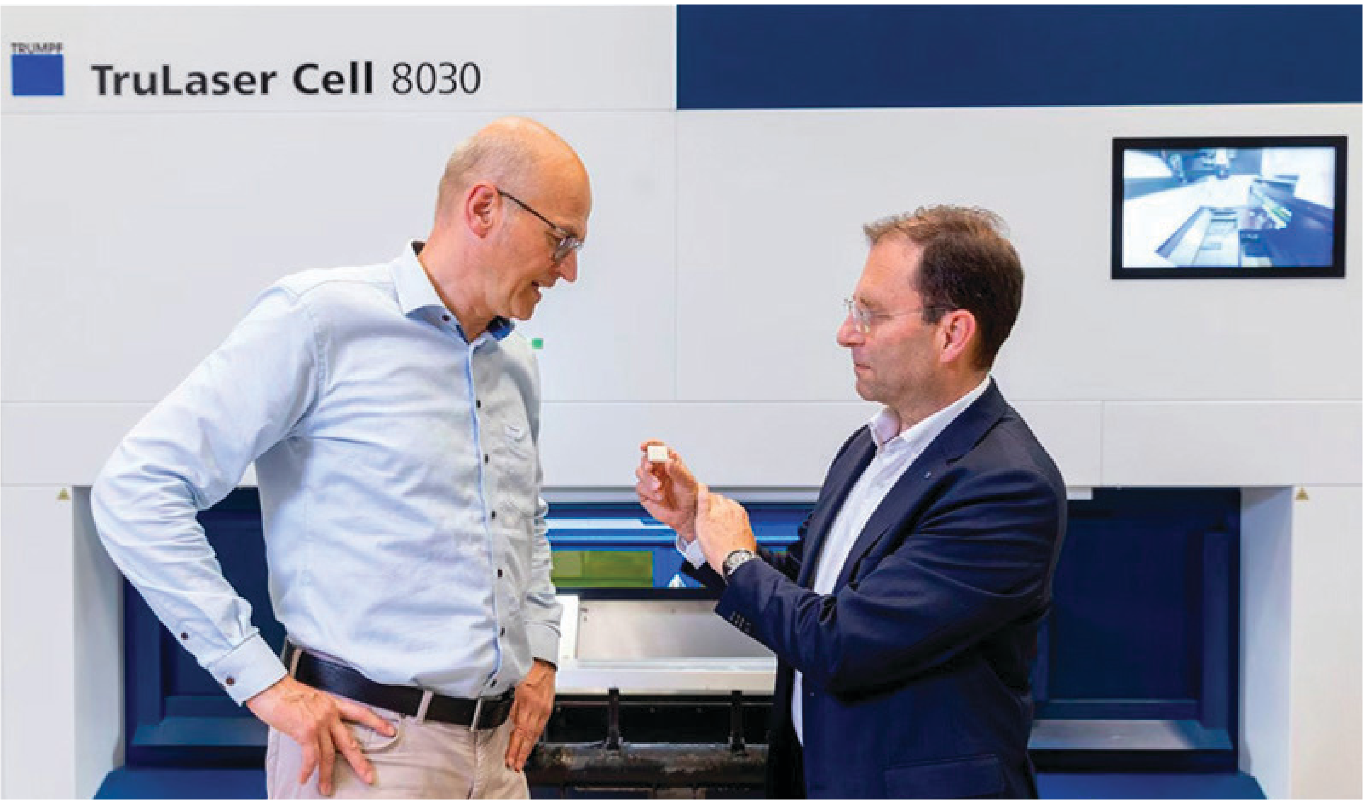


Image: Trumpf.

Richard Bannmüller, CTO Trumpf Laser Technology, and Harald Kröger, Head of Sales and President of Automotive Business at SiMa.ai, discuss the topic of artificial intelligence.

Oxford PV debuts commercial solar module with record 26.9% efficiency

Module measuring 1.6 m2, weighing 25 kg, is specified for residential applications.

Oxford PV, a developer of solar photovoltaic technology, is claiming a new world record in solar module efficiency with its latest product that is specified for residential deployments.

The UK-based firm's new 60-cell residential-size module, produced with Oxford PV's own perovskite-on-silicon tandem solar cells, achieves "an unprecedented efficiency of 26.9%", surpassing the current best silicon modules which typically achieve 25% efficiency with a similarly-specified module area.

The breakthrough double-glass module, with a designated area just over 1.6 m2, weighs under 25 kg and is a suitable specification for residential applications. The efficiency was independently measured and certified by the Fraunhofer CalLab.

Manufacturing in Germany

Oxford PV produces the proprietary high efficiency tandem solar cells at its manufacturing facility in Brandenburg an der Havel, Germany, and uses both in-house and contract services for the module assembly.

David Ward, CEO, commented, "Oxford PV's record-setting module represents a significant advancement for solar power generation. Homeowners along with commercial and utility customers will benefit from upwards of 20% more power with the same footprint. Not only does this save installation costs, it also speeds up the decarbonisation journey and can contribute to the global energy transition in a meaningful way."

Photo: Oxford PV.

Oxford PV produces high-efficiency tandem solar cells at its manufacturing facility in Brandenburg an der Havel, Germany.

Chris Case, CTO, added, "This achievement follows our previous efficiency achievement of 25% on an industrial-size module, which we reported in January 2024. For the past decade, our team has continued to demonstrate the potential for perovskite on silicon tandem solar cells, setting and breaking efficiency records along the way. Now, we are taking the next steps to bring this high-efficiency solar technology into commercial use to support our vision of an all-electric future."

Oxford PV recently exhibited at the Solar technology at Intersolar Europe, in Munich, Germany, (June 19 – 21). The company plans to scale up its manufacturing of tandem solar cells to gigawatt volumes within the next few years, to address the multi-terawatt market needs.

oxfordpv.com

https://optics.org/news/15/6/33

Camera inspired by avian eye improves multispectral imaging

IBS South Korea develops new type of device that specializes in object detection.

A project at South Korea's Institute for Basic Science (IBS) has developed a perovskite-based camera with a design mimicking the eye of a bird.

Published in Science Robotics, the project's findings point towards new camera units capable of detecting and tracking remote objects in dynamic environments.

Bioinspired vision systems have been heavily researched in recent years, motivated by their novel optics architectures and imaging capabilities. Insect eyes have been a particularly fruitful source, as in the 3D camera mimicing a fly's eye developed by UCLA.

The IBS project looked instead at the eyes of birds, where evolution has developed central foveae or depressions in the avian retina, helping to refract incident light and create a magnified image of a target. In birds requiring sharp vision for hunting prey and detecting predators, these foveae are especially deep and pointed.

Bird eyes also have four cone photoreceptors that respond to ultraviolet (UV) as well as visible RGB light. This multispectral tetrachromatic vision enables birds to acquire abundant visual information and effectively detect target objects in a dynamic environment.

"Despite notable advances in artificial vision systems that mimic animal vision, the exceptional object detection and targeting capabilities of avian eyes via foveated and multispectral imaging remain under-explored," commented the IBS team in its paper.

The project modeled avian eyes by first designing an artificial fovea with a Gaussian profile, and fabricated it from a clear elastomer. This was then mounted on a set of four vertically stacked perovskite layers, each responsive to different wavelengths from UV to RGB through careful bandgap control.

Distant objects spotted quickly and accurately

"We developed a new transfer process to vertically stack the photodetectors," commented Jinhing Park from IBS. "By using a perovskite patterning method developed in our previous research, we were able to fabricate the multispectral image sensor that can detect UV and RGB without additional color filters."

The new design is intended to overcome one key limitation of imaging systems, whereby a central target object may be in focus but its surroundings are not. The IBS camera perceives both a distant object through magnification in the foveal region and nearby objects in the peripheral region, distinguishing UV and RGB light in those areas.

By comparing these two fields of vision, the bird-eye-inspired camera can achieve greater motion detection capabilities than a conventional camera, according to the IBS project. In addition, the new camera is more cost-effective and lightweight, distinguish UV and RGB light inherently without added filters or components.

In simulations the new camera demonstrated a confidence score of 0.76 in object recognition, said to be about twice as high as an existing camera system's confidence score of 0.39. The motion detection rate also increased by 3.6 times compared to the existing camera system, indicating significantly enhanced sensitivity to motion.

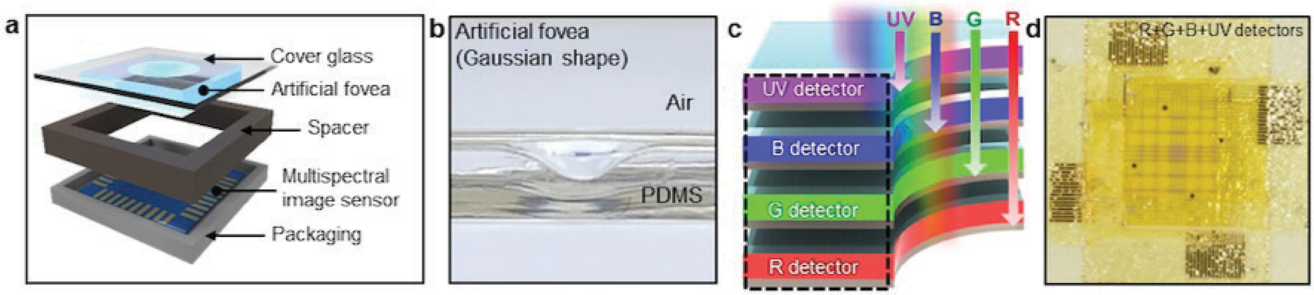
"Birds' eyes have evolved to quickly and accurately detect distant objects while in flight," commented Dae-Hyeong Kim of IBS. "Our camera can be used in areas that need to detect objects clearly, such as robots and autonomous vehicles. The camera has great potential for use on drones operating in environments similar to those in which birds live."

science.org/doi/10.1126/scirobotics.adk6903

ibs.re.kr/eng.do

optics.org/news/13/8/25

https://optics.org/news/15/6/3



Credit: IBS/Science Robotics.

Bird-eye-inspired camera. (a) Schematic view of bird-eye-inspired camera. (b) Artificial fovea. (c) Schematic of a multispectral image sensor. (d) Multispectral image sensor.

UCL laser printing creates sensors inside chicken embryos

Two-photon process creates elastic spring structures responding to physical forces during growth.

A project at University College London (UCL) and the University of Padua has created mechanical force sensors directly in the developing brains and spinal cords of chicken embryos.

Published in Nature Materials, the breakthrough could lead to better understanding and prevention of birth malformations such as spina bifida.

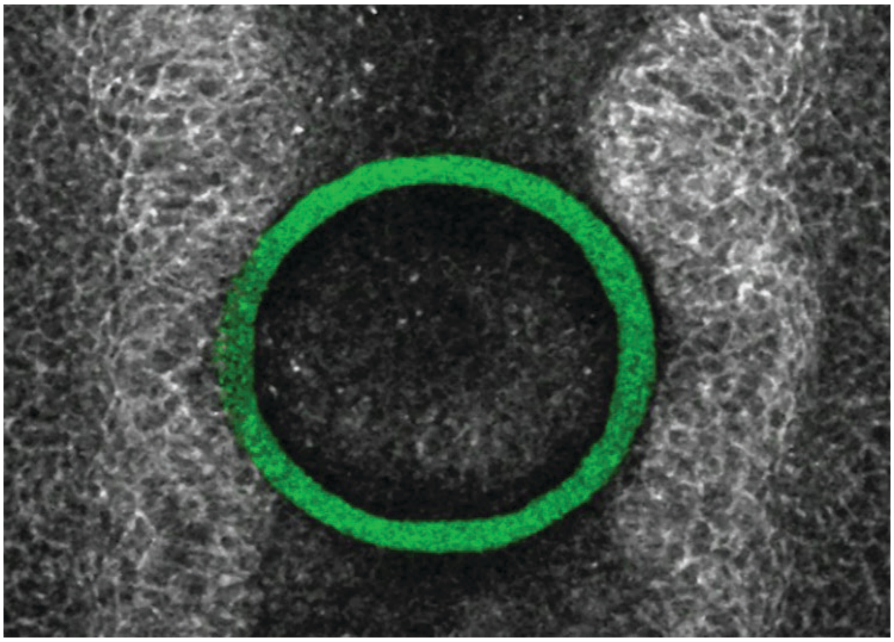
The mechanical forces exerted by the embryo during its development are crucial to the formation of organs and anatomical structures, such as the creation of the neural tube that ultimately gives rise to the central nervous system.

Monitoring these "morphogenetic" forces in living embryos has been challenging, and although methods to quantify mechanical or tensile stresses within individual large cells have been developed, a method to quantify dynamic tissue-level forces has been missing, said the project team.

"The force sensor technology must be compatible with embryo development to provide mechanical read-outs over developmentally relevant time frames of several hours, not seconds to minutes," said the project in its paper. "Sensor size, spatial position and orientation should be precisely controllable through in situ microfabrication at cell-level and tissue-level length scales during live imaging."

The team's answer was to apply laser bioprinting and create elastic shapes within the embryos through two-photon polymerization of a suitable material, expanding on previous research at the University of Padua into intravital 3D (i3D) bioprinting operations.

In 2020 a Padua project demonstrated that an i3D technique could successfully crosslink gelatin constructs to support and organize cell development, and create millimeter-scale structures under the epidermis of the skin in mice.



iMeSH shapes printed between chick embryo neural folds.

Advanced microscopy and novel biomaterials

The new project has built on this work, redeveloping the technique to enable micrometer-scale photo-crosslinking of biocompatible photo-active polymers in a three-dimensional elastic hydrogel, to suit the demanding and fragile environment of a developing embryo and in particular the folds of the developing neural tube.

Two-photon bioprinting was identified as the route to crating the 3D shapes with high positional and structural accuracy directly in chick embryos, crosslinking a i3D polymer introduced into the area of interest. When exposed to a strong laser, the liquid transforms into a spring-like solid attached to the growing spinal cord of the embryos and deformed by the mechanical forces produced by the embryo's cells, said the project.

"We adapted i3D bioprinting to create elastic, compliant shapes anchored to the closing neural folds, such that their deformation serves as a read-out of forces generated by medial apposition of the neural folds. We refer to these structures as intravital mechano-sensory hydrogels (iMeSHs)."

A combination of live imaging and mechanical modelling was used to monitor the deformation of the new structure during embryo development. This let researchers observe the forces involved in normal growth of the neural tube, and also start to investigate whether pharmaceutical intervention might increase positive forces or decrease negative ones enough to help prevent malformations such as spina bifida.

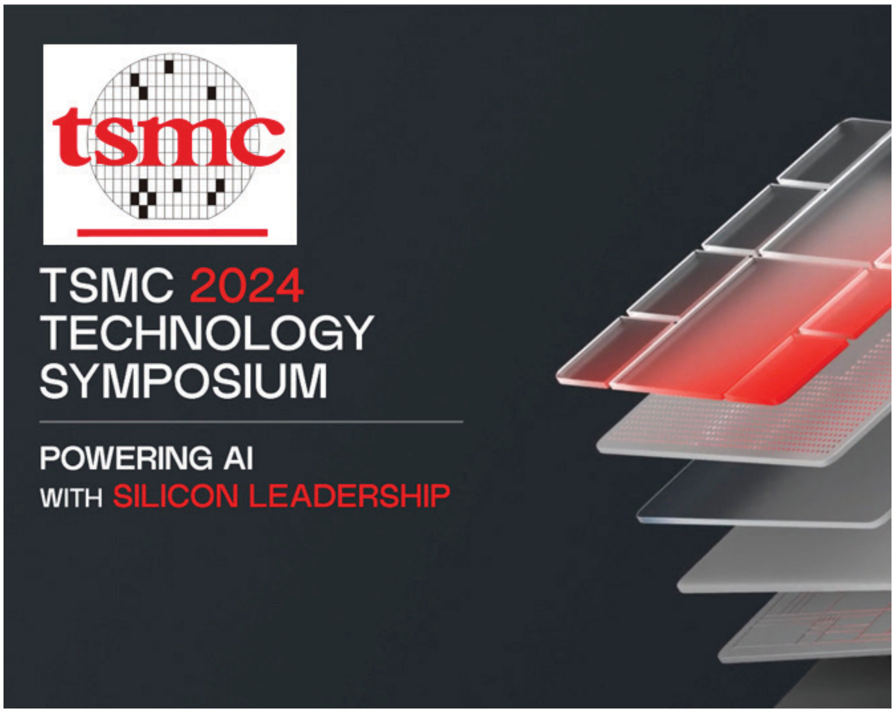
"Thanks to the use of novel biomaterials and advanced microscopy, this study promises a step change in the field of embryonic mechanics and lays the foundation for a unified understanding of development," commented lead author Eirini Maniou. "Our work paves the way for identifying new preventative and therapeutic strategies for central nervous system malformations."

ucl.ac.uk/child-health/research/developmental-biology-and-cancer

unipd.it/en

nature.com/articles/s41563-024-01942-9

https://optics.org/news/15/7/24



The event in Santa Clara kicked off TSMC symposia around the world through the year.

TSMC debuts silicon technologies at its North America Technology Symposium

Chip foundry plans to qualify systems for small form factor pluggables in 2025.

Leading semiconductor foundry TSMC has recently unveiled its newest semiconductor process, advanced packaging, and 3D IC technologies "for powering the next generation of AI innovations with silicon" at the company's 2024 North America Technology Symposium.

The company debuted its TSMC A16 technology, featuring nanosheet transistors with innovative backside power rail solution for production in 2026, bringing greatly improved logic density and performance. It also introduced its System-on-Wafer (TSMC-SoW) technology, an innovative solution to bring revolutionary performance to the wafer level in addressing the future AI requirements for hyperscaler datacenters.

This year marks the thirtieth anniversary of TSMC's North America Technology Symposium, and more than 2,000 people attended, up from less than 100 30 years ago. The event in Santa Clara, California, kicked off TSMC symposia around the world through the year. The meet-up features an "Innovation Zone," designed to highlight the technology achievements of TSMC's emerging start-up customers.

"We are entering an AI-empowered world, where artificial intelligence not only runs in data centers, but PCs, mobile devices, automobiles, and even the Internet of Things," said TSMC CEO Dr. C.C. Wei. "We are offering customers the most comprehensive set of technologies to realize their visions for AI, from the world's most advanced silicon, to the broadest portfolio of advanced packaging and 3D IC platforms, to specialty technologies that integrate the digital world with the real world."

New technologies showcased

- TSMC A16 Technology: With TSMC's N3E technology now in production, and N2 on track for production in the second half of 2025, TSMC debuted A16, the next technology on its roadmap. A16 will combine TSMC's Super Power Rail architecture with its nanosheet transistors for planned production in 2026. It improves logic density and performance by dedicating front-side routing resources to signals, making A16 suitaed to HPC products with complex signal routes and dense power delivery networks.
- TSMC NanoFlex Innovation for Nanosheet Transistors: TSMC's upcoming N2 technology will come with TSMC NanoFlex, the company's development in design-technology co-optimization. TSMC NanoFlex provides designers with flexibility in N2 standard cells, the basic building blocks of chip design, with short cells emphasizing small area and greater power efficiency, and tall cells maximizing performance.
- N4C Technology: Bringing TSMC's technology to a broader range of applications, TSMC announced N4C, an extension of N4P technology with up to 8.5% die cost reduction and low adoption effort, scheduled for volume production in 2025. N4C offers area-efficient foundation IP and design rules that are fully compatible with the N4P, with better yield from die size reduction.
- CoWoS, SoIC, and System-on-Wafer (TSMC-SoW): TSMC's Chip on Wafer on Substrate (CoWoS) has been an enabler for the AI revolution by allowing customers to pack more processor cores and high-

continued on next page

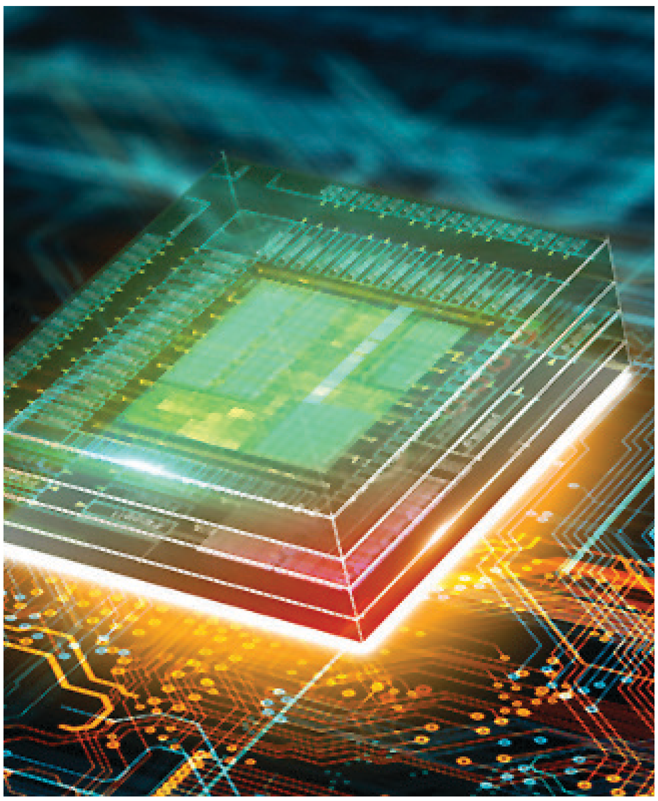
continued from previous page

TSMC debuts silicon technologies at its North America Technology Symposium

bandwidth memory stacks side by side on one interposer. At the same time, TSMC's System on Integrated Chips (SoIC) has established itself as a solution for 3D chip stacking, and customers are increasingly pairing CoWoS with SoIC and other components for the ultimate system-in-package (SiP) integration.

- Silicon Photonics Integration: TSMC is developing its Compact Universal Photonic Engine (COUPE™) technology to support growth in data transmission that comes with the AI boom. COUPE uses SoIC-X chip stacking technology to stack an electrical die on top of a photonic die, offering the lowest impedance at the die-to-die interface and higher energy efficiency than conventional stacking methods.
- Automotive Advanced Packaging: After introducing the N3AE "Auto Early" process in 2023, TSMC is developing InFO-oS and CoWoS-R solutions for applications such as advanced driver assistance systems (ADAS), vehicle control, and vehicle central computers, targeting AEC-Q100 Grade 2 qualification by fourth quarter of 2025.

https://optics.org/news/15/5/6



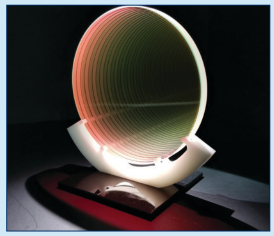
TSMC unveiled its newest semiconductor process, advanced packaging, and 3D IC technologies.

Iridian Spectral Technologies

"More signal, less background – custom wavelength selective optical filters"

Need a way to manage optical signal from background/noise in your optical systems?

Iridian designs and manufactures wavelength selective optical filters from 300nm-15um including narrow single or multi-band/edge/notch filters as single element filters or multi-zone/multispectral filter arrays customized to meet the needs of applications such as remote sensing and detection *(Earth observation, LiDAR, astronomy, NDIR gas detection)*, spectroscopy *(Raman, fluorescence)*, communications *(telecom/datacom/satcom)* and many more.



Contact Details

Iridian Spectral Technologies
2700 Swansea Crescent, Ottawa, ON, Canada K1G6R8
www.iridian.ca
istsales1@idexcorp.com
Tel: +1 (613) 741 4513
LinkedIn
@IridianSpectral

New Imaging Technologies (NIT) Visit us at Booth #443

InGaAs sensors & SWIR cameras

InGaAs sensors & SWIR cameras, from Line-scan to Full HD resolution designed & manufactured by NIT, in France. High Sensitivity, Patented HDR (120dB) or Unique dual-response mode.

New release: SenS 1920 - Full HD SWIR camera, including NIT's high-performance InGaAs sensor, 2MPIX resolution (1920x1080px@8µm pixel pitch). Ultra-low noise of only 25e- & a dynamic range of 64dB ensures exceptional image clarity. Frame Rate: >40Hz full frame and more with sub-windowing. USB3.0 interface. Applications: Intelligence, Surveillance, Reconnaissance (ISR) & Semiconductor, Wafer, Solar Panel Inspection.

Contact Details

New Imaging Technologies (NIT)
1 impasse de la Noisette
91370 Verrières le Buisson – France
info@new-imaging-technologies.com
Tel: +33 1 64 47 88 58

NREL examines degradation mechanisms of perovskite solar cells

Novel hybrid polymer retains high efficiency and improves UV stability outdoors.

Photo by Werner Slocum, NREL.

Senior scientist Tim Silverman checks wiring connections on PACT minimodules at the Outdoor Test Facility at NREL. Photo by Werner Slocum, NREL. Perovskite solar cells (PSCs) are promising next-generation solar photovoltaic (PV) cells with high performance and low production costs compared to silicon. However, one of the primary challenges to widespread adoption of PSCs is stability and durability.

New research funded by the U.S. Department of Energy (DOE) has examined degradation mechanisms of perovskite solar cells (PSCs) under the unfiltered sunlight of the outdoors in comparison with widely used light-emitting diodes.

The research, titled Strong-Bonding Hole-Transport Layers Reduce Ultraviolet Degradation of Perovskite Solar Cells, published in Science, revealed that a special hybrid polymer material synthesized as part of the research and placed within the perovskite cell helps to retain high efficiency and improved ultraviolet stability in outdoor testing.

The team of researchers for the study was led by the University of North Carolina at Chapel Hill with support from the Colorado School of Mines; National Renewable Energy Laboratory; University of California, San Diego; and University of Toledo. A key component of the research was an independent verification of the results by DOE's Perovskite PV Accelerator for Commercializing Technologies (PACT) center.

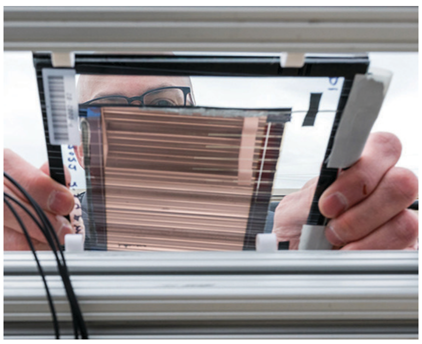


Photo by Werner Slocum, NREL.

Tim Silverman installs a PACT minimodule at the Outdoor Test Facility at NREL.

Perovskite durability

Most PSC testing occurs in the controlled environment of the lab using light-emitting diodes as light sources. To expedite PSC commercialization, real-world outdoor performance testing is needed to understand underlying mechanisms of sunlight and temperature degradation.

Outdoor conditions are different from indoor light-soaking or maximum power point tracking in several ways. Temperature, irradiance, and UV light intensity constantly change outdoors. Perovskite thin-films can decompose when they react with moisture and oxygen or when they spend extended time exposed to light, heat, or applied voltage.

The team investigated the mechanism of UV light-induced degradation in p-i-n structured PSCs with organic hybrid hole transport materials (HTMs) and developed a method to narrow the gap between indoor and outdoor durability.

In perovskite solar cells, an electric field separates and drives the electron-hole pairs generated from sunlight shining on the device out of the absorbing semiconductor material to generate electricity. The transport layer collects and moves electrons or holes from the perovskite layer to the electrodes, allowing for the flow of electricity.

The researchers determined that the weak chemical bonding between the perovskite layer, polymer HTM layer, and transparent conducting oxide (TCO) layer was found to dominate the degradation. This causes PSC degradation under sunlight with strong UV components.

Focusing on the weak chemical bond, researchers demonstrated that a synthesized polymer was found to strengthen the chemical bonding at the perovskite/HTM/TCO region. This hybrid HTM layer was independently verified at the PACT center, and the champion module demonstrated an initial period where the operational efficiency increased a few percent to about 16%. After 29 weeks of outdoor testing, the operational efficiency remained over 16%.

New perovskites

In 2021, the DOE Solar Energy Technologies Office (SETO) established the PACT center to initiate testing and evaluation standards to assess and validate performance and reliability claims for fast-evolving perovskite PV technology.

"We believe this is the first published demonstration of outdoor performance showing perovskite mini modules with an area greater than 15 cm2 that had a measured aperture efficiency above 16 percentafter 29 weeks of outdoor testing," said Laura Schelhas, NREL chemistry researcher, deputy director of PACT, and PACT reliability team lead. "Real-world demonstration is a critical step towards commercialization, and we hope by PACT offering these capabilities researchers and companies can leverage this data toward improved reliability."

https://optics.org/news/15/7/4

Rochester group funded to investigate developing ‘gamma ray laser’

Federal money to allow U.S. and European collaboration to study coherent light sources beyond x-rays.

U.S. Federal funding will support scientists at the University of Rochester and their European collaborators to study the feasibility of coherent light sources beyond x-rays. Since the laser was invented in the 1960s, scientists have worked to increase lasers’ peak power and to design sources to produce coherent light at progressively shorter wavelengths that can improve image resolution and enable probing of quantum nuclear states.

Progress has been made with regard to peak power, most notably with the invention of chirped pulse amplification by Rochester researchers in the 1980s, a breakthrough that garnered the Nobel Prize in Physics in 2018. However, developing lasers that produce very high energy outputs, such as gamma rays, has remained elusive.

To overcome this obstacle, Rochester researchers secured National Science Foundation (NSF) funding in collaboration with colleagues from ELI Beamlines in the Czech Republic to investigate the coherence properties of the radiation emitted when dense bunches of electrons collide with a strong laser field. In doing so, the researchers aim to understand how to produce coherent gamma rays and use these new radiation sources for research and applications to create antimatter, study nuclear processes, and image dense objects or materials, such as scanning shipping containers.

Photo courtesy of ELI Beamlines.

Beam us up: A newly funded research project combines the theoretical expertise of University of Rochester scientists with the theoretical and experimental capabilities of ELI Beamlines in the Czech Republic. Pictured is the compressor for generating the ultrahigh-intensity laser pulses required for the project.

“The ability to make coherent gamma rays would be a scientific revolution in creating new kinds of light sources, similar to how the discovery and development of visible light and x-ray sources changed our fundamental understanding of the atomic world,” said Antonino Di Piazza, a professor of physics at Rochester and a distinguished scientist at the university’s Laboratory for Laser Energetics, who is the lead investigator on the NSF grant.

US–Europe connections

The scientists will use complex theories and high-tech experiments to study how fast-moving electrons interact with the laser to emit high-energy light. They will start by looking at simpler cases, such as how one or two electrons emit light, before moving on to more complicated scenarios with many electrons, to produce coherent gamma rays. Such a result builds on the work of scientists who have created coherent x-rays, including the teams at SLAC National Accelerator Laboratory, European XFEL, and SACLA.

“We are not the first scientists who have tried creating gamma rays in this way,” said Di Piazza. “But we are doing so using a fully quantum theory—quantum electrodynamics—which is an advanced approach to addressing this problem.”

If successful, this project could lead to the creation of a gamma-ray free electron laser, a major goal in the scientific community, according to Di Piazza. “Of course,” he says, “step one is to show that the science is possible before building such a device.”

This work is also expected to contribute to advancing the science case for a potential future NSF OPAL high-power laser user facility at the University of Rochester, another NSF-funded project on which Di Piazza is a co-principal investigator, and which has the potential to be a unique open-access resource for the global scientific community.

NSF OPAL is part of NSF X-lites, an international network of networks studying extreme light in intensity, time, and space formed to address the grand challenge questions defined at the frontiers of laser-matter coherent interactions at the shortest distances, highest intensities, and fastest times.

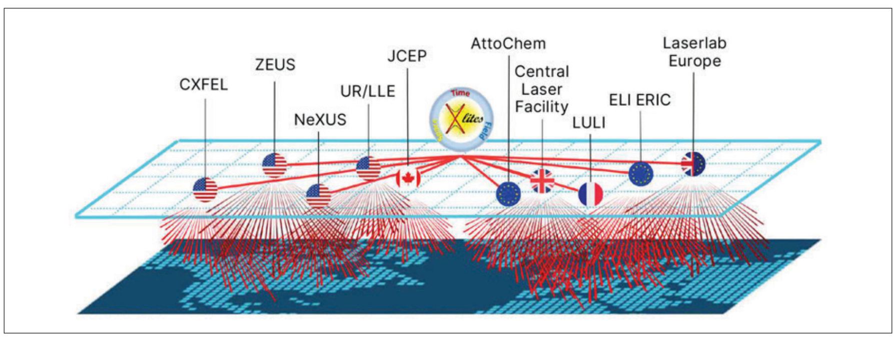


Image courtesy NSF X-Lites.

Net(work) effect: The University of Rochester’s Laboratory for Laser Energetics is part of the NSF X-Lites, a “network of networks” studying extreme light in intensity, time, and space.

rochester.edu

eli-beams.eu

https://optics.org/news/15/7/48

Lasers and 2D materials adapted to fight global plastic threat

Texas Engineers use transition metal dichalcogenide and laser process to tackle problem polymers.

A global research team led by engineers at the University of Texas (UT), Austin, TX, has developed a way to laser-treat the molecules in plastics and other materials to break them down into their smallest parts for future reuse.

The discovery, which involves laying these materials on top of two-dimensional materials called transition metal dichalcogenides and then lighting them up, has the potential to improve the disposal of plastics that are nearly impossible to break down with current technologies.

"By harnessing these reactions, we can explore new pathways for transforming environmental pollutants into valuable, reusable chemicals, contributing to the development of a more sustainable and circular economy," said Yuebing Zheng, professor in the Cockrell School of Engineering's Walker Department of Mechanical Engineering and one of the project leaders. "This discovery has significant implications for addressing environmental challenges and advancing green chemistry."

The research is described in Nature Communications. The team includes researchers from the University of California, Berkeley; Tohoku University in Japan; Lawrence Berkeley National Laboratory; Baylor University; and Pennsylvania State University.

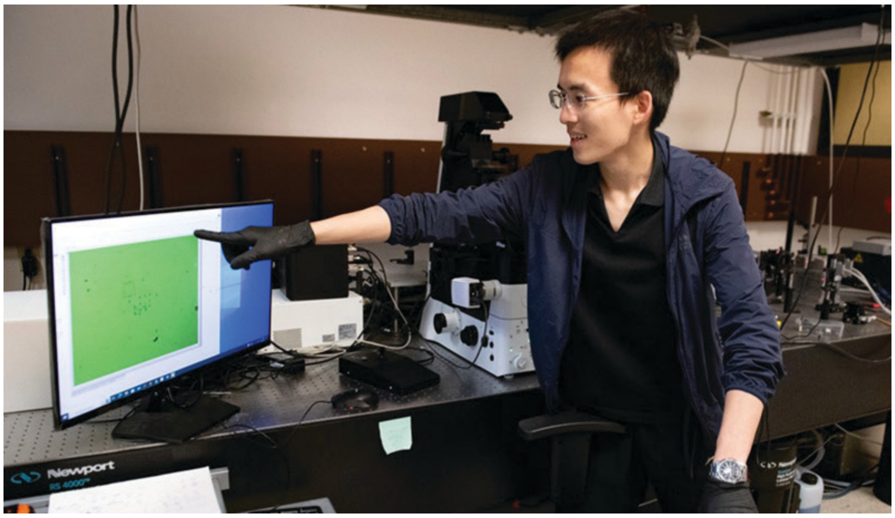


Photo: University of Texas.

Siyuan Huang, a graduate student in Yuebing Zheng's lab demonstrates the technology.

How it works

The researchers used a low-power laser to break the chemical bonding of the plastics and create new chemical bonds that convert the materials into luminescent carbon dots. Experimental work has been undertaken with a 532 nm laser delivering up to 2.5 mW. Other experiments have used a laser transmitting at 660 nm.

Carbon-based nanomaterials are in high demand because of their many capabilities, and these dots could potentially be used as memory storage devices in next-generation computer devices, says the Texas team.

"It's exciting to potentially take plastic that on its own may never break down and turn it into something useful for many different industries," said Jingang Li, a postdoctoral student at University of California, Berkeley who started the research at UT.

The specific reaction is called C-H activation, in which carbon-hydrogen bonds in an organic molecule are selectively broken and transformed into a new bond. In this research, the 2D materials catalyze this reaction that leads to hydrogen molecules morphing into gas. That clears the way for carbon molecules to bond with each other to form the information-storing dots.

Further research and development are needed to optimize the light-driven C-H activation process and scale it up for industrial applications. However, the team says that this study represents "a significant step forward in the quest for sustainable solutions to plastic waste management."

The light-driven C-H activation process demonstrated in this study can be applied to many long-chain organic compounds, including polyethylene and surfactants commonly used in nanomaterials systems.

The research was funded by various institutions, including the U.S. National Institutes of Health, National Science Foundation, Japan Society for the Promotion of Science, the Hirose Foundation and the National Natural Science Foundation of China.

cockrell.utexas.edu

nature.com/articles/s41467-024-49783-z

https://optics.org/news/15/7/20

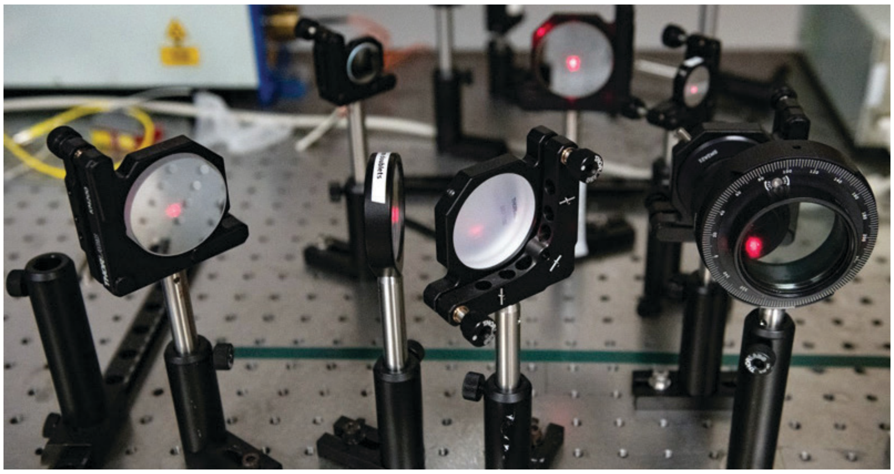


Photo: University of Texas.

A low-power laser breaks the chemical bonding of the plastics and create new chemical bonds.

Optimax launches space optics spin-off with Teledyne collaboration

Starris to offer rapid deployment of space-qualified optical payloads for applications including Earth observation.

Optimax Systems, the precision optics manufacturer based near Rochester, New York, has launched a new company dedicated to applications in space.

Known as "Starris: Optimax Space Systems", the spin-out aims to deliver agile, space-qualified optical payloads that will enable customers to go from idea to launch-ready within one year.

The plan is to integrate space-rated optics, sensors, and electronics into digital cameras and instruments using pre-engineered modular systems, thus reducing risk, cost, and time in delivering custom optical payloads for spaceflight.

Rapid deployment

Starris has already agreed a collaboration with sensor maker Teledyne Space Imaging that will focus on applications including Earth observation, space navigation, in-orbit servicing, in-situ resource ultilization, in-orbit manufacturing, and space domain awareness.

"Starris is powered by three decades of space-qualified innovation and precision optics from parent company Optimax," announced the new company.

"Optics produced by Optimax have enabled a wide variety of space-flight missions, including NASA Mars Rovers and commercial space ventures. Optimax presently has optics on thousands of satellites orbiting the Earth."

In a release announcing the company's impending official launch, at the Small Satellite Conference taking place in Utah next week, Optimax CEO Joe Spilman said:

"The global space economy is at an inflection point, poised to nearly triple by 2025, reaching a staggering $1.8 trillion.

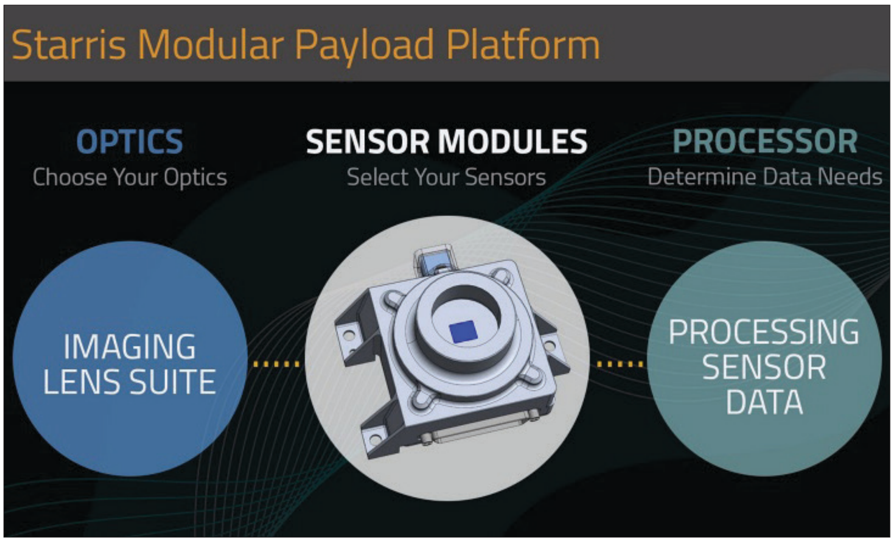


Image: Starris.

Optimax spin-off Starris says that its agile, space-qualified optical payloads will enable customers to enter the space economy quickly and at low risk.

To accelerate our pace, the industry must shift to a new norm where risk, cost, and time to orbit are significantly minimized.

"That is Starris' mission - enable our customers to accelerate their pace. Starris will dramatically reduce the time required to go from concept to orbit with space-qualified optical payloads tailored for aggressive design cycles and rapid deployment."

Eyes on Mars

Starris has determined that many new entrants to commercial space applications have similar mission requirements, so the company has created a pre-tested modular system that integrates lenses, telescopes, sensors, and electronic control systems, with the ability for customization according to individual customer preferences.

Company CTO Kevin Kearney explained: "Legacy space missions take years, if not decades, to get into orbit. We are compressing that multi-year cycle by assembling pre-tested modular payloads that, when launched, will be space-tolerant, reliable, and fulfill customer requirements."

In a separate release outlining the Teledyne collaboration, which aims to develop space cameras for small satellites and lunar ecosystems, Antonino Spatola from the key provider of sensors and focal plane arrays noted:

"Our joint development of these compact camera payloads begins to address a growing and significant market as small-sat applications move beyond LEO [low-Earth orbit] into the cis-lunar economy, which is a stepping stone to Mars habitation."

Spatola's colleague Jack Mills, who heads up sales activity in the Americas region for Teledyne Space Imaging, added: "This partnership recognises the synergies between Optimax and Teledyne Space Imaging, bringing our complementary expertise in optics and sensors together to deliver market-leading products to our global customers."

optimaxsi.com

starris.com

https://optics.org/news/15/8/3

Launching Starris: Optimax Space Systems.

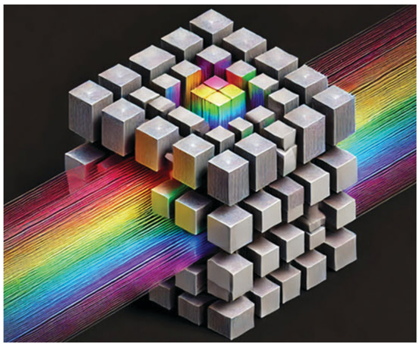
UCLA develops new innovative method for 3D quantitative phase imaging

All-optical multiplane QPI eliminates need for digital phase recovery algorithms.

Quantitative phase imaging (QPI) is a cutting-edge optical technique that reveals variations in optical path length as light moves through biological samples, materials, and other transparent structures.

Unlike traditional imaging methods that rely on staining or labeling, QPI allows researchers to visualize and quantify phase variations by generating high-contrast images that enable noninvasive investigations crucial to fields such as biology, materials science, and engineering.

A recent study reported in Advanced Photonics introduces a cutting-edge approach to 3D QPI using a wavelength-multiplexed diffractive optical processor. The innovative approach, developed by researchers at the University of California, Los Angeles (UCLA), offers an effective solution to a bottleneck posed by traditional 3D QPI methods, which can be time-consuming and computationally intensive.



Credit: Ozcan Lab @ UCLA

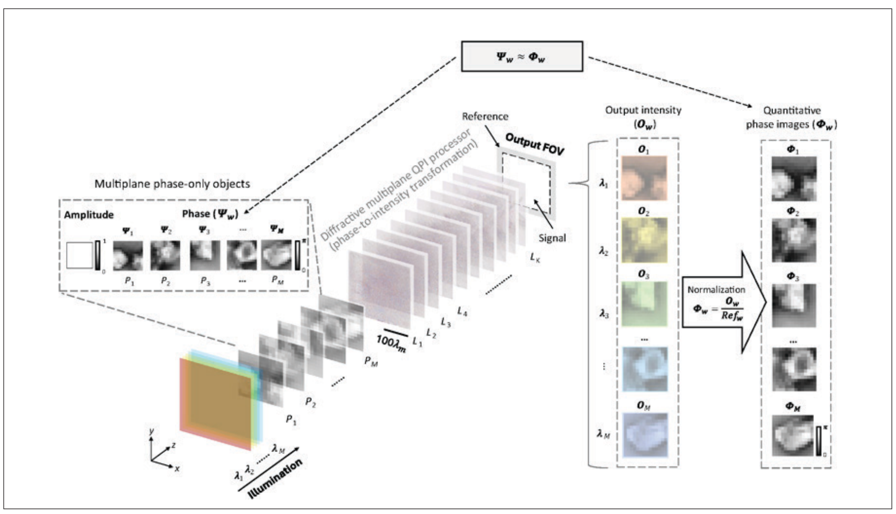
Artistic depiction of a wavelength-multiplexed diffractive optical processor for 3D quantitative phase imaging.

'New approach'

The UCLA team developed a wavelength-multiplexed diffractive optical processor capable of all-optically transforming phase distributions of multiple 2D objects at various axial positions into intensity patterns, each encoded at a unique wavelength channel. The design allows for the capture of quantitative phase images of input objects located at different axial planes using an intensity-only image sensor, eliminating the need for digital phase recovery algorithms.

"We are excited about the potential of this new approach for biomedical imaging and sensing," said Aydogan Ozcan, lead researcher and Chancellor's Professor at UCLA. "Our wavelength-multiplexed diffractive optical processor offers a novel solution for high-resolution, label-free imaging of transparent specimens, which could greatly benefit biomedical microscopy, sensing, and diagnostics applications," he added.

The innovative multiplane QPI design incorporates wavelength multiplexing and passive diffractive optical elements that are collectively optimized using deep learning. By performing phase-to-intensity transformations that are spectrally multiplexed, this design enables rapid quantitative phase imaging of specimens across multiple axial planes. This system's compactness and all-optical phase recovery capability make it a competitive analog alternative to traditional digital QPI methods.



Credit: C. Shen et al., doi 10.1117/1.AP.6.5.056003

UCLA researchers report a new method for quantitative phase imaging of a 3D phase-only object using a wavelength-multiplexed diffractive optical processor. Utilizing multiple spatially engineered diffractive layers trained through deep learning, this diffractive processor can optically transform the phase distributions of multiple 2D objects at various axial positions into intensity patterns, each encoded at a unique wavelength channel. These wavelength-multiplexed patterns are projected onto a single field-of-view (FOV) at the output plane of the diffractive processor, enabling the capture of quantitative phase distributions of input objects located at different axial planes using an intensity-only image sensor – eliminating the need for digital phase recovery algorithms.

Scalable, adaptable

A proof-of-concept experiment validated the approach, showcasing successful imaging of distinct phase objects at different axial positions in the terahertz spectrum. The scalable nature of the design also allows adaptation to different parts of the electromagnetic spectrum, including the visible and IR bands, using appropriate nano-fabrication methods, paving the way for new phase imaging solutions integrated with focal plane arrays or image sensor arrays for efficient on-chip imaging and sensing devices.

This research has significant implications for various fields, including biomedical imaging, sensing, materials science, and environmental analysis. By providing a faster, more efficient method for 3D QPI, this technology can enhance the diagnosis and study of diseases, the characterization of materials, and the monitoring of environmental samples, among other applications.

This article was first published on **spie.org**.

https://optics.org/news/15/8/4

2025 | CALL FOR PAPERS
SPIE. DEFENSE+ COMMERCIAL SENSING
13–17 April 2025
Gaylord Palms Resort & Convention Center
Orlando, Florida, USA
FEATURING MISSION-CRITICAL SENSING INNOVATION BEING DEVELOPED AND DEPLOYED WITHIN INDUSTRIAL AND GOVERNMENT SECTORS
Share your defense, commercial, and dual-use technology research with other researchers, engineers, and program leaders. Submit an abstract and become part of the most important conference on detector and sensor systems, infrared, laser systems, spectral imaging, radar, lidar, autonomous systems, and other advances across the security and defense industry.
Start working on your abstract now and plan to join us as we bring together the best minds in defense and commercial sensing.
Abstracts due: 2 October 2024
SUBMIT YOUR ABSTRACT TODAY
www.spie.org/dcs