Photonic integrated circuit (small metallic rectangle in the image)

Stanford University

PHOTONIC INTEGRATED CIRCUITS

Energy-Efficient Bitcoin Mining with Light

Experiment demonstrates the potential of a laser-based cryptographic scheme

As bitcoin and other cryptocurrencies grow in popularity, their processing eats up an ever-greater fraction of the world's electricity supply. But researchers have now shown it might be possible to slash that energy cost while maintaining network security by using integrated photonic circuits (Optica, doi: 10.1364/OPTICA.476173).

The researchers' scheme still involves a proof-of-work blockchain—one that relies on computational effort to certify blocks. But rather than using bitcoin's SHA-256 hash function, the scheme instead employs a function optimized for energy-efficient analog photonic chips.

To demonstrate their method's potential, the researchers ran computer simulations and experimentally tested an interferometer network capable of processing matrices with as many as four rows and columns. They found that the likelihood of errors shot up dramatically as the number of inputs and outputs increased, but they also showed that using four copies of the circuit can reduce the rate of errors in hashing by up to four orders of magnitude.

Despite their scheme's susceptibility to errors, the researchers conclude that it could make photonic blockchains a reality—reducing energy consumption by up to a factor of seven. They add that the technology might enable other applications, such as being used to train a photonic neural network. —*Edwin Cartlidge*

optica-opn.org/news/0723-bitcoin

OPTOELECTRONICS

Fiber-Based Smart Fabrics

Next-generation textiles containing photodetectors and LEDs can be produced inexpensively at any shape or size

An international team of researchers has developed an integrated textile electronic system with fiber-based electronic components, including photodetectors and quantum dot LEDs (Sci. Adv., doi: 10.1126/sciadv.adf4049). The system, which represents a shift from 2D devices to 1D fiber devices, can be adapted to a wide range of optoelectronic applications in sectors like automotive, electronics, fashion and construction.

Next-generation smart textile that incorporates LEDs, sensors and energy-harvesting and storage devices.
S. Lee

For the study, the team used fiber-based functional devices that can be directly woven into a textile. Devices were fabricated into a fiber form using techniques such as vacuum deposition or solution processing, then encapsulated with protective layers to mitigate mechanical damage during weaving.

First, the researchers developed the key fiber components—a photodetector as input device, supercapacitor as energy-storage tool, field-effect transistor as electronic driver and quantum dot LED as output device—and optimized their performance.

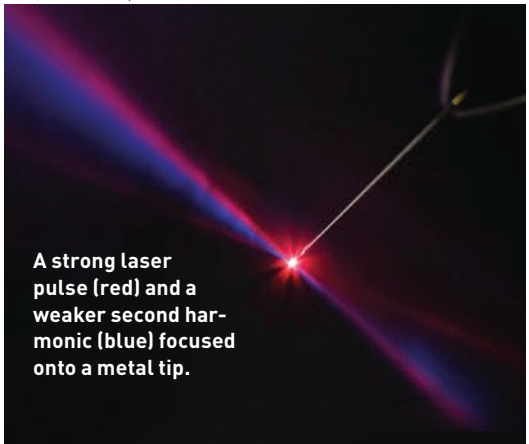
They then used an industrial weaving machine to create smart textiles that consisted of cotton as a platform, conductive threads and the fiber devices. For instance, a photosensing textile had eight UV-detection positions. The generated signals from each photodetector were sent to a signal collector and then to an indicator such as a display or LEDs. A light-up textile had red, green and blue light emissions from the quantum dot LEDs with a peak luminance of 463, 482 and 188 cd/m^2, and electroluminescence peak wavelength of 630, 540 and 450 nm, respectively.

"Building on the capabilities developed in the project, it is possible to conceive the next generation of truly form-factor-free applications, such as building integrated autonomous smart sensor systems, intelligent fabrics and furniture, energy-harvesting smart carpets or curtain-integrated displays, along with e-textile applications in automotive, aerospace and smart cloths," said Luigi Occhipinti, University of Cambridge, UK. —*Meeri Kim*

optica-opn.org/news/0723-fabric

In 2022, the smart-textiles market reached some **US$3.8 billion** in value, according to the research firm IMARC Group.

FAU / T. Boolakee, P. Dienstbier



A strong laser pulse (red) and a weaker second harmonic (blue) focused onto a metal tip.

ULTRAFAST

Attosecond Accuracy

Physicists in Germany have for the first time controlled and measured the light-induced emission of electrons from a metal surface with attosecond precision (Nature, doi: 10.1038/s41586-023-05839-6). The laser-based technique, the team believes, will offer insights into the quantum-mechanical processes underpinning the photoelectric effect and aid the development of a new generation of ultrafast electronic circuits that are controlled by light.

In the experiment, two superimposed laser pulses with different strengths and frequencies were tightly focused onto the apex of a metallic needle. The researchers recorded the energy spectra of electrons emitted from the tip as the phase difference between the two pulses was varied, from which they could determine the intensity and duration of electron emission with a precision of 30 attoseconds.

The team's analysis shows that most of the electrons are emitted over a time window of 710 attoseconds, suggesting that light-controlled electronic circuits have the potential to operate in the petahertz regime. Modulating the phase difference between the two pulses also provides active control of the photoemission. *—Susan Curtis*

optica-opn.org/news/0723-attosecond

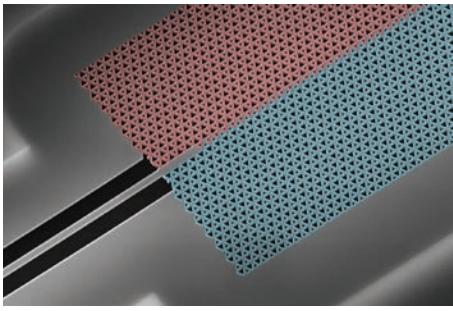
PHOTONICS

Topology May Not Prevent Losses

Painstaking new work from scientists in Denmark raises doubts about the value of topology when it comes to preventing backscattering in integrated photonic circuits (Nat. Photon., doi: 10.1038/s41566-023-01189-x).

For the latest study, the team compared the performance of two types of state-of-the-art silicon waveguides: standard waveguides that confine light, created by removing a line of holes from a conventional photonic crystal, and a novel type of topological waveguide that directs light along an interface between two graphene-like photonic crystals.

The researchers found that their waveguides in fact delivered record-low propagation losses—indicating extremely small numbers of defects. However, that unprecedented performance came not in the topological waveguides but in the standard ones. In other words, topology did not protect against backscattering.



A scanning electron microscope image of a photonic waveguide made from silicon photonic crystals, colored red and blue.

C.A. Rosiek

The team concluded that eliminating the remaining backscattering due to defects will require topological insulators made from materials that break time-reversal symmetry. As the researchers point out, such materials do not exist today—at least not at optical frequencies.

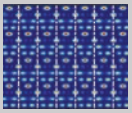
Søren Stobbe, Technical University of Denmark, says he has embarked on theoretical studies of new materials not previously considered for their topological properties. *—Edwin Cartlidge*

optica-opn.org/news/0723-losses

In the Spotlight ...

Here is some interesting research recently highlighted in Optica Publishing Group's *Spotlight on Optics*:

Johann Toudert highlights an *Optics Express* study that examined **a one-meter prototype of the Orbiting Astronomical Satellite for Investigating Stellar Systems' inflatable antenna**.



Hamidreza Ramezani describes a JOSA B paper that studied reciprocal and nonreciprocal dimer lattices and found that **two sets of periodicities can result in reconfigurable Talbot self-imaging**.

For more on this and other research in the spotlight, visit **opg.optica.org/spotlight.**

PHYSICS

Searching for Dark Photons

For more than 40 years, cosmologists have searched for dark matter in the universe—and speculated on the nature of the hypothetical material. In some models of particle physics, dark matter has its own force carrier called the dark photon, analogous to the relationship between the regular photon and electromagnetic waves.

In these models, dark photons may, on occasion, couple themselves with normal photons, which is called kinetic mixing. To seek evidence for such possible interactions, physicists have searched through observational data from China's Five-hundred-meter Aperture Spherical Telescope, currently the world's largest filled-aperture radio telescope (Phys. Rev. Lett., doi: 10.1103/PhysRevLett.130.181001).

In December 2020, the researchers collected 110 minutes of L-band (1 to 1.5 GHz) data from the telescope. For this radio band, the group calculated that the value of ε, a dimensionless parameter quantifying the rate of kinetic mixing, can be no higher than 10^{-12}.

The researchers suggest that more powerful arrays of radio dishes, such as the Low-Frequency Array in Europe and the Square Kilometer Array under construction in Australia and South Africa, may be more sensitive to dark-matter particles. Looking ahead, the team plans to analyze data from space-based radio telescopes, which are sensitive to dark-photon-induced signals at frequencies below those accessible to radio telescopes on Earth.

—Patricia Daukantas

optica-opn.org/news/0723-telescope

The Five-hundred-meter Aperture Spherical Telescope, which sits in a natural basin in China's Guizhou province.
J. Dai

Webb Imagery: Science & Art

The beautiful images from the James Webb Space Telescope (JWST) begin as infrared-light observations beyond what our eyes can detect. Imaging specialists translate the astronomical data into viewable imagery. Here we look at the process for one of JWST's first observations, the Tarantula Nebula (also known as 30 Doradus). For more on the Webb telescope, see this month's cover story (p. 28).

1. SOURCE DATA: Webb's Tarantula Nebula is a multi-image mosaic composed of data from three wideband filters (0.9 μm, 2.0 μm and 4.4 μm) and a continuum subtraction medium-band filter (3.35 μm) from JWST's Near-Infrared Camera (NIRCam) instrument.

2. BUILDING THE BASE

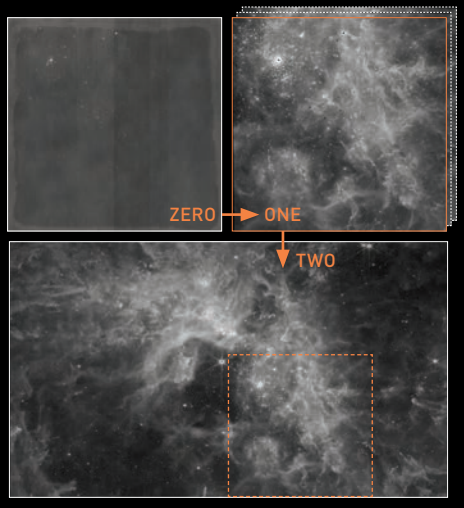
A nonlinear stretch is applied to individual NIRCam exposures to increase the brightness of the darkest pixels while maintaining details in brighter pixels. Artifacts, like oversaturated star cores, are also addressed.

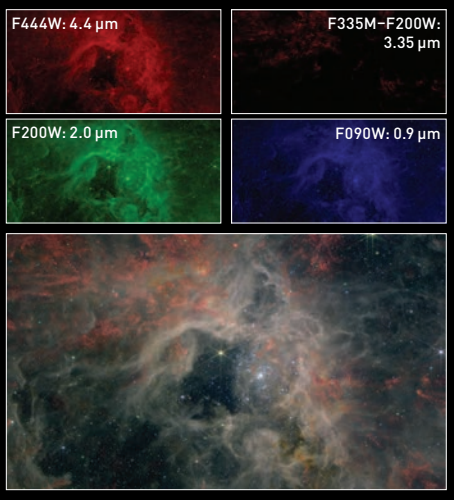
3. DEFINING THE COLOR

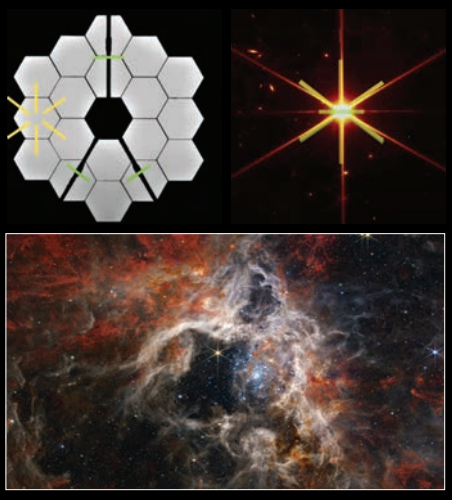
Color is added chromatically, with the shortest wavelengths assigned blue, slightly longer wavelengths green and longest wavelengths red—bringing the visible spectrum to the image.

4. REFINING FOR BEAUTY

Adjustments are made for contrast and color balance, taking care to bring out scientifically significant details. There are also aesthetic decisions, as in the preservation of Webb's star diffraction data.







STAGE ZERO: A single uncalibrated exposure, 161 seconds collecting photons of IR light.

STAGE ONE: Eight individual calibrated and stretched exposures combined into one.

STAGE TWO: The stitched-together mosaic of 30 Doradus for a single filter.

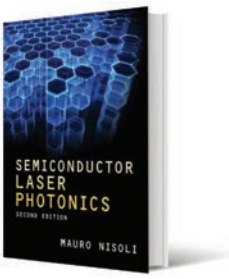
SEEING THROUGH DUST: Continuum subtraction makes it possible to isolate very specific wavelengths of light. The 3.35-μm filter (upper right) highlights the warm dust made of tiny hydrocarbon rings within 30 Doradus. It is overlaid in a reddish orange in the combined color image (bottom), providing depth.

A UNIQUE SIGNATURE: Webb's six-pointed star diffraction pattern comes from interaction with the hard lines of its hexagonal mirrors and support structure (top). This "twinkling" distortion is in all JWST releases, including in the final 30 Doradus image (bottom)—scientific beauty with a touch of art.

Process your own astronomical image: universe-of-learning.org/resources/projects/nasas-astrophoto-challenges

Sources: A. Pagan and J. DePasquale, The Art & Science of Webb Imagery, youtube.com/watch?v=dJX0RAyuqos / illuminateduniverse.org / webbtelescope.org
Tarantula Nebula images: NASA, ESA, CSA, STScI, Webb ERO Production Team and J. DePasquale / Infographic by Alessia H. Kirkland

Semiconductor Laser Photonics



M. Nisoli, Cambridge University Press, 2022

Photonics is a broad subject, and comprehensive coverage requires a long book. This book focuses on semiconductor lasers, giving an in-depth treatment in a friendly length. It is designed for a single-semester course, targeting graduate-level students in physics and electrical engineering.

The first half covers the basic principles and could be used on its own within a course on semiconductor optics. The second half goes through a string of practical photonic devices, from light-emitting diodes and interband lasers to quantum cascade lasers.

The book provides examples, clear diagrams and end-of-chapter exercises. Nisoli has done an excellent job of presenting semiconductor photonics by emphasizing the underlying physical principles. This book should be essential reading for graduate students entering this field.

Review by Mark Fox, Optica Fellow and professor of optical physics, University of Sheffield, UK.

Quantum Physics of Semiconductor Materials and Devices

D. Jena, Oxford University Press, 2022

This textbook presents some of the most exciting developments of the past 50 years within semiconductor electronics and photonics. The whole book is written in a very accessible style, with a clear exposition of all main theoretical concepts and plenty of good exercises for self study. It will be a good resource for undergraduate and graduate students entering the field.

Jena's exposition and choice of topics are well crafted to bring the uninitiated up to speed on a subject that has a long scientific and historical background. This book should certainly be on the shelf of every physicist with an interest in connection with condensed-matter physics and materials science. I recommend it highly.

Review by Christian Brosseau, Optica Fellow and professor of physics, Université de Bretagne Occidentale, Brest, France.

The opinions expressed in the book review section are those of the reviewer and do not necessarily reflect those of OPN or its publisher, Optica (formerly OSA).

PARTNERSHIPS

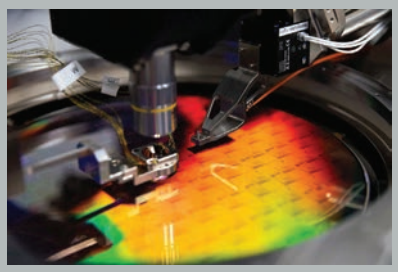
SkyWater–PsiQuantum Collab

The US semiconductor engineering and fabrication foundry SkyWater announced in early May an expanded development and production agreement with the California-based quantum computing firm PsiQuantum. The companies will partner to design and produce silicon photonic chips at SkyWater's manufacturing facility in Bloomington, MN, USA, in what they say is a "significant step" toward securing global leadership of quantum computing.

SkyWater writes in a press release that its silicon photonics integration and manufacturing capabilities will enable PsiQuantum to develop quantum chips that can be measured and tested for long-term reliability—essential for successfully executing the millions or billions of gate operations required for quantum algorithms.

Steve Kosier, SkyWater's chief technology officer, says engineering teams from the two companies are working together to "co-create the reality of a quantum-enabled world," and adds that SkyWater looks forward to supporting PsiQuantum through development and into its production ramp.

optica-opn.org/news/0723-collab



A PsiQuantum silicon wafer.

PsiQuantum

TECHNOLOGY

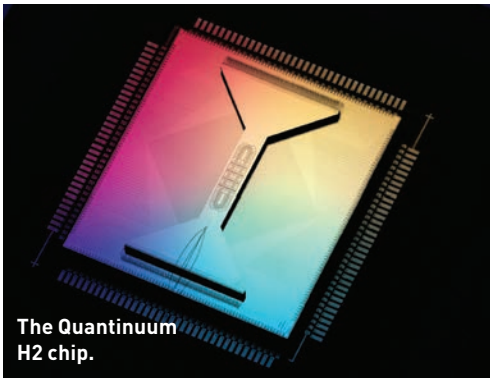
Quantinuum's New Processor

Quantinuum, a maker of quantum processors built on arrays of laser-controlled trapped ions, has officially launched its second-generation system, the Model H2, which the company characterizes as "the highest-performing quantum computer ever built." The company also announced that the H2 had allowed researchers to create and control a heretofore elusive, long-sought quasiparticle excitation that some believe offers a promising route to universal fault-tolerant quantum computing.

The quasiparticles in question, called "non-Abelian anyons," open up the prospect of so-called topological quantum computing, in which complex entangled states are "braided" into structures that are uniquely error-resistant. The demonstration and control of these states on the Quantinuum H2 system doesn't amount to fault-tolerant, topological quantum computing in itself. But the company believes that its processor offers a unique platform for driving toward that goal.

"This was only possible because of our second-generation quantum computer, which—at its level right now, as it's operating—is the highest-performing quantum computer in the world," Tony Uttley, Quantinuum's president and chief operating officer, told OPN. "We are at a stage now in quantum computing where you can start to go do things that are just impossible in any other way."

The H2 system doubles the performance of Quantinuum's H1 processor, with a quantum volume of 65,536. The system is built around a trapped-ion chip with a "racetrack" geometry that enables "all to all" connectivity.



The Quantinuum H2 chip.

Quantinuum

To showcase the capabilities of the H2 system, a research team led by Quantinuum focused on creating and manipulating non-Abelian anyons by teasing out these quasiparticle excitations on the processor. The team used the all-to-all connectivity enabled by the processor to wrangle an array of 27 trapped ions into a specific entangled state. They then walked that state through an increasingly complex set of manipulations, including the braiding of non-Abelian anyons that has been proposed for potential fault-tolerant topological quantum computing.

In an arXiv paper, the team dubs the accomplishment "the first unambiguous realization of non-Abelian [topological order]." However, Uttley notes that there is still far to go between the creation and control of these topological qubits and deploying them in a quantum computer.

The H2 system is available to customers via cloud-based access through Quantinuum, and was scheduled to join Microsoft's Azure cloud service in June.

optica-opn.org/news/0723-qubit

FUNDING

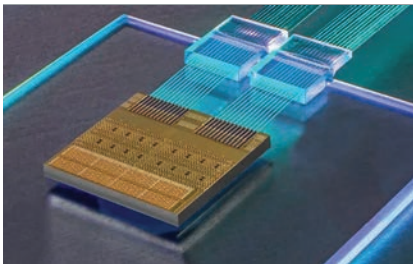
Ayar Labs Targets Generative AI

On 24 May, Ayar Labs, an early-stage Silicon Valley–based developer of optical-interconnect "chiplets" and light sources for high-performance computing and AI, announced a US$25 million increase in its Series C funding. The new Series C1 up-round came from a group including both existing and new investors. The extra cash brought the total value of Ayar's Series C raise, begun in late April 2022, to US$155 million.

In a press release, Ayar said it would use the added funding to "accelerate the implementation and commercialization of its optical I/O [input/output] solutions," especially for the markets promised by generative-AI technology. The company's CEO, Charles Wuischpard, called the new infusion of financing "further validation of our technology and plan to bring silicon photonics–based interconnect solutions to market at scale."

Of particular interest was the participation of Nvidia, the chip-making giant behind the graphic processing units and other systems empowering the recent surge in AI development.

optica-opn.org/news/0723-ayar



Artist view of a 4-Tbps optical I/O system demonstrated by Ayar Labs at OFC 2023. Ayar Labs

Researchers working on the FLUCS system. MPI-CBG

DEVICES

Rapp Licenses FLUCS Technique

The Germany-based company Rapp Optoelectronic will commercially develop a new laser technology called FLUCS (focused light-induced cytoplasmic streaming) that came out of the Max Planck Institute of Molecular Cell Biology and Genetics (MPI-CBG), Germany. According to the researchers, FLUCS—a method of photomanipulation that makes it possible to influence movements in cells and embryos—allows noninvasive control of cells for the first time.

The FLUCS technique was developed by an MPI-CBG research team as part of a cooperation with Rapp Optoelectronic. After a completed license agreement, the FLUCS technology was transferred from MPI-CBG to Rapp.

Rapp OptoElectronic is now offering FLUCS as a market-ready product to researchers and industrial users. A pilot system is located in the Light Microscopy Facility of the MPI-CBG in Dresden, Germany, where it is available for use by scientists both inside and outside MPI.

optica-opn.org/news/0723-flucs

QUICK HITS

Lightmatter's Haul

Lightmatter, the self-styled "photonic supercomputer company," reportedly raised US$154 million in its Series C funding round.

Fusion Funds

Two laser fusion companies, Focused Energy and Xcimer Energy, were among 8 fusion science companies receiving some US$46 million in a recent round of US Department of Energy funding.

Perovskite Pilot

Qcells, Republic of Korea, plans to invest US$100 million toward commercialization of perovskite-based tandem solar cells.

Back in the Game

In early June, Rockley Photonics announced that it had completed its financial restructuring and emerged from Chapter 11 bankruptcy with US$35 million in new funding.

Edwin Cartlidge, Susan Curtis, Patricia Daukantas and Meeri Kim are freelance science writers. Alessia Kirkland is OPN's creative director.