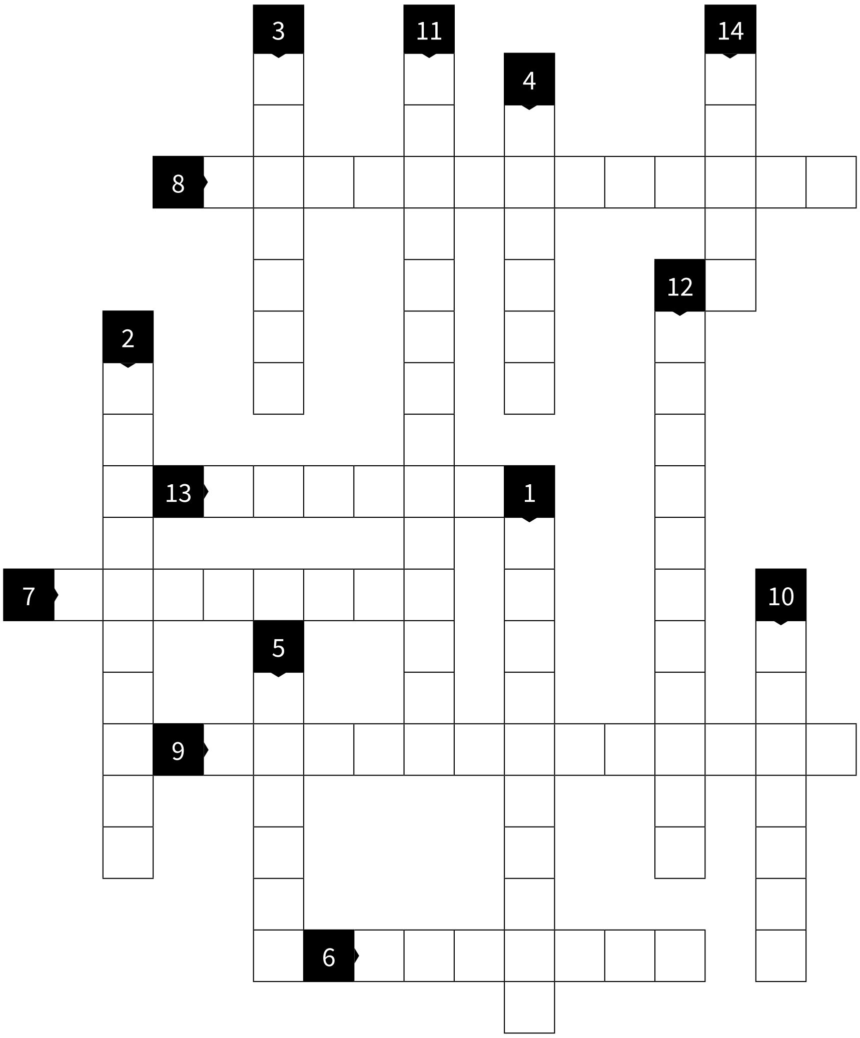
CROSSWORDS
ON BEAMS AND MATERIALS

By Marie-Claire Schanne-Klein (LOB-CNRS)



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KALEO MTF, THE KEY TO COMPLEX HIGH CRA LENSES

The everlasting demand for sharper images using smaller devices, especially in automotive, smartphone and AR/VR industry, is driving the specifications of optical assemblies to new boundaries: more resolution, larger field of view, smaller camera modules, and therefore higher chief ray angle (CRA) and lower F#. This challenge has led Phasics to focus its efforts on developing a brand new test station dedicated to this type of lenses: Kaleo MTF.
Indeed, this station allows a complete characterization of optics, measuring **on and off-axis MTF and wavefront error at multiple wavelengths**. Suitable for many different types of lenses, even with high CRA or large field of views, it can be used in both R&D laboratories or production facilities. After an easy and fast selection of the desired measurement parameters, Kaleo MTF quickly and automatically acquires the sequence, with no alignment required. And thanks to its complete wavefront measurement, Kaleo MTF can generate all kind of analysis, like for example, MTF or OPD vs field angle. ●

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Parametric driving of cavity solitons

Optical pulse trains are currently attracting a lot of attention because they provide a link between the optical and microwave domains. In particular, pulse trains formed by time localized nonlinear solutions that propagate unperturbed in driven optical resonators – Kerr cavity solitons - have been intensely studied recently. In the frequency domain, they correspond to an optical frequency comb, or optical ruler, the inventors of which were awarded the Nobel prize in 2005. Their wide range of applications include atomic clocks, astronomy and high precision metrology. So far, the focus has been on cavity solitons (CSs) driven at their natural oscillation frequency, *i.e.* with a driving laser at the carrier frequency of the soliton. But nonlinear systems can also be parametrically driven, which consists in driving the system by varying one of its parameters. The simplest example of so-called parametric driving is a pendulum which can be excited by periodically changing its length. Importantly, in that case the driving must be at twice the oscillation frequency.

A team of researchers at ULB (Brussels) has demonstrated that cavity solitons can also be driven at twice their carrier frequency. To achieve it, they used an all-fiber optical parametric oscillator that incorporates both second and third order nonlinearity. This special feature confers a totally random character to the sign of the cavity soliton's amplitude. The measurement of this sign allows the generation of a binary random number, paving the way to a new type of all-optical computer such as the Ising machine.

REFERENCE

N. Englebert, F. De Lucia, P. Parra-Rivas *et al.*, "Parametrically driven Kerr cavity solitons," Nat. Photon. (2021).
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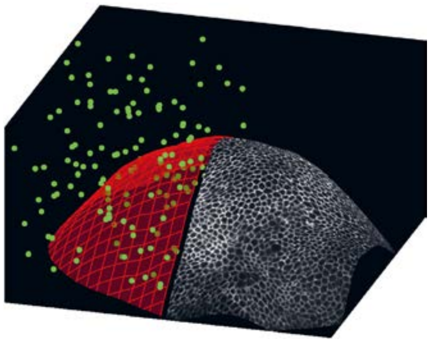
A SMART SCANNING MICROSCOPE FOR BETTER OBSERVATIONS OF CELL SHEETS

Modern biology is based on the observation of living cells, made possible within model organisms by the latest advances in optical microscopy. The widely used confocal fluorescence microscope generates volumetric images with high spatial resolutions, by scanning the volume point by point with a laser beam. However, current techniques are confronted with a problem of toxicity due to the illumination necessary for the excitation of fluorescent markings: prolonged illumination affects and slows down the growth of cells. Nevertheless in many situations, in particular in the case of embryos and developing tissues, cells are organized along sheets lying on curved surfaces. Conventionally, such objects are imaged by scanning the entire volume plane by plane, which is highly inefficient in terms of photon budget.

A team of researchers at Institut Fresnel in Marseille developed a new microscope that automatically estimates the surface on which these cells are distributed from a small number of random acquisitions (~0.1% of the voxels). The microscope can then concentrate the illumination around the surface of interest, allowing cell sheets imaging by scanning typically less than 5% of the volume. Additionally, it can also restrict illumination along the fluorescent cell contours by alternating acquisitions and prediction steps, further reducing the scanned volume up to 1%. The corresponding reduction in light dose on the sample had a profound effect on fluorophore stability and will improve viability of living samples over prolonged imaging.



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F. Abouakil, H. Meng, M. A. Burcklen, H. Rigneault, F. Galland, and L. LeGoff, "An adaptive microscope for the imaging of biological surfaces," Light Sci. Appl. **10**, 210 (2021).
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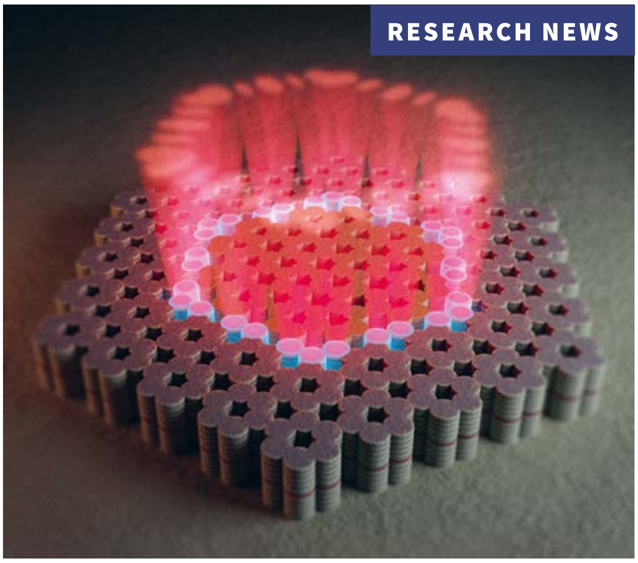


TINY LASERS ACTING TOGETHER AS ONE: COHERENT ARRAY OF VERTICAL LASERS

Topological insulators are revolutionary quantum materials that insulate on the inside but conduct electricity on their surface - without loss.

Several years ago, the Technion group led by Prof. Mordechai Segev has introduced these innovative ideas into photonics, and demonstrated the first Photonic Topological Insulator, where light travels around the edges of a two-dimensional array of waveguides without being affected by defects or disorder. This opened a new field, now known as "Topological Photonics", where hundreds of groups currently have active research. In 2018, the same group also found a way to use the properties of photonic topological insulators to force many micro-ring lasers to lock together and act as a single laser. But that system still had a major bottleneck: the light was circulating in the photonic chip confined to the same plane used for extracting the light out. That meant that the whole system was again subject to a power limit, imposed by the device used to get the light out, similar to having a single socket for a whole power plant.

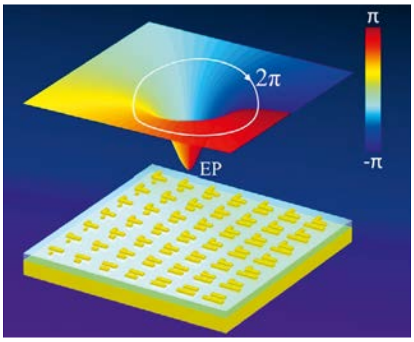
The current breakthrough uses a different scheme that was developed by the groups of Prof. Moti Segev from Technion in Haifa and Prof. Sebastian Klembt from the University of Würzburg: the lasers are forced to lock within the planar chip, but the light is now emitted through the surface of the chip from each tiny laser and can be easily collected. In the new joint research paper published in Science the authors present coherent laser emission from an array of 30 coupled microresonators. The groundbreaking research has demonstrated that it is in fact theoretically and experimentally possible to combine VCSELs to achieve a more robust and highly efficient laser.

REFERENCE
A. Dikopoltsev *et al.*, "Topological insulator vertical-cavity laser array," Science **373**, 1514-1517 (2021) - https://doi/10.1126/science.abj2232

A new technique to manipulate light properties with ultraflat optical components

Metasurfaces are today considered as the next-generation of ultra-flat optical components. They consist of assemblies of thousands, or even millions, of nanostructures with various geometries disposed at interface to modify the light characteristics, namely its amplitude, phase and polarization.

The optical functions of a given metasurface, for example the ability to focus a light beam, are entirely controlled by the light scattering properties on each of these nanostructures. To date, only three mechanisms have been investigated to manipulate light with meta-optics: 1) light scattering by resonant nanostructures, 2) the geometric phase or Pancharatnam-Berry phase and 3) the propagation phase in nanopillars with controllable effective refractive index. Researchers from the Center for Research on Hetero-Epitaxie and its Applications (CRHEA CNRS, Université Côte d'Azur) in collaboration with the "Electrical Engineering and Computer Sciences" department (Berkeley, University of California) have demonstrated a new technique to address the phase of light beam with nanostructures. It relies on the presence of a topological singularity occurring by varying the parameters defining the nanoparticle final geometry (length, width, height, optical index, etc...). The singularity corresponds to an extinction of a given channel connecting input and output light beams (considering transmitted T, reflected R, scattering S or polarization converted channels J matrices). The amplitude of the light wave being zero, *i.e.* R=0 for example, its



phase is no longer defined. Remaining within the parameters of the singularity, in fact encircling the singularity in the space of the parameters, it is possible to draw antennas whose characteristics give the desired phase, between 0 and 2π. Encircling singularity gives full phase control of the wavefront and confers reflected, transmitted light beams exceptional properties, such as non-reflection behavior, perfect absorption on certain light channels, transmission or reflection, anomalous polarization scattering, etc. This work was published in the journal Science.

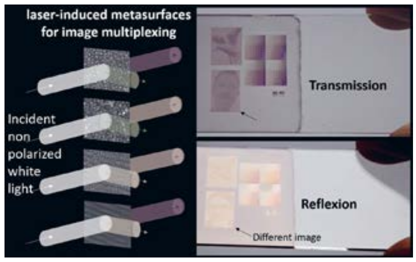
Such components are expected to replace some of the conventional optical devices, such as lenses or mirrors used to control light beams in cell phones, onboard cameras and other miniaturized portable systems. Several breakthrough innovations, including systems requiring wavefront control such as LiDARs or virtual and augmented reality devices, should also benefit from this new technology. In the longer term, these components will find applications in quantum photonics, polarimetry, and for holographic image projection.

REFERENCE
Q. Song *et al.*, "Plasmonic topological metasurface by encircling an exceptional point", Science Vol **373**, Issue 6559 pp. 1133-1137 (2021). https://doi/10.1126/science.abj3179.

IMAGE MULTIPLEXING WITH LASER-INDUCED QUASI-RANDOM PLASMONIC METASURFACES

Encoding several images in a single thin layer in such a way that they could be revealed independently by altering the conditions of observation of the layer has great potential for high-end anti-counterfeiting applications. Recently, the high contrast and dichroic properties of plasmonic colors have been soundly used to develop image multiplexing. Based on perfectly controlled anisotropic metallic nanostructures produced by e-beam lithography, the techniques developed so far have however some drawbacks. The images are too small to be observed by naked eye and the demultiplexing requires either monochromatic or polarized light.

Researchers at Laboratoire Hubert Curien and HID Global CID have developed a laser processing technique that allows printing large multiplexed images at low cost, with a high flexibility, and within very short times. The laser beam tunes the statistical properties of the nanoparticle assemblies, like their size-distribution, their shape anisotropy, and their average spatial distribution through self-organization mechanisms. Yet, the laser processing reproducibly controls the macroscopic optical properties of these random plasmonic metasurfaces and interestingly creates optical properties that are not accessible by other means. The team has demonstrated two- and three-image multiplexing under non-polarized white light, making the technology useful for real applications where an authentication is expected in few seconds.



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Webb: Largest space telescope ready for launch

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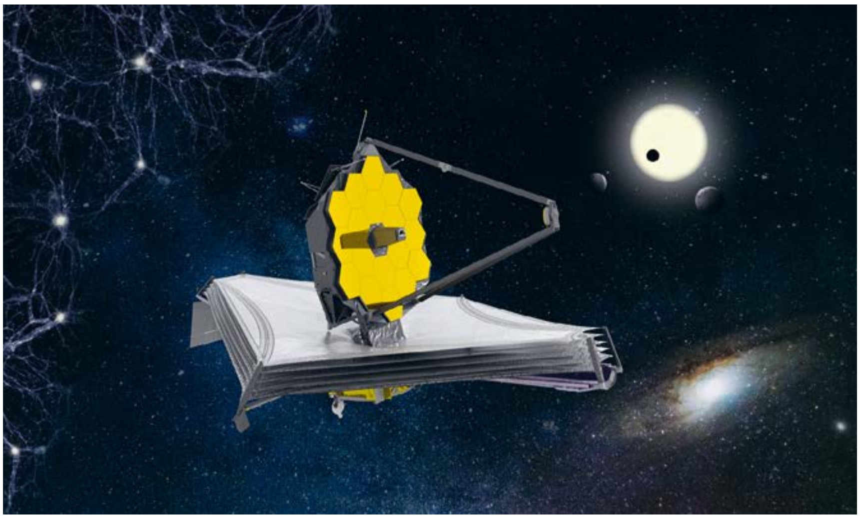


On December 18th 2021, the largest space telescope ever built will be launched from Kourou on Ariane 5. Following the Hubble Space telescope as the next great space science observatory, the James Webb Space Telescope (Webb) is designed to answer outstanding questions about the Universe and to make breakthrough discoveries in all fields of astronomy.

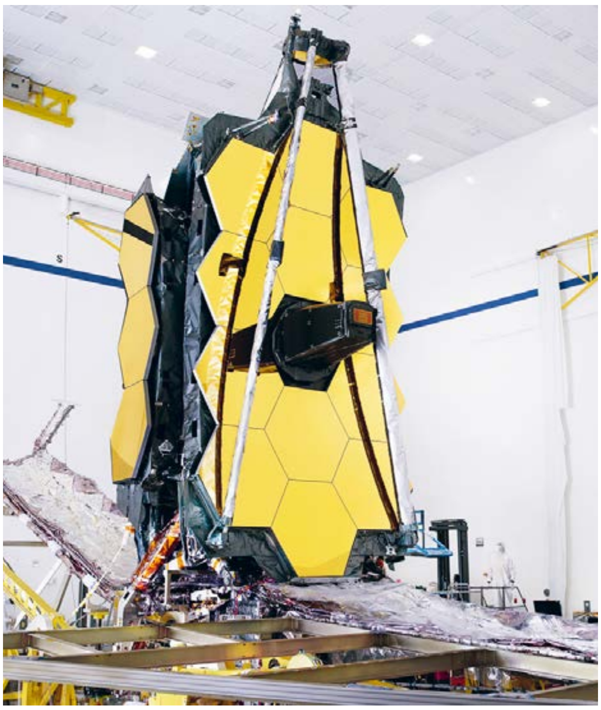
This new space telescope is designed to operate in the infrared to explore four major science themes: the early universe when stars and galaxies formed, the evolution of black holes and galaxies, the lifecycle of stars and planetary systems, the exoplanets and the origins of life.

The large size of the telescope and spacecraft systems require to be folded to fit the Ariane 5 fairing, and then deployed after launch. Even its 6.5 m primary mirror has to be broken up into 18 hexagonal segments folded in three parts to fit the rocket fairing. To restore the primary mirror after launch and unfolding, each segment is supported by seven actuators to co-phase them with a precision better than 50 nm.

Webb will orbit the second Lagrange point (L2), 1.5 million kilometres from Earth in the direction away from the Sun. At L2, the telescope can operate at cryogenic temperature (40 K) required for infrared observations. This passive cooling is achieved using a large deployable sunshield that provides thermal isolation and protection from direct illumination from the Sun and Earth. To reach such a low temperature, the sunshield is built with 5 layers of coated polyimide film (Kapton), each of them with a size of a tennis court (21.2 m x 14.2 m) when unfolded and a thickness of less than 50 micrometers.

A suite of instruments will provide the capability to observe over a spectral range from 0.6 to 28 µm wavelengths with imaging and spectroscopic configurations. The European Space Agency (ESA) contributed two of Webb's four

science instruments: NIRSPEC developed by ESA with Airbus Defence and Space as the prime contractor and MIRI, jointly developed by the US and a nationally funded European Consortium (EC).
NIRSPEC provides spectroscopic observations with resolutions of 100, 1000, and 2700 in the near-infrared (from 0.6 to 5.3 micrometers). The instrument features about a quarter of a million individually addressable micro-shutters, covering a field of view of 9 arcmin^2 for multi-object spectroscopy (MOS mode), an integral field unit with 3×3 arcsec^2 field of view, and five fixed slits, for high-contrast long-slit spectroscopy. The MOS mode allows slit-spectra of about 100 sources to be recorded simultaneously. NIRSpec will be the first spectrograph in space that has this capability.
The Mid-Infrared Instrument (MIRI) provides photometric imaging in between 5 µm and 27 µm over a 2.3 arcmin^2 field of view, low spectral resolving power (R ~ 100) slit-spectroscopy between 7 and 12 µm, coronagraphy in 4 wave-bands between 10 µm and 23 µm and medium spectral resolution (R ~ 1500 to 3500) integral field spectroscopy over a 13 arcsec^2 field of view between 5 and 28.5 µm. The wavelengths where MIRI operates are particularly promising since Webb can detect very faint astronomical sources like galaxies and exoplanets in comparison with the limited sensitivity of even the largest ground-based telescopes due to Earth's thermal radiation.
After 6 months of instruments testing, routine science operations should begin with great discoveries to come. Stay tuned!



Folding and packing the Webb before launch (© ESA).

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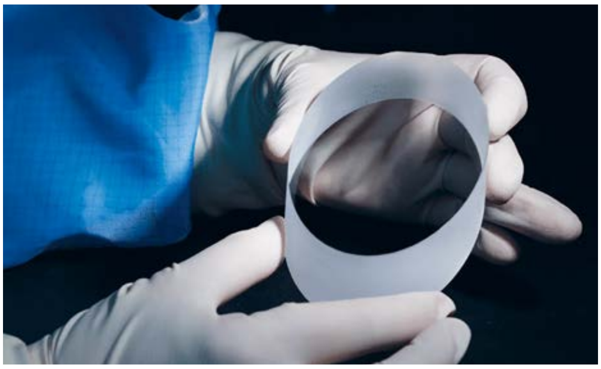
HEF CONSOLIDATES HIS SKILLS IN OPTO-PHOTONICS

The HEF Group, a world expert in surface engineering, is accelerating its diversification into Optics by integrating 3 companies in the first half of 2021: **FICHOU, KERDRY (France), and ABRISA TECHNOLOGIES (USA)**. There are now 200 specialists dedicated to precision optics, the production of components, and coatings for photonics.
With a workforce of 3,000 people (€270 million in sales in 2021), HEF offers its customers a comprehensive service ranging from **research to the process operation and the supply of components, including industrial development and technology transfer**.



Control of an anti-reflection treated lens

From research to pre-series and then to volume production

By pursuing what makes its DNA, the HEF Group is developing a research center with 20 people dedicated to photonics and surface modifications.
HEF is also a stakeholder in the first European femtosecond laser platform for industrial applications.
The photonics division now has 1500 m^2 of cleanrooms (sputtering and evaporation) across three sites in France. This new unit develops complete expertise : for example, it can process large parts up to 1500 mm in diameter and 600 kg. Precision photolithography for substrates up to 200 mm, optical substrates with diameters up to 300 mm, and polishing offered at λ /20, are also part of the offer.
Finally, in the United States, HEF also produces large series of glass substrates and the associated optical coatings for touch screens, filters, mirrors...

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