UNIQUE NANODISK PUSHING PHOTONIC RESEARCH FORWARD

Photonic applications harness the power of light-matter interactions to generate various intriguing phenomena. This has enabled major advances in communications, medicine, and spectroscopy, among others, and is also used in laser and quantum technologies. Now, researchers at Chalmers University of Technology have succeeded in combining two major research fields – nonlinear and high-index nanophotonics – in a single disk-like nanoobject.

The effect arises as a combination of material and optical resonances with the ability to convert light frequency through crystal's nonlinearity. In its fabrication, the researchers have used transition metal dichalcogenide (TMD), namely molybdenum disulfide, an atomically thin material that has outstanding optical properties. The problem with the material is however that it is challenging to stack without losing its nonlinear properties due to its crystalline lattice symmetry constraints. A nanodisk of specifically stacked molybdenum disulfide (3R-MoS2) that preserves the broken inverse symmetry in its volume, and therefore maintains optical nonlinearity, was fabricated for the first time. Such a nanodisk can maintain the nonlinear optical properties of each single layer.

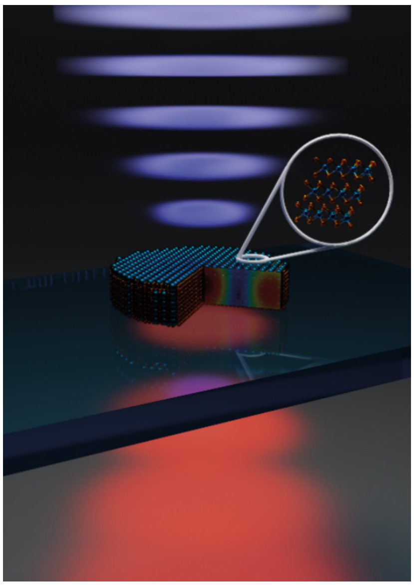
The material has a high refractive index (n>4.5), meaning that light can be more effectively compressed in this medium. Furthermore, the material has the advantage of being transferable on any substrate without the need to match the atomic lattice with the underlying material. The nanodisk is also very efficient in localising electromagnetic field and generating doubled frequency light out of it, an effect called second-harmonic generation. Thus, this nanodisk combines extreme nonlinearity with high-refractive index in a single, compact structure.

The significance of this work lies in the disk's extremely small size. Second-harmonic generation and other nonlinear processes are used in lasers every day, but the platforms that utilise them are typically on the centimetre scale. In contrast, the scale of this nanodisk is only about 50 nanometers, yet it is a very efficient light frequency converter. It is approximately 10,000 times more efficient than the unstructured material of the same kind, proving that nano structuring is the way to boost efficiency.

In future, TMD materials' incredibly compact dimensions, combined with their unique properties, could be used in advanced photonic applications. Specifically, one could dramatically reduce the size and enhance efficiency of optical devices for applications in e.g. nonlinear optics and the generation of entangled photon pairs. ●

REFERENCE

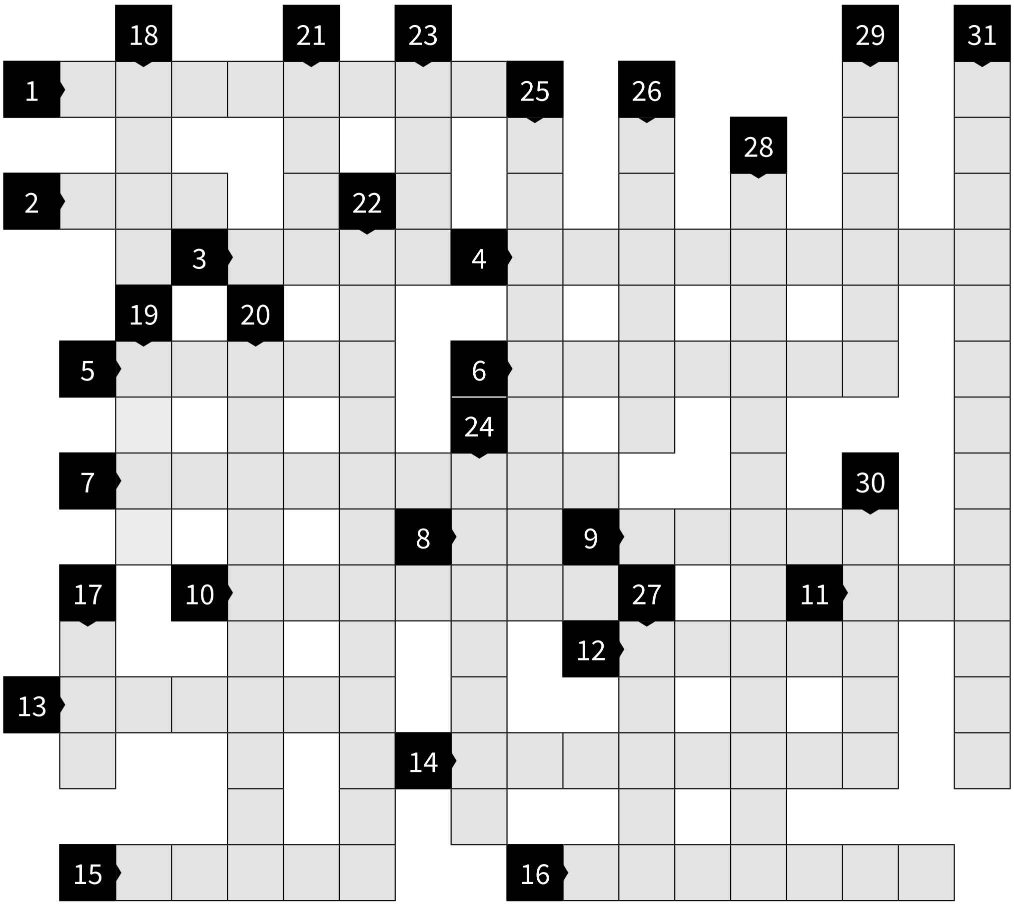
Georgii Zograf, Alexander Yu. Polyakov, Maria Bancerek, Tomas J. Antosiewicz, Betül Küçüköz and Timur Shegai, Combining ultrahigh index with exceptional nonlinearity in resonant transition metal dichalcogenide nanodisks, Nature Photonics **18**, 751 (2024) https://doi.org/10.1038/s41566-024-01444-9



Schematic of the optical experiment: Excitation near-infrared laser (red bottom one) - excites the nanodisk fabricated from the 3R-MoS_2 flake, standing on a glass substrate. © Georgii Zograf

CROSSWORDS ON SUSTAINABILITY

By Philippe ADAM



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8 Among others (AL, Fe, Zn …), compound called a greener metal
9 That kind of panel produces electricity by sunlight conversion
10 Its changes could be dramatic in the future
11 International Agency working to shape energy policies for sustainability
12 Optoelectronic devices, reducing power consumption and therefore considered as ECO-friendly
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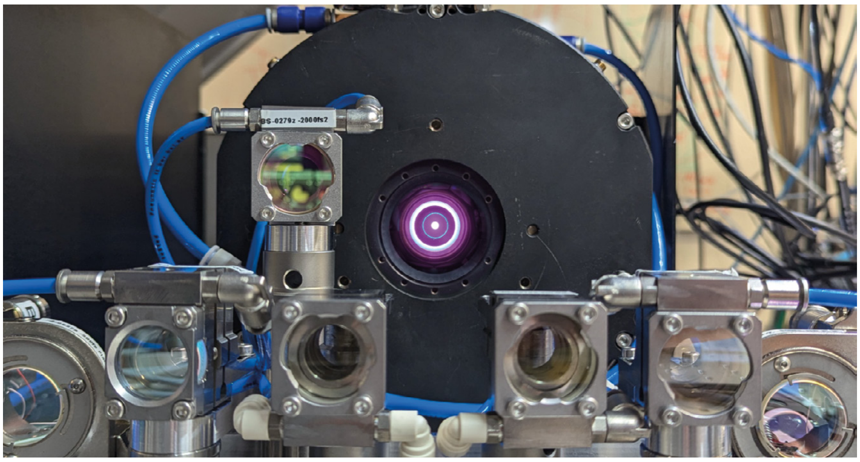
26 Quantum of light energy
27 Made in silicon instead of graphite, boosts the capacity of batteries
28 Optical devices with a minimal carbon footprint
29 Dimensioning request for future energy consumption
30 That kind of industrial operations should be drastically reduced
31 For converting solar energy

Breaking records with high-power ultrafast lasers to enable new physics measurements

Ultrafast high-power lasers are needed in many areas of science and industry, from driving beam lines generating attosecond pulses and providing insights into fundamental physics to machining of materials such as glasses with great accuracy.



In a recent Optica publication, researchers from ETH Zurich have presented a new record for ultrafast laser pulses directly from a laser oscillator. Using a so called thin-disk laser, they were able to achieve 550 W of average power which surpass the previous power maximum by more than 50 percent. Lasting less than a picosecond, pulses are emitted from the laser at a rate of more than five million per second, which is much higher compared to conventional amplifier-based systems. These short pulses reach peak powers of 100 megawatts.

This breakthrough is based on two innovations made by the researchers. Firstly, using a special arrangement of mirrors inside the cavity allows the laser to pass through the gain medium several times before leaving the oscillator through an outcoupling mirror. This arrangement allows to amplify the light without the laser becoming unstable and the intracavity power getting too high. Secondly, the element at the heart of the modelocked laser, a special mirror made from semiconductor materials was improved. This mirror, commonly called a SESAM, has the special property that its reflectivity depends on the strength of light hitting it. This allows the favoring of pulses inside the laser cavity over continuous operation. The researchers developed a new process of bonding this semiconductor structure to a sapphire, which improves the thermal and optical characteristics.

With this laser, the researchers show that high-power oscillators are a good alternative to more complex amplifier-based systems. The fast and strong pulses made possible by the new laser could also see applications in frequency combs in the ultraviolet or X-ray regime, which opens new precision measurement applications or the development of even more precise clocks. In the future this laser could be combined with a pulse compression setup, providing even higher peak powers of the laser pulses. The high repetition rate together with the high peak powers achievable make it very interesting for the generation of high-harmonics or terahertz radiation. ●

REFERENCE

Moritz Seidel, Lukas Lang, Christopher R. Phillips and Ursula Keller, "Ultrafast 550-W average-power thin-disk laser oscillator," Optica **11**, 1368-1375 (2024)