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Bertrand Mongne

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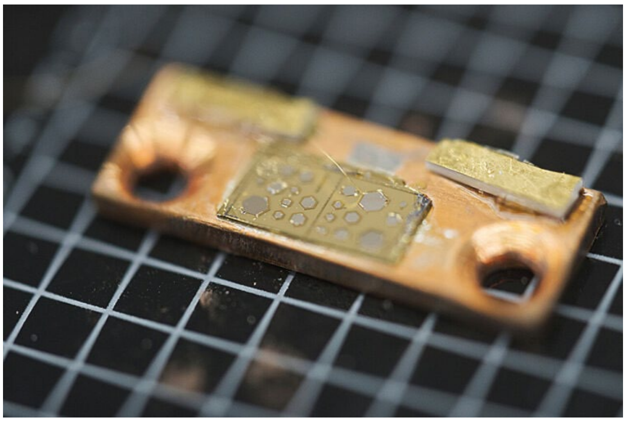
The ultra-compact, energy-efficient laser reduces light loss in all directions



An international team of scientists led by Nanyang Technological University of Singapore (NTU Singapore) has developed a new type of ultracompact laser that is more energy efficient and consumes less power.

Smaller than a grain of sand, the micrometer-sized laser incorporates a special design that reduces light leakage. Minimizing light loss means less energy is required to operate the laser compared to other highly compact lasers.

The laser emits light in the Terahertz region (30 µm – 3 mm), a 6G communication frequency, and could pave the way for high-speed wireless communication of the future.

The research was published in *Nature Photonics*.

Why lasers lose light

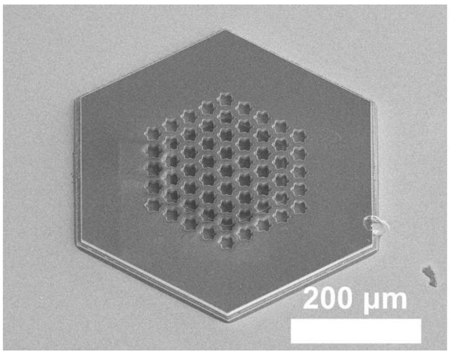
Ultracompact lasers have a wide range of applications in various industries, particularly in small devices. They are also essential for next-generation technologies such as optical computing, data centers, high-speed communications, medical imaging, and advanced sensors.

However, the performance of these miniature lasers is hampered by light loss.

Part of this loss occurs due to side leakage from the laser cavity – a major component of lasers that limits and amplifies light to produce the laser beam.

Light is also lost due to scattering caused by imperfections in the photonic crystal, which is constructed from semiconductor materials to control the propagation of light.

These loss-inducing effects are more significant in ultracompact lasers than larger lasers. In some cases, the light loss is so severe that it prevents tiny lasers from working properly.



Reduce light loss in all directions

To avoid light loss, the new NTU laser exploits flat bands and a phenomenon called multiple states in the continuum (MSC).

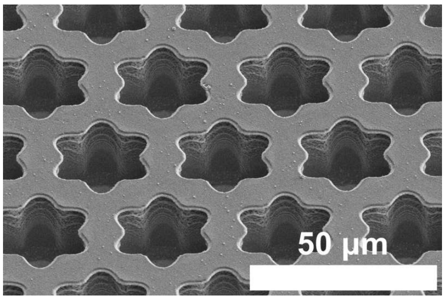
Flat bands are energy bands in the photonic crystal where light waves have a group velocity near zero—a measure of the speed of energy carried by light motion. At near-zero group velocity, the energy carried by light waves remains confined to the horizontal plane of the laser cavity.

On the other hand, multi-Bics reduce light loss in the vertical dimension while still allowing the laser to emit sufficient light for practical use. As with noise-canceling headphones, light-specific wave patterns cancel out parts that would normally escape. The cavity design also effectively minimizes optical signal loss.

To reduce light loss due to leakage and scattering, the researchers designed a laser cavity that combines concepts from both flat stripe and multi-BIC.

They created a periodic arrangement of daisy-shaped holes in a photonic crystal composed of a semiconductor material sandwiched between two layers of gold.

According to the researchers, this could potentially be the "ultimate" solution for eliminating light leakage from a three-dimensional laser cavity.



The laser also produces a highly focused beam with minimal divergence, making it useful for optoelectronic applications.

By scaling the size of the air holes and the lattice constant – the spacing between atoms in the photonic crystal – the design can be extended to create lasers that emit other wavelengths, such as near-infrared and visible light.

“Drawing on our more than fifteen years of experience in photonic band structure engineering, we recognized that combining flat band concepts with BIC could effectively trap light and reduce losses,” says Professor Wang Qijie of NTU’s School of Electrical and Electronic Engineering (EEE) and School of Physical and Mathematical Sciences, who was the principal investigator of the study.

“Our laser overcomes the drawbacks of existing miniature lasers, opening the door to applications ranging from next-generation wearable technology to optical computing,” says Dr. Cui Jieyuan, a researcher at NTU’s EEE, who was the paper’s first author.

“The innovation is a breakthrough in topological photonics and opens a new avenue for compact, robust, and scalable light sources in integrated photonic systems,” said photonics professor Zhen Bo of the University of Pennsylvania, who was not involved in the research.

The researchers are now working to improve the laser's power and integrate it into optoelectronic devices. They have also filed a technical disclosure for the innovation and are seeking industry collaborators to commercialize the technology.

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