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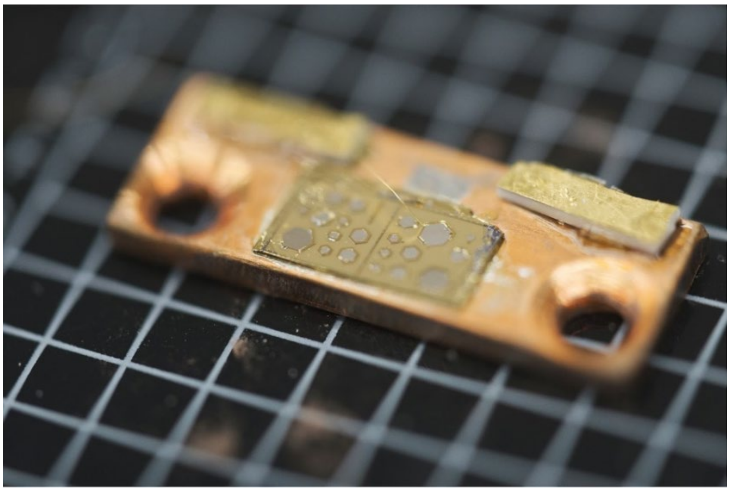
Nanyang Technological University develops new ultra-compact laser with lower optical loss



An international research team led by Nanyang Technological University (NTU), Singapore, has successfully developed a new ultra-compact laser with higher energy efficiency and lower power consumption. Smaller than a grain of sand, this micron-sized laser uses a special design to significantly reduce light leakage, resulting in lower optical losses and significantly lower energy consumption compared to other ultra-compact lasers.

The laser operates in the terahertz frequency band (30 microns to 3 millimetres), covering 6G communication frequencies, and is expected to promote the development of future high-speed wireless communication technology. The relevant research results were published in *Nature Photonics*.

Laser optical loss problem

Ultracompact lasers have broad application prospects in small devices, optical computing, data centres, high-speed communications, medical imaging, and advanced sensors. However, optical loss severely limits the performance of micro-lasers, mainly manifested in the following aspects:

Laser cavity lateral leakage: The laser cavity is used to confine and amplify the light beam, but some light will escape from the sides.

Radiation loss: Light radiation in a photonic crystal structure results in energy loss.

Scattering losses: Fabrication imperfections in photonic crystals cause light to scatter, reducing efficiency.

These loss effects are particularly pronounced in ultracompact lasers, where they can prevent the laser from outputting light with sufficient intensity for practical applications.

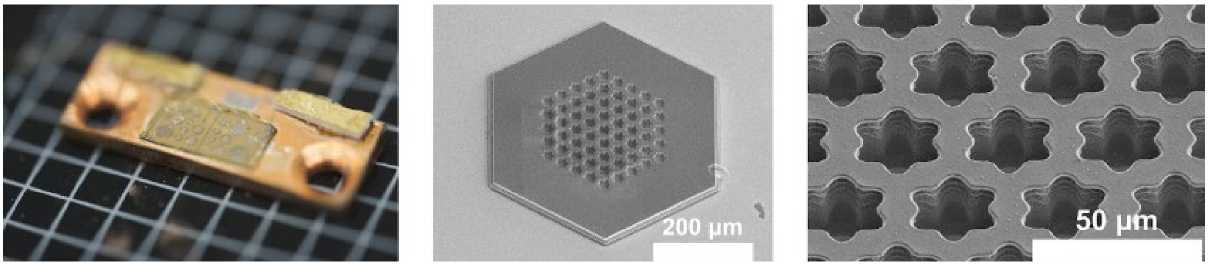
Innovative solution for 3D light leakage suppression

To solve this problem, the NTU team combined two major physical mechanisms: flat bands and multi - BIC.

Flat band structure: The group velocity of light waves in a specific energy band in a photonic crystal approaches zero, making it impossible for light energy to escape from the laser cavity.

Multi-BIC mechanism: cancels out the escape component through light wave interference (similar to the principle of noise-cancelling headphones), achieving light confinement in three-dimensional space.

The researchers designed a novel laser cavity structure, constructing a periodic array of daisy- shaped microholes in a semiconductor photonic crystal sandwiched between two layers of gold films (see Figure 1). This design can simultaneously suppress leakage, scattering, and radiation loss, and the team calls it "the ultimate solution for three-dimensional light leakage suppression."



Left: Laser cavity chip; Middle: Daisy-shaped air hole array effectively reduces light loss; Right: Microscopic view of micropore structure

Technological advantages and application prospects

The laser also features an extremely small beam divergence angle, making it suitable for precision optics. By adjusting the aperture size and the photonic crystal lattice constant, the design can be extended to the near-infrared and visible light bands.

Professor Wang Qijie (NTU School of Electrical and Electronic Engineering/School of Mathematical Physics, lead researcher) said: "Building on our team's 15 years of experience in photonic band engineering, we realised that the combination of flat bands and BICs can efficiently capture photons. This breakthrough overcomes the limitations of existing microlasers and opens new avenues for applications such as wearable devices and optical computing."

Dr. Cui Jieyuan (first author of the paper, School of Electrical and Electronic Engineering, NTU) noted: "Our laser solves a key bottleneck in miniaturised lasers and could be widely used in next-generation communications and computing technologies."

Currently, the research team is working to increase laser power and advance the integration of optoelectronic devices. It has submitted technical patents and is seeking industrial cooperation to promote commercialisation.

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