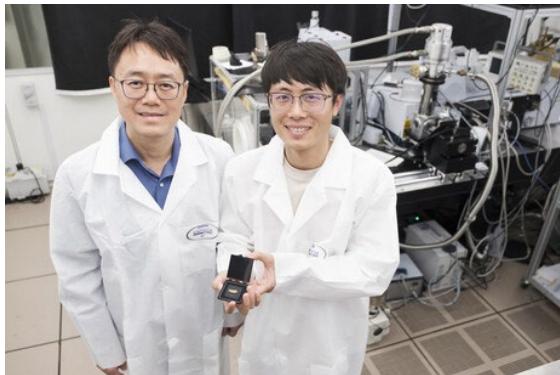


21 August 2025

Ultra-compact laser developed for next-gen tech



Top image caption: Professor Wang Qijie from NTU Singapore's School of Electrical and Electronic Engineering (EEE) and School of Physical and Mathematical Sciences (left) and Dr Cui Jieyuan from NTU Singapore's EEE. Image credit: NTU Singapore.

A team of scientists led by Nanyang Technological University, Singapore (NTU Singapore) has developed a type of ultra-compact laser that is more energy efficient and consumes less power. Smaller than a grain of sand, the micrometre-sized laser incorporates a special design that reduces light leakage. Minimising 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 communications frequency, and could pave the way for high-speed communication in the future. The research findings have been published in *Nature Photonics*.

Ultra-compact lasers have a range of applications across various industries, particularly in small devices. They are also essential for technologies such as optical computing, data centres, high-speed communication, medical imaging and advanced sensors. However, the performance of these miniature lasers is hampered by the loss of light.

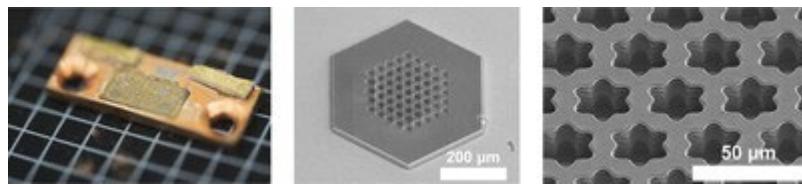
Some of this loss occurs due to side leakage from the laser cavity — a major component of lasers that confines and amplifies light to produce the laser beam. Light is also lost by radiation and when it is scattered by imperfections in the photonic crystal, which is constructed from semiconductor materials to control the propagation of light.

These loss-inducing effects are more significant in ultra-compact lasers than larger lasers. In some cases, the loss of light is so severe that it prevents tiny lasers from emitting sufficient light for practical purposes.

To prevent light loss, the NTU laser harnesses flat bands and a phenomenon known as multi bound states in the continuum (BIC). Flat bands are energy bands in the photonic crystal where light waves have near-zero group velocity — a measure of how fast energy carried by light moves. At near-zero group velocity, the energy carried by light waves does not travel out of the laser cavity.

Similarly, multi BIC confines light in the laser cavity and prevents it from escaping in various directions while allowing the laser to emit sufficient light for practical use. As with noise-cancelling headphones, specific wave patterns in light cancel out the parts that would usually escape. The design of the cavity also makes it difficult for light to get out.

To reduce light loss due to leakage, scattering and radiation, the researchers designed a laser cavity that combines concepts from flat bands and multi BIC. They created a periodic arrangement of daisy-shaped holes in a photonic crystal consisting of a semiconductor material sandwiched between two gold layers.



Left: The chip with the hexagon-shaped laser cavities. Centre: the periodic arrangement of daisy-shaped airholes in the laser cavity reduces light loss by leakage, scattering and radiation. Right: Close-up view of the holes. Image credit: NTU Singapore.

According to the researchers, this could be the “ultimate” solution to suppress light leakage from a laser cavity in three dimensions. The laser also produces a highly focused beam with minimal divergence, making it useful for precise optical applications.

By scaling the size of the airholes 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.

Professor Wang Qijie, the lead investigator of the study, said the researchers drew on more than 15 years of experience in photonic band structure engineering and recognised that combining flat-band concepts with BIC could effectively trap light and reduce losses.

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

The researchers are now working to enhance the power of the laser and integrate it onto optoelectronic devices. They have also filed a technical disclosure for the innovation and are looking for industry collaborators to bring the technology to market.

<https://www.electronicsonline.net.au/content/components/news/ultra-compact-laser-developed-for-next-gen-tech-238302237>