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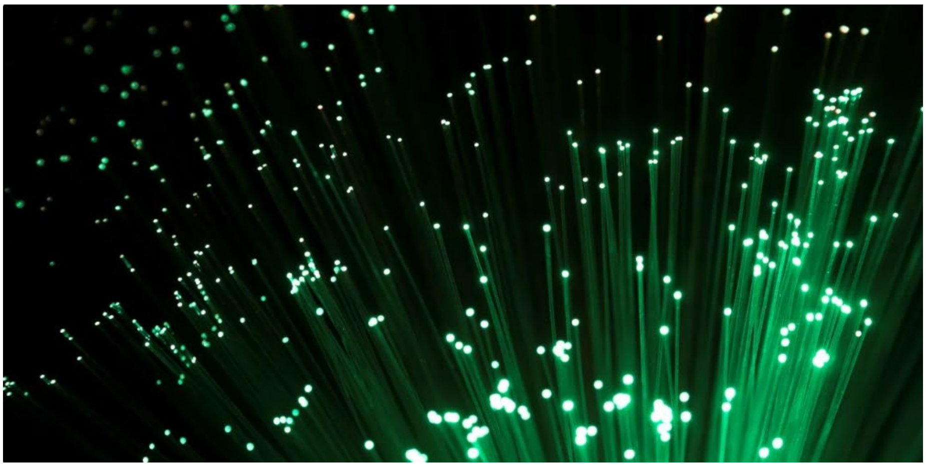
Singapore: NTU Unveils Ultracompact Laser for Next-Gen Tech



Scientists at Nanyang Technological University (NTU) in Singapore have achieved a major breakthrough in photonics by developing an energy-efficient ultracompact laser that promises to transform next-generation wireless communication and integrated photonic systems. Smaller than a grain of sand, this laser tackles a persistent challenge in miniature laser design: light loss.

As lasers shrink, energy tends to escape from the cavity and imperfections in the photonic crystal structures exacerbate scattering, reducing efficiency and limiting practical applications. This innovation offers a solution by minimising these losses while maintaining sufficient light emission for use in real-world technologies, potentially enabling a wide range of applications that were previously impractical.

The NTU research team, led by Professor Wang Qijie and Dr. Cui Jieyuan, approached this challenge by reimagining the design of the laser cavity. Their solution combines two advanced concepts in photonics: flat bands and multi-bound states in the continuum (BIC).

Flat bands are energy bands in which light waves experience near-zero group velocity, confining energy within the horizontal plane of the cavity. This approach ensures that light does not spread uncontrollably across the structure, helping to maintain intensity and focus.

Multi-BICs, on the other hand, reduce light loss in the vertical direction, effectively creating a three-dimensional confinement that allows the laser to emit sufficient light without wasting energy.

By integrating these two concepts, the researchers have developed a laser cavity that minimises energy leakage in all directions, marking a significant improvement over traditional miniature laser designs and setting a new standard for compact photonic devices.

The physical structure of the laser is just as innovative as its conceptual foundation. The NTU team created a periodic arrangement of daisy-shaped airholes within a semiconductor photonic crystal, which is sandwiched between two layers of gold.

This configuration acts as a highly effective trap for light, reducing scattering and leakage. The careful design of the airhole shapes and lattice arrangement is central to the laser's high efficiency, ensuring that energy is concentrated where it is needed and losses are minimised.

This precise engineering represents a culmination of theoretical modeling, material science and nanofabrication techniques, demonstrating how interdisciplinary collaboration can yield breakthroughs in advanced technologies. Researchers believe that these techniques can also inspire future developments in miniaturised optical circuits and photonic sensors.

One of the most promising aspects of this ultracompact laser is its operational range. Functioning in the terahertz region, between 30 micrometers and 3 millimeters, it aligns with the frequency spectrum expected for 6G communication systems. Its compact size and low energy consumption make it an ideal candidate for integration into next-generation wireless networks, wearable devices, optical computing platforms and other emerging technologies that require small, efficient light sources.

Moreover, the design is versatile; by adjusting the size of the airholes and the lattice constant, the laser can be adapted to emit light in other wavelengths, including near-infrared and visible light.

This flexibility opens new possibilities for research and development in integrated photonics and could lead to a new class of customisable, high-performance lasers, making them suitable for medical imaging, environmental sensing and industrial applications.

Published in Nature Photonics earlier this year, this development represents a major milestone in the quest for energy-efficient, miniaturised light sources. As demand grows for faster, more reliable wireless communication and more sophisticated optical technologies, solutions like the NTU ultracompact laser could become foundational components of the digital infrastructure.

By addressing the fundamental issue of light loss in miniature laser systems, the NTU researchers have paved the way for practical, scalable and high-performance photonic devices that may redefine the capabilities of next-generation communication and computing technologies.

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