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NTU Scientists achieve Breakthrough in Quantum computing with Light-Based Technology

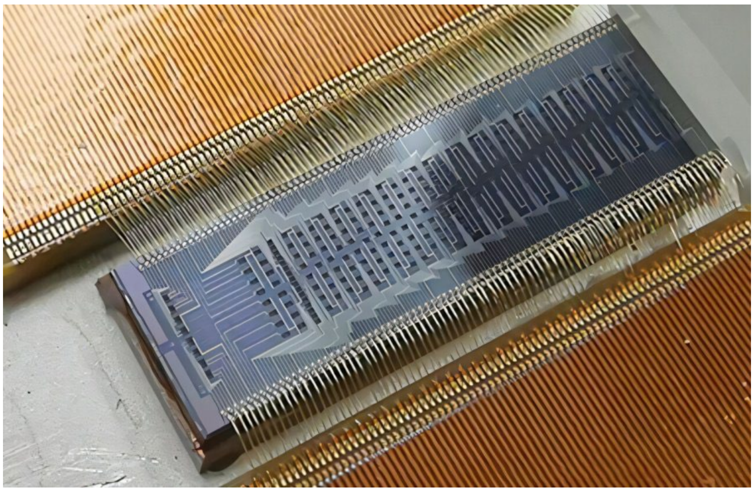
Quantum computing, leveraging the mind-bending principles of quantum mechanics, promises to revolutionize computation by solving complex problems far beyond the capabilities of even the most powerful classical computers. A key element in this revolution is light, specifically the precise manipulation of photons – particles of light – to encode and transmit information.

Researchers at Nanyang Technological University (NTU) in Singapore have announced a meaningful leap forward in this field, developing a groundbreaking technology that could pave the way for practical quantum computers. Their findings, published in *Nature Photonics*, *Physical Review Letters*, and *Nature Communications*, detail a novel approach to generating single photons with unprecedented efficiency.

Emitting Photons on Demand: A Quantum Leap

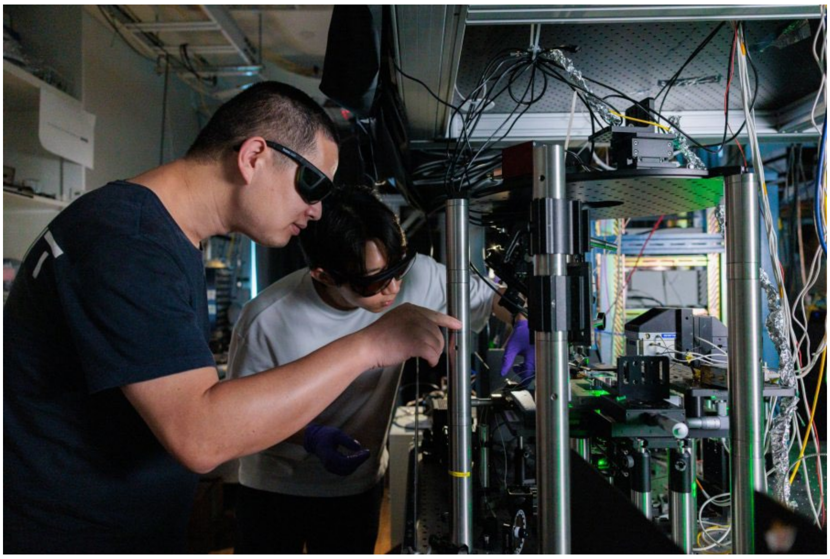
Single-photon emitters, devices that release one photon at a time, are crucial components for quantum computing. However, achieving high quantum efficiency – the ability to reliably emit a photon on demand – and high collection efficiency – the ability to easily capture and utilize the emitted photon – has proven incredibly challenging.

A team led by Professor Gao Weibo, a President's Chair Professor in Physics at NTU and principal investigator at the Center for Quantum Technologies (CQT), has overcome these hurdles using ultrathin two-dimensional (2D) materials. Their innovative approach utilizes a layer of tungsten diselenide (WSe2) overlaid on an array of gold pillars. "This result is the first time that near unity quantum efficiency has been achieved in 2D materials," explains Prof. Gao.



A photo of the quantum photonic chip. Credit: Quantum Science and Engineering Centre, NTU

The process involves using a laser to generate excitons (excited particles) within the WSe2. As these excitons decay, they either emit a photon (radiative decay) or lose energy through other means (non-radiative decay). The NTU team's design dramatically increases the likelihood of radiative decay, resulting in an average quantum efficiency of 76.4%, with some exceeding 90% – remarkably close to the ideal 100% (unity quantum efficiency).



(Front) Co-first author of the research, Dr Cai Hongbing, with the team's experimental setup. Credit: Centre for Quantum Technologies, NTU

This breakthrough has significant implications for the development of practical quantum computers and other quantum technologies. The ability to generate single photons with such high efficiency opens up new possibilities for building more robust and powerful quantum systems, bringing the promise of quantum computing closer to reality.

Quantum Leap: Breakthroughs in Light Control and Quantum Emitters

Scientists at Nanyang Technological University (NTU) in Singapore have made significant strides in quantum technology, reporting two key breakthroughs that promise to accelerate the development of quantum computers and communication systems. These advancements focus on creating highly efficient quantum light sources and controlling the speed of light within photonic chips.

One team achieved near-unity efficiency in a quantum emitter, a crucial component for quantum information processing. Dr. Abdullah Rasmita and Dr. Cai Hongbing, co-first authors of the research, explained that this remarkable efficiency is absolutely possible by minimizing non-radiative decay. “Near-unity efficiency can be achieved if the probability of non-radiative decay is close to zero,” said Dr. Rasmita.

The researchers cleverly used an electric field to separate positive and negative charges within the exciton, effectively suppressing this decay and leading to the near-perfect efficiency. This breakthrough has significant implications for quantum communication and scalable optical quantum computation.

“Our on-demand quantum emitter is desirable for many applications, including quantum communications and scalable optical quantum computation,” said Prof. Gao.

Controlling the Speed of Light

Another team tackled the challenge of slowing light without the drawbacks of conventional methods. Slowing light is essential for effective quantum information processing, allowing for manipulation of qubits—units of quantum information encoded in photons.

Traditional photonic chips, while effective at slowing light, frequently enough suffer from backscattering, limiting their efficiency. This backscattering, caused by light’s diffraction as it passes through narrow openings, is especially problematic at slower speeds. Though, a new approach, developed by researchers co-led by Prof. Zhang Baile, offers a solution.

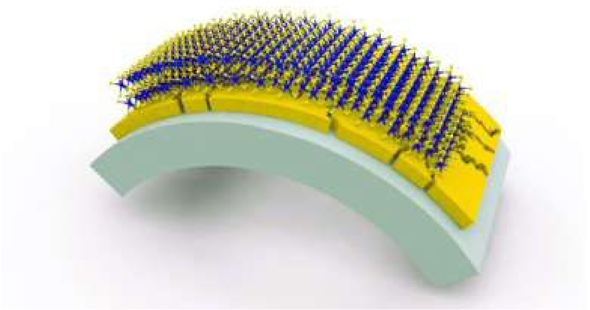
By utilizing a photonic Chern insulator, a unique electromagnetic material, the researchers demonstrated the ability to slow light across a wide range of frequencies without significant backscattering. The light,they explain, effectively “winds” around points in the material’s crystal lattice, known as Brillouin zones, resulting in a significant slowdown.

This innovative chip design overcomes limitations of previous slow-light devices, opening doors for applications like quantum memory—a critical component for quantum computing.

Room-Temperature Quantum Leap: breakthrough in Light-Matter Interaction

A groundbreaking discovery by researchers at Nanyang Technological University (NTU) in Singapore promises to revolutionize quantum computing. They've achieved ultra-strong coupling between light and matter at room temperature, a feat previously only possible at extremely low temperatures.

This breakthrough, detailed in a recent publication, eliminates the need for expensive and energy-intensive cooling systems, a major hurdle in the development of practical quantum computers. The team, co-led by Professor Wang Qi Jie and Associate Professor Wei Lei of NTU's school of Electrical and Electronic Engineering and School of Physical and Mathematical Sciences, harnessed the power of nanotechnology to achieve this milestone.



Left: Illustration of the ultrathin layer of WS2 integrated with gold nanostructures on the flexible substrate. Right: Top view of the nanometer-sized gaps on the integrated surface, creating hotspots for ultra-strong coupling. Credit: NTU

Their approach involved integrating an ultrathin layer of tungsten disulfide (WS_2) with an array of gold nanostructures on a flexible polymer substrate. The nanostructures, featuring densely packed nanometer-sized gaps, create "hotspots" where the interaction between light and matter is considerably amplified.

"Strong and stable light-matter interactions at room temperature open the door to quantum computing applications at ambient temperatures, reducing the stringent cooling requirements for quantum computers," explained Professor Wang. Associate Professor Wei added, "Our work could also pave the way for more exotic light-matter interactions and lead to new insights in fundamental science."

The researchers achieved tunable coupling strength by applying mechanical strain to the material. This controllability is crucial for developing practical quantum devices. the implications of this research extend beyond quantum computing, potentially impacting various fields that rely on precise light-matter interactions.

This breakthrough represents a significant step towards making quantum computing technology more accessible and practical. The potential for room-temperature operation could dramatically reduce the cost and complexity of quantum computers, bringing this transformative technology closer to widespread adoption.

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