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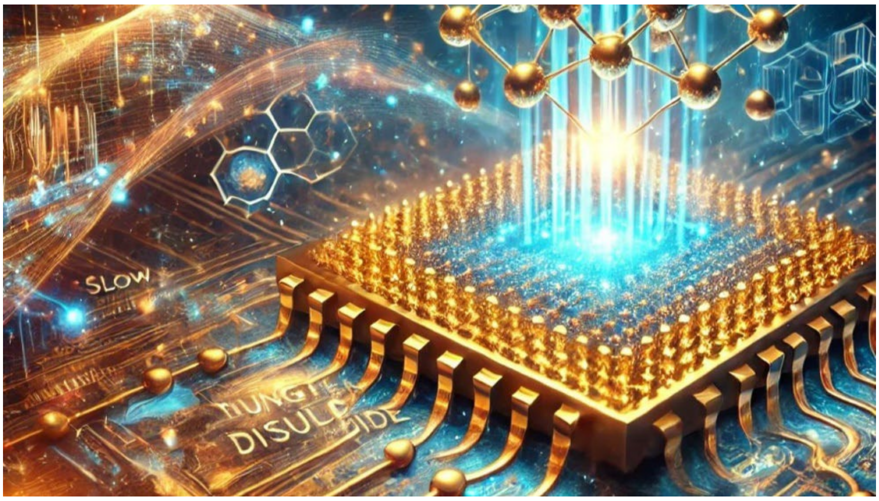
NTU Singapore Advances Light-Based Quantum Technologies



Researchers at Nanyang Technological University (NTU) are making groundbreaking strides in light-based quantum technologies, offering new possibilities for quantum computing, communication, and drug discovery. By harnessing light's unique properties, NTU is driving innovations that may revolutionise computation and scientific discovery.

In quantum technologies, single-photon emitters, which produce one photon at a time, are crucial for computing and communication. However, achieving high quantum efficiency and efficient photon collection remains challenging.

A team led by Professor Gao Weibo, President's Chair Professor at NTU and principal investigator at the Centre for Quantum Technologies (CQT), has achieved a major breakthrough. Using ultrathin two-dimensional (2D) materials, specifically tungsten diselenide (WSe_2), layered over gold pillars, the researchers created single-photon emitters with a quantum efficiency of up to 90%, nearing the theoretical maximum of 100%.

By applying an electric field and leveraging precise material engineering with advanced optical techniques, the team suppressed non-radiative decay—where excitons return to their ground state without emitting light. This breakthrough ensures efficient photon emission, enhancing the device's reliability and scalability for real-world applications in optical quantum computing and secure communications.

Slowing light is essential for quantum information processing, as it enables effective manipulation of quantum information encoded in photons. Photonic chips, which slow light by enabling it to interact with materials, are key to achieving this. However, conventional chips suffer from light backscattering due to diffraction, limiting efficiency.

In a key solution, researchers co-led by Prof Zhang Baile of NTU's School of Physical and Mathematical Sciences (SPMS) developed a photonic chip that slows light over a broad range of frequencies without backscattering. By utilising a photonic Chern insulator, they created a system where light winds around specific points in the material's crystal lattice, reducing scattering.

The researchers showed that this novel design significantly enhances light-matter interactions and transmission efficiency, marking a milestone for advanced photonic circuits and improving performance in critical applications like quantum memory for quantum information systems.

Traditionally, quantum systems require ultra-low temperatures to maintain strong light-matter interactions, increasing energy costs. NTU researchers, co-led by Prof Wang Qi Jie and Assoc Prof Wei Lei, have overcome this limitation by achieving ultra-strong coupling at room temperature.

Using tungsten disulfide (WS_2) flakes on gold nanostructures with nanometre-sized gaps, the team observed enhanced interactions between excitons and surface plasmons – light-induced electron oscillations. By applying mechanical strain, they fine-tuned the coupling strength, achieving the first-ever observation of ultra-strong coupling at ambient temperatures.

This breakthrough reduces the need for extreme cooling, making quantum computing systems more energy-efficient and practical. It also enhances their scalability for real-world deployment, overcoming a long-standing quantum hardware limitation.

It also opens doors to exploring new light-matter interactions, advancing both applied technologies and fundamental science.

Quantum computers hold immense potential for solving complex molecular problems, such as predicting chemical properties for drug discovery. NTU researchers, led by Prof Kwek Leong Chuan, have developed a quantum photonic chip capable of simulating molecular vibronic spectra.

Using a technique called scattershot boson sampling, photons on the chip are manipulated to calculate molecular transition probabilities. As a proof of concept, the team simulated molecules like formic acid and thymine, demonstrating the chip's ability to outperform classical computers in solving such problems.

Compact and operable at room temperature, this chip is a powerful tool for molecular simulations, accelerating the discovery of new drugs and chemical compounds.

The researchers are now focused on scaling this technology to handle larger molecular systems, pushing the boundaries of computational chemistry.

Through these advancements, NTU's light-based technologies are paving the way for faster, scalable, and energy-efficient quantum systems. By leveraging photons, NTU is pushing the boundaries of what quantum computing can achieve, unlocking solutions to some of the world's most complex challenges.

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