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Controlling polaritons at room temperature paves the way for high-speed computing

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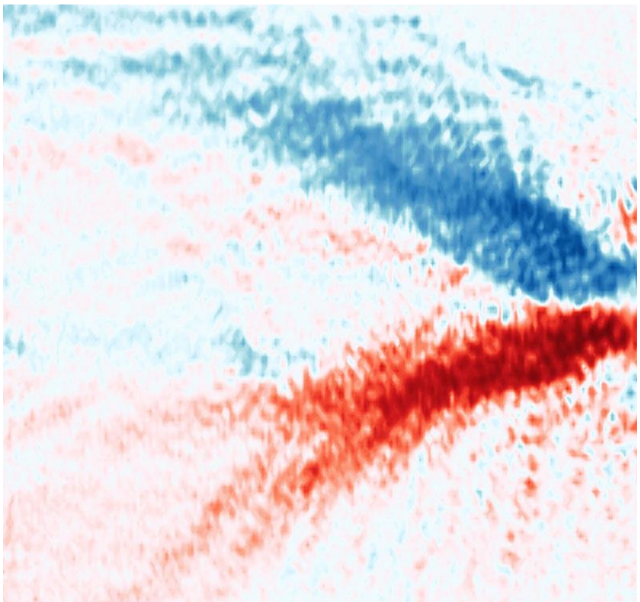
(*Nanowerk Spotlight*) Modern computers process information by moving electrons through circuits, but this approach is reaching its physical limits in terms of speed and efficiency. Scientists have long anticipated that using light instead of electrical signals could lead to developing new types computers that are more efficient. This has led to interest in special particles called polaritons, which combine the properties of both light and matter, potentially offering the best of both worlds for future computing systems.

These polaritons have a unique property called spin, similar to a spinning top rotating either clockwise or counterclockwise. Just as traditional computers store information using the presence or absence of electrical charges, polariton-based systems could store and process data using these spin states. However, controlling polariton spins has proven extremely challenging. Until now, scientists could only achieve precise control by cooling their experiments to temperatures near absolute zero, making practical applications impossibly expensive.

Researchers from Nanyang Technological University, Singapore have now demonstrated a way to control polaritons at normal room temperature. The team, led by Assistant Professor Su Rui and Associate Professor Timothy Liew, created a device that uses synthetic spin-orbit coupling – an artificial interaction that naturally guides polaritons with different spins in opposite directions, much like a traffic system that automatically sorts vehicles onto different paths.

Details of the study are published in *Nature Photonics* ("Polariton spin Hall effect in a Rashba–Dresselhaus regime at room temperature").



An electric field applied to a microcavity structure caused polaritons with different spins to move away from one another in opposite directions. This is visualised here by a spectrometer, with red polaritons spinning in one way separated from blue polaritons spinning the other way after they moved apart. (Image: NTU Singapore)

The researchers' innovation relies on two carefully chosen materials: a special semiconductor called caesium lead bromide and liquid crystal molecules, similar to those found in electronic displays. When arranged in a precise structure called a microcavity, these materials create conditions where polaritons with opposite spins naturally separate and maintain their separation. Similar to a river delta that channels water into permanently separate streams, the system maintains distinct pathways for polaritons over distances that are enormous by quantum standards – up to 45 micrometers.

The system begins working when the researchers shine a green laser on their device, creating polaritons. By applying different voltages to the liquid crystals, they can fine-tune how these particles move and separate. Previous attempts at room-temperature control achieved spin purity of less than 0.5. This meant that separated states mixed significantly, reducing reliability for information processing. The new system achieves a remarkable purity of 0.88, where 1.0 represents perfect separation. This near-doubling of spin purity means the polaritons maintain much more distinct and reliable states – a crucial requirement for accurate information processing.

Through a special instrument called a polarizer, this separation becomes more obvious. The separated polaritons can then be seen using a spectrometer, with polaritons spinning one way digitally colored red and polaritons spinning the other way colored blue. The stability of this separation over relatively large distances represents a crucial advance over previous approaches, where the spin states would quickly become mixed and unusable for computing applications.

The ability to control polaritons at room temperature could enable entirely new types of computing components. These might include devices called spin lasers, spin filters, and spin logic gates – essential building blocks for computers that would process information using both light and matter. Such systems could potentially operate at speeds approaching that of light while maintaining precise control similar to electronic systems, offering substantial improvements over today's technology.

The researchers also showed they could adjust the behavior of their system by changing the voltage applied to the liquid crystals. This electrical control provides a practical way to program and modify how the device works, much like how voltage changes control traditional electronic circuits.

This breakthrough removes one of the main obstacles that has prevented the development of polariton-based computing systems – the need for extreme cooling. By achieving stable control over polaritons at room temperature through synthetic spin-orbit coupling, the research opens a practical path toward computers that could process information in fundamentally new and more efficient ways. While considerable work remains before such systems become commercially viable, this advancement brings us significantly closer to a future where computers harness the unique properties of both light and matter.

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