Quantum laser turns energy loss into gain

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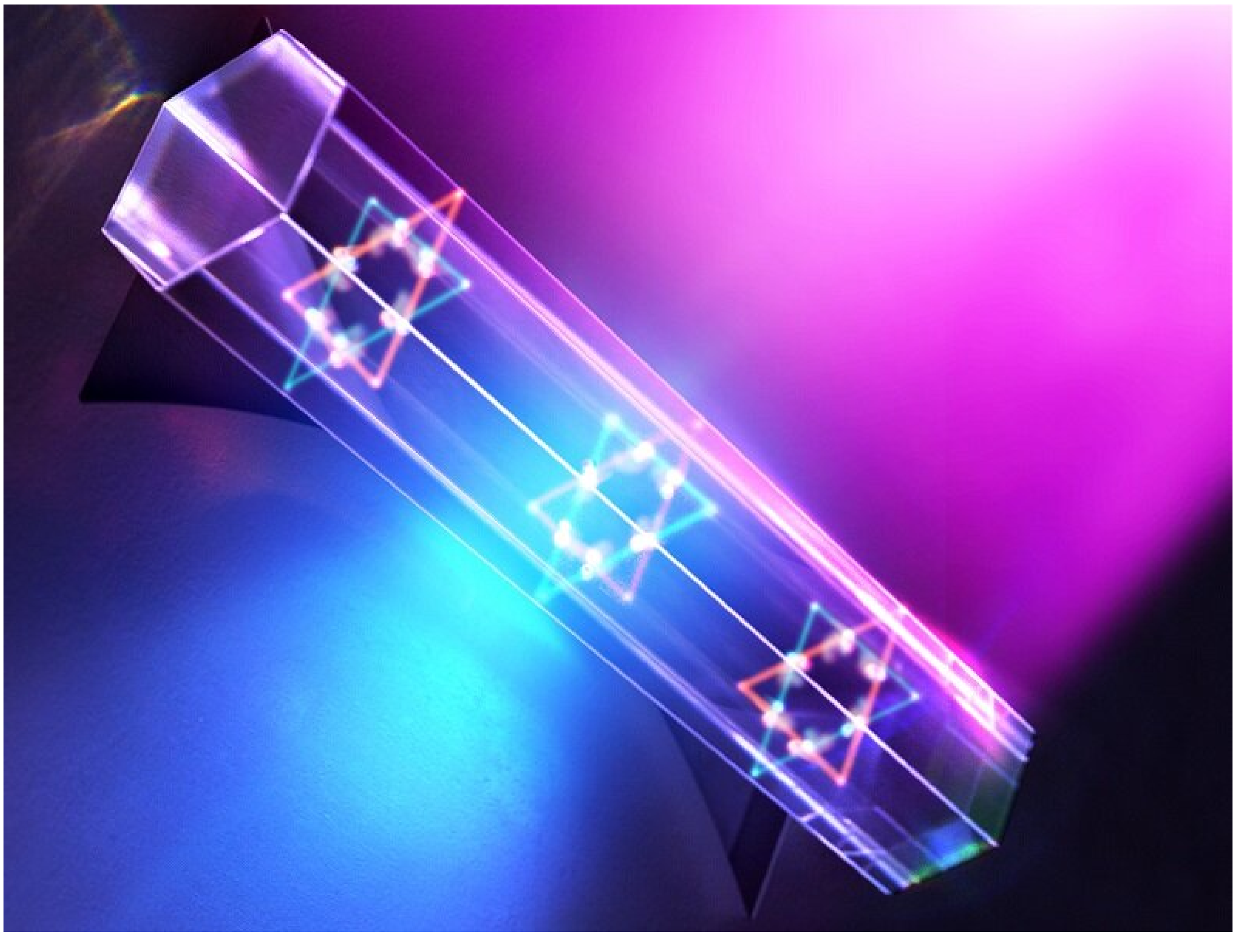

Exciton-polaritonic PT symmetry: Direct coupling between upward- and downward-polariton modes in a six-fold symmetric microcavity with loss manipulation leads to PT-symmetry breaking with low-threshold phase transition. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

Scientists at KAIST have fabricated a laser system that generates highly interactive quantum particles at room temperature. Their findings, published in the journal *Nature Photonics*, could lead to a single microcavity laser system that requires lower threshold energy as its energy loss increases.

The system, developed by KAIST physicist Yong-Hoon Cho and colleagues, involves shining light through a single hexagonal-shaped microcavity treated with a loss-modulated silicon nitride substrate. The system design leads to the generation of a polariton laser at room temperature, which is exciting because this usually requires cryogenic temperatures.

The researchers found another unique and counter-intuitive feature of this design. Normally, energy is lost during laser operation. But in this system, as energy loss increased, the amount of energy needed to induce lasing decreased. Exploiting this phenomenon could lead to the development of high efficiency, low threshold lasers for future quantum optical devices.

"This system applies a concept of quantum physics known as parity-time reversal symmetry," explains Professor Cho. "This is an important platform that allows energy loss to be used as gain. It can be used to reduce laser threshold energy for classical optical devices and sensors, as well as quantum devices and controlling the direction of light."

The key is the design and materials. The hexagonal microcavity divides light particles into two different modes: one that passes through the upward-facing triangle of the hexagon and another that passes through its downward-facing triangle. Both modes of light particles have the same energy and path but don't interact with each other.

However, the light particles do interact with other particles called excitons, provided by the hexagonal microcavity, which is made of semiconductors. This interaction leads to the generation of new quantum particles called polaritons that then interact with each other to generate the polariton laser. By controlling the degree of loss between the microcavity and the semiconductor substrate, an intriguing phenomenon arises, with the threshold energy becoming smaller as energy loss increases.

More information: Hyun Gyu Song et al, Room-temperature polaritonic non-Hermitian system with single microcavity, *Nature Photonics* (2021). DOI: 10.1038/s41566-021-00820-z

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