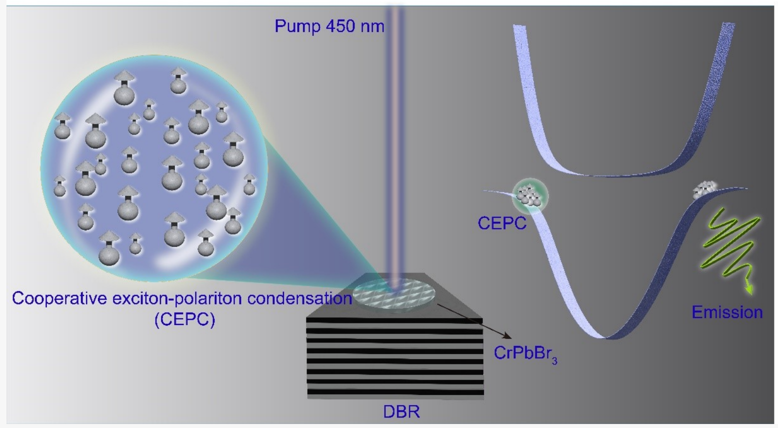
Cooperative Exciton-Polariton Condensate Successfully Created

USA, April 3, 2024 /EINPresswire.com/ -- The superfluorescence effect has garnered attention for its significance in quantum correlation in dipole gases and its applications in intense radiation fields. In this study, Chinese scientists have identified a novel quasi-particle called cooperative exciton-polariton (CEP) in a hybrid structure consisting of a perovskite QDs film on a mirror. Beyond a certain threshold, CEP condensation took place at a nonzero momentum state, facilitated by cooperative excitons. These discoveries hold potential for unconventional light sources.



The cooperative exciton- polariton condensate at a non-zero momentum.

Superfluorescence (SF), as a cooperative radiation effect originating from vacuum quantum fluctuations, is an ideal platform for studying many-body correlation mechanisms in excitons ensemble and for developing optically ultrafast techniques on bright quantum light sources. Recently, there has been a hot topic on the observations of superfluorescence effects based on different radiative materials or under different working temperatures. However, current works mainly focus on studying and discussing the establishment of the SF itself.

In a new paper (https://doi.org/10.1038/s41377-024-01378-5) published in Light Science & Applications, a team of scientists, led by Professor Zheng Sun and Professor Wei Xie from State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai, 200241, China and co-workers have proposed the development of the superfluorescence field through combination with the research field of polariton. Explicitly, they claim for the first time, not only to observe the superfluorescence effect but also to control the collective state of the dipole ensemble by including a new regulatory dimension of coupling light field. Their experimental and theoretical work, described in this paper, gives strong evidence for revealing a new quasi-particle of cooperative exciton-polariton (CEP) and the phase transition from superfluorescence to CEP condensation.

They demonstrate a light-matter hybrid structure of a perovskite quantum dot film and a simple half-layer Bragg mirror. The cooperative exciton-polariton is formalized by coupling an ensemble of synchronized exctions to a selected optical Bragg mode. Above the density threshold, condensation occurs at a nonzero momentum state on the lower polariton branch due to the vital role of cooperative exctions. The phase transition exhibits key signatures of a decrease of the linewidth, an increase of the macroscopic coherence as well as an accelerated radiative decay rate.

These scientists summarize the underlying physical mechanism for the phase transition from the superfluorescence to CEP condensation of their hybrid structure:

“We demonstrate the strong coupling between the cooperative excitons and Bragg photons in a perovskite QDs-based half cavity with a Rabi splitting of 21.6 meV.”

“We achieve the cooperative exciton-polariton condensation. The involved correlated excitons have proven to considerably enhance the coupling strength, which can be attributed to the cooperative effect inducing the synchronization of the random phases of the exciton to be aligned to form a giant dipole. Hence, it allows condensation to take place beyond what is possible at the individual QD level.” they added.

“The present demonstration of the new quasiparticle condensation enables new potential applications for developing ultra-narrow tunable lasers. Additionally, the possibility of controlling the condensation flow and hence exploiting it as the building blocks for various optoelectronic devices is another exciting field offered by such a perovskite QDs system.” the scientists forecast.

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