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Recent advances in exciton-polariton in perovskite

Along with being superior in solar cell applications, perovskites are also gaining popularity as an ideal semiconductor material.

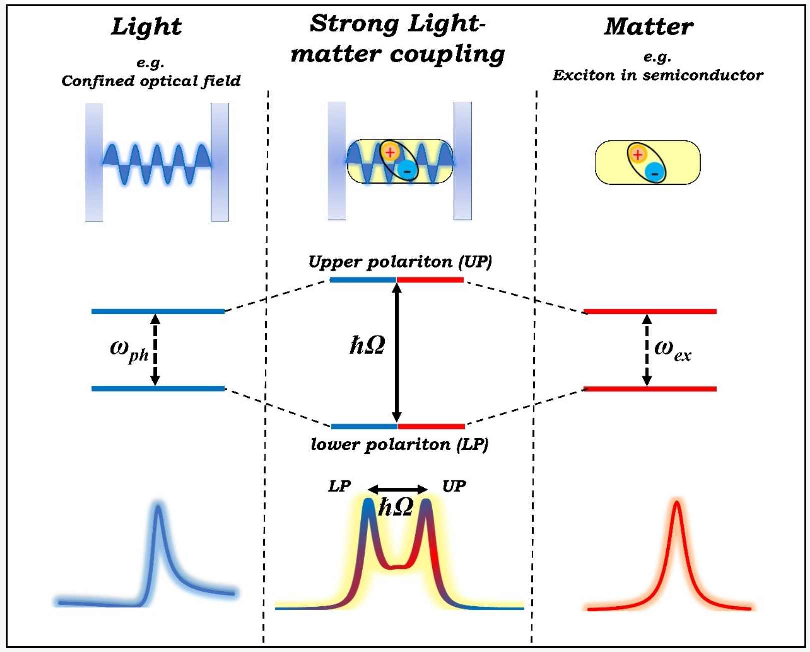

Fig 1. Schematic representation of strong coupling between a cavity mode and an exciton in a semiconductor leading to energy spilt into two branches as shown in energy diagram and absorption spectrum.

CHENGDU, SICHUAN, CHINA, September 15, 2025 / EINPresswire.com/ -- Perovskites, a class of materials known for their stellar performance in solar cells, are now making waves in the world of advanced optics. These versatile semiconductors can capture and emit light in ways that traditional materials like silicon cannot, offering a cheaper and simpler way to create cutting-edge technologies. This review explores a fascinating phenomenon called exciton-polaritons, hybrid particles formed when light and matter merge so strongly that they act as one. This merging, or "strong coupling," happens when light bounces inside tiny cavities, interacting intensely with excitons (pairs of electrons and holes) in perovskites. The result is a unique state that blends the speed of light with the interactivity of matter, opening doors to new devices like efficient lasers and quantum computers.

What makes perovskites special is their ability to achieve this strong coupling at room temperature, unlike other materials that need extreme cooling or costly production. Their large binding energies and tunable colors make them ideal for creating polaritons that work across a wide range of light wavelengths. The motivation behind this research is to harness these properties to build practical, energy-saving devices that could transform industries, from telecommunications to renewable energy. By reviewing recent breakthroughs, the team aims to show how perovskites can bridge the gap between lab discoveries and real-world applications, making advanced photonics more accessible. The significance lies in creating technologies that are not only powerful but also affordable, potentially revolutionizing how we manipulate light for everything from displays to sensors. This work highlights why perovskites are becoming a go-to material for scientists eager to push the boundaries of light-matter interactions.

About the authors:
Led by Professor Andrey E. Miroshnichenko and Dr. Haroldo Hattori from the University of New South Wales, Canberra, this review comprehensively discusses recent progress in generating and utilizing exciton-polaritons in perovskite materials. Initially, the article introduces fundamental concepts of strong coupling, describing how intense interactions between photons and excitons in perovskites create polaritons, enabling phenomena such as ultra-efficient photoluminescence. Crucially, perovskite semiconductors facilitate these interactions at room temperature through relatively straightforward methods, in contrast to conventional semiconductor materials that necessitate sophisticated processing and extreme cooling.

The review highlights three principal approaches for realizing strong coupling. First, mirror-based microcavities trap photons between reflective surfaces, significantly enhancing interaction strength with embedded perovskite materials. Experiments using this approach have achieved polariton lasing and condensation, where coherent polariton states form efficiently at room temperature, leading to low-threshold laser applications. For instance, perovskite nanoplatelets sandwiched between mirrors successfully demonstrated polariton condensation, exemplifying practical device potential. Secondly, plasmonic nanostructures localize electromagnetic fields into subwavelength volumes, dramatically intensifying exciton-photon interactions. Studies involving perovskite-coated metal gratings and perovskite nanowires placed on metal substrates have reported exceptionally high coupling strengths, ideal for developing ultra-compact optical devices such as switches and sensors. Thirdly, dielectric metasurfaces, comprising precisely patterned surfaces, offer unique control over photonic modes, resulting in tailored polaritonic dispersions. Such structures have enabled the realization of exotic emission patterns and significantly boosted Rabi splitting values, paving the way for sophisticated optical circuitry and advanced optoelectronic integration.

The review emphasizes the practical implications of these advances, including energy-efficient LEDs, low-power polariton lasers, and potential quantum computing applications. Nevertheless, persistent challenges such as long-term material stability and scalability for mass production are discussed, highlighting ongoing research efforts aimed at overcoming these hurdles through enhanced materials engineering and optimized cavity designs. By integrating theoretical models with experimental demonstrations, the review provides an informative overview of perovskites' transformative potential in modern photonics, guiding future developments toward robust and scalable photonic technologies.

Conclusion:
Looking forward, perovskite-based exciton-polaritons have significant potential for next-generation optoelectronic devices, including low-threshold polariton lasers, highly efficient LEDs,

and integrated components for quantum computing applications. However, critical challenges remain, particularly concerning the long-term stability of perovskite materials and scalability for practical device manufacturing. Addressing these issues requires further advancements in material science, cavity optimization, and fabrication techniques. Future research directions are likely to involve the development of hybrid structures that integrate perovskites with plasmonic and photonic lattices, exploitation of quantum effects for enhanced functionality, and exploration of novel polaritonic phenomena achievable at room temperature.

About the Research Group:
The research group at the University of New South Wales at Canberra, led by Professor Andrey E. Miroshnichenko and Dr. Haroldo Hattori, focuses on pioneering research in advanced photonics, nonlinear optics, and optoelectronic device engineering. The team's mission is to translate cutting-edge theoretical concepts into practical photonic technologies, emphasizing the strong coupling regime in exciton-polaritons, perovskite semiconductors, and related optical structures. With significant expertise in theoretical modeling, experimental photonics, and nanofabrication, the group's research spans fundamental studies of nanophotonic phenomena to practical implementations in lasers, sensors, and quantum photonic components.

Professor Miroshnichenko is internationally recognized for his contributions to nonlinear nanophotonics and optical nanoantennas, while Dr. Hattori brings extensive experience in optoelectronics, photodiodes, and plasmonic devices. The collaborative environment fosters multidisciplinary projects that have led to highly cited publications and significant advancements in the fields of hybrid dielectric-metal nanoresonators and metasurface technologies. These collective efforts are strategically focused on integrating novel materials and innovative photonic structures into commercially viable devices, ensuring impactful outcomes that bridge the gap between theoretical advancements and real-world applications.

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