A cost-effective realization of exciton-polaritons in single crystals of a 2D layered metal-organic framework

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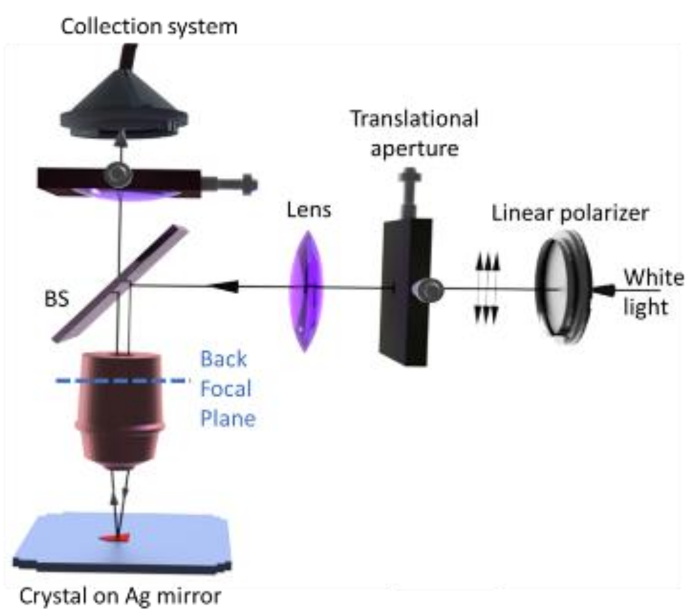
Abstract: Exciton-polaritons are quasiparticles that are formed when a sufficiently strong interaction is maintained between electron-hole pairs (excitons) inside a material and photonic modes of an optical microcavity[1]. Exciton-polaritons offer the implementation of intriguing technological applications such as inversionless lasers, polariton routers, polariton transistors and others. However, a cost-effective and large-scale implementation of these quantum devices at room temperature is mainly hindered by the complex and sophisticated growth techniques involved in the fabrication of a high-quality exciton-polariton microcavity. In this context, we report an extremely simple realization of exciton-polaritons, for the first time, in single-crystalline microplates of a layered Metal-Organic Framework (MOF), which can be synthesized through a facile solvothermal approach. Such a MOF microplate consists of both an excitonic material and a high-quality optical microcavity, and hence, eliminates the costly, time-consuming fabrication process of a high-quality polariton microcavity.



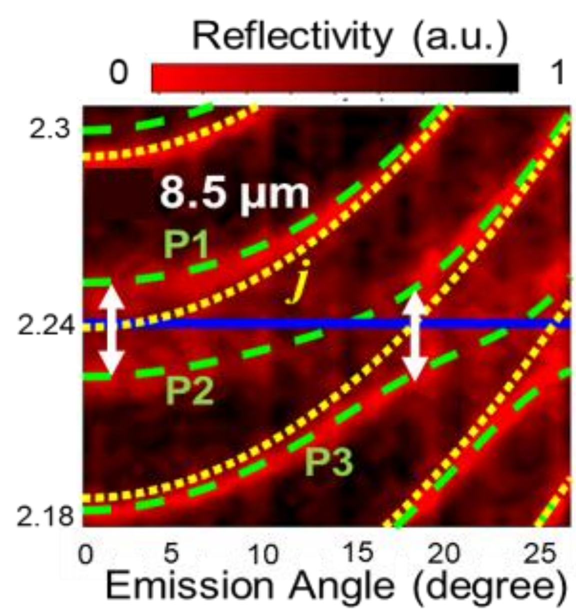


Figure 1: (a) angle-resolved reflectivity experimental set up to investigate exciton-polaritons in MOF crystals. (b) Dispersion diagram showing clear anti-crossing at 2.234 eV for a MOF crystal of thickness 8.5 µm.

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MOFs are a novel class of artificial materials where a metal ion or metal ion clusters are coordinated to organic linkers in a repeating fashion forming a well-defined structure with a high degree of crystallinity and porosity. Researchers have already demonstrated their potential in the field of photonics and nonlinear optics. However, the presence of quasiparticles such as exciton-polaritons in MOF has never been reported in the literature. With combined experiments and theoretical modelling, we demostrate[2] that these particles are formed in our MOF at room temperature because of the strong coupling between Fabry-Perot cavity modes inherently formed by two parallel surfaces of a microplate and Frenkel excitons provided by the 2D layers of Rhodamine B linkers in the MOF. Microscopy experiments such as photoluminescence and angle-resolved reflectivity (Figure 1a) measurements are conducted to investigate these bosonic particles. Unequally spaced modes in photoluminescence signal and clear anti-crossing (Figure 1b) in the dispersion diagram of the crystal (obtained from the angle-resolved reflectivity) proves the presence of these particles beyond doubt. Hence our work introduces the MOF as a new potential candidate to achieve exotic phenomena such as Bose-Einstein Condensation, superfluidity etc., in a cost-effective way

Biography: Mr. Dileep Kottilil received his B.Sc. in Physics from MES College, Ponnani, Kerala (2011). He completed his M.Sc. degree (2013) in Physics from IIT, Madras. Currently, he is doing his joint PhD at National University of Singapore, Singapore and IIT Madras, Chennai. His research interests include nonlinear optics, nanomaterials, strong light-matter interaction in Metal-Organic Frameworks etc.

Reference:

[1] Weisbuch, C., Nishioka, M., Ishikawa, A. & Arakawa, Y. Observation of the coupled exciton-photon mode splitting in a semiconductor quantum microcavity. Physical Review Letters, DOI:10.1103/PhysRevLett.69.3314.

[2] Dileep Kottilil, Mayank Gupta, Kapil Tomar, Feng Zhou, Cherianath Vijayan, Parimal K. Bharadwaj, and Wei JiA cost-effective realization of multimode exciton-polaritons in single-crystalline microplates of a layered metal-organic framework, ACS Applied Materials & Interfaces, DOI: 10.1021/acsami.8b20179.

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