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Department of Physics

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Polaritons for improving the performance of organic optoelectronic devices

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ABSTRACT

Optical microcavities are photonic structures consisting of two reflective mirrors that concentrate light to small volumes within their in-between distance. They are often used to improve and modify the outcoupling of light, via Purcell enhancement, in light-emitting materials and devices. This is the so-called weak light-matter coupling regime where decay rates of emitter and photons in the cavity are faster than their interaction, thus they can be treated as independent entities[1]. By carefully designing the cavity resonance to overlap with the emitter's exciton in energy, space and polarization, the system can transition to the strong light-matter regime. There, excitons and photons give their place to new eigenstates called polaritons. Because polaritons inherit both exciton and microcavity-photon properties, their hybrid part-matter/part-photon nature makes them an excellent platform for studying a plethora of fascinating phenomena such as stimulated scattering, parametric amplification, Bose-Einstein condensation and superfluidity[2]. From the practical standpoint, molecular semiconductors are a favourable material for studying polaritons because their large exciton binging energy allows them to exist up to and beyond room temperature. While polaritons were initially attracted only fundamental research interest, the realization of polaritons in molecular semiconductors has given a new twist to the field and has enabled polaritons to find their niche in applied research. Notably, the ability of polaritons to change the energy landscape of a molecular system offers a novel approach towards the modification and optimization of the chemical and physical properties of organic semiconductors[3,4]. Thus, infusing polaritonics into organic optoelectronics can pave the way for addressing several challenges in organic light-emitting devices such as the low operational lifetime and low external quantum efficiency. For example, tuning a polariton state close to a singlet or triplet state can enhance intersystem crossing, enable reverse intersystem crossing, and modify the spectrum of a molecular emitter. In addition, the photonic component of polaritons inherits its delocalization character to the molecular excitons which can lead to non-radiative radiative energy transfer beyond the sub-10nm Förster radius limit. For example, this exciton delocalization can be beneficial in organic photovoltaic and light-emitting devices that are based on host-guest configurations. In the lab conditions, we create polaritons in optical microcavities that sandwich an organic semiconductor thin film. Because polaritons decay out as photons, we use spectroscopy to study the properties of the system and a combination of theoretical tools namely coupled harmonic oscillator and transfer-matrix modelling, to further improve our devices[5–7]. In this talk, I'll give a brief introduction to polaritons, discuss the experiments for characterizing polaritonic samples, and how in my group we engineer organic light-emitting diodes coupled with microcavities for improved efficiency.

References

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