Room-temperature polariton condensates in all-dielectric microcavities

Cavity polaritons are bosonic half-light half-matter quasi-particles that, under the right conditions, form a macroscopic condensate in the ground state: a phenomenon analogous to Bose-Einstein condensation (BEC). The nonlinear character of polariton condensates makes microcavities one of the most versatile systems for realizing and studying fascinating phenomena, such as superfluidity and the formation of dark solitons and vortices. However, the majority of studied microcavity systems have used CdTe- and GaAs-based semiconductors whose operation is limited to cryogenic temperatures due to their small exciton binding energy. Recently, wide band gap semiconductors, such as ZnO and GaN, have emerged as viable materials for room-temperature applications. In this context, organic semiconductors are especially attractive due to their large exciton binding energy. Moreover, organics offer the advantage of a broad spectral range beyond that covered by GaN and ZnO and can be easily fabricated without the need for epitaxial growth.

In this seminar, I will present a room temperature organic polariton condensate [1]. The studied samples consist of a thermally evaporated oligofluorene thin film enclosed in an all-dielectric (SiO_2/Ta_2O_5) microcavity. On increasing the pump fluence, a threshold of 39 $\mu J/cm^2$ is found that is followed by a superlinear increase of the photoluminescence (PL). This increase is accompanied by a simultaneous blueshift of the emission energy due to nonlinear interaction between Frenkel excitons. In addition, by using a Michelson interferometer in a retroreflector configuration, we study the emergence of spatial coherence and demonstrate several unique features stemming from the peculiarities of this material set and the unique non-equilibrium character of this polariton condensate [2]. Despite the disordered nature of the organic film, we find that correlations extend over the entire spot size and we measure $g^{(1)}(r, r')$ values of nearly unity at short distances and of 50% for points separated by nearly 10 µm. By imaging single-shot realizations of an organic polariton quantum fluid, we observe strong shot to shot fluctuations and centrosymmetric fork dislocations to emerge as varying phase gradients and defects. These are attributed to vortex cores and modulation instabilities [3]. In addition, we show that superfluidity in our system can be achieved at room temperature [4]. This is partially attributed to large polariton densities attainable in organic microcavities, which compensate for their weaker nonlinearities.

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