Electrically Controlled Formation of Extended Lasing States in a Dye-Filled Liquid-Crystal Microcavity

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Non-equilibrium Bose-Einstein condensates (BEC) in photonic systems are promising for exploring and engineering phases of matter under extreme conditions and can be used to perform analogue simulations at both cryogenic and room temperatures. In order to establish a robust and scaleable platform for computing based on non-equilibrium photonic condensates problems of tuneability and reconfigurability should be addressed. Here we demonstrate the realisation of coherent coupling between individually pumped lasing states and formation of spatially extended macroscopically occupied states in a weakly coupled microcavity filled with liquid crystals (LC) and P580 dye (dye-doped LCMC) at room temperature. The saturation of the optical transition in P580 laser dye leads to the blueshift of the photoluminescence abothe the lasing threshold similar to the mechanism of the emission blueshift reported for strongly coupled organic microcavities. It results in a ring-shaped emission profile in the momentum space and sufficient in-plane momentum of the coherent emission leading to coherent energy exchange between spatially separated individually pumped states, similar to the well known behaviour of polaritonic BEC in GaAs systems at cryogenic temperatures. We bring optical reconfigurability by controllable driving of each lasing state with a focused non-resonant optical excitation and utilise it to form a coupled state in a dyad, 1D chain, and a 2D lattice of condensates with the coupling strength defined by the distance between the pumping spots, pump power, and polarisation of the pump. We demonstrate the possibility of going beyond the nearest-neighbour limit of coupling in a chain of coherently coupled emitters by controlling the polarisation of the pump. Furthermore, we show electrical control over interaction between coupled lasing states by applying external voltage. High birefringence of the LC provides wide range tuneability of the dispersions for the microcavity optical modes with different polarisation and allows for control over coupling efficiency by changing the in-plane component of the emission. Figure 1 shows 3 distinctive regimes of interaction.

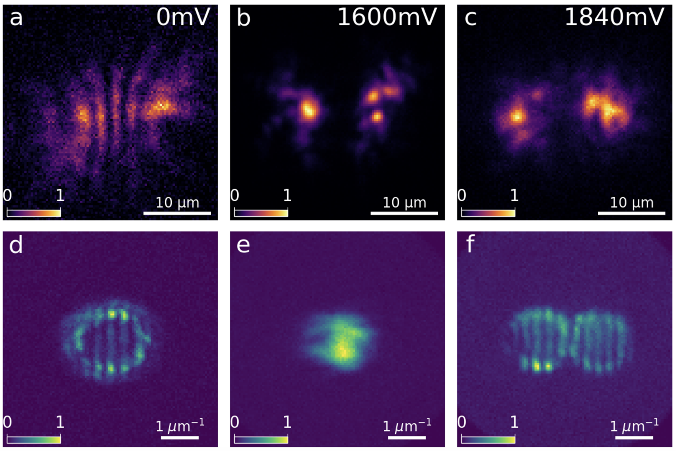

Figure 1: **Electrically tuneable coupling in a dyad configuration**. Experimental images of the lasing state emission in **a-c** real-space, **d-f** momentum space for two pump spots at **(a,d)** 0 V, **(b,e)** 1.6 V, and **(c,f)** 1.84 V, showing **(a)** coupled supermode lasing state, **(b)** uncoupled separate lasing spots, and **(c)** extended lasing state in Rashba-Dresselhaus spin-orbit coupling regime correspondingly.

Acknowledgments

This work was supported by the European Union Horizon 2020 program, through a Future and Emerging Technologies (FET) Open research and innovation action under Grant Agreement No. 964770 (TopoLight).

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