Dirac exciton–polariton condensates in photonic crystal gratings

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Bound states in the continuum (BICs) are confined wave-mechanical objects that offer advantageous ways to enhance light–matter interactions in compact photonic devices. In particular, their large quality factor in the strong-coupling regime has recently enabled the demonstration of Bose–Einstein condensation of BIC polaritons [1]. I will discuss recent experimental results that have demonstrated polariton condensation into a negative-mass BIC which exhibits interaction-induced state confinement [2]. This allows us to optically tailor artificial molecular complexes using polariton BIC droplets with unusual polarization topological charge structure [2]. We demonstrate the scalability of our technique by constructing artificial mono- and diatomic chains of BIC polariton condensates that display single- and double Bloch band formation. These resulst offer exciting insights into large-scale and reconfigurable polariton quantum fluids for emulation of complex many-body systems.

I will then present results on the development of the single- and many-body theory of these new effective relativistic polaritonic modes and describe their mean-field condensation dynamics facilitated by the interplay between protection from the radiative continuum and negative-mass optical trapping [3]. Our theory accounts for tunable grating parameters giving full control over the diffractive coupling properties between guided polaritons and the radiative continuum, unexplored for polariton condensates. In particular, we discover stable cyclical condensate solutions mimicking a driven-dissipative analog of the zitterbewegung effect characterized by coherent superposition of ballistic and trapped polariton waves. We clarify important distinctions between the polariton nearfield and farfield [3] explaining recent experiments [1,2] on the emission characteristics of these long lived nonlinear Dirac polaritons.

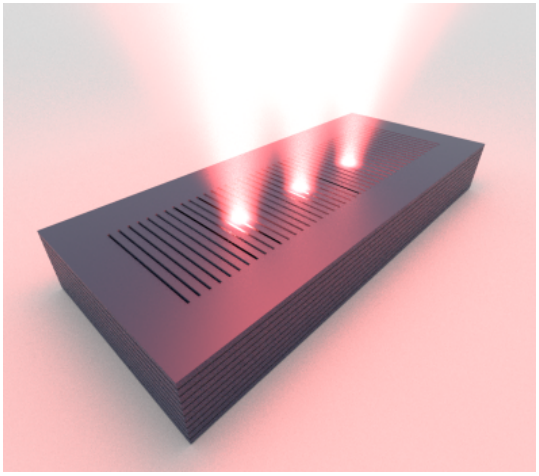

Figure 1: Subwavelength grated semiconductor waveguide supporting pumped exciton-polariton condensates

[1] V. Ardizzone, H. C. Nguyen, H. S. Nguyen, D. Sanvitto et al., *Nature* **605**, 447 (2022).
[2] A. Gianfrate, H. Sigurðsson, V. Ardizzone, H. C. Nguyen, H. S. Nguyen, D. Sanvitto et al., *Nature Physics* **20**, 61 (2024).
[3] H. Sigurðsson, H. C. Nguyen, H. S. Nguyen, *Nanophotonics* (2024).