Splitting Polariton Condensates With 1D Microcavity Couplers

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In this work, we delve into the capabilities of spin-based integrated devices utilizing polariton waveguides forming codirectional couplers. Under specific coupler parameters, we observe a transfer of condensates between the coupler's arms, resulting in Josephson-like oscillations. The ability of adjust these oscillations' periodicity paves the path for designing polaritonic circuits with controllable signal directionality towards the output terminals.

The sample comprises a multitude of directional couplers with diverse size parameters [1, 2], such as their width (w=2 or 6 µm, the transversal dimension of the waveguide), coupling length (L_C < 2 to 100 µm, the extent over which waveguides run parallel), and separation between the arms (d = 0.2 µm to 0.5 µm). The couplers are pumped at one of the input terminals, while the second arm is eventually populated by the tunneling of the condensate wavefunction to the adjacent waveguide. This transfer of population is marked by a robust signal oscillating between the two arms when they are in close proximity. The period of these oscillations increases with the coupler's separation until they cease for d = 0.5 µm (Fig. 1 (a)). Choosing the appropriate coupler parameters, such as coupling length and arm spacing, it is possible to steer polariton condensates towards either output terminal, controlling the splitting ratio between left and right terminal, $R = I_L/(I_L+I_R)$, and proving these semiconductor nanostructures as potential light-matter splitters (Fig. 1 (b)).

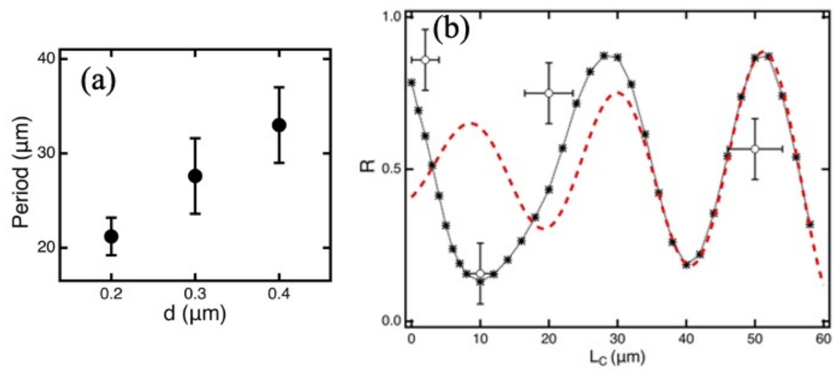

Fig.1. (a) Periodicity of the Josephson-like oscillations along the coupling region as a function of the separation between the coupler's arms. (b) Numerically simulated splitting ratio R as a function of the coupling length (L_C). Open dots represent the value of R found from the experiments.

As a further step, we explore the response of these devices to linearly polarized excitation, investigating the dynamics of linear polarization at the output terminals of long couplers. These insights offer significant implications for spin-based polariton devices, such as efficient polariton switches and logic gates. Our findings are substantiated by numerical simulations based on the generalized Gross-Pitaevskii equation, capturing the coherent polariton dynamics in spatially non-uniform systems. We demonstrate how coupling and controllable spin degrees of freedom in polariton couplers foster innovative optical architectures and functionalities.

References

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