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Controlling the transverse flow of light in optical microcavities for photon BEC experiments

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Abstract

Controlling the flow of light is a fundamental requirement for the realization of complex photonic matter and simulations with light. Two techniques for controlling the transverse motion of photons in high-finesse optical microresonators are presented: permanent nanostructuring of the surface of dielectric mirrors via direct laser writing [1], and in-operation tuning based on a thermo-responsive polymer enclosed within the microresonator. In both methods, a laser beam locally heats an absorptive Si layer situated between the dielectric stack and the substrate. For high enough optical powers this permanently expands the Si layer, allowing for the creation of smooth surface profiles with heights of up to 1 μm with a resolution better than 0.1 nm. With lower optical powers in an assembled microresonator, the heat is transferred into the thermo-responsive polymer resulting in a fully tunable trapping potential. With these techniques at hand, we experimentally demonstrate tunable tunneling between two photon Bose-Einstein condensates [2], realizing an optical analogue of a 0,π-Josephson junction, which can act as a building block for an ultrafast all-optical spin glass simulator. Furthermore, we investigate the Bose-Einstein condensation of a photonic Bose gas in an environment with controlled dissipation and feedback, by realizing a potential landscape that effectively acts as a Mach-Zehnder interferometer [3].

[1] Realizing arbitrary trapping potentials for light via direct laser writing of mirror surface profiles, C. Kurtscheid et al , EPL, 130 (2020), 54001

[2] Controllable Josephson junction for photon Bose-Einstein condensates, M. Vretenar et al, Phys. Rev. Research 3, 023167 (2021)

[3] Modified Bose-Einstein condensation in an optical quantum gas, M. Vretenar et al, arXiv:2105.10708 [cond-mat.quant-gas]