Resonant Control of Pseudospin Precession and Optomechanical Coupling in Polariton Time Crystals

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Ga(Al)As semiconductor microcavities offer a versatile platform for exploring strong exciton-photon coupling and their interactions with GHz cavity phonons (bulk acoustic waves, BAWs). This coupling gives rise to exciton-polaritons—composite quasi-particles that inherit the low effective mass and propagation properties of cavity photons, along with the strong non-linear interactions of excitons. Additionally, polaritons in these structures exhibit highly efficient coupling to confined cavity phonons, with frequencies ranging from 7 to 100 GHz. Under non-resonant continuous-wave laser excitation, polaritons can condense into a Bose-Einstein state at sufficiently high pump power, forming condensates with a well-defined pseudospin—a degree of freedom arising from the coupling between light's polarization and the exciton's spin.

It has been shown that non-resonant excitation can induce a self-sustained precession of the pseudospin, breaking continuous time translation symmetry. This spontaneous emergence of a stable dynamical state, or limit cycle, in a many-body quantum system is an example of a continuous time crystal (CTC) [1]. When coupled to the cavity's mechanical mode, the periodic oscillations of the CTC generate an optical force with a well-defined frequency. Increasing the optical excitation leads to enhanced polariton nonlinearities, causing the precession frequency to increase. When this frequency approaches that of the mechanical mode, self-oscillation of the cavity's mechanical vibrations can be triggered [2]. This process, mediated by back-action, ultimately results in frequency locking of the CTC to the phonon frequency [1].

In this work, we extend the study of the CTC phase by introducing a resonant excitation alongside the non-resonant laser that sustains the pseudospin precession. We demonstrate coherent control of the pseudospin dynamics through frequency pulling and injection locking to the resonant laser, allowing us to tune the precession frequency or suppress the dynamics entirely. These mechanisms could provide a novel approach for resonant excitation of mechanical modes, coherent control of the CTC dynamics, and inter-site coupling in polariton condensates arrays, with potential applications in non-reciprocal transport.

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References

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