Relaxation oscillations and reservoir filling dynamics in an exciton-polariton condensate

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Exciton-polaritons enabled the creation of a novel class of bosonic condensates characterized by dissipative nonlinear dynamics. As demonstrated in recent experimental works, exciton-polariton condensates under non-resonant optical pulsed excitation can exhibit oscillatory behaviour in time [1,2]. The manifestation of polariton condensate complex dynamics takes place when the density of incoherent exciton reservoir is rapidly depleted while increasing condensate density [3]. By analogy to the well know semi-classical non-linear physical systems (eg. B-class semiconductor lasers), this type of dynamic behaviour is called “relaxation oscillations”.

In this work, we performed numerical and analytical investigation of relaxation oscillations in the nonresonantly pumped polariton condensate. The presented considerations are based on the analysis of the open dissipative Gross-Pitaevskii equation with multistep free carrier-exciton-polariton relaxation process. The experimentally observed time-evolution of condensate density can be explained by studying the topology of phase space trajectory in the physical system. We used bifurcation analysis for the classification different regimes of condensate dynamics, e. g. fast stabilization, slow oscillations and ultrashort pulse emission. Next, we defined the analytical condition for the observation of relaxation oscillations. Additionally, we used the simple nonlinear oscillator model for the description of condensate time-evolution and oscillations. The analytical solution are in excellent agreement with both the results of numerical simulations and experimental observations [1,2].

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