Hybrid regime of stabilization in exciton-polariton condensates

P. Miętki, A. Opala, M. Matuszewski

Institute of Physics PAS, Al. Lotników 32/46, 02-668 Warsaw, Poland

Exciton-polariton condensates modeled with open-dissipative Gross-Pitaevskii and exciton reservoir density equations are characterized by strong instability, especially for short living polariton particles. We inspect the influence of the energy relaxation β on the stability in such systems[1]:

$$i\hbar\frac{\partial\psi(\boldsymbol{r},t)}{\partial t}=\left[-(1-i\beta)\frac{\hbar^2}{2m^*}\Delta+\frac{i\hbar}{2}(Rn_R(\boldsymbol{r},t)-\gamma_C)+g_C|\psi(\boldsymbol{r},t)|^2+g_Rn_R\right]\psi(\boldsymbol{r},t),$$

$$\frac{\partial n_R(\boldsymbol{r},t)}{\partial t}=P(\boldsymbol{r},t)-(\gamma_R+R|\psi(\boldsymbol{r},t)|^2)n_R(\boldsymbol{r},t).$$

Including the mechanism of relaxation is necessary since in many experiments there are no observations of instabilities in contrast to the theoretical predictions.

Using the Bogoliubov-de Gennes method, we derive the condition for the stability in the case of uniform pumping that depends on the relaxation parameter β. The analytical results that agree with numerical simulations are shown in Fig. 1. For sufficiently large β factor it is possible to achieve stabilization in entire parameter space, where γ_C^{-1}, γ_R^{-1} are the polaritons and reservoir excitons lifetimes, respectively and P/P_{th} is the ratio of the pumping rate to the threshold value when condensation occurs.

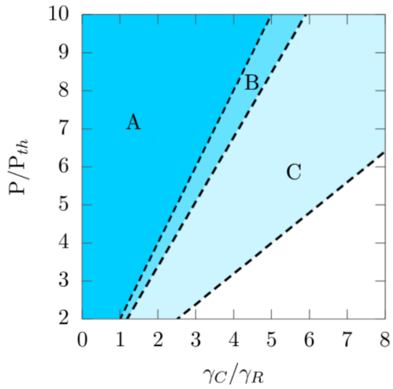

Fig. 1: Diagram of stability for different values of energy relaxation factor β. Stable regimes are marked with colors, where A: β=0, B: β=0.4, C: β=1.6

`Moreover, we analyze the behavior of the condensate in the case of perturbation by a short optical pulse under stationary uniform pumping. Despite being in the stable regime according to the Bogoliubov analysis, the condensate reveals intermittent instabilities in the case of a strong perturbation. Surprisingly, this hybrid regime occurs only for non-zero energy relaxation parameter values. Examples of the condensate evolutions in the cases where relaxation is absent or present are shown in Fig. 2.

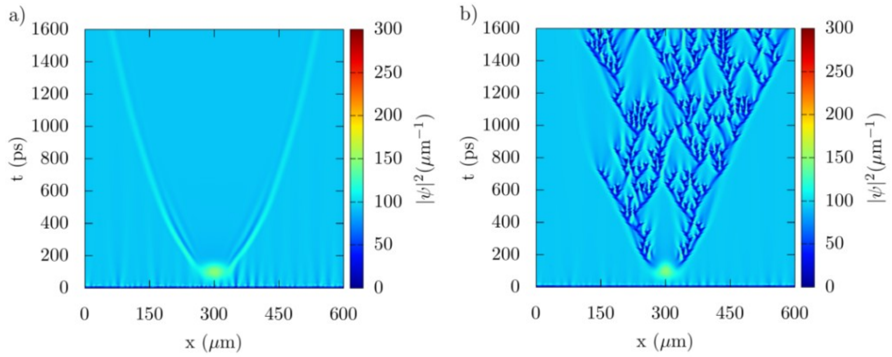

Fig. 2: The evolution resulting from a strong pulsed perturbation in a stable regime. (a) relaxation factor $\beta = 0$: the condensate proceeds to a stationary state. (b) $\beta = 0.4$: while the steady state is stable, perturbed condensate ends up in a spatiotemporal intermittent regime [2].

References

[1] N. Bobrovska, E. A. Ostrovskaya, and M. Matuszewski, Phys. Rev. B. **90**, 205304 (2014).
[2] M. van Hecke, Phys. Rev. Lett. **80**, 1896 (1998).