Fingering instability in exciton-polariton condensates

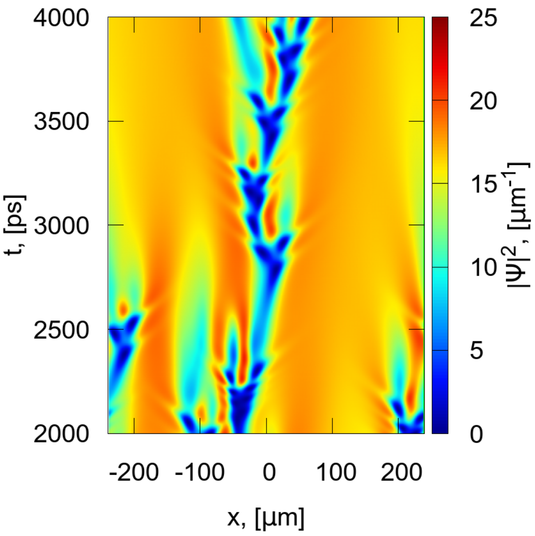
Nataliya Bobrovska and Michał Matuszewski

Institute of Physics, Polish Academy of Sciences, al. Lotników 32/46, 02-668 Warsaw, Poland

Exciton-polaritons are quantum quasiparticles composed of a photons and excitons, resulting from the strong coupling in semiconductor microcavities. The extremely low effective mass of polaritons, of the order of $10^{-5}m_e$, and strong exciton-mediated interparticle interactions make them interesting objects for study in both fundamental and applied research. Experimental observations revealed polariton Bose-Einstein condensation [1] and superfluidity [2] at temperatures much higher than in the case of ultracold atomic gases. In some material configurations, the critical condensation temperature can be higher than room temperature [3]. Recently, it has been demonstrated that in the case of polariton condensates pumped by a nonresonant laser source, the interaction with incoherent reservoir may lead to a dynamical instability [4].

We study the consequences of the instability and the nature of the resulting quasi-condensed state. We investigate in detail the experimental conditions at which one may expect the appearance of chaotic dynamics. Within the formalism of open-dissipative stochastic Gross-Pitaevskii model, we study the spatio-temporal pattern formation in exciton-polariton condensates that occurs at the onset of instability in parameter space.

We find that the resulting dynamics reveal intricate spatiotemporal patterns in the form of fingering and branching. The physics of the system in the unstable regime becomes very similar to that occurring in systems described by reaction-diffusion models, including the fingering instability in combustion [5], bacterial growth and colonial development, or self-replicating pattern formation [6]. As a result, we find that polariton systems in the unstable regime display rich dynamics that is very different from the superfluid and inertial physics observed in the stable regime, and provide an analogy to a number of extensively studied soft-matter systems.



[1] J. Kasprzak, M. Richard, S. Kundermann, A. Baas, P. Jeambrun, J. M. J. Keeling, F. M. Marchetti, M. H. Szymańska, R. André, J. L. Staehli, V. Savona, P. B. Littlewood, B. Deveaud, and L. S. Dang, *Nature* **443**, 409 (2006).

[2] A. Amo, J. Lefrère, S. Pigeon, C. Adrados, C. Ciuti, I. Carusotto, R. Houdré, E. Giacobino, and A. Bramati, *Nature Physics* **5**, 805 (2009).

[3] G. Lerario, A. Fieramosca, F. Barachati, D. Ballarini, K. S. Daskalakis, L. Dominici, M. de Giorgi, S. A. Maier, G. Gigli, S. Kéna-Cohen, and D. Sanvitto, *Nature Physics* **13**, 837 (2017).

[4] N. Bobrovska, M. Matuszewski, K. S. Daskalakis, S. A. Maier, S. Kéna-Cohen, *ACS Photonics* **5**, 111 (2018).

[5] O. Zik and E. Moses, *Phys. Rev. E* **60**, 518 (1999).

[6] W.N. Reynolds, , J. E. Pearson, S. Ponce-Dawson, *Phys. Rev. Lett.*, **72**, 2797 (1994).