Instability of an exciton-polariton condensate

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I will show that recent observations witness the existence of inherent instabilities of exciton-polariton condensates both in the case of nonresonant and resonant pumping. Despite the remarkable developments, the understanding of the fundamental properties of polariton quantum fluids is still incomplete. We fill one of the gaps still remaining: we report the first observation of the long-sought reservoir-induced instability [1]. This instability is an inherent property of the open-dissipative Gross Pitaevskii model, widely used for simulating the dynamics of polariton condensates. Since to date there was no experimental evidence of this instability, its physical relevance was unclear.

In our work we exploit the unique property of organic condensates, which are characterized by strong photon emission and allow for direct single-shot imaging of polariton density patterns. We show that the instability is a real phenomenon by direct experimental observations and comparing them with simulations in the unstable regime of parameters. Excellent agreement allows us to dismiss the competing theoretical model based on the complex Ginzburg-Landau equation [2].

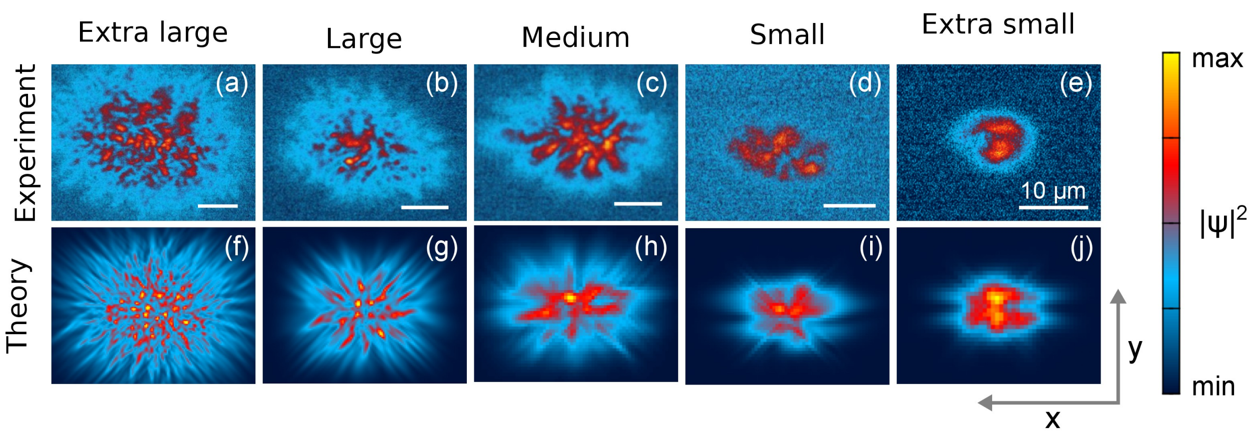

Figure 1. Experimental (top) and numerical (bottom) polariton field density is shown. The size of the pump spot decreases from (a), (f) to (e), (j). The instability leads to the creation of polariton domains.

In the case of resonant excitation, the observation of the real-space collapse of the polariton fluid is explained by the effective attractive interactions mediated by the lattice phonons. The local heating of the lattice leads to the redshift of the exciton resonance, which is equivalent to attractive or self-focusing nonlinearity. Remarkably, this thermal process occurs on the picosecond time scale, which allows to observe a clear collapse of the polariton cloud under pulsed pumping [3].

The observation of instabilities may alter our understanding of superfluidity, coherence, and critical properties of these systems. We believe that our findings can also have impact on other fields of physics where nonequilibrium condensation phenomena are investigated, including cold atom systems, magnon, exciton, or photon condensates.

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[2] N. Bobrovska, M. Matuszewski, K. S. Daskalakis, S. A. Maier, and S. Kéna-Cohen, arXiv:1603.06897.
[3] L. Dominici, M. Petrov, M. Matuszewski, D. Ballarini, M. De Giorgi, D. Colas, E. Cancellieri, B. Silva Fernandez, A. Bramati, G. Gigli, A. Kavokin, F. Laussy, and D. Sanvitto, Nature Commun. **6**, 8993 (2015).