# Spatial Dynamics of an Extended Exciton-Polariton Condensate in a Disordered Environment

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Condensates of exciton-polaritons, quasiparticles created from coherent strong coupling between photons and excitons, have opened the way for studies of novel out of equilibrium physics, where competition between gain and loss drives the rich dynamics of the system, although keeping many similarities to photon lasers, Bose-Einstein condensates and nonlinear systems. Disorder, which is inevitably present in semiconductor microcavities, plays often a crucial role in the formation of topological excitations [1], or nonlinear scattering of polaritonic waves, leading to the occupation of virtual ghost branch states [2].

In this work, we investigate the spatial dynamics of exciton-polariton condensate created in a highly disordered microcavity based on GaAs, with embedded InGaAs quantum wells (disorder amplitude in the sample is comparable to II-VI material based microcavities). The structure was excited nonresonantly with a pulsed laser focused to a small pump spot on the sample surface, which created a local repulsive potential providing the excess energy for radial ballistic polariton ejection. In the vicinity of high potential defects in the structure (having energies comparable with the polariton interaction induced blueshift) the polaritonic waves can be scattered or localized in potential minima. On the other hand, in more homogeneous parts of the sample polariton condensate can freely propagate, forming an extended macroscopic cloud. We tracked these rich dynamics with a streak camera with a 3 ps resolution and record these scenarios. Moreover, we observed the peculiar oscillatory behavior in dynamics of the extended polariton condensate, which depend on the excitation power. Previously it was only observed in the case of localized polariton states [3].

To fully understand the observed phenomena, we performed theoretical simulations within the mean field approach, using dissipative Gross-Pitaevskii equation coupled to incoherent reservoir kinetic equations governing the full dynamics of the system. We used time constants extracted from experiments and carefully adjusted the phenomenological parameters to meet the observed behavior. We reconstructed the experimental observations with a very good qualitative agreement. More importantly, the oscillatory behavior is predicted to be the natural state within this range of parameter space of polariton condensation, where slow reservoir relaxation takes place. We discuss and propose polariton condensates as potential sources of ultra-short pulses of coherent light, without the need for employment of external passive mode-locking architectures.

[1] K. Lagoudakis et al., *Nature Phys.* **4**, 706 (2008)
[2] M. Pieczarka et al., *Phys. Rev. Lett.* **115**, 186401 (2015)
[3] M. De Giorgi et al., *Phys. Rev. Lett.* **112**, 113602 (2014)