Time evolution of spatial coherence in exciton-polariton condensates

T. Donda[a,b], B.R.S.Fabricante[a,b], A.G.Truscott[b], E.Estrecho[a,b], and E.A. Ostrovskaya[a,b]

[a]*ARC Center of Excellence in Future Low-Energy Electronics Technologies,*

[b]Department of Quantum Science and Technology, *Research School of Physics,*

The Australian National University, Canberra ACT 2601, Australia

Exciton-polaritons (polaritons herein) are bosonic quasiparticles formed when an exciton is coupled to a cavity photon in a semiconductor microcavity [1]. These hybrid light-matter quasiparticles form Bose-Einstein condensates at elevated temperatures due to their very small effective mass. However, polariton condensates are inherently non-equilibrium because of the ultrashort lifetime of polaritons and coexistence with a reservoir of high-energy excitons feeding the condensate. As such, they can exhibit new quantum phenomena.

One of the defining features of polariton condensation is the spontaneous appearance of long-range order both in space and in time above a threshold particle density. Understanding how the long-range spatial coherence is established is not trivial due to the condensate's overlap with the incoherent excitonic reservoir [1].

Here, we present time-resolved measurements of the ultrafast evolution of long-range spatial coherence of a trapped polariton condensates spatially separated from the reservoir. A femtosecond pulsed laser shaped into a ring creates the circular reservoir that feeds and traps polariton condensates in its centre. The condensate then decays emitting photons, which we send to a modified Michelson interferometer and image by a streak camera to measure the time-evolution of the first order correlation function, $g^{(1)}(\Delta x)$.

After the laser pulses arrive, we observe a fast increase and redistribution of polariton density into a relatively homogeneous ground state [2]. However, the spatial coherence grows at a much slower rate, suggesting that it takes time for a single phase to be established over the entire condensate. Once established, the spatial coherence is maintained despite the continuous decrease of density due to polariton decay, suggesting that the development of the condensate coherence is enabled by depletion of the incoherent reservoir [3]. At much later time, the spatial coherence disappears once the polariton density decreases below the threshold density.

These measurements on the ultrafast growth and decay of spatial first-order coherence will provide useful insights for understanding the nature of polariton condensation [1].

[1] T. Byrnes, et al., Nature Physics 10, 803-813 (2014).

[2] E. Estrecho, et al., Physical Review B 100, 035306 (2019).

[3] E. Estrecho, et al., Nat. Commun. 9, 2944 (2018).