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Transient Coherence Dynamics of Trapped Exciton-Polariton Condensates

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Exciton-polaritons (polaritons), hybrid quasiparticles formed by excitons coupled to microcavity photons, are known to undergo Bose–Einstein condensation at elevated temperatures. One of the defining features of polariton condensation is the formation of long-range order both in space and time, as demonstrated in continuous wave measurements, which is non-trivial due to the inherently non-equilibrium nature of the system. Since coherence lies at the heart of most polaritonic applications, understanding how long-range order is established within the condensate is crucial for designing polaritonic devices.

Here, we study early dynamics of the temporal evolution of a trapped polariton condensate’s spatial coherence by measuring the first-order correlation function under pulsed excitation conditions.

Our results reveal a significant time gap between condensate formation and coherence establishment. Before coherence is fully established, there is transient behavior characterized by the sudden growth and decay of spatial coherence for up to ~ 300 ns. After the transient period, the system transitions into a steady-state regime characterized by high correlation values, indicating a well-established, high degree of coherence within the condensate. This later behavior persists, even though polariton density is continuously decaying after the initial excitation.

Our results suggest that the observed transient dynamics comes from the multimode character of the polariton condensate at the early stages of condensation. In particular, the overlap between the incoherent excitonic reservoir and the higher-energy modes of the condensate, degrades the polariton coherence and competes with the energy relaxation process that drives the condensation into a highly coherent ground state. As the condensation progresses, all polariton population collapses to the ground state (trap’s center), spatially separating the condensate from the reservoir and eradicating the decoherence effects.

The insights gained from this study will enable more precise engineering of stable, coherent polariton condensates, and therefore enhance the scalability and performance of polaritonic devices.

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