Exploring universal scaling laws in the coherence of polariton condensates

Q. Fontaine [1], D. Pinto Dias [1], F. Hélluin[2], A. Lemaître[1], M. Morassi[1], I. Sagnes[1], L. Le Gratiet[1], A. Harouri[1], A. Minguzzi[2], L. Canet[2], S. Ravets[1], J. Bloch[1,*]

[1]Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies, 91120 Palaiseau, France
[2] Université Grenoble Alpes , CNRS, Laboratoire de Physique et Modélisation des Milieux Condensés, 38000 Grenoble, France

Revealing universal behaviors across different systems is a fundamental goal of statistical physics. It enables the classification of physical systems into broad families characterized by common statistical properties, independent of microscopic details. Initially developed for equilibrium systems, these concepts have been successfully extended to out-of-equilibrium systems, where novel phenomena emerge, such as self-organized criticality. Several universality classes have been identified in non-equilibrium critical phenomena, including the Edwards-Wilkinson (EW) class, which describes smooth stochastic interface growth [1], and the Kardar–Parisi–Zhang (KPZ) class, originally associated with the kinetic roughening of growing interfaces[2].

Exciton-polariton condensates, being intrinsically driven-dissipative, provide a promising platform for studying universal non-equilibrium phenomena. Within a specific parameter range, theoretical predictions suggest that the phase of polariton condensates behaves as an interface whose spatiotemporal evolution is described by the KPZ equation [4] and recent experiments have confirmed that the coherence of one-dimensional polariton condensates exhibits spatiotemporal decay characteristic of KPZ physics [4]. By tuning the nonlinearity of the phase dynamics, we aim to experimentally explore different universal regimes in two-dimensional (2D) polariton condensates: the weakly nonlinear EW regime; the strongly nonlinear KPZ regime, where phase fluctuations grow in a superdiffusive manner; and a vortex-dominated phase at even stronger interaction strengths, where both density and phase dynamics play significant roles [5].

In this talk, we will present Michelson interferometry experiments on extended 2D polariton condensates. By measuring the spatiotemporal decay of the first-order coherence function for different microscopic parameters, we observe a stretched exponential decay near the condensation threshold, with an exponent compatible with the expected KPZ critical exponent. At higher pump powers, the coherence behavior evolves toward a logarithmic decay in space and time, which we associated to EW dynamics. These results provide new insights into the phase diagram of 2D polariton condensates, highlighting their potential as a versatile platform for studying non-equilibrium universality classes in driven-dissipative quantum systems.

References

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*E-mail: jacqueline.bloch@universite-paris-saclay.fr