Self-interference effects in condensed matter systems

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The phenomenon of interference is one of the main manifestations of the wave-like nature of quantum particles. In the Schrödinger picture, particles are well-described by wave packets, and their interference naturally follows from the principle of superposition. The self-interference of a single packet can occur, *e.g.* when bouncing against a potential wall. However, a wide range of quantum systems allow for dispersion engineering, with the appearance of regions of negative effective mass permitting the free propagation of self-interfering wave packets in the absence of an external potential or applied forces. This effect was first predicted theoretically for exciton-polariton systems [1]. It was later observed in 1D atomic spin-orbit coupled Bose-Einstein condensates (SOC-BEC) [2,3] and also found to be at the origin of the formation of polariton nonlinear X-waves [4]. Here we show that self-interference can develop due to the presence of nonlinear interactions, despite being a pure linear effect of the dispersion relation. We demonstrate how the X-wave formation can be understood using the wavelet transform, a spectral decomposition that provides unique insights into the nontrivial dynamics of wave packet propagation that can fully characterize self-interfering wave packets. The wavelet transform also provides a new perspective on another well-known non-spreading wave packet: the Airy beam, a solution of the free Schrödinger equation with surprising properties [5].

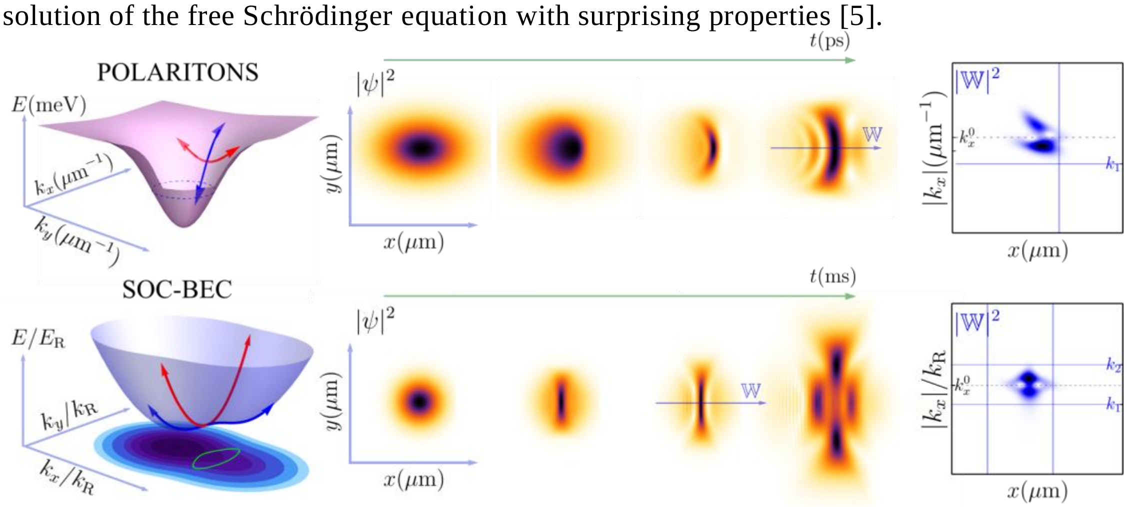

Figure 1: Propagation of nonlinear X-waves in an exciton-polariton system (top row) and in a 2D SOC-BEC system (bottom row). The X-wave is self-generated from an initial Gaussian wave packet that is initially placed in the hyperbolic region of the dispersion relation. The wavelet analysis reveals the interference mechanism that leads to the X-wave formation.

References

[1] D. Colas and F. P. Laussy, Phys. Rev. Lett. **116**, 026401 (2016).
[2] M. A. Khamehchi *et. al.*, Phys. Rev. Lett. **118**, 155301 (2017).
[3] D. Colas, F. P. Laussy and M. J. Davis, Phys. Rev. Lett. **121**, 055302 (2018).
[4] D. Colas, F. P. Laussy and M. J. Davis, Phys. Rev B. **99**, 214301 (2019).
[5] D. Colas, F. P. Laussy and M. J. Davis, *in preparation* (2019).