Exciton-Polaritons as a platform for quantum optics in solid-state systems

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Exciton-polaritons are hybrid light-matter excitations arising from the strong coupling between an electromagnetic mode and an excitonic transition of a semiconductor material. As mixed particles, they get the best of two worlds: low effective mass and long coherence from their photonic component and strong interactions from their matter component.
This unique mixture of features makes them an excellent playground to explore the physics of interactive bosons in solid state systems. As bosons, polaritons tend to macroscopically occupy the same macroscopic quantum state resulting in the celebrated Bose-Einstein polariton condensate[1,2].
A question that has naturally risen and is currently highly debated is if polariton-polariton interactions can be used in quantum optics, namely as interactive qubits. Should this be the case, a new generation of solid-state chips could provide quantum optics functionalities like deterministic C-NOT quantum gates, qubits routing, and entangling.
To explore the potential of quantum polaritonics, we have excited polaritonic semiconductor microcavities with quantum light. We have observed the propagation of single polaritons and directly proved their wave-particle duality[3]. We have also demonstrated that entanglement is conserved in the photon-polariton-photon conversion and that it can be retrieved after polariton propagation inside a nonlinear medium[4].
More recently, we have been studying polariton waveguides acting as nonlinear integrated circuits[5], showing that these systems provide a promising platform for deterministic quantum gates operating at the few particles level.
These results confirm that polaritons are an alternative, promising platform for quantum information processing in solid-state systems.

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