Measuring Exciton-Polariton Interactions at the Few Particle Level

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Exciton-polaritons are hybrid part-photon part-exciton quasi-particles behaving like photons dressed with giant inter-particle interactions coming from their excitonic component. These interactions have enabled a wide range of effects from optical condensation to single photon switching and an emerging area of quantum polaritonics [1, 2, 3, 4]. Despite a wealth of experiments at medium and high densities important questions still remain about the details of these interactions, even in the well known GaAs-based systems [5, 6].

Here we present the latest developments in our experimental techniques which allow few-particle all-optical switching and high sensitivity measurement of polariton interactions in the very low density regime. It is based on our previous work measuring single polariton cross-phase-modulation in solid micropillar cavities [3]. Compared to that work we make a number of significant experimental advances that greatly improve the utility of the method for characterising nonlinearities. We now employ a highly flexible open-access cavity [7] which allows tuning the optical states to measure frequency dependencies. We furthermore generate pump and probe pulses using electronically triggered high speed electro-optical modulators allowing electronic control of repetition rate, pump-probe delay, and pulse width in the range ~ 50 ps to 1 ns. Time-tagged single photon counting using avalanche detectors and external marker channels allows separation of pump and probe by temporal shape, high-speed polarisation dependence sweeps, and high signal to noise ratio needed to resolve nonlinear response at very low densities suitable for studying quantum optical effects and where complicating thermal and free carrier effects are minimised.

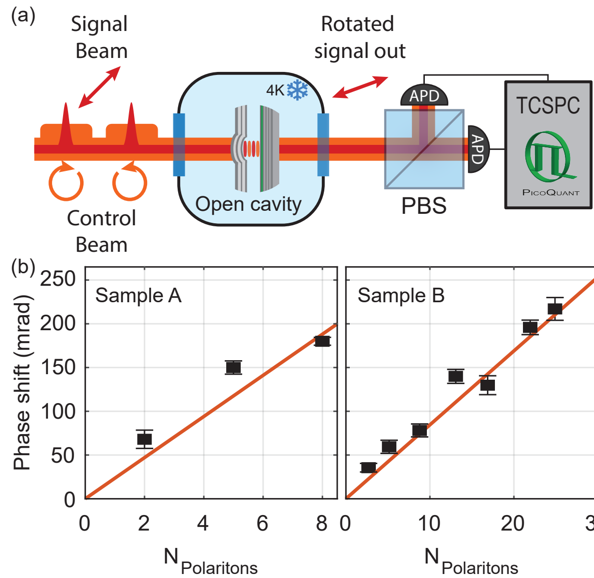

Fig. 1. (a) Simplified schematic of the experimental setup. (b) Measured phase shift as a function of the excited polariton number.

For GaAs-based cavities we have so far measured single photon nonlinear modulation of up to 21 mrad for the co-circularly polarised component of the interaction constants, $\sim$ 7x higher than in solid cavities [3]. We find that the saturation effect previous observed with continuous wave excitation is greatly reduced, allowing up to 25% modulation of the probe pulses using control pulses containing only $\sim$ 5 aJ of energy. We also use the cavity tuneability to explore the frequency dependence of the interactions and saturation. Going forward, this system can allow detailed study of single particle nonlinearities in a wide range of material systems [8].

References

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