Multi-Quantum Coherences Measure the Exciton-Polariton Ladder of States in a Microcavity

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Exciton-polaritons result when the coherent exchange of energy between excitons and light is strong, giving new eigenmodes. We study these eigenmodes using a collinear approach to 2D near-IR spectroscopy. Multi-quantum coherences reveal higher-order avoided crossings inaccessible in standard experiments. These avoided crossings reveal the structure of the cavity polariton.

Exciton-polaritons are quasiparticles from the collective strong coupling of excitons and light. Strong light-matter coupling is characterized by the formation of new eigenmodes when the rate of energy exchange between an absorbing medium and an electromagnetic field exceeds loss rates [1]. The light-matter interaction can be enhanced by placing the absorbing medium in a microcavity. The regime of strong coupling is characterized by avoided crossings between polariton states. The exciton and other collective systems are predicted to possess higher lying states and avoided crossings, which have proven difficult to observe [2].

We use collinear multi-quantum coherent spectroscopy [3] to observe these higher states and their avoided crossings. Our sample consists of three InGaAs quantum wells surrounded by doped Bragg mirrors. These doped Bragg mirrors create a cavity and form a p-i-n diode. The cavity ensures strong coupling while the diode allows for signal collection as a photocurrent. Changing the exciton-cavity detuning as a function of incident excitation angle/wave-vector, and using collinear pulses, prevents the wave-vector mixing of higher lying states. Measurement of doubly and triply excited dispersion curves reveals the existence of strong coupling at higher excitation levels. The doubly excited spectrum Fig. (1) exhibits three states and a doubly avoided crossing, while the triply excited state exhibits four states and a triply avoided crossing.

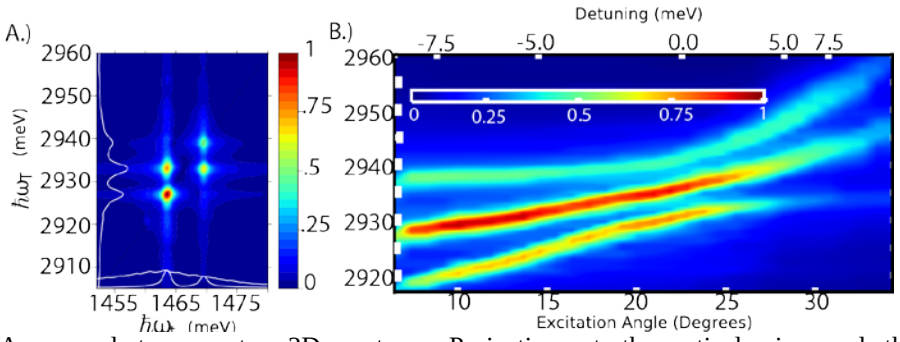

Figure 1. A). An example two-quantum 2D spectrum. Projection onto the vertical axis reveals three states. B). Measurement of the doubly excited exciton-polariton avoided crossing as a function of incident e. This spectrum shows two avoided crossings between three states. The high energy state is a doubly excited upper polariton. The lowest energy state corresponds to a doubly excited lower polariton. The middle energy state is an admixture of an upper and lower polariton.

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