Isolation and Characterization of Individual Interfacial Quantum Dots Using 2D Coherent Spectroscopy

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Via an original collinear multidimensional coherent spectroscopy (MDCS) technique, we resolve and measure individual oscillators in a layer of interfacial quantum dots. Only a few oscillators are excited by focusing tightly, which is possible in a fully collinear geometry. Unfolding the signal spectrum in 2D further isolates the emitters.

Excitons localized in a semiconductor quantum dot are typically modeled as isolated atom-like systems. Due to their isolation and often long coherence times, excitons confined to a quantum dot have been proposed as a potential system for quantum information applications. In interfacial quantum dots, islands of monolayer fluctuations formed in a thin (15 monolayer) quantum well, long-range interactions have been measured between these localized excitons [1]. Though interactions should degrade the coherence times, they also open the door for use of interfacial dots as qubits with electronic degrees of freedom. Understanding the nature of this interaction is important in order to generate a complete theory of quantum dots.

We have developed a variant of the method used in references 2 and 3 that uses heterodyne detection to measure a radiated TFWM signal, shown in Fig. 1. The collinear geometry and a ~1.5 μm spot helps us spatially isolate few dots [4], and our detection allows for a high signal collection efficiency. We measure a homogeneous linewidth of 90 μeV and isolate spectral features with the same linewidth. With MDCS tools now available we can better isolate dots, measure coupling between them, and directly measure fine structure due to dot asymmetry.

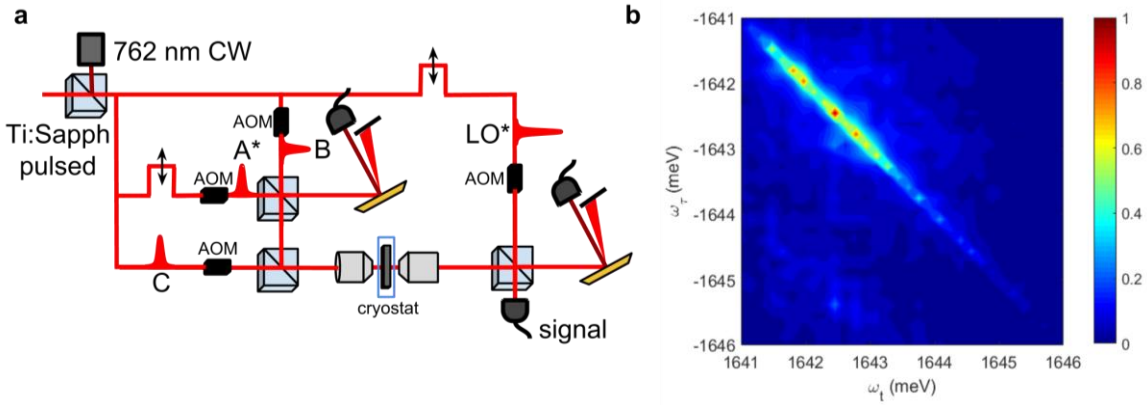

Fig. 1 **a.** A simplified diagram of the experimental setup. Three excitation pulses A*, B, and C are frequency tagged with acousto-optical modulators (AOM), and combined before the sample. They are focused down to ~1.5 μm diameter at the interfacial quantum dot sample by a 100x microscope objective, a spot size at which there are few enough dots to resolve them individually. The emitted transient four-wave mixing signal (TFWM) is interfered with a local oscillator (LO*) on a detector, and the TFWM signal is extracted with lock-in detection, similar to [2, 3]. A weak continuous-wave beam (CW) co-propagates with the pulsed laser to sample mechanical fluctuations of the signal phase, and it is used to generate the reference isolating the phase-resolved signal. **b.** The absolute magnitude of the rephasing signal shows large fluctuations along the diagonal that are indicative of the spectral isolation of individual quantum dots. Unfolding the spectrum in two dimensions allows for isolation of dots in a larger sample volume than would be possible with a one-dimensional scan. The resolution here is limited by scan duration.

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