Carrier transfer between InGaAs/GaAs quantum dots observed by differential transmission spectroscopy

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Abstract: We employ two-color differential transmission spectroscopy to investigate coupling between InGaAs/GaAs QDs. Resonantly excited carriers escape and are captured by non-resonant dots with a time constant of 32 ps at room temperature.
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We observe carrier transfer between self-assembled InGaAs/GaAs quantum dots (QDs) at temperatures above 230 K using differential transmission spectroscopy (DTS). The sample is a single layer of QDs embedded in a semiconductor waveguide to increase the interaction length of the weakly absorbing QDs [1]. Pump and probe light is generated by an optical parametric oscillator synchronously pumped by a mode-locked Ti:sapphire laser. The probe signal is isolated from the pump by either optical gating with the residual Ti:sapphire beam or by high frequency modulation and detection with an RF lockin amplifier.

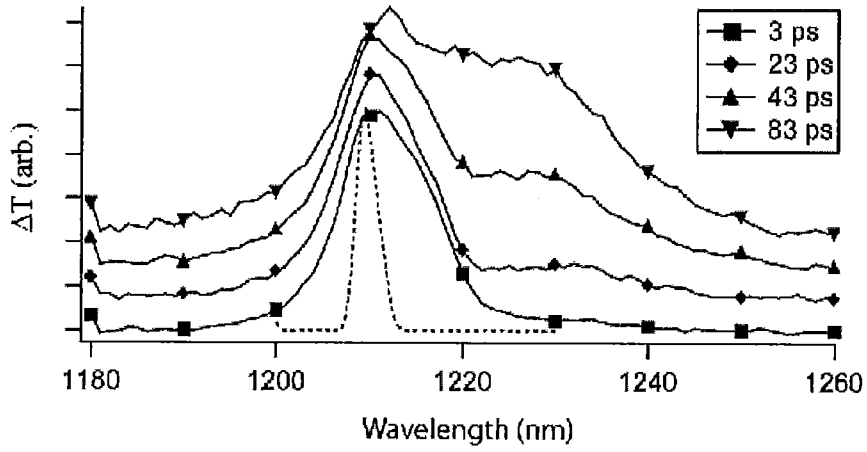

Fig. 1. Spectrally resolved differential transmission for various delay times. The dashed line indicates the pump spectrum. Traces are offset for clarity.

Fig. 1 is the spectrally resolved DT on the ground state of the QDs at various delays between pump and probe. For this measurement the pump beam is spectrally filtered to a bandwidth of ~ 2 nm with a zero-dispersion pulse shaper and the probe beam is spectrally resolved with a monochromator after interaction with the QDs. This allows us to observe the evolution of the DT signal for QDs resonant and non-resonant with the pump excitation. At small pump-probe time delays, the DT signal indicates a spectral hole much larger than the pump bandwidth. We believe that the width of this initial signal (12 nm FWHM) is representative of the homogeneous linewidth of the QDs and is in reasonable agreement with data from four-wave mixing [2] and single-dot photoluminescence [3]. As the delay is increased, a signal is observed

at wavelengths not covered by the initial spectral hole. After analyzing the time dependence of these two contributions to the differential transmission signal, it was determined that the decay time of the spectral hole and the rise time of the non-resonant signal were almost identical (~32 ps). This is clear indication that carriers initially generated in resonant QDs escape, and are recaptured by non-resonant QDs. Previous DT measurements have shown this initial recovery of the absorption bleaching, but were not able to resolve the transfer of carriers to non-resonant QDs [4,5].

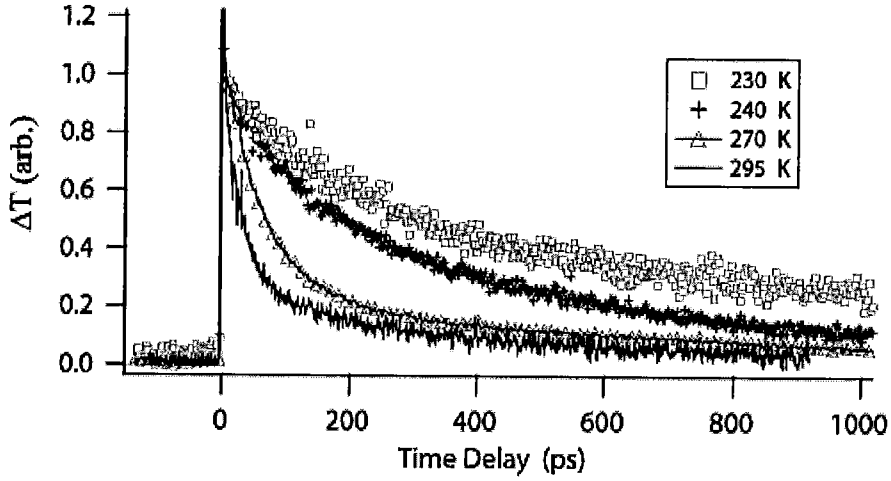

Fig 2. Temperature-dependent differential transmission on the ground state transition of the quantum dots

To further investigate the carrier escape process, we performed temperature-dependent, degenerate, DT measurements on the same sample. The results are displayed in Fig. 2. Ground state absorption recovers with a time constant that increases from 32 ps to 130 ps as the sample temperature is reduced from 295 K to 230 K. We fit the time dependence of this recovery, and obtain an activation energy of 128 meV, which corresponds to approximately 4 LO phonons in InGaAs. These results are consistent with temperature-dependent photocurrent spectroscopy on InAs QDs [6].

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