Room-temperature dephasing in InAs/GaAs quantum dots

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When the relaxation energy matches an available phonon energy, the emitted photons fulfill the resonance condition by the emission of a LO phonon. Therefore, the observed PLE resonances are attributed to resonant Raman features.

These results provide new insights into the relaxation process in SAQDs as follows: the carriers can relax within continuum states, and make transitions to the excited ground state by resonant phonon scattering before PL emission, thus allowing for the intense PL peak observed for SAQDs.

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**Room-temperature dephasing in InAs/ GaAs quantum dots**


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Semiconductor quantum dots (QDs) are receiving increasing attention for fundamental studies on zero-dimensional confinement and for device applications. Quantum-dot lasers are expected to show superior performances, like high material gain, low and temperature-independent threshold current and chirp-free operation, due to the delta-like density of states (DOS).

In this work we have measured the dephasing time at room temperature of InAs QDs embedded in a waveguide to estimate the lower limit for the energy-broadening of the DOS given by the homogeneous linewidth. The sample consists of 3 stacked layers of InAs/GaAs/GaAs quantum dots in the center of 120 nm GaAs embedded between two AlGaAs cladding layers, in a ridge structure 8 µm wide and 400 µm long, with tilted facets. In Fig. 1 the responses of the device under injection of Fourier-limited optical pulses of different spectral widths are shown. The energy of the pulse at the output of the waveguide is measured by a Ge-detector with lock-in technique. A beating of the absorption with increasing input intensity is clearly observed. Additionally, short pulses experience increasing absorption with input intensity due to two-photon absorption.

For a constant input spectral energy $E_\text{in}$ (energy per unit frequency) different beating occurs for different pulse-widths. This is simulated (solid lines in figure) by modeling the spectral hole-burning of the absorption coefficient induced by a pulse with a spectral width larger (open square) or smaller (open circle) than the homogeneous broadening of the dots. The beating shows a linear decrease of the absorption versus $E_\text{in}$ with a slope that depends on pulse-width and dephasing time $T_\text{2}$. In the inset, the slopes obtained from the initial beating are shown, with a fit according to our model, giving $T_\text{2} = 189 \pm 67$ fs.

Another technique for measuring dephasing is four-wave mixing (FWM). FWM in thin films with spatial selection of the non-linear signal has been widely reported. However, FWM on InGaAs QDs has not yet been reported due to the weak signal from the small interaction volume and the large homogeneous broadening. We have used the heterodyne technique discussed in Ref. 4 to perform FWM in the waveguide geometry, with the advantage of using the entire length of the device as interaction length. Figure 2(a) shows the amplitude of the time-resolved FWM electric field, by scanning over the delay of the reference beam, at different delay times $\tau$ of the exciting beams. Excitation and reference pulses had 200 fs intensity autocorrelation width. The photon-echo nature of the FWM is seen by the time-shift of the signal. A fit of the signal for $\tau = 350$, 400 fs is performed by using the formula: $E(t) = E_0e^{-\sigma/\sqrt{2\pi}}e^{-\sigma^2t^2/4}$, where $\sigma$ is 1.4 times the standard deviation of a Gaussian distribution. $T_\text{2} = 189 \pm 5$ fs is obtained. The integrated area of the FWM intensity is shown in Fig. 2(b) for the field reported in Fig. 2(a) and for half the excitation intensity. A fit of the decay is shown and the corresponding values of $T_\text{2}$ are indicated, together with the zero-density extrapolated value. These values are in good agreement with the ones reported in Fig. 1 within error bars.

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