PNONON EMISSION BY OPTICALLY PUMPED INDIUM ARSENIDE QUANTUM DOTS IN GALLIUM ARSENIDE

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The possible mechanisms of energy relaxation by zero-dimensional electrons in quantum dots are the subject of continuing controversy. It is predicted that relaxation between the discrete "atom-like" electron states is inefficient due to the so-called phonon bottleneck effect. That is, high energy acoustic phonon emission is assumed to be weak due to momentum conservation considerations and, unless the separation between levels matches exactly the optic phonon energy, optic phonon emission is not possible. However, the InAs/GaAs quantum dot system is observed to have high photoluminescence efficiency which implies that electron relaxation in the dots is efficient.

In earlier experiments [1] we observed evidence for strong acoustic phonon emission from InAs quantum dots embedded in GaAs. In a later paper [2] we attributed this to exciton relaxation: instead of considering the electron and hole separately, we considered the exciton formed when an electron and a hole are captured by a dot. The closest energy spacing of the exciton levels is similar to the separation of hole levels. This is small enough for transitions accompanied by strong low-energy acoustic phonon emission to occur.

In this paper we describe new measurements on a vertically coupled quantum dot array. Owing to efficient electron tunneling between dots, is was expected that carrier relaxation in such an array would show some features associated with quantum wires.

The sample structure was grown by molecular beam epitaxy on 0.38 mm-thick semi-insulating GaAs wafers. It consisted of 10 layers each of 1.8 monolayers of InAs capped with 1.7 nm-thick GaAs. With such thin capping layers, the Stranski-Krastanov growth mode leads to vertical alignment of the InAs dots. Carriers were excited optically in the GaAs surrounding the dots using 10 ns pulses of ? = 524 nm radiation from a frequency doubled Q-switched Nd-YLF laser focussed to a spot 30 µm-diameter on the sample. The phonons emitted as the carriers were captured into the dots and the relaxation phonons and luminescence emitted by carriers in the dots were detected using superconducting bolometers on the back face of the substrate. By scanning the laser spot over the sample, images of the luminescence intensity and phonon emission were made. We compare the time resolved, heat pulse, phonon signals and the phonon images obtained using the coupled dot array with our earlier results on uncoupled quantum dots.

[1] P Hawker, A J Kent and M Henini, *Appl. Phys. Lett.* **75**, 3832 (1999).
[2] R Bellingham, A J Kent, A V Akimov and M Henini, *Phys. Stat. Sol.* **224**, 659 (2001).