Quantum-Dot-Array Based Terahertz Detectors

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We examine the terahertz conductivity response of lithographically defined quantum dot arrays as a function of temperature, dot size and photo excitation. Quantum dot structures have been explored as possible compact sources and detectors of THz radiation. Currently convenient terahertz sources and detectors are in demand for surveillance and materials characterization applications. However to date most successful device strategies are based on SET type detection at or below 4K. To a large extent the limitation has been due to limited radiative interaction with the device. Antenna coupling used to enhance coupling to single dots often suffers from large ohmic losses in the antenna itself. Here we consider a lithographically defined array with high uniformity and high duty cycle to increase FIR optical density. Specifically we examine the cross over from continuum to discrete response as the quantized energy level spacing becomes commensurate with the FIR. Samples are lithographically defined using $GaAs/Al_{0.3}Ga_{0.7}As$ modulation doped two dimensional electron gas wafers with nominal 4 K mobility of 2 x 10^6 cm^2/Vs and 2D charge density of $n = 2.7 \times 10^{11}$ cm^{-2}. Quantum-dot arrays are fabricated using e-beam lithographically and wet etching or RIE. Measurements of the complex conductivity response at THz frequencies are made using terahertz time domain spectroscopy. We compare the absorption with Drude type absorption with nonparabolicity effects due to the pushing of the Fermi energy to higher energy due to confinement within the dots. We extract from the model a momentum relaxation time and consider how well it resembles that predicted by temperature dependent mobility. Results are shown for an unprocessed 2DEG sample in the figure, where we find good agreement between the terahertz measured momentum relaxation time and the mobility characterization. We will discuss the implication of these results on the realization of FIR detectors based on QD arrays. Work funded in part by the Office of Naval Research (N00014-98-0594) and the Department of Energy (DE-FG03-01ER45920).

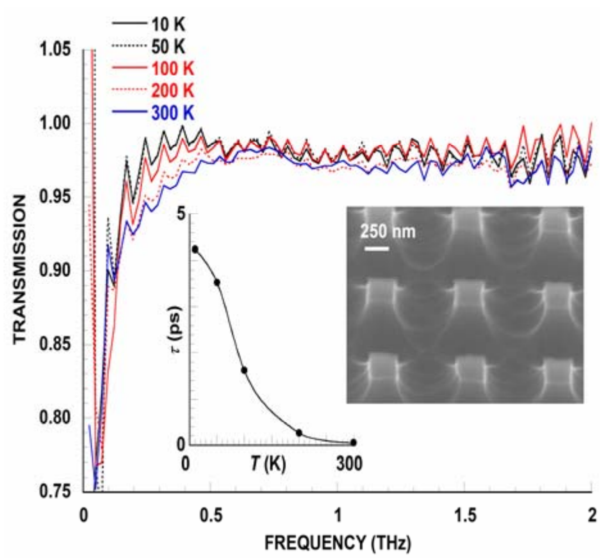

Figure 1: The main panel shows the THz transmission of a GaAs two-dimensional electron gas, measured relative to a blank substrate. The left inset shows the variation of relaxation time with temperature extracted from the measurements. Right inset shows a scanning-electron micrograph of the quantum-dot arrays that we also study.