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Optical properties of modulation-doped InAs/GaAs quantum dots

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We have investigated the many-body effects and the relaxation processes of InAs/GaAs modulation-doped quantum dots (MDQD's) by using the steady-state and time-resolved photoluminescence (PL) measurements. InAs QDs were grown by MBE during the deposition time corresponding to 2.5 ML thickness, and covered with 10 nm layer and 50 nm Si doped GaAs layer. As the modulation doping concentration of GaAs barrier increases, the peak positions of the MDQD's PL spectra shift to low energy. A relation between the renormalization energy (ΔE_g) and the electron density (N) occupying MDQD's is given by $\Delta E_g \propto N^{1.9}$. The larger exponent value for MDQD's than that (0.32) for quantum wells is attributable to the disappearance of exchange interaction of electrons within a single state. We also obtained from the time-resolved PL measurement that the lifetimes of three MDQD's are longer than that of undoped QD's, and increases with the excitation intensities. These results show that the interaction between the electrons inside the QD's is screened by the electrons at the GaAs-doped layer as well as the photogenerated 2D carriers. It is apparent that the screening effect due to the carriers at GaAs matrix play an important role in determining the radiative recombination rate of the MDQD's spectra. We also report the observations of phonon bottleneck effects and Auger processes in MDQD's by using various excitation wavelengths.