Fock, Darwin, Coulomb and the Magneto-Luminescence of Highly Homogeneous Quantum Dot Ensembles

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We demonstrate that a well-controlled strain-driven self-assembly technique combined with a simple annealing procedure is capable of producing large ensembles of virtually identical semiconductor quantum dots analogous to the precise assembly of identical molecular structures in molecular electronics. Despite the fact that each dot plus its solid state environment consists of millions of atoms, we show that their emission/absorption spectra can be understood in terms of a simple harmonic oscillator model, the Fock-Darwin Spectrum (F-D) [1]. The occurrence of the FD spectrum in semiconductor nanostructures has previously been deduced from Coulomb blockade spectroscopy of a single microfabricated sub-micron electrostatic quantum dot [2]. In that case the spectrum needs to be separated from an additional charging energy term which usually dominates the addition spectrum. In contrast, by following the interband emission of charge-neutral electron-hole pairs in a large array of nano-size self-assembled islands subject to ultra-high magnetic fields (28T), we directly observe the F-D spectrum representative of the QD-ensemble. Thus, one can amazingly observe basic quantum mechanical effects, previously associated with an ideal single-particle system, in an artificial system made of a large number of spontaneously assembling nanostructures composed of billions of atoms with corresponding number of interacting electrons. This provides a clear demonstration of the potential use of self-assembly to obtain cost-efficient, large scale integrated quantum devices.

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