Electronic Properties of Nanostructured Quantum Dots

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Abstract
In this paper, property analysis of quantum dot cuboid nanocrystals with different nanostructures are shown by simulation results for particular device structure and boundary conditions of Light and dark Transitions for the X, Y and Z-Polarized for different structures and so forth. EOM is a systematic method to derive analytic expressions for GF Wise (sometimes) extrapolation of perturbation theory. Applied to Anderson model, excellent for not-too-strong correlations fair qualitative picture of the Kondo regime self-consistency improves a lot. Finally from the simulation, it is evident that, the characteristics are almost equivalent for different nanostructures for a particular boundary condition. In this paper electronic properties of nanostructured quantum dots are analyzed.

Keywords: Quantum dot, nanocrystals, nanostructure.

1. Introduction
A quantum dot is a semiconductor nanostructure that confines the motion of conduction band electrons, valence band holes, or excitons (pairs of conduction band electrons and valence band holes) in all three spatial directions. A quantum computer is any device for computation that makes direct use of distinctively quantum mechanical phenomena, such as superposition and entanglement, to perform operations on data. The quantum properties of particles can be used to represent and structure data and that quantum mechanisms can be devised and built to perform operations with these data. Any solid material in the form of a particle with a diameter is comparable to the wavelength of an electron. Quantum Dots is man-made artificial atoms that confine electrons to a small space. As such they have atomic-like behavior and enable the study of quantum mechanical effects on a length scale that is around 100 times larger than the pure atomic scale. Quantum dots offer application opportunities in optical sensors, lasers, and advanced electronic devices for memory and logic. Quantum dots were predicted to exhibit interesting cooperative behavior in many-dot systems with overlapping wave functions, due to the resulting miniband structure, and also as elements in cellular neural networks. However, no scheme for using discrete quantum dots for computing was proposed during this period. These “dots” were not quantum dots in the energy quantization sense, but rather relied on their ultra small capacitance, which was a consequence of their very small size, to reveal measurable voltage changes with charge variations of only a single electron. Such behavior is classical, except for tunneling between dots. In confined semiconductor dots, the energy quantization is superimposed on the Coulombic effects, but is not the primary phenomenon of interest. At the heart of the fluorescence of Quantum dot nanocrystals is the formation of excitons, or Coulomb correlated electron-hole pairs. The exciton can be thought of as analogous to the excited state of traditional fluorophores; however, excitons typically have much longer lifetimes (up to ~μseconds), a property that can be advantageous in certain types of "time-gated detection" studies. Yet another distinction arises from the direct, predictable relationship between the physical size of the quantum dot and the energy of the exciton (therefore, the
wavelength of emitted fluorescence). This property has been referred to as “tuneability”, and is being widely exploited in the development of multicolor assays. Quantum dot nanocrystals are also extremely efficient machines for generating fluorescence; their intrinsic brightness is often many times that observed for other classes of fluorophores. Another practical benefit of achieving fluorescence without involving conjugated double-bond systems is that the photostability of Quantum dot nanocrystals is many orders of magnitude greater than that associated with traditional fluorescent molecules; this property enables long-term imaging experiments under conditions that would lead to the photo-induced deterioration of other types of fluorophores. The main objective of our experiment was to Study and understand the electronic properties of coupled quantum dots and to determine the coupling between these dots using vertical electric fields. For that, we have to assemble optical techniques of Photocurrent Measurements and Photoluminescence. Single quantum dot ensembles are: PC technique successfully applied to single layer of quantum dots, Stark Shifts and Oscillator Strengths. But we have to sort out for coupled quantum dot.

2. Electronic Structure and Dimensions

For Optical Excitation, the characteristics of Exciton are it is bound electron-hole pair and for the Excite semiconductor, it is creation of electron-hole pair. There are postulates behind these: There is an attractive potential between electron and hole. In hydrogenic system, mass of hydrogen is greater than electron and from Bohr Theory, Binding energy is determined. The excitons confined to the dot are discrete energies and Degree of confinement determined by dot size and Exciton absorption is function-like peaks in absorption. Now for the clarity of the nanostructure of dot, an analysis on comparison between Bits and Quantum bits are discussed. These are: a Quantum bit can hold a one, a zero, or, crucially, a superposition of these. A classical computer has a memory made up of bits, where each bit holds either a one or a zero. The Quantum bits can be in a superposition of all the classically allowed states. The register is described by the phases of the numbers can constructively and destructively interferes with one another; this is an important feature for quantum algorithms. For an $n$ quantum bit quantum register, recording the state of the register requires $2^n$ complex numbers (the 3-quantum bit register requires $2^3 = 8$ numbers). Consequently, the number of classical states encoded in a quantum register grows exponentially with the number of Quantum bits. For $n=300$, this is roughly $10^{90}$, more states than there are atoms in the observable universe. Electronic structure can be Formed during epitaxial growth of lattice mismatched materials e.g. InAs on GaAs (7% lattice mismatch) and Form due to kinetic and thermodynamic driving forces – energetically more favourable to form nanoscale clusters of InAs. Some general properties are: Perfect crystalline structures, High areal density (10-500µm-2), Strong confinement energies (100meV), Lasers (Jth<6Acm-2) in visible and near infrared, Quantum Information and Cryptography. For SAQDs - z-axis confinement is generally much stronger than transverse quantisation x,y (Ez>>Exy). QD states are often approximated as a 2D Harmonic oscillator potential – Fock-Darwin states. Orbital character of QD states similar to atomic systems. The shells $n=1,2,3$ - often termed s,p,d,... in comparison with atomic systems. Dipole allowed optical transitions $D_n=0$. Single X transitions observable in absorption experiment. QDs should be self-assembled (for economic gains, not quite in reach of nano-lithography) for the reasons of semiconductor with smaller bandgap embedded into matrix with large bandgap, just right size, large enough to accommodate an exciton, small enough in all directions for quantum confinement, no structural defects such as dislocations. The key factor here is uniformities of size, shape, chemical composition, strain distribution, crystallographic phase, and mutual alignment. For optoelectronics, there is no contacting problem, only problem QD array homogeneity, active medium in lasers, (In,Ga,Al)As based 1.3 µm, far infrared detectors, novel device concepts such as quantum cellular automata, Isolation of a single Quantum Dot, Emission spectroscopy, and Power-dependence reveals the different configurations.
Dimensions and Results

For a free electron, \(3/2k_B T = \frac{\hbar^2}{2m} \approx 60\) for quantum effects: \(\approx 10^5\); in semiconductors, use \(m_e^*\) (effective mass) instead: \(m_e^*/m_e \approx 1/10\), for quantum effects: \(100\)s \((10\) nm\). The number of atoms \(\approx 10^3 - 10^6\). Properties are determined by size of Quantum dots. Small quantum dots, such as colloidal semiconductor nanocrystals, can be as small as \(2\) to \(10\) nanometers, corresponding to \(10\) to \(50\) atoms in diameter and a total of \(100\) to \(100,000\) atoms within the quantum dot volume. At \(10\) nanometers in diameter, nearly \(3\) million quantum dots could be lined up end to end and fit within the width of a human thumb. Quantum wires, which confine the motion of electrons or holes in two spatial directions and allow free propagation in the third. Quantum wells confine the motion of electrons or holes in one direction and allow free propagation in two directions. Both have a discrete energy spectrum and bind a small number of electrons. In contrast to atoms, the confinement potential in quantum dots does not necessarily show spherical symmetry. In addition, the confined electrons do not move in free space but in the semiconductor host crystal play an important role for all quantum dot properties. In contrast to atoms, the energy spectrum of a quantum dot can be engineered by controlling the geometrical size, shape, and the strength of the confinement potential. It is relatively easy to connect quantum dots by tunnel barriers to conducting leads. If now Motion technique applied to quantum dot models, according to the Anderson model

\[
\mathcal{H} = \sum_{\sigma = \uparrow, \downarrow} \varepsilon_\sigma n_\sigma + U n_\uparrow n_\downarrow + \sum_{k\sigma} \left( V_{k\sigma}^C c_{k\sigma}^\dagger d_{\sigma} + V_{k\sigma}^{*} d_{\sigma}^\dagger c_{k\sigma} \right) + \sum_{k\sigma} \varepsilon_{k\sigma} c_{k\sigma}^\dagger c_{k\sigma}
\]

Here Generalizations are structured leads ("mesoscopic network"), multilevel dots / multiple dots with capacitative / tunneling interactions, Spin-orbit interactions and many-body interactions restricted to the dot are essential. We have to treat Anderson model using Perturbation theory (PT) in \(\Gamma\), tricky to extend into strong coupling (Kondo) regime, Map to a spin model and do scaling, Numerical Renormalization Group (NRG), accurate low energy physics, integrability condition too restrictive, finite \(T\) laborious, Equations of motion (EOM).

3. Conclusion

The main objective of our experiment was to study and understand the electronic properties of coupled quantum dots and to determine the coupling between these dots using vertical electric fields. In this paper electronic properties of nanostructured quantum dots are analyzed. Finally from the simulation, it is evident that, the characteristics are almost equivalent for different nanostructures for a particular boundary condition. In this paper electronic properties of nanostructured quantum dots are analyzed.

References


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