Quantum dot addition energies: magnetic field and interaction screening

Antonio Puente, Rashid Nazmitdinov and Miquel Pons Viver

Departament de Física, Universitat de les Illes Balears, E07122 Palma de Mallorca, Spain
toni.puente@uib.es

Quantum dots (QDs) have drawn a great deal of experimental and theoretical attention in recent years. In particular, this interest is due to the fact that QDs may provide a natural realization of quantum bits. It is also related to fundamental aspects of strongly correlated finite systems, which are different from bulk and can be controlled experimentally [1].

A convenient starting point to deal with the theoretical description of finite systems is, in many cases, a mean field treatment like the Hartree-Fock (HF) approach, either in space-restricted (RHF) or space-unrestricted (UHF) schemes. As the case may require, depending on the model confining potential, post HF projection techniques can be applied to restore broken symmetries [2]. In this framework, selfconsistency between the mean field and the single-particle orbitals and total energy minimization are the basic conditions. The HF energy is a non linear functional of the single-particle states and a careful search for the absolute minimum, particularly important at high magnetic fields, is an essential requirement of the method. Moreover, one of the difficulties encountered in analyzing individual dot data is that energies have to be computed to very high precision. Experimental transport data through these systems, often presented as a difference between the gate voltages for two successive current peaks, can be related to the addition energy, $E_A(N)=E_{N+1}-2\,E_N+E_{N-1}$, the second difference of the total energy with respect to the number of electrons in the dot. In typical QDs, the addition energy is around a few meV while total dot energies can be 1 to 3 orders of magnitude larger so that high precision is needed. This implies not only a good model description, but also as mentioned above a careful search for the ground state energies, which becomes harder in the high magnetic field regime where the density of states around the energy minimum increases.

In this work we analyze the role of screening in the electron-electron interaction in the description of addition energies as a function of vertical magnetic field intensity and parabolic confinement, within a RHF formalism. We discuss the evolution of the quantum dot geometry for the ground and first excited states, and the structure of the density of states near the absolute energy minimum. Spin transitions and *N*-dependent ring shape isomers develop with the intensity of the applied magnetic field at a rate which scales with the interaction strength vs the parabolic confinement ratio, the so called Wigner parameter, R_W. A comparison with available experimental data [3] is shown.

References

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