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Some Theoretical Results on Semiconducting Spherical Quantum Dots

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Quantum Dots (QDs) have appeared in the last twenty years as one of the hot topics in Nano-physics. In the foreseeable future, they have emerged as the carriers of a wide range of new applications, e.g. as sources for a semiconductor laser or single photons in quantum optics, as qubits for quantum information processing, as single-electron transistors in electronics, or as artificial fluorophores for intra-operative detection of tumors, biological imaging or cell studies. Thus, a close theoretical investigation on their behavior and resources as a quantum object seems to be justified.

In this work, we are interested in semiconductor spherical QDs for which many of the quantum effects at the nanometric level have been observed and measured. To apprehend correctly the quantum properties of a confined interactive electron-hole pair, we follow an analytical approach built upon the effective mass approximation in a spherical infinite confinement potential well to which a new pseudo-potential is superimposed. The modelling of the confinement by a finite step potential, and its consequences on the proposed pseudo-potential is also investigated. The merit of this set-up is that it allows to carry out analytic calculations generally to terms. On this basis, we are able to establish several results.

First, under the weak field assumption, the Stark shift of the QD ground state can be analytically computed in precise domains of validity. The result is found to be in better agreement with experimental or computational data as compared to existing calculations in the literature. In particular, the role of the semiconductor polarization in countering the effect of the electron-hole pair Coulomb potential is revealed very clearly by the analytic structure.

Second, the analytic scheme lends itself also to the computation of the Lamb shift of the QDs energy levels. The predicted orders of magnitude brought to light seem to allow observation of the electron-hole pair ground state Lamb shift for judiciously chosen semiconductor and radius. Because of the intrinsic non-degeneracy of the QDs energy levels, a new *Gedankenexperiment*, based on the Casimir effect, is proposed to observe this Lamb shift.

Finally, taking advantage of the QDs adjustable quantum energy spectrum, which depends only on their size, we explore the possibility of using the Purcell effect in semiconducting QDs to initiate LASER emission. A three-level LASER, whose LASER transition takes place in the red part of the visible spectrum, is shown to work in principle, as an example.

Thus, it appears that this analytic approach to spherical semiconductor QDs may lead to more interesting results when upgraded and properly extended.

Keywords spherical Quantum Dot, semiconductor, exciton, Stark effect, Lamb effect, Casimir effect, Purcell Effect.

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