Band Structure Modelling of GaAs-Based Quantum Dots Designed for Single Photon Sources at Telecommunication Wavelengths

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Semiconductor quantum dots (QDs) have been demonstrated as ideal candidates for sources of single and entangled photons for quantum computation and quantum information processing. However, simple implementation of this kind of device as a QD embedded in a semiconductor matrix suffers from a poor extraction efficiency of the emitted photons. Therefore, additional structure modifications enhancing the photon extraction efficiency have been developed. Recently, a deterministic etching of GaAs microlenses on top of a chosen QD has been demonstrated as an approach of controlled and high yield of the obtained devices [1] However, the emission wavelength of these structures was below 1 μm, i.e. far of 1.3 or 1.55 μm required in fiber-based secure communication schemes. As for the long wavelength quantum communications the InAs-InP material system is explored and seems to be the most promising, the short to mid distance transmission systems could operate employing the GaAs-based quantum-dot single photon sources, in which the high extraction efficiency architecture is combined with the properly designed emitter.

In this work we model In(Ga)As/GaAs QDs designed for telecommunication wavelengths, to achieve the desired active region for microlens single photon source to be used in fiber-based technologies. We employ multi-band **k·p** modeling of a the three-dimensional QD structure, taking into account strain and piezoelectric fields. We explore different approaches to shift the QD emission to longer wavelengths, such as enlarged InAs dots on GaAs [2],InGaAs strain-reducing layer [3] or dot-in-a-well design [4]. We calculate the single particle states and analyse strain piezoelectric field profiles to find the most suitable design of such QDs. Additionally, we determine the optical transitions as well as the s-p shell splitting (in order to maximize the latter for the necessary good thermal stability of such sources), i.e. parameters crucial with respect to the exploitation in the microlens single photon source fabricated within the GaAs mature technology.

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