Tailoring of Intraband Luminescence and Lifetime properties of Quantum Dots

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Quantum dots (QD) are seen as the best candidates for obtaining high temperature inversion population in order to perform intraband terahertz lasing. Two very important quantities are critical for successful lasing. Namely, those are upper laser level non-radiative lifetime and luminescence strength between upper and lower level.

The luminescence strength of lasing transition is quantified via optical dipole matrix elements and energy spacing which influence the lasing cross-section.

Non-radiative intersublevel lifetimes of excited carriers in quantum dots, although larger then in their quantum well counterparts, are still far from long lifetimes predicted by bottleneck effect[1]. Lifetime reduction is usually ascribed to strong coupling of electrons and longitudinal optical phonons which leads to formation of fast decaying quasiparticles-polarons. Fast polaron relaxation is due to the lattice anharmonicity perturbation which enables an efficient energy exchange between different polaron modes[2]. There are two effects that can lead to increase of the excited polaron lifetime. The first one is the reduction of the level spacing where anharmonicity perturbation becomes inhibited[2]. The second one is the reduction of the coupling between electrons and LO phonons. In this report we show that these two effects follow the same trend when one changes the QD geometrical and compositional properties.

We derived theoretical model for the ratio between optical cross-section (responsible for lasing) and non-radiative lifetime giving it as a simple function on the QD geometrical and compositional parameters. The model was based on approximate polaron Hamiltonian diagonalization[3] and close links between electron-LO phonon and electron-photon interaction in quantum dots. Based on this approach, we give guidelines towards quantum dot optimization as possible active mediums in future intersubband lasers. We also indicate further possible experimental and theoretical aspects of the link between electron-photon and electron-LO phonon interaction.

References

[1] Bockelman U and Bastard G 1990 *Phys. Rev. B.* **42** 8947
[2] Zibik E A et al 2009 *Nat. Mat.* **8** 803
[3] Stauber T and Zimmermann R 2000 *Phys. Rev. B.* **62** 7336