Modelling the emission extraction efficiency from a quantum dot in a zinc blende InP nanowire at telecom spectral range: geometry optimization

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A field of modern photonic quantum information technology is in need of a good quality single photon sources (SPSs). Particularly interesting are SPSs emitting at telecom wavelengths as they exhibit minimal losses and dispersion when coupled to optical fibers. One of the promising practical implementations of such devices are InAsP quantum dots (QDs) embedded into InP nanowires (NWs). Properly designed NW acts as a waveguide, which impose directionality of spontaneous emission (SE) by coupling it to a single optical mode of the NW and increase extraction efficiency (EE), i.e. collection of SE upwards [1]. The available growth methods enable to control the QD size, composition, position along the NW axis, as well as the NW parameters, with very high precision and reproducibility [2].

In this contribution, I will present results of geometry optimization for electric dipole simulating QD embedded into InP NWs on InP substrate. The simulations were performed in commercial Ansys Lumerical software, using finite-difference time-domain method. Firstly, the dipole was placed inside an infinite length, square based InP NW in order to find a thickness of the NW shell for optimal optical confinement providing a single mode propagation along NW - Fig. 1a. Then, a realistic geometry was used for 3D calculations of EE – a square-based tapered NW with trapezoidal cross section on bulk InP - Fig. 1b. This simulation was focused on finding an optimal NW length, taper angle, position of the QD inside the NW and the thickness of the InP shell. The main aim was to maximize photon extraction efficiency upward (the two planes marked in yellow in Fig. 1b) within experimentally feasible numerical aperture from 0.4 to 0.65. These results give valuable insight into target system geometry design, as well as provide theoretical data for expected extraction efficiency to be compared with experimental results.

a)

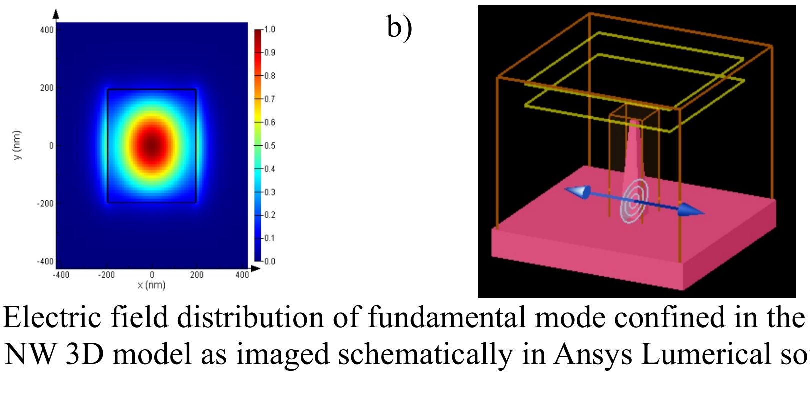

Figure 1. (a) Electric field distribution of fundamental mode confined in the NW and (b) tapered NW 3D model as imaged schematically in Ansys Lumerical software.

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