Numerical Study of Local Density of States in Photonic Crystal Waveguides

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Abstract

Introduction
In this contribution we study how a planar photonic crystal waveguide (PhCW), Figure 1a, created by introducing a line defect in the photonic crystal, can modify the projected local density of states (LDOS) for a dipole emitter[1,2,3]. In particular, we study the dependence of LDOS on position and orientation of emitter for two different ranges of frequencies; a) for a dipole in resonance with a waveguide mode (blue curve Figure 1b) and b) a dipole inside the band gap of the photonic crystal (green area in Figure 1b). Comparing the LDOS in the two cases allows extracting the coupling efficiency of the emitter to the waveguide mode[4,5].

Figure 1 shows a PhCW and its primary mode profile for two different group velocities, and the corresponding dispersion curve.

Details and results of numerical simulations
We use the COMSOL Multiphysics® RF Module to carry out finite element studies on PhCW. In order to calculate the primary eigenvectors of the waveguide mode, we setup eigenvalue calculations. When the dipole is in resonance with the waveguide mode, the enhancement Fp of emission with respect to the emitter in the homogenous medium can be calculated for different dipole orientations[4,5]. The map of Fp for a dipole oriented in x(y) direction is shown in Figure 2a(2c).

If the dipole is outside the waveguide mode and in the band gap of PhC, the only channels for the emitter to decay into are the coupling to evanescent tails of the radiation modes. In order to calculate the Fp for these dipoles we carry out frequency domain simulations with a dipole embedded in the waveguide.

According to Figure 2, emission from the dots in the band gap of waveguide is highly suppressed while in general the dipoles in resonance with the waveguide mode are enhanced. This proves the high potential of PhCW structures for efficient funneling of the radiation from embedded emitters to single mode of the waveguide.

Conclusions
In conclusion, we studied the LDOS in a photonic crystal waveguide for different positions of the emitter at different frequencies. These results prove, the existence of efficient and position

insensitive coupling between embedded emitters and PhCW modes.

Reference

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Figures used in the abstract

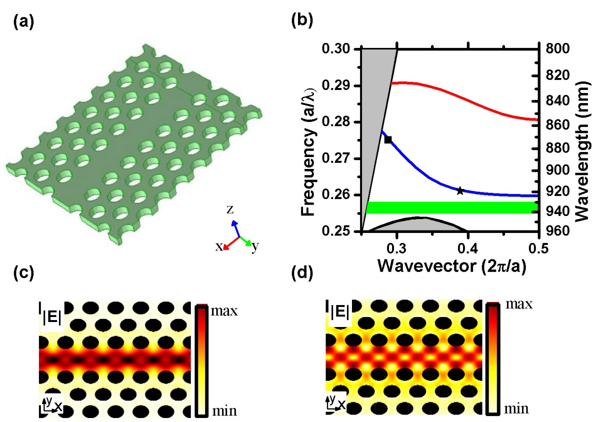

Figure 1: Figure 1. (a) Photonic crystal waveguide (b) the dispersion curve. The green shaded area is the frequency range where no mode is allowed to propagate and the blue band is first guided mode of the structure. (c) and (d) mode profile of the primary mode (blue line in part b) for two different frequencies. The group index for the two frequencies indicated by a square and star in part (b) is calculated to be 5 and 57.

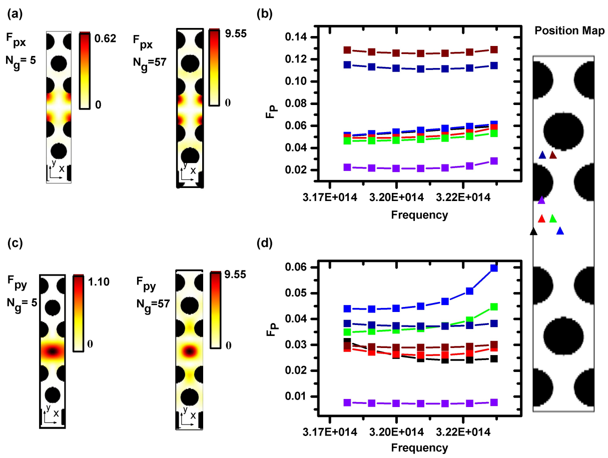

Figure 2: Figure 2. (a) and (c), Fp map for a dipole in resonance with waveguide modes at two different frequencies oriented along x and y respectively. (b) and (d) Fp for few selected points in the right hand side for a range of frequencies which lay in the green area in Figure 1b.