96. Magnetic-field tuning of semiconductor-based photonic crystals

O. Glushko*, R. Meisels, F. Kuchar

Institute of Physics, University of Leoben, Franz-Josef str. 18, A-8700 Leoben, Austria

In this contribution we investigate the possibility of tuning optical properties of semiconductor 1D photonic crystals by an external magnetic field.

Semiconducting materials with free carriers cover an intermediate regime between insulating dielectrics and metals where the imaginary part ε_i of the dielectric function ε is neither much smaller nor much larger than the real part ε_r. The free carriers and the electrical conductivity can make significant contributions to ε_i and ε_r in certain frequency ranges [1]. Regarding the tunability, the contributions can be varied by the application of a magnetic field, e.g. by tuning to the cyclotron resonance condition. In an insulating loss-free PhC the periodicity or lattice constant determines in which frequency ranges the photonic bands and gaps appear [2]. In a semiconducting PhC the strength of the contribution of the free carriers is determined by their density and mobility. The frequency ranges of strong contributions depend mainly on the density (plasma frequency) and the effective mass of the free carriers (cyclotron resonance frequency).

In this work we investigate one-dimensional PhCs in the full regime of low and high magnetic fields particularly where the magnetic field causes large and strongly varying contributions of the free carriers to the dielectric function. We show results at frequencies close to the plasma frequency (microwave regime) and at much higher frequencies in the mid infrared. For the investigations we use simulations on the basis of a multiple scattering method and present first experimental results for an InSb PhC at microwave frequencies.

The transmittance, reflectance and absorbance spectra are calculated for 1D photonic crystals with parameters typical for electrons in InSb and transverse-mass electrons in Si. We show that transmittance and reflectance spectra of a photonic crystal are modified due to the dependence of the dielectric function on the external magnetic field. In particular, it is possible to "switch" a photonic crystal from a transparent to an opaque regime by changing the external magnetic field and vice versa. Experimentally we measure the microwave reflection from an InSb 1D photonic crystal (500 μm thick InSb layers separated by 500 μm gaps) at 4.2 K applying the external magnetic field in the range -10…10 T. Good agreement between calculations and experiment was achieved, however, the simulations give some additional peaks which are very weak or do not appear in the experimental reflectance spectra.

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[2] Joannopoulos J D, Johnson S G, Winn J N, and Meade R D 2008 *Photonic Crystals: Molding the Flow of Light,* 2nd edn., (Princeton University Press)

* Corresponding author: email: oleksangr.glushko@unileoben.ac.at