Electromagnetic metamaterial devices for terahertz frequency range

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Abstract—New approach to design beam splitter on basis of the transformation optics using angle constitutive parameters distribution of medium was proposed for terahertz (THz) frequency range. Magneto-tunable photonic crystal with graphene layer as narrow band filter was investigated for THz frequency range. The magneto-tunable peaks of transmissivity in band-gaps of photonic crystal that caused by excitation of surface waves were obtained. The band-gap structure of photonic crystal made of metasurface/sitall/teflon layers was discussed for THz frequency range.

Keywords— terahertz frequency range; metamaterials; filters; beam splitters

I. INTRODUCTION

Today metamaterials are very popular structures for investigation of unusual effects in quantum physics, acoustic and electromagnetics [1,2]. The most interesting properties of metamaterial are band gap structure, negative refractive index, near zero refractive index, inverse Doppler’s effect, inverse Vavilov – Cherenkov’s effect, special distribution of constitutive parameters and etc. Last years the interest is attached to development of tunable filters, beam splitters and couplers on basis of metamaterials for application in the field of biomedicine, spectroscopy, detection & security systems, photonic chips and micro schemes for THz frequency range. The applicable criteria that follow.

II. OBJECTS AND METHODS

We introduce new approach based on the transformation optics and devoted to consideration of space transformation using special angle distribution for development of beam splitter. The detailed description of the mathematical formalism for definition of constitutive parameters tensors of metamaterial medium is presented in this paper. The band gaps of four photonic crystal structures were considered for development of tunable filters. The first PC structure has 5 bilayer cells and each cell consists of SiO₂ and Si layer. The 2nd structure is 5-layered SiO₂/Si PC composite bounded by graphene layer on SiO₂ substrate. The 3rd structure is PC - SiO₂ - graphene - PC composite. External magnetic field was applied perpendicularly to PC layers surface. The 4th PC is made of alternating layers of metasurface (SRRs + sitall CT-50-1 substrate) and teflon. The photonic crystal consists of 10 bilayers: one having permittivity (ε_{teflon}=2.25 ) and thickness (h_{teflon}=300 um) of teflon and another – that of metasurface/sitall layer (experimentally obtained ε_{sitall}(ω) and h_{sitall}=550 um).

III. RESULTS

The model of beam splitter with angle dependence parameters based on the transformation optics mathematical apparatus was simulated for the ideal and reduced tensors of permittivity and permeability of metamaterial medium for the TM polarized electromagnetic wave. These results can be used for developments of couplers/splitters based on the metamaterials for the THz frequency range. The possibility of transmission control of photonic crystal bounded by graphene layer under magnetic field influence was shown. The magneto-tunable surface waves in the PC-graphene-PC bandgap structure were excited. The numerically simulated spectra of photonic crystals with different metasurface lattice constant were obtained. The narrow tunable peaks were observed. Tunable filters can find extensive use in THz biomedical applications – for example such filters can be used to cut THz frequencies that give negative impact on biological cells under study.

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REFERENCES