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Analysis of cutoff frequency in one dimensional ternary superconducting photonic crystal

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ABSTRACT

By means of two fluid model and transfer matrix method, we have theoretically investigated the transmittance property of a one dimensional ternary photonic crystal consist of a pair of superconducting materials and a dielectric in the infrared frequency region. We mainly focus on the analysis of cutoff frequency since the calculations can be useful in the fabrication of optical devices such as reflector, high pass filter etc. The study reveals that the cutoff frequency is sensitive to thickness of superconducting materials, dielectric layer thickness, operating temperature and refractive index of intermediate dielectric. Cutoff frequency shifted to higher frequency region on increasing number of periods and superconductor layer thickness where as it reduces on increasing dielectric thickness, operating temperature and refractive index of intermediate dielectric. Furthermore, we compared the cutoff frequency of three different 1D ternary photonic crystals comprising of a dielectric and a pair of high-high, high-low and low-low temperature superconducting materials. Our comparison results shows that the cutoff frequency can be effectively modified with different combination of superconducting materials.

1. Introduction

Photonic crystals (PCs) are artificial nano structures composed of two or more media in which the dielectric function periodically varies in space. The concept of PCs were theoretically discussed and experimentally demonstrated by Yablonovitch [1] and John [2] in 1987. The most significant features of PC is so called photonic band gap (PBG) where the propagation of electromagnetic waves are forbidden. PBG often called bragg gap since they arise from the bragg scattering in the periodic composition and are similar to the electronic band gap in solid. Because of this photonic band structure, PCs can manipulate and control the propagation of electromagnetic waves in optoelectronic devices [3–13]. Besides above mentioned works, some experimental studies also have been reported [14–16].

Over past few years researchers paid attention on superconducting photonic crystal [17–24] due to its tunability and negligible loss. Since the dielectric permittivity of a superconducting material can be tuned with temperature and external magnetic field, superconducting photonic crystal has advantage over metallic and dielectric PCs.

The frequency below which electromagnetic waves restricted to propagate through PC is called cutoff frequency. Recently Aly and Mohamed [25] reported an analysis of cutoff frequency in ID binary superconductor-dielectric PC. They mention that the cutoff frequency can be tuned effectively by various parameters and the numerical results can be put into applications such as high pass filter, reflectors etc. In addition, the numerical investigation of cutoff frequency in 1D binary superconductor-metamaterial [26], superconductor-magnetized cold plasma [27] PCs were explored in microwave region. Currently Aly et.al [28] investigated the properties of cutoff frequency in two dimensional superconducting PC. Thus a detailed analysis of cutoff frequency should be needed in required frequency region for the proper implementation of numerical calculations into the applications.

Recently Zamani [29] investigated the optical properties of 1D all superconducting PC comprising pair of high-high, high-low and low-low superconductor materials in the visible region. They studied the dependence of temperature and incident angle on the transmission and reflection spectrum of different types of 1D all superconducting PCs. Motivated from above studies, In the present communication, we theoretically describe the transmittance property of a 1D ternary PC consisting a pair of superconductors and a dielectric in the infrared frequency region using transfer matrix method. Our numerical results show that various parameters can strongly affect the position of cutoff frequency. Moreover, a comparison of cutoff frequency between three different

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