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광결정과 왼손물질에서의 특이한 빛의 전파현상

Unusual light propagation phenomena in photonic crystals and left handed materials

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Photonic crystals (PCs) are dielectric materials whose refractive index is periodically modulated in space. With a proper design, PCs can exhibit photonic band gaps (PBGs) [1], the frequency ranges in which light propagation is completely prohibited in any direction. There have been a number of attempts made to control the flow of light by utilizing the effect of PBG [2-4].

In recent years, there has been a growing interest in anomalous dispersion properties of PCs [5-8]. One of the most interesting phenomena originating from complex spatial dispersion is the self-collimated propagation of light beam in PCs. This interesting phenomenon, an incident light propagating with almost no diffraction along a definite direction could provide a new way to control the flow of light in PCs [8]. Thus, photonic crystals can give an opportunity to engineer the dispersion properties.

Recently, another way to engineer the dispersion properties of materials, especially, magnetic permeability μ, has attracted much attention. It has demonstrated that an artificial medium made up of an array of conducting nonmagnetic split ring resonators could exhibit negative μ in a certain microwave range [9]. This discovery has aroused much interest of new artificial materials, left handed materials (LHM) having a negative ε and negative μ simultaneously [10]. In facts, Veselago investigated the characteristics of the LHM in 1968 [11]. In this kind of material, since the direction of energy flow defined by $\boldsymbol{E} \times \boldsymbol{H}$ (group velocity) is opposite to that of wave propagation $\boldsymbol{k}$ (phase velocity), the triplet ($\boldsymbol{E}$, $\boldsymbol{H}$, $\boldsymbol{k}$) builds a left-handed triad. This is a reason to give for this material a name, LHM, in contradiction to a common material with right-handed triplet of ($\boldsymbol{E}$, $\boldsymbol{H}$, $\boldsymbol{k}$), right handed material (RHM). The LHM was expected to exhibit the unusual phenomena such as reversal of Snell's law (negative refraction) [12], the Doppler effect, and Cerenkov radiation because its refractive index is negative $n = -|\varepsilon\ \mu|^{1/2}$. A LHM can act as a phase compensator due to its negative refractive index. Thus the LHM provides possibility for having complete optical tunneling devices [13] and subwavelength thin resonators [14]. Thus the presence of LHMs in optical resonant systems can give rise to unusual resonant phenomena.

In this talk, first, we introduce the anomalous dispersion properties of photonic crystals giving rise to superprism effects and self-collimation beam propagation. The theoretical methods to design and analyze the dispersion properties are also introduced. Second, we show that an introducing line defects in a PC structure can allow the bending and splitting of the self-collimated beams and moreover, the power ratio between two split self-collimated beams can be controlled systematically by varying the radii of rods or holes in the line defect (see Fig. 1). Third, the brief historical introduction and recent interesting results of LHMs are presented. Finally, we show that the resonant transmission through a metallic Fabry-Perot (FP) cavity in the presence of a LHM layer can be prohibited, due to the optical annihilation effect and the penetration depth of a metallic mirror (see Fig. 2). Other unusual light propagation through LHMs will be discussed.

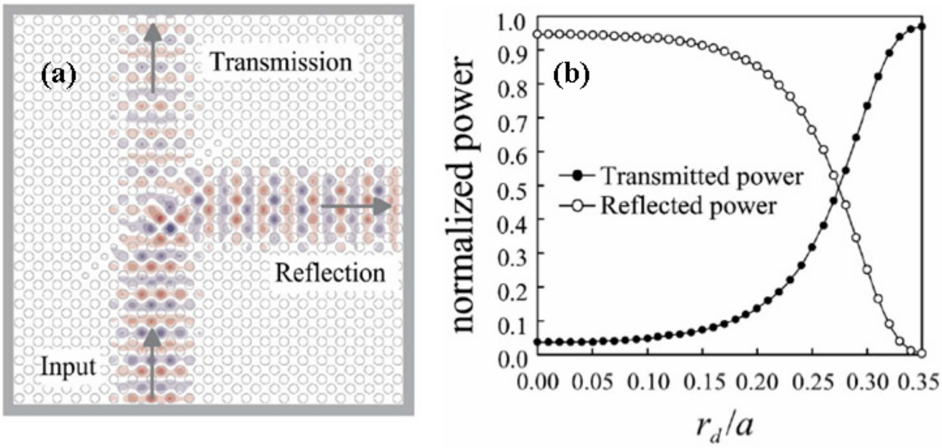

Fig. 1 (a) Simulated spatial distribution of the steady-state electric-field of the *E*-polarized mode at f=0.194 c/a in the line defect beam splitter composed of 15 defect rods with the radii r_d aligned in the (10) direction, where c is the speed of light in free space and a is the lattice constant of square array. (b) Reflected and transmitted powers which are normalized with respect to the input power as a function of r_d.

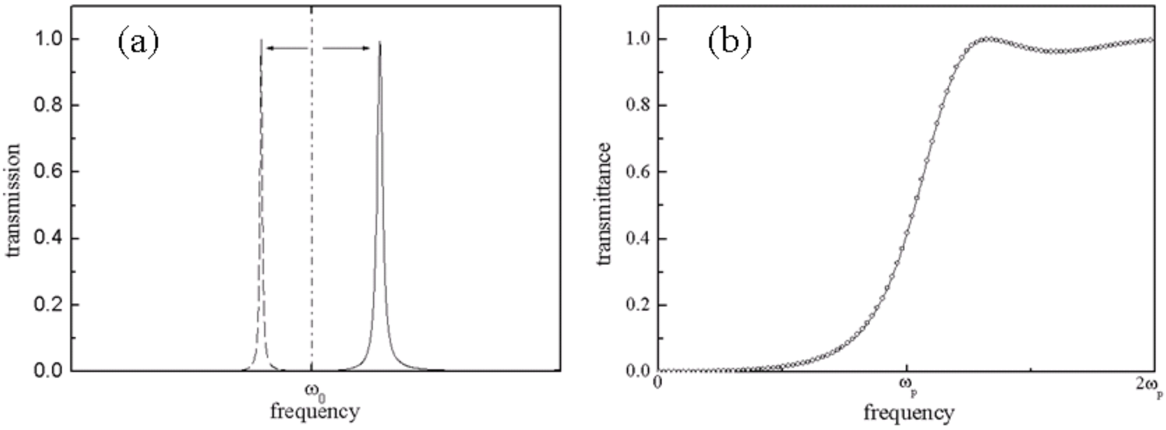

Fig. 2. (a) Simulated transmission spectra through the Fabry-Perot cavity with the air layer (dashed line) and the anti-air layer (solid line). $\omega_0=\pi c/d$, where c is the light velocity in free space and d is the thickness of the layer. The dielectric constant of the metallic mirrors was assumed to be $\varepsilon(\omega)=1-\omega_p^2/\omega^2$, where ω_p is the plasma frequency and chosen to be 5 ω_0. The thickness of mirror is chosen to be 0.1 d. (b) Simulated transmission spectrum of the FP cavity with a half air and half anti-air layer (solid line). Note that the spectrum does not show any resonant transmission below ω_p. and is identical to that of the metallic mirror with the double thickness (circles).

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