New Phenomena in Photonic Crystals

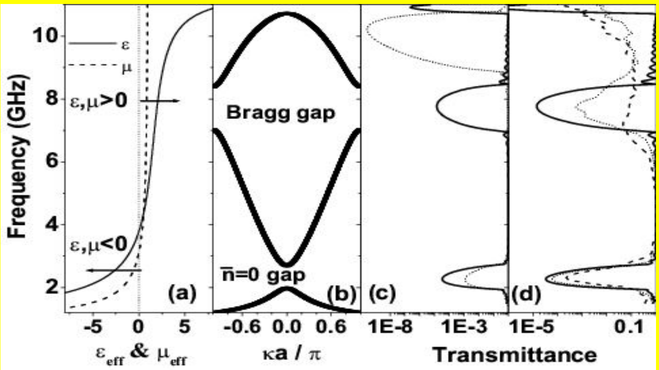

FIG 1 (a) Effective ε and μ of the negative-*n* material; (b) Dispersion relationship of a photonic crystal with alternate layers of air (12mm) thick the negative-*n* material (6.0mm thick) with material parameter as shown in (a); (c) Solid line: Transmittance through 16 unit cells, corresponding to the band structure in (b). Dotted line: Transmittance through 16 unit cells, with various degree of disorder in thickness.

Photonic Band Gap from a Stack of Positive and Negative Index Materials

Layered heterostructures combining ordinary and negative refractive index materials are shown to display a new type of photonic band gap corresponding to zero (volume) averaged refractive index. Distinct from band gaps induced by Bragg scattering, the zero-$\overline{n}$ gap is invariant upon a change of scale length and is insensitive to disorder that is symmetric in the random variable. A metallic structure that exhibits such a band gap is explicitly designed, and its properties are calculated with accurate finite difference item domain simulations. For details, see J. Li, L. Zhou, C.T. Chan and P. Sheng, *Phys. Rev. Lett*. **90**, 083901 (2003).

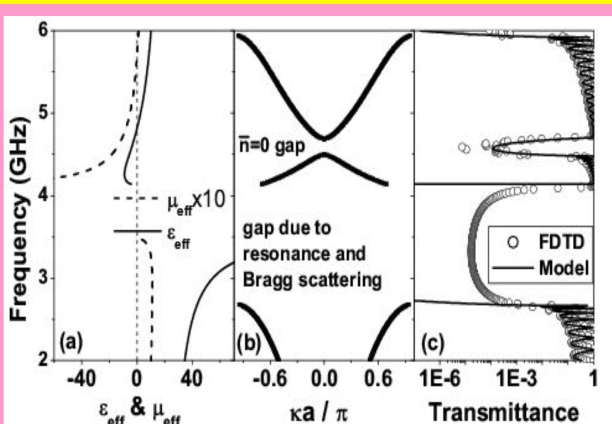

FIG 3 (a) ε_{eff} and μ_{eff} as function of frequency of the negative-*n* material shown in Fig 2; (b) band structure for a photonic crystal with alternating layers of air (7mm thick) and the designed negative-*n* material [thickness=3.5mm, ε_{eff}, μ_{eff} shown in (a)]; (c) Transmittance through a slab consisting of 16 unit cells with details described above, through direct FDTD simulation (open circles) and material properties represented by ε_{eff} and μ_{eff} (Solid line).

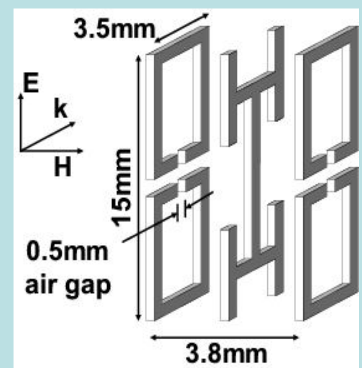

FIG 2 Structural details of the negative-*n* material

Multifrequency Gap Solitons in Nonlinear Photonic Crystals

We have predicted the existence of multifrequency gap solitons (MFGSs) inside the gaps of nonlinear photonic crystals (NCP) both in one and two dimensions. Each of these solitons is a single intrinsic mode possessing multiple frequencies. They form a new class of gap solitons and can only be excited by using multiple beams. Its existence is a result of synergic nonlinear coupling among solitons or soliton trains at different frequencies. Its formation can significantly enhance certain nonlinear optical effects such as nondegenerate two-beam coupling. For details see Ping Xie and Zhao-Qing Zhang , *Phys. Rev. Lett*. **91**, 213904 (2003).

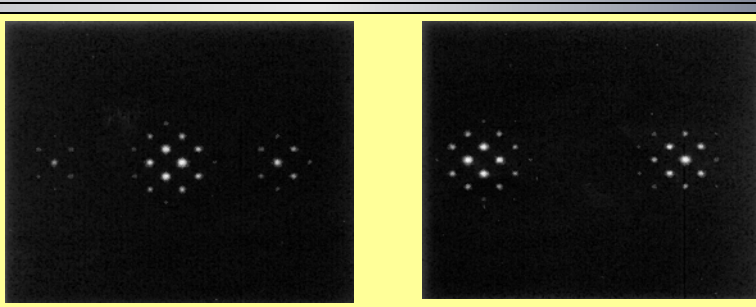

Fig. 2 shows a typical MFGS in a 2D NCP possessing two frequencies inside the gap. Two panels show the intensity distributions of the respective frequencies. Its transmission behavior is similar to the one shown in 1D NPC, i.e. exhibiting multi-stability for each frequency with common resonant point.

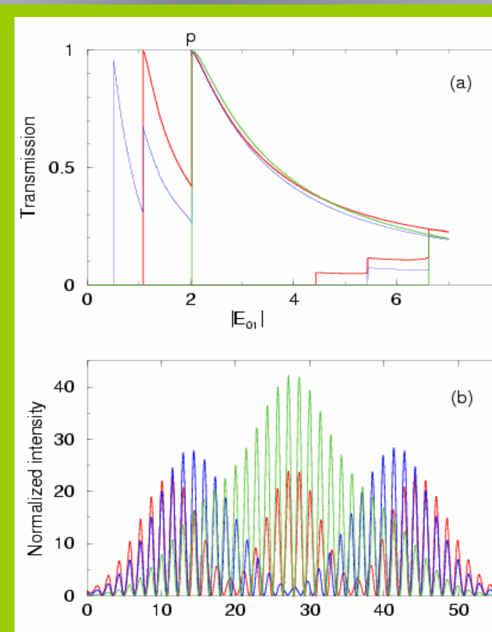

Fig. 1 shows a typical MFGS in a 1D NCP possessing three frequencies inside the gap. (a) Transmission as a function of incident amplitude from three beams at different frequencies (in red, blue, and green) The amplitudes of three beams are kept at fixed ratios. (b) Intensity distributions at Pont P for the respective frequencies.