Control of the index of refraction in coherently driven media with magnetoelectric cross coupling

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Optical metamaterials, or more specifically left-handed materials incorporating a negative phase velocity with power flow in the opposing direction, have been theoretically proven to exhibit phenomena such as sub-wavelength resolution, reverse Doppler effect, and Cherenkov radiation to name a few [1,2]. Although experiments have verified the existence of negative index materials [3,4] by inducing a strong magnetic and electric response from the medium, losses remain a major limitation in the optical regime [5,6]. For this purpose, it has been shown that some gases such as neon could be used to induce a negative index of refraction with low absorption rates affecting optical wavelengths of light in coherently driven media [7,8]. In addition, recent publications have pointed out that if one considers magnetoelectric cross coupling, a negative index of refraction can be achieved without requiring negative permeability, which has been the largest impediment thus far in the field, since typical transition magnetic dipole moments are smaller than electric ones by a factor of the order of the fine structure constant [9,10]. Using a semi-classical approach to model the interaction of light with atomic media, we simulate pump-probe experiments and investigate the effects of the material's response, i.e. its polarization and magnetization, that could lead to media which are tunable between the active and passive regimes as well as bistable in its permittivity and permeability. Potentially active and/or bistable media could be used to conceive a new class of “ambidextrous” materials which can be easily manipulated between left and right handedness.

References

[1] V .G. Veselago, Sov. Phys. Uspekhi, **10** (1968) 509-514.
[2] J. Pendry, Phys. Rev. Lett., **85** (2000) 3966.
[3] R. A. Shelby et al., Science, **292** (2001) 77.
[4] D. R. Smith et al., Phys. Rev. Lett., **84** (2000) 4184.
[5] V. M. Shalaev, Nature Photonics, **1** (2007) 41-48.
[6] W. Cai and V. M. Shalaev, *Optical Metamaterials: Fundamentals and Applications*, (Springer 2009) Ch. 2.
[7] Q. Thommen and P. Mandel, Phys. Rev. Lett., **96** (2006) 053601.
[8] P. P. Orth et al.,(2008) arXiv:0711.0303v1.
[9] J. Kästel et al., Phys. Rev. A, **79** (2009) 063818.
[10] J. Kästel et al., Phys. Rev. Lett., **99** (2007) 073602.