Electromagnetic Radiation Pressure on Left- and Right-handed Dissipative Media

H. Lezec[1], A. Agrawal[1], M. Abashin[1], S. Rajauria[1], and K. Chau[1,2]

[1]Center for Nanoscale Science and Technology, NIST, Gaithersburg, MD, USA.
[2]University of British Columbia, Okanagan, Kelowna B.C., Canada.

We investigate both experimentally and theoretically the radiation pressure exerted by a plane wave of visible-frequency light on a flat slab of dissipative material which is either left handed [1] or right handed (i.e. having electric permittivity and magnetic permeability which are both negative or both positive, respectively).

We characterize the radiation-pressure response of an optical-frequency, broadband, left-handed metamaterial based on stacked Ag/Si/Ag plasmonic waveguides, each designed to be left-handed over most of the visible spectrum. A fully-absorbing flat slab of this metamaterial integrated onto a low-stiffness cantilever is shown to experience a pull when illuminated at normal incidence by a plane-wave of free-space wavelength in the range 460 nm to 600 nm. Radiation-induced pull is further confirmed by observation of levitation of free-standing slabs of the metamaterial under illumination at 532nm.

An analytic model is proposed which is consistent with the spectral dependence of the measured pressure response. In this model, the real part of the effective refractive index of the metamaterial contributes to a proportionately-large, negative absorption force, which, when it exceeds the positive Lorentz force, yields in a net negative pressure on the object. The origin of the implied momentum-transfer non-equivalence between Lorentz and dissipative forces, related respectively to the wave and particle nature of the photon, is investigated through finite-difference-time-domain simulations of optomechanical pulse-slab interactions, as well as via interferometric measurements of the radiation-pressure response of thin films of high-index, dissipative, right-handed materials on silicon-nitride membranes.

[1] V. Veselago, Sov. Phys. Usp. 10, 509-514 (1968).