Negative Radiation Pressure

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We demonstrate that free-space electromagnetic radiation is able to exert a negative pressure on a slab of ponderable material. It is shown that this becomes possible when the material is both left-handed [1] - having a negative refractive index resulting from simultaneously negative values of electric permittivity and magnetic permeability - and dissipative. Though left-handed materials do not exist in nature, they can be realized in the form of artificial metal-dielectric metamaterials. Here we characterize the radiation- pressure response of an optical-frequency, volumetric metamaterial based on stacked Ag/Si/Ag plasmonic waveguides, each designed to be left-handed over most of the visible spectrum with a negative refractive index varying broadly over this range. 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 located in the range 460 nm to 600 nm. An analytic model describing the net radiation pressure, which takes into account both Lorentz and dissipative forces, is developed and validated by comparison to the spectral dependence of the measured pressure on the metamaterial. The model reveals that the real part of the effective refractive index of the metamaterial contributes to a proportionately-large, negative dissipative force, which, when it exceeds the always-positive Lorentz force, results in a net negative pressure on the object.

1. V. Veselago, Sov. Phys. Usp. 10, 509 (1968).