Radiation Pressure Response of a Left-Handed Plasmonic Metamaterial

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The phenomenon of radiation pressure was first predicted by Maxwell in the late 1800s as a natural consequence of the energy and momentum content of electromagnetic waves. By the early 1900s, radiation pressure was measured by observing the light-driven deflection of mirrors suspended in vacuum. Due to co-linear propagation of electromagnetic energy and momentum in vacuum and nearly all naturally occurring materials, the canonical direction of radiation pressure is in the direction of light propagation. That is, light tends to push, rather than pull. In 1968, Veselago predicted that a mirror immersed in a hypothetical left-handed medium would experience negative radiation pressure, a unique situation where light would pull, rather than push. This was the consequence of contra-directional energy and momentum flow characteristic of electromagnetic waves in left-handed media.

In this work, we measure the radiation pressure response of a left-handed medium realized in the form of a metamaterial. The metamaterial is composed of a stack of metal-dielectric waveguides designed to sustain backward-propagating surface-plasmon polariton modes for transverse-magnetic (TM) polarization over the visible spectral range. The metamaterial is fabricated on top of a pliable cantilever, which is then mounted within a scanning electron microscope used to visualize nano-scale optically-driven displacements in real-time. We observe that the cantilever recoils towards the light source (i.e. a pull) when the metamaterial is illuminated by TM-polarized visible-frequency light. The recoil is directed away from the light source (i.e., a push) for two control experiments: illumination of the metamaterial with transverse-electric (TE) polarization and illumination of a silvered surface with either TM or TE polarization. This work provides the first experimental measurement of negative radiation pressure due to left-handed electromagnetic behavior.