Magnetic Resonance on a ``Petals'' Structure and the Associated Surface Plasmon Polariton

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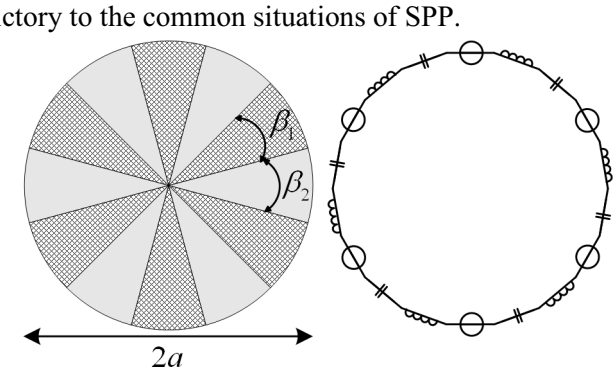
Designing metamaterials often begins from designing the sub-wavelength sized inclusion that gives resonating response to the electric or magnetic excitation. Periodic arrays may then be assembled from such inclusions whose effective permittivity (ε) and/or permeability (μ) may show resonant feature. Typical inclusions working in the radio frequency (RF) domain include metal wires that provide electric response and split ring resonators (SRRs) that provide magnetic response. Achieving magnetic response in the optical domain is much more difficult, although there have been some studies either theoretical or experimental (for example, Alù, Salandrino and Engheta, Opt. Express, 14, 1557; Yen, et. al, Science, 303, 1494; Sarychev, Shvets and Shalaev, Phys. Rev. E, 73, 036609). The main reason is due to the optical properties of metals that are very different to those in the radio frequency domain.

We propose in this paper a geometry that can provide strong magnetic response in the optical domain. For the sake of mathematical simplicity, here only a 2-dimensional (2D) cylindrical inclusion is discussed which is invariant along its axis, but the same argument can be applied to 3D inclusion design. The particle is composed of plasmonic material blocks and conventional dielectric blocks, arranged in the way shown in the left panel of the figure. An intuitive understanding is to use the concept of the optical circuit element (Engheta, Science, 317, 1698, 2007). Since in the optical domain the plasmonic particles can be described as inductors while the dielectric part as capacitors, the equivalent circuit to the geometry is shown in the right panel of the figure. Thus the scattering from such a inclusion gives resonance feature under TE-wave (i.e. the electric field is perpendicular to the axis of the cylindrical structure) incidence, even when the radius is much smaller than the free space wavelength of the incident wave. We specifically show that, such a scattering resonance is also related to a surface plasmon polariton (SPP). However, different to the TM-type SPP related to the scattering resonance of a plasmonic sphere, here the SPP is of TE mode, contradictory to the common situations of SPP.