Enhanced backscattering of light from randomly rough gratings on negative magnetic metamaterials

Ramón Paniagua-Domínguez, J.A.Sánchez-Gil
Instituto de Estructura de la Materia CSIC, Serrano 121 (28006), Madrid, Spain
Phone: +34 91 5616800, Fax: +34 91 5645557

P. Albella, J. M. Sáiz, F. González, F. Moreno
Grupo de Óptica, Departamento de Física Aplicada, Universidad de Cantabria,
Avd. de los Castros s/n (39005) Santander, Spain
ramon.paniagua@iem.cfmac.csic.es

We investigate the scattering formalism of the Green's theorem [1,2] including a discontinuity in the magnetic permeability μ (isotropic and homogeneous). For this purpose we make use of the continuity or saltus conditions for the EM field across the interface between media having different ε and μ. We consider the latter to be a 1D function $\zeta=\zeta(x)$ and linearly polarized light. We perform the analysis of both s-polarization and p-polarization. In this configuration we find that in p-polarization the discontinuity of the magnetic permeability has no effect on the discontinuity of the only non-zero component of the magnetic field, while in s-polarization it does affect to the discontinuity of the only non-zero component of the electric field. Having made such analysis, we find a symmetry in the intensity of the scattered fields between s- and p-polarizations when interchanging the values of ε and μ. In particular, this symmetry is also present for the intensity of the reflected fields. As a consequence, same backscattering patterns are found for s-polarization with given $\varepsilon>0$ and $\mu<0$ values and for p-polarization having ε and μ resulting of interchanging their values. Numerical analysis has been made with the aim of testing the reported symmetry for media having one of the constitutive parameters positive and the other negative. The rough surface is generated by the Montecarlo method and thus possesses a known Gaussian power spectrum characterized by the rms height δ and the correlation length of the random height a. Some studies have been performed in this direction [3] but, to the best of the authors' knowledge, the symmetry has never been pointed out.

Results

As an example, a numerical calculation of the incoherent intensities of the scattered light for p- and s-polarization is shown in Fig.1 for given values of permittivity and permeability, together with the same calculation for the symmetric situation. The enhanced backscattered peak in p-polarization for ε=-5 and μ=1 stems from the multiple scattering of SPPs, in turn excited by sub-wavelength roughness. Conversely, s-polarized SPPs exist in the case of ε=1 and μ=-5 [4]. Thus, enhanced backscattering peaks also occur in the angular patterns of s-polarized light (see Fig.1), identical to those of p-polarized light with interchanged ε and μ. Similarly, it will be shown that symmetric enhanced backscattering is also observed due to multiple scattering of light, when the surface roughness (correlation length a) is larger than the wavelength.

References

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Figures

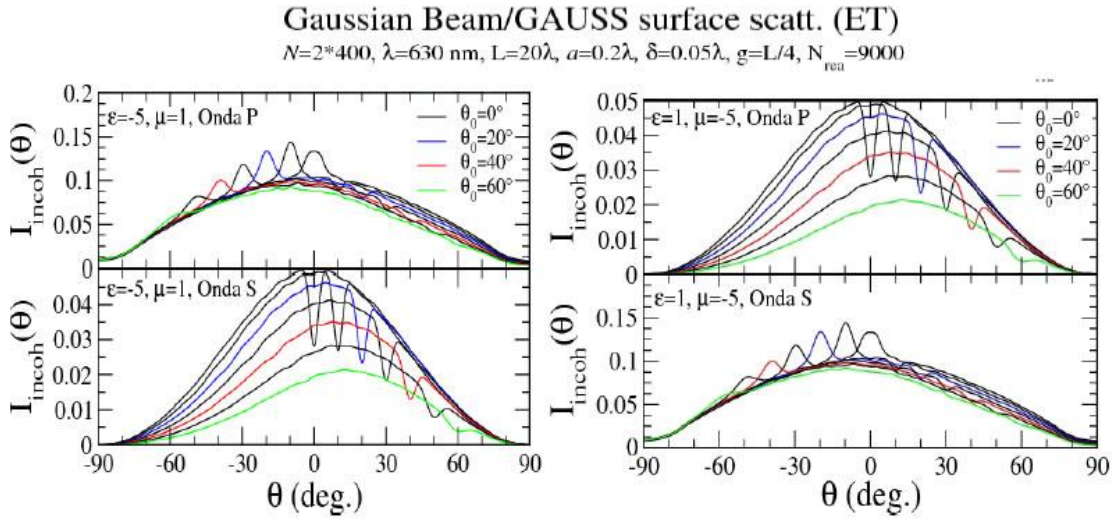

Fig.1. Angular distribution of intensities for the reflected fields. The incoherent intensities are plotted for each polarization. The reported symmetry can be readily observed.