Faraday Effect and Selective Reflection of Electromagnetic Waves in Absorbing Stratified Periodic Media

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Abstract

In this paper we calculate the optimum parameters of a stratified periodic structure. We obtaine the dependences of intensity, ellipticity and angle of turn of the main axis of polarization ellipse of reflected and transmitted waves on the quantity of the cells, on the frequency of the electromagnetic waves and on the magnetic field strength. We show there is the possibility of use of such structure, having selective reflection of electromagnetic waves, as the polarization converter controlled by a magnetic field.

1. Theory

One of the possibilities of creation of controlled converters of electromagnetic waves polarization is the use of stratified periodic structures, combining the properties of their components. We consider stratified periodic structure, consisting of any quantity of repeating elementary cells, placed in an external magnetic field. It is supposed, that the first layer of such cell is isotropic, and does not possess the chiral properties. The second layer is also isotropic, but adsorbing and however possesses the magnetic gyrotropy, that brings about to circular birefringence of waves inside a layer. For a gyrotropic layer of such structure the constitutive equation have the form

$$\vec{D} = \varepsilon \vec{E} + i \vec{g} \times \vec{E} \tag{1}$$

$$\vec{B} = \mu \vec{H} \tag{2}$$

where $\vec{g}$ is the vector of gyrotropy.

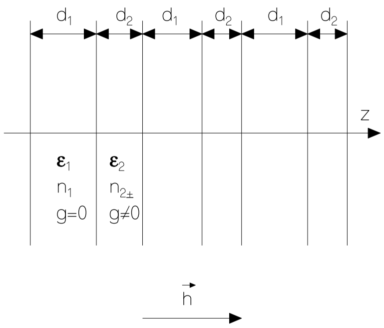

Figure 1: Schematic representation of stratified periodic medium.

For the description of absorbing gyrotropic crystals, except complex tensor of permittivity, it is necessary to introduce also complex tensor of gyrotropy. The real part of tensor of gyrotropy describes circular birefringence, and the imaginary part describes circular dichroism. Using boundary conditions for waves in each layer, we have calculated a matrix M, which connects a incident wave to transmitted and reflected waves [1]-[3]

$$M = I_{21} D_1 I_{12} D_2 \tag{3}$$

where I_{ij} is the matrix of transmission of wave through the boundary of media, D_j is the matrix of propagation of wave in medium.

If the stratified periodic structure consist of N elementary cells, we have to raise the matrix M to power N. The matrix M^{eff} for the whole stratified periodic structure can be written down as product

$$M^{eff} = I_a M^N I_b \tag{4}$$

where I_a and I_b are matrixes of transmission of electromagnetic wave through the boundaries between air and structure. Through elements of this matrix the complex coefficients of transmission and reflection of waves for all layered structure are expressed

$$T = \frac{1}{M^{eff}_{(1,1)}}, R = \frac{M^{eff}_{(2,1)}}{M^{eff}_{(1,1)}} \tag{5}$$

To obtain the maximum of reflection by each cell, the thicknesses of layers have to satisty to following relations

$$2k_1 d_1 = (2m_1 + 1)\pi, 2k_2 d_2 = (2m_2 + 1)\pi \tag{6}$$

where m_1 and m_2 are integer numbers, k_1 and k_2 are wave numbers of right- or lefthanded circularly polarized waves in the first and the second layer. Selecting the thickness of gyrotropic layer, depending on frequency of electromagnetic waves and strength of a magnetic field we can obtain the maximum reflection for one circularly polarized wave and simultaneously minimum for opposite polarization. Then at increase of number of cells of structure the intensity of one reflected circularly polarized wave monotonously increases and reaches the saturation. The value of saturation of intesity depends on a sign of imaginary part of the tensor of gyrotropy. Intensity of other circularly polarized reflected wave oscillates, periodically accepting close to the zero value. It enables to obtain the polarization of a reflected wave close to circular.

2. Numerical Calculation

One can see on fig. 3, that the maximum of ellipticity both for reflected and transmitted waves take place at calculated value of external magnetic field strength.

As is obvious on fig. 4, at the calculated value of the external magnetic field strength the intensity of reflected lefthanded wave is maximum, while the intensity of righthanded wave is close to the zero. When changing an external magnetic field or the frequency of electromagnetic waves the polarization properties change both of transmitted and of reflected waves.

3. Conclusion

As result there is the possibility of use of such structure, having selective reflection of electromagnetic waves, as the polarization converter controlled by a magnetic field.

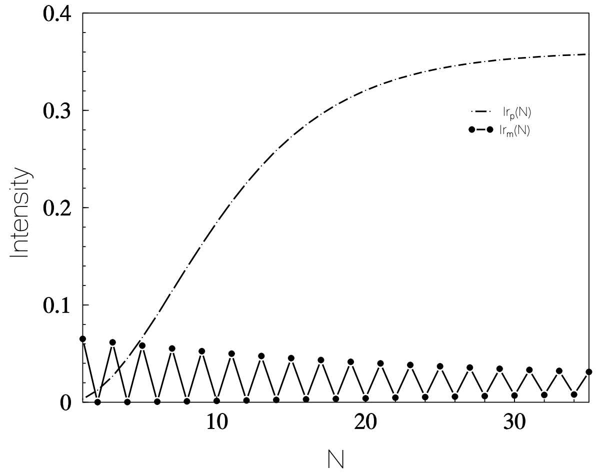

Figure 2: Dependence of normalized intensity of reflected and transmitted waves on the number of cells.

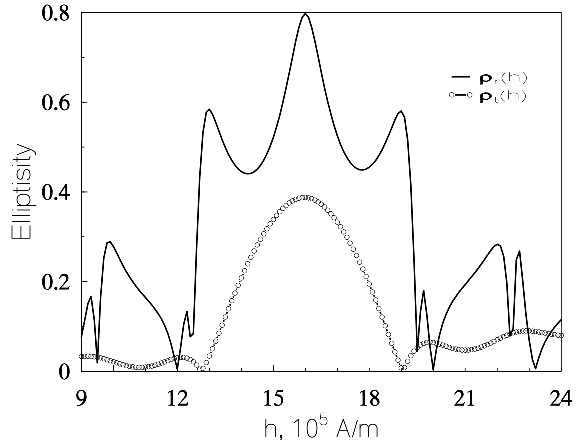

Figure 3: Dependence of ellipticity of reflected and transmitted waves on the strength of an external magnetic field.

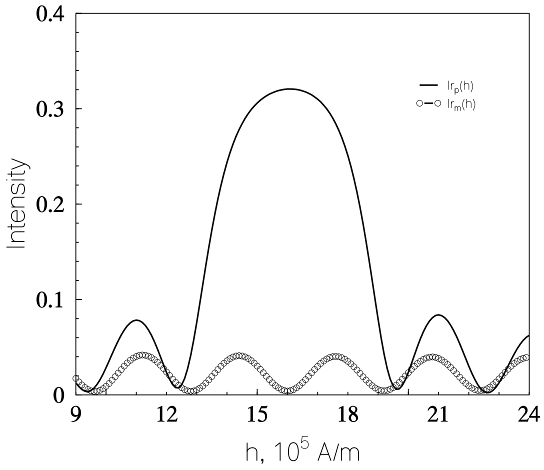

Figure 4: Dependence of intensity of reflected left- and righthanded circularly polarized waves on the strength of an external magnetic field.

References

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[3] J. Zak, E. R. Moog, C. Liu, and S. D. Bader, "Additivity of the Kerr effect in thin-film magnetic systems", *J. Magn. and Magn. Mater*, vol. 88, no. 3, pp. 261–266, May 1990.