Reflection and transmission matrices for plane anisotropic gradient structures with torsion

N.M. Moiseeva[1]

[1]*Volgograd State University, University Avenue 100, Volgograd, Russia, 400086*

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We propose the 4×4 matrix solution for calculating the projections of the electric and magnetic field vectors in an anisotropic gradient planar structure with an arbitrary dependence of the optical axis orientation on the transverse coordinate, obtained using the quasi-classical approximation. The obtained matrix record of the solution, in contrast to the multilayer model, allows us to avoid artificial discontinuities of the optical properties of the medium and field projections at the boundaries of the layers.

Keywords

planar structures, metamaterials, transmission matrix, cross polarization of light

1. Introduction

Planar structures based on metamaterials [1] and liquid crystals [2] are promising for new applications of photonics [3]. The unusual properties of artificial media allow you to direct [4], control the phase and polarization [5], modulate [6], switch optical signals [7]. Matrix methods usually reduce media with inhomogeneous parameters to thin homogeneous layers, that is, artificial gaps in the values of the dielectric and magnetic permeability of the medium appear in the problem, as well as gaps in field projections at nonexistent boundaries. Controlling the polarization of light during reflection and propagation in liquid crystals gives rise to promise for optical vortex beams used for high-speed optical communications and optical tweezers [8]. Improving the methods for calculating the cross-polarization of light upon reflection by inhomogeneous anisotropic media is of interest in the development of optical technologies. The 4×4 matrix form of the Wentzel-Kramers-Brillouin (WKB) method is a transfer matrix for the gradient layer, taking into account its anisotropy and the torsion of the optical axis. The advantage of this method is that the "stitching" of the tangential components of the fields $\vec{E}$ and $\vec{H}$ is performed only on two layer boundaries.

2. Formulation of the problem

Based on Maxwell's equations, we consider the case of oblique incidence of a plane electromagnetic wave (EMW) on an inhomogeneous anisotropic layer with an arbitrary orientation of the optical axis. We will consider an E7 nematic liquid crystal with $\varepsilon_{\perp} = 1.54^2$ $\varepsilon_{\parallel} = 1.75^2$ [9]. The backing of the system is glass, $\varepsilon_n = 2.37$. The angle between the optical axis of an anisotropic liquid crystal (director axis) and the normal 0Z to the interface between the media is denoted by φ. The angle of rotation of the optical axis around 0Z relative to the Y0Z plane is denoted by ϕ. If these angles are different from zero and the angle ϕ depends on z, the dielectrical tensor $\hat{\varepsilon}$ has nine nonzero components $\varepsilon_{ij} = \varepsilon_{ij}(z)$. The propagation of an EMW in a medium is described by the system of ordinary differential equations 4×4 for projections of field vectors

$$\frac{d\vec{Q}}{dz} = ik_0 \hat{\mathbf{A}} \vec{Q}. \quad (1)$$

Here $\vec{A}$ is a 4 * 4 matrix, $\vec{Q} = \left(E_y \quad H_x \quad H_y \quad E_x\right)^T$. In accordance with [10], a Cauchy matrix was obtained for an inhomogeneous anisotropic layer. The solution found makes it possible to match the fields for the incident, reflected and transmitted waves at the boundaries of the layer with thickness d.

$$\vec{Q}_t(d) = \hat{N}(d,0)\left(\vec{Q}_i(0) + \vec{Q}_r(0)\right). \tag{2}$$

This relationship leads to formulas for the reflection and transmission matrices.

$$\mathbf{R} = \begin{pmatrix} R_{pp} & R_{ps} \\ R_{sp} & R_{ss} \end{pmatrix}, \tag{3}$$

$$\mathbf{T} = \begin{pmatrix} T_{pp} & T_{ps} \\ T_{sp} & T_{ss} \end{pmatrix}. \tag{4}$$

The figure shows the results of calculating the absolute values of the coefficients of the matrices (3) and (4) for angles φ = 0, ϕ = 0 and Δϕ = 90^0.

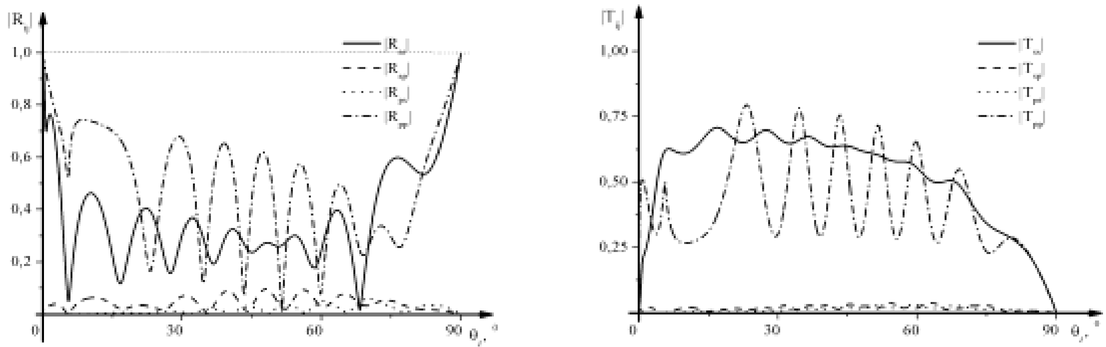

Figure1: Absolute values the coefficients of the reflection and transmission matrices

3. References

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