1. Introduction

Near the point of excitation of a guided wave in a coated dielectric grating an abrupt change in the reflectivity of the system occurs [1,2]. The theoretical limit of 100% reflectance proves to be a consequence only of the symmetry of the system [1]. Another interesting feature of this phenomenon is that the zeroth order acquires wavelength selectivity. A narrow band tunable optical filter in a reflection regime with a half-width of 3 Å has been demonstrated [1]. A very interesting bistable behaviour of the reflected light in the vicinity of guided wave resonance has been reported in refs. [3,4]. However, both the theoretical and the experimental investigations in refs. [1–4] have been carried out for the case when the incident wave vector is perpendicular to the grooves. In some cases it is important to know the behaviour of the system in conical diffraction mounting. For example, some of the plane gratings in the XUV region, in the monochromator, as well as most of the concave gratings operate when the light propagation direction lies out of the plane perpendicular to the grooves. Very recently, we have discussed the application of the conical diffraction to the mode coupling phenomena in planar corrugated waveguides [5].

The difficulties in the conical diffraction treatment follow from the fact that neither the Maxwell equations, nor the boundary conditions can be divided into two independent fundamental cases of polarization, thus rigorous electromagnetic theories have to be used. An extension of rigorous electromagnetic methods based on the integral [6] and differential [7] formalisms have been reported. In this paper we have utilized the approach in ref. [6] to analyze the effect of guided wave excitation in off-plane light incidence.

2. Numerical example

Let us consider a corrugated symmetrical waveguide with \( n_1 = n_2 = 1, n_3 = 2.3 \) and \( \lambda = 0.1 \) μm (Fig. 1). The grating is sinusoidal with a period \( d = 0.3 \) μm and \( h = 0.02 \) μm so that in the whole domain of the incident angles only the zeroth reflected and transmitted orders exist. The planar system can support one TE and one TM mode with propagation constants \( \beta_{TE} = 1.7065 \) μm \(^{-1}\) and \( \beta_{TM} = 1.18012 \) μm \(^{-1}\).

With TE (TM) type we denote the polarization of the incident wave when the electric (magnetic) field vector is perpendicular to the plane of incidence determined by \( k_x \) and the y-axis.

In the rectangular coordinate system \( Oxyz \) (Fig. 1) the incident wave vector \( k_i \) is given by \( k_i = k_0(\cos \theta, -\sin \theta, \sin \phi) \), the reflection wave vector by \( k_0(\cos \theta, \cos \phi, \sin \phi) \) and the transmission wave vector by \( k_0 \cos \theta, -\cos \phi, \sin \phi \).
\[ \theta_0, \quad \text{where} \quad k = 2\pi/\lambda \ \text{and} \ \lambda \ \text{is a wavelength.} \]

If the phase matching condition is satisfied,

\[ \theta = \theta_0 \tag{1} \]

then in the waveguide a mode is excited with angle of propagation \( \theta \) with respect to the grating vector \( K = 2\pi/d \) given by

\[ \theta = \theta_0 + n \pi, \quad n = 0, \pm 1, \pm 2, \ldots \tag{2} \]

The reflectivity of the system in conical diffraction mounting in the vicinity of TE mode excitation is shown in fig. 2 for the two polarizations of the incident wave. Contrary to the in-plane case, where TE or TM modes can be excited only by TE or TM polarized wave, in conical diffraction mounting the reflectivity in the both polarizations is influenced by the interaction.

The general behavior of the anomaly for non-polarized light is displayed in fig. 3. The minimum and the maximum of the curves are located on two circles, each one with centre \( (\theta_0 = \lambda d, d_0) = 0 \) and radius approximately equal to \( \theta_0 \).

3. Effect of non-excitation of guided waves

If the grating vector is collinear with the mode wave-vector the coupling of guided waves into radiation modes is accomplished with a polarization conservation. At oblique to the grating grooves incidence the radiation modes become, in general, elliptically polarized. The polarization of a vector plane wave is characterized by the parameters \( \delta \) and \( \pi \) \cite{3}, defined respectively as a phase difference and a ratio of the amplitudes of the parallel and perpendicular to the plane of incidence components of the electric field vector.

The dependencies of the radiation field components on \( \phi \) for TE and TM excited modes are shown in fig. 4 calculated by the numerical method described in ref. \cite{5}. From the reciprocity theorem it follows that at each angle of propagation \( \phi \) the coupling is maximum for the parameters of the incident wave given in
It is well known that the same eigenmode can be decomposed into two alternatively polarized eigenmodes, not mutually orthogonal. The total field in such a system has a form of a superposition of two waves, with the plane of polarization orthogonal to the plane of incidence. However, in some cases, the two waves may have different phase velocities, and the superposition of these waves can result in a standing wave pattern.

In the present paper, we have shown that the

\[ \psi(x) = \psi_1(x) + \psi_2(x) \]

where \( \psi_1(x) \) and \( \psi_2(x) \) are the solutions of the wave equation in the two regions.

The calculations of the field components have been performed by the method of moments. The results show that the field components are

\[ E_1(x) = E_{11}(x) e^{i \omega x} + E_{12}(x) e^{-i \omega x} \]

where \( E_{11}(x) \) and \( E_{12}(x) \) are the coefficients of the two waves, and \( \omega \) is the angular frequency.

The polarization of the field is given by

\[ P(x) = E_1(x) \times B(x) \]

where \( B(x) \) is the magnetic field.

The calculations have been done for a variety of cases, including different materials and different wavelengths. The results indicate that the polarization of the field can be significantly different from that of the incident field.

In conclusion, the study of the polarization of the field in such systems is of great interest for the development of new technologies and devices.
Reflectance can be achieved with a properly polarized incident wave. This is illustrated in Fig. 5 for an elliptically polarized wave with parameters \( \tau = -87.25^\circ \) and \( \phi = 43.65^\circ \).

References