Optimization of Binary Polarization-Selective Diffractive Optical Elements by Genetic Algorithm

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Recently, polarization-selective elements (PSE) have a number of applications such as optical pickup head, optical switching system, optical interconnection network, and so on. Conventionally, such an element works on the birefringence phenomenon encountered in anisotropic media (quartz crystal for instance). Another way for gaining the polarization properties is to use diffraction gratings with subwavelength features. According to the previous work by Vu *et al.*,[1] holographic diffraction gratings can be used as polarizing beamsplitters with high extinction ratio as long as appropriate index modulations are produced. However, the behavior of such a holographic polarizing grating is strongly dependent upon the parameter of index modulation of which the desired quantity is difficultly achieved. The non-massive production is also a limitation of the holographic gratings. Fortunately, the limitations are free for surface-relief gratings in general and binary gratings in particular. In this paper, we optimized a binary grating to gain a polarizing beamsplitter with high polarization selectivityby means of the genetic algorithm. Throughout the optimizing process, the rigorous coupled-wave analysis (RCWA) method was used to evaluate the polarizing performance of the grating.

In the RCWA method,[2] the grating is divided into a large number of thin layers (typically 50-100) parallel to the surface as shown in figure 1. Each layer is approximated as a planar grating. It is assumed that the field inside each layer is the combination of many electromagnetic waves traveling along variety of directions. The wave equations, which the field must satisfy, are solved by using the state-variables method. Then boundary conditions (continuity of tangential **E** and tangential **H**) are applied to determine the general solution. Both TE and TM polarizations must be considered when one analyzed the polarization properties of that grating.

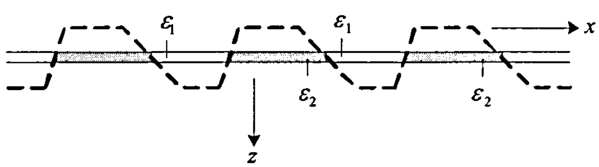

Figure 1. Approximation of a surface-relief grating.

The grating taking into account in this work is shown in figure 2. Each grating period consists of N subperiods. Each subperiod is either a ridge (bit 1) or a groove (bit 0). The widths of the subperiods are identical and below the desired wavelength. The grating period is equal to the wavelength. If we use a period longer than the wavelength, then several high-order diffracted waves other than the 0 and +1 orders retain.. In this case, the energy incident on the grating is distributed to many diffracted waves traveling along directions different from each other, and consequently, the diffraction efficiencies of the waves become lower than those in case of the period equal to the wavelength. For convenience, the readout beam is perpendicular to the grating surface. Therefore, only three diffracted waves (0 and 1) retain. The extinction ratio r, which is the most significant quantity for the polarizing grating, is given by

$$r = \frac{\eta_{+1}^{TM}}{\eta_{+1}^{TE}}$$

where η_{+1}^{TE} and η_{+1}^{TM} are the diffraction efficiencies of the first-order diffracted wave when the TE- and TM-polarized incident waves are taken into account, respectively.

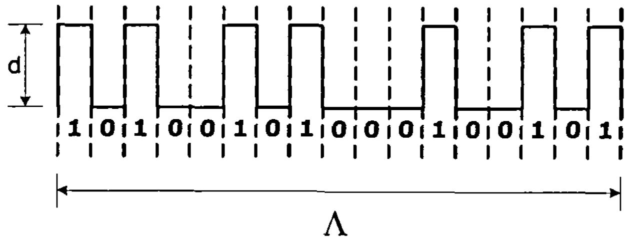

Figure 2. Grating profile for the optimization.

In the genetic algorithm deployed in this paper,[3] each individual in a population has the form of the binary profile shown in figure 2. The fitness of the individual is expressed as the extinction ratio. The individuals have sizes of 16, i.e. there are 16 subperiods in a grating period. The population size (the number of individuals in a population) is as high as 100 for diversity preservation. The selection of individuals for reproducing a next generation is according to the normal rule

$$p_i = \frac{r_i}{\sum r_i}$$

where p_i and r_i are the selection probability and the fitness of the *ith* individual, respectively. The crossover and mutation probabilities are respectively 0.6 and 0.03.

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