# Polarization Separation using Symmetric Binary Grating

Viet Tien Vu, Nam Kim, Seok-Hee Jeon*, Sang-Keun Gil**
Department. of Information & Communication Engineering, Chungbuk National University
* Department of Electronic Engineering, Incheon University
** Department of Electronic Engineering, Suwon University
e-mail tienvv@osp.chungbuk.ac.kr

The aims of this paper are to design and to optimize a symmetric binary grating in order to achieve a polarizing beamsplitter (PBS) with high extinction ratios.

The behavior of the binary grating when a light wave meeting the +1st-order Bragg condition impinges to it is shown in Fig. 1. In this case, 0th and +1st-order waves may have higher diffraction efficiencies than those of the others. Therefore, we desire a polarization separation between the two waves (i. e. 0th and +1st-order waves are fully s- and p- polarized, respectively, or vice versa) while ignoring the other waves. The profile of one grating period is shown in Fig. 2. We choose the grating period $\Lambda = \lambda$ so that only 0th and $\pm$1st orders propagate. The dielectric constants $\epsilon_1$ and $\epsilon_2$ are also fixed at 1(of free space) and 2.292 (of silicon), respectively. Two grating parameters, which are the feature width $w$ and the grating depth $d$, remain to determine the desired grating.

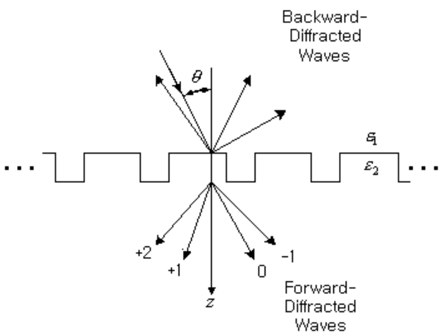


Fig. 1. Diffraction of the grating.

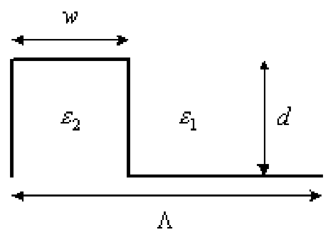


Fig. 2. Profile of one grating period.

We design a binary grating in which the p polarization is diffracted in the +1st order and the s polarization retains in the 0th order. To be as a PBS with high extinction ratios, the grating should simultaneously have high diffraction efficiencies for both the +1st-order wave in p mode ($DE_{p,+1}$) and the 0th-order wave in s mode ($DE_{s,0}$). Therefore, for simplicity, we construct a new fitness function for handling both of those requirements as follows

$$f = DE_{p,+1} + DE_{s,0}, \quad (1)$$

where we apply the rigorous coupled-wave approach method[1] to calculate the diffraction efficiencies.

We use a genetic algorithm[2] (GA) which based on the mechanics of natural selection and natural genetics as the optimizing method in order to maximize the fitness as high as possible. The GA starts with an initial population consisting of 100 gratings generated randomly. Then, three basic operators of GA: selection, crossover, and mutation, are used with the population to generate a new population which have exactly 100 new gratings. The average fitness of the new population is most likely higher than that of the previous one. We repeat that process until the average fitness converges. The grating with the highest fitness among those in the last population is considered as the solution.

Figure 3 shows the average fitness as a function of the population number. The initial population (# 0) has the low average fitness of about 1.0527. After 70 populations, the average fitness gets convergent and is improved significantly. The obtained grating has the feature width and depth of approximately 0.52 and 13.09 wavelength, respectively. The behavior of the grating is shown in Table 1. In p-mode, the incident wave is mostly diffracted to the forward +1st order with the $DE_{p,+1}$ of 96.77%. If the s-polarized wave impinges on the grating, then 92.25% energy of the wave goes to the forward 0th order. The other diffracted waves carry a small amount of energy. Accordingly, the extinction ratios of the +1st order ($DE_{p,+1}/DE_{s,+1}$) and the 0th order ($DE_{s,0}/DE_{p,0}$) are respectively 9677 and 9225. From the theoretical aspect, such a grating can be used as a PBS with very high extinction ratios. Polarization characteristics of the grating are described in Fig. 4. Note that the polarization angle is the angle evaluated between the polarization orientation of the incident wave and the normal to the incident plane.

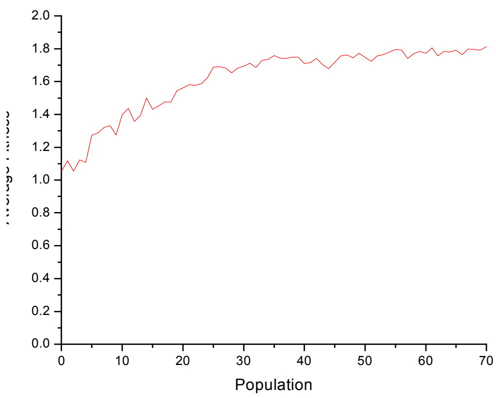


Fig. 3. Run of the genetic algorithm.

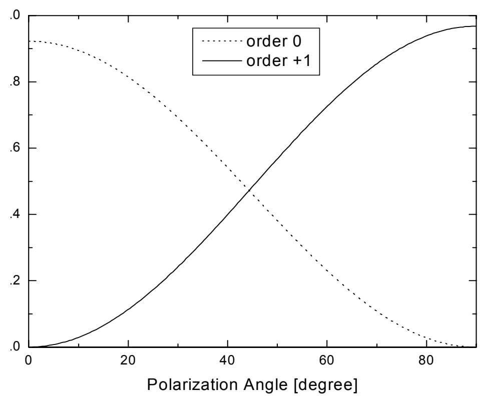


Fig. 4. Polarization characteristic of the grating.

## Acknowledgement

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## References

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2. D. E. Goldberg: Genetic Algorithms in Search, Optimization, and Machine Learning, eds. D. Edward (Addison-Wesley, Massachusetts, 1989) 1st ed.