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Diffraction properties of transmission binary blazed grating

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The properties of binary blazed grating were theoretically analyzed with finite-difference time-domain (FDTD) method. The diffraction efficiencies and diffraction angles of –1, 0, and +1 order for the grating varying with wavelength, grating structure, and the etch depth were studied when the incident angle was 30°. The numerical simulations revealed that the binary blazed grating presented high stability of diffraction efficiencies with wavelength shift.

Keywords: binary blazed grating, diffraction efficiency.

1. Introduction

The regular blazed grating (RBG) can attain high diffraction efficiency for special order with periodic sawtooth modulation in the surface. It has been widely used as diffraction gratings since its introduction in the early 1900s, but its effectiveness is ultimately limited by the effects of shadowing at the edges of the teeth. An alternative approach, so-called binary blazed grating (BBG), has recently been reported to be available. The development of nanotechnology has made it possible to generate subwavelength structures, such as grooves [1–4], pillars [5–7], or holes [8–10], which are not resolved by the light (in the sense of far-field diffraction) and possess an “effective refractive index”. According to the literature [5, 7–12], the refractive index can be modulated by adjusting the profile and duty cycle of the subwavelength structure, therefore BBG is a good approximation to RBG, and the structure parameters of the BBG are very important for fabricating the grating.

In this paper, the efficiency and angle varying with the structure type and wavelength of the BBG were calculated theoretically by finite-difference time-domain (FDTD) method [13]. The results of the theoretical simulation made some sense in the fabrication of the BBG.

2. Design

A transmission BBG was designed, as shown in Fig. 1**b**, as an approximation of the RBG (Fig. 1**a**) and such a BBG style was relatively more feasible in nanotechnology. Assuming that the refractive index of the grating substrate was n_2, while that of the surrounding media was n_1, the m-th order interference angle θ_m, blazed angle θ_b and incident angle θ_i matched Snell's law $n_1 \sin(\theta_i - \theta_b) = n_2 \sin(\theta_m - \theta_b)$. The grating equation was $m\lambda = b(n_1 \sin\theta_i + n_2 \sin\theta_m)$, where λ was the wavelength of the input field. If $n_1 = 1.457$ and $n_2 = 1.9$, the RBG period of 6 μm and blazed angle 41.87° were chosen to give a significant –1 order diffraction efficiency. The number of grooves in one period and depth of the grooves were varying to optimize the BBG.

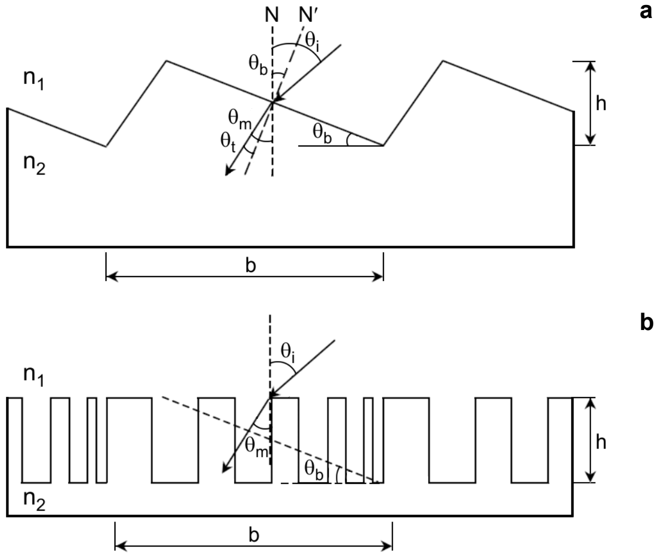
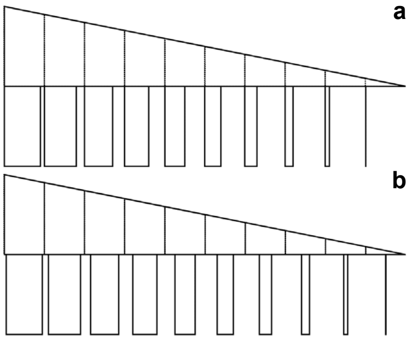


Fig. 1. Schematic diagram of the RBG (**a**) and BBG (**b**).

3. Discussion

3.1. Diffractive efficiency and angle for different structures

Note that BBG being an approximation to RBG, the diffractive efficiency and angle would be somewhat different from the theoretical value of RBG. The structure was one of the effective factors. When one period of the RBG was divided into several uniform parts, there were two kinds of structure as indicated in Fig. 2: the ribs were at the side or in the middle of the uniform part for structure 1 or 2, respectively. Figure 3 presents diffractive efficiencies for the two structures when one period was divided into different numbers of uniform parts. It is clear that the efficiency of –1 order



◀ Fig. 2. Two kinds of structure for BBG.

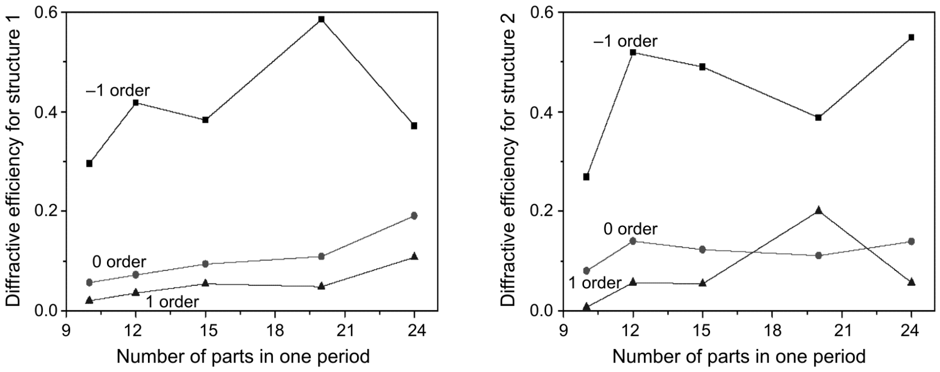
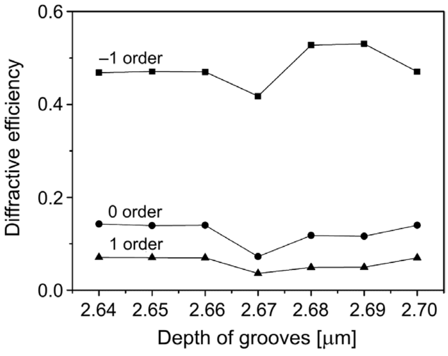


Fig. 3. Diffractive efficiency of structure 1 and 2 varying with part numbers in one period.

reached the highest value of about 60% when there were 20 parts in one period for structure 1 and about 55% when there were 24 parts for structure 2. So, we could get higher diffractive efficiency with less parts if structure 1 was employed.

3.2. Diffractive efficiency for different etched groove depths

The groove depth also affects the diffractive efficiency. The efficiency as a function of the groove depth for structure 1, with the period being divided to 12 uniform parts,



◀ Fig. 4. Diffractive efficiency of structure 1 as a function of the depth of grooves.

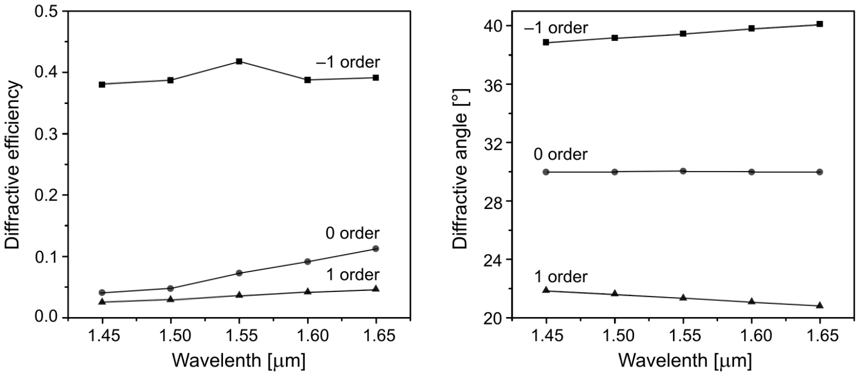


Fig. 5. Diffractive efficiency and angle of structure 1 varying with wavelength.

is shown in Fig. 4. It was found that the drift efficiency for –1 order was about 10% when the depth varied from 2.64 to 2.70 μm. That is to say, the BBG could work normally even though the grating was not so precisely fabricated.

3.3. Diffractive efficiency and angle for different wavelengths

Figure 5 shows the diffractive efficiency and angle of the BBG as a function of the wavelength. It can be seen that with an increase of the wavelength, the diffractive angle increases for –1 order , decreases for 1 order, and is constant for 0 order. As far as the efficiency is concerned, it appears to be very stable at least in the range of ±100 nm centred at 1.55 μm.

4. Conclusions

The BBG is a good approximation to RBG. The diffractive efficiency of BBG can reach about 60%, and it can work in a long wavelength range of about 200 nm. The demand for the fabrication is not so tough.

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