Fabrication of Holographic Grating by alternative setting of Michelson Interferometer

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Abstract. This paper presents the method and experimental results of the fabrication of holographic grating. The holographic grating was fabricated by using an alternative setting of Michelson Interferometer. In general, the interference pattern produces by Michelson interferometer is a circle fringe pattern. By an alternative setting of the interferometer, we could obtain a fringe pattern that has a linear shape. The angles between the two arms of Michelson interferometer, cross-beam angle, were adjusted until a linear interference pattern occurs. The interference pattern was projected onto a screen where a photoresist film is located. The photoresist film functional as a collective material of an interference pattern, i.e., a holographic grating. The film is developed and then fixed by a chemical process. By the chemical process, the holographic grating is permanence recorded on the film. After the fabrication process, we analyzed the physical properties of the holographic grating. We also measured the grating space by Scanning Electron Microscope (SEM). Relationships between cross-beam angles and grating space are shown and discussed. Experimental results show that we could apply the proposed method to fabricate a holographic grating.

1. Introduction

Fabrication of holographic grating is based on the interference of light beams. Many researchers have been proposed a method for fabricating the holographic grating [1–3] and the grating properties were also investigated. To fabricate a holographic grating, an interference pattern is created and captured on a medium so that the grating can fabricate into various types of substance [4–7]. In recent years, several applications of holographic grating have been proposed [8–10].

This paper proposes the method to fabricate a holographic grating base on interference beams of Michelson interferometer. The angles between the two arms of the interferometer called cross-beam angle are adjusted until a linear interference pattern is obtained. The interference pattern is captured by a photoresist film, then the film is developed and fixed so that the holographic grating is permanence recorded on the film. After fabrication, the physical properties of the grating are investigated. The diffraction pattern of the grating was observed by the illumination of laser beam. Then the diffraction efficiency and the grating spaces were calculated. The grating periods and the grating spaces are also observed by Scanning Electron Microscope (SEM). The grating spaces obtain from both methods are compared. The relationship between cross-beam angle and grating space are shown and discussed.
2. Experiment

2.1. Experiment setup
The experiment setup for the fabrication of holographic grating by the alternative setting of Michelson Interferometer is shown in figure 1. He-Ne laser was used as a light source. Objective lens and pinhole are combined and function as beam expansion apparatus. By adjusting the position of both the objective lens and pinhole, we obtained the expanded beam. The amount of beam area is controlled by an iris-diaphragm. The beam splitter, mirror M1 and M2 provide an interference pattern. The interference pattern was captured by a photoresist film.

![Figure 1. Schematic diagram of an experiment setup to fabricate a holographic grating.](image)

2.2. Experiment method
First, adjust the mirror M1 and M2 of the interferometer until a circular interference pattern occurs. Adjust an angle between the mirrors, cross-beam angle ($\beta$), to 0.2°, where a linear shape of the interference pattern is achieved. Then recorded the interference pattern on the photoresist film, i.e., the holographic grating is captured, where the size of the fabricated grating is 2 x 2 cm$^2$ and the exposure time is 5 seconds. Repeat the experiment by varying the cross-beam angle ($\beta$), in steps, each step is 0.4°, 0.6°, 0.8°, and 1.0° respectively. After captured the interference pattern, the photoresist film is developed by a chemical solution, AGFA G150 developer, and then fixed by AGFA G335 fixing bath. Finally, the holographic grating is permanence recorded on the film.

3. Results and discussion

3.1. Measurement of grating space by illumination laser beam
The experiment setup for observation of diffraction patterns from a fabricated grating is shown in figure 2. The grating is illuminated by He-Ne laser then a diffraction pattern appears on a screen. After the diffraction angle is measured, the grating space is calculated by the following equation,

$$d = \frac{\lambda}{\sin \alpha}$$

(1)
where $\lambda$ is wavelength of He-Ne laser and $\alpha$ is a diffraction angle. Relationships between grating space ($d$) and the inverse value of function sine of cross-beam angle ($1/\sin(\beta)$) are shown in figure 3.

![Figure 2. The experiment setup for measuring the grating space.](image)

![Figure 3. The relationships between the grating space and the inverse value of function sine of cross-beam angle.](image)

Figure 3 shows that, the relationships between the grating space and the inverse value of function sine of cross-beam angle are linearly relation with $R^2 = 0.9992$. The y-interception on Y-axis represents the optical path difference between mirror M1 and M2. Thus, we could obtain more grooves’ density of a grating by increasing the optical path difference between both mirrors, the interference fringe of the interferometer is narrower, i.e., causing the grooves' density of a grating increase.

3.2. Measurement of grating space by scanning electron microscope

The grating space is observed and measured by scanning electron microscope (SEM). Figure 4 shows the image of a holographic grating. The grating spaces are shown in table 1. The diffraction efficiency and grooves density of gratings are shown in table 2.
Figure 4. Image of holographic grating obtained by SEM, where the cross-beam angle are (a) $\beta = 0.2^\circ$, (b) $\beta = 0.4^\circ$, (c) $\beta = 0.6^\circ$, (d) $\beta = 0.8^\circ$, and (e) $\beta = 1.0^\circ$, respectively.

Table 1. The grating spaces measured by SEM.

| Line No. | $\beta = 0.2^\circ$ | $\beta = 0.4^\circ$ | $\beta = 0.6^\circ$ | $\beta = 0.8^\circ$ | $\beta = 1.0^\circ$ |
|----------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 1        | 184.00              | 86.06               | 58.68               | 45.38               | 39.33               |
| 2        | 180.00              | 84.50               | 57.12               | 44.26               | 39.33               |
| 3        | 182.00              | 86.06               | 57.89               | 45.34               | 38.94               |
| 4        | 184.00              | 84.50               | 57.12               | 45.32               | 39.73               |
| 5        | 180.00              | 86.07               | 58.69               | 45.33               | 38.93               |
| Average  | 182.00              | 85.44               | 57.90               | 45.13               | 39.25               |

Table 2. Diffraction efficiency and grooves density of gratings.

| Cross-beam angle ($\beta$) | Diffraction efficiency (%) | Grooves density (line/cm) |
|-----------------------------|----------------------------|---------------------------|
| 0.2$^\circ$                 | 4.29                       | 55.00                     |
| 0.4$^\circ$                 | 18.63                      | 110.00                    |
| 0.6$^\circ$                 | 29.21                      | 152.00                    |
| 0.8$^\circ$                 | 38.16                      | 200.00                    |
| 1.0$^\circ$                 | 43.65                      | 245.00                    |
4. Conclusion
The experiment method for the fabrication of holographic grating base on adjusting interfering beams of Michelson Interferometer is presented. In the method, a fringe pattern is captured by a photoresist film and the holographic grating is obtained. After fabrication, the grating space is measured and confirmed by two different methods. Experimental results show that the grating spaces obtain form both methods are in agreement well. Imaging obtained by SEM shows that, for cross-beam angle varied between 0.2° and 1.0°, the grating spaces are in the range between 39.25 μm and 182.00 μm. For this experiment, the maximum groove density is 245.0 line/cm. The relationship between cross-beam angle and grating space is plotted and it shows that the grating space is inverse proportional to the sine function of cross-beam angle. This means that the wide cross-beam angle, the narrow grating space. In conclusion, we could apply the method to fabricate a holographic grating where the grating space could control by varying the cross-beam angle of the interference beams and the grooves’ density could control by adjusting the optical path difference between the mirrors of an interferometer.

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