Experimental research on measuring image energy in the spectrum imaging system

CHEN Maoxin, HE Xiaorong, ZHANG Weiping, LI Xiaofang
The College of Physics Science and Technology, Guangxi University,
Nanning, 530004, P.R.CHINA

ABSTRACT

We reported the previous research of spectrum imaging with a double-grating imaging system in 2001. In this paper, we will investigate the energy of the image obtained using the same imaging method. A mercury-vapor lamp was used as the light source to measure the light energy of the image at different positions for four grating combinations. The experimental results were analyzed systematically. The factors affecting the brightness of the image were also discussed in this paper.

Keywords: convergent spectrum, converged images, spectrum imaging

1. INTRODUCTION

Grating is such an important optical element that it has been investigated extensively and intensively for long. Our reported results provided new insights into the properties of grating, that is the object spectrum diffracted by the first grating can be converged by the second grating to form images of the original object [1]. The method for imaging by grating spectrum differs from those reported in the literature [2, 3, 4]. In this paper, we focus on the in energy study for the image obtained by our spectrum imaging method.

The light from the object will form object spectrum after being diffracted by a grating G_1 with higher spatial frequency. After close observation, we found that images of the original object can be observed at different positions when the object spectra converged by a grating G_2 with lower spatial frequency. The converged images observed at these positions correspond to the first, second, ..., and nth order diffraction spectrum of grating G_2. We also found that the converged images obtained at the positions far from the object spectrum correspond to lower diffraction orders while the images at positions near the object spectrum correspond to higher diffraction orders. The energy of the observed converged image does not correlate with its distance from the object spectrum. Therefore, the energy of the converged image cannot be determined simply by the distance between the converged image and the object spectrum.

In this paper, based on the experimental measurements, we will investigate the energy of the converged image and try to find the relationship between the converged image and the diffracting order and the positions.

2. EXPERIMENTAL PROCEDURE

The optical path of the spectrum imaging and measuring by using two gratings can be described schematically as follow In Fig. 1, S, S' (formed after S being diffracted by G_1), L, D are mercury lamp (light source), virtual light source, lens,

Holography, Diffractive Optics, and Applications II, edited by Yunlong Sheng, Dahsiung Hsu, Chongxiu Yu, Byoungho Lee, Proceedings of SPIE Vol. 5636
(SPIE, Bellingham, WA, 2005) · 0277-786X/05/$15 · doi: 10.1117/12.579363

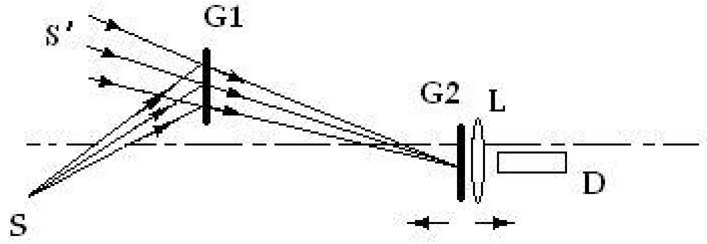

Fig. 1. Optical path of the spectrum imaging and measuring

and detector, respectively. G_1 and G_2 are two gratings with different spatial frequencies. In this optical path, G_1 is used to diffract the object waves to form the object spectra, while G_2 is used to converge the object spectra from G_1 to form reductive object waves so that images of the original object can be observed behind G_2 by naked eyes.

The converged image observed by naked eyes is a virtual image, i.e., its energy can not be detected directly by a detector. In fact, the converged image is formed through converging the monochromatic light beams by the converging grating. Therefore, the energy of the converged image can be determined by measuring the energy of monochromatic light beam which contributes to the converged image. If the converged image is formed by using many separate monographic light sources as object spectra, at least three light sources are needed. However, monochromatic light sources are difficult to be used directly for the following reasons, 1) it can hardly be realized to put the monochromatic light sources at the exact positions so that the object spectrum from these light sources form images at the same position; 2) though the converged image can be observed clearly by naked eyes, the energy of the converged image is fairly low and the photocurrent detected by detector for some diffraction order could be as low as the magnitude of 10^{-8}~10^{-9}A. However, a ordinary optoelectronic detector has no sensitivity like this. The monochromatic light sources used to form converged image must possess enough energy so as to be detected by the detector for all the diffraction orders, but it is also difficult to obtain monochromatic light sources which have high and same intensities. For this reason, we use mercury lamp with slit as the object. Our proposed optical path is shown in Fig. 1, the light rays from the mercury lamp form object spectra after being diffracted by grating G_1. Converged image can be formed if put the grating G_2 at a proper position inside the object spectrum. Thus, the energy of the converged image can be measured. Three wavelengths, 453.8nm (purple), 546.1nm (green), and 578.0nm (yellow) were used as monochromatic light sources whose energy are the highest and nearly the same. In the experiment, their energy were measured behind G_2 for the corresponding diffraction order.

First of all, fix the position of G_1 and observe the converged image behind G_2 by naked eyes, then move G_2 so that the brightest image can be obtained. Put a 8mm slit just in front of G_2 and 5mm slit in front of G_1 and adjust the relative position so that only one of the three colors purple, green, and yellow can reach the slit in front of G_2 (the slit of G_2 permits only the light ray falling on it to pass). After measuring the energy of the three light beams passing through G_2 respectively, the energy of the different diffraction order can be determined. Move G_2 to another position of the converged imaging and repeat the above measurements.

In actual measurement, a photocell was used as the detector to measure the energy of the light beam corresponding the diffracting order of the converged image. The light beams from the mercury lamp were diffracted by G_1 and then converged by G_2 to form an image, so the photocurrent excited by some diffracting order is as low as the magnitude of 10^{-8}~10^{-9}A order after the two times of diffracting process. Because the sensitivity of an ordinary photocell detector is not so high to be used to measure accurately the energy of the corresponding diffracting order, we improve the detecting part to satisfy the measurement needs. The purpose of the measurement is to compare the relative energy of the converged images with different diffracting order, not to measure the absolute intensity of the spectrum energy. Thus, the relative energy of the converged images of different diffracting orders can be compared even if the sensitivity of the photocell is not the same for the colors with different wavelength.

3. RESULTS

The purpose of this study is to investigate the correlations of the energy of converged image with the factors such as corresponding diffraction order, position of the converged image. In order to compare the energy effectively, the data are illustrated in such a way that every curve represents for the energy variation with the monochromatic light wavelength (three colors, purple, 453.8nm; green, 546.1nm; yellow, 578.0nm) for a diffraction order.

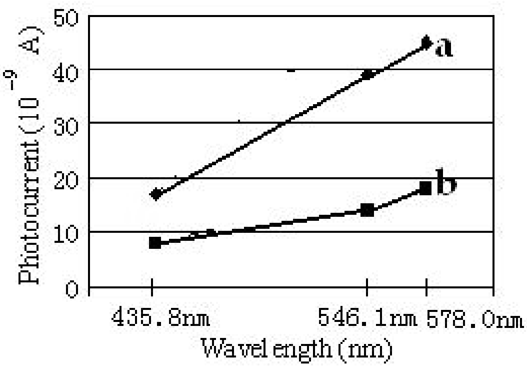

Figure 2 The spectrum energy variation of the converged image with the wavelength when grating combination of 1000L/mm—100L/mm used.

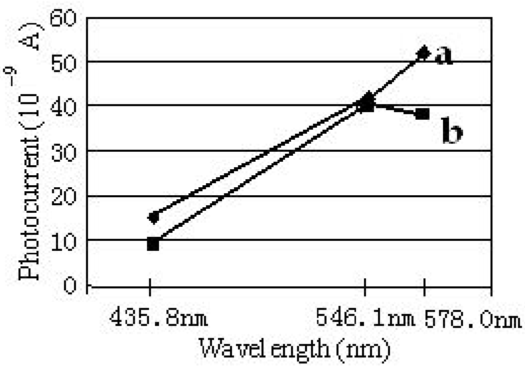

Figure 3 The spectrum energy variation of the converged image with the wavelength when grating combination of 1000L/mm-300L/mm used.

Figure 2 shows the spectrum energy for the grating combination of 1000L/mm---100L/mm, curve a corresponds to the second order image when the spacing between G_2 and G_1 is 40.5cm, curve b corresponds to the third order image when the spacing between G_2 and G_1 is 29.1cm. Figure 3 shows the spectrum powerr for the grating combination of 1000L/mm---300L/mm, curve a corresponds to the first order image when the spacing between G_2 and G_1 is 43.8cm, curve b corresponds to the second order image when the spacing between G_2 and G_1 is 9.0cm. Figure 4 shows the spectrum energy for the grating combination of 1000L/mm---136L/mm, curve a corresponds to the first order image when the spacing between G_2 and G_1 is 54.6cm, curve b corresponds to the second order image when the spacing between G_2 and G_1 is 22.5cm, curve c corresponds to the third order image when the spacing between G_2 and G_1 is 18.5cm. Figure 5 shows the spectrum power for the grating combination of 600L/mm---100L/mm, curve a corresponds to the second order image when the spacing between G_2 and G_1 is 36.5cm, curve b corresponds to the first order image when the spacing between G_2 and G_1 is 101.0cm, curve c corresponds to the third order image when the spacing between G_2 and G_1 is 17.3cm.

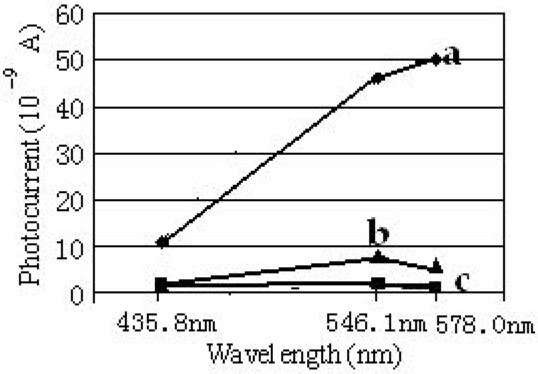

Figure 4 The spectrum energy variation of the converged image with the wavelength when grating combination of 1000L/mm-156L/mm used.

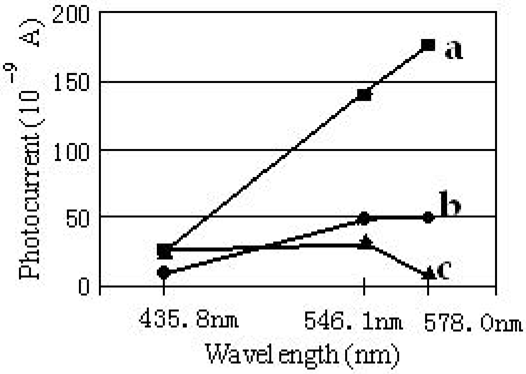

Figure 5 The spectrum energy variation of the converged image with the wavelength when grating combination of 600L/mm-100L/mm used.

Figures 2~5 show the spectrum energy of the converged images when different grating pairs are used. Taking Fig. 2 for example, curve a shows the second diffraction order spectrum energy of three monochromatic light beams (purple, 435.8nm; green, 546.1nm; yellow, 578.0nm) when the distance between G_2 and G_1 is 40.5cm, curve b shows the second diffraction order spectrum energy of the same monochromatic light beams when the distance between G_2 and G_1 is 29.1cm, it can be seen that all the spectrum energys of curve a are larger than those of curve b over the regime of wavelength discussed. The intensity of the converged image formed by the three light beams of the former will surely higher than that of the image formed by the beams of the latter. Similar results can be obtained for Figs 3~5.

4. ANALYSIS AND DISCUSSION

Based on the above measurements, it can be concluded that for the grating combinations of 1000L/mm---100L/mm、1000L/mm---156L/mm、1000L/mm---300L/mm with the spatial frequency of G_1 fixed at 1000L/mm, the intensities of the converged image have the following characteristics: the energy of low diffraction order converged image is larger than that of the high order image and spacing between G_2 and G_1 corresponding to low diffraction order converged image is larger than the spacing corresponding to higher diffraction order converged image, that is to say the energy of the converged image is determined by the corresponding diffraction order. When the spatial frequency of G_1 is fixed at 600L/mm, the energy of the converged image for the grating combination of 600L/mm---100L/mm has a similar characteristic as the above cases when G_1 has a spatial frequency of 1000L/mm, i.e., the energy of the converged image corresponding to larger spacing between G_2 and G_1 (36.5cm) is higher than that of the image corresponding to smaller spacing (17.3cm).

The position of the above converged images corresponds to the case of small distance between G_2 and G_1 (e.g., smaller than 1 meter). According to the measurements, the energy of the light falling on G_2 which is from G_1 will attenuate when the distance between G_2 and G_1 increases. In this case, the energy of low order converged images will no longer surpass over that of the higher order converged images. In Fig. 5, it can be seen that the first order converged image corresponds to the space of 101.0cm between G_2 and G_1 when grating combination of 600L/mm---100L/mm adopted and its energy is lower than the second order converged image when the spacing of G_2 and G_1 is 36.5cm, i.e., the energy of the converged image is not determined completely by the diffraction order and the position effects of the converged image should be considered.

From the obtained data, it can be noticed that the energy of zero order converged image is lower than that of the first order converged image for some grating combinations, but this will be reversed for other combinations. Therefore, the energy of converged image correlates to some extent with the diffraction efficiency of the gratings used

5. CONCLUSIONS

Therefore, based on the above measurements we can conclude; 1) when the distance between G_2 and $G_1$is relatively small (e.g., less than 1 meter), the energy of the converged image is determined by the correponding diffracting order and the effect of the position of the converged image can be ignored; 2) when the distance between G_2 and $G_1$is larger (e.g., more than 1 meter), the position of the converged image will affect its energy to some extent; 3) it is obvious that many factors will affect the energy of the converged image.

In this study, we focuses on the effects of diffracting order of the converged image on its energy. In order to know the energy distribution of the converged image comprehensively, it is necessary to take the effects of diffracting order, converging position, diffraction eficiency of the grating on the energy of the converged image into account. So further research on these is needed.

ACKNOWLEDGEMENT

The authors appreciate the support of the National Natural Science Foundation of China, Grant No. 10364001； and the support of the Natural Science Foundation of Guangxi Province, Grant No. 0043001

REFERENCES

1. Weiping Zhang, Wenlou Wei. Method for Spectrum Imaging. PROCEEDINGS OF SPIE .2001,Vol.4548 99-102
2. Lunazzi JJ, Rivera NI. Pseudoscopic imaging in a double diffraction process with a slit. OPTICS EXPRESS. 2002.10 (23): 1368-1373
3. Zhan, Li. Split of Fourier spectrum of the double-grating diffraction-interference effect under near coherent illumination. Optics Communications. 1997,139(4-6).-170-176
4. Daniel Crespo, Jose Alonso, Eusebio Bernabeu . Generalized grating imaging using an extended monochromatic light source. Journal of the Optical Society of America A: Optics and Image Science, and Vision 2000,17(7).-1231-1240