The influence of wavefront of the writing beams on angle Bragg selectivity in volume holographic storage

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ABSTRACT

Angular selectivity of volume grating limits the capacity of holographic 3-dimensional storage. In this work, we investigated experimentally the influence of wavefront shapes of the writing beams on the angular selectivity of thick grating in a $LiNbO_3$ crystal. The experimental results showed that longer wavefront curvature results in more critical Bragg angular selectivity.

Keywords: holographic storage, angular selectivity, wavefront curvature

1. INTRODUCTION

Holographic 3-dimentional storage offers an extremely important way for optical information storage because of the large theoretical capacity of $\sim V/\lambda^3$ bits in a volume of V[1]. The high capacity of the holographic storage is due to the critical angular selectivity and the small spatial area of the gratings in the media. With the assumption that two writing beams are all planar, many works have been done to discus the properties of the holographic storage, from the angular selectivity[2] to the cross-talk of gratings[3-4]. However, in practices the wave-front of the reference and the signal beam are inevitably curving because of different reasons, such as the Guassion profile of the writing beams. Several researchers[5-6] had investigated the angular selectivity when the reference beam is spherical. The results show that in the Fresnel regime, gratings written by spherical reference beams have almost the same angular selectivity as the gratings written by planar beams. In these works, the reference beams have short curvature radii and the results are useful for the storage with the shift multiplexing. In normal angular-spatial multiplexing, the curvature radii of the writing beams are normally quit large. In this work, we investigate experimentally the grating properties written by beams with large wavefront curvature radii. The results show that in order to get large storage capacity, the lager curvature radii make the gratings have more critical Bragg angular selectivity.

2. EXPERIMENTAL SETUP AND RESULTS

Fig.1 shows schematically our experimental setup. A $LiNbO_3$ crystal ($a\times b\times c$= $14.0\times4.5\times12.0mm^3$) doped with iron (0.05wt.%) and zinc (0.8mol%) was used as the storage medium. The crystal was mounted on a rotate stage with the angular resolution of 0.00175^o. Beams of 532nm in extraordinary polarization were used to write gratings of which wavevector are parallel to the c axis of the crystal. The diffraction efficiency here is defined as: $\eta=I_d/(I_t+I_d)$ where I_d and I_t are the intensities of the diffracted and transmitted beams respectively. Lens L_3(f=100mm) made the waist of reference beam, point O_1, 140mm behind L_3. The radius of the laser waist of the laser was 1.0mm and the waist at point O_1, $\omega_{01,}$ was calculate to be 0.05mm. The crystal was place 625 mm away from the point O_1. Lens L_4 with focus length of 100mm was inserted between point O_1 and crystal. L4 was mounted on a linear stage and the distance between L_4 and O_1, d, can be adjust from 25mm to 50mm.

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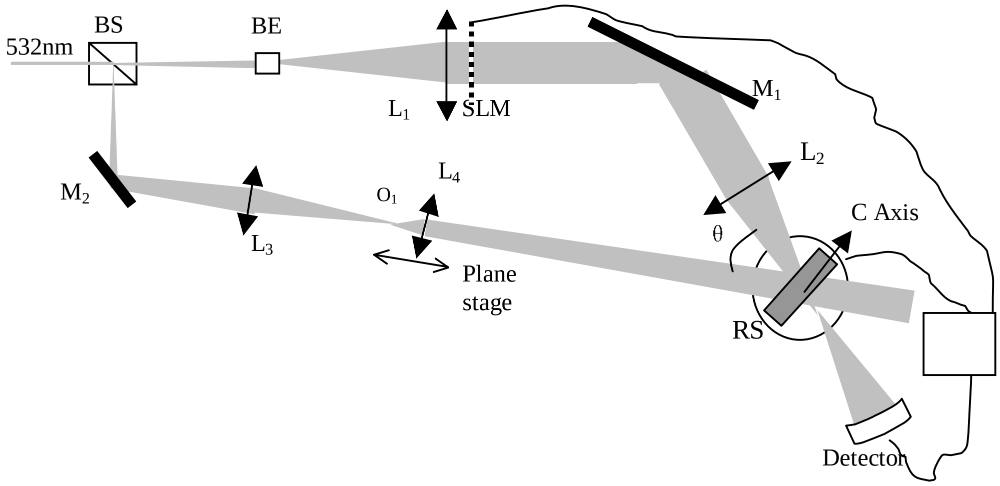


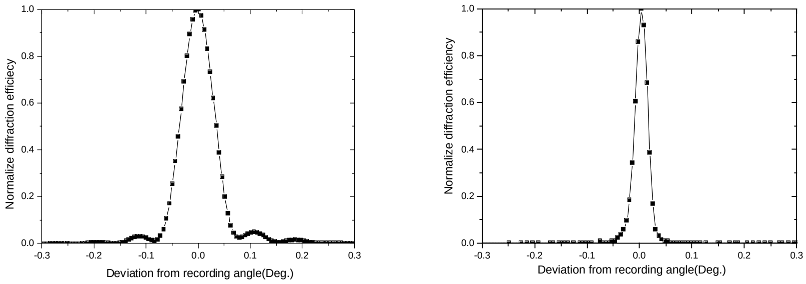
Fig.1 Experimental setup: **BS:** Beam Split; **BE:** Beam Expander; **SLM:** Spatial Light Modulator**; M's:** Mirror; **L's:** Lens; **RS:** Rotate Stage; **PC:** Personal Computer. Here L_4 was mounted on a linear stage.

According to optical transformation of the Gaussion beam through lens, we can calculate the radius of the reference beam on the crystal by the formula:

$$R = (625-d)\left\{1+\left[\frac{\pi\omega_{01}^2 \times [1+(\frac{\lambda d}{\pi\omega_{01}^2})^2]}{\lambda(625-d)}\right]^2\right\} \quad \text{---------------(1)}$$

Here λ is the wavelength of the beam. When d changes from 25mm to 50mm, the radium of the reference beam changed from 600.5mm to 575.6mm. In the signal arm, the beam was collimated by the beam expender and the lens L_1, and then was imaged on the crystal by lens L_2 with focus length of 300mm.

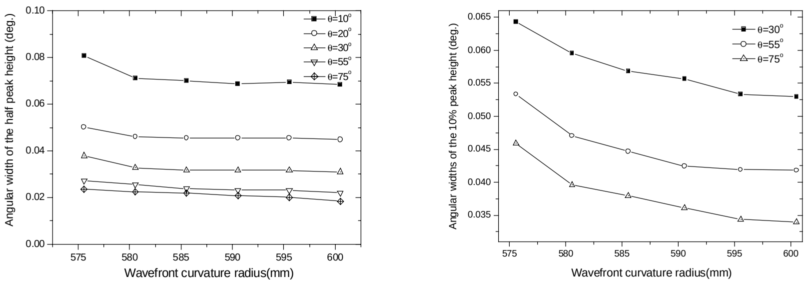
In our experiments, the reference beam and the signal beam intersected on the center of the rotate stage with a crossing angle θ in the air. Through the photorefractive processes, gratings were recorded in the $LiNbO_3$ crystal on the rotate stage. We wrote the gratings with the diffraction efficiency of 10^{-4}. To check the angular selectivity of the gratings, we rotated the crystal and checked the rocking curve of the diffraction beam with a very weak readout beam (the intensity was 10μW/cm^2). Two typical normalized rocking curves of the gratings were shown in Fig. 2. In Fig. 2 (a) and (b), d were both 50mm but the intersection angle between the two writing beams changed from 10^o to 50^o. We can see that with the decrease in the crossing angle of the writing beams the Bragg angular selectivity becomes worse.



(a) (b)

Fig. 2. Rocking curves of the gratings when (a) θ=10°, d=50mm; and (b) θ=50°, d=50mm

We check the rocking curve with different crossing angles between the writing beams and different reference beams with different curvature radii. The angular widths of the half peak height and the angular widths of the 10% peak height were plotted in Fig. 3. It can be seen that the width of angular selectivity of the volume grating decreases while the reference beam curvature approaches to planar one. From Fig. 3 (a) and (b), we can find both of the angular width of the half peak height and the 10% peak height decreased about 20% when the wavefront curvature radii changed from 575.6mm to 600.5mm. And with the increase in the crossing angle between the writing beams, the gratings have more critical angular selectivity.



(a) (b)

Fig.3. The dependence of angular width of, (a) the half peak height, and (b) the 10% peak height, on the wavefront curvature radii of the reference beams.

In the experiment above, we used a lens with the focus length of 300mm as the imaging lens. In our experiment, we put the crystal on the focus of L_2. Because of the divergence of the beam before and after the waist of the Gaussion beam, signal beam inside the crystal is not a planar beam. It is difficult to describe quantitatively the shape of the wavefront curvature of the signal beam, so here we just investigated the dependence of the angular selectivity of the grating on the focus length of the image lens. We checked the angular width of the half peak weight when the imaging lens L_2 has the focus length of 300mm and 400mm, respectively. The experimental results were shown in Fig. 4. We can find the same tendency of the dependence of the angular selectivity on the wavefront radii of the reference beam when focus length of the imaging lens changes from 300mm to 400mm. Angular selectivity becomes worse when the reference beam bents more seriously. On the other hand, the width of half peak height when f=300 are about 10% larger than the width when f=400mm.

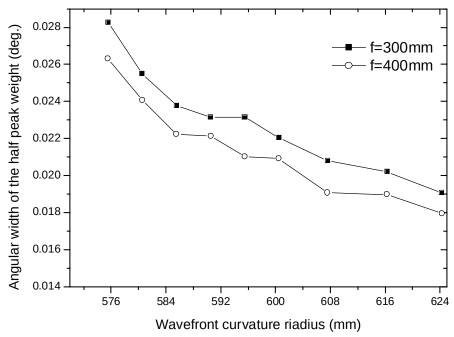


Fig. 4 The angular width of the half peak height when the focus length of the imaging lens is 300mm and 400mm, respectively.

3. DISCUSSIONS AND CONCLUSIONS

In this work, we studied experimental the influence of the curvature shape of two writing beams on the angular selectivity of the volume gratings. According to the angular selectivity, to get larger storage capacity need the reference beam with the curvature radius as large as possible, i.e. the optimal reference beam is planar one. But it means the spatial multiplexing decrease. In order to get planar reference beam, imaging system should be used to im-prove the properties of the incident Gaussion beam. When the curvature radium increases, the diameter of the re-ference on the crystal will increase. In our experiments, when the curvature radium of the reference beam increased from 575.6mm to 600.5mm, the diameter of the reference beam on the crystal changed from 3mm to 6mm. The larger reference beam size means that during the recording process, the erasure effect of the writing beam on the grating at adjacent spatial location becomes more serious. Taking into our account the spatial multiplexing of the holographic storage, planar beam is not the optimal reference. We must balance the angular selectivity and the spatial multiplexing at the same time to get larger storage capacity.

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REFERENCES

1. P.J.Heerden, *Theory of Optical Information Storage in Solids*, Appl. Opt. 2(1963)393.
2. H. Kogelnik, Cuupled *Wave Theory for Thick Hologram Gratings*, Bell Syst. Tech. J. 48 (1969)2909.
3. G.Barbastathis,M.Levene,and d.Psaltis, *Shift multiplexing with spherical reference waves*, Appl.Opt. 35(1996)2403
4. C.Gu, J.Hong, I.Mcmichael, R.Saxena, and F. Mok, *limited storage capacity of volume holographic memory*, J. Opt. Soc. Am. A 9 (1992)1978.
5. X.Yi and P.Yeh, *Cross-talk noise in volume holographic memory with spherical reference beams*, Opt.Lett. 20, (1995)1812.
6. X.Li, Q.He, M.Wu,Y.Yan, G.Jin, *Diffraction properties of a volume hologram with spherical reference beams*, Opt.Comm. 149(1998)13.