P2-27 High-Resolution Incoherent-to-Coherent Photorefractive Optical Converter

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We demonstrate a photorefractive incoherent-to-coherent optical converter in which there is a ~ 45° angle between the incoherent image and the grating vector. A resolution as high as 283 line pairs/mm, which is the resolution of out projection system, is obtained for a one-dimension resolution target.

High-performance spatial light modulator, which can produce coherent replicas of incoherent images, plays a key role in optical information-processing systems. Up to now, the highest resolution is 175 line pairs/mm in a ferroelectric liquid-crystal spatial light modulator.[1] In the paper we propose a novel method to perform incoherent-to-coherent conversion in a bulk photorefractive crystal. A resolution as high as 283 lp/mm is obtained.

The schematic diagram of the experimental setup is shown in Fig. 1. Two s-polarized laser beams, I_{w1} and I_{w2}, from a He-Ne laser at 632.8 nm were used as the writing beams. I_{w2} had a diameter of 5 mm and the width of I_{w1} w was adjusted by a slit. I_r was the readout beam from another He-Ne laser at 632.8 nm with a p-polarization and a diameter of 6 mm. For convenience, an uniform s-polarized laser beam from a cw doubled Nd:YVO$_4$ laser operating at 532 nm with a diameter of 5 mm was used as the incoherent input beam I_i. The incoherent beam was modulated by a resolution target and the incoherent image was imaged on the crystal by a telescope. The crystal was a Ce and Rh double doped BaTiO$_3$ crystal. It had dimensions of 7.3 mm x 6.6 mm x 5.7 mm and the *c*-axis was along the 7.3-mm edge. I_{w2} was incident upon the – c face of the crystal by a polarized beam splitter and I_{w1} and I_{w2} wrote a photorefractive grating. The vector of the grating had a ~ 45° angle to the c axis of the crystal and I_i. The input incoherent image was used to modulate the grating selectively. When we used the readout beam I_r to read the grating, the output beam should have the same spatial information with the input image. From Fig. 1 we can see that the interaction length between the input image and the grating is the width of I_{w1} w. Because there is a ~ 45° angle between the input beam and the grating vector, the number of the grating periods in a single picture element (pixel) does not depend on the width of one pixel, namely the resolution of the input image. Thus the resolution is not limited by the diffraction limitations[2] and a high resolution can be obtained. In the experiment a one-dimension resolution target (Edmund Scientific Variable Frequency Resolution Target, the resolution is from 5 lp/mm to 200 lp/mm) was used to measure the output resolutions.

When we measured the resolution of the output image, the intensity of I_{w1} and I_{w2} were 168 mW/cm$_2$ and the intensity of I_r was 40 mW/cm$_2$. The intensity of the incoherent beam I_i was changed by neutral intensity filters. Here we used a telescope composed of two lenses with focal lengths of 500 mm and 300 mm, respectively, to image the resolution target on the crystal. The diameters of the lenses were 100 mm. The resolution target was placed at the focal plane of the 500 mm-focal-length lens. Because of the limit diameter of the lenses, the highest resolution of the incoherent image on the crystal was 283 lp/mm. When we adjusted the direction of the writing and readout beams to let the output beam had the same direction with the input beam I_i, a resolution of 283 lp/mm was obtained and it did not depend on w. The output image with a resolution of 283 lp/mm is shown in Fig. 2 for w = 2 mm and I_i = 312 mW/cm$_2$. We also rotated the resolution target in its plane to change the angle between the grating vector of the resolution target and

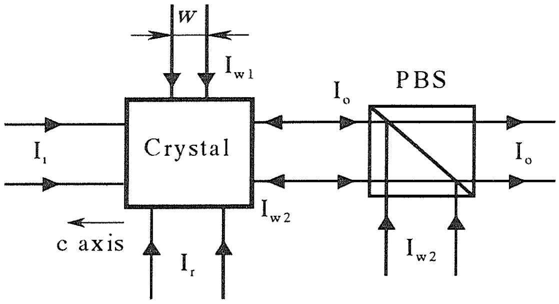

Fig. 1. Schematic of the experimental setup. PBS, polarized beam splitter.

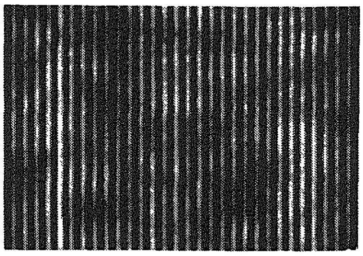

Fig. 2. Photograph of the output coherent image with a resolution of 283 lp/mm

horizon and the resolution of the output image did not change. In Fig. 2 we can see that there are clear edges between the dark lines and bright lines. We believe that a higher resolution should be achieved if a better projection system is used because the resolution of the output image dose not limit by the diffraction limitations.

Then we removed the resolution target to measure the diffraction efficiency of the readout beam versus the intensity of the incoherent beam. Here the diameter of the readout beam was 2 mm and w = 3 mm. Fig. 3 is the normalized diffraction efficiency. The diffraction efficiency η = 6.5% when I_i = 0 and it decreased with the increase of I_i. Thus increase I_i can increase the contrast of the output image. When I_i was larger than 600 mW/cm_2, the contrast of the output image was better than 10:1. It should be noted that the diffraction efficiency does not change against the resolution of the input image for incoherent-to-coherent conversion. We also measured the setup times of the photorefractive grating versus the intensity of the writing beams at λ = 632.8 nm. Here the two writing beams had the same intensity. The setup time can be fitted with $t = 114/I^{0.88}$ mW/cm^2.

From the above experimental results we can see that a very high resolution can be obtained by use of the method. The reason is that the number of the grating periods in one pixel does not depend on the resolution of the incoherent image. The resolution of the incoherent image influences the diffraction efficiency slightly. This characteristic is important for an incoherent image with different resolutions. Furthermore, the resolution does not depend on the wavelength of the writing and readout beams. The response time can be decreased by increase the intensity of the writing beams or using writing beams with a shorter wavelength.

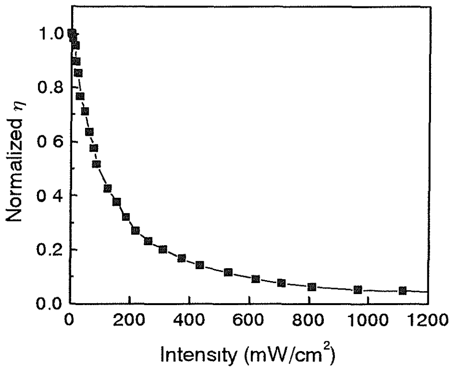

Fig. 3. Normalized diffraction efficiency of the readout beam versus the intensity of the incoherent beam.

In summary, we have demonstrated a high-resolution photorefractive incoherent-to-coherent optical converter. In the crystal there is a ~ 90° angle between the two writing beams and a ~ 45° angle between the incoherent beam and the grating vector. Thus the resolution is not limited by the diffraction limitations. When the output image has the same direction with the incoherent incident beam, the resolution does not depend on the interaction length between the incoherent beam and the grating, which is the width of one writing beam. A resolution as high as 283 lp/mm, which is the resolution of out projection system, is obtained for a one-dimension resolution target. A higher resolution can be expected for a better projection system. In order to decrease the response time further writing beams with a shorter wavelength can be used.

References:

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[2]P. Amrhein and P. Günter, Opt. Lett. **15**, 1173 (1990).