P23 フォトリフラクティブ・ファンニング効果による厚い動的歪み媒質中の伝送画像の補正

Image transmission through a thick dynamic distorter by the photorefractive fanning effect

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Abstract-A new method of one-way image transmission through a thick dynamic distorter was demonstrated without a reference beam and a four-wave mixing process. In this method, there are only one object beam and one sampling beam. The response time of the photorefractive crystal must be much longer than the fluctuation period of the dynamic distorter. Thus the crystal responds only to the time-averaged intensity pattern of the rapidly varying object beam. The reconstructed images with high-fidelity are picked up using the photorefractive fanning effect.

The holography and real-time four-wave mixing (FWM) have been used for one-way image transmission through inhomogeneous media for many years. In most of these methods, the distorter must be a thin one, namely, it should be a phase object at the FWM material. Imaging through a thick dynamic distorter has been also demonstrated using slow response materials. In this Letter, we demonstrated a new method to perform one-way image transmission through a thick dynamic distorter such as the turbulent atmosphere, in which no reference beam is required.

In this method the response time of the crystal is much longer that the fluctuation period of the distorter. The crystal responds only to the time-averaged intensity pattern, it does not "see" the rapidly varying intensity pattern. The time-averaged intensity pattern can be considered as a superposition of the undistorted image and an approximate homogeneous noise background, namely, the maximum time-averaged intensity pattern has the spatial information of the undistorted image. Recently we proposed a new incoherent-to-coherent converter[1], in which the transmission of the coherent beam increases with increasing intensity of the incoherent beam. We used this property to pick up the undistorted image from a noise background and demonstrate that one-way image transmission through a thick dynamic distorter can be carried out without a reference beam or a FWM process.

The experimental setup was schematically plotted in Fig. 1. A cw doubled Nd:YVO_4 laser operating at 532 nm was used as the transmitting and receiving light source. Although general natural light beam is principally available for the object beam I_O, a laser beam from the Nd:YVO_4 laser with an ordinary-polarization and a diameter of 6 mm was used for an I_O beam in this work. After it passed through the U.S. Air Force resolution chart RC, I_O bore the spatial information of the image of RC. The transmitting and receiving telescopes were composed of L1, L2, L3 and L4, respectively. The distance between L2 and L3 was 800 mm. Two 1200 W electronic fan-heaters placed between L2 and L3 were used to generate hot air, which acted as a dynamic distorting medium. The total length of the distorting medium along the propagating direction of the object beam was ~ 550 mm, which was much longer than the collection optics' depth of field (~ 4mm). Therefore it should be completely considered as a thick distorter. The measured turbulence fluctuation period of the hot air was round about 10 ms. The photorefractive crystal was a Ce:$BaTiO_3$, which had dimensions of 7.38 mm × 7.22 mm × 6.34 mm and with the *c*-axis along the 7.38-mm edge. In the receiving side the sampling beam I_S, which was a collimated uniform laser beam from the Nd:YVO_4 laser, had an extraordinary-polarization and a diameter of 6 mm. It was mutually-incoherent with I_O because the path difference between them was

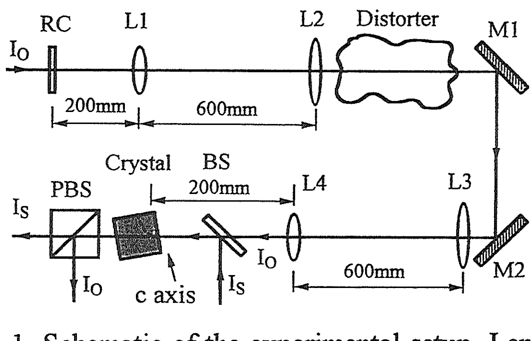
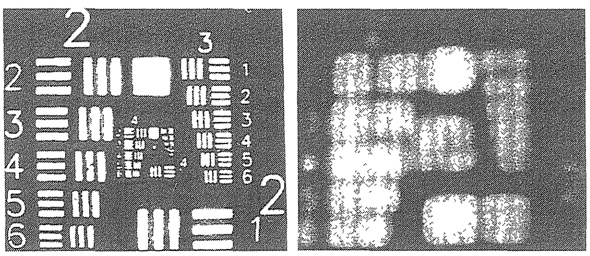


Fig. 1. Schematic of the experimental setup. Lenses L1 and L4 have a focal length of 200 mm; lenses L2 and L3 have a focal length of 400 mm. M1, M2, mirrors. Other abbreviations are defined in text.

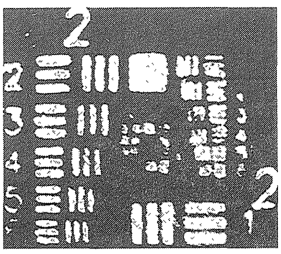
much longer than the coherent length of the laser. It should be noted that in fact the object beam and the sampling beam can come from two different light sources, respectively. I_S and I_O were incident upon the crystal coaxially by a beam splitter BS in order to obtain a high resolution. The external incident angle was 25°. The crystal was located at the focal plane of L4 and the U.S. Air Force resolution chart RC was imaged on the crystal by L1, L2, L3, and L4 with the same size as the original object. A polarized beam splitter was used to separate the object beam I_O and the output sampling beam I_S. The photographs of the transmitted image and the reconstructed image were taken from a screen or a CCD camera system.

First we demonstrated the image reconstruction using the experimental setup of Fig. 1. Because of the strong fanning effect of the crystal, the transmission of the sampling beam I_S was very small. When we used the object beam I_O, which bore a dynamically distorted image of the U.S. Air Force resolution chart, to erase the fanning gratings, the output intensity pattern of the sampling beam was modulated by I_O selectively. The output intensity of I_S should increase in proportion to the time-averaged intensity of I_O over a period, as a result, the output maximum intensity pattern of I_S bore the spatial information of the maximum time-averaged intensity pattern of I_O. According to the previous discussion, the maximum time-averaged intensity pattern in the object beam should bear the spatial information of the undistorted image. Thus the output I_S should bear the spatial information of the undistorted image. By using a CCD camera to detect the output sampling beam the reconstructed image could be recorded.

When the intensity of the object beam I_O and the sampling beam I_S were 150 mW/cm^2 and 34 mW/cm^2, respectively, the establishing and erasing



(a) (b)



(c)

Fig. 2. Photographs of the transmitted image (a) before and (b) after the distorter was truned on. (c) The reconstructed image.

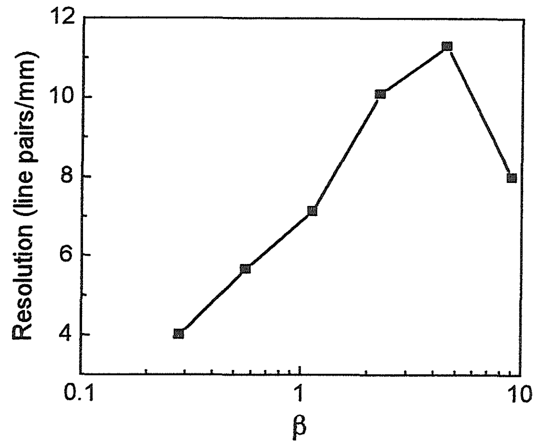


Fig. 3. Resolution of the reconstructed image versus β. The solid curve is a guide for the eye.

time of fanning were 6.4 s and 1.3 s, respectively, which were much longer than the fluctuation period of the distorter. The transmitted images borne by the object beam on the crystal before and after the distorter was turned on were shown in Fig. 2 (a) and (b), respectively. It can be seen that the original image was blurred fully by the dynamic distorter. By using the slow responding characteristic of the crystal, the reconstructed image with a high resolution was obtained and shown in Fig. 2 (c).

Then we fixed the intensity of I_O at 150 mW/cm^2 and changed the intensity of I_S to measure the resolution of the reconstructed image, as shown in Fig. 3, in which β is the intensity ratio of I_O to I_S. It can be seen that the reconstructed image had a high resolution over a large range of β. When β became small, noises and unstability increased evidently.

In summary, we demonstrated a new method to perform one-way image transmission through a thick dynamic distorter without a reference beam and a FWM process. In this method, there are only one object beam and one sampling beam. The response time of the photorefractive crystal must be much longer than the fluctuation period of the dynamic distorter. Thus the crystal responds only to the time-averaged intensity pattern of the quickly varying object beam. By use of the photorefractive fanning effect, the time-averaged intensity pattern of the object beam modulates the transmission of the sampling beam directly. As a result, the output sampling beam bears the spatial information of the undistorted image. By using this method reconstructed images with high-fidelity have been obtained.

References

1. J. Zhang, H. Wang, S. Yoshikado, and T. Aruga, Opt. Lett. **22**, 1612 (1997).