E2 単一方向画像伝送における伝送画像の忠実度

Fidelity of output images in one-way image transmission

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***Abstract**-We investigated and explain the dependence of the fidelity of the reconstructed output images on the position of the distorting medium for one-way image transmission through a thin distorting medium by using four-wave mixing phase conjugation in a photorefractive crystal.*

Optical phase conjugation has an impressive fascination because it can make severely distorted beam or image to be reconstructed to original, unaberrated state. This distinctive property suggests a great lot of potential applications, in which the image transmission is always provoked some researcher's interest. In this work, we investigate and explain the dependence of the fidelity of the reconstructed output images on the position of the distorting medium for one-way image transmission through a thin distorting medium.

The experimental scheme is illustrated in Fig. 1. Light source is a frequency-doubled Nd:YAG pulsed laser operating at λ = 532 nm with a pulse width of 3.0 ns and a repetition rate of 80 Hz. The output of laser is collimated and expanded and is diverged by beam splitters to produce three beams 1, 2 and 4. The nonlinear material is a $BaTiO_3$:Ce crystal which had dimensions of 10×7.3×1.5 mm^3 with *c*-axis along the edge of 10 mm. The two 4× telescope systems composed of lenses L_{j1} and L_{j2} (f_{j1} = 80 cm, f_{j2} = 20 cm, j = 2, 4) are respectively interposed in beam-paths 2 and 4. The crystal has a distance of f_{j2} from L_{j2}. An input image is situated at the front focal plane of L_{21}. A thin phase distorting medium (DM) is placed at a plane *D* attached a coordinate system (x_D,y_D) in beam-path 4. We use *d* to represent the distance between the plane *D* and the front focal plane *F* of L_{41}, and assume $d > 0$ if the plane *D* is in the right of the plane *F*.

We carry out the experiment of the one-way image transmission using the configuration in Fig. 1. The experimental results are shown in Fig. 2. Figures 2a1~a4 are the one-way output images corresponding to four different positions of DM, d = 20, 0, -2, and -20 cm, respectively. It is obvious that the output images are well distinguishable although there have some incompleteness or lack of fidelity. We can also see that Fig. 2a2 has the highest fidelity among Figs. 2a1~a4. The experimental results indicated that the input image can be transmitted from the left side of DM to the right, namely, one-way image transmission through a distorting medium has been achieved. Figure 2a5 is the output image when there are no any distorting media in all beam-paths, its fidelity is higher than that with DM (Figs. 2a1~a4). When DM deviate from the plane *F*, the one-way output image becomes worse and worse.

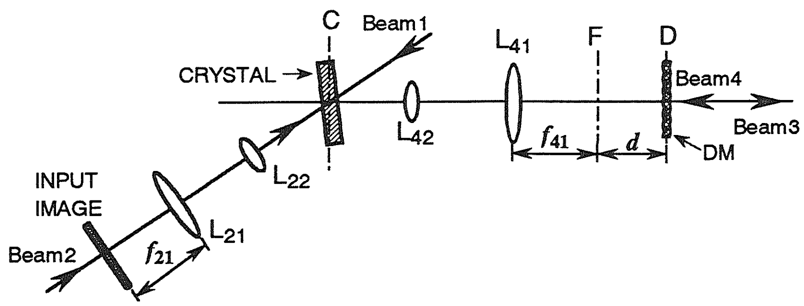

Fig.1 Experimental scheme for one-way image transmission through a thin phase distorting medium.

Here we assume that beams 2 and 4 are co-linear. That is to say, two back focal planes of L_{22} and L_{42} are coincided at the same plane, which is referred as a plane *C*. A coordinate system (x_C,y_C) is attached to the plane *C*. If using $\varphi(x_D,y_D)$ to express the phase distribution of DM, the complex amplitude transmittance of DM is

$$t_D(x_D,y_D) = \exp[j\varphi(x_D,y_D)]. \quad (1)$$

Then the disturbance of the field on plane D is

$$U_D(x_D,y_D) \propto \exp[j\varphi(x_D,y_D)]. \quad (2)$$

In fact, the disturbance at a point (x_C,y_C) on the plane C may be regarded as a convolution of $U_D(x_D,y_D)$ with an impulse response function $h(x_C,y_C;x_D,y_D)$. In general, the disturbance at point (x_C,y_C) on the plane C is determined by superposition of the disturbances of all points on the plane D. However, if the plane D is situated at the front focal plane F of L_{41} (d = 0), then the impulse response function h reduces to a simple δ function. As a result, the disturbance at point (x_C,y_C) on the plane C is

$$U_C(x_C,y_C)|_{d=0} \propto U_D(-x_C/M_0, -y_C/M_0), \quad (3)$$

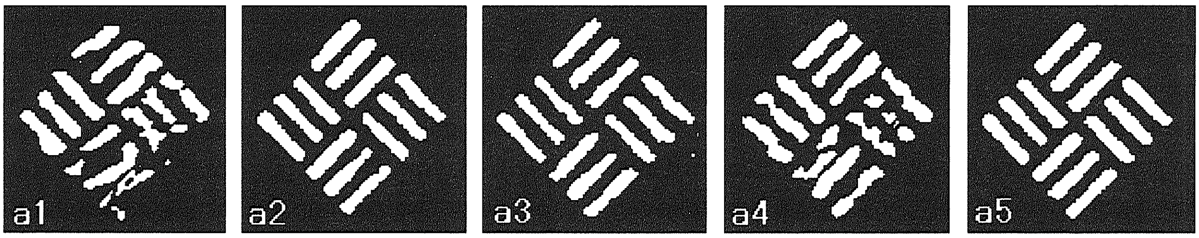

Fig.2 Experimental results of one-way output images. a1: d = 20 cm; a2: d = 0; a3: d = − 2 cm, a4: d = − 20 cm; a5: without distorting medium.

where $M_0 = f_{42}/f_{41}$. From Eq.(3), we can find that when DW is placed at the plane F, the disturbance at point (x_C,y_C) on the plane C is solely determined by its corresponding object point (x_D,y_D) on the plane D and is independent of any other points. From the viewpoint of information processing, if the plane C is the image-plane of the plane D, then point (x_C,y_C) on the plane C carries only all information of its corresponding object point (x_D,y_D) on the plane D, but not any information of other points; otherwise it will bear partial information of all points on the plane D. As mentioned before, for the case of Fig. 2a2, which is corresponding to the case that the plane C is the image-plane of the plane D, point (x_C,y_C) on the plane C carries all information of its object point (x_D,y_D) on the plane D, but not any information of any other points. If point (x_C,y_C) on the plane C overlaps with the bright region of image-bearing beam 2, all information carried by point (x_C,y_C) can be conjugated and returned to its corresponding object point (x_D,y_D), thus the distorting medium will be completely corrected or canceled. On the other hand, if point (x_C,y_C) coincides with dark regions, then no phase conjugate signal is produced. Therefore, an undistorted replica of the input image can be reconstructed after passing through DM. Now we see the other cases corresponding to Figs. 3a1, a3 and a4. In one aspect, point (x_C,y_C) on the plane C contains partial information of every point on the plane D. If point (x_C,y_C) overlaps with the dark region of beam 2, no signal can be generated, thus this part of information of all points on the plane D related to point (x_C,y_C) will vanish. As a result, the distortion cannot be thoroughly restored although the generated signal beam 3 retraces the telescope system and DM. In another aspect, there appear the nonuniform intensity diffraction pattern on the plane C, especially the intensity is very weak or even zero in some regions. When these regions overlap with the bright region of beam 2, then those information of the input image will be lost because the phase conjugate signal cannot be generated. Therefore, the output image is inferior and cannot be improved by increasing the apertures of beams when $d \neq 0$. This is the reason why the fidelity of the output images becomes lower and lower when DM gradually departures from the plane F.

In conclusion, we have demonstrated the one-way image transmission through a thin distorting medium by using four-wave mixing phase conjugation in a photorefractive crystal. The dependence of the fidelity of the output images on the position of the distorting medium was investigated and explained. The results and analysis indicated that high fidelity one-way reconstructed image can be obtained provided the distorting medium is not thick.

References

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