Development of multicolor-holographic flip-books systems using lithium-niobate crystals

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ABSTRACT

A multicolor holographic flip-books system is presented, in which angle-multiplexed image plane holograms are recorded using an Fe-doped $LiNbO_3$ (LN) crystal as recording media with a 532-nm green laser. A 633-nm red He-Ne laser, the 532-nm green laser, and a 432-nm blue diode laser were used to illuminate the recorded holograms. Multicolor flip-books are obtained when the LN crystal was slowly rotated. Bragg mismatching from the use of three wavelengths is compensated by changing the reconstructing angles.

1. INTRODUCTION

We describe a multicolor-holographic flip-books system using Fe-doped $LiNbO_3$ (LN) crystals. By using the system, color animation can be observed by rotating the crystal about the half angle of the recording beam.

Being different from the conventional hologram recorded on a thin recording material, volume hologram using a thick material allows the angle-multiplexed hologram recording [1]. Thus, volume hologram has proved to be very useful for optical memory due to the large storage capacity and fast transfer rate. Moreover, photorefractive materials like LN crystal can be used as a rewritable recording media, the images can be erased and rewritten again. Thanks to the angle-multiplexing property, it's interesting to use the LN crystal as a holographic recording material for recording multicolor flip-books.

Fourier-transform scheme has been used to record the hologram in LN crystals. However, Bragg-mismatch occurs when we use a light source with a different wavelength for hologram reconstruction. We will be able to get only a part of image rather than a whole original image since volume hologram acts as a band pass filter getting through the bandlimited spatial frequencies of an input image. Several techniques have been proposed to relieve that problems: using a spherical [2] or polychromatic [3] reconstructing wave to match the Bragg condition. On the other hand, an image hologram [3] can produces a whole image. We demonstrate the whole-image reconstructions from an image-plane volume hologram with a Fe-doped LN crystal. A LN volume hologram can record a number of multiplexed images with the rotation of a crystal [4].

2. CONCEPT

The concept of the proposed multicolor-holographic flip-books system [5,6] is schematically shown in Fig.1. The images forming the flip-books are multiply recorded on an LN crystal as holograms while the LN crystal is rotated by an angle of 0.2°. After that, we can observe a color animation by rotating the LN crystal with respect to a laser beam, otherwise by using a LED broad-spectral source [7].

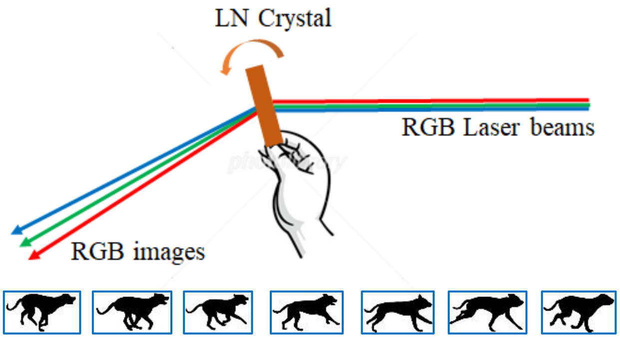

Fig. 1 Concept of the flip-books

3. THEORY AND OPTICAL SYSTEM

Fig. 2 shows a schematic configuration of the optical system used for recording and reconstructing the flip-books system.

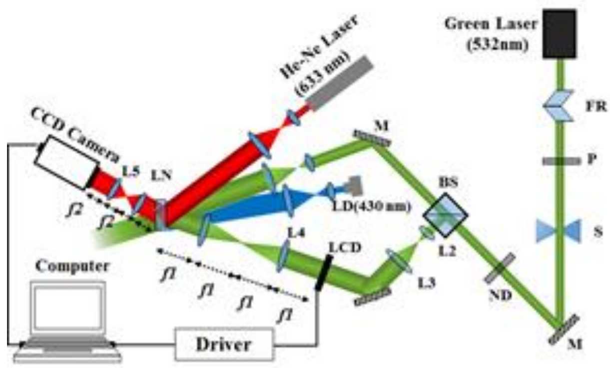

Fig. 2 Optical setup

A diode-pumped solid-state (DPSS) laser (Coherent Compass 315M-100SL, 532nm, 100mW) is used for recording the holograms. The light beam from the DPSS laser is split using a Beam-split into two beams. One is used to illuminate a liquid-crystal device (LCD) on which the input images were displayed, and the light wave passing through the LCD was imaged with a *4-f* optical system onto the LN crystal as the object wave. The other beam is expanded and then used as a reference wave. The object and reference waves with a cross angle of 30° overlapped on the LN crystal and form an interference fringe patterns. In the bright region of the fringe patterns, the electrons of Fe level were excited, moved to dark region and finally formed a space-charge field that produces a space refractive index distribution via Pockels effect. In this way the input image was recorded on the LN crystal as a transparent image hologram. Because of the sharp Bragg condition, the next image can be recorded by slightly rotating the crystal.

In multi-color observation of the flip-books, a He-Ne laser (632.8nm, 10mW), a DPSS laser described above, and a diode-laser (432nm, 8mW) were used as light sources. The incident angle θ_R for a red laser beam and θ_B for a blue laser beam are set as $\theta_R = \sin^{-1}\left(\lambda_R / \lambda_G \cdot \sin\theta_G\right)$ and $\theta_B = \sin^{-1}\left(\lambda_B / \lambda_G \cdot \sin\theta_G\right)$ to match the Bragg condition due to the wavelength difference between the recording and readout lasers.

4. EXPERIMENTAL RESULTS

4.1 Exposure time reduction

In our experiments, a Fe-doped LN crystal of 10-mm square and 4-mm thickness was used. Usually, a relatively long time up to several minutes was required to record the hologram into LN crystal. We developed the recording efficiency for different polarization condition for the first time. The p-polarization is quite better than s-polarization usually used. The intensity dependence on the exposure time is shown in Fig. 3. The exposure time can be reduced from hundreds to seconds.

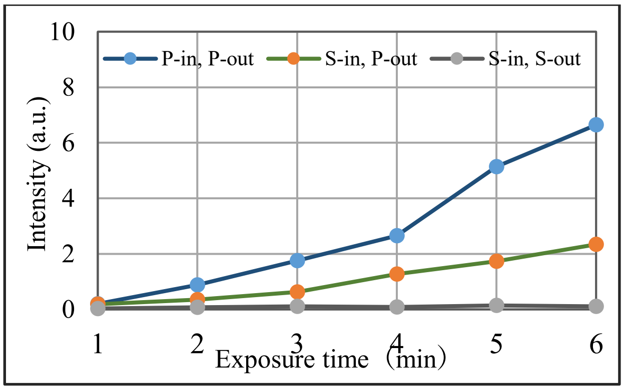

Fig. 3 Reconstruction image intensity at different polarization condition

4.2 Angle separation

Another important issue in forming flip-books is angle separation. We found there is no cross talk with a minimum angle separation of 0.2°as shown in Fig. 4.

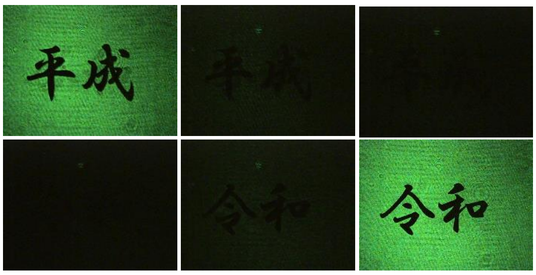

Fig. 4 Reconstructed images with an angle-separation of 0.2°

4.3 Demonstration of color flip-books

As a demonstration, multi-color flip-books was made. During the experiments, the original images was send to LCD one by one, and recorded with the reference beam, while the LN crystal was rotated by 0.2 degree between two adjacent images.

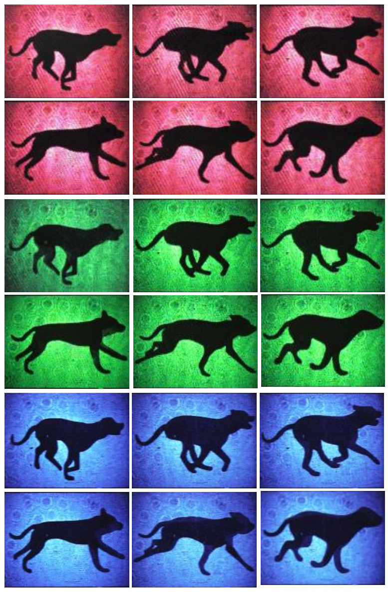

Fig. 5 Demonstration of a RGB color flip-books

5. CONCLUSION

A multicolor holographic flip-boos system is presented. The original images were recorded on a rewritable photorefractive media, Fe-doped LN crystal, we can observe a color animation by slowly rotating the crystal with RGB illumination laser lights. By optimize the incident light polarization condition, the exposure-time reduction from hundreds to seconds enabled us to easily record a large amount of images into the crystal.

6. Acknowledgment

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