Video-rate color holographic displays using doped liquid crystals

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Abstract

Real-time holographic displays are achieved with dye-doped and quantum-dot doped liquid crystals. Reconstructed holographic videos at a refresh rate of 60 Hz are demonstrated by experiments with color multiplexing capability.

I. Introduction

Three-dimensional (3D) display technology has attracted worldwide attention and been developed vigorously since the blockbuster movie "Avatar" was released. There are at least two common types of 3D displays according to principles of stereopsis. One type is based on binocular parallax, and the other type is based on light field reconstruction. Among these 3D display techniques, holographic display is considered as an ultimate goal to provide realistic image of a real object or a scene, because it has the ability to reconstruct both the intensity and phase information of a true nature of an object or a scene, allowing the observer to perceive the light as it would be scattered by the real object itself without the need for a special eyewear. Therefore, many research groups have studied the holographic displays of real 3D images. Optical holography based on the dynamic recording materials might be an effective method for its wide viewing angle and scalability in display size. However, one major difficulty in optical holographic display is to dynamically show real-time 3D images. This imposes challenges in materials, devices and system structures. Here we demonstrate real-time holographic displays with dye-doped and quantum-dot-doped liquid crystal (LC) cells. Reconstructed holographic videos at a refresh rate of 60 Hz are obtained in experiments with color multiplexing capability. The response time and diffraction efficiency of the displays are investigated with respect to the light intensity, polarization of reading beam, grating period, and applied voltage.

II. Experiments and Results

We present a real-time holographic display featured by an azo-dye-doped LC. This material enables a video-rate display as each hologram can be refreshed in the order of several milliseconds. We have successfully demonstrated a real-time holographic video, sourced from a spatial light modulator (SLM) and reconstructed by an azo-dye (DR1) doped nematic LC cell without any applied electric field [1]. The performance of the proposed device is studied by the response time, including both recording anCd erasing time. Its dependence on the recording intensity, polarization direction, and polarization state has been experimentally revealed. By adjusting the above parameters, response time can be measured in the order of several milliseconds, sufficiently fast for the video-rate display applications. In addition to its decent performance, the material availability as well as the scalability of this LC-based material grants itself a promising future for the large size, dynamic, colorful holographic display. Fig. 1 shows the experimental setup to achieve optical hologram in such dye doped LC cell. Fig. 2 is a series of snapshots of reconstructed images at different times, showing its dynamic display property. The sample can also function at different colors of probe lights when illuminated by three different wavelengths of 632.8 nm, 532 nm, and 488 nm, respectively, revealing its potential towards color display if proper color multiplexing is realized.

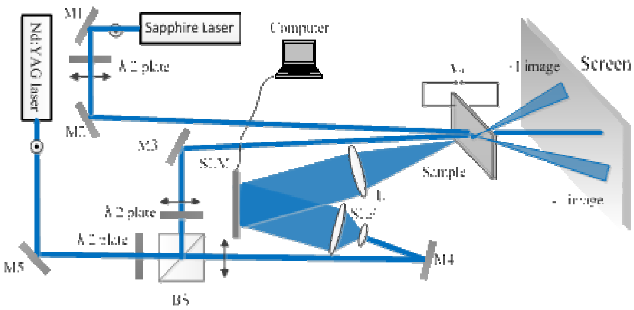

Fig. 1. Experimental setup. M: mirror, BS: beam splitter.

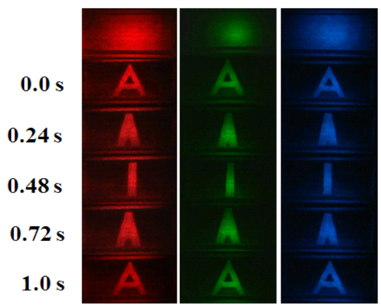

Fig. 2. Snap shots of reconstructed images based on azo-dye doped liquid crystal.

However, the diffraction efficiency and thermal stability of the dye doped system are insufficient. The photorefractive effect in the dye doped LC is weak, resulting in a low diffraction efficiency of 0.6%.

Semiconductor nanoparticles doped LC materials are a kind of photorefractive materials based on the effect of space charge field and LC's birefringence. By doping quantum dots (QDs) into the L [2], the photorefractive effect is found to be greatly enhanced. With an external voltage applied to the material, our device exhibits fast response, and a significantly improved diffraction efficiency of 20%, up from 0.6% compared to the case of DR1 doped LC. Fig. 3 shows the measured diffraction efficiencies of the QD doped LC and pure LC, respectively. The maximum efficiency reaches 20% at a properly applied voltage. Fig. 4 shows the video-rate pictures snapped from three diffracted holographic videos of different colors this verifies the feasibility as a color holographic display.

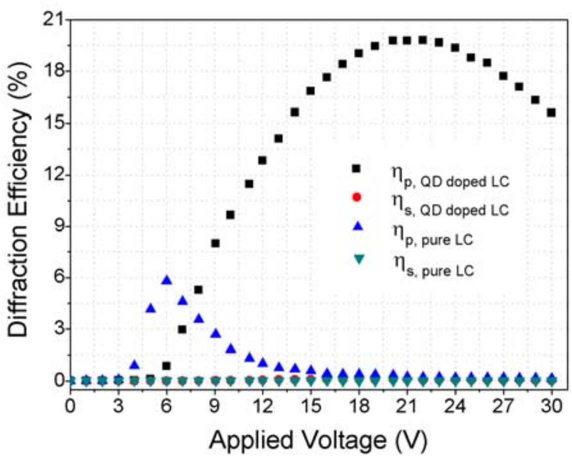

Fig. 3. Dependence of first-order diffraction efficiency on the applied voltage for pure and QD doped LCs with s- and p- polarized probe beams.

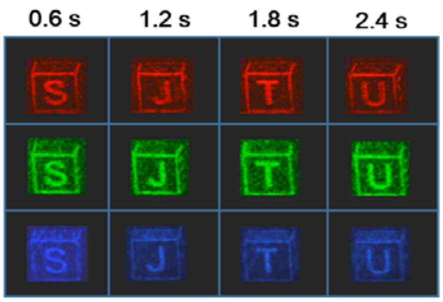

Fig. 4. Snap shots of reconstructed images based on QD doped liquid crystal at 60 Hz.

III. Conclusions

We have demonstrated real-time holographic video displays. The one based on DR1 doped LC achieves fast response time on the millisecond scale, but with a low diffraction efficiency of 0.6%. The efficiency can be improved to 20% by using QD doped LC. Both displays possess color multiplexing potential.

Acknowledgment

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References

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