Micro-Holograms in a Methyl Red-Doped Polymer-Dispersed Liquid Crystal (E48:PVP)

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ABSTRACT

Feasibility of a holographic point-by-point storage in a methyl red-doped Polymer-Dispersed Liquid Crystal (PDLC) is determined. Micro-holograms (gratings) are recorded next to each other. Smallest grating diameter obtained is 69.9 mm, with minimum grating distance of 80 mm. Recording of adjacent grating reduces the diffraction efficiency of existing grating by 17% (average).

INTRODUCTION

Research on high-density storage has been fueled by the need for larger storage capacity and parallel data acquisition (Ichioka et al., 1996). Commercially available technologies have almost reached their full potential with these parameters.

With the recent advances in materials and photo detection research, several groups have proposed techniques to overcome the storage density limit and fast retrieval of information (Ueki et al., 1996). These techniques are based on optical storage system.

Among the most promising optical storage techniques are the multi-layered bit storage and volume holographic storage. In multi-layered bit storage, small refractive index change is recorded in different layers of three dimensional non-linear materials. The density of bit storage depends on the size of the bit datum, which is determined by the size of the beam spot (Tanaka & Kawata, 1996). The smaller and the more local the refractive index change, the higher the density.

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Recently, groups working on bit-recording have succeeded in recording up to 30 layers of data at axial-separation of 7 mm and a dot separation of 2 mm for photopolymers, and three layers of data at axial-separation of 24 mm and dot separation of 4 mm for $Li:NbO_3$. However, a confocal phase contrast microscope is needed to read the stored information. This makes the set-up impractical.

On the other hand, volume holographic techniques use several multiplexing schemes in recording information. Multiplexing is possible because of strict Bragg selectivity in several non-linear materials (Adibi et al., 1999). These schemes include: (a) shift-multiplexing (Markov et al., 1999; Curtis et al., 1994); (b) peristropic-multiplexing (Curtis et al., 1994); (c) angle multiplexing (Chuang & Psaltis, 1997; Yu & Psaltis, 1994); and (d) wavelength multiplexing (Yu & Psaltis, 1994; Guerrero, 2000). Shift-multiplexing makes use of spherical or speckle reference wave. This scheme is based on the features of selectivity of a non-planar reference-wave hologram.

Physical rotation of the holographic material after an exposure is called "peristrophic multiplexing". The control of the read-out information is dependent on the angle at which the holograms are recorded. Angular multiplexing uses different angles between the reference waves and the data to be recorded. One angle corresponds to a hologram. Upon reconstruction, only the hologram recorded at that angle with the reference beam is reconstructed. However, cross-talk between hologram is the main issue with this scheme. Both techniques are mechanically bulky.

Wavelength multiplexing is done by recording different holograms with different wavelengths. This requires a tunable coherent light source, which is economically costly. Combination of these multiplexing schemes enables recording of up to 1,000 holograms (Chuang & Psaltis, 1997).

In this paper, a technique for data storage in a dye-doped PDLC is presented. This scheme is different from the ones discussed above since holograms are not multiplexed, but are stored much like a bit datum–in the smallest space possible.

EXPERIMENTS

Our material is a polymer dispersed liquid crystal (E48:PVP) doped with a small amount of methyl red dye. The experimental set-up is an off-axis holographic set-up, as shown in Fig. 1. A beam from an Ar-ion laser is collimated. The diameter is controlled by an iris before being split into two. These beams are focused with a lens to limit the size of the diameter as they intersect the sample. Recording is done for 15 minutes. After recording, the sample attached to a translation stage is moved by 100 mm. The translation stage has a 10 mm smallest travel, with straightness of ±2 mm. Recording is again done with the new position. Change in the diffraction efficiency of the previous grating is noted. The diffraction efficiency *h* is the ratio of the first order diffraction and the sum of all the outgoing beams given by the equation

$$\eta = \frac{I_{first-order}}{I_{total}} \qquad (1)$$

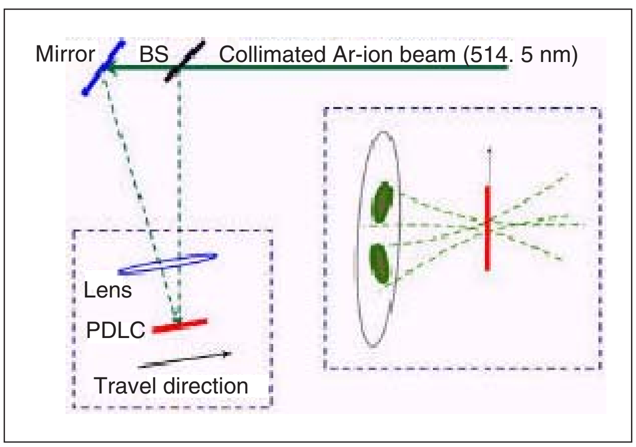

Fig. 1. The experiment set-up.

RESULTS AND DISCUSSION

Table 1 shows the summary of the diffraction efficiencies before and after recording of another set of grating. All the second gratings were written 100 mm from the first grating. The highest change observed was 26% while the lowest was 8.5%. The average change in diffraction efficiency is 17.25 %. The small change in the diffraction efficiency is due to the isolation made by the polymer matrix.

Three samples of holograms written side-by-side is shown in Fig. 2. In Fig. 2a, the holograms were separated by 72 mm from their tips, with a center-to-center distance of 508 mm. The bigger hologram is 533.4 mm wide while the smaller one has a diameter of 330 mm. It is interesting to note that there is a noticeable boundary between the holograms and the sample matrix. This is a visual confirmation of the small change in the diffraction efficiency and the role of the sample matrix as an isolator.

Another set of holographic grating is shown in Fig. 2b. The region encircled is an overlap between two holograms. Considerable damage is done on both holograms at this region. However, outside this overlap, the distinctive gratings in both holograms can still be seen. This indicates that grating beyond the overlap is not damaged.

Fig. 2c is a photomicrograph of the smallest diameter hologram possible with the current set-up. A diameter of 69.6 mm is measured. Eighty-seven micrometers away from this hologram is another hologram with a

Table 1. Comparison of diffraction efficiencies before and after recording of another grating.

Sample Grating	Diffraction Efficiency		% Change
	Before	After	
1	5.36	4.39	18.1
2	1.84	1.36	26.0
3	4.79	3.95	17.5
4	1.64	1.57	8.5

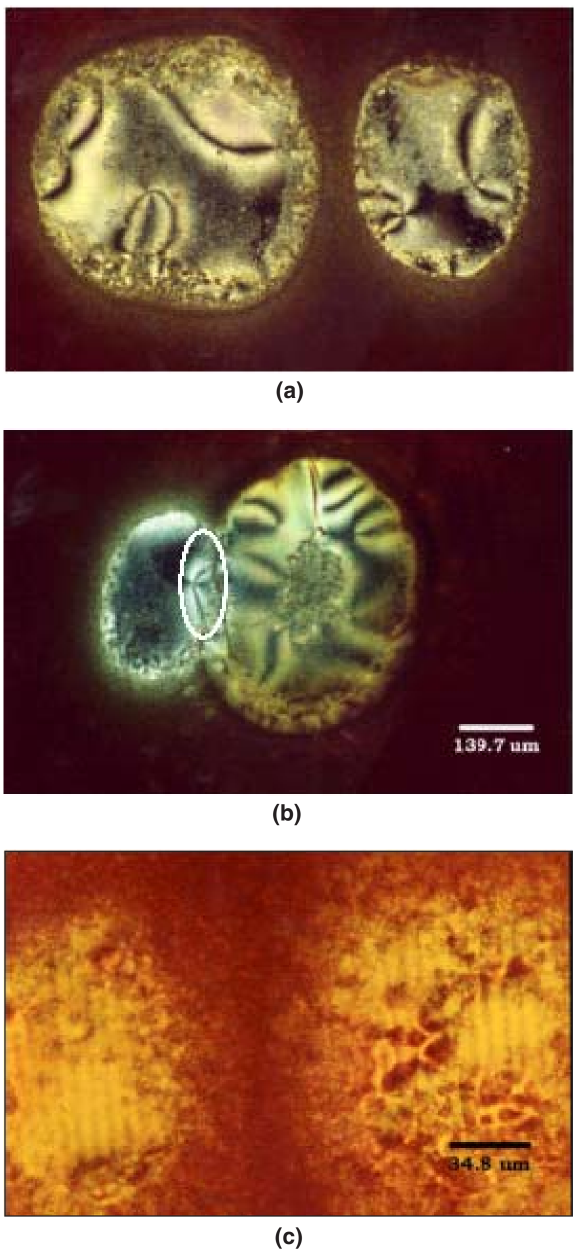

Fig. 2. Micro-holograms in a PDLC (Polymer-Dispersed Liquid Crystal).

diameter of 109 mm. Their distance is 139.5 mm center to center.

The implication of this is astounding. If an alternating grating and space is recorded with the 70 mm grating diameter and a 90 mm spacing, 62 holograms can be placed in a centimeter. In one cubic centimeter, more than three thousand holograms can be stored.

CONCLUSION

Micro-holograms are stored in a methyl red-doped PDLC. The smallest hologram recorded is 69.6 mm. Another hologram with a diameter of 109 mm is recorded near this hologram. The distance between these holograms is 87 mm. Noticeable is the clear boundaries between the grating and the sample matrix.

It was observed that an average of 17% of the grating efficiency is lost. A maximum and a minimum loss of 26% and 8.5 %, respectively, reported.

The current set-up limits the recording of smaller holographic grating. An improved set-up is needed to enable recording of smaller holograms.

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