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CTUL5 Multiplexed storage permanent and real time holograms in photorefractive bismuth silicon oxide for image processing and spatial light modulation

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We present a technique for storing holograms in crystals of bismuth silicon oxide (BSO) that combines reversible photochromic effects with the more usual real time photorefractive characteristics. Photochromic effects have been observed before in these sillenite crystals but have generally been considered a problem rather than a possible mechanism for holographic storage. As the normal photorefractive (PR) behavior is unaffected, however, simultaneous spatial multiplexing of both photorefractive (real time) and photochromic (permanent) holograms is possible in the same crystal volume.

Hologram exposure times ranged from some seconds to more than 300 min. Figure 1 shows a typical recording of the temporal development of a permanent hologram for a Bragg angle of $\theta = 1.25°$. The exposed region of the crystal took on a light brown coloration, darker than the usual yellow color of BSO. Similar absorption effects have been observed in Ref. 1 and have been attributed to the existence of Cr and Mn impurities or natural defects formed during crystal growth. The effect is reversible, and we have found that the photochromic discoloration can be erased by indirectly heating the crystal in silicone oil at 150°C for ~1 h.

We have demonstrated a number of applications ranging from image synthesis to holographic interferometry.[2,3] These operations are mostly based on the inherently separate nature of these two holographic gratings, which can lead to relative phase shifts between the two simultaneously scattered fields by shifting the real time grating with respect to the permanent one, using optical techniques.

Figure 2 shows the results of several operations achieved. Figure 2(a) shows the reconstructed phase conjugate (PC) replica of an object (part of a test chart) obtained by permanent recording, and Fig. 2(b) shows the real time PCs of other objects used. The operations of coherent addition [Fig. 2(c)] and image subtraction [Fig. 2(d)] between these images are demonstrated. Another possible operation using this scheme is 2-D differentiation.

The permanent holograms also show unexpected dynamic behavior in which a fast increase in diffraction efficiency is observed on illumination by a beam at the highly absorbed blue wavelengths. We report a novel scheme for spatial light modulation (SLM) based on this spatial enhancement of the diffraction efficiency of photochromic holograms stored in crystals of BSO and BGO.[4]

Our observations have shown that only ~2 mW cm^{-2} of enhancing illumination is enough to produce a sixfold increase in diffraction efficiency of the permanent hologram. Specifically, we have found that the enhancement factor or contrast is critically dependent on the polarization of the He-Ne readout beam and on the particular crystal orientation used. By varying these two parameters, we have obtained a controllable contrast factor of between values of ~1 and ~6.

We have demonstrated spatial light modulation via this irradiance-dependent enhancement effect. Figure 3 shows preliminary results. The resolution of the images obtained here is ~25 μm, but it is possible that a further improvement in resolution is achievable.

In addition we discuss a possible cause of the enhancement effect, its advantages over other photorefractive SLM schemes, and other possible enhancement techniques.

1. W. Wardzynsky, R. Lukasiewicz, and J. Zmija, "Reversible Photochromic Effects in Doped Single Crystals of Bismuth Germanium ($Bi_{12}GeO_{20}$) and Bismuth Silicon ($Bi_{12}SiO_{20}$) Oxide," Opt. Commun. **30,** 203 (1979).
2. N. A. Vainos, S. L. Clapham, and R. W. Eason, "Multiplexed Permanent and Real-Time Holographic Recording in Photorefractive BSO," Appl. Opt. **28,** 4381 (1989).
3. N. A. Vainos, S. L. Clapham, and R. W. Eason, "Applications of Multiplexed Real-Time and Permanent Holographic Recording in Photorefractive BSO," Appl. Opt. **28,** 4386 (1989).
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CTUL6 Phase conjugate holographic interference novelty filters

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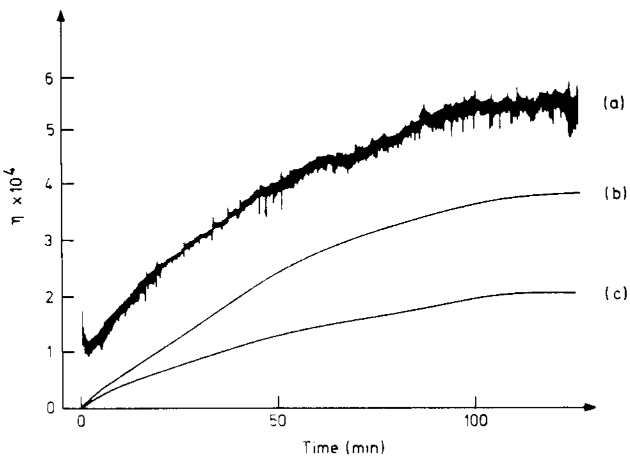
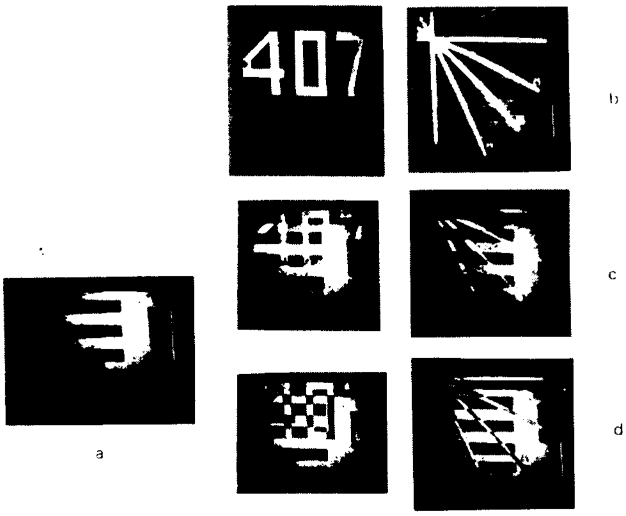
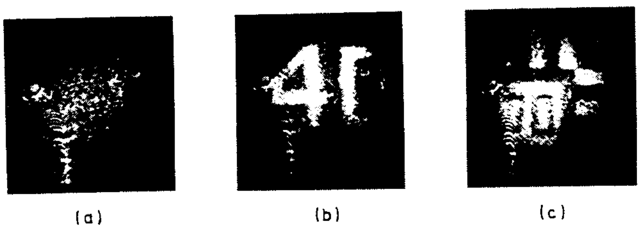
Experimental results are presented for a novelty filter operating on a complex am-



CTUL5 Fig. 1. Temporal development of a permanent hologram. Recorded diffraction efficiency of (a) the combined permanent and real time holograms η_T and (c) the permanent hologram only η_p. Curve (b) shows the enhanced diffraction efficiency of the permanent hologram in the presence of one of the writing beams.



CTUL5 Fig. 2. Examples of image synthesis operations: (a) image reconstructed by a permanent hologram; (b) images reconstructed by real time holograms; (c) their coherent addition; and (d) their subtraction.



CTUL5 Fig. 3. Results of the spatial enhancement of a permanent hologram: (a) a permanent hologram stored in BSO; (b), (c) test chart images corresponding to those parts of the hologram enhanced by the illuminating object beam.