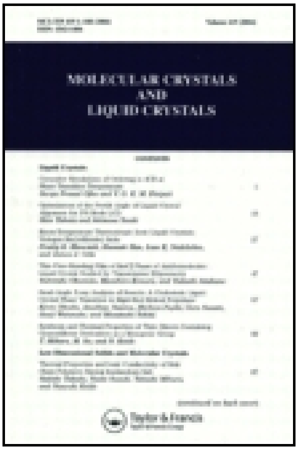

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Ferroelectric Liquid Crystal Spatial Light Modulator

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Ferroelectric Liquid Crystal Spatial Light Modulator

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Ferroelectric liquid crystal devices are capable of fast switching and intrinsic bistability. These advantages over nematic liquid crystals are important in a photoaddressed two-dimensional spatial light modulator. The first experimental results of such a device using bismuth silicon oxide as the photoaddressing medium are reported.

Keywords: ferroelectric, liquid-crystal, spatial-light-modulator, light-valve, optical-processing, display

INTRODUCTION

The liquid crystalline state is firmly established as an efficient medium in the electro-optic and display industries. Current developments in ferroelectric liquid crystals (FLC) extend applications to areas demanding high speed and bistability. The FLC may well provide the most cost-effective, large-scale X-Y matrix-addressed device.[1]

The photoaddressed FLC device has received little or no attention. A two-dimensional photoaddressed spatial light modulator (SLM) or light valve provides incoherent/coherent light conversion and gain.[2] Such devices find application in optical processing systems and projection TV. We have demonstrated the first photoaddressed FLC-SLM and present some of the initial results.

DEVICE STRUCTURE

Figure 1 outlines the device configuration. Bismuth silicon oxide (BSO) is used as the photoaddressing medium. The effectiveness of BSO has been demonstrated in a photoaddressed nematic SLM.[3] The photorefractive crystal BSO is readily available and can be polished to optical quality. Although the detrapping time constants limit frame rates to the order of 10 Hz, the write time can be much faster according to write light intensity. High resolution, of the order of 100 lp/mm, has been demonstrated, and the BSO transparency favors observation of the FLC structure in transmitted light. The polished surface of BSO provides an excellent basis for subsequent FLC alignment processes.

A transparent indium tin oxide (ITO) electrode, deposited on a massive glass substrate, is capacitively coupled to the BSO crystal (Sumitomo) by a thin optical cement bond. A similar ITO counter electrode completes the FLC cell. The BSO crystal is 25 mm square by 1/2 mm thick and polished on both sides. The cell is operated in the surface-stabilized ferroelectric liquid-crystal mode (SSFLC), where the cell spacing is small compared with the FLC pitch. The FLC is viscous enough to maintain an appropriate spacing (of order 1 μm), therefore, the spacer was eliminated in the initial experiments.

The cell is filled with the FLC mixture W7/W82 (Displaytech).[4] This aligns perpendicularly to the BSO surface, therefore, a surface alignment agent is essential. Both the BSO and ITO surfaces are spin coated with 6/9 nylon from a cresol solution.[5] The nylon surfaces are

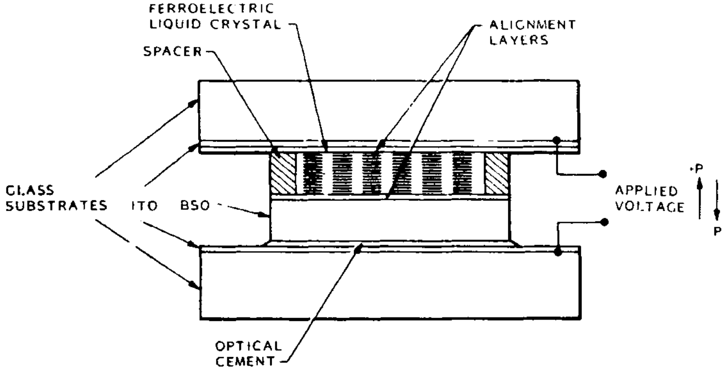


FIGURE 1 Bismuth silicon oxide photoaddressed surface-stabilized ferroelectric liquid-crystal spatial light modulator.

then rubbed to provide unidirectional alignment. The FLC is introduced as a small drop, which flows to completely fill the cell as the temperature is raised to 60°C.

EXPERIMENTAL

At modest white-light intensity, the BSO is sufficiently conducting to switch the FLC with less than 10 V applied. This allows microscopic examination of the structure and switching behavior prior to the SLM test.

The SLM test setup is illustrated in Figures 2 and 3. The acousto-optic modulators allow the argon laser to provide a write and a read pulse or readout via the HeNe laser. The write pulse illuminates the SLM via a Twyman-Green interferometer, giving a sinusoidal input pattern at the SLM input plane. The spatial frequency of this input pattern is controlled by an adjustment of the interferometer. Alternatively, a resolution chart or transparency can be imaged onto the input plane. A variety of voltage waveforms can be applied to the SLM in synchronism with the optical pulses. The length of the write and read pulses and of the advance or retard times can be varied.

The BSO-SLM is generally written with the argon laser green light and read continuously with the HeNe laser. The BSO crystal has negligible photoresponse to red light. The green light is isolated from the read plane by a dichroic filter. A readout TV camera in the image plane and a second readout TV camera in the Fourier plane monitor

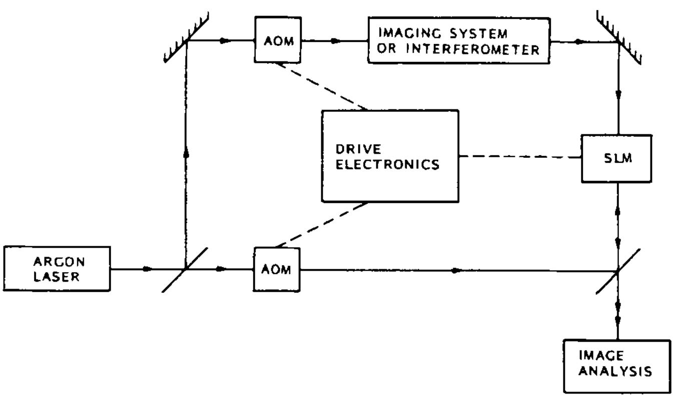


FIGURE 2 Simplified spatial light-modulator test bed.

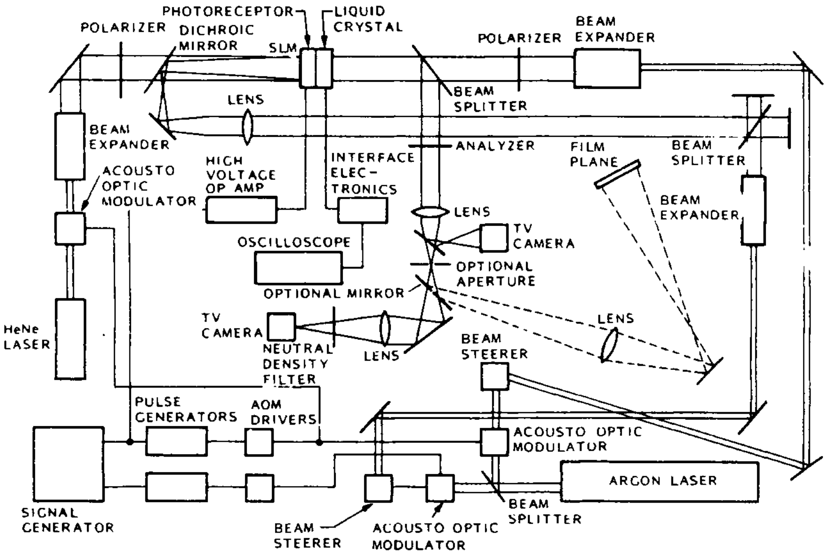


FIGURE 3 Spatial light-modulator test bed.

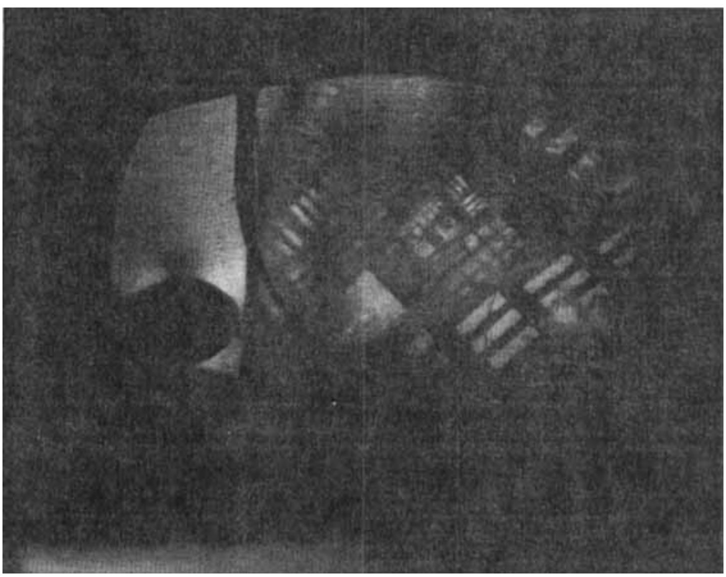
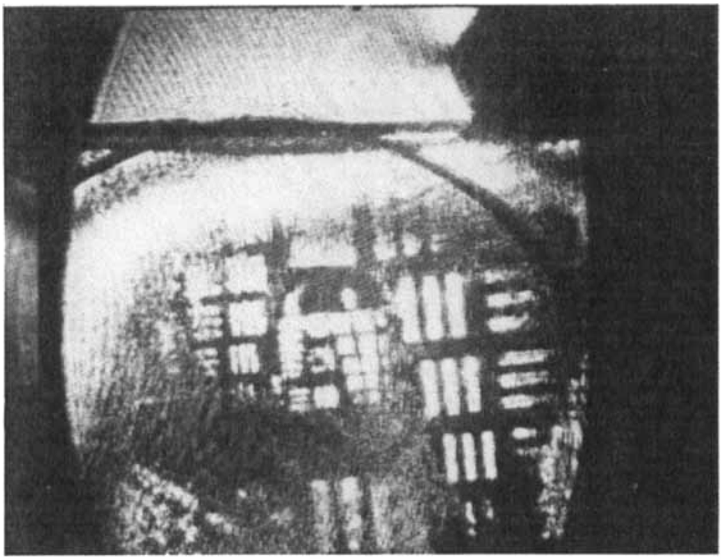
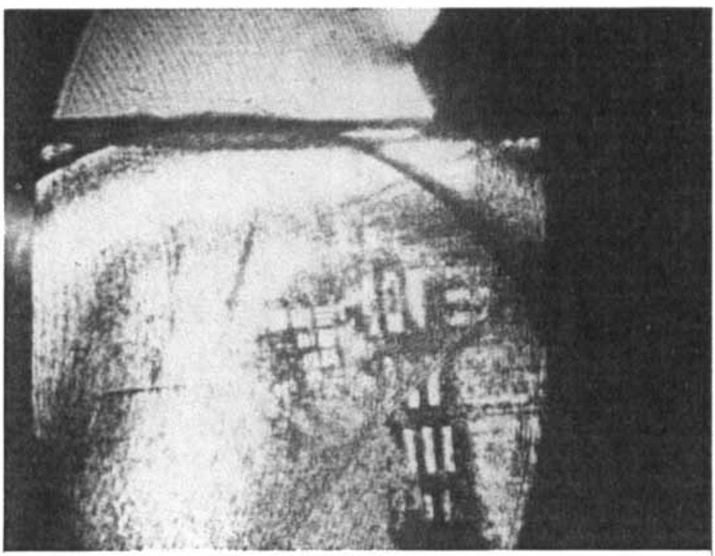


FIGURE 4 Readout image of BSO-FLC-SLM.



REFRESH



OVERNIGHT
STORAGE

FIGURE 5 Comparison of refreshed and stored image in BSO-FLC-SLM.

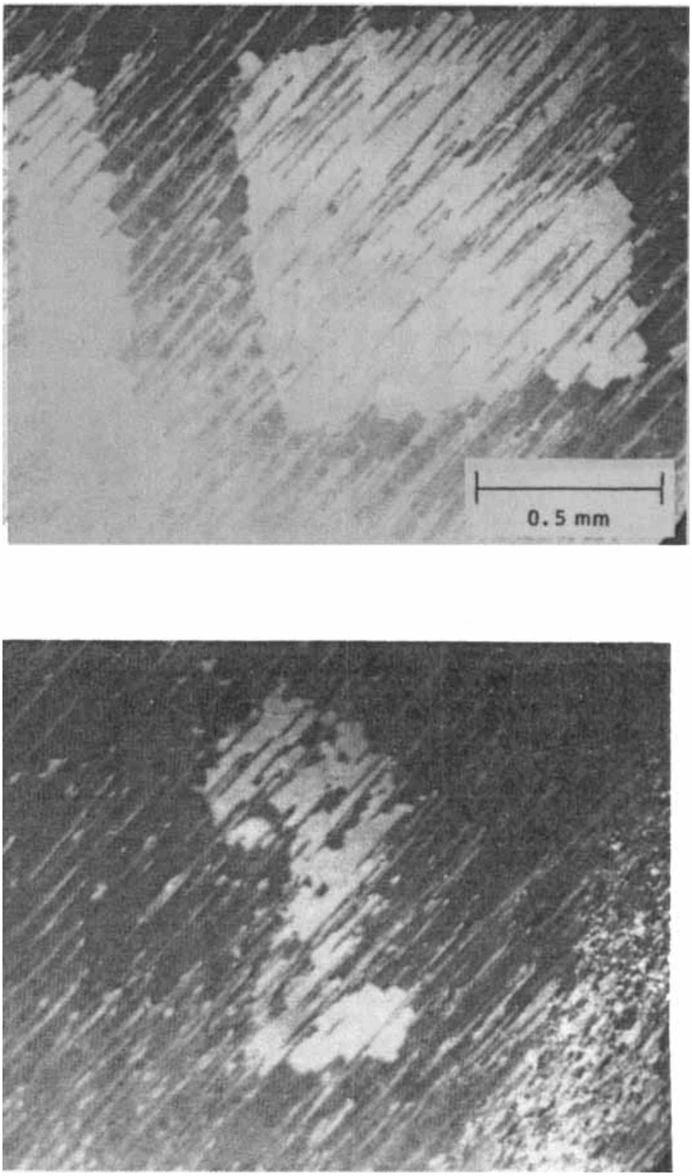


FIGURE 6 Microscopic appearance of stored image in BSO-FLC-SLM.

the SLM performance for different operating conditions. Alternatively, the readout image can be photographed directly, thereby avoiding TV resolution limitations.

RESULTS

The performance of the FLC-BSO-SLM is compromised by space-charge effects in the BSO. This was not expected to be a significant effect in ac operation.[3] We initially applied a 500-Hz ac square wave to the SLM, expecting the FLC to switch from dark to bright on every cycle in the presence of write illumination. However, only a transient image was observed over an input voltage range of 10 to 100 V. This is explained by a lack of bistability or storage in the FLC and space-charge accumulation in the BSO. In subsequent experiments, weaker alignment promoted FLC bistability and hence a non-fading image without cyclic refresh.

Figure 4 shows the TV appearance of the USAF 1951 resolution test target immediately after writing. The nonuniformities are associated with variations in the FLC thickness and alignment properties. Figure 5 compares the refreshed image with the same image stored overnight, where some deterioration is apparent. The storage is assessed with the BSO completely discharged by uniform optical irradiation.

Figure 6 shows the microscopic appearance of the stored resolution test image. The large number of defects apparent is associated with the FLC alignment problem.

We have successfully addressed a SSFLC cell with a 15-μm-thick film of photoconducting amorphous selenium. Space-charge accumulation in the selenium again compromises the performance. We have initiated experiments in a silicon photodiode addressing technology, which should allow the full speed potential of the FLC to be realized.[6] With crystalline silicon, space-charge effects are absent and fast switching rates are easily achieved. We have observed beyond 10-lp/mm resolution with significant diffraction efficiency in a silicon photoaddressed FLC-SLM.

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