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TECHNICAL REPORT-RD-WS-93-3

SPATIAL LIGHT MODULATORS (SLMs) SURFACE QUALITY

Tracy D. Hudson
Weapons Sciences Directorate
Research, Development, and Engineering Center

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U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35898-5000

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The phase modulating properties of spatial light modulators (SLMs) have been investigated for optical pattern recognition purposes for many years. An interferometric microscope was recently utilized to investigate the surface uniformity, and thus phase distortion, of several SLMs that are commercially available. These interferometric results are presented here and verify that the optical uniformity of SLMs should be considered when phase modulating properties of the devices are to be applied in optical systems.

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I. INTRODUCTION

The phase modulating properties of spatial light modulators (SLMs) have been investigated for optical pattern recognition purposes for many years. SLMs investigated include Hughes Liquid Crystal Light Valve (LCLV), Ferroelectric Liquid Crystal (FLC) devices, liquid crystal spatial light modulators from Loral and Lockheed Corporations, and Liquid Crystal Televisions (LCTVs) to name a few. Researchers have attempted to exploit the phase modulating properties of these devices for phase-only matched filtering, computer-generated binary phase-only filters, and optical associative memories [1]. Early investigations of LCTVs for these applications found that a liquid gate was required because of the nonuniform glass sandwich structure of the devices. More recent investigations verify the continued existence of phase distortions from less than one fringe across the device to more than two for recent liquid crystal displays [2].

II. EXPERIMENTAL DATA

An interferometric microscope (Graham Optics Fringe Printer II) was recently utilized to investigate the surface uniformity of several SLMs that are commercially available. This microscope utilizes the Fizeau interferometric architecture discussed elsewhere [3]. The reference surface is four inches in diameter and specified as flat to $\lambda/20$ at $\lambda=0.6328$ µm. The modulators tested include two Hughes LCLVs, two FLC SLMs, and liquid crystal spatial light modulators from Loral and Lockheed Corporations.

A Hughes LCLV (CdS photoconductor, 50 × 50 mm clear aperture) was initially placed under the interferometric microscope. The Hughes LCLV was positioned so the front reflection of the read surface was interfered with the reference wave. The resultant interferogram is shown in Figure 1. This interferogram consists of uniformly parallel fringes, thereby denoting a uniformly flat optical surface. The Hughes LCLV evaluated above was originally manufactured in the mid-1970s. A more recently manufactured light valve from Hughes Corporation was then tested. This light valve was the input SLM to the portable correlator unit utilized in MICOM's missile optical guidance program [4]. The resulting interferograms from the read and write surfaces of the device are shown in Figure 2. The read surface is flat to $\approx 2\lambda$ across the 50 mm diameter aperture and concave in shape. The write surface is flat to 1-1/2λ over the 50 mm diameter aperture and convex in shape.

The optical surface quality of two FLC SLMs was then measured using the above techniques. The interferograms from an optically addressed FLC SLM manufactured by the University of Colorado-Boulder in 1988 are shown in Figure 3. This FLC SLM has a consistent interference pattern, known as Haidinger fringes, due to the parallelism between the front (read) and back (write) surfaces of the device. This consistent pattern is shown in Figure 3(a). There is no dielectric mirror present in this modulator. Furthermore, optical flats were not used to sandwich the SLM structure. The front surface (read input window) of the device is not flat when compared to the reference waveform. This result is shown superimposed with the results of Figure 3(a) in Figure 3(b). Each of these interference patterns results in a series of concentric or Newtonian rings. The read surface of this SLM is concave in shape with a surface error of ≈2λ over the 12.5 mm diameter aperture. The interferograms from a more recently fabricated FLC SLM from Displaytech are shown in Figure 4. Unlike the previous FLC SLM, this device does employ optical flats and a dielectric mirror. The read surface is convex with a surface error of 1λ across the 23 mm diameter aperture. The write surface was measured to be flat to λ/20 over the effective aperture, the resolution limit of the optical reference flat of the interferometric microscope.

Two additional liquid crystal SLMs were then tested. These devices are a Loral Corporation SLM which employed a nematic liquid crystal with an As_2Se_3 photosensor and a Lockheed SLM with a twisted nematic structure and GaAs photosensor. The interferograms from the Lockheed and Loral Corporation SLMs are shown in figures 5 and 6, respectively. The read and write input windows of the Lockheed SLM are flat to ≈3-1/2 and 5λ with the surfaces convex and concave, respectively. The Loral SLM's write side input window is flat to λ/2 with some coarse Haidinger fringes present. These fringes are most likely due to reflections between the dielectric mirror and input glass window. The read side of the Loral SLM is very nonuniform in structure as shown by the interferogram of Figure 6(b). This nonuniformity appears to be a separation between two or more layers within the device's multilayered structure.

III. CONCLUSION

These results verify that the optical uniformity of SLMs should be considered when phase modulating properties of the devices are to be applied in optical systems. From the above devices, the most likely candidate for such applications without modification to the optical system appears to be the mid-1970s edition of the Hughes LCLV. The other SLMs may be used if immersed in a liquid gate. However, liquid gates introduce complexities in optical systems to the SLM such as proper index matching of sometimes carcinogenic fluids.

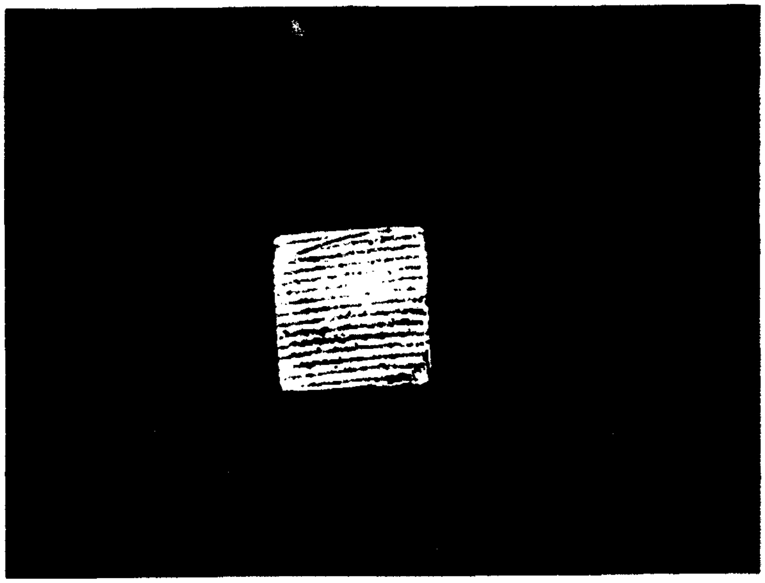
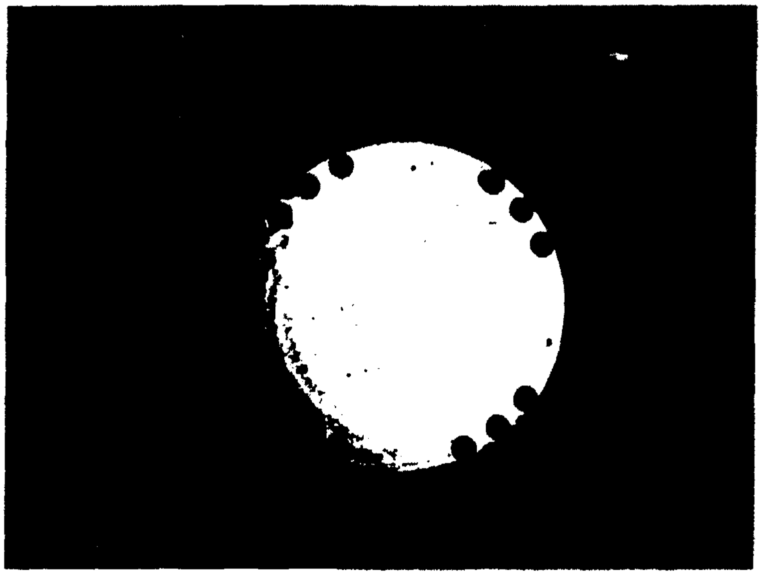
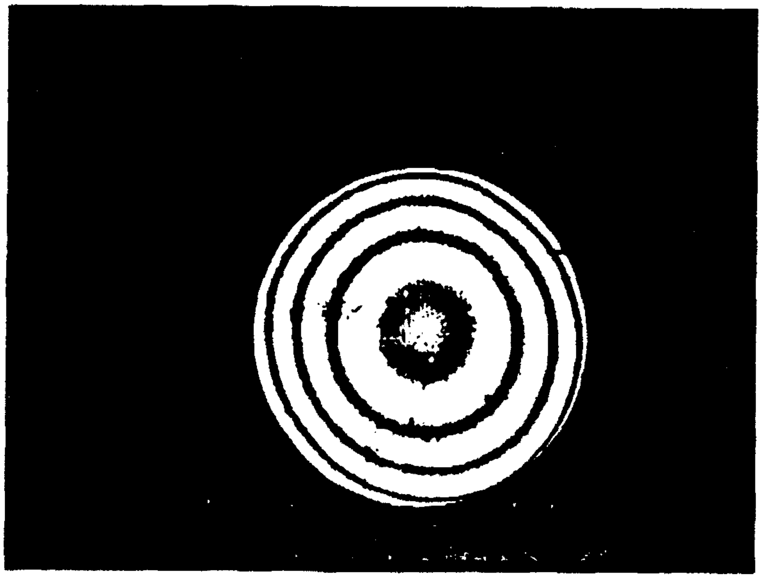


Figure 1. Interferogram of Read Side of mid-1970s Edition Hughes Corporation Liquid Crystal Light Valve

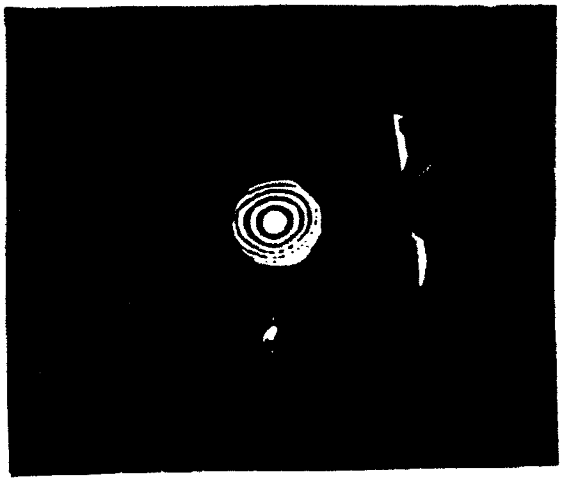


(a)

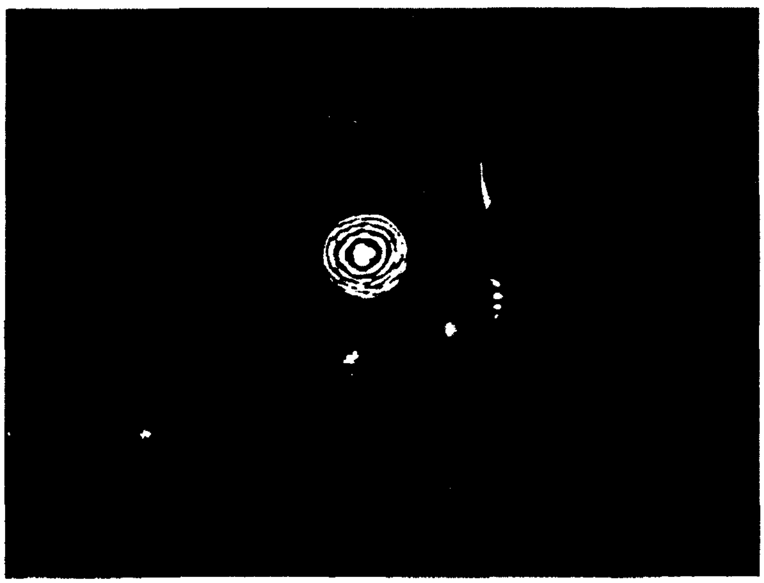


(b)

Figure 2. Interferograms from the (a) Read and (b) Write side of Hughes Corporation LCLV Manufactured in mid-1980s



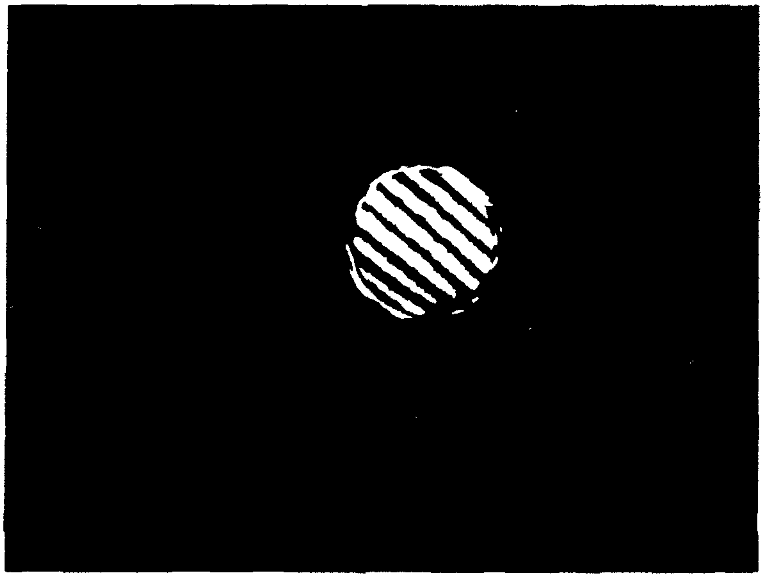
(a)



(b)

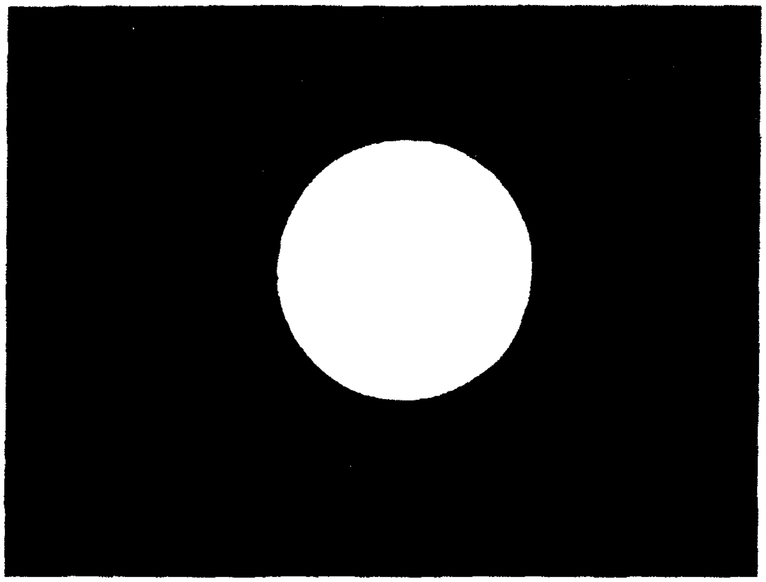
Figure 3. Interferograms of FLC SLM Manufactured by University of Colorado-Boulder: (a) The Haidinger Fringe Structure Due to Parallelism Between the Read and Write Surfaces of the Device. (b) The Read Side Input Window Superimposed on the Haidinger Fringe Structure

(a)

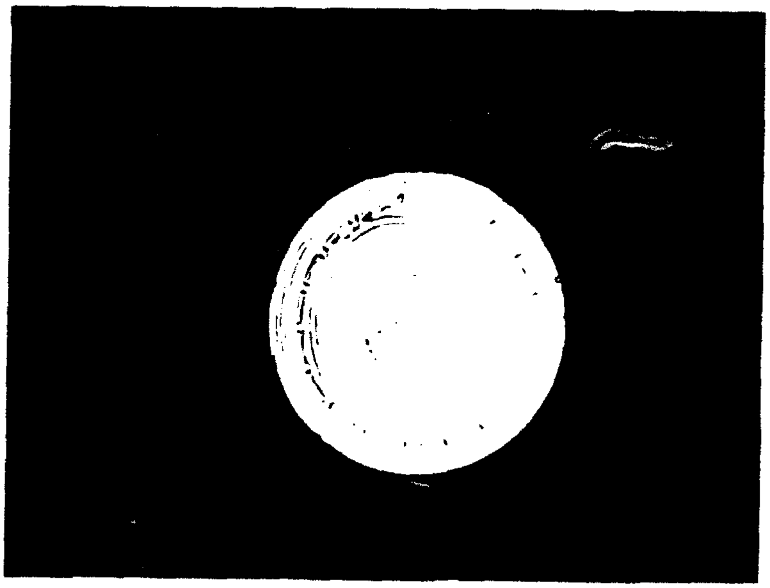


(b)

Figure 4. The Interferograms from the (a) Read and (b) Write Input Windows of the FLC SLM Fabricated by Displaytech



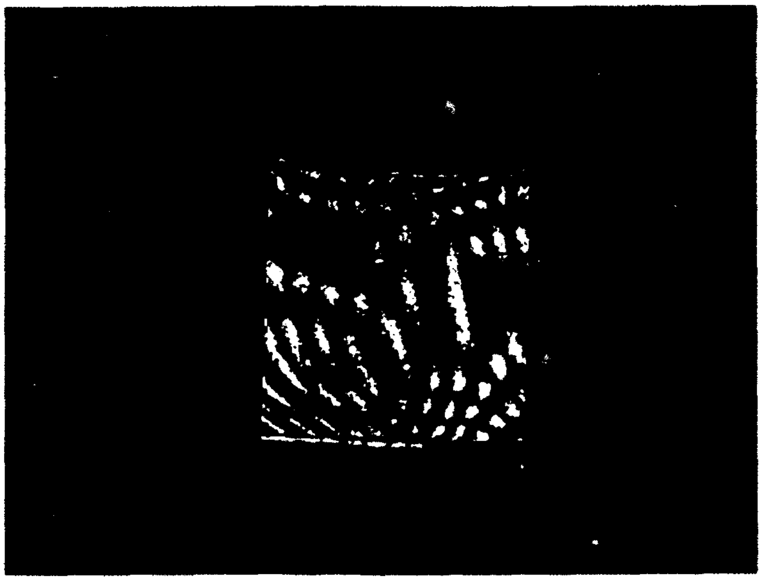
(a)



(b)

Figure 5. Interferograms of the (a) Read and (b) Write Windows of a Lockheed Liquid Crystal SLM

(a)



(b)

Figure 6. Interferograms of the (a) Write and (b) Read side of a Loral Corporation Liquid Crystal SLM

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