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HOLOGRAPHIC DATA STORAGE CRYSTALS FOR THE LDEF*

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SUMMARY

Crystals of lithium niobate were passively exposed to the space environment of LDEF. Three of the four crystals contained volume holograms. Although the crystals suffered the surface damage characteristic of that suffered by other components on the Georgia Tech tray, the crystals remained suitable for the formation of volume holograms.

INTRODUCTION

Lithium niobate is a significant electro-optic material, with potential applications in ultra high capacity data storage and processing systems. Lithium niobate is the material of choice for many integrated optical devices and holographic mass memory systems. The objective of the experiment is to test the spaceworthiness of electro-optic crystals for use in ultrahigh capacity space data storage and retrieval systems.

VOLUME HOLOGRAPHIC STORAGE

Volume holographic storage offers a unique capability for ultrahigh capacity data storage and processing systems. In addition to the potential storage of up to 10^{10} bits in a single crystal, holographic storage is insensitive to point damage of the medium. Holographic storage is particularly suitable for the processing of data in page-oriented form and can be used either in a read-write-erase mode or in an archival

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storage mode. By using electro-optic beam deflectors, mechanical motion can be eliminated. The principal advantages of volume holographic storage are listed in Table 1.

To record the volume holograms in the lithium niobate, two plane waves, produced by the same laser, are interfered within the crystal, as shown in Fig. 1. The interference maxima and minima produce a corresponding refractive index variation in the photorefractive crystal, which produces the volume hologram. By passing one of these beams, the "object" beam through a data page mask prior to incidence on the crystal, digital data in page oriented format may be stored as a volume hologram. The data page may be displayed by subsequent illumination with the reference beam alone. This writing and reading process is shown in Fig. 2. By rotation of the crystal with respect to the laser beam, multiple pages of data can be stored. Figure 3 illustrates the data storage in a page-oriented optical phase holographic memory.

OPTICAL SYSTEM

Much of our effort centered on developing a precise system for writing and evaluating the holograms. Systems were developed for hologram formation with both helium-neon ($\lambda = 632.8$ nm) and argon ($\lambda = 514.5$ nm) lasers. The apparatus for the holography study with helium-neon lasers is shown in Fig. 4. This apparatus achieves page rotation by rotating the reference beam angle with respect to a stationary object beam and stationary recording crystals. The reference beam angle is controlled by a stepper motor that drives a rotating mirror. The angular rotation resulting from a single step is 19.6 milliradians. [1]

LDEF EXPERIMENT

For the LDEF experiment, holograms were recorded in 10 mm x 10 mm x 2 mm samples of iron-doped lithium niobate, with the optic axis lying in the plane of the surface. The crystals were specified to be iron doped to .005 mole percent iron in the melt. The samples were flown as part of the overall Georgia Tech experiment, LDEF experiment S0050, "Investigation of the Effects of Long-Duration Exposure on Active Optical Components," with principal investigator M.D. Blue. Our experiment consisted of the materials shown in Table 2.

The diffraction efficiency (diffracted power divided by incident power) as a function of read beam angle for a typical plane wave hologram is shown in Fig. 5. This diffraction efficiency could be used to monitor the degradation of the hologram with time.

RESULTS

To date, no holograms have been observed remaining in any of the samples because of the long exposure time involved. Although the crystals were recovered intact, they

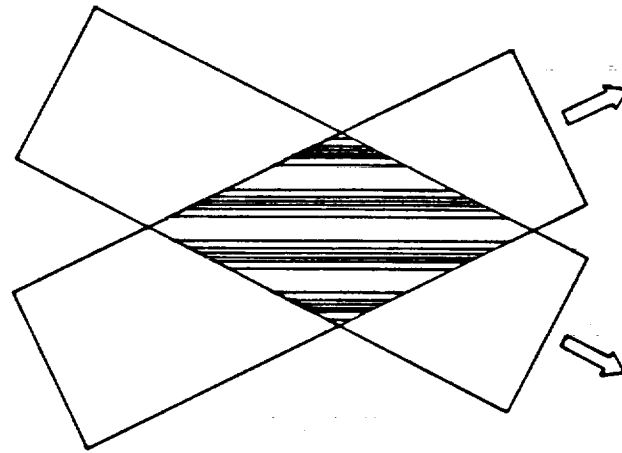
suffered the same surface damage characteristic of that of other optical components on the Georgia Tech tray. A very significant result is that the crystals still retained their photosensitivity. A recently recorded hologram from one of the LDEF crystals is shown in Fig. 6.

ACKNOWLEDGMENTS

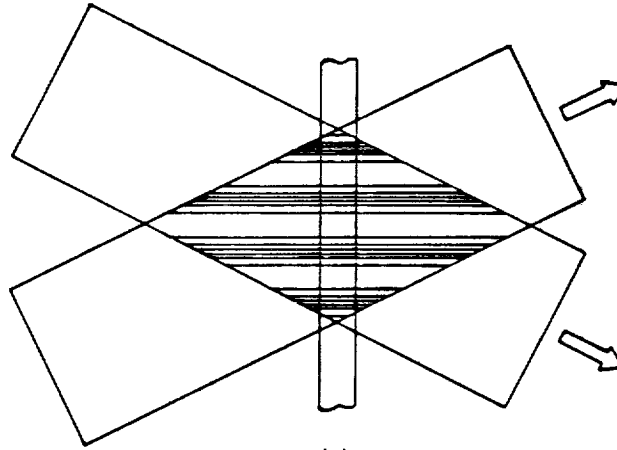
The authors express their appreciation to NASA for sponsoring this research, and to Mr. Mark Lehi Jones for the photographs shown in Fig. 6.

REFERENCE

1. J.E. Weaver, "Angular Addressing Properties of Volume Fourier Transform Holograms in Iron-doped Lithium Niobate," Ph.D. Thesis, Georgia Institute of Technology, 1979.



(a)



(b)



(c)

Figure 1. Volume hologram recording (a) interfering beams (b) crystal recording (c) recorded holograms.

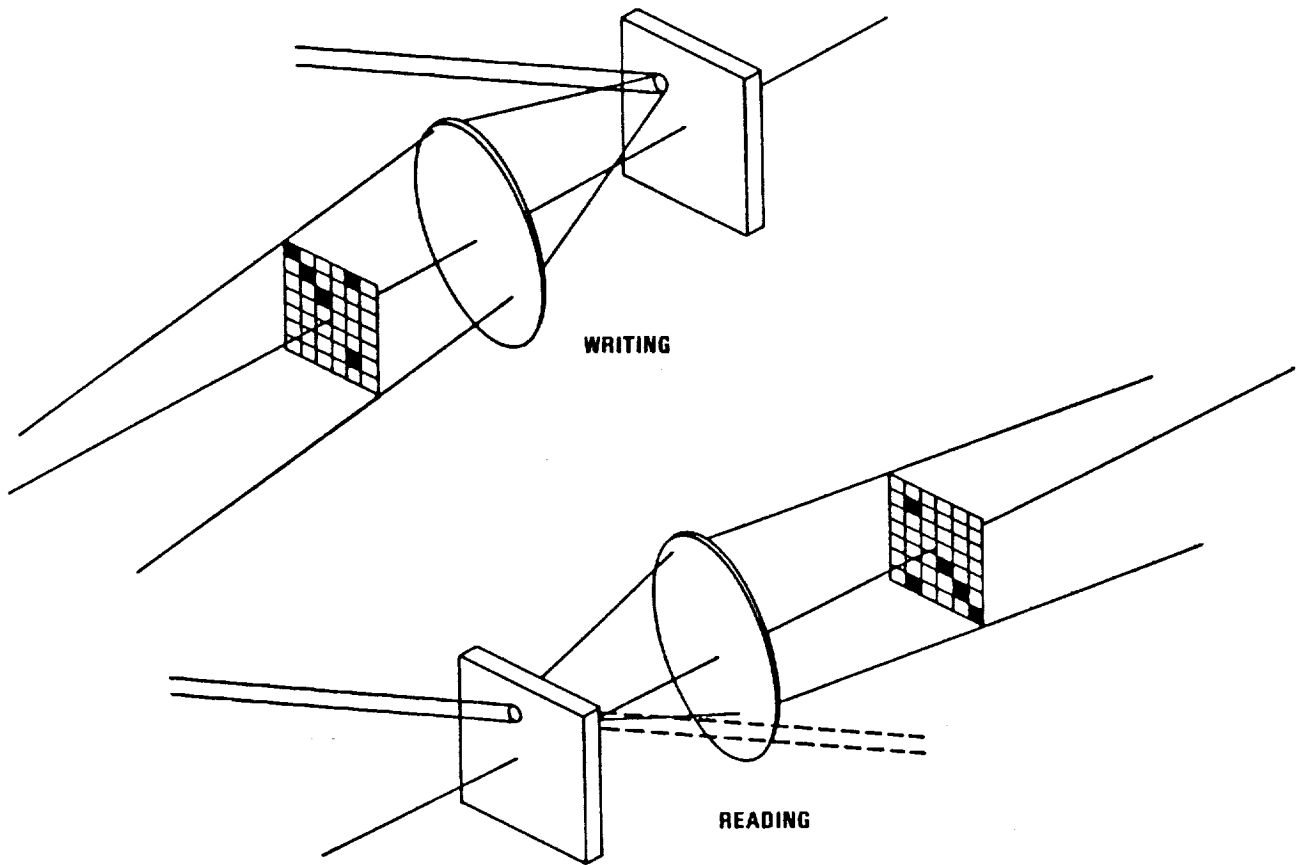


Figure 2. Writing and reading a data page hologram.

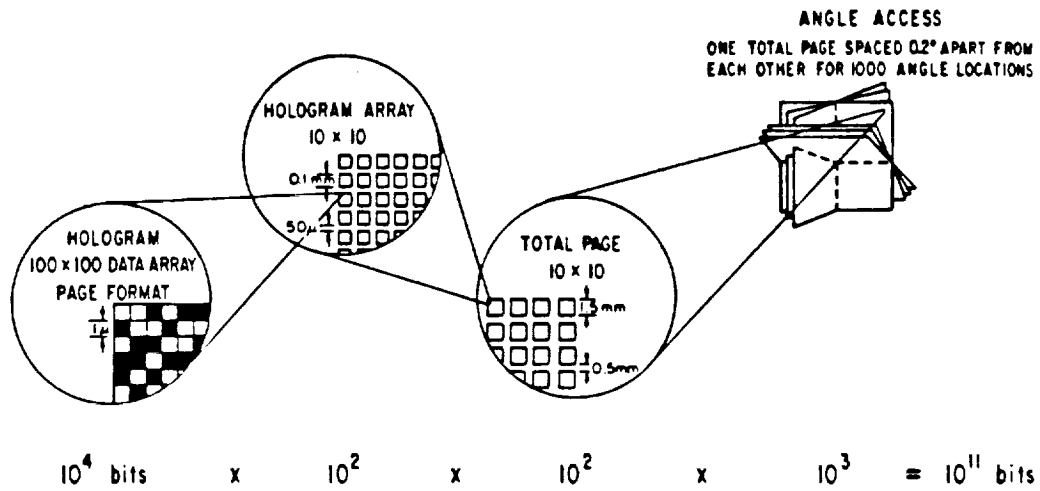
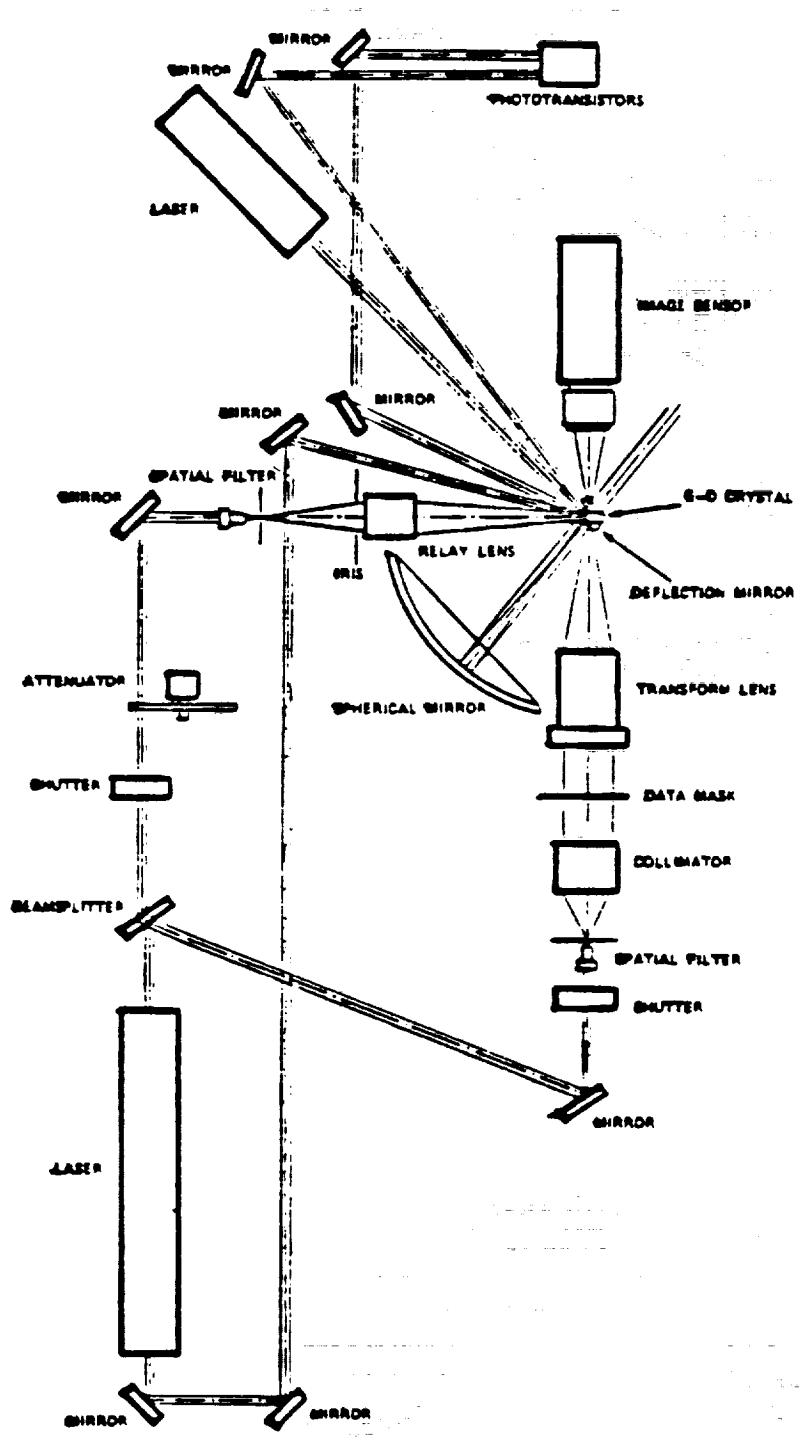


Figure 3. Data storage in a page-oriented optical holographic memory.



Optical System Diagram

Figure 4. Hologram recording and reading apparatus (helium-neon laser) (reference 1).

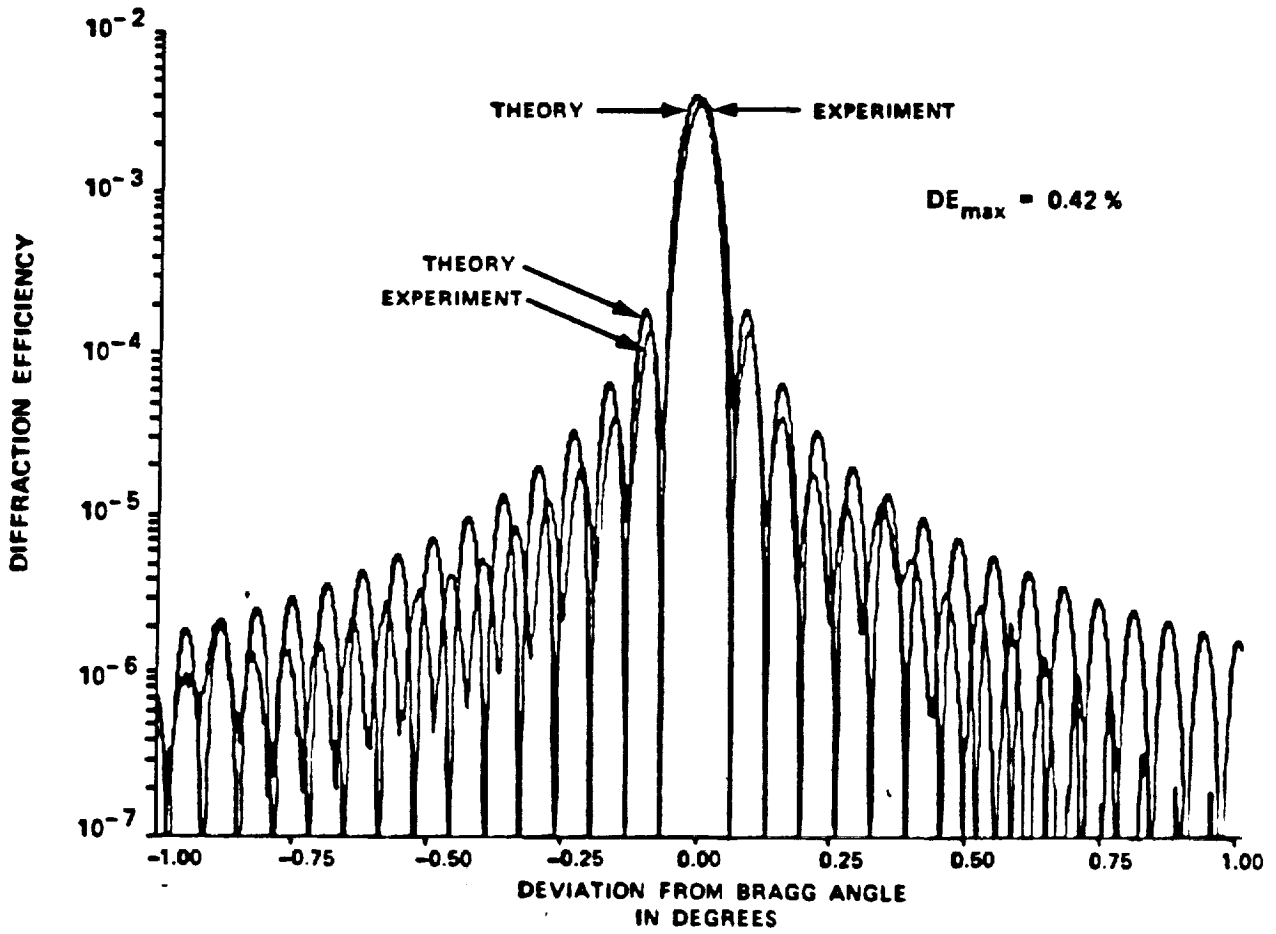
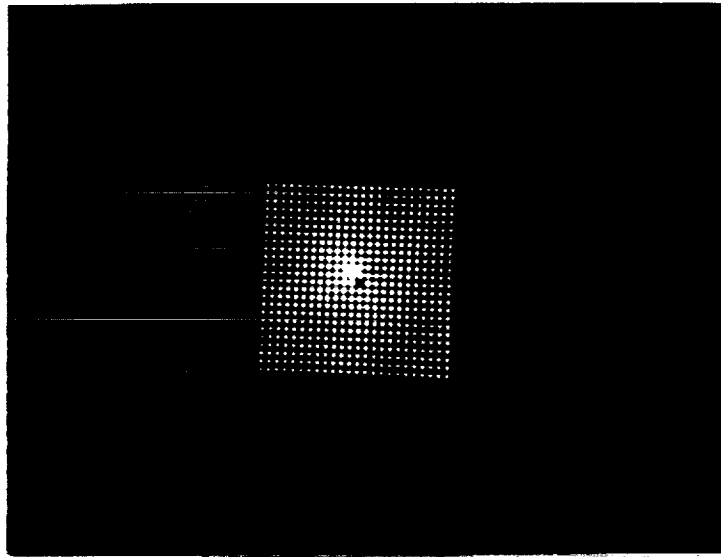
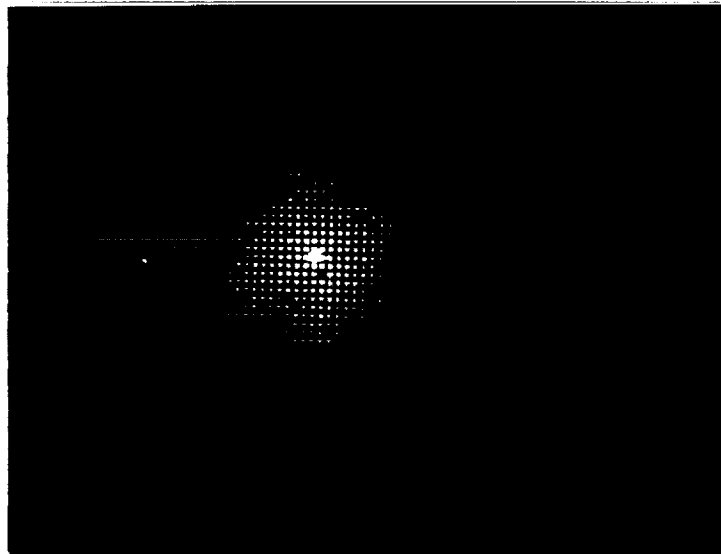


Figure 5. Diffraction efficiency versus angle (reference 1).



(a)



(b)

Figure 6. Hologram produced with LDEF crystal (a) object beam data page (b) hologram of object beam.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Table 1. Characteristics of volume holographic storage.

VOLUME HOLOGRAPHIC STORAGE

HIGH INFORMATION CAPACITY
REDUNDANT
READ-WRITE-ERASE OR ARCHIVAL
NON MECHANICAL (ELECTRONIC & OPTICAL)
INHERENT TWO-DIMENSIONAL STORAGE
PROCESSING CAPABILITY

Table 2. LDEF samples.

FIVE SAMPLES FLOWN

1. LITHIUM NIOBATE, HEAT TREATED FOR MAXIMUM SENSITIVITY, BLANK
2. LITHIUM NIOBATE, PLANE WAVE HOLOGRAM, HELIUM-NEON LASER
3. LITHIUM NIOBATE, PLANE WAVE HOLOGRAM, ARGON LASER
4. LITHIUM NIOBATE, SPOKE PATTERN HOLOGRAM, ARGON LASER
5. GLASS CONTROL SAMPLE

TWO CONTROL CRYSTALS

1. LITHIUM NIOBATE, PLANE WAVE HOLOGRAM, HELIUM NEON LASER
2. LITHIUM NIOBATE, PLANE WAVE HOLOGRAM, ARGON LASER

THE GREAT EASTERN

Insurance Company of New York

NEW YORK

Capital and Surplus

Assets

Liabilities

Profit and Loss

Statement of

Income and Expenses

for the Year

ended December 31, 1910

Balance Forward

Income

Expenses

Balance Forward

Profit

Dividends