Volume Holograms for Optical Interconnections

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ABSTRACT

We present application of volume holograms for three-dimensional interconnections in optical information processing systems. System design and optical experimental results are presented.

1. INTRODUCTION

Volume holographic storage has received much research interest when it was first introduced in 1960s and since then there has been a rapid progress in this field [1-3]. In recent years, the advances in volume holographic data storage has demonstrated the potential of achieving tera-byte storage capacity with data access rate of exceeding giga-bit per second. [4-6]. In fact, volume holographic gratings are not only useful for data storage but also are good for optical interconnections in information processing systems. The most advantages of volume holograms are their large storage capacity and the parallelism of information readout. By using a suitable multiplexing technique, thousands of holograms can be recorded at a single location of a recording medium, with each hologram be readout independently with low cross-talks between neighboring channels. Furthermore, by illuminating the holograms with a single reading beam the whole page of 2-dimensional information can be retrieved at one time. Which means instead of having physical “linking the incident light signals can be split and distributed into many desirable positions to achieve interconnections. These unique features of volume holograms could find many important applications for optical information processing. In this paper we describe a volume hologram for a re-configurable holographic optical interconnection. Theoretical analysis and the experimental results will be presented.

2. SYSTEM DESIGN

Figure 1 represents a generic diagram of a optical computing module, which consists of opto-electronics circuit boards. Light beams provide the optical interconnections between these opto-electronic circuit boards. Each opto-electronic board consists of logic processing chips and hologram reading/writing mechanisms such as holograms, lasers, light deflecting devices, and photo-detectors. Let us consider the interconnection from the first board to the second board. By recording a hologram of the interference pattern of lights coming from the recording plane and input plane, the interconnection patterns and strengths are stored in the holographic media. Then, light beams emitting from the first board and incident on the hologram are diffracted into the second board. Thus, parallel interconnection from the first board to the second board can be achieved. If many holograms have been superimposed on the same recording medium using a suitable multiplexing technique then the interconnections can be re-configurable. It should be noted that in order to obtain a noise-free interconnection, the cross-talks between the neighboring channels should be kept to a minimum. This can be achieved through an appropriate construction of the recording and reading structure. In our system we sued a shift multiplexing method that uses spherical waves to reconstruct the interconnection patterns in volume holograms. This is practical because the light source from a laser diode can be approximately treated as a point source, and different laser sources on different circuit modules can be treated as a shift of the point source on the input plane. Assume that a spherical reading wave is originated at a distance z_0 from the recording media, the thickness of recording media is L, laser wavelength is λ, and the desirable interconnection light pattern incidents at angle θ_s with

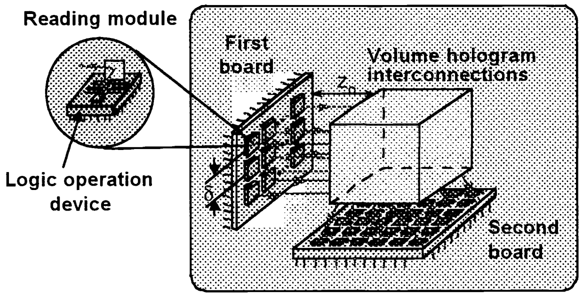

Fig. 1 Schematic drawing of our optical interconnections

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Optics for the Quality of Life, Giancarlo C. Righini, Anna Consortini,
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respect to the optical axis; then the minimum separation between two reading lasers can be derived by using the scalar Born approximation. The results are expressed as follows

$$\delta_x \approx \frac{\lambda z_o}{\mathrm{L}\tan\theta_s}, \quad \delta_y \approx \sqrt{\frac{\lambda z_o}{\mathrm{L}}}, \quad \delta_z \approx 3.5\frac{\lambda z_o^2}{\mathrm{L}^2 \sin^2\theta_s} \tag{1}$$

where δ_x, δ_y and δ_z represent the minimum separation of the lasers along different directions. In addition, if angular multiplexing of the holograms is added to each reading laser then the minimal angle separation between two holograms can be derived to be

$$\Delta\theta \approx \frac{\lambda}{2\mathrm{L}\sin\theta_s} \tag{2}$$

Eqs. (1-2) provide the basic design rules for the reading modules in our interconnection system. As an example, λ =0.5 μm, L =1 cm, z_o =10 cm, θ_s=90°, we obtain δ_x~5 μm, δ_y ~707 μm, δ_z ~500 μm and $\Delta\theta$ ~0.003° If the chip size is 1cm x 1cm, then the geometric size limits the number of the reading laser module on a single chip to be as large as 4000.

3. EXPERIMENTAL RESULTS

To verify our theoretical analysis, we performed a preliminary experiment to construct a lensless parallel optical interconnection using shift-multiplexed volume hologram technique. The optical setup is illustrated in Fig. 2. We used a phase conjugation recording and readout configuration. During the recording stage, the LCTV provide the object beam, which contain the interconnection pattern and converging spherical wave (shutter 1 is closed, shutter 2 is opened) provides the reference beam. The interference fringes are recorded in a 1-cm x 1-cm $LiNbO_3$ photorefractive crystal. After one recording, the crystal is shifted around 5 μm along the direction indicated by arrow and then next interconnection pattern is input and recorded. We record twenty different interconnection patterns in the crystal. During the readout, a phase conjugated spherical wave (shutter 2 is closed, shutter 1 is opened) reconstructs the hologram and the reconstructed pattern is detected by a CCD camera. The reading beam is moved up and down to reconstruct the different interconnection pattern at the different position. Thus the CCD is equivalent to the photodetector chip set on the second board and the point source represents the different laser module chip set on the first board. The experimental results are shown in Fig. 3. It can be seen that all of the interconnection patterns can be retrieved by the corresponding reading point source. The cross-talks between channels are not obvious.

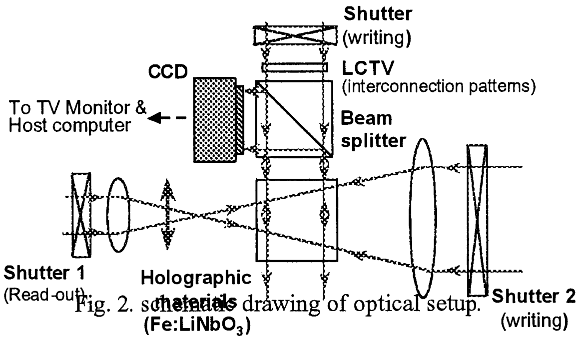

Fig. 2. schematic drawing of optical setup.

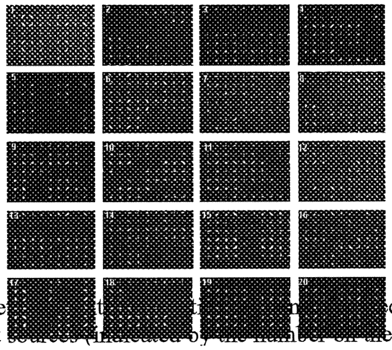

Fig. 3. The re[illegible] d by different point [illegible] e left corner).

3. CONCLUSIONS

In summary, we have proposed a structure of the board-to-board optical interconnections by volume holograms. The design rule has been theoretically described. The preliminary optical experiments have been demonstrated. We are grateful for the financial support, in part from the Ministry of Education, Taiwan, ROC under Grant 89-E-FA06-1-4 and, in part from the Lee & MTI center for Networking Research at National Chiao Tung University.

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