Holographic data storage with 100 bits/μm^2 density

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Summary

Holographic data storage offers several advantages when compared to conventional storage devices. The data stored and retrieved is organized as a two dimensional page, consisting of a large number of pixels (bits). The read-out rate can be very high since an entire page of data is presented when a hologram is reconstructed. For example, accessing a page of data consisting of 1,000 × 1,000 pixels within 1 ms would give a data transfer rate of 1 gigabits per second. Furthermore, holographic data storage allows many pages of data to be stored at the same location with little cross-talk by using multiplexing techniques such as angle, wavelength, phase-code, fractal, peristrophic, and shift.

As a benchmark, we would like to compare holographic memory with optical compact discs. They are both removable, high capacity, and can be randomly accessed. The next generation compact disc due in early 1997, the Digital-Versatile-Disc (DVD), will have a capacity of ~ 6 Gbytes per layer, for a maximum planned capacity of ~ 20 Gbytes per double-sided disk with two layers on each side. That translates to a surface density of approximately 20 bits/μm^2 for the 4 layered DVD disk. In order for holographic 3-D disks to be competitive, we must demonstrate a much higher surface density than the most advance DVD.

In a previous experiment [1], we demonstrated a storage density of 10 bits/μm^2 using the 100 micron thick DuPont photopolymer. This was achieved by storing shift multiplexed [2] holograms on a disk with similar dimensions as the compact disc. To demonstrate that a much higher surface density can be achieved holographically with a recording material similar in thickness to the compact disc, we constructed a holographic memory system using a 1 mm thick $LiNbO_3$ (see Figure 1). A pair of Nikon *f*/1.4, 3.9-cm-aperture camera lenses were used to image an E-beam lithographed chrome plated data mask to a CCD detector. A total of 590,000 pixels fit in the apertures of the two Nikon lenses, and a sharp image of the entire field was obtained at the detector plane. The center-to-center spacing of the pixels was 45 μm and the fill factor was 100%. The recording material, 2 cm × 2 cm × 1 mm iron doped $LiNbO_3$ was mounted on two translation stages for shift multiplexing. Instead of recording the holograms with a planewave reference beam, a spherical reference beam was formed by using a *f*/1.1 projection lens. If a hologram recorded with a spherical reference beam is shifted slightly during reconstruction, the wavefront it experiences will be different from the wavefront used to record it. Therefore, the reconstruction will be suppressed and another hologram

could be recorded, partially overlapping the previous hologram. For this experiment, horizontal displacement of the recording material (parallel to the plane of interaction) was provided by a Klinger CC1.2 linear stage and controller. Vertical displacement was provided by a manual translation stage. The holograms were recorded with the $LiNbO_3$ slightly past the Fourier transform plane of the Nikon lenses for a more uniform signal beam.

A surface density of 100 bits/μm^2 was achieved by storing 590,000 pixels in each hologram, over an effective hologram area of 5850 μm^2 (7.8 μm horizontal displacement × .75 mm vertical displacement per hologram). The resulting estimated raw bit-error-rate (BER) was approximately 10^{-4} and no errors were observed in the sampled hologram when localized threshold values were used. At 100 bits/μm^2, we have a comfortable margin over the projected surface density of the most advanced DVD system. Furthermore, the results obtained from this experiment can be applied to a shift multiplexed holographic 3-D disk system. The capacity per 120 mm disk at 100 bits/μm^2 is approximately 100 Gbytes.

References

[1] A. Pu and D. Psaltis. "Shift multiplexed holographic 3-D disk system," *International Symposium on Optical Memory and Optical Data Storage*, JTuA6, Hawaii, July 1996.

[2] D. Psaltis, M. Levene, A. Pu, G. Barbastathis, and K. Curtis. "Holographic storage using shift multiplexing," Opt. Lett. 20(7):782-784 (1995).

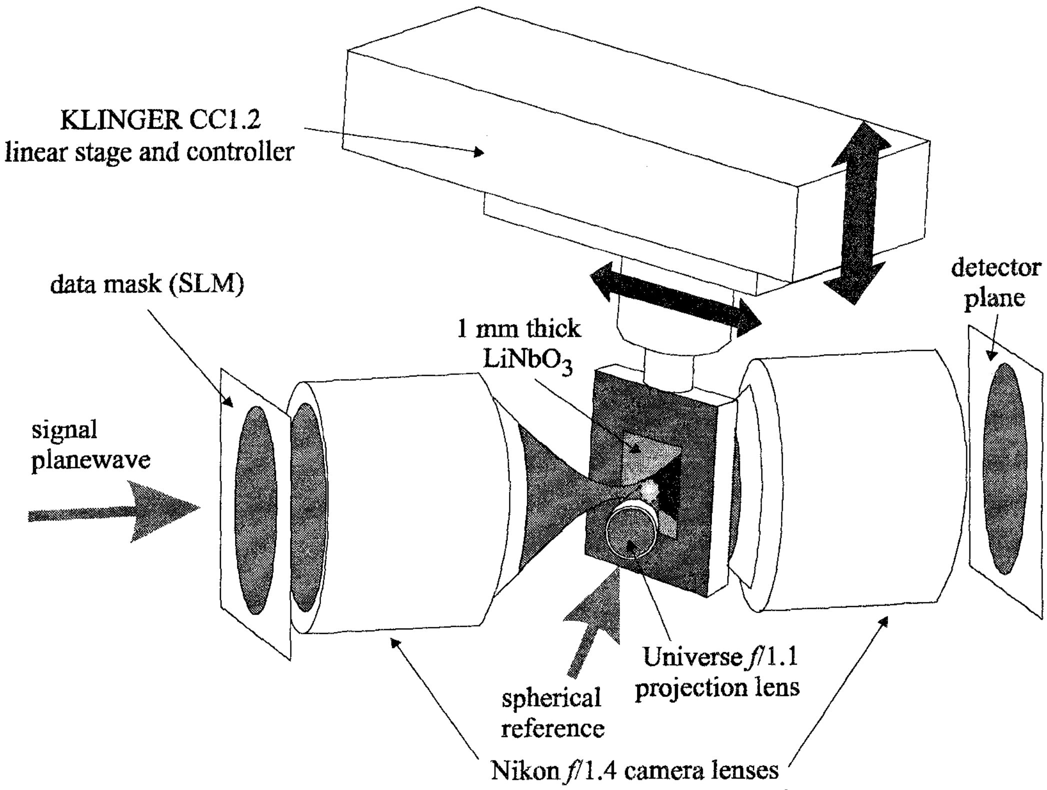

Figure 1 : Schematic diagram of the 100 bits/μm^2 setup.