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Compact lens-less holographic memory

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A common problem of many holographic memory systems is that they must occupy relatively large areas in order to accommodate the various imaging optics necessary for system operation. A typical memory system requires an imaging lens system between the input and output devices, such as a spatial light modulator (SLM) and charge-coupled device (CCD). The system may also require a rotating mirror and another lens system to perform angular multiplexing. Although the optics are simple, the system is necessarily bulky due to the path lengths required for the lens systems. The SLM and detector array must also be aligned to within a fraction of a pixel size (typically a few micrometers) along both transverse axes.

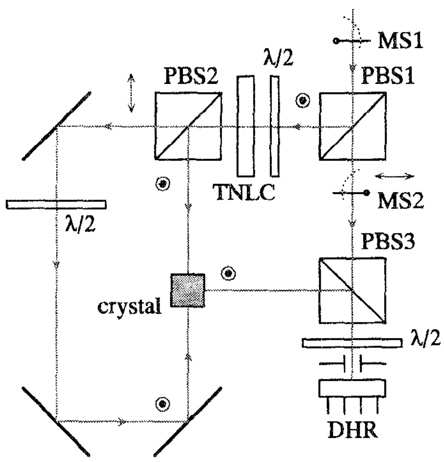

Figure 1: Integrated memory architectures.

The memory system we describe here integrates the various system components very closely to the crystal by using a smart pixel array[1] and making use of phase-conjugate read-out to eliminate the need for imaging optics. This significantly reduces the alignment requirements and the number of required components. Our angularly multiplexed integrated read/write memory system is shown in Figure 1. An optoelectronic integrated circuit, which we refer to as the *Dynamic Hologram Refresher* (DHR), functions as both a spatial light modulator and a detector array. Liquid crystal beam steerers are attached to the two faces of the crystal perpendicular to the signal beam path. These beam steerers address the angularly multiplexed memory. Holograms are recorded by the interference of the signal beam (from the DHR) with the forward reference wave entering the top face of the crystal (as shown in the figure); when writing holograms, the DHR acts as a spatial light modulator. The *counter-propagating* reference wave (illuminating the crystal from the bottom) is employed to reconstruct holograms. The reference beam is steered into either the forward or conjugate paths by means of a twisted-nematic liquid crystal (TNLC) device which switches the polarization in the reference arm. Because the counter-propagating reference is a conjugate of the reference used for writing the hologram, the phase-conjugated reconstruction propagates back towards the DHR, where it is imaged onto the detector array on the chip without the need of any imaging optics. This system corrects for any aberrations introduced by the crystal due to the phase conjugating nature of its readout operation. Note that the entire system is lens-less; hence, all of the components could be abutted together to form a very compact memory module.

Furthermore, the angularly multiplexed system shown in Figure 1 is well suited to *refresh* holograms. In a read/write holographic memory system, holograms slowly decay because each access (read or write) involves an exposure to the reference beam. The solution is the same as in electronic dynamic RAMs: the memory needs to be periodically refreshed by reading its contents and writing them back. In a conventional system with separate SLM and CCD, this requires detecting the data page with the detector array, electronically transferring the data to the spatial light modulator, and re-recording the hologram. The operation is simpler in Figure 1, since each individual pixel in the DHR contains a photodetector, a static latch and a liquid crystal modulator. The reconstructed data page is sensed by the DHR; each pixel latches its corresponding bit from the data page being read out and displays it on its modulator to rejuvenate the hologram. No inter-chip communication is required.

The results of a refreshing experiment are shown in Figure 2. A hologram of the image, "CIT", was recorded off of the DHR and written until its diffraction efficiency exceeded a set upper threshold. At this point the hologram was allowed to decay under illumination by the reference beam until its efficiency dropped below a fixed lower threshold. The hologram was then read out with the DHR and refreshed as described above. This process was repeated for 50 decay/refresh cycles with no error.

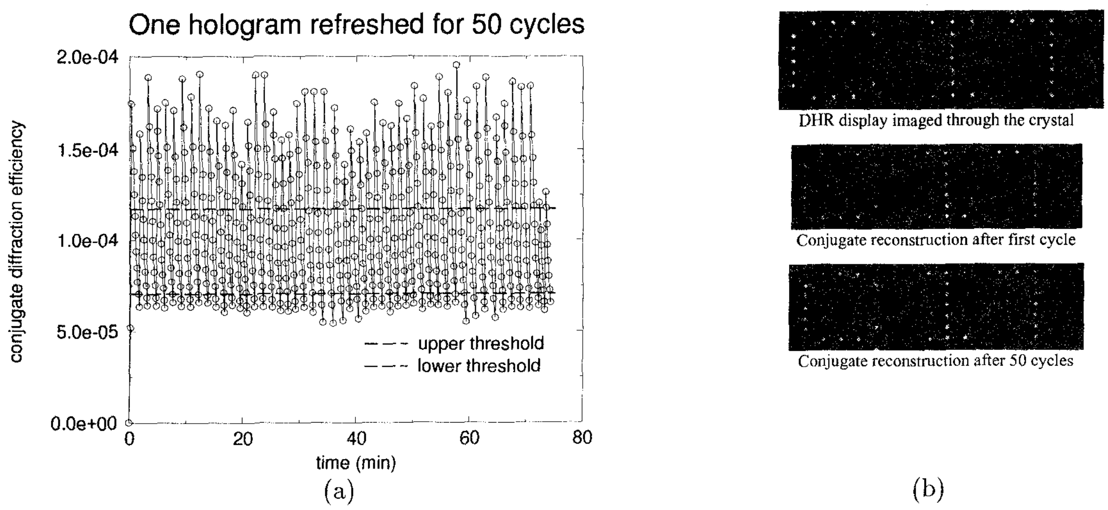

Figure 2: Experimental results from refreshing a hologram for 50 cycles: (a) diffraction efficiency vs. time, and (b) input and reconstructed images.

References

[1] J. Drolet, G. Barbastathis, J. Patel, and D. Psaltis. "Liquid crystal devices for volume holographic memories". In *OSA Annual Meeting*, September 1995.