Holographic Optical Disc

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We report the implementation of a holographic optical disc for high-capacity, digital data storage application. The holographic disc utilizes the Bragg-selectivity of the volume hologram to achieve a storage density of 40 bits/μm^2. The 12 cm disc is spun continuously at 600 r.p.m., and pixel-matched holographic data is readout from the disc in real-time.

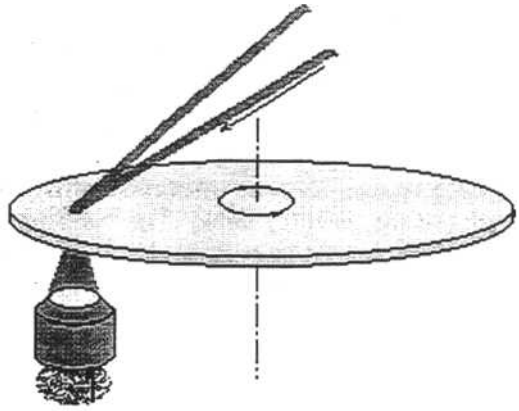

Figure 1. The Holographic Optical Disc System

Figure 1 illustrates the holographic disc system where the holograms are arranged on concentric tracks. Each spot contains a number of multiplexed holograms that can be read out in separate steps by steering the reference beam to different angles. In our system, each hologram contains 180,000 pixels, and the entire page is stored in an area of roughly 0.6 mm in diameter. This gives us a storage density of 0.5 bits/μm^2/hologram. We multiplex 80 holograms over each spot to achieve a density of 40 bits/ μm^2. Figure 2 shows the custom-designed imaging lens that we used

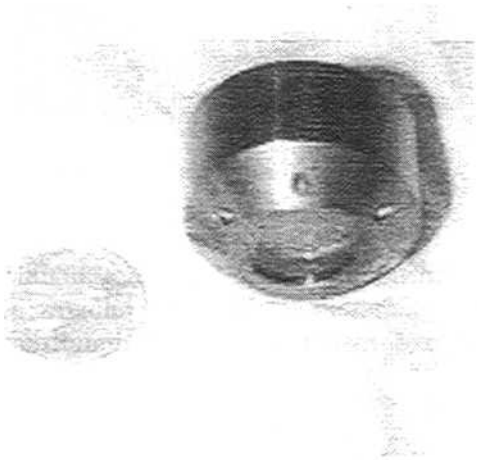

Fig.2. Imaging optics for holographic disc.

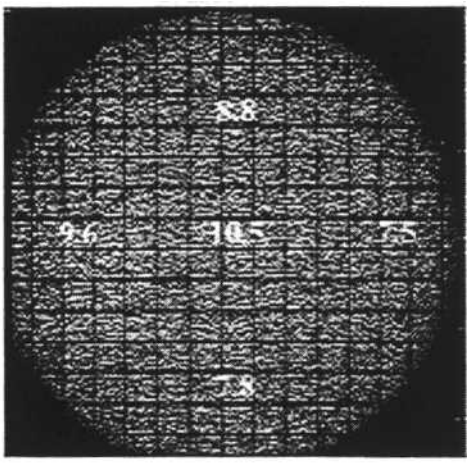

Fig.3. SNR of the imaging system

to achieve the result. The performance of the imaging system is shown in figure 3. The pixels on the SLM are imaged and one-to-one matched to the detector array, for the entire field of view. The SNR of the transmitted image varies from 10.5 in the center to 7.5 at the edge. The performance of the imaging optics is sufficient for the target specifications of our disc system.

When the holographic image is readout from the spinning disc, the reconstructed images could be shifted, distorted, or defocused. These may be caused by disc wobble, disc decentration, and by mechanical deformation in the disc substrate. When these happen, the readout holographic image is degraded and the bit error rate becomes exceedingly high. In order to maintain image alignment and good pixel registration, we have designed a servo system that detects the readout error in the hologram and automatically compensates for the disc error in real time. Figure 4 is the schematic of our holographic disc system. The laser beam (from the top) passes through the modulator and enters the scanner. The scanner can change the laser beam propagation direction along two orthogonal axes in space. The laser beam is directed to the disc and the stored images are read out. Alongside the main readout image, there are two separate pixels in each hologram which we call control pixels. The control pixels are directed to two quadrant photodetectors, respectively. If the disc were at still and at correct position, the control pixels would be focused at the center of each quadrant detector. Since the disc spins continuously, the control pixels actually sweep across the detector, as does the main reconstructed image. We pulse the laser to readout a stationary image onto the detector array. The laser pulse timing is slaved on the gap-crossing of the left control pixel. As the laser fires, the holographic image is registered, and the signals from the quadrant photodetectors are sampled. A controller derives the appropriate error signals from the quadrant detector, and drives the scanner to compensate for image shift and rotation in real time.

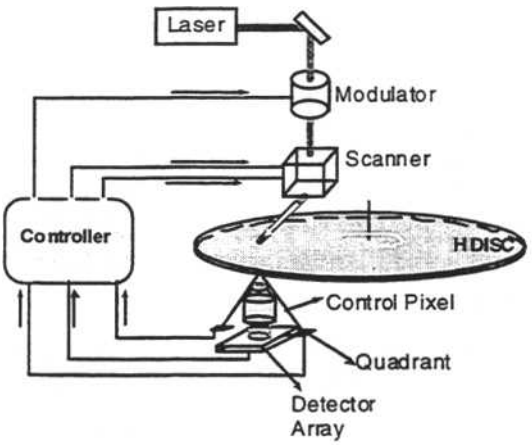

Fig. 4. Schematic of the holographic disc.

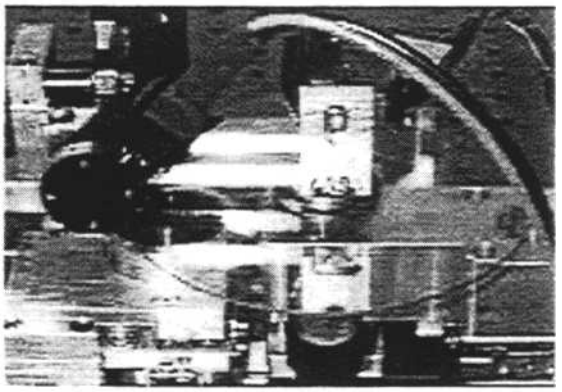

Fig.5. Picture of the implemented system.

Figure.5 is a picture of the disc system that we have implemented. We use frequency doubled YAG laser as the light source. The disc is fabricated by laminating a layer of holographic photopolymer onto a glass substrate. We have achieved pixel-matched readout of digital data from the disc spinning at 600 r.p.m..