Pit depth encoded memories

David S. Marx and Demetri Psaltis

California Insititute of Technology,Department of Electrical Engineering
MS 116-81, Pasadena, CA 91125

Gabriel Sirat

Le Conoscopie
rue de General Valin 75015 Paris, France

ABSTRACT

Modulation of the pit depth of an optical disk can increase its storage density. We measured a linear response to depth over the range of depth of focus using a conoscopic read head.

1. PIT DEPTH MODULATION TO INCREASE DENSITY

The storage density of optical disks is approximately 1 bit/λ^2, limited by the size of a focused read spot of light. If we modulate the depth of the pits, then the storage density will increase to $\log_2(k)/\lambda^2$, where k is the number of possible depths each pit can have. The maximum range of depths will be restricted by the depth of focus, and k will be restricted by the accuracy of writing and reading a pit depth. For example, if the range of depths is $1\mu m$, and the depth accuracy is less than $0.1\mu m$, then each pit location can store three to four bits.

2. CONOSCOPIC HOLOGRAPHY

We measure the pit depth using conoscopic holography. When a cone of light emanating from a point source propagates through a birefringent crystal, sandwiched between two polarizers, a conoscopic figure results (Fig.1).[1] The fringes are due to the dependence of polarization rotation on angle of propagation through the crystal. The light intensity on the observation screen goes as[2]

$$I(x) \approx 1 + \cos(\frac{2\pi L\Delta n}{\lambda}(x/z)^2),$$

where L is the thickness of the birefringent crystal, $\Delta n = n_e - n_o$, is the birefringence of the crystal. z is the distance from the point source to the screen, and x is a point in the plane of the screen. As the point source moves closer or farther from the screen, the fringes will expand or compress. Counting all the fringes on the screen gives a measurement of z. By placing a single detector at a specific x, we can measure δz, the relative movement of the point source in z.

The sensitivity of the δz measurement depends on where in the screen we place the detector. If the detector is placed close to the center of the screen, then the δz required for a maximum change in intensity at the detector, will be very large. Conversely, if the detector is placed at the edge of the screen, then the intensity at the detector will be very sensitive to a small change in z. Therefore, we want to design the placement of the detector so that the maximum allowable change in pit depth of our memory results in a maximum change in intensity at the detector, without any ambiguity. For example, if $L = 10$mm, $\Delta n = 0.17$, (calcite crystal) $\lambda = 633$nm, and $x/z \approx \text{NA} = 0.5$, then if z changes by $1.5\mu m$, the intensity will swing from its maximum value to zero if the detector is placed at the 672^{nd} fringe.

3. READ HEAD

Our conoscopic read head, Fig. 2, uses polarized light at the input, and the calcite crystal and analyzer are placed after the beam splitter. The calcite crystal is tilted so that a sufficiently "fast" fringe (i.e. the fringe that has maximum intensity change for the maximum change in pit depth) is moved to the center of the screen. Also, since the light propagating through the crystal is nearly collimated, there is only one fringe on the screen. We used one detector to cover half the fringe, but two detectors in a differential mode would make use of all the light in the detector plane.

We measured the sensitivity of the read head to changes in pit depth by translating a blank, reflective substrate through the focal plane of the objective. The translation step size was $0.1\mu m$. For this experiment, the crystal tilt was coarse adjusted to move a sufficiently "fast" fringe onto the detector, and it was fine adjusted so that when the substrate was exactly in the focal plane, the intensity on the detector was a middle gray level. The response, shown in Fig. 3 was nearly linear over a $\pm 1.5\mu m$ range.

4. PIT DEPTH MEMORY

To avoid corruption of the pit depth modulation signal by noise sources such as disk wobble or vibration, and to allow focus servo control, the pit depth modulation will have to be encoded to gaurantee that the signal is high pass with a low frequency cutoff greater than the frequency of the wobble and disk vibrations. If there are significant high frequency vibrations, a second beam focused on land between the grooves will provide a signal with only noise that can be subtracted from the information signal resulting in noise rejection.

Mastering of an optical disk memory using pit depth modulation can be accomplished by laser patterning in photoresist or electron beam lithography. We currently have a sample using a rastered laser on a photoresist, and we are having a second sample fabricated with electron beam lithography.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. Born and Wolf, *Principles of Optics*, ch. 14, Pergamon Press, Oxford, 1980. Adam Hilger Ltd, Bristol.

2. Sirat and Psaltis, "Conoscopic Holography," Optics Letters, vol. 10, pp. 4-6, 1985.

Conoscopic Holography

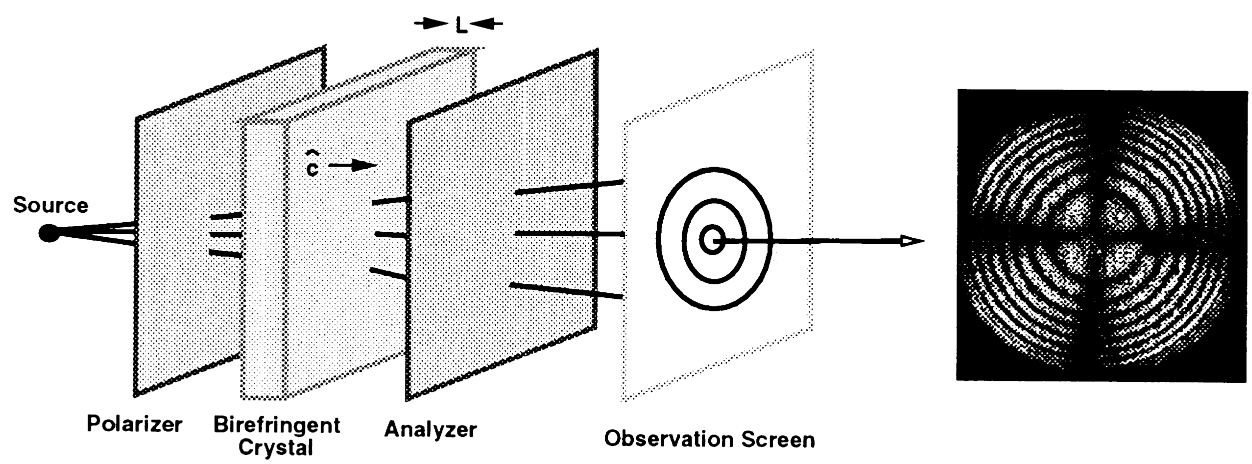

FIGURE 1

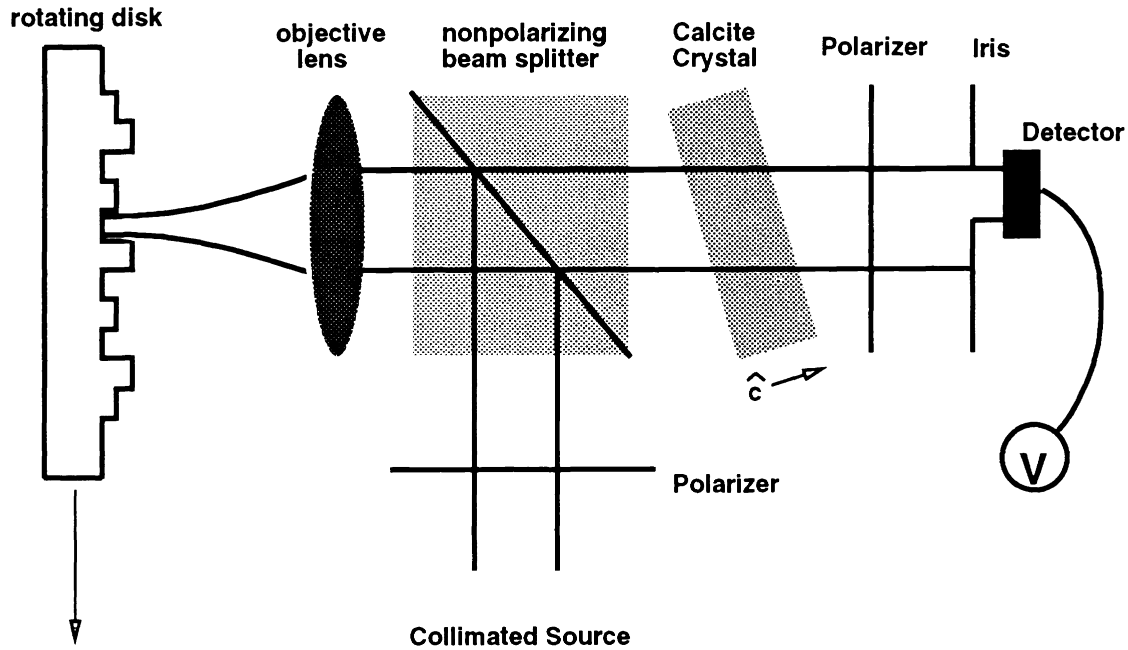

Figure 2. Conoscopic Read Head

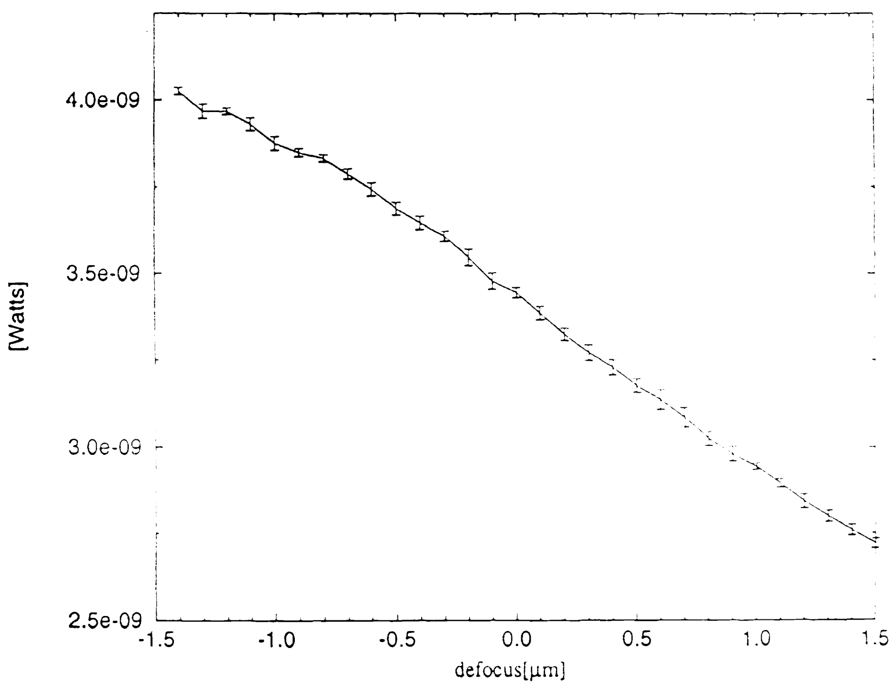

Figure 3. Conoscopic Response