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APPLICATION OF HOLOGRAPHIC OPTICAL ELEMENTS TO MAGNETO-OPTIC READ/WRITE HEADS

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OBJECTIVES

Objectives of this research are to determine the theoretical and practical performance limits of holographic optical elements (HOEs) formed in different recording materials, and to evaluate the application of these components to magneto-optic read/write heads.

PROGRESS

Hologram Characterization, Modeling, and Design

We completed measurements of the refractive index profile of dichromated gelatin emulsions for recording volume holograms. Characterizing the refractive index profile is important for realizing accurate designs using our diffraction models. Measurement techniques based on Brewster angle and Fresnel reflection coefficients were used to determine the emulsion's surface index. An interferometric method with oil index matching was used to determine the bulk refractive index of the emulsion. The experiments showed that the surface index was higher than the bulk index, which contradicts the change expected due to exposure, dehydration, and the resulting airation of the emulsion. We suspect that the emulsion surface collapses during development, forming a layer with higher refractive index. We found some references to experimental data that support this hypothesis, but we would like to confirm this model on our own with additional experiments and SEM analysis. A short proceedings paper summarizing these findings is reproduced in Appendix D.

Gene Campbell is examining the application of volume gratings for polarization and phase components. His model, based on rigorous coupled wave theory, allows the index and permittivity modulation to be varied as a function of emulsion depth. This characterization is necessary for an accurate description of the phase and polarization properties of diffracted fields. Figure 1 shows the calculated phase difference between s-polarized and p-polarized diffracted fields as a function of permittivity modulation for a zero-order beam passing through the grating. As indicated, a permittivity modulation of about 0.17 ($\Delta n \sim 0.0623$) provides a $\lambda/4$ phase delay, and a modulation of 0.27 ($\Delta n \sim 0.10$) produces $\lambda/2$ retardation. Both of these modulation values can be achieved in DCG, and it may be possible to reduce the required index modulation value by forming thicker emulsions. Figure 2 shows the efficiency of a polarization beam splitter (PBS) as a function of grating strength with an interbeam angle of 60° within the emulsion. The grating strength is defined as the product of $\Delta\epsilon d/\lambda$. To achieve a grating strength of 1.2 to make the PBS with $\lambda = 0.50\ \mu m$ and $d = 8.3\ \mu m$, an index modulation of 0.027 is needed, which can be realized in DCG.

We also examined the effect of saturation on the efficiency properties of volume gratings during this period. The model used for a saturated refractive index modulation is

$$n(\vec{r}) = N_o[1 - \exp(-E(\vec{r})/E_o)] ,$$

where $n(\vec{r})$ is the saturated index modulation, N_o is a proportionality constant, $E(\vec{r})$ is the grating exposure, and E_o is a saturation constant. (This model also was used by workers at Solymar's group at Oxford.) Figure 3 shows the efficiency with a saturation constant of 1000 mJ/cm^2, and N_o of 0.5. Some of the important consequences of saturation is that the TE efficiency does not go to zero, and the non-oscillatory efficiency function for the TM polarized field. The more commonly quoted results of Kogelnik have TE and TM polarized fields that have a $\sin^2$ dependence on increasing modulation and thickness. This difference will greatly influence the design of many types of polarization beam splitters.

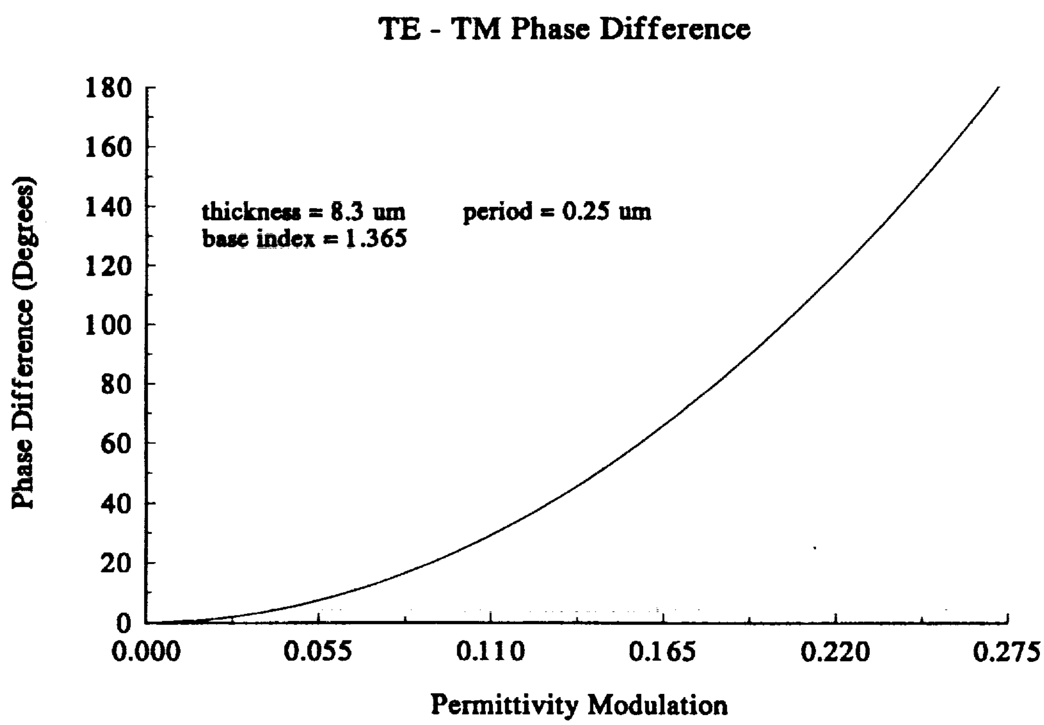

Figure 1. Zero-order holographic waveplate.

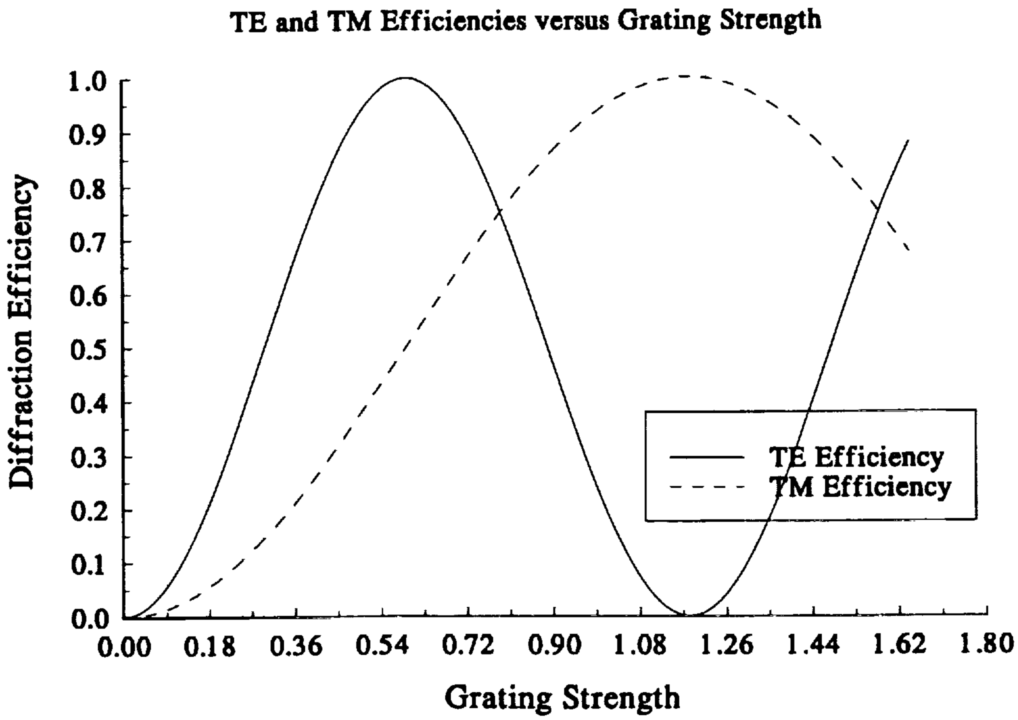

Figure 2. Sixty-degree polarization beam splitter.

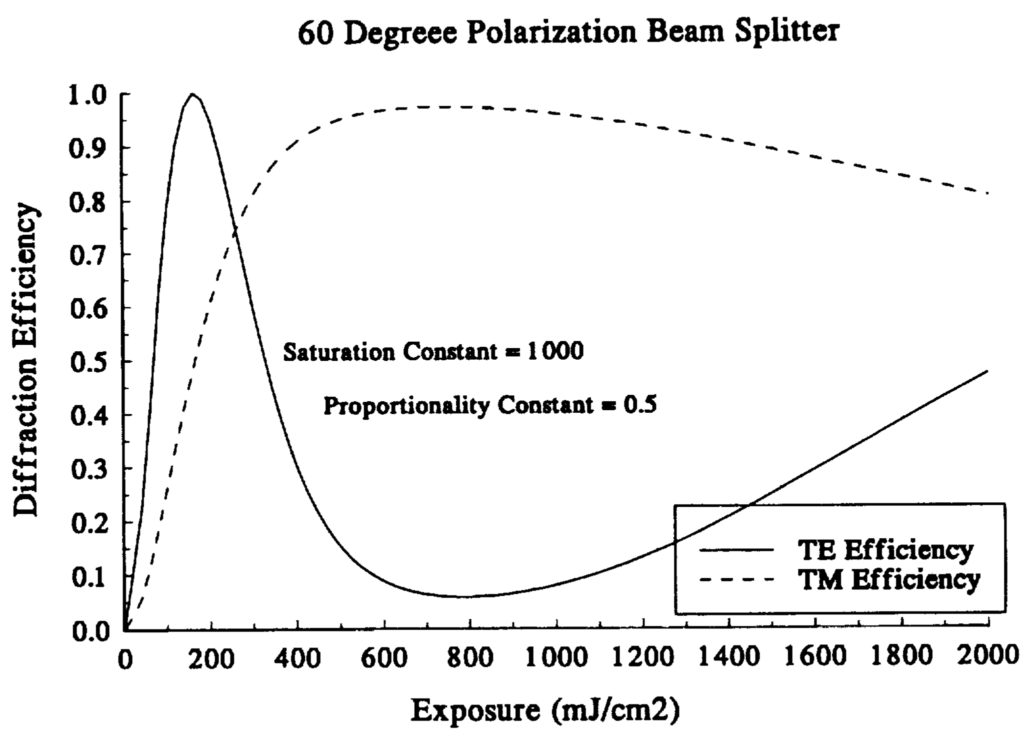

Figure 3. Effect of permittivity modulation saturation.

PLANS

Our future efforts will be directed toward: 1) designing and fabricating phase control components in DCG and surface relief grating elements; 2) helping a new student become familiar with the surface relief grating model developed by Charles Haggans (now at 3M); 3) investigating hybrid diffractive optical components that combine surface relief and volume type gratings; and 4) extending and verifying new modeling efforts that include diffraction of finite beams, converging beams, and cascaded grating systems. We also would like to expand our modeling capability to incorporate finite element analysis techniques, which are important for chirped grating analysis.

We are currently preparing a final report summarizing our grating model work for IBM. The future of this program, however, is unclear since it is no longer supported by ODSC or IBM. We hope to secure funding for this project from other sources that are primarily directed toward optical interconnect applications and that also require the use of diffraction models.