Phase-Shifting Holography Using Bragg and Non-Bragg Orders in Photorefractive LiNbO₃

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Abstract
We investigate the Bragg and non-Bragg diffraction orders due to the two-beam coupling on a photorefractive material experimentally and theoretically. In this work, we propose and realize a method that simultaneously yields the different intensity distributions in one shot (one exposure) by utilizing diffraction in Bragg and non-Bragg orders during the recording process.

Introduction
Some materials show a change in their refractive index when they are illuminated with light. These types of materials are usually known as nonlinear materials where the nonlinearity evolves from various optical effects. The photorefractive (PR) effect is one of the optical effects that can cause nonlinearity in materials such as crystals and causes a change in refractive index. Generation of the Bragg and non-Bragg orders can be used for a unique way of determining the object amplitude and phase profile, using phase shifting holographic interferometry. When an object is deformed, the optical path changes and by recording the optical path difference, the amount of deformation can be measured using holographic interferometry.

Objective
In this proposed work, we will use real-time HI (RHI) to obtain details of a deformed object. Holographic recording in photorefractive (PR) materials plays an important role in RHI. PR materials are used to store 3d information holographically and are also erasable. Diffraction patterns of the Bragg and non-Bragg orders can be simultaneously generated by mixing two waves in a PR material. In this work, we propose a novel one-shot method that utilizes these different intensity distributions to extract 3d information about the object.

Methodology
➢ Experiment
The holograms will be recorded in a PR lithium niobate (LN) crystal and the generated Bragg and non-Bragg diffraction orders will be monitored. Two beams (created with a beam splitter) starting out from an Ar-ion laser will be interfered in the crystal and the formation of diffraction orders are observed in real time.

➢ Theory
These Bragg and non-Bragg orders produced during two beam coupling in PR materials will be simulated using MATLAB® for the plane wave assumption as well as for the beam assumption. Simulation results also can be used to determine the phase of a deformed object.

Intensity and the phase of the diffraction orders can be obtained by solving coupled differential equations for each order. For example, for the Bragg order, the differential equation can be expressed as follows.

\[
\frac{d\hat{E}}{dz} = -j\lambda \left(\hat{E}_{1\text{B}} \cdot \hat{E}^*_{-1\text{B}}\right) \hat{E}_{-1}\]

Results
Higher order diffraction patterns observed in the lab from the LiNbO₃ crystal. Preliminary results are shown below for a CD-ROM which is deformed by heating with a focused laser beam.

Future Work
➢ Determination of an exact shape of different objects..
➢ Cross check the information of the original with the simulations
➢ Obtain the exact solutions for both cases, plane waves and beam assumption.

References