Phase-Shifting Holography Using Bragg and Non-Bragg Orders in Photorefractive $LiNbO_3$

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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

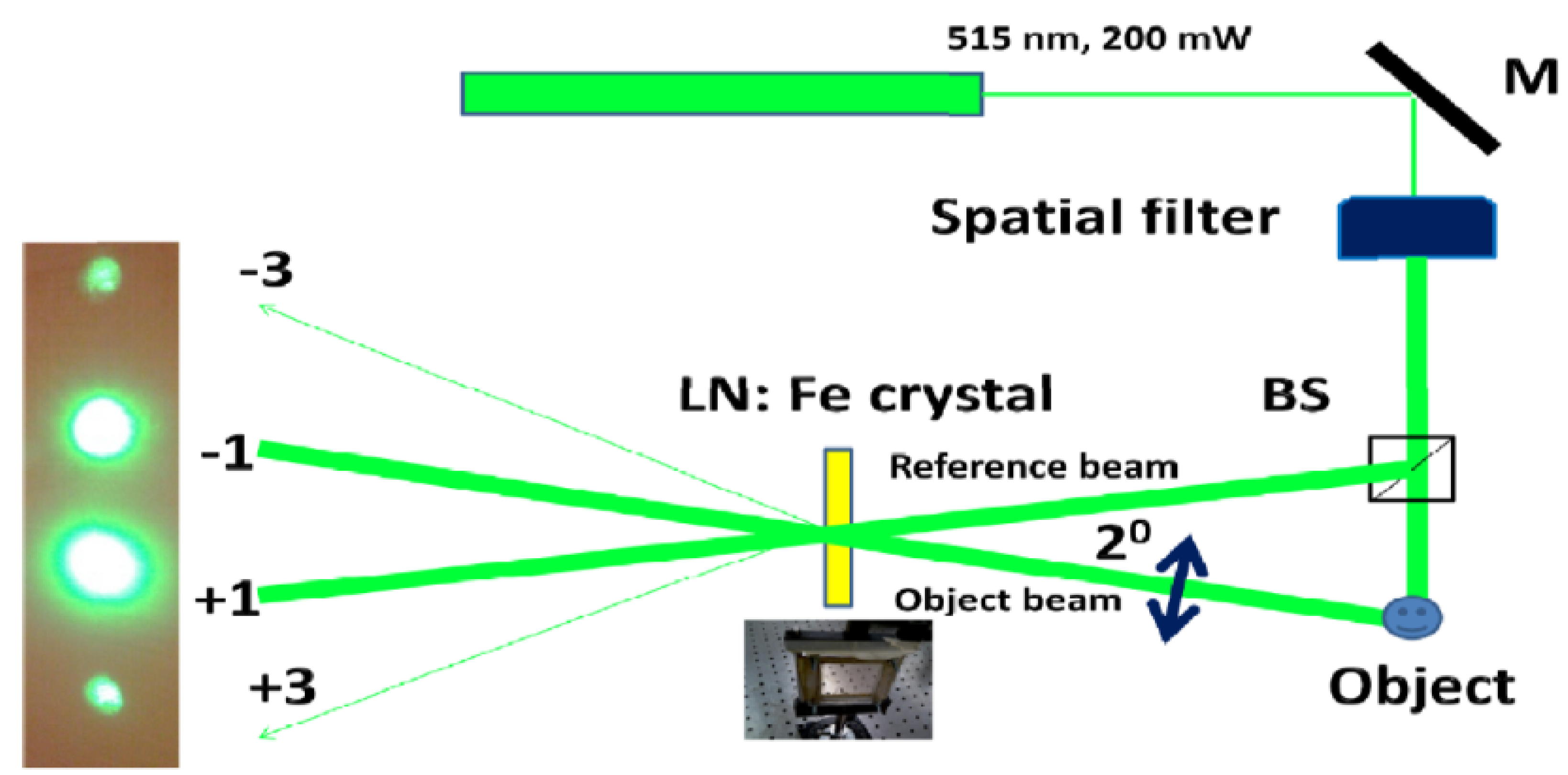
In this proposed work, we will use *real-time* HI (RHI) to obtain details of a deformed object. Holographic recording in photorefractive (PR) materials plays an important role in RHI. PR materials are used to store 3d information holographically and are also erasable. Diffraction patterns of the Bragg 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.

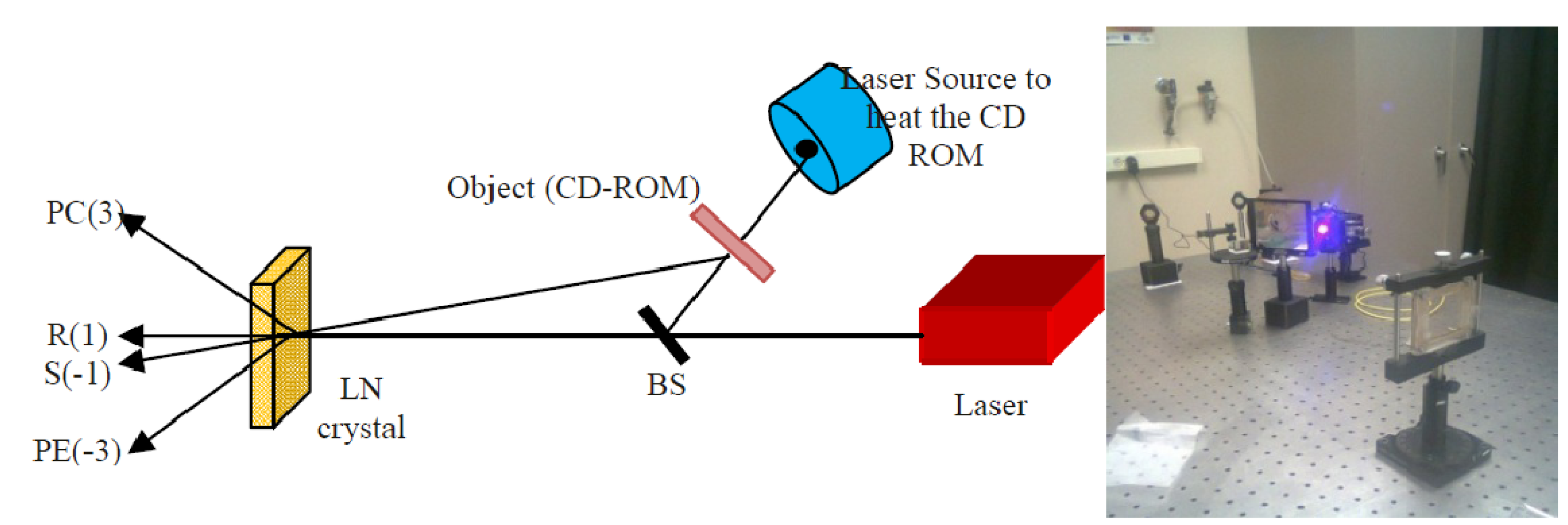
Experimental setup

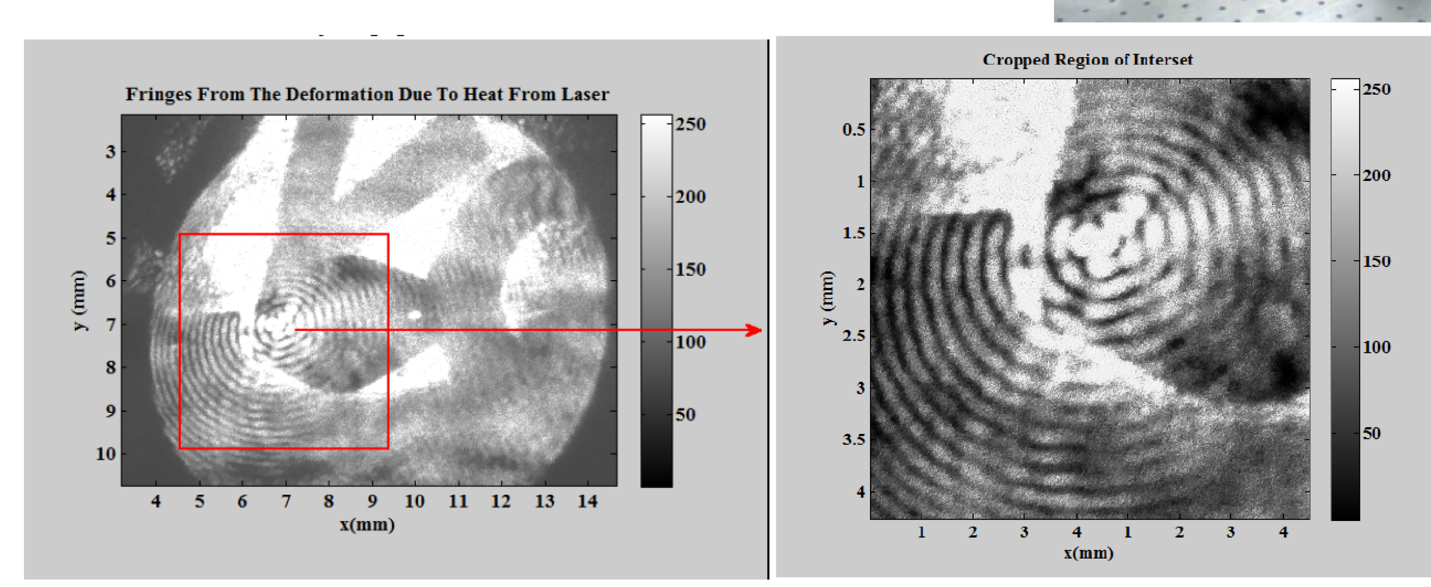


Experimental setup for the recording the hologram on LN:Fe crystal with two beams. Bragg and Non-Bragg orders are also shown as ±1 and ±3 respectively

One of the beams will contain the information of the object as it is reflected or scattered off its surface. Once the phase and the amplitude of the optical field at the recording plane are known, the original object can be obtained by back-propagating the complex optical field using the Fresnel diffraction formula.

Experimental setup for a test object (CD-ROM)





➢ Theory

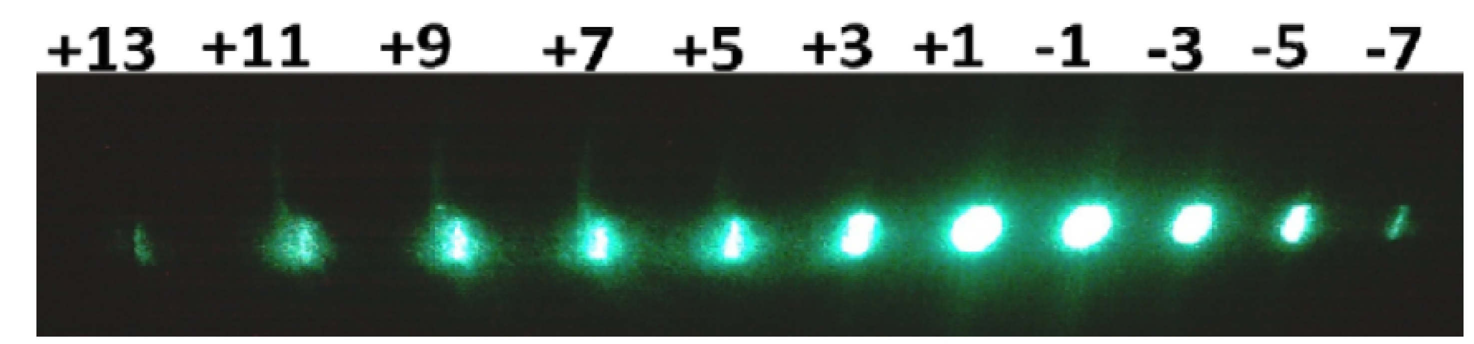
These Bragg and non-Bragg orders produced during two beam coupling in PR materials will be simulated using MATLAB® for the plane wave assumption as well as for the beam assumption. Simulation results also can be used to determine the phase of a deformed object.

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, +1 the differential equation can be expressed as follows.

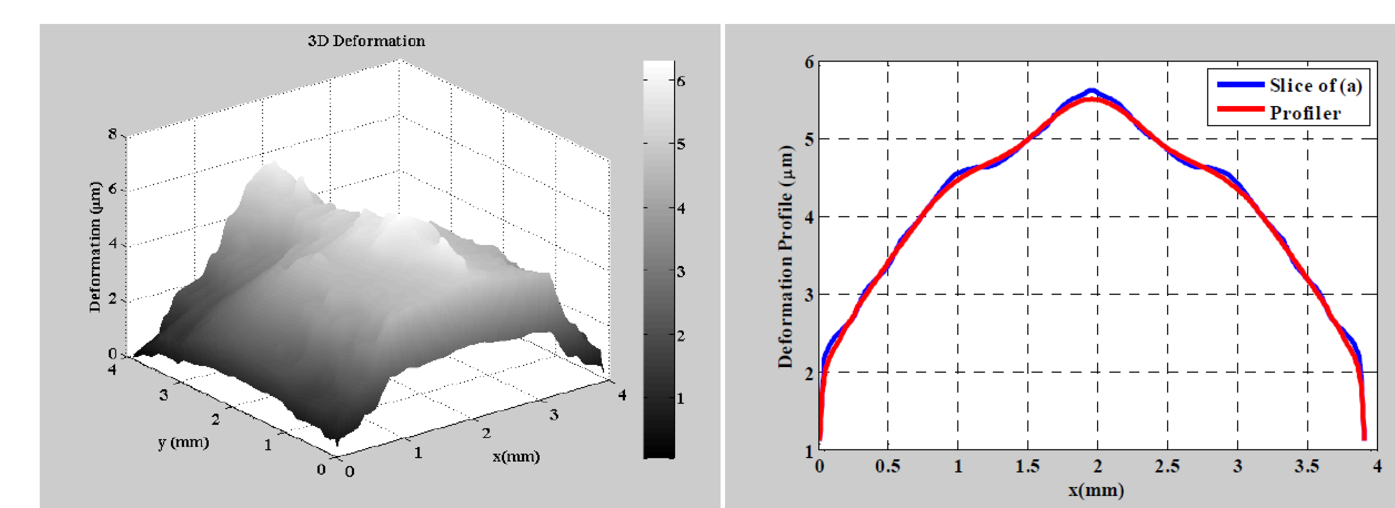
$$\frac{d\hat{E}}{dz} = -jc\left(\hat{E}_1 \hat{E}^*_{-1}\right)\hat{E}_{-1}$$

Results

Higher order diffraction patterns observed in the lab from the $LiNbO_3$ 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

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