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Phase Conjugation in $BaTiO_3$ at 830 nanometers

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ABSTRACT

We have demonstrated self-pumped phase conjugation of semiconductor lasers at 830 nanometers in barium titanate using a self-contained geometry. The reflectivities and response times of this geometry are compared to those reported for self-pumped ring passive phase conjugate mirrors.

2. INTRODUCTION

There is considerable interest in developing photorefractive phase conjugate mirrors pumped by semiconductor laser diodes for such applications as phase locking laser diodes. Self-pumped ring passive phase conjugate mirrors with reflectivities as large as 56% and response times on the order of tens of seconds have been reported.[1] This device requires two carefully aligned external mirrors. Another type of phase conjugator has been reported that is entirely self-contained.[2,3] This device has advantages over the ring passive conjugators in that it is self-aligning. In the present work we have demonstrated self-contained phase conjugation in $BaTiO_3$ at 830 nanometers.

3. EXPERIMENTAL SETUP

Figure 1 shows the experimental setup used to produce the self-contained phase conjugate mirror. The laser used in this experiment was a single longitudinal mode semiconductor laser (Melles Griot 06 DLL 507). The head includes the laser diode, collimating optics, a cylindrical lens to correct for astigmatism, and a pair anamorphic prisms to produce a circular beam. The beam was approximately 8.0mm in diameter after exiting the head. Also included in the head is a monitor photodiode and a thermoelectric cooler. An inverted telescope, formed by lens L_1 and L_2, was used to focus the beam to approximately 2mm to match the clear aperture of the optical isolators (I_1 and I_2). Each isolator uses the Faraday effect to provide 30dB of isolation. The optical isolators rotate the polarization of the beam 45 degrees. Half-wave plates (H_1 and H_2) are positioned after both isolators to correct for the polarization rotation. A beam splitter (BS) was inserted in the beam path to direct the phase conjugate reflection to detector D. A 70 mm focal length lens (L_3) was used to slightly expand the beam in the crystal. All optics were AR coated for 830nm. A CCD camera was used to observe the crystal.

The crystal was oriented so the beam makes an angle of approximately 50° with the c axis inside the crystal. This internal angle is necessary to compensate for the low gain in $BaTiO_3$ at 830 nanometers by taking advantage of the larger r_{42} coefficients. This internal angle cannot be achieved in air due to the large index of refraction of $BaTiO_3$ (approximately 2.4). To achieve this internal angle, the crystal was placed in a cuvette with parallel sides and immersed in a liquid with an intermediate index of refraction. The liquid used in this experiment was glycerol with an index of refraction of 1.6. The temperature of the glycerol was not controlled.

Optical isolation of the laser diode from its phase conjugate reflection was extremely important to achieve large reflectivities. Without isolation beam fanning would begin; however, feedback into the laser diode induced frequency shifts in the laser diode output. The frequency shifted beam no longer matched the gratings previously written in the crystal and phase conjugate reflectivity subsided until a new set of gratings was formed. The crystal appeared to flash on and off as this effect repeated itself. The result was an unstable phase conjugate mirror with low reflectivity. We found that it was necessary to include two Faraday isolators to provide sufficient isolation for a substantial phase conjugate reflection to develop.

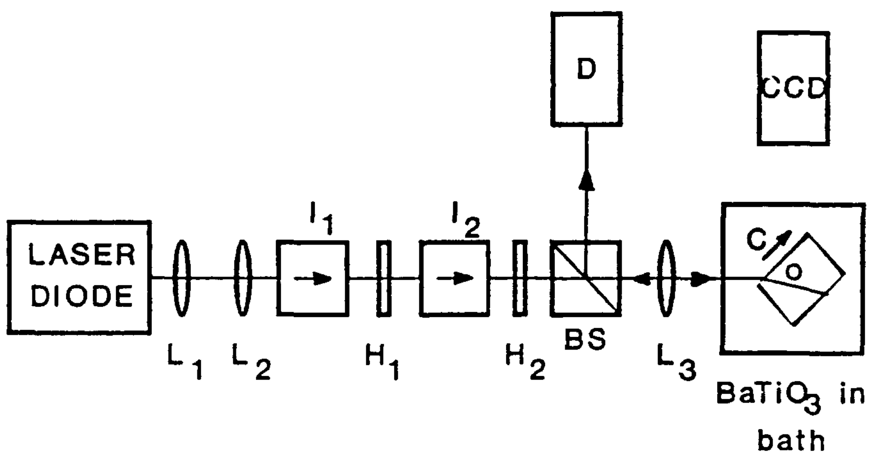

Fig. 1. Self-contained phase conjugate mirror.

4. EXPERIMENTAL RESULTS

We obtained phase conjugate reflectivities of 10% with the Melles Griot laser diode with response times on the order of 50 seconds. Higher reflectivities (30%) were achieved with the same crystal and a different laser diode. It has been shown that the phase conjugate reflectivity depends on the laser mode structure and linewidth.[4] The linewidth of the Melles Griot laser diode was much narrower than that of the other laser and should have a lower phase conjugate reflectivity.

Figure 2 shows the build-up of the self-contained conjugator. For incident power levels of 2.4, 4.3, and 5.3mW, the phase conjugate signal was plotted versus time. An incandescent lamp, illuminating the crystal from above, was used to erase all gratings in the crystal prior to measuring the phase conjugate reflection. The turn-on time was on the order of tens of seconds and the phase conjugate signal did not reach saturation until after 300 seconds. The reflectivities and build-up-time were similar to results reported for self-pumped ring passive phase conjugate mirrors without optical isolation,[5,6] but the reflectivities were less and the saturation time was much longer than that of ring passive phase conjugate mirrors with optical isolation.[1]

It is a common mistake to measure photorefractive response times after incompletely erasing previous gratings. In addition to erasing the gratings with an incandescent lamp, we also attempted to erase the gratings with the laser diode by rotating the C axis of the crystal parallel to the beam. A comparison of the build up of the phase conjugate reflectivity after erasure with the laser diode and incandescent lamp is shown in figure 3. After 300 seconds the phase conjugate reflectivity after erasure with the laser diode was over 3 times greater than the reflectivity for the same time period after erasure with white light. A possible explanation for the difference in response times is that the build-up time of a self-pumped phase conjugator is significantly reduced if grating fragments are present in the crystal.

5. CONCLUSIONS

The performance of the self-contained phase conjugate mirror was similar to that reported for ring passive phase conjugate mirrors without optical isolation. While the performance was inferior to that of the ring passive mirror with isolation, the self-aligning properties of the self-contained phase conjugate mirror may be advantageous in certain applications.

6. ACKNOWLEDGEMENTS

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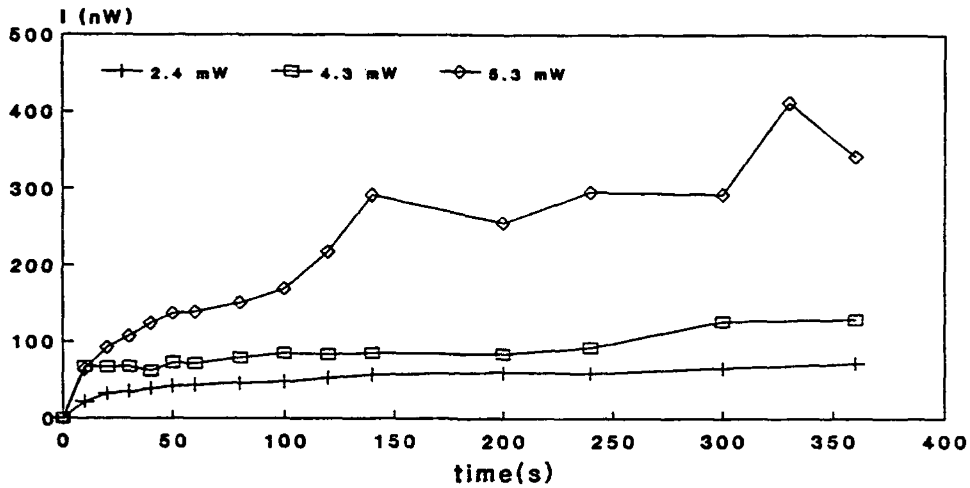

Fig. 2. Self-pumped conjugator response time.

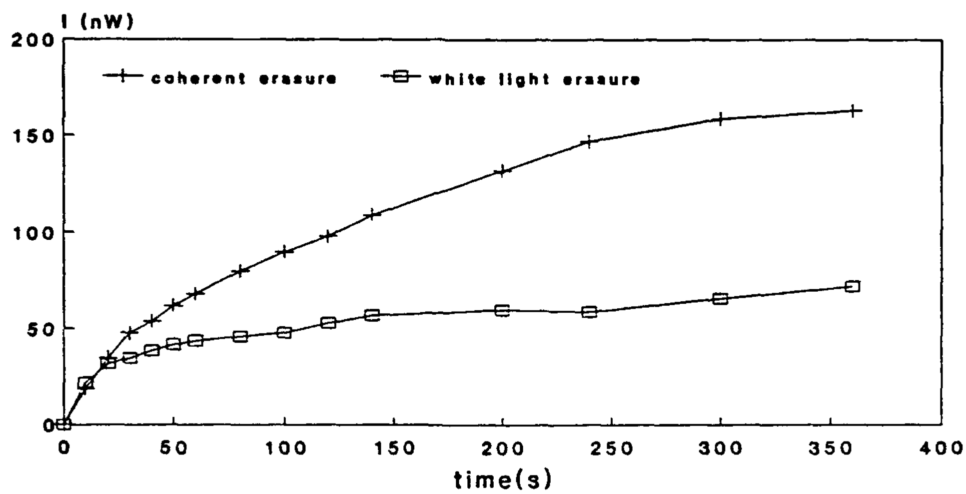

Fig. 3. Response time dependence on erasure technique.