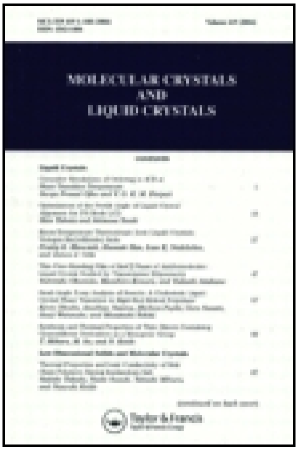

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Low Threshold Self-Pumped Phase Conjugation of an Ar$^+$-Laser Beam in Dye-Doped Nematic Liquid Crystals

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Abstract. Investigations of self-pumped phase conjugation (SPPC) of a low power cw-laser using a dye-doped nematic liquid crystal are reported. The phase conjugated signal was generated by stimulated thermal scattering. Threshold power for phase conjugation at a wavelength of 514.5 nm was about 10 mW and maximum power-reflectivities up to 6 % have been obtained. The ability to compensate phase aberrations caused by an etched glass plate has been demonstrated.

Keywords: Dye-Doped Nematic Liquid Crystals, Phase Conjugation, Thermal Optical Nonlinearity

1. Introduction

Since the phenomen of optical phase conjugation was discovered by Zel'dovich et al.[1,2] in 1972 researchers have tried to obtain phase conjugated beams with different nonlinear media and various techniques for many applications[3]. Phase conjugation could be realized for example by stimulated Brillouin scattering[4,5] (SBS) or degenerate four wave mixing[6,7,8,9]. In contrast to the SBS-effect which is characterized by a high threshold power in the range of about[5] 10 kW it was shown[10] that self-pumped phase conjugation (SPPC) in liquid crystals can be realized by wave mixing effects with threshold powers less than 1 W.

Several authors report on SPPC in liquid crystals based on thermal and orientational scattering processes[11,12,13,14]. An experimental setup comprising two pump-beams that have nearly opposit direction with an external loop arrangement has been used successfully[11]. However, the use of several external mirrors in that arrangement leads to a high SPPC-threshold of about 200 mW due to losses at the mirrors and surfaces. The aim of our investigations was to avoid a complicated external optical arrangement in order to reduce threshold and improve the performance of self-pumped phase conjugation in liquid crystals.

2. Experimental Setup

The experimental setup is shown in Fig. 1. The linear polarized beam of a continuous wave Argonion-laser at 514.5 nm wavelength was mechanically chopped with pulse durations between 0.5 ms and 5 ms and duty cycles of 1:30. The PC-experiment was insulated from the laser-source by using a Faraday-rotator in order to eliminate instabilities caused by feedback into the resonator. The beam passed a wedged glass in order to measure the intensity of the incident and the phase conjugated beam with calibrated photodiodes. A diaphragm eliminated the linearly backward reflected part of the laser beam. Lenses of different focal length (75 mm to 200 mm) were used to focus the beam into the the liquid crystal cell. The diameter of the gaussian laser beam inside the LC-cell was estimated to range around 0.1 mm.

Homogeneous planar orientation in the liquid crystal film of 1 mm thickness was obtained with an electric field perpendicular to the wave vector of the pump beam. An 50 Hz ac-voltage of 600 V was conducted across two brass-electrodes which were posed in a distance of 5 mm. The rear window of the container was coated with a dielectric high reflecting mirror and the front plate was coated with an antireflection layer. The 5CB-liquid crystal was doped with a dichroic dye (D37 from Merck) in order to increase the absorption of the nonlinear medium. The absorption coefficient at the used wavelength was determined to range around 50 cm^{-1}.

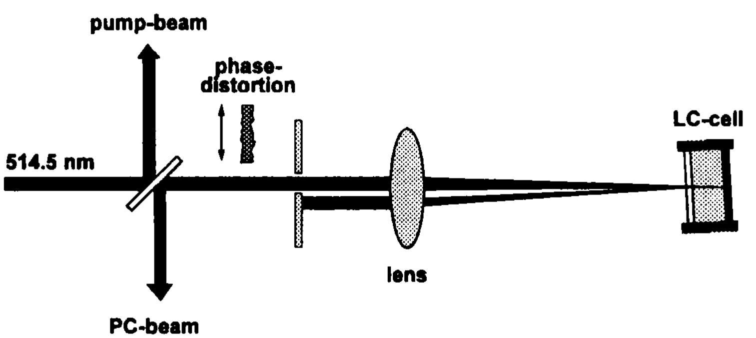


Fig. 1: Experimental setup for self-pumped phase conjugation

The principles of phase conjugation in the investigated setup are shown in Fig. 2. The incident pump beam and the reflected beam are coherently scattered into different spatial components by statistical thermal fluctuations of the optical nonlinear material. The coherently scattered noise is able to interact with the pump beams to create several gratings inside of the liquid crystal. However, for a given angle of incidence only distinct components of the scattered noise that are conform to the wave-vector condition shown in the lower sketch of Fig. 2 are able to share a common thermal grating. In contrast to other scattered beams these particular components obtain gain by the wave mixing process. As a result, the scattered noise is amplified into a strong coherent signal, the PC-beam. A more detailed description of the mechanism of the phase conjugation process is given e.g. in ref. 12.

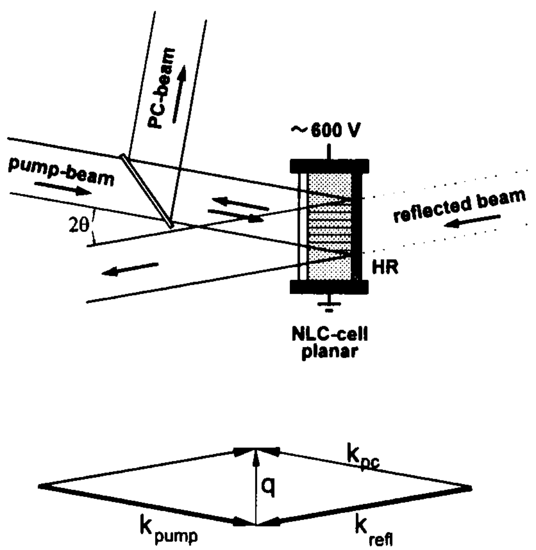
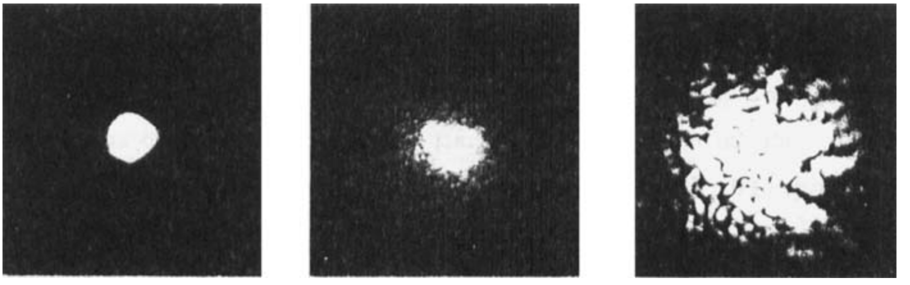


Fig. 2: Schematic representation and wave-vector condition for phase conjugation

3. Results

The phase conjugated beam was observed in the far field at 5 m distance from the LC-cell (Fig. 3). The PC-beam generation was observed both for a gaussian pump beam and for a phase disturbed pump beam. The PC-beam in the undistorted case shows a good beam quality that is comparabel to the gaussian pump beam. The phase conjugating effect was also sufficient to compensate strong phase distortions which were maintained



(a) (b) (c)

Fig. 3: Photograph of the PC-beam for a gaussian pump beam (a) and a phase disturbed pump beam (b); (c) the phase disturbed pump beam without phase conjugation

by an edged glass plate. However, the compensation was not complete what was obvious by some scattered noise underlying the PC-signal. The dynamics of the PC-process are shown in Fig. 4. There is a strong correlation between the power of the pump beam and the so called onset time (see also ref. 11). The onset time of the PC-signal decreases with increasing pump power. The PC-signal exhibits a strong maximum and decreases later until a certain stationary value is obtained. To understand the dynamics of the PC-signal one has to consider that there is no energy transfer between the pump and PC-beam in the stationary case for nonlinear media with local response, which is usually the case with thermal nonlinearities in liquid crystals[12,15]. Energy transfer is observed, however, in the case of pulsed exitation with materials in which the build-up time of the refractive-index change is comparable to the pulse-width[15]. The peak maximum of the signal may attributed to these dynamic effects. The remaining stationary part of the PC-signal can be explained, if a small frequency shift between pump and the PC-wave starting from Rayleigh-wing scattering[16] is assumed, which leads to a moving index grating and energy transfer[15]. The onset time also decreases with higher temperatures of the liquid crystal medium due to an increase of the thermal optical nonlinear coefficient[12] near the transition into the isotropic phase. However, the PC-effect is limited for high pump powers by heating the liquid crystal up to the isotropic phase where the PC-effect vanishes.

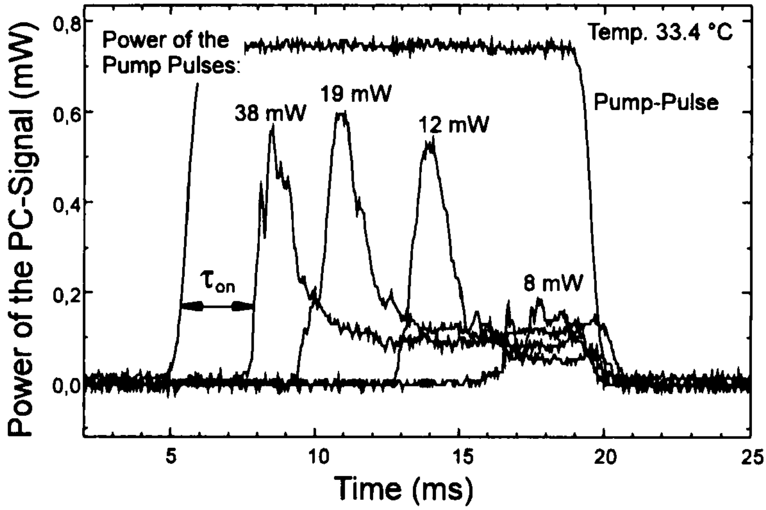


Fig. 4: Dynamic of the SPPC-Signal for different pump-powers

The useful range of pump powers for different temperatures is shown in Fig. 5. The minimum threshold (less than 10 mW) was achieved with a temperature near the transition temperature which was 35°C in the case of 5CB. However, the maximum peak power reflectivity for the phase conjugated signal always was in the range between 5 and 6 % and did not depend strongly on the temperature which is shown in Fig. 6.

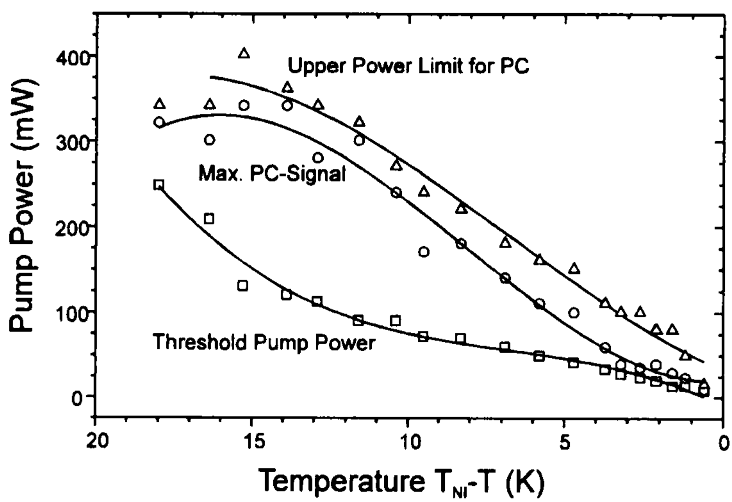


Fig. 5: Dependence of the useable range of pump-power for SPPC from the LC-temperature

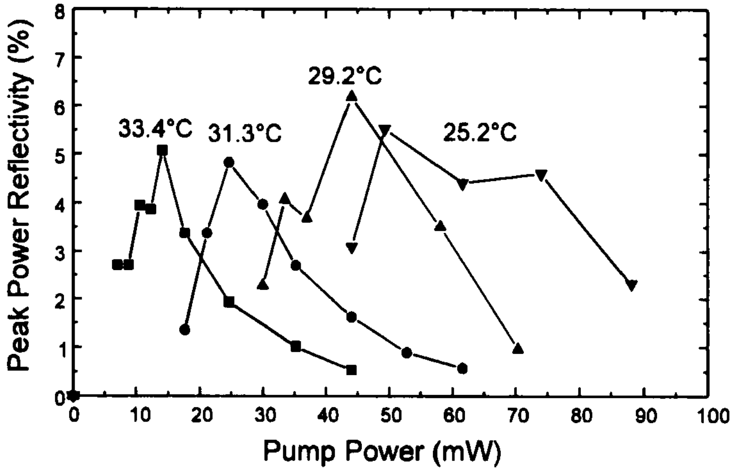


Fig. 6: Peak power reflectivities for different LC-temperatures

4. Summary

Low-threshold SPPC of visible radiation using a nematic liquid crystal-cell with a high reflecting rear window has been investigated. The minimum threshold power achieved in our experiments was less than 10mW and is by an order of magnitude lower than the threshold for the PC-wave generation using an external feedback loop[11]. Dynamics of the phase conjugated signal have been investigated for different intensities and the influence of temperature on peak reflectivity and threshold was shown. The investigated phase conjugation process was sufficient to compensate strong phase aberrations. Further experiments will be done to investigate the fidelity of the self-pumped phase conjugation.

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References

1. B.Ya. Zel'dovich, V.I. Popovichev, V.V. Ragul'skii, and F.S. Faizullov, JETP Lett. **15**, 109 (1972)
2. B.Ya. Zel'dovich, N.F. Pilipetsky, and V.V. Shkunov: *Principles of phase conjugation*. Springer-Verlag Berlin 1985.
3. A. Yariv, IEEE J. of Quant. Electr., **QE-14**, 650 (1978)
4. V. Wang and C.R. Giuliano, Opt. Letters, **2**, 4 (1978)
5. A. Kummrow, H.J. Eichler, J. Chen and H. Meng: *Laser and Ultrafast Processes*. Vol. 4, pp. 94-101, Vilnius University Press 1991.
6. A. Yariv and D.M. Pepper, Opt. Letters, **1**, 16 (1977)
7. R.W. Hellwarth, J. Opt. Soc. Amer., **67**, 1 (1977)
8. S.L. Jensen and R.W. Hellwarth, Appl. Phys. Lett., **32**, 166 (1978)
9. D.M. Bloom and G.E. Bjorklund, Appl. Phys. Lett., **31**, 592 (1977)
10. O.L. Antipov, Opt. Commun., **103**, 499 (1993)

11. I.C. Khoo, Opt. Letters, **18,** 1490 (1993)
12. I.C. Khoo: *Liquid Crystals: Physical Properties and Nonlinear Optical Phenomena.* John Wiley & Sons, Inc., New York 1995.
13. O.L. Antipov, N.A. Dvoryaninov, V. Sheshkauskas, JETP Lett., **53,** 610 (1991)
14. O.L. Antipov, Quant. Electr., **24,** 411 (1994)
15. H.J. Eichler, P. Günther, D.W. Pohl: *Laser-Induced Dynamic Gratings.* Springer Ser. in Opt. Sc.; Springer-Verlag Berlin Heidelberg 1986.
16. R.W. Boyd: *Nonlinear Optics.* Academic Press, Inc., San Diego, London 1992.