Self-Focussing without external field in $BaTiO_3$

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We achieved self-focussing of a laser beam in $BaTiO_3$ without external field by use of laser beam intensities between 0.016W/cm² to 0.75W/cm². This effect we observed at diameters of the laser beam between 4µm and 40µm. We used ordinarily as well as extraordinarily polarized light and investigated the effect at the 633nm wavelength regime as well as at 532nm.

1 Introduction

Usually an external electric field is used to change the refractive index of a material by electro-optic effect, and so to generate a self-focussing effect. This excites in balance with self-diffraction screnning solitons [1]. In $BaTiO_3$ a strong self-focussing effect occurs by use of external fields in the range of 2.8kV/cm² [2]. But there is also the possibility to generate self-focussing without an external field by use of high laser intensities, which leads to thermal focussing effects. In barium titanate this effect occurs at short laser pulses in the range of $10^2 \ldots 10^3$W/mm² [3]. It is also known that self-focussing can occur without an external electric field, only by use of the intrinsic fields and the anisotropic properties of the material [4]. There also a balance between self-focussing and diffraction can be achieved, which leads to photovoltaic solitons [5]. Until now photovoltaic solitons were only observed in $LiNbO_3$ crystals [6, 7].

We could show that self-focussing without external field occurs also in $BaTiO_3$, using only an intensity of 0.2 W/cm². This effect depends on the crystal doping and cut, the polarization direction of the laser beam, the intensity, the beam diameter but it does not depend on wavelength

2 Experimental Set-Up

The here presented investigations of the optical induced chances of the diameter of a laser beam were performed at room temperature on a poled single crystal of ferroelectric $BaTiO_3$. which had a 45° cut and was nominel pure. The sample lay clamp free on a board and had the dimensions 4.8×6.3×5mm. We used a He-Ne-laser La with λ=633nm, whose beam first passed an intensity filter IF, like it is shown in fig. 1. After passing a Glan-Thompson-polarizer P the beam was expanded by two lenses L1 and L2. By an aperture B the beam diameter can be chosen. The lens L3 focussed the laser beam on the front face of the crystal K and the beam diameter at the rear face of the crystal is imaged by a telescope system L on a CCD C.

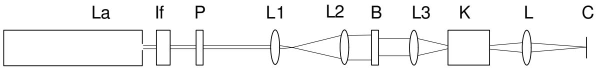

Abb. 1 *Experimantal setup: La : He-Ne-Laser, If : intensity filter, P : Glan-Thompson-Polarizer, L1 and L2 : lenses, B : aperture, L3 : lens, K : crystal, L : telescope system, C : CCD-Matrix.*

3 Observations

We investigated the change of the beam diameter at the rear face of the crystal. The following observations we made:

1. By use of ordinarily polarized light the beam diameter at the rear face of the crystal scaled down about 15% within 17 minutes in the horizontal as well as in the vertical direction. By contrast, if an extraordinarily polarized beam was applied its horizontal diameter scaled down about 22%, but the beam diameter perpendicular to the optical axis only ran through a transient minimum. This temporal development is shown in fig. 2 and 3 in comparison with the diameter of ordinarily polarized light.

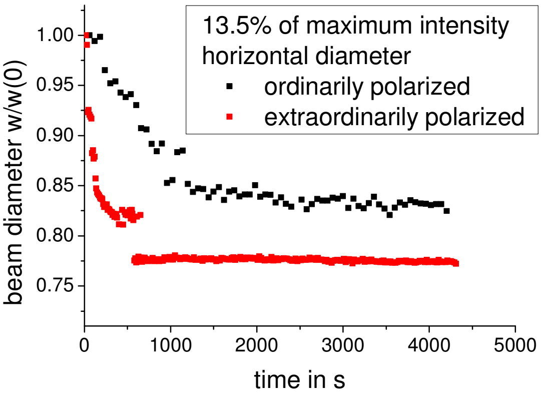

Abb. 2 *Temporal development of the beam diameter coplanar to the optical axis.*

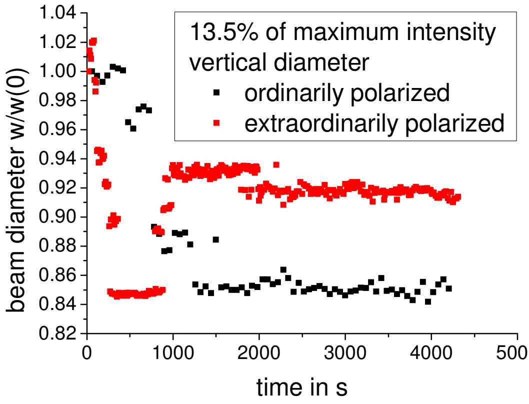

Abb. 3 *Temporal development of the beam diameter perpenticular to the optical axis.*

2. The crystal needed at least 4 minutes (by use of an intensity of 0.2 W/cm^2) to stabilise the beam at the new diameter and then remain in balance above 10 hours.

3. The focussing did not depend on wavelength. If extraordinarily polarized light was used, it did not depend on background illumination, too.

4. We investigated the depence on input diameters between 4µm and 40µm, which is shown in fig. 4. If input diameters smaller than 8µm were applied, defocusing occurred. Between 10µm and 40µm the beam diameter at the rear face of the crystal scaled down more than 50%.

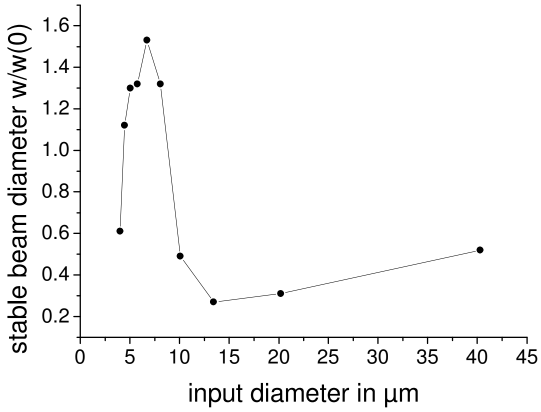

Abb. 4 *Beam diameter at the rear face of the crystal after 30 minutes in depence on the input diameter*

5. There was a dependence of the focussing on intensity of the laser beam of course, too. Starting at an intensity of 0.016W/cm^2 the focussing improved with rising intensity like it is shown in fig. 5. It is remarkable that at intensities higher than 0.2µW the focussing was approximately constant and above 0.3µW defocusing occurred by use of extraorinarily polarized light. If the main reason for the self-focussing would be thermal effects the focussing should grow stronger with rising intensity. So most likely the self-focussing is partially photovoltaic.

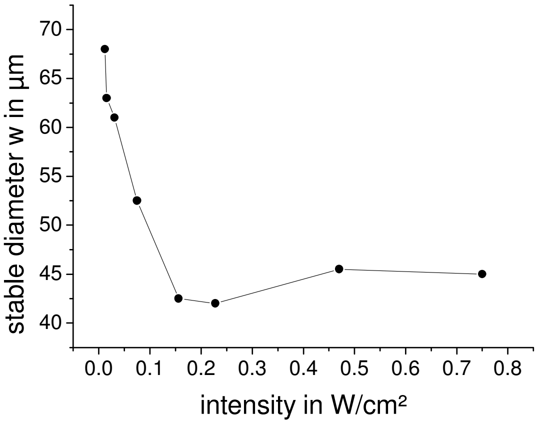

Abb. 5 *Beam diameter at the rear face of the crystal after 30 minutes in depence on intensity.*

4 Acknowledgements

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