2D-Interaction of photorefractive solitons in a SBN crystal

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In this work we present results of theoretical and experimental investigations of the influence of the distance between two-dimensional bright photorefractive coherent solitons on their interaction in a photorefractive SBN crystal under optimal experimental parameters for the fast formation of photorefractive solitons.

1 Introduction

Photorefractive solitons have been widely investigated during the last 15 years. The most interesting field in this area is the interaction of (2+1)D photorefractive solitons. In spite of a great number of papers dealing with (2+1)D soliton interactions, in almost all of them only the interaction of mutually incoherent laser beams is considered. There are only a few papers [1-5], where the conditions for the coherent interaction of (2+1)D solitons were considered. However, these papers do not describe the threshold distance between input laser beams for the soliton interactions.

In this work we present the first theoretical and experimental results of the investigation of coherent photorefractive solitons.

2 Experimental setup

The interaction of solitons in a photorefractive SBN crystal is studied using the setup shown in Fig. 1. (Schrift in der Zeichnung ist zu klein!)

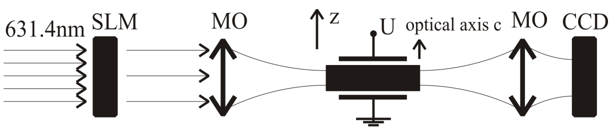


Fig. 1 *. Schematic arrangement of the experimental setup. SLM is the spatial light modulator; MO are the microobjectives; SBN is the crystal; U is the applied voltage.*

A laser diode (λ = 631.4 nm) is used as a source of the linearly polarized wave. The spatial light modulator SLM like a double pin hole let pass two parts of the plane wave each of them with a diameter of about 160 µm. These parts are focused into the photorefractive SBN crystal by the micro-objective MO. The intensity of each input beam is 10 mW/cm^2. The SBN-crystal has the dimensions 5 mm x 5 mm x 20 mm, whereas the light beam propagates along the 20-mm side. An external electric field is applied to the crystal in *z*-direction. The light propagates through the crystal, and the second micro-objective MO projects it onto the CCD-camera, which takes the profile of the beam. A computer program processes the data and calculates the final diameter of the output beam. The beam reaches its stable state in about 20 min.

3 Theoretical results

The simulations of the coherent interaction of the laser beams are performed out according to the experimental values of the external parameters and the parameters of the crystal (Fig. 1.). The distribution of the initial amplitude of the light beam is a Gaussian function with a waist (FWHM) of 23 µm. An external electric field E_0 = 3 kV/cm is applied to the crystal so that the photorefractive nonlinearity appears and the formation of solitons is possible. The ratio of the beam peak intensity to the background illumination I_d is about $2{\cdot}10^3$. The parameters E_0 and I_d are obtained experimentally and correspond to the fastest formation of the most stable photorefractive soliton in SBN.

Fig. 2 shows the ***interaction region*** of the solitons for beams with equal input intensities, where α is the angle of rotation of the axis between the beams relatively to the optical axis ***c***.

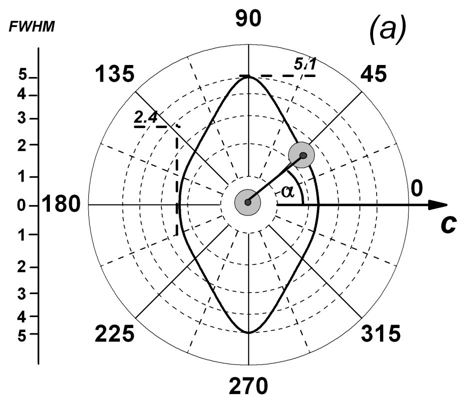


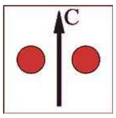
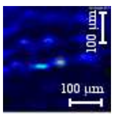
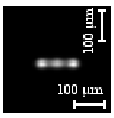
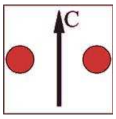
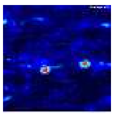
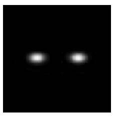
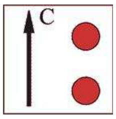
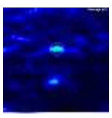
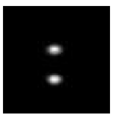
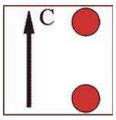
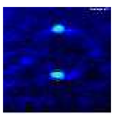
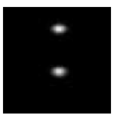
Fig. 2 *.* ***Interaction region*** *of the beams with equal input intensities. The beam diameters are d = 23 µm, the applied electric field is* E_0 *= 3 kV/cm, and the ratio of the beam peak intensity of the weaker beam to the background illumination* I_d *is* $2{\cdot}10^3$.

As the input beams in Fig. 2.a have equal intensities the minimal distance between beams is determined by the first quadrant, whereas the figure has two symmetrical axes parallel and perpendicular to the direction of the applied field. One can observe that the minimal threshold distance is 2.4 FWHM and this one corresponds to the parallel configuration of interacting beams. This is connected with the strong screening properties of the waveguides in the direction of the applied electric field. The increasing of the rotation angle of the interaction axis in the first quadrant leads to higher threshold values up to 5.1 FWHM for the orthogonal position of the axes.

4 Experimental results

The experimental results of the interaction of solitons are presented in Tab. 1 for two different distances between the input beams (“input distance”). The magnitude of the experimental interaction is presented by the different between the ratios of the powers of input and output beams (ΔP_{ration}). We suppose that the beams propagate without interaction if this different is below 10%.

The typical theoretical intensity distribution in comparing with experimental one along the optical is presented in the Fig. 3 for the case 4.

№	Orientation	Description	Experiment	Theory
1		- d≈3.7 FWHM - ΔP_{ration}=17%		
2		- d≈6.6 FWHM - ΔP_{ration}=6%		
3		- d≈3.7 FWHM - ΔP_{ration}=44%		
4		- d≈6.6 FWHM - ΔP_{ration}=2%		

Tab. 1 *Soliton interaction: comparison of the theoretical and the experimental results*

Tab. 1 shows the propagation of photorefractive solitons with input intensities for perpendicular and orthogonal orientation relative to the optical axis for distances between input beams of 3.7 and 6.6 FWHM. The theoretical threshold values are 2.4 and 5.1 FWHM. One can observe the redistribution of the intensity between solitons if the distance is less than the threshold value (Table 1.1) for the orthogonal orientation and no interaction for both orientations when the input distance is 6.6 FWHM (Table 1.2, 1.4). The difference between experiment and theory for the parallel orientation (Table 1.3) is connected with the self-bending of beam.

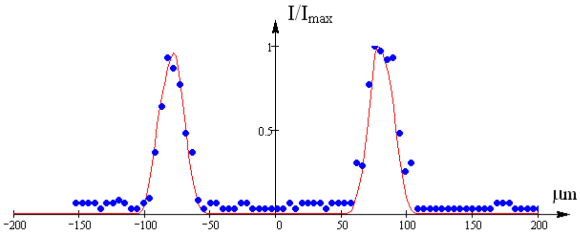


Fig. 3 *. Experimental (points) and theoretical (line) output intensity distribution along the optical axis for the parallel configuration. The beams have equal input intensities, and the input distance is 6.6 FWHM.*

5 Conclusions

We have investigated to our mind for the first time theoretically and experimentally the threshold distance of the coherent interaction between bright photorefractive solitons in a SBN crystal. Using the paraxial wave equation and the equation for the potential of the internal electric field we have found numerically the threshold distances, which were necessary to provide the independent propagation of solitons. The numerical scheme was prepared using the Douglas-Rachford method.

The behaviour of solitons was studied for different orientations of the solitons relatively to the optical axis. We showed theoretically that the increase of the rotation angle (from 0^0 to 90^0) between the optical axis and the axis placed through the centres of the input beams leads to an increase of the threshold distance.

Acknowledgement

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References

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