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Beam self-trapping in pyroelectric photorefractive crystals

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While most photorefractive (PR) beam self-trapping configurations require application of a high external voltage [1] we instead propose to use PR pyroelectric medium to efficiently trap beams by simple temperature control. This new concept is based on uniform temperature change of a pyroelectric PR crystal which creates an internal electric field that is screened under a local illumination by nonlinear photorefractive effect. Experimental demonstration is performed in the widely available photonic material Lithium niobate (LiNbO_3).

A pyroelectric solid exhibits a change in spontaneous polarization ΔP under a temperature variation ΔT given by $\Delta P = p\Delta T$ where p is pyroelectric coefficient of the medium. This polarization change gives an internal electric field E can then be calculated through the relation $E = -1/(\epsilon_0\epsilon)p\Delta T$ where ϵ is the medium dielectric constant and ϵ_0 is the permittivity of vacuum. Free charges can move under the influence of this electric field as if an external voltage was applied to the crystal. The idea behind the concept of pyroelectric spatial beam self-trapping is to light-induced the screening of this pyroelectric electric field by photorefractive effect. For efficient beam trapping to occur, light-induced field screening response time has to be shorter than response of field compensation by charge sorption on the polar surface of the crystal. Moreover, the amplitude of the pyroelectric field has to be large enough to form a deep waveguide by electro-optic effect. LiNbO_3 possesses adequate characteristics to demonstrate this concept.

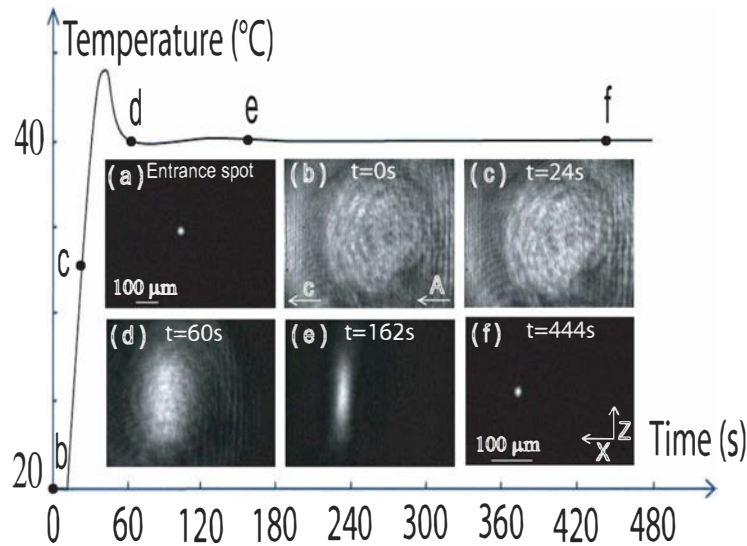


Fig. 1 Self-focusing dynamic in 20mm long undoped stoichiometric lithium niobate (LiNbO_3) of an extraordinary polarized beam at $\lambda=532\text{nm}$ under a temperature change $\Delta T=20^\circ\text{C}$. Images at the input face (a), at the output face at different instant (b-f) and crystal temperature evolution (curve). Parameters: input beam power: $80\mu\text{w}$, input beam size: $20\mu\text{m}$ (FWHM).

Experiments are performed in a 20mm long undoped stoichiometric LiNbO_3 sample. A moderate temperature change of 20 degrees is sufficient to trigger the self-trapping of a beam as shown by the dynamic depicted in figure 1. Similar results are obtained for both ordinary and extraordinary light polarization in congruent or stoichiometric LiNbO_3 samples. Bright spatial solitons can even be formed with proper experimental conditions.

A new kind of PR spatial soliton based on the pyroelectric effect is demonstrated. It provides a very simple way to induce waveguides or periodic index structures in ferroelectric crystals by temperature control. The demonstration performed in photonic grade LiNbO_3 crystal brings even greater potential for practical applications.

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