$MgO-LiNbO_3$ films: an appealing photorefractive medium

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Introduction

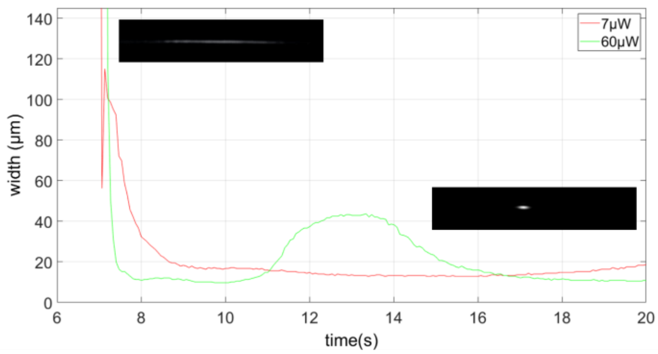
$LiNbO_3$ films (LNF) are presently at the heart of an intense research activity due to a strong potential for RF components, exploiting piezoelectric properties, and for the development of integrated optical chips, using electro-optical and nonlinear properties [1-3]. This material is also known as a holographic medium due to its photorefractive (PR) properties [4] which has been mainly studied and exploited in bulk crystals but several reasons motivate the study of the photosensitivity of LNF.

First of all, PR performance such as sensitivity and response time can be improved thanks to a slab geometry. Moreover, the interaction between beams is facilitated due to the 1-D light confinement. In addition, new architectures are possible such as the control of guided beams using external beams. Finally, the potential applications are enlarged with the possibility of integrating photonic and electronic components in the case of LNF on silicon substrate.

LNF considered in this work are fabricated from photonic grade 500µm thick $LiNbO_3$ wafers doped with 5%mol of magnesium oxide (MgO). A buffer layer of silica (typically 1 µm) is first deposited onto one face of the wafer followed by the sputtering of a typical 200 nm gold layer. A similar gold layer is then deposited on a high flatness silicon wafer. Both wafers are then placed into contact and pressed to form a strongly gold bonding. The bonding process is realized at room temperature in order to avoid mechanical stresses due to the different thermal coefficients of silicon and $LiNbO_3$. Finally, the formed heterostructure is ground and polished to give a slab waveguide consisting of a 7µm thick LNF on a silicon substrate with a silica and gold buffer layers. This hybrid wafer is cut using a precision saw to form rectangular samples with polished faces.

The PR properties of such planar waveguides are then analyzed using a 532nm CW beam of about 15µm diameter (FWHM) injected by the saw-cut faces. The samples temperature can be modified and stabilized using a Peltier module in order to induce a homogeneous pyroelectric field inside the sample [4]. In presence of an adequate PR effect, the beam self-confines laterally and gives rise to propagation without diffraction, a solitonic regime can thus be reached [5, 6]. It is important to note that the LNF used in the present study is doped with MgO which is known to avoid the PR effect so that stable operation can be obtain for photonic components (modulator, frequency converters, …) made out of $LiNbO_3$.

The experiment carried out here shows to the contrary that an efficient self-focusing takes place for low power beams giving rise to soliton beams. As an illustration, figure 1 shows that an injected beam of 60 µW self-focusses in less than 300ms when the temperature of the structure is raised 5°C above room temperature. Few microwatts power beam can self-trap in few seconds as revealed by the second measurement. The analysis confirms that the response time decreases inversely proportional to the injected power, which allows us to deduce that light power of a few mW would give a response time near a few ms. Furthermore, it should be noted that this efficient self-focusing induces a memorized



2-D waveguide in the material. This can thus be used as a reconfigurable waveguide to transmit a signal at a wavelength for which the photosensitivity is negligible as in the near IR.

Figure 1: Transverse beam width evolution observed at the output face of a 2 cms long LNF:MgO for two different beam power. Insert corresponds to output images of at two characteristic time (initial and best focusing).

Conclusions

This surprising high photosensitivity combined with response times which are at least two orders of magnitude lower than the responses in bulk undoped $LiNbO_3$ opens the way to the realization of reconfigurable structures in MgO:LNF. The underlying physics along with a detailed description of the dynamics and potential applications will be presented in details.

References

[1] J. Lu et.al, “ultralow-threshold thin-film lithium niobate optical parametric oscillator”, Optica **8**, 539-544 (2021).
[2] V. Pêcheur et. al., “Watt-level SHG in undoped high step-index PPLN ridge waveguides”, OSA continuum, 4, 1404-1414, (2021).
[3] M. Zhang et. al., “Integrated lithium niobate electro-optic modulators : when performances meets scalability”, optica **8**, 652-667 (2021)
[4] A.M. Glass et.al., “Highvoltage bulk photovoltaic effect and the photorefractive process in LiNbO3”, Applied Physics Letters, **25**, 233-235, (1974)
[5] J. Safioui, F. Devaux, and M. Chauvet, “ Pyroliton: pyroelectric spatial soliton ”, Opt. Express **17**, 22209, (2009)
[6] M. Chauvet et. al., “Fast-beam self-trapping in LiNbO3 films by pyroelectric effect”, Optics Letters, 40, 1258-1261 (2015).