Soft-proton exchange on Lithium Niobate substrates doped with Magnesium-oxide: route toward efficient and power-resistant nonlinear converters.

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Wavelength nonlinear conversion is an attractive approach to coherently shift the wavelength of an optical beam in regions of the spectrum where sources, optical components and detectors are more reliable and practical. Among the different nonlinear materials congruent Lithium Niobate (CLN) is one of the most widely used thanks to its large nonlinear coefficient. Through quasi-phasematching technique, a wide set of three-wave mixing process can be addressed. In addition during these years several techniques have been developed in order to fabricate optical waveguide inside the substrate. However CLN suffers from Photo-Refractive Damage (PRD). The resistance to PRD can be improved by doping the lithium-niobate substrates with several dopants and Mangnesium-Oxide doped Lithium-Niobate substrates are the most accessible. Unfortunately, these substrates are less suitable for waveguide fabrication: the titanium indiffused process strongly reduces the benefit of Mg doping, while Annealed Proton Exchange (APE) waveguides show a nonlinear conversion less efficient than that of CLN. Several studies [1] reported that the crystallographic structure of Mg-doped LN crystals is more severely affected by the proton exchange than that of CLN.

An alternative to APE, Soft-Proton Exchange (SPE) [2] allows the increasing of refractive index without degrading the structural properties of the material. Technically SPE consists in a proton exchange performed at higher temperatures in a sealed ampoule with a diluted proton bath. When the proton concentration is sufficiently low, the exchange preserves both the crystal structure and the nonlinear coefficient.

In this work we report about the fabrication of waveguides starting from 5 mol% MgO-doped LN substrates using SPE. Through the measurement of the nonlinear coefficient by means of a scanning-SHG-microscopy setup [3] for different proton concentrations, we identified the threshold below which the original nonlinearity is preserved (see Fig.1(a)). We fabricate two photonic chips consisting of straight waveguides of 6 μm width. Transmission losses have been estimated respectively at 0.1 dB/cm and 0.8 dB/cm. The refractive-index profile is comparable to the one obtained for CLN substrates (see Fig.1(b)). Finally we qualitatively compare the resistance to the PRD between CLN and Mg-doped optical waveguides. Samples have been tested at 30°C by injecting an optical beam generated by a 76-MHz mode-locked laser with picosecond pulses at 710 nm. The total transmitted power is firstly measured with a power meter. Then the output beam is slightly defocalized so that only a portion of the beam is collected in the power meter. If the photorefractive effect takes place, the beam profile is distorted inducing a fluctuation in the power measured at the power meter. Figure 1 (c) compares the normalized optical power, $\frac{P-P_{avg}}{P_{avg}}$, measured by the power meter for the two waveguides. The label for each trace indicates the total power outcoming from the waveguide. Already at 100 µW we observed a strong fluctuations due to PRD in the CLN chip. On the contrary, in the Mg-doped waveguide this effect is still not measurable at 300 µW.

In conclusion, we fabricated for the first time waveguides starting from Mg-doped substrates using the SPE technique. Our results demonstrate that SPE provides clear advantages compared to other techniques to produce efficient and power-resistant nonlinear waveguide in this material.

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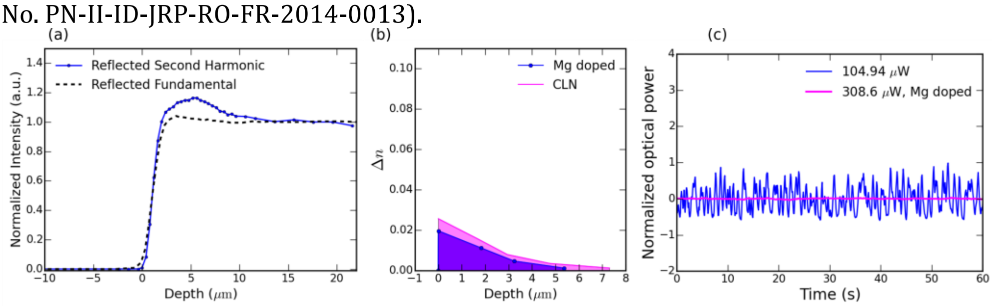

Fig. 1. (a) Reflected fundamental and Second Harmonic intensities versus depth for a slab waveguide based on MgO-doped substrates. (b) Refractive index profile measured at 633 nm for a SPE waveguide fabricated either on a MgO doped LN or on a CLN. (c) Normalized optical power transmitted trough a waveguide fabricated either on a CLN substrate or an Mg-doped substrate. The legend indicates the power outputting from the waveguide. The beam is slighty defocalized to collect only a portion on the power meter. The distortions induced by the PRD are directly translated in power fluctuations. The Mg-doped waveguide (magenta) is clearly more resistant to PRD.

References

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