GUIDES D'ONDES NONLINEAIRES ENTERRES TRES CONFINANTS REALISES PAR ECHANGE PROTONIQUE SUR NIOBATE DE LITHIUM COUPE Z

O. Stepanenko, I. Krasnokutska, E. Quillier, P. Baldi, M. De Micheli

Laboratoire de Physique de la Matière Condensée, Université Nice Sophia Antipolis, UMR CNRS 7336, Parc Valrose, 06108 NICE CEDEX, France

Pascal.Baldi@unice.fr

RÉSUMÉ

Afin de réaliser des guides d'ondes enterrés très confinants sur niobate de lithium sans dégrader le coefficient nonlinéaire d'ordre deux, nous avons combiné un échange protonique direct modifié appelé High Index Soft Proton Exchange (HISoPE) et un échange inverse (Reverse Proton Exchange – RPE). La cinétique du processus RPE est dicutée, ainsi que son influence sur le profil d'indice. Les caractérisations linéaires et nonlinéaires effectuées sur un premier échantillon montrent la complexité du profil d'indice obtenu.

MOTS-CLEFS : *guides d'ondes enterrés ; niobate de lithium ; optique nonlinéaire.*

1. INTRODUCTION

Fabrication of highly confining nonlinear waveguides on lithium niobate (LN) has always been a challenge. The proton exchange (PE) technique proposed in the 1980's is able to achieve a high value of $\delta ne = 0.1$, however such waveguides no longer benefit from the intrinsic nonlinear properties of the substrate.[1] Since then, many modifications of the PE process have been tested in order to find a compromise between the confinement and the nonlinearities. Techniques such as Annealed Proton Exchange (APE) and Soft Proton Exchange (SPE) do realize waveguides with preserved nonlinear coefficients but with a rather weak confinement, the value of the index change, being in any cases lower than 0.03 at $\lambda = 1.55\ \mu m$.[2-5] We have developed a new Proton Exchange process, which allows realizing waveguides on LN with a δne of 0.1 and without degradation of the nonlinear coefficient. However, to avoid strains and stresses due to an important lattice parameters mismatch, which is typical for H:LN structures with high concentration of protons, we reconstructed the LN substrate near the surface using the Reverse Proton Exchange (RPE) process.[6] Embedding a waveguide in such a way, allows "erasing" the surface layer presenting the higher mismatch and preserving the deeper part of waveguide whose index increase is at least equivalent to SPE waveguides. However, this approach is difficult to control, as the kinetics of RPE depends on the crystalline phase of the initial proton exchanged LN.[7] In the present work, we discuss the main problems that one can meet during the fabrication of nonlinear waveguides using a combination of PE and RPE processes.

2. PLANAR WAVEGUIDE FABRICATION AND CHARACTERIZATIONS

3" Z-CUT wafers were used for the waveguides fabrication. The PE consists in immersing the crystal in a bath of benzoic acid (BA) containing a certain percentage of lithium benzoate (LB), which is chosen low to obtain waveguides with high index change (Fig. 1). But on the other hand this concentration is chosen as high as possible to avoid the degradation of the nonlinearities. Waveguides are fabricated in a hermetically closed and evacuated down to 3 mbar metallic container at a temperature of 300°C. The exchange time can vary from several hours to several days depending on the desired depth of the waveguide. Further characterizations of the waveguides reveals that the index profile is composed of a step section followed by a graded index section (Fig. 2) and that the nonlinear properties are non degraded. We call them High Index Soft Proton

Exchanged waveguides, and X-Ray diffraction characterization indicates that these waveguides are composed of $\varkappa_2$ phase and α phase (Fig. 3).

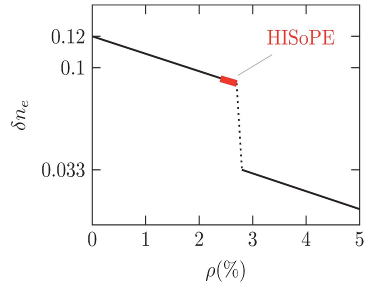

Fig. 1: Concentration of LB used for waveguide fabrication.

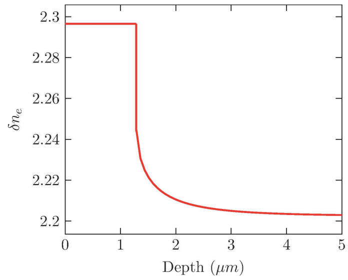

Fig. 2: Typical index profile of HISoPE waveguides.

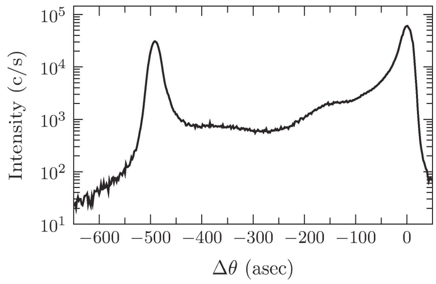

Fig. 3: X-ray rocking curve of (00.12) atomic planes of HISoPE waveguide.

For the RPE process, the crystal is immersed into a melt of KNO_3:$NaNO_3$:$LiNO_3$ in the proportions 1:1:0.1 and heated up to 300°C. The study of RPE kinetics indicates that the step portion of the index profile is rather rapidly erased while the RPE seems to be much slower in the graded index part of the waveguide (Fig. 4). This behavior is quite interesting and indicates that the tolerances to produce an embedded graded index waveguide should be quite loose.

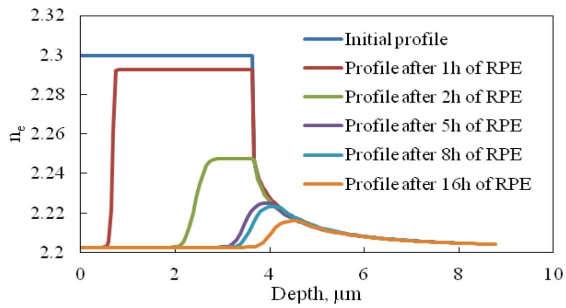

Fig. 4. Index profiles obtained after a direct PE step followed by a RPE process whose duration is varying between 1 and 16 hours.

3. Channel waveguides fabrication and characterizations

Contrary to what occurs in planar waveguides, the different kinetics of RPE raise a problem for channel waveguides fabrication. Indeed, the κ_2 part of the channel waveguide being erased more rapidly by RPE, the resulting waveguide can be quite complicated (Fig. 5). We will see in the following that a profile corresponding to the one sketched in Fig. 5 behave more or less as two highly coupled waveguides.

Fig. 5. Channel waveguide before and after RPE.

Indeed, measuring SHG as well as SPDC spectra (Figs. 6-7) of embedded waveguides fabricated in the way described above in PPLN, we could observe multiple peaks of phase matching. The distribution of these peaks cannot be explained by a multimode nature of the waveguide, but fits quite well with the assumption that the embedded waveguide behaves like a directional coupler.

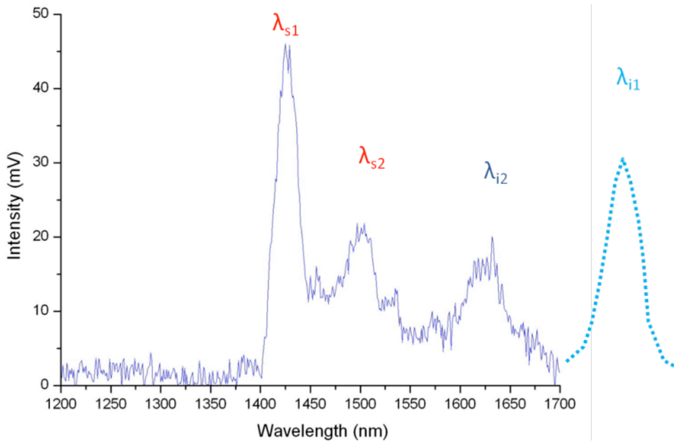

Fig. 6. Observation of the different families of signal and idler frequency in spontaneous parametric down conversion (SPDC) experiment. The idler of the first family is not observable as its wavelength was out of the detector sensibility range.

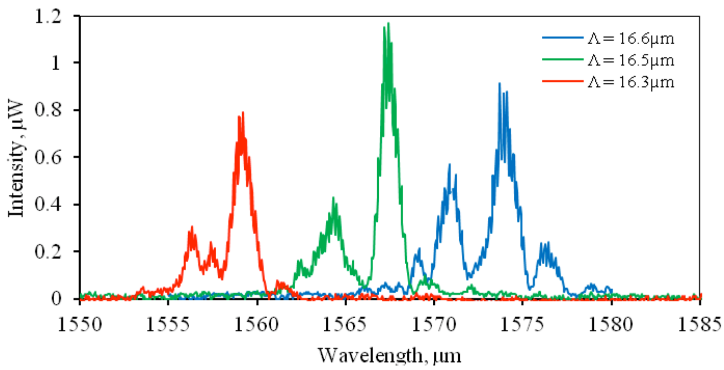

Fig. 7. SHG response in function of the pumping wavelength measured for waveguides with PPLN periods of 16.3, 16.5 and 16.6 μm.

4. Conclusion

The combination of direct and reverse proton exchange we proposed, allows realizing highly confining (up to δn_e=0.1) embedded waveguides on LN without degradation of the nonlinear coefficient. All the details concerning the first linear and nonlinear channel waveguides characterization will be presented at the conference. Especially the influence of the propagating losses and the Fabry-Perot cavity effect that can be seen on Fig. 7 will be discussed.

References

[1] F. Laurell *et al.*, *Appl. Phys. Lett.*, **60**(3), pp.301-303 (1992).

[2] P. Baldi *et al.*, *Opt. Eng.*, **37**(4), pp.1193-1202 (1998).

[3] L. Chanvillard *et al.*, *Appl. Phys. Lett.*, **76**, pp.1089-1091 (2000).

[4] M. L. Bortz *et al.*, *Opt. Lett.*, **20**(1), pp.49-51 (1995).

[5] M. H. Chou *et al.*, *Opt. Lett.*, **24**(16), pp.1157-1159 (1999).

[6] J. L. Jackel and J. J. Johnson, *Electron. Lett.*, **27**(15), pp.1360-1361 (1991).

[7] Yu. N. Korkishko and V. A. Fedorov., *J. Appl. Phys.*, **82**(3), pp.1010-1017 (1997).