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UV-written channel waveguides in proton-exchanged Lithium Niobate

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We report on the direct UV-writing of channel waveguides in annealed proton-exchanged (APE) and reverse proton-exchanged (RPE) layers in $LiNbO_3$ and demonstrate efficient guiding within single mode channels at telecom wavelengths.

Waveguide technology underpins the wide deployment of $LiNbO_3$ (LN) planar (electro-, acousto- and nonlinear optical) devices. Recently, a novel technique for patterning optical channels in congruent LN without photolithography has been demonstrated [1]. It relies on an UV-induced refractive index increase which allows direct writing of waveguides in the crystal, but the magnitude of these index changes is still one order of magnitude less than what can be achieved through conventional techniques for integrated optics in LN, e.g. annealed proton-exchange (APE) [2] or annealed and reverse-proton exchange (RPE) [3].

Here we demonstrate the possibility of UV-writing channels into slab APE:LN and RPE:LN layers and the fabrication by these means of single-mode waveguides at telecom wavelengths. The exchange processes can add flexibility in engineering the UV-written waveguides (for instance by enhancing the modal confinement in the vertical direction) and also allow the creation of novel structures combining surface and buried waveguides.

The fabrication process consisted of two main steps. First, we fabricated surface (APE) and buried (RPE) slab waveguides in z-cut LN supporting only the TM_0 mode in the 1530 – 1600 nm wavelength range. Then we used a custom-built system described elsewhere [1] to define channels in the APE and RPE LN samples by UV-writing ($\lambda = 244$ nm, spot size ~ 7 μm, C. W. writing powers $20 \leq P_{UV} \leq 80$ mW, scan speeds $10 \leq v_{scan} \leq 1000$ mm/min).

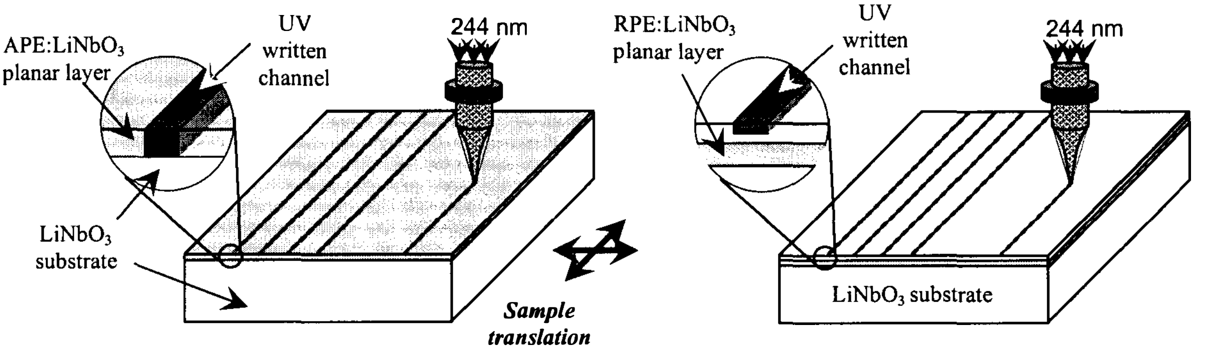

Fig. 1. Sketch of the UV-writing process in APE:LN and RPE:LN samples.

We systematically characterised the UV-written channels at 780, 1550 and 1600 nm by standard fibre butt-input-coupling to one of the polished end faces with analysis of the mode profiles at the output.

UV powers $P_{UV} \geq 50$ mW resulted in surface damage in both APE and RPE samples and impaired the guidance at visible and infrared wavelengths in the irradiated regions. Conversely, powers $30 \leq P_{UV} \leq 40$ mW proved effective in yielding good lateral confinement (Fig.2). RPE:LN samples appeared slightly more prone to UV-damage and the properties of their channels were more sensitive to the UV writing speed used.

In all cases, the strongest lateral confinement occurred close to the sample surface. For APE:LN samples this yielded guiding channels written within the surface APE slab, while in RPE:LN more complex structures could be observed, such as channels guiding extraordinarily polarised light on top of the buried RPE slab.

We are currently investigating the propagation losses of the channels and their compatibility with periodically poled structures.

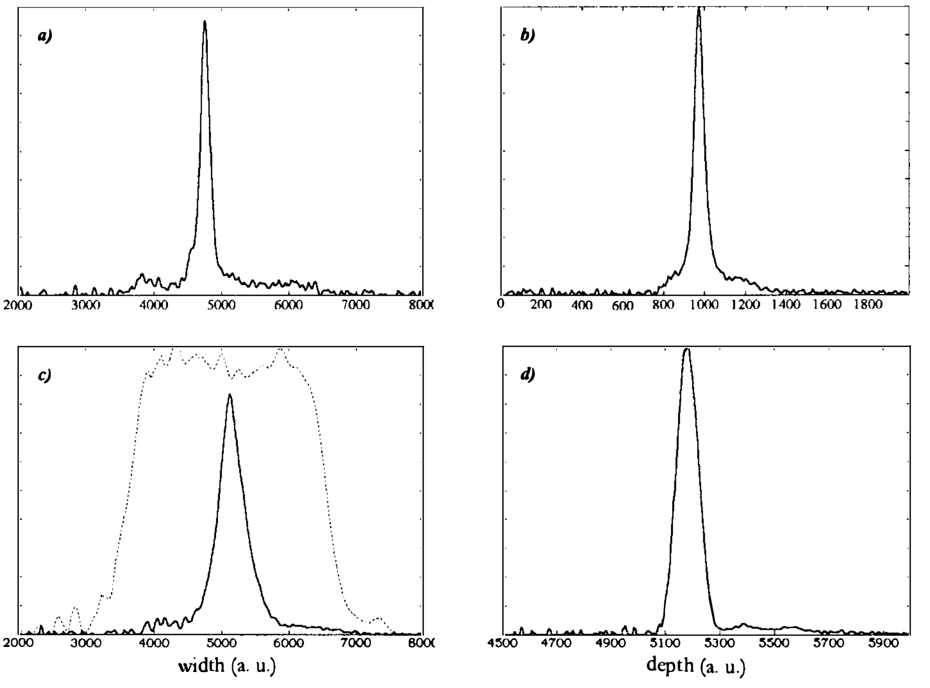

Fig. 2. Near-field intensity distributions in width (*a* and *c*) and depth (*b* and *d*) of the modes guided at 1.55 µm by channels in: *a)-b)* APE:LN and *c)-d)* RPE:LN, written at UV powers of 40 mW and speeds of 800 and 10 mm/min, respectively. The axes units are arbitrary. The dashed line in *c)* shows the aperture of the imaging system used in the measurements.

[1] S.Mailis, C.Riziotis, I.T.Wellington, P.G.R.Smith, C.B.E.Gawith, R.W.Eason, "Direct UV writing of channel waveguides in congruent lithium niobate single crystals", *Opt. Lett.* **28**, 1433-1435 (2003).

[2] P. G. Suchoski, Jr., T. K. Findakly, F. J. Leonberger, "Stable low-loss proton-exchanged $LiNbO_3$ waveguide devices with no electro-optic degradation", *Opt. Lett.* **13**, 1050-1052 (1988).

[3] J. L. Jackel and J. J. Johnson, "Reverse exchange method for burying proton exchanged waveguides", *Electron. Lett.* **27**, 1360-1361 (1991).