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Planar optical waveguide formation in $LiNbO_3$ by means of high energy ion implantation

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Abstract. $LiNbO_3$ crystals were implanted at room temperature with MeV-range O^{2+} and O^{3+} ions at different energies (at 5 and 13 MeV respectively) and fluences (ranging from 1.0x10^{14} to 2.0x10^{14} O/cm^2). After annealing at 230 ^{o}C for 40 min., the near surface damage is fully recovered. The obtained planar waveguides were characterized by the prism-coupling method. The reflectivity calculation method (RCM) was applied to simulate the refractive index profiles in the waveguides.

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Lithium niobate is a crystal with excellent physical properties for the fabrication of integrated optical devices: high electro-optic coefficients, low propagation loss and high Curie temperature. To achieve devices of high degree of optical integration, the formation of a wave guide of dimensions similar to the wavelength becomes indispensable. In the last years several procedures for production of $LiNbO_3$ waveguides have been developed: by diffusion, ionic exchange and ionic implantation [1,2]. The damage produced by the use of MeV ions near the surface material (where the electronic stopping power is dominant) can be strongly reduced by means of a suitable annealing conditioning. Near the end of the range of the incoming ions, the nuclear collisions are the most important process, producing a layer of damage of definite

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depth. Using the 20MV Pelletron Tandem accelerator at Tandar, implanted planar waveguides in $LiNbO_3$ were fabricated at room temperature. To avoid channeling effect the samples were tilted 7^o off the beam direction. Fig. 1 shows the scheme of the device used during the implantation. The beam of ^{16}O remains fixed in space while the sample moves continuously (up and down alternatively) until the required dose is reached.

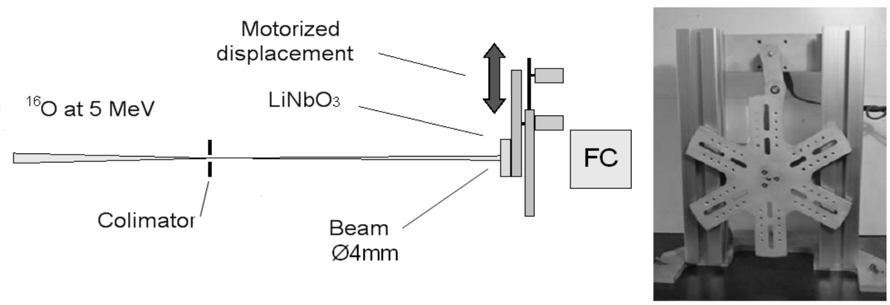

Fig. 1. Irradiation device and photograph of the motorized displacement mechanism.

The refractive index profile was obtained by the coupling prism dark m-line spectroscopy technique [3] (using an He-Ne laser beam) and the theoretical values of the depth ($\simeq 2.7\mu$m) and width ($\simeq 0.3\mu$m) of the optical barrier calculated by means of the SRIM2003 code. Using a step refractive index distribution model, the mean refractive index of the guiding region (n_{wg}=2.205) and the mean refractive index at the end-range of the damage region ($n_{barrier}$=2.17) were adjusted, to obtain the best fit of the effective refraction index (n_{eff}), as shown in Fig. 2.

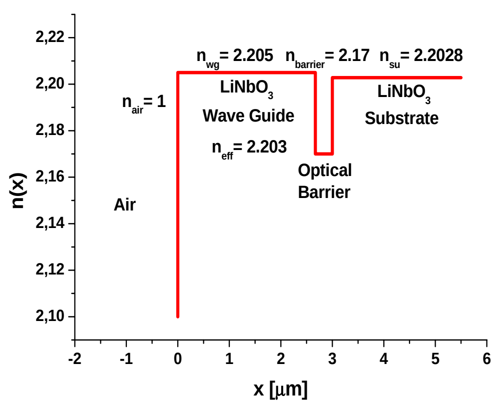

Fig. 2. Step extraordinary refractive index distribution model for 1.5x10^{14} O/cm^2 implanted $LiNbO_3$ sample (λ=632.8 nm).

Fig. 3 shows the slab waveguide, about 4 cm long, obtained by 5 MeV ^{16}O implantation at 1.5x10^{14} O/cm^2 with a current density of 5 nA/cm^2 and annealed for 30 min at 230^{o}C in dry oxygen atmosphere (to recover the damage produced by the implantation into guiding region).

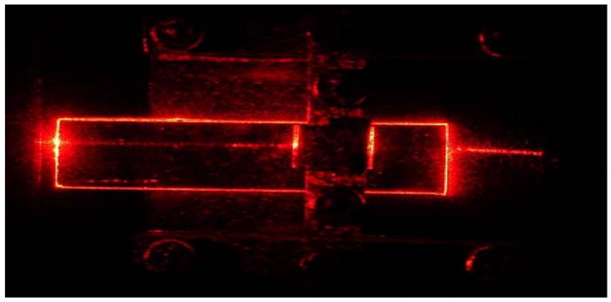

Fig. 3. The laser light (at 632.8 nm) propagating through the waveguide. A laser light signal at the end of the waveguide is clearly observed.

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