Control of the properties of micro-structured waveguides in $LiNbO_3$ fabricated by direct femtosecond laser inscription

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Lithium Niobate (LN) is a widely used material for fabrication of optical waveguides (WGs) because of its acousto-optic, electro-optic and nonlinear properties, and a wide transparency range. The major drawback of the traditional methods used for WG fabrication in LN is that WGs can only be produced near the crystal surface and with little or no control over their properties. In order to expand the applicability of LN devices this issue has to be addressed.

In this paper, we report on buried waveguides fabricated in LN by the method of direct femtosecond (fs) laser inscription [1]. 5% MgO doped $LiNbO_3$ [2] was chosen as the host material because of its high quality and damage threshold, as well as relatively low cost. Direct fs inscription by astigmatically shaped beam in crystals [3] usually produces multiple 'smooth' tracks (with reduced refractive index), which encircle the light guiding 'core', thus creating a depressed cladding WG. Figure 3c shows an example of fs-written WG with a circular shape. A high-repetition rate fs laser system [4] was used for inscription at a depth of approximately 500 μm.

We performed numerical simulations of the WG properties with the COMSOL software package and using the parameters found experimentally for the individual tracks. The results in Fig. 3a-b reveal that the dispersion of the WG can be controlled by its geometry, even for the small induced refractive index contrasts characteristic of the fs inscription. This is a demonstration of the general concept used in modern photonics since the emergence of photonic band-gap fibres [5].

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a) b) c)

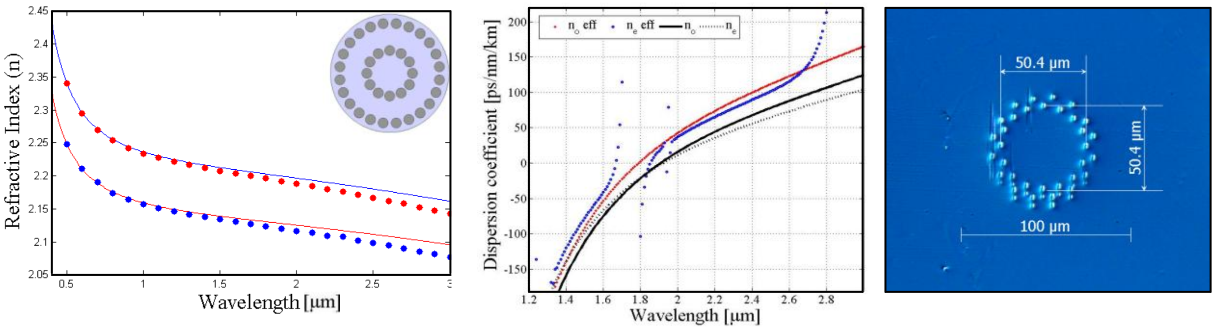

Fig. 1 a) Refractive indexes of $LiNbO_3$: 5% MgO (solid curves) and effective refractive indexes of depressed cladding waveguide structure (dots) versus wavelength. The dependence of n_o (ordinary polarization) on wavelength is shown in blue colour, and the dependence of n_e (extraordinary polarization) in red. The inset is the waveguide structure. b) Wavelength dependence of the calculated dispersion coefficient. c) Example (side-view after wafer cutting and polishing) of micro-structured waveguide with a circular cross-section, fabricated in z-cut $LiNbO_3$:MgO wafer at 500 μm depth.

In conclusion, using numerical modelling we have demonstrated that the properties of fs-written WGs can be controlled by the WG geometry. Buried, depressed-cladding WGs in LN host with circular cross-section were also demonstrated. Combining control over the WG dispersion with quasi-phase matching will allow various ultralow-pump-power, highly-efficient, nonlinear light-guiding devices – all in an integrated optics format.

References

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