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Modelling of UV Direct-Write Waveguides In Single Crystal Lithium Niobate

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It has been shown that waveguide structures can be directly written into single crystal $LiNbO_3$ through the influence of a focussed c.w. laser source at a wavelength of 244nm scanned across the surface [1]. A possible cause for this effect is the thermally induced diffusion of Li ions away from the regions heated by the laser beam leading to a local decrease in the refractive index which is dependant upon the Li concentration [2]. Figure 1 shows a schematic of this process.

The diffusion of heat within the crystal has been modelled initially by analytical methods which include a Kirchhoff integral transform to include the effect of a temperature dependant thermal diffusivity. Using this analytical model we have investigated the characteristics of the temperature distribution in the vicinity of the scanning beam with variation of exposure parameters such as beam spot size, incident optical power and scanning speed. It has been found that the temperature distribution in the reference frame of the moving beam is independent of the scan speed for all practical speeds.

A finite difference model has also been constructed for a static beam and the results compare very closely with the analytical model. The finite difference model has allowed the inclusion of a temperature-dependant heat capacity as well as a temperature-dependant thermal diffusivity. It has been found however, that the temperature-dependant heat capacity has only a small additional effect and so this justifies the use of the analytical model where only the thermal diffusivity is temperature-dependant.

The equations describing diffusion of Li ions in a dynamic, spatially non-uniform, temperature distribution have been derived and used to extend the finite difference temperature model into a model of Li diffusion induced by the scanning beam. For an incident power of 80mW, scan speed of $8 \times 10^{-4}ms^{-1}$ and spot size of 3.25µm a peak Li concentration change was calculated to be about 1% in the preliminary results. Calculations of the refractive index changes based on these predicted Li concentration changes will be presented and compared with measured values achieved via direct waveguide writing.

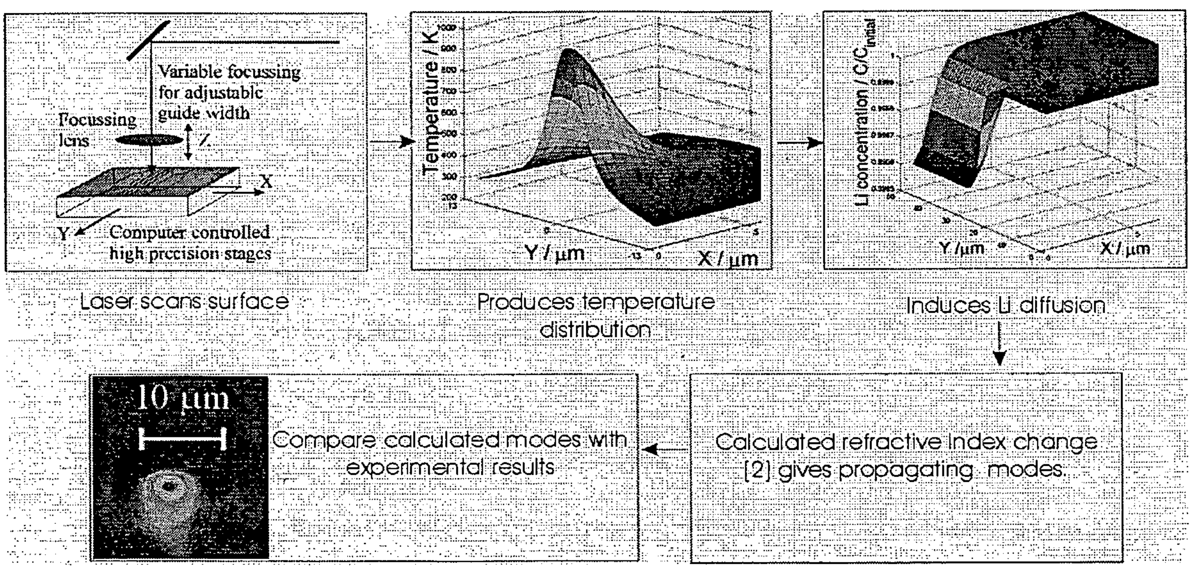

Figure 1: Schematic of guide writing and modelling process.

[1] S. Mailis, C. Riziotis, I. T. Wellington, P. G. R. Smith, C. B. E. Gawith and R.W. Eason *"Direct ultraviolet writing of channel waveguides in congruent lithium niobate single crystals"* Opt. Lett, **28**, 16, 1433-1435, (2003).

[2] U. Schlarb and K. Betzler, *"Refractive indices of lithium niobate as a function of wavelength and composition."*, J. Appl. Phys. **73**, 7, 3472-3476, (1992).