UV direct writing of low loss waveguides at 1.5μm in single crystal $LiNbO_3$

I.T. Wellington, C.B.E. Gawith, G.J. Daniell, P.G.R. Smith, R.W. Eason, S. Mailis.
Optoelectronics Research Centre and Dept. of Physics & Astronomy, University Of Southampton, Southampton, SO17 1BJ, UK

Single mode channel waveguides at a wavelength of 1 .52μm have been fabricated in the +z-face of congruent single crystal lithium niobate using c.w. UV laser illumination at 244nm. Propagation losses of 0.21dB cm^{-1} have been calculated from cut-back measurements.

Recent experiments have demonstrated the technique of direct-writing of waveguides in single crystals of lithium niobate using a focussed c.w. laser source at a wavelength of 244 nm (frequency-doubled Ar^+ laser) scanned across the crystal surface [1]. The UV light at this wavelength is absorbed in the near-surface region, and under typical conditions of ~100mW incident power, and a spot size of ~3-5μm the incident power is sufficient to induce surface melting.

For lower incident laser powers of order 60-70mW however, and at scan rates of ~50-100 mm per minute, the interaction between the UV light and the surface produces waveguides that are both permanent and low loss. We have previously reported waveguides designed for single-mode operation at the He-Ne wavelength of 633nm [1], but residual photorefractive damage produces a gradual increase in propagation loss.

We have now optimised the writing conditions for TM mode waveguide production for the He-Ne wavelength of 1.523μm, on the +z crystal face, and have obtained low loss guides for writing conditions of ~70mW in a spot size of 6 μm at a scan speed of 50mm per minute. Shown below in figure 1 is the single-mode profile obtained from the output end of the guide.

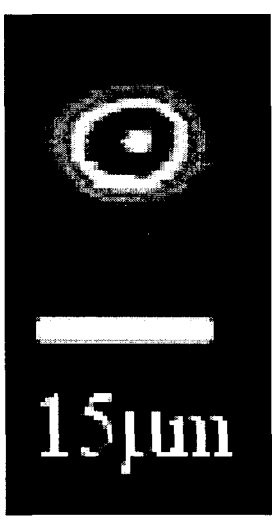

Fig 1. Mode profile of 1.523μm light from the exit face of the UV written waveguide.

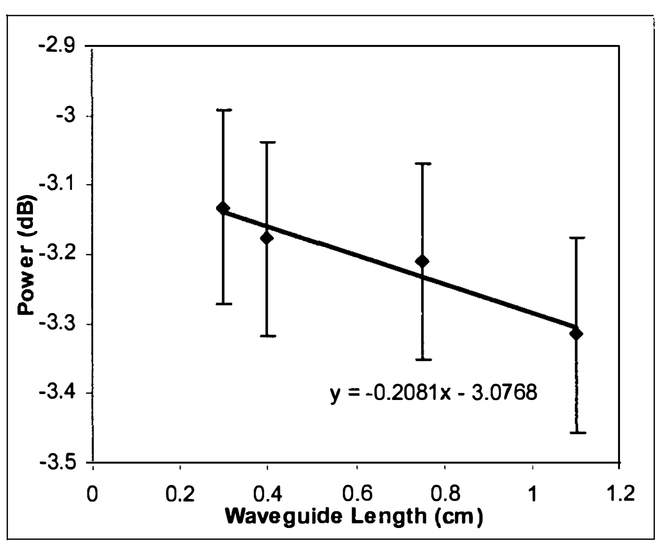

Fig. 2. Loss measurements via the cut-back technique. The plot shows output power in dB versus guide length.

To determine the propagation loss, we have performed cut-back measurements on a series of identically written guides of lengths 3, 4, 7.5 and 11mm, all previously cut and end-polished, and the results are shown in figure 2. From the gradient we deduce a value of propagation loss of 0.21dB cm^{-1}, which we believe can be further reduced with additional attention to scan speed and spot-size. Errorshave been realised due to coupling in-ef f iciencies. We also note that f or incident powers at a value of 80mW, under identical scan speeds and spot sizes, double-moded guides have been produced, indicating that the most important parameter in this method of UV writing is the incident laser power.

We have also written guides on the –z crystal face, but to date these guides are far less thermally stable. We are currently investigating the mechanism responsible for guide formation, and believe that a rapid sideways diffusion of a small quantity (<1 %) of lithium from the laser-heated region may well be responsible. Modelling is underway to determine whether this is indeed the case, and we are in the process of quantifying the lithium content within the guide region.

Further applications of this technique including the fabrication of splitters, variable attenuators and other advanced structures will be discussed.

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