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JTUA5 Ion implanted crystal waveguide lasers

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Ion implantation is a very useful technique which can be used to modify the optical properties of insulators.[1] In particular, much interest has been caused by the ability to create a refractive index profile so that optical waveguides and integrated optical devices can be fabricated. A large amount of work has been carried out on crystals such as $LiNbO_3$, which is of interest due to its high electrooptic coefficient. However, due to the physical nature of the ion implantation process, refractive index changes and hence optical waveguides can be created in a wide range of crystals. This raises the possibility of creating waveguides in very many interesting solid state laser systems, and such waveguides have potentially very low thresholds for laser operation if the guide losses and other cavity loss mechanisms can be kept small.

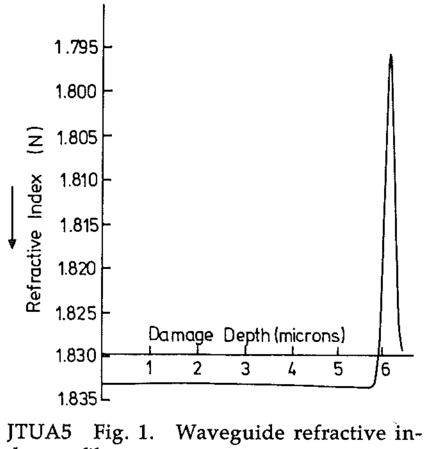
For our initial demonstration of an ion implanted crystal waveguide laser, we chose to look at Nd doped YAG. The waveguide was created by a multienergy implant of He^+ ions at 77 K, with ion energies up to 2.8 MeV at a total dose of 6×10^{16} ions cm^{-2}. The refractive index profile, calculated by fitting to the observed mode characteristics,[2] is shown in Fig. 1. The waveguide supports two confined spatial modes at the pump wavelength of ~590 nm, with the mode indices having values larger than the substrate index and just one mode at the signal wavelength of ~1.06 μm.

Observation of the fluorescence spectra in the implanted region shows that the lines are significantly broadened, typically by a factor of ~2. The relative peak intensities of emission lines are also affected, with the 1.062-μm line becoming comparable with the normally dominant 1.064-μm line at an ion dose of ~7×10^{16} ions cm^{-2}.

The laser cavity configuration is shown in Fig. 2. The 5-mm long waveguide reached threshold with ~33 mW of pump power launched into the guide. A calculation allowing for the measured propagation loss of 1.5 dB cm^{-1}, the increased fluorescence linewidth and diffraction loss in the unguided plane, predicts a threshold of ~7 mW. The discrepancy between these figures is thought to be mainly due to poor butting of the mirrors to the ends of the guide because of the slight curvature of the polished crystal endfaces. Future work using guides with dielectric mirror coatings applied directly to the endfaces should thus bring improved results. However, a major improvement in threshold should be brought about by the formation of channel guides using suitable masking techniques. A channel guide has already been fabricated in Nd:YAG with a measured transmission, including launch and propagation loss, of ~40% at ~620 nm.

A calculation based on a 7-mm long 6- × 6-μm guide with propagation losses of ~1 dB cm^{-1} predicts a threshold of ~100 μW for Nd:YAG. It is also interesting to note that similar calculations on such broadly tunable lasers as $Ti:Al_2O_3$ and $Cr:LiCaAlF_6$ give thresholds in the region of 10 mW. Both these crystals, along with others including doped $LiNbO_3$, GSGG, $YAlO_3$ and various glasses, are currently under investigation. Thus we believe that a new and very interesting field of study has just begun.

1. P. D. Townsend, "Optical Effects of Ion Implantation," Rep. Prog. Phys. **50**, 501–558 (1987).
2. P. J. Chandler and F. L. Lama, "A New Approach to the Determination of Planar Waveguide Profiles by Means of a Non-Stationary Mode-Index Calculation," Opt. Acta **33**, 127–143 (1986).



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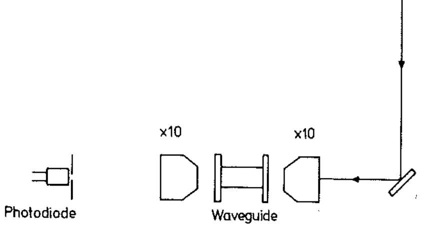

JTUA5 Fig. 2. Laser resonator and pumping scheme.