Proton implanted buried planar and channel waveguides in sapphire and Ti:sapphire

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Generally, high performance in integrated optics can be expected from buried devices. Burying the waveguiding structures possesses the two advantages of avoiding propagation losses due to surface scattering and decreasing the vertical mode asymmetry commonly encountered in surface waveguides. Most of the methods reported for the fabrication of buried waveguides are appropriate to glassy materials. In this paper, we report on the fabrication of buried guiding structures in sapphire and Ti:sapphire by use of proton implantation. The reduction of the refractive index resulting from high-energy proton implantation [1] is exploited to fabricate both passive and active planar and channel buried waveguides.

The dependence of localization and amount of the refractive-index decrease in sapphire on incident proton energy and dose, respectively, was investigated by use of dark m-lines spectroscopy. The obtained knowledge allows the controlled writing of low-refractive-index barriers to confine the light propagating inside the bulk of the material.

Successive implantation with different energies was employed to produce either a single buried planar waveguide or multiple stacked planar waveguides, depending on whether the optical and geometrical parameters prohibit or permit light propagation in zones contained between two damaged areas. Implantation parameters for the former were optimized to permit fundamental transverse-mode propagation at $\lambda = 780$ nm near the maximum of the Ti^{3+} fluorescence. When pumped with an Ar^+ laser into the Ti^{3+} absorption band, the experimental fluorescence output profile of the Ti:sapphire buried waveguide shows good light confinement (Fig. 1). The excellent agreement with the simulation presented in Fig. 2 in terms of light confinement and localization demonstrates the good control over the implantation parameters.

Buried channel waveguides were obtained by proton implantation through a slit mask [2] to produce strip-damaged areas inside the buried planar waveguide region. Figure 3 shows the fluorescence output profile of a 6-μm wide channel waveguide produced from the buried planar waveguide described above. Both horizontal and vertical directions exhibit good light confinement. Detailed results on fluorescence guiding in Ti:sapphire waveguides will be reported at the conference.

The excellent properties of these buried waveguides in sapphire and Ti:sapphire result from the flexibility of the fabrication technique as well as the good control over the implantation parameters. The present results are promising for applications such as channel-waveguide lasers and channel-waveguide arrays to be used as broadband emitters for interferometry [3].

Fig. 1. Fluorescence output profile of a buried planar waveguide in proton-implanted Ti:sapphire.

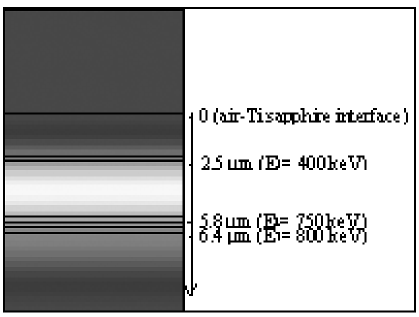

Fig. 2. Implantations and calculated mode-field pattern at $\lambda = 780$ nm for the waveguide structure of Fig. 1.

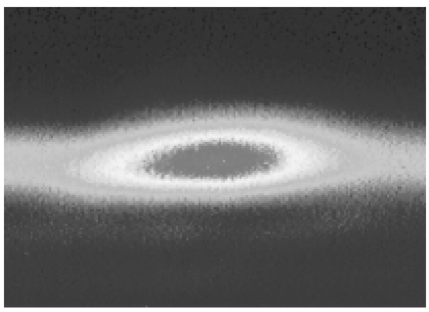

Fig. 3. Infrared fluorescence output profile of a buried channel waveguide in proton-implanted Ti:sapphire.

[1] P.D. Townsend, P.J. Chandler, L. Zhang, "Optical effects of ion implantation" (Cambridge University Press, Cambridge, 1994).
[2] P. Moretti, M.F. Joubert, S. Tascu, B. Jacquier, M. Kaczkan, M. Malinowskii, J. Samecki, Opt. Mater. **24**, 315 (2003).
[3] A.M. Kowalevicz, T. Ko, I. Hartl, J.G. Fujimoto, M. Pollnau, R.P. Salathé, Opt. Express **10**, 349 (2002).