Proton-implanted Ti:sapphire buried channel-waveguide lasers

C. Grivas, D.P. Shepherd, and R.W. Eason
Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, United Kingdom

L. Laversenne and P. Moretti
Physical Chemistry of Luminescent Materials, Claude Bernard-Lyon 1 University, F-69622 Villeurbanne, France

M. Pollnau
Advanced Photonics Laboratory, Institute of Imaging and Applied Optics
Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Ti:sapphire is a widely used laser system with broad tunability (650-1100 nm) and a large absorption bandwidth (400-650 nm). Realisation of miniature Ti:sapphire waveguide lasers with channel geometries would offer the possibility to develop compact, broadly tunable ultra-short-pulse laser sources with low pump power laser thresholds. Here, we report on the laser performance of buried channel waveguides fabricated in a Ti:sapphire crystal by high-energy proton implantation. This technique ensures excellent control over the size of the induced refractive index changes and, moreover, allows for deeper damage profiles and reduced lattice damage in the guide region compared to implantation with other ions. Proton implantation has recently been proved capable of producing low-loss buried waveguides in undoped sapphire crystals [1].

To achieve vertical confinement in a 5-µm-thick buried planar waveguide one upper and two lower barriers were fabricated using H^+ doses of $0.5x10^{16}$ (ion energy 0.5 MeV), $1x10^{16}$ (0.95 MeV), and $1x10^{16}$ ions/cm^2 (1 MeV), respectively. Lateral barriers were produced through 10- and 15-µm-wide slits with 1-MeV proton irradiation using four different angles of incidence 65º, 55º, 50º, and 40º and doses of $4x10^{16}$, $8x10^{16}$, $8x10^{16}$ and $4x10^{16}$ ions/cm^2, respectively. As a result, 5-µm deep buried channel-waveguides with widths of 10, 15 and 25 µm have been produced, separated (depending on the used slit) by a distance of 10 or 15 µm. The propagation losses of the 10- and 15-µm-wide channels were 1.3 and 1.0 dB/cm, respectively, as measured by the self-pumped phase conjugation technique [2].

The laser performance was investigated using an Ar^+ pump laser operating on all lines. To form the laser cavity two highly reflecting lightweight thin mirrors were attached at the end faces of the 5.1-mm-long guides. Laser thresholds of 260 and 230 mW of absorbed pumped power were obtained for channels with 15 and 10 µm width, respectively, and continuous, π-polarized laser emission was observed near 780 nm (Fig. 1). Beam propagation factors (M^2), with values of 2.5 and 1.25 for the horizontal and vertical axes, respectively, were measured for the 15-µm-wide channels. Near-diffraction-limited laser emission (Fig. 1) was obtained from channels with 10 µm width and the corresponding values for the propagation factors were $M_x^2 = 1.5$ and $M_y^2 = 1.2$, respectively. Figure 2 shows the laser output characteristics as a function of the absorbed power using a T = 4.6% output coupler. Slope efficiencies of 3% and 2.2% with respect to the absorbed pump power were obtained for the 15- and 10-µm-wide channels, respectively, with corresponding outputs of 17 and 12.4 mW for 1-W pump powers.

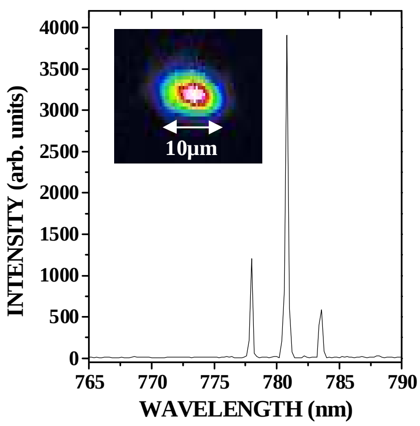

Fig. 1. Laser spectrum and mode intensity profile from a buried channel waveguide with 5 µm height and 10 µm width (individual lasing spikes represent etalon effects).

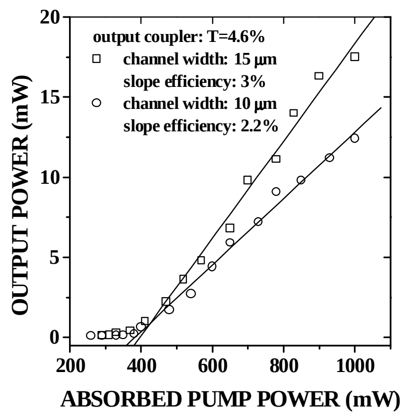

Fig. 2. Output power versus absorbed pump power for two buried channel waveguide lasers with 5 µm height and widths of 15 and 10 µm, respectively.

[1] L.Laversenne, P.Hoffmann,M.Pollnau, P.Moretti, J.Mugnier, Appl. Phys. Lett. **85**, 5167 (2004)
[2] S. Brülisauer, D. Fluck, C. Solcia, T. Pliska, P. Günter, Opt. Lett. **20**, 1773 (1995)