An ion-exchanged Thulium-doped germanate glass channel waveguide laser operating near 1.9 μm

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Solid-state lasers operating in the eye-safe region near 2 micron are of considerable interest owing to various application areas such as remote sensing, spectroscopy and LIDAR. Thulium-based gain media have several attractive features including a broad emission bandwidth, a broad absorption band near 800 nm that can be diode pumped and the possibility of obtaining a quantum efficiency of up to 200% due to the process of cross-relaxation. Guided-wave devices can offer additional advantages of compactness and integration, as well as lower thresholds and high slope efficiencies if low propagation losses can be obtained. Such devices, when combined with integrated saturable absorber elements, can also be passively modelocked to generate femtosecond pulses with multi-GHz repetition rates [1].

An ion-implanted Tm:lead germanate glass planar waveguide laser has previously been demonstrated [2], however ion implantation is an expensive technique and it can be difficult to fabricate suitable masks for channel waveguide production. A channel waveguide laser around 1.9 μm was also demonstrated recently by ultrafast laser writing [3]. Compared to the above techniques, ion-exchange is a more readily available low-cost technique, which can be used for the fabrication of low-loss channel waveguides [1]. In this work we demonstrate, to the best of our knowledge, the first ion-exchanged Tm: glass channel waveguide laser operating near 1.9 μm.

Tm:germanate glass with a composition of 65.5 GeO_2 - 12 Al_2O_3 - 4.5 BaO – 18 Na_2O (mol %) doped with 1mol % Tm_2O_3 was fabricated by a melting and quenching technique. Annealed glasses were then sliced to dimensions of 20 mm x 20 mm x 2 mm and were surface polished for channel waveguide fabrication. Figure 1(a) shows the absorption spectrum of Tm:germanate glass. A 35 ± 5 nm aluminium (Al) film was deposited on the polished glass. Channel openings on the Al film, with widths varying from 1 μm to 10 μm, were defined by photolithography and Ar-ion beam milling. Since the glass is reactive to the Al etchant, a dry physical etching process was employed in contrast to the conventional wet chemical etching for the channel openings. The glasses were then ion-exchanged with a melt composition of 43 mol% KNO_3 – 55 mol% $NaNO_3$ – 2 mol% $AgNO_3$ at 300 ^oC for 20 min resulting in diffused channel waveguides with a diffusion depth of 4.6 μm and an index change of $\Delta n \sim 0.06$ at 1553nm (figure 1(b)). After ion-exchange the Al mask was removed by Ar-ion beam milling. The end facets of the glass were polished to a length of 11.5 mm.

For lasing experiments, the glass sample was mounted on a Peltier-cooled copper mount kept at a constant temperature of 15°C. A titanium sapphire laser tuned to the peak of absorption at 790 nm, was used as a pump source and a variable neutral density filter was used to control the pump power. An 11-mm aspheric lens was used to couple the pump into the waveguides. Thin mirrors with a reflectivity>99.8 % and 32% at the lasing pump wavelengths respectively were butted onto the end-facets to form the laser cavity. The incident power threshold for lasing was found to be 83 mW and the lasing wavelength was centred at 1875 nm as seen from figure 1 (c). Relaxation oscillations were measured at different pump powers and from these an upper limit for the propagation loss was estimated to be 0.3 dB/cm [4].

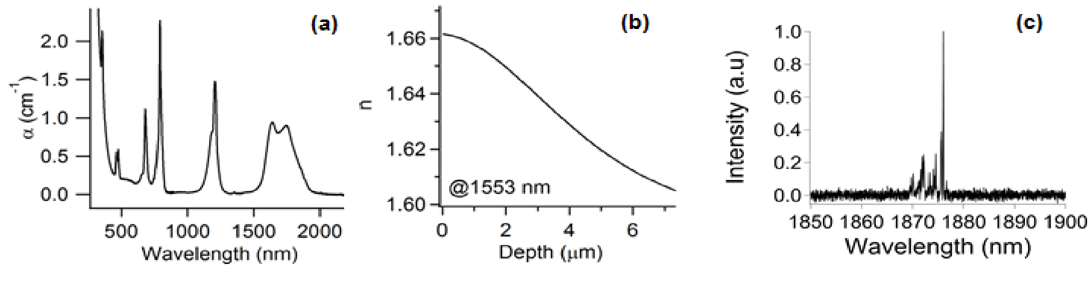

Fig. 1 (a) Absorption spectrum of Tm:germanate glass, (b) Variation of refractive index (@ 1553 nm) with depth of the waveguide and (c) laser spectrum of the Tm:germanate glass waveguide laser.

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