Waveguide Tm:Lu_2O_3 ceramic laser fabricated by ultrafast laser inscription

N. K. Stevenson[1,3], J. Morris[1,2], H. Bookey[1], A. K. Kar[2], C. T. A. Brown[3], J. -M. Hopkins[1], M. D. Dawson[1,4] and A. A. Lagatsky[1]

[1]Fraunhofer Centre for Applied Photonics, Fraunhofer UK, Technology and Innovation Centre, Glasgow, G1 1RD, UK
[2]School of Engineering and Physical Sciences, David Brewster Building, Heriot-Watt University, Edinburgh, EH14 4AS, UK
[3]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, UK
[4]Institute of Photonics, University of Strathclyde, Technology and Innovation Centre, Glasgow, G1 1RD, UK

Ultrafast laser inscription (ULI) allows the fabrication of compact, highly-efficient and robust laser sources over a broad range of crystalline, ceramic and glass gain media. For instance, subsurface waveguides can be formed by the stress induced refractive index modification effect which takes place between two parallel modified regions referred to as “Type II” guiding [1]. Previously, a family of laser hosts known as sesquioxides, namely Lu_2O_3, Sc_2O_3 and $LuScO_3$, have been shown to demonstrate efficient, high-power and tunable laser operation around the 2 μm region in both continuous-wave and pulsed regimes when doped with Tm^{3+} [2, 3]. Combining the Tm^{3+}-doped sesquioxide material properties with the ULI waveguide laser geometry provides a means to produce compact, low-threshold and efficient laser sources near 2 μm with the potential for high pulse repetition rate ultrafast operation. Here we report, to the best of our knowledge, the first demonstration of a ceramic Tm:Lu_2O_3 waveguide laser source fabricated by ULI.

The 9 mm long waveguides were fabricated in a polished 2.3×5×9 mm sample of 1 at.% Tm doped Lu_2O_3 ceramic using an ultrafast laser (Light Conversion) emitting 200 fs pulses at 500 kHz pulse repetition rate at 1040 nm. The laser beam was circularly polarised and focussed with a 0.4 NA aspheric lens 300 μm beneath the sample surface, and the sample was translated at 5 mm/s through the focus. Type II guiding was observed in the structures inscribed at pulse energies between 0.8 μJ and 3 μJ with track separations of 20 μm and 30 μm. Optimal lasing performance was found for a waveguide written with 2 μJ pulses at a 30 μm track separation.

The laser cavity was constructed with two plane dielectric mirrors mounted up against the uncoated 2.3×5 mm end facets of the sample. The input pump mirror was coated for a high reflectivity in the range of 1900 – 2100 nm and a high transmission at the pump wavelength of 795 nm, while a number of different output couplers were investigated (T=2%, 9%, 20%, 30%, 40% and 75%). The pump source was a tunable Ti:sapphire laser producing a maximum output power of 2 W at 795 nm and a polarisation orientated in the *y*-axis. The slightly astigmatic pump was coupled into the waveguide using a 20 mm focal length lens resulting in an average diameter spot size of 27.5 μm. A maximum output power of 80.8 mW at 1942 nm was generated using the 40% output coupler for an absorbed power of 1.18 W (Fig. 1). A maximum slope efficiency, assuming perfect coupling, of 9.5% was achieved at optimal conditions and thresholds were observed to be in the range of 50 – 120 mW. The pump and signal modes were imaged using commercial visible and mid-IR cameras, respectively (Fig. 2). The signal mode was calculated to have a diameter of 22.5 μm and 25.2 μm in the *x* and *y* directions, respectively. By detuning the pump source to a non-absorbing wavelength of 860 nm, a total insertion loss for the pump was estimated to be 1.6 dB. From the laser experiments the propagation loss for the laser wavelength was estimated to be 0.99 dB/cm.

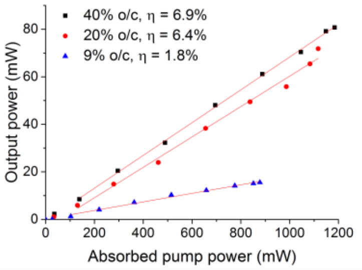

Fig. 1 Input-output characteristics of the Tm:Lu_2O_3 waveguide laser with different output couplers assuming no coupling losses.

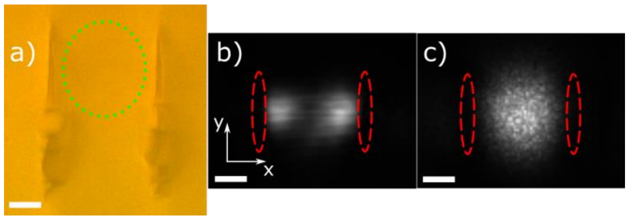

Fig. 2 a) Microscope image of a pair of tracks (separation 30 μm, pulse energy 2 μJ). b) and c) show the pump (795 nm) and the laser (1942 nm) mode images, respectively. A 10 μm scale bar is included. The green dotted circle shows the unmodified guiding region. Red dashed ellipses indicate the inscribed tracks.

References

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