CMOS-Compatible High Index Contrast Ytterbium-Doped Tantalum Pentoxide Rib Waveguide Lasers

A. Aghajani[1], G. S. Murugan[1], N. P. Sessions[1], V. Apostolopoulos[2] and J. S. Wilkinson[1]

1. Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, Hampshire. SO17 1BJ

2. School of Physics and Astronomy, University of Southampton, Highfield, Southampton, Hampshire. SO17 1BJ

Waveguide based solid-state lasers are key components in the quest to realise a compact, robust fully integrated optical circuit with advanced functionality including pulsed operation. Ta_2O_5 has been a promising host material for the realization of an integrated rare-earth doped waveguide laser as it offers many important attributes such as good ability to host rare-earth ions, a high refractive index ($n \approx 2.124$ at $\lambda \approx 980$ nm) and a large third order nonlinearity [1]. Here, we present an integrated rib waveguide laser in Yb:Ta_2O_5 with quantification of the laser slope efficiency and threshold in respect to absorbed pump power as well as presenting its lasing spectrum. Symmetrical rib waveguides with a thickness of 1 µm defined by a shallow etch of 150 nm were fabricated in Yb:Ta_2O_5 and encapsulated in silica cladding. These waveguides were designed for single mode operation for wavelengths ranging from 970 nm to 1100 nm, covering typical operational regions of Yb-doped materials. The fabrication process used conventional CMOS technologies which have been previously reported in [1], where spectroscopic characterisation of similar Yb-doped waveguides was included.

A 10.8 mm long laser cavity was formed from a high reflector (HR) mirror and an output coupler (OC), affixed to the end facets. Demonstration of lasing was achieved with two different output couplers with transmission properties of 5% and 10%. To determine the characteristics of the waveguide laser, a 977 nm pump source was focused into the end facet of a 5.4 µm wide waveguide using an aspheric lens (NA = 0.68). Light emerging from the output was collected using another aspheric lens (NA = 0.68) and passed through a set of long pass filters with a cut-off wavelength of 1 µm to remove the residual pump radiation. The lasing output power is plotted against the absorbed pump power and is shown in Fig. 1a for the two mirror configurations. For a mirror configuration comprising of a 5% OC the laser threshold and slope efficiency were measured to be ~20.2 mW and 1.1%, while for a 10% OC the slope efficiency improved to 2.3% but required a higher threshold of ~32.5 mW. A spectrum with 5% OC was measured using an optical spectrum analyser and showed lasing occurring for wavelengths between 1015 nm to 1030 nm as seen in Fig. 1b.

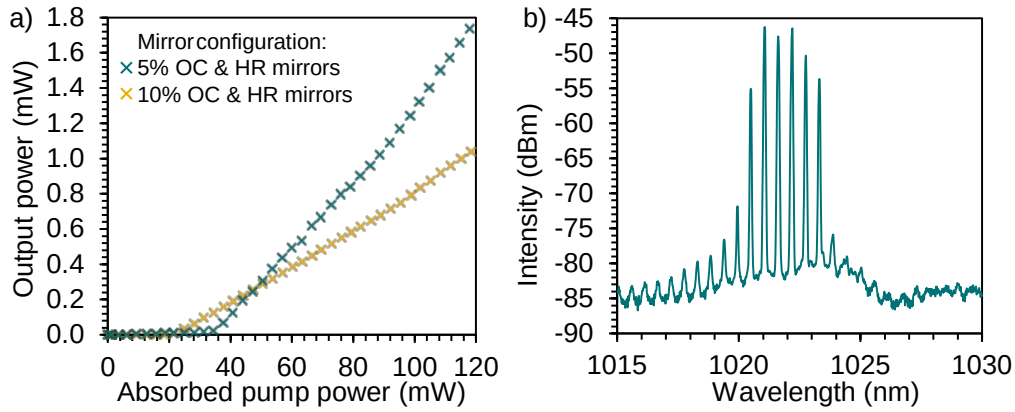

Fig. 1. a) Laser output power vs absorbed pump power plotted for different mirror configurations with a calculated coupling efficiency of 46.6 %, b) Lasing spectrum of Yb:Ta_2O_5 for cavity form with a HR mirror and a 5% OC.

In conclusion, we have demonstrated an Yb:Ta_2O_5 rib waveguide laser fabricated by RF magnetron sputtering on a silicon wafer, and determined its lasing characteristics. Lasing was observed with different mirror configurations for wavelengths between 1015 nm and 1030 nm while end-pumped with a 977 nm laser diode. The absorbed pump power threshold and slope efficiency were measured to be 20.2 mW and 1.1% for 5% OC and 32.5 mW and 2.3% for 10% OC, respectively. The waveguide laser demonstrated here, provides a low cost mass producible platform to develop monolithically integrated components where functionality can be added, such as ring resonators exploiting the high index contrast and high third order nonlinearity of tantalum pentoxide for modelocking or frequency comb generation [2].

References

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