Towards Fabrication of 10 W Class Planar Waveguide Lasers: Analysis of Crystalline Sesquioxide Layers Fabricated via Pulsed Laser Deposition

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Planar waveguides lasers are compact, power-scalable devices that have excellent thermal management properties owing to their high surface area to volume ratio [1]. However, the fabrication of these waveguides can be labour-intensive. A simple, versatile technique known as pulsed laser deposition combines tailored, uniform planar layer deposition with relatively high growth rates approaching 5μm per hour for our set-up. In this technique, a target material is ablated by a laser pulse, with the resultant plume incident onto the surface of a single-crystal substrate on which single crystal layers can grow [2]. We will present both the X-ray diffraction (XRD) analysis and laser performance of ytterbium-doped crystalline yttria (Yb:Y_2O_3) and undoped crystalline yttria thin films, grown on a variety of substrates using a 248 nm, 20 ns pulsed excimer laser operating at a repetition rate of 20 Hz.

XRD using a Rigaku Smartlab X-ray diffractometer was performed on the waveguides, including a Yb:Y_2O_3 planar waveguide capable of producing 1.2 W when diode-end-pumped using a 8.5 W pump [3]. XRD data for a single layer of Yb:Y_2O_3 grown on <100> YAG is displayed as a (222) pole figure with <111> orientation in Fig. 1(a), showing the film has highly ordered crystalline structure. Owing to the possibility of multiple orientations for lattice matching in the <111> direction, the growth of a crystal layer with a single domain orientation is difficult and so multiple domains of crystal growth occur, with the possible domain orientations shown in Fig. 1(b). The existence of these four different domain orientations within the thin crystal layer lead to structural inhomogeneity, as observed in scanning electron microscope analysis, and likely contributed to a higher optical loss compared with that expected from a single-domain sample.

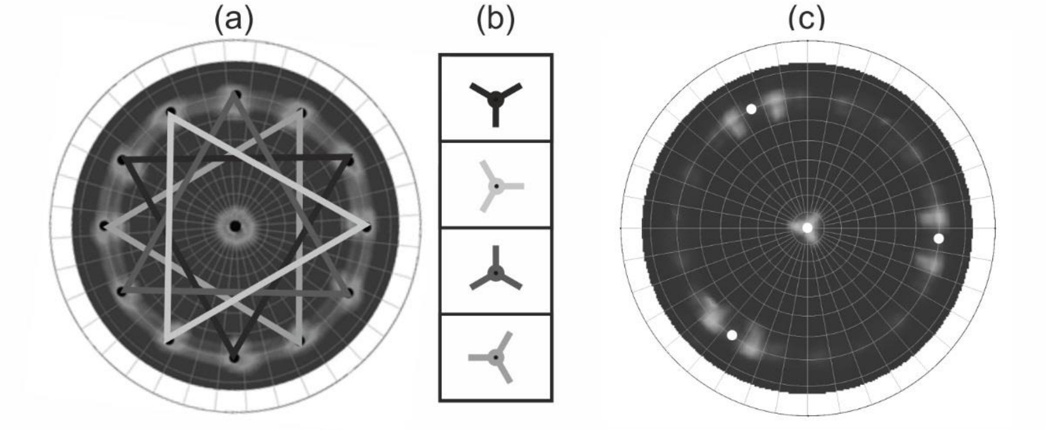

Fig. 1 (a) Pole figure of single layer Yb:Y_2O_3 grown on <100> YAG with overlay (black dots) of predicted (222) pole figure with <111> orientation and 4 possible domain orientations (b) 4 possible domain orientations (c) Pole figure of single layer Yb:Y_2O_3 grown on <111> YAG with overlay (white dots) of predicted (222) pole figure with <111> orientation.

A pole figure of Yb:Y_2O_3 grown on <111> YAG, in which only one orientation can potentially lattice match, is shown in Fig. 1(c), and displays splitting of the XRD peaks, and the waveguides show higher optical propagation loss. This is due to the greater lattice mismatch between the cladding and the guiding layer than in the case of Yb:Y_2O_3 grown on <100> YAG allowing slight shifts in the orientation of the growth. Analysis of undoped thin films, such as PLD-grown yttria on a single crystal yttria substrate, show that when there is little or no lattice mismatch with only one potential lattice orientation match, there is a single domain growth with expected well-defined XRD peaks, meaning that, as will be reported, correct substrate crystal orientation choice combined with good lattice match between cladding and doped guiding layer is likely to be necessary for single crystal growth and thus efficient lasing output of ~10 W, our intended near-term target.

References

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