Waveguiding thin Y_2O_3 films grown on sapphire substrates

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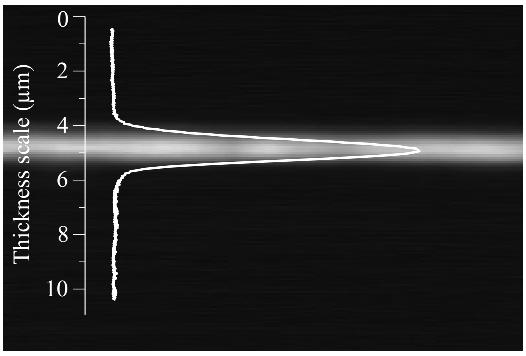
Miniaturization of optical technologies creates a demand for high-quality waveguiding devices. Yttria (Y_2O_3) is a promising material for integrated optics, because it is a good host for rare-earth-ion doping and, furthermore, yttria has excellent mechanical properties and high thermal conductivity. Laser action was also demonstrated in rare-earth-ion doped yttria.[1,2] In this work, thin yttria films were deposited on top of sapphire substrates and their waveguiding properties were studied.

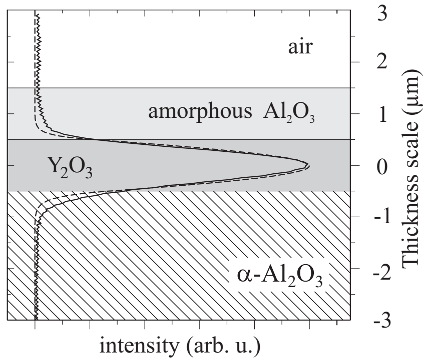
The yttria films were grown using two different methods: crystalline yttria films by pulsed laser deposition (PLD) and amorphous yttria films by electron beam evaporation (EBV). The films were grown on <0001> oriented sapphire substrates. This provides a good lattice matching for <111> oriented yttria, which has a cubic structure. The thickness of the PLD-films reached 800 nm. X-ray diffraction (XRD) experiments confirmed good crystallinity and <111> orientation of the yttria PLD-films. The thickness of the amorphous EBV-deposited yttria layers was 1 µm. Also a 1-µm thick amorphous Al_2O_3 cover layer was deposited on top of an yttria film in order to reduce scattering at the film surface and to make the waveguide symmetrical.

Planar waveguiding experiments were performed with the EBV-films. Both end faces were polished and an Ar-ion laser operating at 488 nm was coupled into the waveguide using an optical fiber. The output end of the waveguide was imaged onto the sensor of a CCD-camera using a 40x microscope objective. Planar waveguiding in the yttria film was achieved. The waveguide is depicted in Fig. 1a. The mode size measured at $1/e^2$ of the peak intensity is 1.4 µm. The transverse intensity distribution of the guided mode almost coincides with the modal intensity distribution calculated from Maxwell's equations (Fig. 1b). Some small deviations can be observed at the periphery, possibly due to the assumption in our calculation that the refractive index of the amorphous yttria film is equal to the refractive index of crystalline yttria (n = 1.93 @ 488 nm), although it is expected to be slightly lower.

Future work will be aimed at the study of the correlation between process parameters and waveguiding properties of PLD and EBV films, the demonstration of waveguiding in yttria PLD-films and achieving channel waveguiding. The goal is to fabricate waveguides with minimum loss and mode dimensions in order to demonstrate waveguide laser operation in doped yttria films.



(a)



(b)

Figure 1. a) Image of the end surface of a guiding yttria EBV-film and transversal intensity distribution profile. b) Experimental (solid line) and calculated (dashed line) intensity profiles in yttria film

1 Fornasiero, L.; Berner, N.; Dicks, B.-M. et al., Advanced Solid-State Lasers, OSA Trend in Optics and Photonics Series (Optical Society of America, Washington, D.C. 1999), Vol. 26, pp. 450-453.

2 Mix, E.; Fornasiero, L.; Heumann, E. et al., Technical Digest. Conference on Lasers and Electro-Optics. (Optical Society of America, Washington, D.C. 1999), p.392.