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$Nd:LaF_3$ Waveguide Laser Fabricated by Molecular Beam Epitaxy

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Abstract

We describe the first demonstration of laser action in a dielectric waveguide grown by molecular beam epitaxy. Laser emission at 1.063µm is obtained from a $Nd:LaF_3$ thin film grown on a CaF_2 substrate.

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Summary

The fabrication and study of rare-earth-doped thin films is an active area of research for applications in integrated optics and novel laser sources. Here we report, for the first time, laser action in rare-earth-doped fluoride waveguides fabricated by molecular beam epitaxy (MBE). The MBE fabrication technique allows very accurate control of the thin-film growth parameters such that precise, multi-layer, waveguide structures can be produced. It also offers the potential for novel active waveguide design, e.g. a controlled doping profile for laser ions and/or refractive index change. The ability to make rare-earth-doped, fluoride, thin films by MBE was first demonstrated by Bausa et al[1], and following work demonstrated how MBE can be used to grow such films on GaAs or Si substrates[2] indicating a potential for integration. Fluoride hosts are attractive due to their low phonon energies, offering the possibility of lasing from energy levels that suffer from efficient non-radiative decay in oxides, a transmission window that extends to longer wavelengths, and the potential for upconversion pumping mechanisms.

In our current work we have used MBE to grow $Nd:LaF_3$ thin films, with CaF_2 cladding layers, on CaF_2 substrates. Low thresholds (~10mW) and high slope efficiencies (~50%) have

previously been demonstrated in bulk Nd:LaF_3 end-pumped lasers operating at 1.06μm[3] .The MBE growth of Nd:LaF_3 on GaAs waveguides has also been previously studied[4] but no laser action was obtained due to high propagation losses.

The guide used in these experiments had a 3.6μm deep Nd:LaF_3 core with a 0.5μm CaF_2 cladding layer. It was cut and end-polished to a length of 7.5mm. The fluorescence and absorption spectra of the films were found to be consistent with those reported in the literature for bulk material, and the measured fluorescence lifetime of ~450μs is similar to that found in bulk material with a Nd doping level of ~3at.%. The laser cavity was constructed by butt-coupling two plane mirrors to the end-faces of the waveguide and a Ti:Sapphire laser was used as the pump source. The pump beam was shaped by two cylindrical lenses and then coupled into the guide by a X20 microscope objective such that a line focus was produced at the input face of the guide. This set-up allows the spot sizes in the guided and non-guided dimensions to be independently optimised. The input mirror was HR at 1.06μm and high transmission at the pump wavelength, and the laser performance with various reflectivity output couplers was investigated. TM polarised (parallel to the c-axis) laser emission was obtained at 1.063μm with thresholds as low as 85mW. Using a 23% output coupling we obtained an 11% slope efficiency with output powers of nearly 30mW. The variation of the threshold with the output coupling suggests a waveguide propagation loss at 1.06μm of 1.2dB/cm. Having obtained this first laser result, future work will initially concentrate on further lowering the propagation loss and creating channel waveguides by ion-milling.

E.Daran, D.P.Shepherd, T. Bhutta and F.Lahoz: Nd:LaF_3 Waveguide Laser

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