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A low-loss pulsed laser fabricated garnet waveguide laser

C. Grivas, T.C. May-Smith, J. Wang, D.P. Shepherd, and R.W. Eason
Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, United Kingdom

Planar waveguide lasers have attracted increased attention in the recent years, particularly with a view to developing high average power diode-pumped solid state lasers. For diode-pumped schemes, the planar waveguide design can address requirements for optimal laser performance such as efficient coupling of the diode bar pump light into the guide due to both the excellent geometric match of the pump beam to the profile of waveguide facet as well as the possibility to confine non-diffraction limited beams by designing high numerical aperture structures, control of the spatial output of the waveguide by introducing design schemes such as double-cladding, large-mode-area waveguides, multimode interference as well as tapers and unstable resonators [1]. The planar geometry is also ideal for efficient thermal handling and therefore, circumvention of problems such as thermal lensing, birefringence and fracture and in combination with a suitable fabrication technique, such structures can show with low propagation losses.

In an attempt to develop thick waveguiding layers as laser sources, which would combine characteristics such as high numerical apertures (NA) together with low propagation loss, we report here pulsed laser deposition of epitaxial, single crystal Nd:$Gd_3Ga_5O_{12}$ (Nd:GGG) films on $Y_3Al_5O_{12}$ (YAG) substrates with thickness up to 135 μm. Rutherford Backscattering Spectrometry (RBS) has shown constant stoichiometry for the films throughout their depth [2] . A laser threshold of 18 mW of absorbed pump power has been obtained and lasing action has been observed at 1060.6 nm for pump powers close to the lasing threshold, and at both 1059.0 and 1060.6 nm at pump power levels of approximately 1.5 times above threshold. A slope efficiency of 17.5% was derived using an output coupler with a transmission of 4.5%. The propagation losses of these structures were as low as 0.1 dB/cm , which we believe to be the lowest levels ever recorded in laser fabricated waveguides [3]. The combination of low propagation losses and high NA (0.75) for the waveguides indicates the potential of the fabrication technique to produce high quality thick multi-layer waveguides.

Further work is currently being carried out towards the development of three-layer geometries and at a later point of multilayered structures with the aim to develop a high power amplifier/ laser that delivers diffraction-limited output from a multimode waveguide. Three-layered structures are suitable for self-imaging devices (Figure 3). The operation of such devices is based on the fact that an optical beam of a given spatial profile will periodically re-image within a highly multimode thick waveguide. This scheme offers the possibility to increase the cross-sectional area of the waveguide and therefore achieve power and energy scaling by reproducing any desired beam profile.

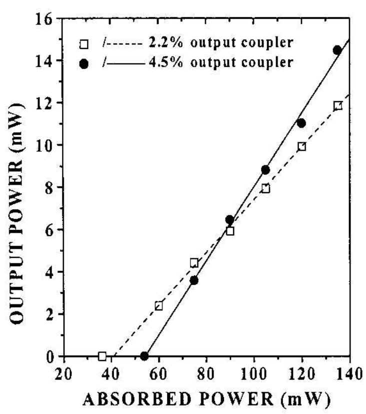

Fig. 1. Dependence of the output power as a function of the absorbed power for two output couplers: (□) 2.2% and (●) 4.5% transmission respectively

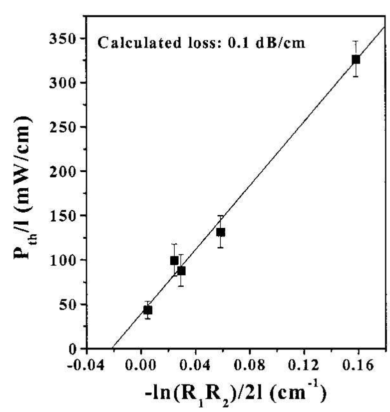

Fig. 2. A plot of P_{th} / l as a function of -ln(R_1R_2) / 2l . The position of the intercept on the x axis yields the propagation attenuation coefficient (α_L~0.02 cm^{-1})

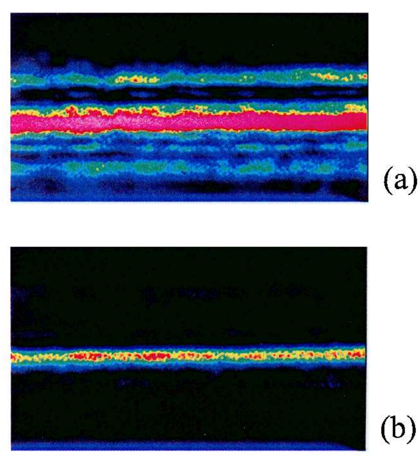

Fig. 3. Propagation in a 40 μm thick Nd:GGG waveguige (a) without and (b) with self-imaging

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[2] T.C. May-Smith, C. Grivas, D.P. Shepherd, R.W. Eason, Appl. Surf. Sci. **223**, 361, (2004)
[3] C. Grivas, T.C. May-Smith, D.P. Shepherd, R.W. Eason, Opt. Commun. **229**, 255, (2004)