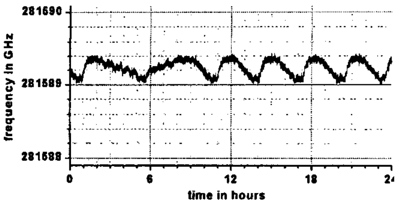

CFH3 Fig. 3. Frequency change during thermal vacuum test for a temperature range from –40°C to +40°C.

remained in a 400 MHz range without any active temperature compensation electronics.

All tests were sucessfully passed, even mechanical shocks with 1500 g in 3 axes had no influence on the optical or electrical performance of the device.

Conclusion

Full suitability for space applications of an ultra stable NPRO Laser Transmitter has been successfully demonstrated for the first time with an extensive space environmental test program. All tests were passed successfully.

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CFH4 **11:00 am**

Amplification of cw and high repetition rate pulsed radiation in an ultra-compact Nd:YAG planar waveguide power amplifier, face-pumped by diode bars.

G.J. Friel, J.R. Lee, H.J. Baker and D.R. Hall, *Department of Physics, Heriot-Watt University, Riccarton, Edinburgh. EH14 4AS; E-mail: H.J. Baker@hw.ac.uk*

Recently we have reported operation of the planar waveguide type of Nd:YAG laser at up to 121 W cw output, using a 200 mm thick, 1.1 % at. Nd doped active layer, diffusion bonded to 400 μm non-doped YAG claddings.[1,2] This is face-pumped by ten cw diode bars in a configuration using a slotted -mirror pump chamber.[3] The waveguide section is 11 mm × 60 mm in area, with 50 mm pumped length. To demonstrate the power output and efficiency, the waveguide laser has initially been operated with external plane mirrors in a multi-mode cavity, showing that the laser is capable of sustaining continuous pumping without damage when mounted in a water cooled transverse flow pump chamber. An overall optical conversion efficiency of 28% has been achieved.

In this paper we emphasise the excellent amplifier capabilities of the planar waveguide format. The active layer is currently pumped with a power density of 4 kW.cm^{-3}, very much larger than conventional bulk rod and slab lasers. Consequently the cw gain coefficient is high, making the planar waveguide an ideal candidate for amplification of the low power diode pumped Nd:YAG now available using mini-rod or microchip configurations. These offer excellent beam quality and are readily matched to the fundamental transverse waveguide mode of the amplifier. Initially we have used a 200 mW cw source laser with M^2<1. 2 to characterise cw gain coefficients, beam quality preservation and polarisation characteristics. In single-pass measurements, the gain coefficient is measured at between 25 and 32 m^{-1} at full pump power. The transmitted beam quality in small signal amplification is only weakly dependent of pump power, with a transverse value of ~1.7. The linear polarisation is unchanged by amplification to within measurement uncertainty. These results show that the planar waveguide amplifier, which supports many modes in the 200 μm thick core, can operate as a high beam quality source, largely unaffected by pump level variations, when correctly coupled to a single transverse mode source.

To exploit these characteristics, we are currently investigating a MOPA system, consisting of the 200 mW cw source laser and alternatively a passively Q-switched microchip laser, an isolator and multi-pass optics for the amplifier. In the Q-switched case, the typically 1 ns duration, 20-40 kHz pulse rate of the source will have average power characteristics similar to the cw case, but realise pulse energies typically 100 times the present microchip laser energy, giving peak powers suitable for micro-machining applications. The beam folding system uses 5 passes through the amplifier with a continuously diverging beam in the lateral direction, combined with transverse mode maintaining optics in the transverse direction. It is expected that further development of this approach will provide an ultra-compact, high beam quality laser source to powers beyond 100 W.

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CFH5 **11:15 am**

Ti:sapphire planar waveguide coherent broadband emitter

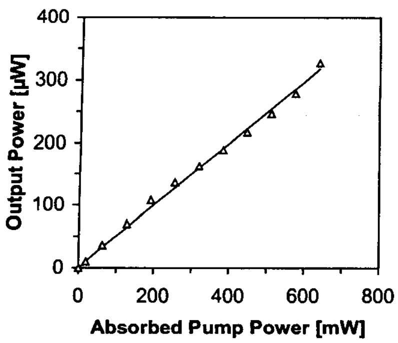
T. Bhutta,[1] R.P. Salathé,[2] D.P. Shepherd,[1] R.W. Eason,[1] and M. Pollnau,[2] *1) Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, United Kingdom; 2) Institute of Applied Optics, Department of Microtechnique, Swiss Federal Institute of Technology, CH-1015 Lausanne, Switzerland; Email markus.pollnau@epfl.ch*

In recent years, broadband fiber interferometers have become very popular as basic instruments used in optical coherence tomography (OCT) for imaging applications in the biomedical field.[1] A major challenge in the further development and applicability of OCT has been the improvement of both its spatial resolution and dynamic range. The longitudinal resolution is inversely proportional to the optical bandwidth of the light source. Broadband luminescence from transition-metal-ion doped materials (e.g., Ti:sapphire) can significantly improve the longitudinal resolution[2] compared to superluminescent diodes (~30 nm FWHM), but the low brightness of its luminescence is insufficient for achieving a useful dynamic range in OCT. Femtosecond lasers have, therefore, been used as large-bandwidth high-brightness light sources, and subcellular imaging has recently been demonstrated in this way.[3] However, current femtosecond light sources do not necessarily meet the requirements of compactness, ease of use, and low cost.

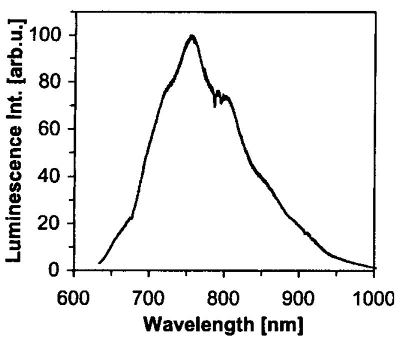
We present here a simple broadband light source based on a Ti:sapphire planar waveguide. It operates in a wavelength region near 800 nm, applicable to the investigation of biotissue and detectable with simple silicon diodes, with a bandwidth comparable to that of a femtosecond light source. We generate output powers of several hundreds of μW with high transverse confinement. This level of brightness is several orders of magnitude larger than that obtained from simple broadband light sources based on black-body radiation, whose output power in a single mode is in the sub-μW range.[4] With this brightness, a luminescent light source can provide a dynamic range in OCT that is sufficient to replace a femtosecond light source in a number of applications.

The Ti:sapphire planar waveguide investigated was grown by pulsed laser deposition[5] and contained approximately 0.1 wt.% of Ti$_2$O$_3$. The dimensions were 9 mm in length and approximately 10 μm in thickness. The sample was pumped by an all-lines continuous-wave 1-W Ar-ion laser. The pump light was focused into the guiding layer by a × 16 microscope objective. The coupling efficiency was 85%. The effective absorption length was 3.0 mm, leading to 95% of the launched pump light being absorbed.

Measurements of the output power (Fig. 1) were taken with an incoupling mirror only, which transmitted approximately 86% of the pump light. The maximum output power was 318 μW, with a corresponding slope efficiency of 5×10^{-4}. The spectral bandwidth of the output spectrum (Fig. 2) was ~132 nm FWHM. While the reflectivity of the incoupling mirror was largest around 730 and 870 nm, the largest increase in spectral output power compared to a measurement without incoupling mirror oc-



CFH5 Fig. 1. Input-output curve of the Ti:sapphire planar waveguide.



CFH5 Fig. 2. Luminescence spectrum (~132 nm FWHM) of the Ti:sapphire planar waveguide.

curred in the Ti:sapphire gain maximum around 800 nm, indicating that a small gain was present in the one-mirror waveguide configuration. The luminescence mode profile in the unconfined axis was concentrated within an angle similar to that of the diverging single-mode pump beam. In the confined axis, the output was single-mode. Single-mode operation is a requirement for efficient coupling into a single-mode fiber interferometer for OCT.

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CFH6 **11:30 am**

End-Pumped Double-Clad Waveguide Laser

J.I. Mackenzie, C. Li, and D.P. Shepherd, H.E. Meissner,* *Optoelectronics Research Centre, University of Southampton, Highfield, Southampton SO17 1BJ, U.K.; Email:dps@orc.soton.ac.uk, *Onyx Optics Inc., 6551 Sierra Lane, Dublin, California 94568, USA*

The use of a double-clad guiding structure to allow efficient pumping by non-diffraction-limited high-power diodes, and yet still obtain diffraction-limited laser output, has been extensively studied in optical fibres[1]. Recently, a one-dimensional version of this technique has been applied to planar waveguides, allowing the development of very compact, proximity-coupled, diode-bar side-pumped waveguide lasers[2]. CW powers of >10W have been obtained in this way[3] but, with the use of a monolithic plane/plane cavity, the output is still highly non-diffraction-limited in the non-guided direction. Here we investigate the use of similar double-clad structures end-pumped by a 4W broad-stripe diode obtaining >1W in a beam with measured M^2 values of 1.0 by 1.8. Figure 1 shows the waveguide structure used in these experiments.

The 1cm long guide was fabricated by direct bonding by Onyx Optics. The 4W 808nm broad-stripe diode laser was obtained from Boston Lasers and has an emission width of 200µm. After fast-axis collimation the diode had measured M^2 values of 4 by 40 in the fast and slow axes respectively. The large numerical aperture (NA) sapphire/YAG guide can easily contain the focused diode light, which is gradually absorbed by the central doped region. In contrast to double-clad fibres, where a strictly single mode core is normally used at the expense of a large increase in the absorption length, here single guided mode laser operation is obtained due to the restriction of the gain to the central region of a multimode composite guide. This design allows a much smaller increase in absorption length and so is more suited to compact planar devices. Due to the better beam quality of the broad stripe diode in the slow axis compared to diode bars, simple cylindrical lens focusing can lead to efficient end-pumping with a relatively narrow gain region, allowing near-diffraction-limited output from a plane/plane monolithic cavity. Initial results have given M^2 values of 1.0 by 1.8 in the guided and non-guided planes for operation at 1.064µm, with output powers of up to 1.3W. Figure 2 shows a typical output mode imaged onto a CCD camera.

Lasing at 946nm and 1.32µm has also been demonstrated and, without optimization of the output coupling, >0.5W and >0.3W of output power have been obtained respectively. Increasing the output power to several Watts by polarization coupling of two pump diodes, the use of integrated components such as passive q-switches[3] to increase functionality, and moving to wavelengths which can be harder to produce as bulk lasers such as 3µm Er:YAG, could make this an attractive option for compact laser sources.

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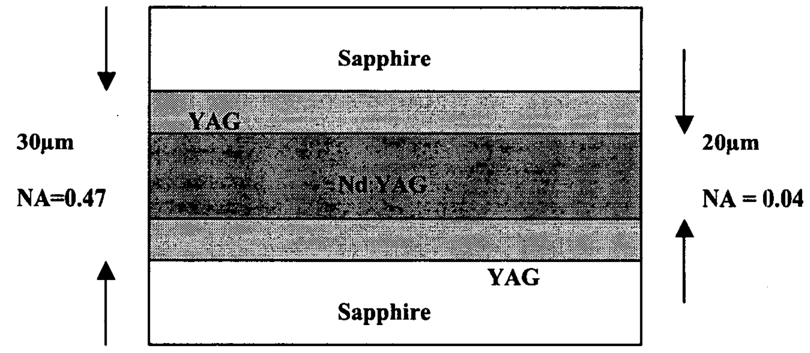
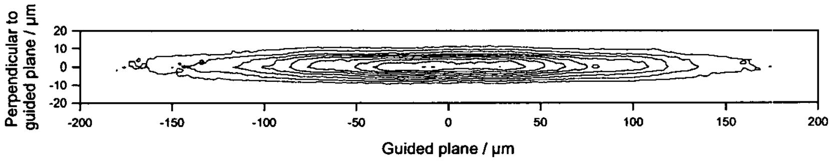


CFH6 Fig. 1. Double-Clad Planar Waveguide Structure.



CFH6 Fig. 2. Output mode profile imaged on a CCD camera.