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/cm², 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. This offers excellent beam quality and are readily matched to the fundamental transverse mode of the amplifier. Initially we have used a 200 mW cw source laser with M²<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/W at full pump power. The transmitted beam diameter at the amplifier output 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-machning 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 10 W.


References

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

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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 cladding. This is face-pumped by ten cw diode bars in a configuration using a slotted ‘mirror’ pump chamber. The waveguide section is 11 mm x 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.
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. 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. CW powers of >10W have been obtained in this way 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 broadstripe diode obtaining >1W in a beam with measured M² 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 broadstripe diode laser was obtained from Boston lasers and has an emission width of 200μm. After fast-axis collimation the diode had measured M² 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 M² 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-switchers 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.

References