Mode-controlling in a diode-side-pumped, short-cavity Nd:YVO_4 laser with 74% slope efficiency

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Recent achievements in high efficiency diode-side-pumped resonators have demonstrated the usefulness of the bounce configuration, which incorporates a total internal reflection in grazing incidence angle at the pump face [1]. A slope efficiency of 72% and optical-to-optical efficiency of 68% have been achieved in multimode operation and up to 23 W in TEM_{00} operation using a single diode bar [2,3]. In all cases, the cavity set-up involves difficult to align optics, mostly cylindrical intracavity lenses. This makes the cavity difficult to stabilize in face of the very strong thermal lens in the y-direction, which is of the order of a few centimetres.

We developed, to out knowledge, the most compact, diode-side-pumped, grazing incidence angle Nd:YVO_4 resonator so far reported. Its total length is less than 7.6 cm. It uses easy to align spherical optics and generates up to 22 W of output power in multi-mode operation for a maximum input power of 34.9 W. The slope efficiency is 74% and the highest reported to our knowledge for this kind of cavity. This single-bounce resonator uses a 50 cm radius of curvature high reflector (M1) and a flat output coupler with 36% transmission (M2), symmetrically disposed around the gain media with 1.1 mol% neodymium doping, dimensions of 22 x 5 x 2 mm^3 and 5º angled edge faces. Grazing incidence angle is 5º. A maximum of 35 W of 808 nm pump radiation is focused in the y-direction with a f = 6.4 mm focal length cylindrical lens into the crystal.

TEM_{00} operation is obtained by special mode-controlling as is explained next: Due to the high absorption cross-section of Nd:YVO_4 (30cm^{-1}), the pump-induced population inversion is limited to a short layer behind the pump facet. The laser operates in TEM_{00} mode as long as its overlap integral with the inversion is higher than for the next higher order mode (TEM_{10}). This is easily achieved with cylindrical intracavity optics that result in a large TEM_{00} mode in the x-direction, but not with spherical optics, as is our case. We therefore inserted a third, flat high reflector (M3) immediately before mirror M2 with the purpose to achieve a broadening of the area occupied by the TEM_{00} mode in the x-direction and therefore a better overlap with the inversion.

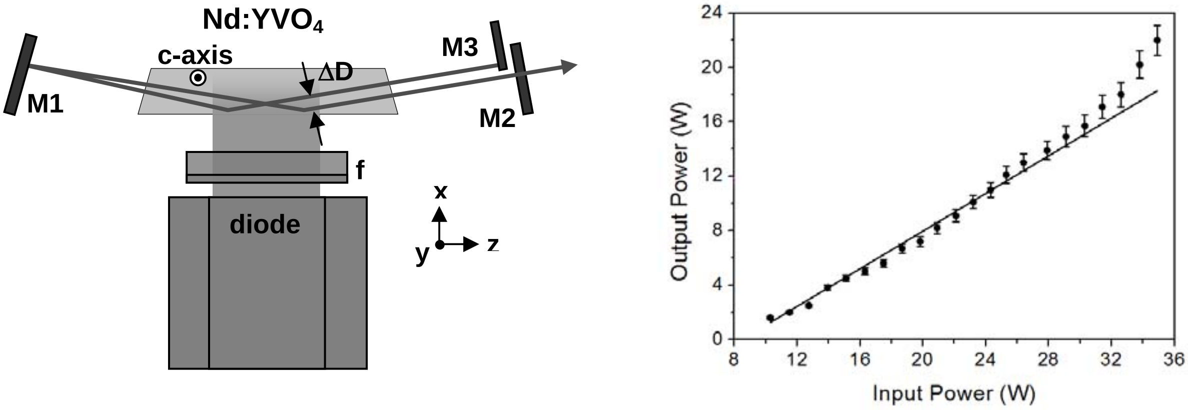

Fig. 1 Left: Double bounce cavity configuration. The single bounce configuration is without mirror M3. Right: Output power and efficiency versus diode pump power for the single bounce configuration.

Tuning of the distance ΔD between the two beams inside the active media is very important. If the beams are too far apart, there is enough inversion between both beams to permit higher order mode oscillation and if they are too close, the inversion farther away from the pump facet is also enough to allow for higher order modes. This behaviour is easily observed: when increasing ΔD from 0.3 mm to 2 mm, the beam passes from multimode operation to TEM_{00} and back to multimode. Stable single-transversal mode operation is obtained from 0.6 mm to 1.1 mm. The highest output power is obtained in the middle of this interval in TEM_{00} mode and is higher than for multimode operation outside this interval. With this double bounce configuration, we achieve 17 watt and a significant improvement in beam quality, resulting in a M^2 of 1.7 x 1.4 in the horizontal and vertical directions, respectively.

References

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