Direct comparison of the thermal lenses of diode-end-pumped Nd:YVO_4 and Nd:$GdVO_4$ lasers using a simple evaluation technique

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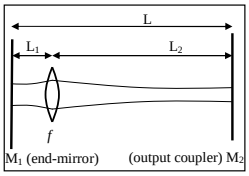
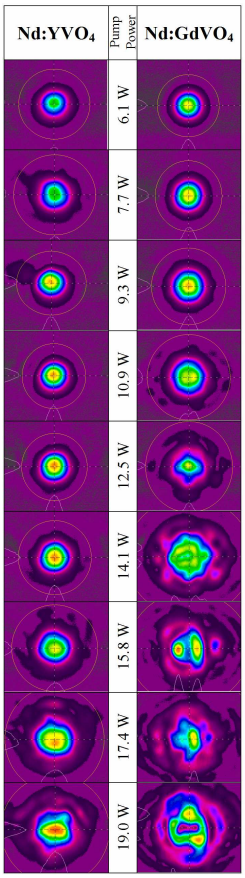


Knowing the pump-induced thermal lens of a laser material is crucial for the design of high-power diode-end-pumped solid-state lasers. The thermal lens depends on a number of parameters, including material properties such as the thermal conductivity, *dn/dT* and the absorption and emission cross sections at the pump and laser wavelengths. However, the published values for these properties vary in the literature. This is especially true for the thermal conductivity of the relatively new laser material Nd:$GdVO_4$. A design based only on calculated values of the thermal lens of Nd:$GdVO_4$ will be uncertain and a comparison with Nd:YVO_4 will be inconclusive. An alternative approach is to evaluate the thermal lens inside a laser under the same pumping and cooling configurations as it will be employed in the high-power laser to be designed.

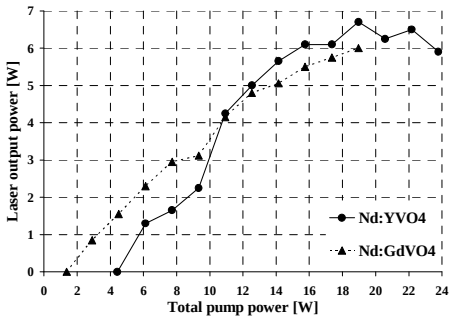
In this work, the thermal lenses generated in diode-end-pumped Nd:YVO_4 and Nd:$GdVO_4$ lasers were evaluated and compared using a simple technique based on the stability criteria of a plane-parallel laser resonator [e.g. 1], as shown in the top figure. The general stability parameters still hold for this resonator with a thin thermal lens close to the end-mirror of the cavity [2]. By increasing the pump power into the laser crystal, the resonator will become unstable when the thermal lens length is equal to the fixed length L_2, at the point where the stability criterion $0<g_1g_2<1$ no longer holds.

Additional considerations were made while using this technique to avoid ambiguous and incorrect results. The fundamental resonator mode size on the end-mirror (M_1) was calculated for a decreasing thermal lens focal length *f* up to the point of instability. With this information, the pump beam radius of 375 μm was chosen for the resonator lengths L_1 = 30 mm and L_2 =123 mm. This was to ensure high overlap efficiency of the pump beam and resonator mode inside the laser crystal. Just before the point of instability where the fundamental mode in the crystal approaches infinity, the overlap efficiency became poor which resulted in a decrease of laser output power and beam quality.



The second aspect considered was the high gain of both Nd:YVO_4 and Nd:$GdVO_4$ which allowed the laser to operate even when the resonator was well within the unstable region. The increasing thermal lens strength did not necessarily result in a decrease in output power, even when it was beyond the stability point of the resonator and operated as an unstable resonator. Because of this, the laser beam profile was also monitored while increasing the pump power into the laser. Analysis of this measurement served as an essential indicator of when the resonator became unstable, and it indicated the point where the overlap between the resonator mode and the pump beam became poor.

It can be seen from the experimental data that the 0.27 % (at.) doped Nd:YVO_4 and Nd:$GdVO_4$ lasers produced different results when pumped from both ends with 30 W fibre-coupled laser diodes in the same resonator and cooling configuration. The Nd:$GdVO_4$ laser experienced a detrimental change in its beam profile at a total pump power of 10 – 11 W where it produced 4 W of continuous wave output power. The same detrimental effect for Nd:YVO_4 only appeared at a pump power above 14 W where the output power was 5.7 W. It was concluded that the thermal lens in Nd:$GdVO_4$ was stronger than in Nd:YVO_4 at the same pump powers. It is clear from the results presented here that the output power still increased after the point of instability, and that both lasers operated in an unstable mode at high pump powers.



It was concluded that the point where the laser slope efficiency decreases to zero or becomes negative cannot be used as the decisive indicator for the instability of the plane-parallel resonator. The beam profile also needs to be considered to evaluate the thermal lens. It was demonstrated that this simple technique can be a reliable tool in comparing the thermal lens behaviour of high-power diode-end-pumped Nd:YVO_4 and Nd:$GdVO_4$ lasers.

[1] F. Song *et al.* Applied Physics Letters **81** (12) 2145-2147 (September 2002).
[2] W. Koechner "Solid-state laser Engineering" 5th rev and updated ed. Springer-Verlag (1999).