Comparative Study of Thermal Lensing in Low-doped $Nd:YVO_4$ and $Nd:GdVO_4$ of Equal Doping Concentration

H. J. Strauss[1,2], C. Bollig[1], H. M. von Bergmann[2] and M. J. D. Esser[1]

1. National Laser Centre, Council for Scientific and Industrial Research, PO Box 395, Pretoria 0001, South Africa

2. Laser Research Institute, Stellenbosch University, Stellenbosch 7600, South Africa

$Nd:GdVO_4$ is a relatively new laser material with spectral properties very similar to those of $Nd:YVO_4$. It was initially reported that it had almost twice the thermal conductivity of $Nd:YVO_4$, and therefore was said to reduce negative thermal effects. Sato and Taira [1] recently re-measured the thermal conductivity and its temperature dependency and found that it was significantly lower than that of $Nd:YVO_4$. They also reported that dn/dT in the higher gain π-polarisation of $Nd:YVO_4$ is 7.92 at 1064 nm, compared to 10.1 for $Nd:GdVO_4$. One would therefore expect that $Nd:YVO_4$ would have weaker thermal lensing, since it is influenced by both the thermal conductivity and dn/dT. To our knowledge, a direct comparison of the thermal lens of the two materials has never been performed with equal doping concentrations and dimensions. Therefore, we aimed to compare the two materials directly under diode-end-pumping by performing thermal lens measurements during lasing with a HeNe probe beam using identical low-doped (0.15%), 4x4x18 mm^3 crystals. Our setup was such that we could separately analyse the dioptric powers in the σ and π polarisations.

The measured dioptric powers for the two polarisations of both materials are shown in Figure 1 as a function of absorbed diode pump powers at relatively high levels. We observed that for both polarisations the thermal lens of $Nd:YVO_4$ is weaker than that of $Nd:GdVO_4$. It is also shown that it is much stronger in the σ polarisations than in the π polarisations in both crystals. Also plotted in red are the dioptric powers of the π polarisation of $Nd:YVO_4$ measured under *non*-lasing conditions. It is significant that there is almost no difference between non-lasing and lasing dioptric powers, which indicates that upconversion is negligible, probably due to the low doping concentration of the crystals. Similar results were obtained for $Nd:GdVO_4$.

There are a number of values in the literature for dn/dT of the $Nd:YVO_4$ π polarisation at 1064 nm, ranging from 3.92×10^{-6} to 10.4×10^{-6} [1-3]. In addition, most manufacturers' data sheets state a value of 3×10^{-6}. In order to validate this, we performed thermal lens measurements at 1064 nm using a modified version of Neuenschwander's method [4]. This entails characterising the TEM_{00} output beam and then calculating what the thermal lens is in the laser crystal. By using TEM_{00} beams of ~65% of the size of the pump beam in the crystal, we effectively measured only the relatively unaberrated central part of the thermal lens.

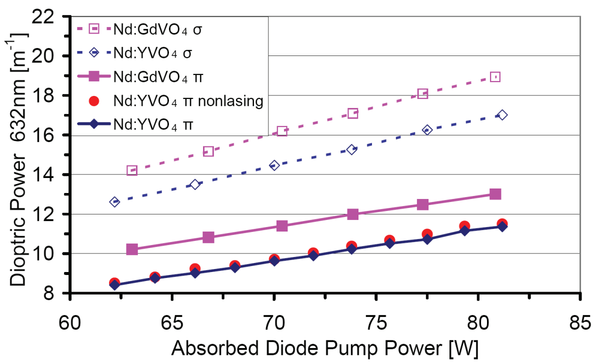

Fig.1 Dioptric powers at 632 nm of both polarisations of $Nd:GdVO_4$ and $Nd:YVO_4$ under diode end pumping.

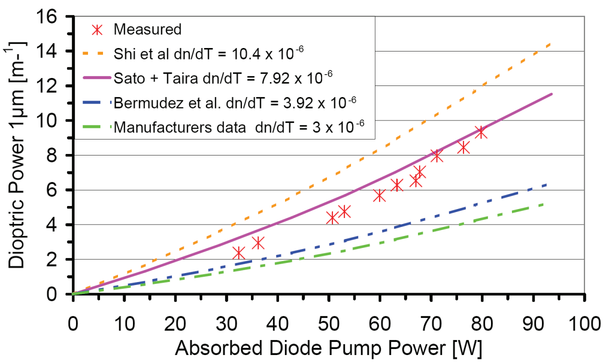

Fig.2 Measured and calculated dioptric powers at 1064 nm in the π polarisation of $Nd:YVO_4$ under diode end pumping.

We subsequently modelled the temperature distribution in the crystals with the three dimensional FEA simulation program LASCAD to obtain the dioptric powers versus the absorbed diode pump power for the published dn/dT values. The model took into account the temperature dependence of the thermal conductivity taken from [1], the average kurtosis parameter of the pump beam and the varying pump absorption due to the shifting wavelength of the high power diode laser with increasing power. The results illustrated in Figure 2 show that the dn/dT value given by Sato and Taira [1] best fits our data. The simulations also revealed that the seemingly nonlinear behaviour of the measured dioptric powers was a result of the changing pump wavelength.

References

[1] Y. Sato and T. Taira, "Thermo-optical and -mechanical parameters of $Nd:GdVO_4$ and $Nd:YVO_4$," in Conference on Lasers and Electro-Optics, OSA, paper JWA87 (2007).

[2] H. Shi, G. Zhang, and H. Shen, "Measurement of Principle refractive Indices and the Thermal Refractive Index Coefficient of Yttrium Vanadate," J. Synth. Cryst. (Chinese), **30**, 85 (2001).

[3] J.C. Bermudez, V.J. Pinto-Robledo, A.V. Kiryanov, and M.J. Damzen, "The thermolensing effect in a grazing incidence, diode-side-pumped $Nd:YVO_4$ laser," Opt. Commun. **210**, 7582 (2002).

[4] B. Neuenschwander, R. Weber, and H.P. Weber, "Determination of the Thermal Lens in Solid-state Lasers with Stable Cavities," IEEE J. Quantum Electron. **31**, 1082 (1995).

978-1-4244-4080-1/09/$25.00 ©2009 IEEE