Continuous-wave self-Raman and intracavity doubled laser operation in Nd:$GdVO_4$ at 586.5 nm

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Raman lasers which employ intracavity Raman shifting in crystalline materials have become widely recognized as a highly efficient and practical means of extending the spectral coverage of established Nd laser systems. Of particular interest is the yellow-orange wavelength region, which can be efficiently accessed through intracavity frequency doubling of the Stokes field. These systems are simple and versatile, and by choosing different laser and Raman crystals, a range of output wavelengths can be obtained for potential applications in the areas of medicine, biomedicine and remote sensing. Self-Raman lasers are a subgroup of intracavity Raman lasers in which the laser crystal is also Raman-active. Self-Raman laser action has been investigated in a variety of media including; Nd:$GdVO_4$, Nd:YVO_4, Nd:$PbMoO_4$, and Nd:$KGd(WO_4)_2$. To-date however only Nd:KGW[1] has been demonstrated to operate in a cw mode due its high Raman gain and the long crystal lengths available. In this paper we report for the first time cw self-Raman laser operation in Nd:$GdVO_4$ at 1173 nm and intracavity-doubled cw output in the yellow at 586 nm.

The laser comprised a fibre coupled diode end-pumped near hemispherical cavity with a flat input mirror coated HT at 808 and 586 nm, and HR at 1063 and 1176 nm. For output coupling of the stokes field a mirror with a 20 cm RoC and 0.4%T at 1173 nm was used, while for doubling of the Stokes field a 25cm RoC mirror coated HT at 586 nm and HR at 1063 and 1173 nm was used.

In the cavity optimised for Stokes output (Fig. 1) using the shortest cavity length possible (13 mm) we obtained threshold for lasing at the fundamental for 0.7 W of pump power while Raman oscillation was obtained with 4.6 W of pump power. At maximum pump power (22 W) we obtained 2.04 W at 1173 nm before damaging the coatings on the crystal. For a 24 mm long cavity the Raman output power rolled over above 18 W of pump power indicating the thermal lens in the Nd:$GdVO_4$ crystal was approximately 17 mm.

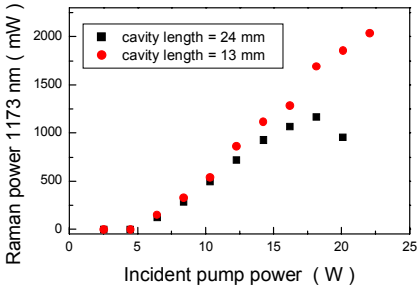

Fig. 1 Stokes output as a function of pump power for 13 and 24 mm cavity lengths.

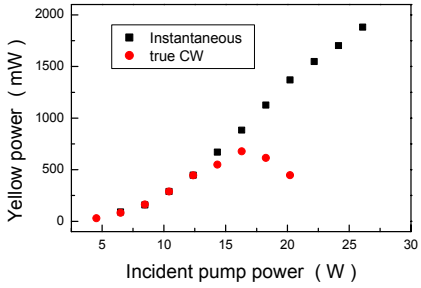

Fig. 2 Cw and quasi-cw 586 nm output as a function of pump power.

For studies of intracavity frequency-doubling of the Raman optical field the resonator length was extended by 12 mm to accommodate the 10 mm LBO frequency-doubling crystal. In this configuration Raman threshold was obtained with 2.4 W of pump power. Maximum output powers at 586 nm of 678 mW were obtained with incident pump powers of 16.3 W (Fig. 2). Residual fundamental and Raman powers were less than 200 and 50 mW respectively. We expect that similar powers (at 586 nm) were generated in the opposite direction to those measured and were either absorbed in the Nd:$GdVO_4$ laser crystal (the absorption coefficient at 586 nm was measured to be greater than 2 cm^{-1}) or lost through the input mirror. The maximum yellow power was restricted by thermal lensing driving the cavity towards the limit of resonator stability. To explore the potential for generating higher cw yellow output powers at higher pump powers we undertook experiments in which the diode pump was operated at reduced (50%) duty cycle. The reduced thermal load in the laser crystal in quasi-cw mode of operation permitted instantaneous pump powers up to the maximum available without any roll-over in output power. In this mode of operation we obtained 1.88 W (940 mW average) at 586 nm for instantaneous diode pump powers of 26 W (13 W average) with a corresponding optical-to-optical conversion efficiency of 7.2%.

In summary, we have demonstrated what we believe is the first diode-pumped continuous-wave self-Raman operation in Nd:$GdVO_4$ with output at 1173 nm and intracavity doubled output at 586 nm. We have generated up to 2 W at 1173 nm and 678 mW at 586 nm, limited by thermal lensing in the gain medium. Operating at 50% duty cycle allowed generation of 1.85 W of quasi-cw power at 586 nm. It is expected that by managing the thermal loading and collecting all the generated yellow emission, cw yellow output powers of greater than 3 W will be obtained.

1. A. A. Demidovich, A. S. Grabtchikov, V. A. Lisinetskii, V. N. Burakevich, V. A. Orlovich and W. Kiefer, Opt. Lett., **30**, 1701-1703 (2005).