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The Prospects for Yb- and Nd-Doped Tungstate Microchip Lasers

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Potassium gadolinium and yttrium tungstates doped with trivalent Nd, Yb or Tm ions are widely used crystals for efficient diode-pumped lasers. They are usually oriented along the *b* crystallographic axis, which is also the N_p axis of optical indicatrix. The N_p-cut is characterized by a strong thermal lens with opposing signs along N_m and N_g [1]. This is unsuited to microchip lasers which require a positive thermal lens for a stable cavity. Therefore, a detailed investigation of thermo-optic effects and microchip laser potential of other crystallographic orientations in tungstate crystals is of interest.

N_g-cut tungstate crystals provide a positive and near-spherical thermal lens [1]. This enabled the demonstration of a N_g-cut Tm:KY(WO$_4$)$_2$ (KYW) laser in a plane-plane cavity at 1.94µm [2]. In this study, we present for the first time, to the best of our knowledge, the results of CW laser performance of N_g-cut Nd: KGd(WO$_4$)$_2$ (KGW) and Yb:KYW crystals in a quasi-microchip plane-plane cavity. Proof-of-concept quasi-microchip lasers were demonstrated using 3 at. % Nd:KGd(WO$_4$)$_2$ (KGW) and 10 at. % Yb:KYW crystals cut for light propagation along the N_g axis. Both crystals were uncoated and had a thickness of 250µm. The samples were capillary-bonded between the two synthetic diamonds (sandwich configuration, see Fig. 1 (a)) for better thermal management. Diamond heat-spreader #1 was antireflection (AR) coated at 808 and 1064nm in the case of Nd:KGW crystal and was uncoated in the case of the Yb:KYW crystal. Diamond heat-spreader #2 was coated for high reflection (HR) within 808-1064nm. The composite samples were mounted in brass mounts chilled to 10°C via water cooling. The total cavity length was ~2mm in both cases. 10W fibre-coupled (200µm core diameter) diode lasers at 808 (Nd:KGW) or 980nm (Yb:KYW) were used as pump sources. The pump spot radii in the Nd:KGW and Yb:KYW crystals were 150 and 125µm, respectively. The best slope efficiency and output power of the Nd:KGW laser were 33% and 906mW respectively (fig. 1(b)), both for an output coupling of 2.4% and limited by de-bonding of the sandwich structure. For Yb:KYW, the best slope efficiency and output power were 41% and 795mW respectively, for a 2% output coupling and limited by the available pump power. Improvements in the bonding and optimisation of the coatings should significantly improve performance of these lasers.

Initial theoretical estimates of thermal lens sensitivity factors $M=dD/dP_{abs}$ (D is the thermal lens strength and P_{abs} is the absorbed pump power [2]) for N_g-cut Nd:KGW and Yb:KYW, taking into account the diamond heat-spreaders bonded to the crystals, are presented in Fig.1 (c, d). For the Nd:KGW laser, the thermal lens at an absorbed pump power of 4W was estimated from Fig. 1 (c) to be ~50mm, giving a TEM$_{00}$ mode radius of ~60µm, which is smaller than the pump spot radius of 150µm and therefore further optimisation of the laser is required. In the case of Yb:KYW laser and for laser emission polarised along the N_m axis, the thermal lens at an absorbed pump power of 4W is ~570mm (from Fig. 1 (d)), giving a TEM$_{00}$ mode radius of ~110µm. This is close to the pump spot radius of 125µm suggesting the pump radius may be close to optimised for this absorbed pump power. Indeed, with the smaller pump spot radius of 100µm the output power of the laser drops and the same effect, although not as marked, was observed when the pump spot radius was increased to 160µm.
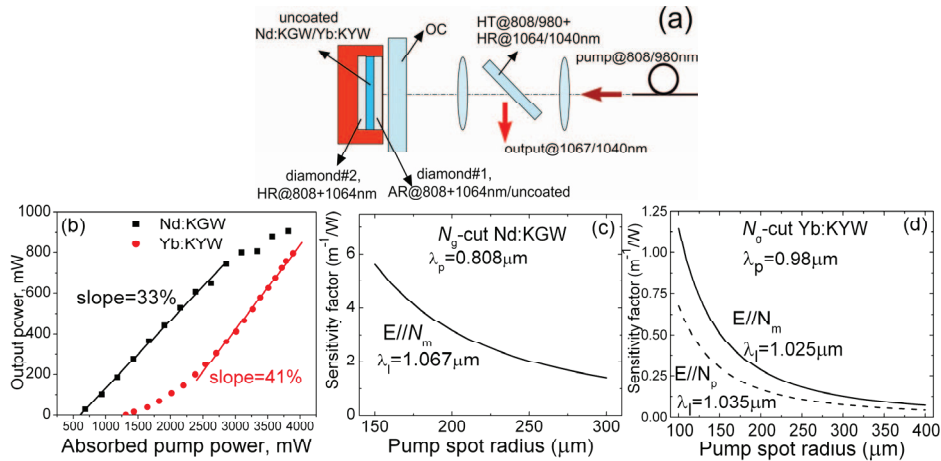

Fig. 1 (a) Quasi-microchip laser setup : OC – output coupler ; (b) output powers of Nd :KGW and Yb :KYW quasi-microchip lasers as function of absorbed pump power ; (c) calculated sensitivity factor of thermal lens in N_g-cut Nd:KGW crystals for light polarisation along N_m axis ; (d) calculated sensitivity factor of thermal lens in N_g-cut Yb:KYW crystals for light polarisation along N_m and N_p axes.

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