Growth, spectroscopy and diode-pumped laser operation of acentric Yb:KGd(PO$_3$)$_4$ crystal

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Bifunctional crystals capable of hosting laser-active rare-earth ions and allowing for frequency doubling are of interest for applications in compact visible lasers. This can be realized in crystals exhibiting non-centrosymmetric structure, which provides the necessary $\chi^{(2)}$ nonlinearity. So far, such crystals were mainly doped with Nd^{3+} ions. However, ytterbium (Yb^{3+}) ions are also very attractive for such laser designs as they provide longer upper laser level lifetimes, higher Stokes pump efficiency, weaker heat loading and broader emission bandwidths which is of interest for the generation of fs pulses in the green spectral range [1]. In the present work, we report on the growth, polarized spectroscopy and first diode-pumped laser operation of an acentric crystal, Yb:KGd(PO$_3$)$_4$.

The Yb:KGd(PO$_3$)$_4$ crystals were grown by the top-seeded solution growth slow-cooling method, Fig. 1(a). The doping concentration was measured by electron probe microanalysis, N_{Yb} = 1.0×10^{20} cm^{-3} (2.4 at.% Yb). Yb:KGd(PO$_3$)$_4$ is monoclinic (sp. gr. $P2_1$) and optically biaxial (it is phase-matchable for type I second harmonic generation) [2]. The absorption, σ_{abs}, and stimulated-emission (SE), σ_{SE}, cross-sections for Yb^{3+} measured for light polarized along the optical indicatrix axes are shown in Fig. 1(b). The maximum σ_{SE} in the region where the laser operation is expected, amounts to 0.73×10^{-20} cm^2 at 1006 nm for $\boldsymbol{E} \parallel N_m$. The radiative lifetime of the $^2F_{5/2}$ multiplet is relatively long, 1.22 ms. The Stark splitting for Yb^{3+} resolved at 6 K is shown in Fig. 1(c).

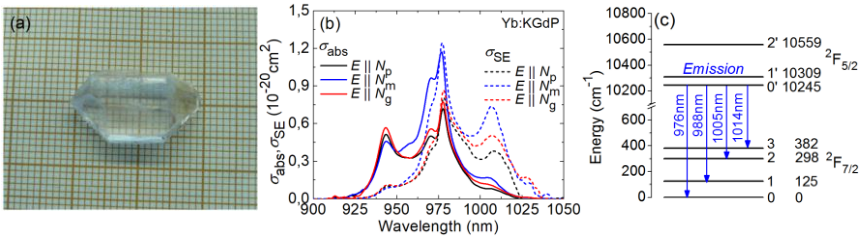

Fig. 1 Growth and spectroscopy of Yb:KGd(PO$_3$)$_4$: (a) Photograph of the as-grown crystal; (b) absorption, σ_{abs}, and stimulated-emission, σ_{SE}, cross-sections for Yb^{3+} ions with polarized light; (c) crystal-field splitting of Yb^{3+} multiplets.

Laser operation of Yb:KGd(PO$_3$)$_4$ at the fundamental wavelength (~1 μm) was achieved under diode-pumping by a fiber-coupled InGaAs laser diode at 966 nm. The N_g-cut uncoated crystal was 7.03 mm-thick; it was mounted in a Cu-holder cooled by flowing water (14 °C). A compact plano-plano cavity was employed and the laser mode was stabilized by the positive thermal lens in the crystal. The laser generated a maximum output power of 1.57 W at 1040.7 nm with a slope efficiency of 44.4% (vs. absorbed pump power) and a threshold of 0.68 W (for transmission of the output coupler T_{OC} = 0.5%), Fig. 2(a). The laser emission was linearly polarized ($\boldsymbol{E} \parallel N_m$) and the wavelength experienced a blue-shift with T_{OC}, Fig. 2(b). The laser operated at the fundamental mode, Fig. 2(c).

Yb:KGd(PO$_3$)$_4$ is promising for mode-locked lasers with self-frequency-doubling yielding green fs pulses.

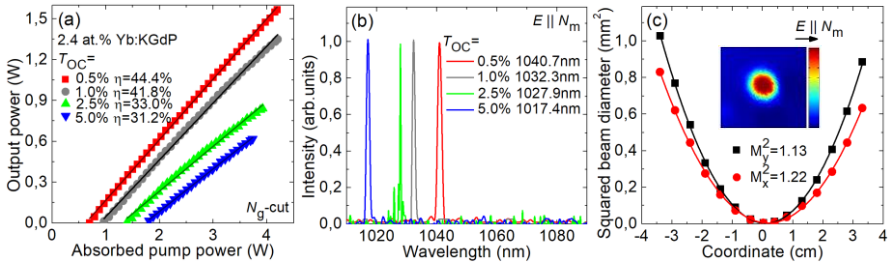

Fig. 2 Diode-pumped 2.4 at.% Yb^{3+}:KGd(PO$_3$)$_4$ (Yb:KGdP) laser: (a) Input-output dependences, η – slope efficiency; (b) typical spectra; (c) evaluation of the beam quality factors, $M^2_{x,y}$; *inset*: far-field mode profile, T_{OC} = 0.5%, P_{abs} = 3.6 W. The laser polarization is $\boldsymbol{E} \parallel N_m$ (horizontal, $\parallel x$).

References

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