New Yb:LYSB bifunctional crystal for efficient near-infrared laser emission and self-frequency doubling conversion

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Nowadays, solid-state lasers with emission in the visible (VIS) spectral range are used in a large variety of applications, from manufacturing and materials processing technologies to medicine, optical communication or military applications. A widely used method for the obtaining of efficient laser sources in VIS range is based on frequency conversion of solid-state near-infrared laser emission by nonlinear optical (NLO) processes, such as second harmonic generation (SHG) or self-frequency doubling (SFD).

In this work, we report on the development of Yb:LYSB as new bifunctional laser and NLO crystal. Based on our experience on growing undoped $La_xY_ySc_{4-x-y}(BO_3)_4$ - LYSB - type crystals [1], a special heating assembly that allows an effective control of both B_2O_3 evaporation and thermal gradients over the crucible and in the melt, was used for the growth of the incongruent melting Yb:LYSB crystal by the Czochralski method (Fig. 1). The XRD analysis revealed the existence of the single trigonal phase, space group *R32*; the unit cell parameters were determined to be a= 9.8114(4) Å and c= 7.9808(9) Å. The chemical composition of the crystal was found to be $La_{0.78}Y_{0.32}Yb_{0.04}Sc_{2.86}(BO_3)_4$. The segregation coefficient of Yb^{3+} ions in the LYSB crystal matrix was determined to be k_{eff} = 0.8, corresponding to an Yb^{3+}-doping concentration of 4 at.% in the grown crystal. The absorption cross-section, σ_a at 980 nm for σ-polarization is about 0.6×10^{-20} cm^2 with a bandwidth (FWHM definition) of 33 nm, being ~1.65 times larger than that of Yb:YAB crystal [2]. In the case of π-polarization, the highest σ_a was determined to be 0.37×10^{-20} cm^2 at 904 nm, being close to the value reported for Yb:LGSB crystal [3]. Furthermore, spectroscopic studies revealed an intrinsic disorder due to the presence of Yb^{3+} ions in the trigonal prismatic sites occupied by La^{3+} and Y^{3+} ions and also in the octahedral sites occupied by Sc^{3+} ions.

Efficient laser emission at the fundamental wavelength λ_{em}= 1028 nm was obtained with a ***c***-cut 4-at.% Yb:LYSB uncoated medium, having a thickness of 3.5 mm. The pump was done at 971.5 nm with a fiber-coupled (100-μm diameter, NA= 0.22) diode laser. A short (8-mm length) linear plane-plane resonator was used in the experiments. With an out-coupling mirror having transmission T= 0.01, the Yb:LYSB medium yielded laser pulses with maximum energy E_p= 1.5 mJ at 4.25 mJ energy of the absorbed pump pulse, E_{abs}; thus, overall optical-to-optical efficiency, with respect to E_{abs}, was η_{oa}= 0.35. The slope efficiency was as high as η_{sa}= 0.57 (Fig. 2), proving the good optical quality of Yb:LYSB grown crystal.

Fig. 1 Yb:LYSB as-grown crystal.

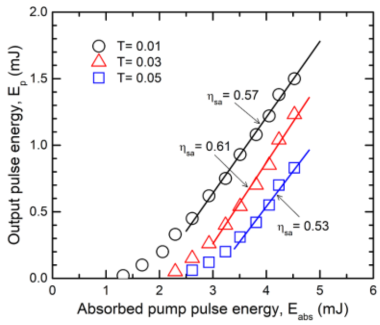

Fig. 2 Laser pulse energy, E_p vs. absorbed energy of the pump pulse, E_{abs}. T is the out-coupling mirror transmission.

The NLO properties of Yb:LYSB crystal were determined from the refractive indices measurements. The effective nonlinear coefficient, d_{eff} for type I SHG of λ_{em}= 1028 nm was determined to be 1.08 pm/V, confirming the good NLO properties of huntite-type Yb:LYSB crystal. Further experiments to determine the full potential of Yb:LYSB crystal as bifunctional laser and NLO crystal in SFD configuration are now in progress.

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