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HIGHLY EFFICIENT ER,YB:YAL$_3$(BO$_3$)$_4$ LASER EMITTING IN THE 1.5-1.6 µM SPECTRAL RANGE

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Abstract: The highly efficient Er,Yb:$YAl_3(BO_3)_4$ laser emitting in the 1.5-1.6 µm spectral range was demonstrated. A maximal output power of 1.6 W in CW and 2.7 W in QCW regimes with slope efficiency up to 40 % was obtained at 1522 nm.

Erbium-doped laser materials are widely used for laser operation in the 1.5-1.6 µm spectral range with promising applications including eye-safe laser range finding, medicine, fiber-optic communication systems, and optical location. Phosphate glasses currently are the leading Er^{3+},Yb^{3+} co-doped laser materials, because they combine very efficient energy transfer from Yb^{3+} to Er^{3+} ions (η≈90 %) with a long lifetime of erbium upper laser level $^4I_{13/2}$ (7-8 ms) and short lifetime of the $^4I_{11/2}$ energy level (2-3 µs), which prevents the depopulation of this level by means of excited-state absorption and up-conversion processes. However, phosphate glass has poor thermo-mechanical properties (a thermal conductivity of 0.85 $W\times m^{-1}\times K^{-1}$), that limits the average output power of Er,Yb:glass lasers due to the thermal effects [1].

The Er,Yb-codoped oxoborate crystals possess abovementioned spectroscopic characteristics and high thermo-mechanical properties for efficient laser operation. CW room-temperature laser operation was demonstrated for the following Er,Yb-codoped oxoborate crystals: $GdCa_4O(BO_3)_3$ [2], $LaSc_3(BO_3)_4$ [3], $YCa_4O(BO_3)_3$ [4]; while for $Li_6Y(BO_3)_3$ [5], $Sr_3Y_2(BO_3)_4$ [6], $Sr_3Gd_2(BO_3)_4$ [7], and $LuAl_3(BO_3)_4$ [8] quasi-continuous-wave regime of operation was realized.

In this work we present the highly efficient Er,Yb:$YAl_3(BO_3)_4$ laser emitting in the 1.5-1.6 µm spectral range.

The laser experiments were performed in Z-shaped cavity. The plane-plane Er(Xat.%),Yb(11at.%):YAB (where X=1.5at.%; 2at.%; 3at.%; 4at.%) crystal 1.5 mm long antireflection coated for both pump and lasing wavelengths was mounted on the copper thermoelectrically cooled heatsink. The temperature of the active element was kept at 18°C. As a pump source a 15 W fiber-coupled (Ø 105 µm, NA=0.12) laser diode emitting near 976 nm was used. A combination of two lenses (f_1= f_2=80 mm) was used to focus pump beam into the gain medium. The cavity-mode diameter at the active element was close to the pump beam waist. The transmittance of output coupler was 5 % at the laser wavelength.

Input-output characteristics of CW Er(1.5at.%),Yb(11at.%):YAB laser are plotted in Fig. 1. The laser threshold was measured to be about 1.5 W of absorbed pump power. The maximum CW output power of 1.2 W with slope efficiency near 26 % was obtained at 1522 nm at about 6.2 W of absorbed pump power. After further increasing of pump power, the rising of output laser power wasn't observed. It provides evidence for the influence of thermal load in the crystal on laser performance. To reduce the thermal load, laser experiments with quasi-CW (QCW) pumping were performed. By using a chopper with a duty cycle of 1:5 in the pumping channel, the maximal output peak power up to 2 W with slope efficiency of 35 % was obtained at the absorbed peak pump power of 7.3 W (Fig. 1).

For Er(2at.%),Yb(11at.%):YAB the maximum CW output power of 1.6 W at 1522 nm was demonstrated with slope efficiency of 32 % and 1.7 W laser threshold of absorbed pump power. While for QCW regime of operation laser emission was observed at 1543 nm with slope efficiency near 32% at low pump power, however, at an absorbed peak pump power of more than 5.5 W the emission wavelength switched to 1522 nm and the slope efficiency was increased drastically to 41 %. The maximal output peak power of 2.7 W was obtained in that case at an absorbed pump peak power of more than 9 W (Fig. 2).

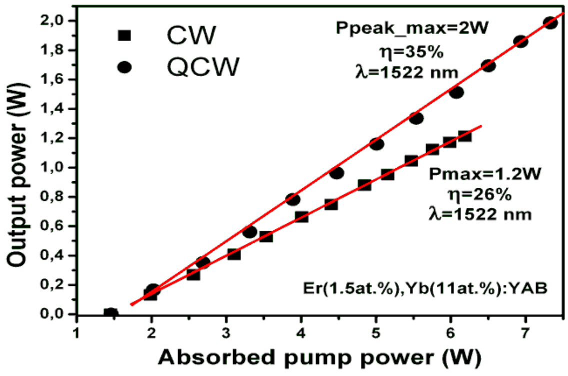

Fig. 1. Input-output characteristics of CW and QCW Er(1.5at.%),Yb(11at.%):YAB diode-pumped laser

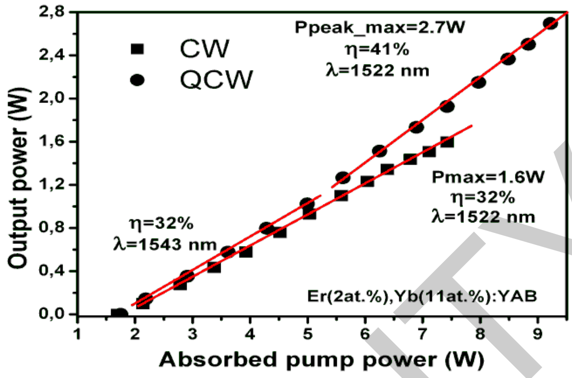

Fig. 2. Input-output characteristics of CW and QCW Er(2at.%),Yb(11at.%):YAB diode-pumped laser

Figure 3 shows input-output diagrams of CW and QCW Er(3at.%),Yb(11at.%):YAB diode-pumped laser. For CW operation the slope efficiency was reduced to 23 %. The maximal output power of 0.6 W in this case was limited by the damage of active element. To prevent destruction of the crystal further experiments were carried out with quasi-CW pumping. The maximal output peak power of 2.5 W with slope efficiency of 35 % was obtained at 1522 nm.

Laser experiments with Er(4at.%),Yb(11at.%):YAB were held in QCW regime of operation. The laser threshold was measured to be about 2.6 W of absorbed peak pump power. The maximum QCW output peak power of 2.2 W with slope efficiency near 40 % was obtained at 1531 nm at about 9 W of absorbed peak pump power (Fig. 4).

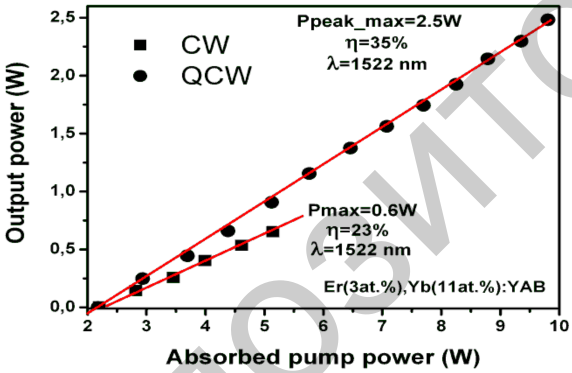

Fig. 3. Input-output characteristics of CW and QCW Er(3at.%),Yb(11at.%):YAB diode-pumped laser

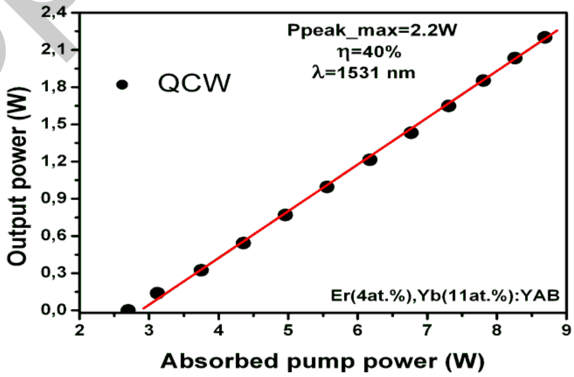

Fig. 4. Input-output characteristics of QCW Er(4at.%),Yb(11at.%):YAB diode-pumped laser

In conclusion, the highly efficient Er,Yb:$YAl_3(BO_3)_4$ laser emitting in the 1.5-1.6 μm spectral range was demonstrated. A maximal output power of 1.6 W in CW and 2.7 W in QCW regimes with slope efficiency up to 40 % was obtained at 1522 nm.

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