Cryogenic Laser Operation of a “Mixed” Yb:YLuAG Garnet Crystal

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In recent years, solid state lasers based on Ytterbium (Yb3+) ions emitting at ~1 μm have attracted significant attention due to their vast technological and scientific applications. At room temperature, Yb3+ ions represent a quasi-three-level laser scheme because of the finite population of Stark sub-levels of the ground state (2F7/2), leading to reabsorption at the laser wavelength that increases the laser threshold and hinders the optical efficiency. To overcome this limitation, the active medium could be cooled down to cryogenic temperatures, approaching the quasi-four-level laser scheme leading to much lower laser thresholds [1]. In addition, this helps to improve the thermal and thermo-optical properties of the gain material. Yttrium aluminium garnet Y3Al5O12 (YAG) is the state-of-the-art laser host crystal for Yb3+ doping. In the present work, we report on the cryogenic laser operation of a compositionally “mixed” (Y,Lu)3Al5O12 (YLuAG) garnet doped with Yb3+ ions.

A single crystal of Yb:YLuAG was grown by the Czochralski method using an [111] oriented seed in an Ar atmosphere. According to the ICP-AES analysis, its composition was (Y0.554Lu0.280Yb0.166)3Al5O12. The crystal possessed a cubic garnet structure. The selected “mixed” composition is motivated by: (i) lower melting point compared to Lu3Al5O12, (ii) lower consumption of the Lu2O3 reagent, (iii) additional inhomogeneous broadening of Yb3+ spectral bands [2].

The cryogenic laser experiments were carried out using an L-shaped asymmetric cavity. The uncoated laser element had an aperture of 4×4 mm2 and a thickness of 2 mm. It was mounted in a copper holder at normal incidence and fixed to the cold finger of the optical cryostat providing a heat load of 13 W at 100 K. To maintain the sample temperature, a 50 Ω heater was connected to the cold finger and the sample temperature was monitored using a silicon sensor. As a pump source, a Volume Bragg gratings (VBG) stabilized fiber-coupled diode laser emitting at 969 nm with a spectral bandwidth of 0.40 nm (N.A. = 0.22, fiber core diameter: 105 μm) was used. The unpolarized pump radiation was reimaged using achromatic lenses with a ratio of 1:2.5. For passive Q-switching, Cr4+:YAG saturable absorbers (SAs) with 85% and 95% initial transmissions were used.

Continuous-wave (CW) laser operation was realized initially at different temperatures in the range of 80 - 280 K with a step of 20 K using the same output coupler transmission (TOC = 20%). As a result, we determined an optimum crystal temperature of 140 K for efficient laser operation, see Fig. 1(a) for the input-output dependences. The cryogenic diode-pumped Yb:YLuAG laser generated a maximum CW output power of 10.65 W at 1029 nm with a slope efficiency of 56% (with respect to the incident pump power) for TOC = 40%. Figure 1(b) shows the far-field beam profile measured at the maximum output power corresponding to the fundamental transverse mode.

References