Compact cryogenic Tm:LiYF4 laser

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Lasers operating around 2 µm in the spectral range emit in the so-called eye-safe region and find applications in medicine, material processing, laser radar and atmospheric monitoring and research as well as defense. Such 2 µm lasers are achieved by doping the laser host materials with Tm^{3+} ions (here after Tm). Concerning the host, we considered $LiYF_4$ (YLF), which belongs to the fluoride family that exhibits low phonon energy, broad emission bands and long radiative lifetime, which make these materials interesting candidates for high power laser development in the 2 µm region. To date, many results based on Tm:YLF have been reported mainly at room temperature [1] and references therein. However, at room temperature reabsorption losses exist due to the quasi-three level laser nature of these systems, limiting the overall output power and efficiency. These drawbacks can be mitigated when the active medium is cooled down to cryogenic temperatures. The cryogenic cooling will result in enhancing the material thermal properties leading to improved laser performance. Cryogenic laser based on Tm:YLF has been demonstrated using broad band pumping in one of our previous work using an L-shaped asymmetric cavity. A maximum output power of 2.55 W with a slope efficiency of 22.8% was achieved [2]. In the present work, to have a compact laser setup and to enhance the laser output, we studied cryogenic laser operation of Tm:YLF using a modular setup increasing the output power above 6 W with excellent beam quality. The laser experiments were carried out using a compact modular cryogenic vacuum chamber, which has the provision to mount the optics and sample as close as possible to form a compact laser cavity. As active medium, an a- cut 5 at.% Tm:YLF crystal with 2 mm in thickness and 5×5 mm^2 aperture was used. The uncoated crystal was mounted in a copper holder at normal incidence and was placed between two plane mirrors to form a compact plane – plane cavity inside the modular chamber. As a pump source, a Volume Bragg Grating (VBG) stabilized fiber-coupled diode laser emitting at 793 nm was used and was imaged into the crystal using achromatic lenses with a ratio of 1:1.5. As output couplers, different transmissions 5, 15, and 30% were used. The cryogenic cooling of the sample was achieved by a closed cycle helium cryostat having heat load of 13W at 100K. To maintain the crystal temperature a 50 Ω heater connected to the cold finger was used.

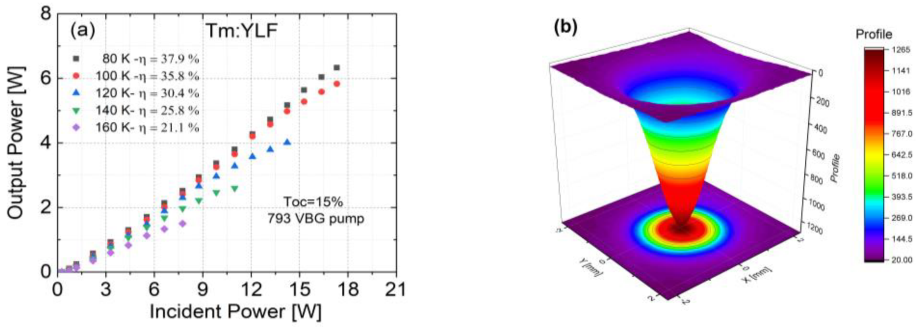

Fig. 1 (a) Input - Output power characteristics of 5at.% Tm:YLF for different temperatures, T_{OC} = 15% ; (b) Measured beam profile at maximum output power

The cryogenic continuous-wave (CW) laser was characterized by varying one of the following parameters: 1) the heat-sink temperature of the pump, 2) the output coupler transmission and 3) the temperature of the sample. In all the cases, one parameter was varied and the other two parameters remained fixed. Figure 1 (a) shows the input–output power characteristics of Tm:YLF for different temperatures with Toc=15%. From the figure, one can infer that the output power increases and laser threshold decreases with decrease in temperature. A maximum output power of 6.50 W with a slope efficiency of almost 40% at 80 K was achieved. Figure 1(b) shows the measured beam profile at maximum power, which shows an excellent Gaussian fitting as a result of the cryogenic temperature. It is worth to note, that we observed contribution of both polarizations (π and σ). At low output power levels (< 2 W), the π polarization was dominant and emits at 1876 nm and at high output power levels (>4 W), the σ polarization was dominant and emitting at 1901 & 1912 nm. All the experimental details along with the obtained results will be presented. Currently, we are focusing on pulsed laser operation using Cr:ZnS and Cr:ZnSe as saturable absorbers inside the cavity.

References

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