1.6 µm Er:YAP and Er:YAG Lasers Resonantly Pumped by Er:Glass Laser

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Received March 3, 2009; in final form, March 13, 2009

Abstract—1623 nm Er:YAP and 1648 nm Er:YAG lasers resonantly pumped by a solid state Er:glass laser operating at 1535 nm were investigated. Laser generation was reached for Er:YAP and two Er:YAG crystals with different Er ion concentration. The maximal output energies were 20 and 45 mJ for Er:YAP and Er:YAG laser systems, respectively.
PACS numbers: 42.55.Rz, 42.60.Jf
DOI: 10.1134/S1054660X09150213

1. INTRODUCTION

Many fields, such as satellite communication, range finding, and atmospheric sounding, could use laser source generating in the range from 1.5 to 1.6 µm. Further requirements for these applications are high efficiency and good beam quality. Materials doped by Erbium ions are one of promising direct sources of this particular radiation. As pumping systems for such materials, standard diodes operating around 970 nm could be utilized, but then a problem arises with heating the bulk laser material resulting in strong thermal lensing. These factors can decrease laser beam quality and efficiency [1]. The alternative method is resonant pumping directly to lasing bands [2]. A small quantum defect [3] and low thermal stress are one of the advantages of resonantly pumped lasers, which significantly reduce the necessity of active crystals cooling [4–6]. Low-doped crystals with Er 3+ reduce the undesirable effects of ground state reabsorption and up-conversion and provide better thermal management for good beam quality [3].

The aim of the work was to investigate resonant pumping of the Er:YAP laser and to compare the results with the similarly pumped two Er:YAG lasers differing by the concentration of the Er 3+ ions and the length of active media. All systems were pumped by the Er:glass laser radiation. The present work summarized our previous work [7] and shows new results obtained with other Er:YAG crystal. To our best knowledge, the 1.6 µm radiation obtained by resonant pumping of the Er:YAP crystal has been reached for the first time. The generated radiation pertains to the eye safe region [8].

The article is published in the original.

2. Er:GLASS PUMPING LASER SYSTEM

The Er:glass laser generated at 1535 nm was utilized as coherent end-pumping source for Er:YAP and Er:YAG laser systems. The resonator was formed by a flat total-reflected copper mirror and flat output dielectric mirror (R = 42% @ 1530 nm). Between these mirrors, a ceramic diffuse cavity with an Xe-flashlamp and Er:glass rod (3.9 × 76.0 mm) was placed.

This Er:glass laser system working in free-running long-pulse regime with a repetition rate of 0.5 Hz was characterized. The maximal energy for subsequent resonant pumping was 640 mJ in multimode Er:glass laser output beam. To obtain this value, pumping flashlamp energy 172 J was expended for Er:glass system. To focus radiation into the active Er:YAP or Er:YAG crystal, a CaF 2 lens with a focal length of 70 mm was chosen. The corresponding beam diameter in the focal plane was about 400 µm.

3. ACTIVE CRYSTALS AND OPTICAL RESONATOR

The Er:YAP (Erbium:Yttrium Aluminum Perovskite, YAlO₃) active crystal with 1 at % Er/Y concentration was 10 mm in length and 5 mm in diameter. The faces of crystal were covered by anti-reflection layers, the losses in the 1.5–1.7 µm range being lower than 1%.

Radiation generation for two Er:YAG crystals (5 mm in diameter) with different Er ion concentration but similar transmission (T ~ 74%) at pumping wavelength were compared. The parameters of active media were 10 mm in length with 0.5 at % Er/Y concentration and 25 mm in length with 0.2 at % Er/Y concentration. The same anti-reflection layers as for...
the Er:YAP crystal were prepared. For all resonantly pumped laser systems, only one all-purpose optical resonator was constructed. As pumping mirror, we used a concave dielectric mirror with high transmittance at the pumping wavelength ($T > 95\%$ @ 1535 nm) and maximal reflectance at the oscillating wavelength (about 1640 nm). The output coupler was flat with 85 and 90\% reflectance for 1535 and 1640 nm, respectively. The air-cooled active media were placed in the adjustable simple $V$-groove.

4. ABSORBED ENERGY DETERMINATION

The absorbed energy was calculated from the input energy into an active crystal and measured transmission of pumping radiation by the crystal (Figs. 1 and 2). The input energy was obtained from the incident pumping energy including transmission parameters of mirror and the focusing lens. The measurement of transmission by crystal was carried out without output coupler (i.e., without laser generation). We studied the dependence of output energy from crystal on the incident pumping energy. Then, the transmission value for threshold energy of generation was considered and an absorption coefficient was set for this value. Hence, it was the upper estimate of differential efficiency of the output energy on absorbed energy because the absorption during lasing could be only higher than without radiation generation.

5. RESONANTLY PUMPED Er:YAP LASER

The output energy, temporal profile, and beam spatial structure were investigated. The chart of output energy dependence on absorbed energy is given in Fig. 3. The laser threshold energy and slope efficiency in respect to absorbed pumping energy were 26.3 mJ and 32.1\%, respectively. The maximal output energy reached was 20 mJ for the incident pumping energy 640 mJ. For the radiation generation, the corresponding pumping threshold energy into crystal was 160 mJ. The measured wavelength was 1623 nm (Oriel mono-
chromator 77250), and output beam spatial profile was close to fundamental TEM$_{00}$ mode (Fig. 4).

6. RESONANTLY PUMPED Er:YAG LASERS

For this case, the results of laser characteristics were similar for both the investigated crystals. The dependence of output energy on absorbed energy for Er:YAG lasers is given in Fig. 5. The slope efficiency and pumping threshold energy in respect to absorbed pumping energy were 60.7% and 4.5 mJ for 5 × 10 mm (0.5 at %) crystal, and 58.8% and 4.3 mJ for 5 × 25 mm (0.2 at %) crystal, respectively. The corresponding maximum output energy reached up to 45 mJ (465 mJ incident pumping energy) and 42 mJ (481 mJ incident pumping energy). The fundamental TEM$_{00}$ output beam spatial structures were observed and they are shown in Fig. 6. The generated wavelength measured was 1648 nm.

7. CONCLUSIONS

The 1623 and 1648 nm laser action in the Er:YAP and Er:YAG crystals has been demonstrated for 1535 nm Er:glass pumping wavelength. The obtained output beam spatial profiles were close to the fundamental TEM$_{00}$ mode. The 20 and 45 mJ maximal energy was reached for Er:YAP and Er:YAG laser systems, respectively. The slope efficiency of the output energy to the absorbed energy was 32.1% for Er:YAP active medium (5 × 10 mm, 1 at % Er/Y). The Er:YAG lasers with the 5 × 10 mm active crystal (0.5 at % Er/Y) or 5 × 25 mm crystal (0.2 at % Er/Y) reached a 60.7 or 58.8% slope efficiency, respectively. The stability of all laser systems output parameters was excellent without cooling any crystals. The systems both could be used for the applications where the eye-safe wavelength is required. In Er:YAP system also the output beam polarization can be utilized.

ACKNOWLEDGMENTS

This research has been supported by the Grant of the Czech Ministry of Education No. MSM6840770022 “Laser Systems, Radiation, and Modern Optical Applications.”
REFERENCES


