1,64 mkm Er:YAG laser resonantly pumped by a solid state Er:glass laser

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Abstract— We report on theoretical and experimental studies of Er:YAG pulsed laser working in a quasi-three-level scheme. A numerical simulation of an optical multiple laser scheme is carried out. Electro-optically Q-switched operation of an Er:YAG laser at 1645 nm end-pumped by a laser Er-Yb phosphate glass is demonstrated. Pulse energies up to 3 mJ have been generated at a pulse repetition frequency of 10 Hz.

Keywords: Er:YAG, diode-pumped, Q-switched lasers, solid-state lasers.

I INTRODUCTION

Solid-state Er:YAG lasers with a resonant pumping by GaAs diode lasers and operating in a quasi-three level scheme demonstrate superior performance among solid-state sources of coherent radiation. Despite of the strong up-conversion decay of the upper laser level restricting the use of crystals with a concentration of erbium less than 1 atm.%, and low stimulated emission cross-section 0.45×10⁻²⁰ cm², there have been demonstrated high generation efficiency in a CW mode. An alternative approach is to use an Yb-Er phosphate glass laser as a pump source. Analysis of the studies is presented in this paper.

II CALCULATED AND EXPERIMENTAL RESULTS

We have carried out calculations on the basis of a numerical model describing the dynamics of the radiation intensity in the cavity and the kinetic parameters of the active medium. The calculations assumed: the concentration of erbium ions 0.5...1 at.%, the upconversion parameter 3.5×10⁻¹⁸ cm² / s, the radiative decay rate of the upper laser level 154 s⁻¹. For efficient generation of Er:YAG laser it is necessary to excite a significant proportion of the total number of active ions from the ground state to the upper level. The maximum possible population of the excited upper level relative to the ground state population by pumping with a wavelength of 1536 nm is 0.47. The generation of radiation at a wavelength of 1645 nm will occur at excitation levels < 0.4. However, a laser effect in Er:YAG laser may already be realized if the degree of excitation is not less than 10%. Since the wavelength of the erbium glass laser (1536 nm) a absorption coefficient is low (0.305 cm⁻¹), the length of the active medium must be large enough to ensure effective absorption of the pump. On the basis of these was selected the crystal length of 30 mm for the calculation and the experiment. The calculations were performed for the case of the pumped volume in laser rod is a cylinder with a diameter of 1 mm, and for the following options:

1. End pumping with erbium ion concentration is of 0.5 at.%, the pump radiation wavelength λₚ = 1536 nm, the absorption cross section σₚ=0.25×10⁻²⁰ cm²).
2. The same as variant (1), but the pump radiation has a wavelength λₚ = 1532 nm, σₚ=0.6×10⁻²⁰ cm².
3. The same as variant (1), but the erbium ion concentration of erbium ions is of 1 at. %.

Table 1 shows the energy balance of the pump radiation for three variants of the calculation. Here: Eₚ - pump pulse energy at the input end of the laser rod; Eₚₑ - pump pulse energy absorbed in the laser rod; Eₚₑ - stored in the upper laser level of the pump pulse energy; Eₜₑ - pump pulse energy unabsorbed in the laser rod; Eₜₑ/V - density of pulse energy stored in the laser rod; Eₜₑ/Eₚₑ - pumping efficiency.

In the experiment described here: the YAG laser rod was single-end pumped in a straight cavity, stable plano-concave cavity with a flat dichroic mirror. The laser rod has a cylindrical shape with a diameter of 2.5 mm and a length of 30 mm. The erbium ion concentration of 0.5 at.%. A RTP crystal is used as a Q-switch.

The pump source is a diode-pumped Yb-Er-Glass laser in free running mode. The pump pulse duration of 5 ms. Pumping radiation from a Yb-Er-Glass laser after collimation was coupled into the rod end through a dichroic piano-piano mirror. Pumping region was formed in the laser rod with a cylindrical shape with a diameter of 2.5 mm and a length of 30 mm.

Table 1 shows the energy balance of the pump radiation for three variants of the calculation. Here: Eₚₑ - pump pulse energy at the input end of the laser rod; Eₚₑ - pump pulse energy absorbed in the laser rod; Eₚₑ - stored in the upper laser level of the pump pulse energy; Eₜₑ - pump pulse energy unabsorbed in the laser rod; Eₜₑ/V - density of pulse energy stored in the laser rod; Eₜₑ/Eₚₑ - pumping efficiency.

In the case of Yb-Er-Glass laser pump energy of 160 mJ with a wavelength of 1536 nm the absorbed energy in the Er:YAG rod not exceed 28%. Q-switched maximum energy Er:YAG laser was 3 mJ with a pulse width at half-width of 19 ns.

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<th>Eₚₑ</th>
<th>Eₚₑ</th>
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<th>Eₜₑ</th>
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