Dynamic properties of passively Q-switched LD-pumped erbium laser

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1. Introduction

Eyesafe laser sources, emitting in the 1.45 – 1.70 µm window, are used extensively within the commercial and scientific communities [1]. During the last years, Q-switched Er:glass lasers operating around 1.5 µm have been investigated extensively [2-7]. Dynamic properties of the eye-safe solid state lasers are important characteristics from application point of view. Our work is devoted to theoretical studying the role of the cavity trapped amplified luminescence (CTAL) in the dynamics of the diode pumped passively Q-switched ytterbium-erbium glass laser.

2. Schemes of the laser and energy levels of AE and Q-switch

The scheme of the laser and the diagrams of energy levels for the active element (AE) and Q-switch on the base of Co:MAO crystal are presented in Fig. 1 and 2.

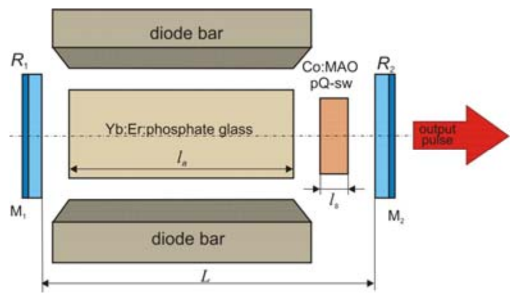

Fig. 1. Diode laser side pumped Yb:Er: phosphate glass with Co:MAO passive shutter laser scheme

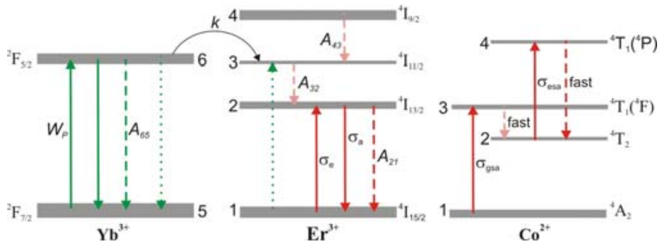

Fig. 2. Energy level diagrams of the diode-pumped Yb-sensitized Er: phosphate glass laser with Co:MAO passive shutter

3. Mathematical model and results of simulations

Mathematical modelling was based on numerical solving the self-consistent equations set of point laser model which included the lasing as well as the CTAL photon fluxes similar to the method used in [8].

Using the level scheme from Fig.2. and spectroscopic parameters of the passive Q-switch (typical for Co2+: spinel crystal [9-11]) and for the Yb, Er: phosphate glass the rate equation set (1) was formed and solved numerically.

$$
\begin{cases}
\dfrac{dn_6}{dt} = W_P(n_{Yb} - 2n_6) - kn_6n_1 - A_{65}n_6, \\
\dfrac{dn_1}{dt} = \eta_\lambda(\sigma_a n_2 - \sigma_e n_1)(u+v) + A_{21}n_2 - kn_6n_1 + C_2n_2^2, \\
\dfrac{dn_2}{dt} = -\eta_\lambda(\sigma_a n_2 - \sigma_e n_1)(u+v) - A_{21}n_2 + A_{32}(n_{Er} - n_2 - n_1) - 2C_2n_2^2, \\
\dfrac{dn_3}{dt} = kn_6n_1 - A_{32}n_3 - kn_3(n_{Yb} - n_6) + W_P n_1 + C_2n_2^2, \\
\dfrac{dn_{1s}}{dt} = -\eta_\lambda \sigma_{gsa} n_{1s}(u+v) + \dfrac{(n_{Co} - n_{1s})}{\tau_{Co}}, \\
\chi\dfrac{du}{dt} = \Big(l_a(\sigma_a n_2 - \sigma_e n_1) - \big(\sigma_{gsa} l_s n_{1s} + \sigma_{esa} l_s (n_{Co} - n_{1s})\big) + \Delta_{las}A_{21}n_2LS - K_{las}\Big)u, \\
\chi\dfrac{dv}{dt} = \Big(l_a(\sigma_a n_2 - \sigma_e n_1) - \big(\sigma_{gsa} l_s n_{1s} + \sigma_{esa} l_s (n_{Co} - n_{1s})\big) + \Delta_{lum}A_{21}n_2LS - K_{lum}\Big)v.
\end{cases}
$$

Equation set for diode pumped passive Q-switched Yb,Er: glass laser modeling: n_i - population densities on i-level (see Fig. 2); n_{Yb}, n_{Er}, n_{Co} - Yb, Er, Co concentrations; W_P – pump speed; k – Yb-Er energy transfer coefficient; A_{ij} – i to j level transfer possibility; u and v – laser and CTAL intensities; σ_a, σ_e - absorption and emittion crossections; σ_{gsa}, σ_{esa} - ground state and exited state Co:MAO absorption crossections; τ_{Co} - Co:MAO $^4T_1$ level lifetime; Δ_{las}, Δ_{lum} - laser and CTAL spontaneous emission factors; K_{las}, K_{lum} - laser and CTAL loss factors; χ, η_λ - normalizing parameters.

It has been found that the influence of the CTAL photon flux becomes apparent first of all in the change of the lasing onset delay time. In particular, the value of $\Delta T = T_1 - T_2$, where T_1 and T_2 are the lasing delay times with and without taking into account the CTAL flux, can be positive or negative depending on the lasing resonator parameters, Q-switch transparency and pump excitation level. As is evident from the picture the contribution of the CTAL photon flux to the lasing delay time can be controlled by changing the output mirror reflection coefficient value and/or the initial transmission of the laser Q-switch element. The CTAL flux effect on the dependence of lasing output pulse energy on the Q-switch transparency was revealed for the investigated laser system also.

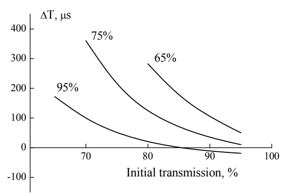

Fig. 3. Dependencies of the ΔT value on the initial transmission of the Q-switch element for different output mirror reflection coefficients R = 65, 75 and 95% of the LD pumped erbium laser. The second laser mirror was totally reflecting one

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