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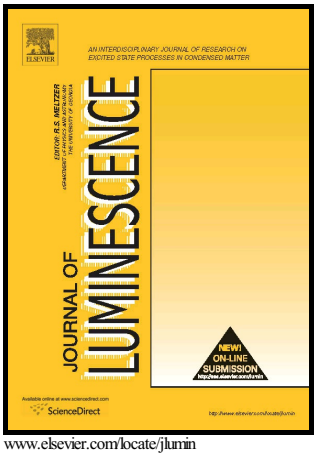

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Spectroscopic and laser properties of Tm^{3+} ions in $Ca_3(VO_4)_2$ crystal

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Abstract

The spectroscopic properties of Tm^{3+} ions in $Ca_3(VO_4)_2$ crystal were investigated and diode pumped tunable lasing was demonstrated. The maximum absorption and emission cross-sections for E⊥c at $^3F_4$-$^3H_6$ 2-μm transition were calculated to be ~1x10^{-20} cm^2 and ~1.3x10^{-20} cm^2 respectively. Noticeable $^3H_4$-$^3F_4$ $^3H_6$-$^3F_4$ cross-relaxation was observed resulting in a slope laser efficiency up to 15% at ~1960 nm under 792-nm laser diode pumping. Broadband tuning of the oscillation wavelength within the 1850–2070-nm spectral range was realized.

Key words: thulium optical centers, laser, nonlinear crystals, fluorescence spectra

1. Introduction

Lasers based on Tm^{3+}-doped materials are well-known sources of broadly-tunable laser radiation in the 2-μm spectral region [1]. However, search for new perspective Tm^{3+}-doped matrices, especially combining laser and nonlinear properties for further oscillation wavelength conversion, is still actual. $Ca_9La(VO_4)_7$ crystal with whitlockite-type structure was shown to be a good material for RE^{3+} ions doping [2, 3]. Recently, Tm^{3+} doped $Ca_9La_{0.94}Tm_{0.06}(VO_4)_7$ crystal was demonstrated to be a promising medium for development of tunable 2-μm lasers [4].

The undoped calcium orthovanadate $Ca_3(VO_4)_2$ with similar whitlockite-type structure is known to belong to trigonal symmetry crystals and has been investigated earlier for high-temperature ferroelectricity (T_C = 1383 K) [5], second-harmonic generation [6], and stimulated Raman (Ω_R = 854 cm^{-1}) scattering [7]. In this work, $Ca_3(VO_4)_2$:Tm^{3+} crystals were grown by Czochralski method in Pt crucibles in air. The growth direction was perpendicular to the optical c-axis. The Tm_2O_3 concentration in the melt was varied from 0.05 to 2 wt %, which corresponds to the Tm^{3+} concentrations in synthesized crystals from 0.007 to 0.26 at %. The orthovanadate structure of the grown Tm^{3+}-doped samples was controlled by X-ray diffraction analysis. Detailed description of $Ca_3(VO_4)_2$:Tm^{3+} crystals synthesis and investigation of their physical-chemical properties can be found in [8].

2. Spectroscopic properties

The polarized absorption spectrum of $Ca_3(VO_4)_2$ crystal was measured using a Cary-5000 spectrophotometer with Glan prisms as polarizers. The results are presented in Fig. 1a and demonstrate a stronger absorption for the E⊥c case. For $^3H_6$-$^3H_4$ (790 nm