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Investigation of the mechanisms of upconversion luminescence in Ho^{3+} doped CaF_2 crystals and ceramics upon excitation of $^5I_7$ level

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ABSTRACT

The mechanisms of upconversion luminescence of CaF_2:Ho crystals and ceramics from $^5F_3$, $^5S_2(^5F_4)$, $^5F_5$ and $^5I_6$ levels upon excitation of $^5I_7$ level of Ho^{3+} ions were investigated. Different mechanisms are responsible for the populating and depletion of the energy levels of Ho^{3+} ion in CaF_2:Ho crystals and ceramics upon excitation of $^5I_7$ level. The upconversion luminescence from $^5F_3$, $^5F_5$, and $^5I_6$ levels in CaF_2:Ho crystals and ceramics is explained by energy transfer upconversion processes. Our results also confirmed that both excited-state absorption and energy transfer upconversion are responsible for the populating of $^5S_2(^5F_4)$ level.

1. Introduction

Investigation of the mechanisms of upconversion luminescence in rare-earth-doped systems is of fundamental scientific interest. Also this investigation is useful for developing IR visualizer, upconversion lasers and IR Quantum Counter.

From available literature data, it is known that the upconversion luminescence of Ho^{3+}-doped calcium fluoride crystals in the visible and near-IR wavelength regions upon excitation of $^5I_6$ [1], $^5I_5$ [2], $^5I_4$ [2,3], $^5F_5$ [2,4–6] and $^5S_2(^5F_4)$ [2,7] levels has been widely studied. However, we have not found papers of upconversion luminescence in CaF_2:Ho crystals excited by two-micron laser radiation to the $^5I_7$ level of Ho^{3+} ions.

Previously in [8] we presented upconversion luminescence spectra of Ho^{3+} ions in the visible and near-IR regions upon excitation of $^5I_7$ level by two-micron laser in CaF_2:Ho crystals. We have demonstrated that CaF_2:Ho crystals are possible candidates for visualizer of two-micron laser radiation. Laser emitting at 2 μm is used in medicine surgery, lidar systems etc. Also in Ref. [8] we estimated the energy efficiency of the conversion of two-micron laser radiation to radiation in the red spectral range 620–680 nm by the CaF_2:1 mol%HoF_3 crystal.

In present paper we continue our investigations of upconversion luminescence of Ho^{3+} ions in CaF_2 crystals. Nowadays rare-earth-doped ceramic materials play an important role in the photonics because fabrication technique of transparent ceramics allows manufacturing of large size elements. Advantages of ceramics also include high concentrations and homogeneous distributions of dopants, possibility to synthesize novel optical media of various compositions [9–11]. The goal of the present work is to study the mechanisms of upconversion luminescence in CaF_2:Ho crystals and ceramics from $^5F_3$, $^5S_2(^5F_4)$, $^5F_5$ and $^5I_6$ levels upon excitation of the $^5I_7$ level by the laser radiation at a wavelength of 1912 nm.

2. Experiment

In present paper we investigated CaF_2:Ho crystals and ceramics. The CaF_2:Ho crystals samples with HoF_3-concentration 0.2 mol%, 0.5 mol%, 1 mol% and 5 mol% were grown by the vertical directed crystallization method (Bridgman method) in vacuum in graphite crucibles, with a graphite resistance heater and graphite heat shields [8,12]. The CaF_2:Ho ceramics samples with HoF_3-concentration 0.2 mol%, 0.5 mol%, 1 mol% and 3 mol% were obtained by hot forming method [12,13]. The samples for luminescence investigations were made in the form of plane-parallel

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