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Site-selective spectroscopy of Ce^{3+} and Yb^{3+} ions in double-doped $SrAlF_5$ crystals



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ABSTRACT

This paper reports a study of absorption, luminescence and excitation spectra of single- and double-doped $Ce^{3+}, Yb^{3+}:SrAlF_5$ (0.5 at.%) single crystals. Spectral properties of different types of impurity centers of Ce^{3+} , Yb^{3+} and Yb^{2+} ions are described. Experimental energy level diagrams for optically nonequivalent Ce^{3+} , Yb^{2+} and Yb^{3+} centers in double-doped Ce^{3+} , $Yb^{3+}:SrAlF_5$ single crystals are suggested. Lasing on $Ce:SAF$ single crystal at 290 nm under 248 nm pumping was demonstrated for the first time.

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1. Introduction

$Ce^{3+}:SrAlF_5$ (SAF) crystal is a promising material for UV lasers and phosphors based on 5d–4f interconfigurational transitions [1]. However in this crystal host there is no suitable cation site for trivalent rare-earth ions (RE^{3+}), which would meet the requirements of the Goldschmidt rule as well as isovalent substitution conditions. Generally this yields two basic factors that complicate an achievement of laser effect (increase oscillation threshold and reduce lasing efficiency): (1) low segregation coefficient of Ce^{3+} ions in $SrAlF_5$ host and (2) several types of optically nonequivalent cerium impurity centers formation. In the case of $SrAlF_5$ crystal, Ce^{3+} ions substitute for Sr^{2+} host cations in four nonequivalent positions [2]. Therefore, taking into account numerous possible ways of charge compensation, more than four types of optically nonequivalent cerium centers can be expected. This is important because strong overlapping of the absorption bands associated with 4f–5d transitions of various types of Ce^{3+} -impurity centers leads to the consumption of excitation (pumping) energy by all centers while only one is lasing (e.g. like it was observed in $Ce^{3+}:LiCAF$ active medium [3]).

Here the results of spectroscopic studies of $SrAlF_5$ crystals doped by Ce^{3+} and co-doped by Yb^{3+} ions are reported. It has been demonstrated before that Co-doping by Yb^{3+} ions effectively suppresses color centers formation processes in several UV active

media, such as $LiYF_4:Ce^{3+}$, $LiLuF_4:Ce^{3+}$, $KY_3F_{10}:Ce^{3+}$ [4–6]. Some promising results has also been achieved in Yb-codoped $Ce:SrAlF_5$ crystals [7]. On the other hand co-doping occasionally leads to variation of relative concentration of cerium centers and quenching of cerium 5d–4f luminescence as compared with the results for crystals doped by Ce^{3+} ions only [5].

Besides a low segregation coefficient of impurity ions generally means that crystal lattice in the presence of dopants undergoes a distortion. As a result amount of crystal lattice defects, which serve as seeds for color centers formation, increases. In these terms, most of Ce^{3+} -doped fluorides exhibit degradation of optical properties under intense UV irradiation mostly because of considerable color centers formation processes. Therefore special crystal growth procedures improving host lattice perfection and/or co-doping techniques [4] have to be employed to suppress such processes.

This paper reports on different types of impurity centers fluorescent properties associated with 4f↔5d and 4f↔4f transitions of Ce^{3+} , Yb^{3+} and Yb^{2+} ions, and energy level diagram for distinct Ce^{3+} , Yb^{2+} and Yb^{3+} optical centers in double-doped Ce , $Yb:SAF$ single crystals is suggested.

2. Experimental details

2.1. Preparation of materials

$Ce:SAF$ and $Ce,Yb:SAF$ crystals were grown in Ar-atmosphere in carbon crucibles using Bridgman–Stockbarger technique in Kazan

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