

Article

Selective Laser Spectroscopy of the Bixbyite-Type Yttrium Scandate Doped by Rare-Earth Ions

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Abstract: Yttrium scandate crystals doped by Nd^{3+} and Tm^{3+} ions have been successfully grown in the form of fibers using the laser-heated pedestal growth (LHPG) technique. The selective laser spectroscopy methods have identified and distinguished three distinct types of optically active centers associated with Nd^{3+} and Tm^{3+} ions. The substitution of Y^{3+} and Sc^{3+} for rare-earth ions in the C_2 structural site leads to the formation of two distinct basic long-time centers. In $\text{Nd}^{3+}:\text{YScO}_3$, another type of center (a short-lifetime one) is formed known as the $\text{Nd}^{3+}\text{--Nd}^{3+}$ aggregate pair. This center arises from the substitution of Y^{3+} or Sc^{3+} for Nd^{3+} cation in the adjacent MO_6 polyhedra that share an edge. In $\text{Tm}^{3+}:\text{YScO}_3$, the third optical center is formed as a result of the substitution of Y^{3+} or Sc^{3+} for Tm^{3+} in the MO_6 octahedra with the C_{3u} site symmetry. The fluorescence decay lifetimes of Nd^{3+} and Tm^{3+} ions in the YScO_3 crystal structure have been accurately measured and estimated. A Stark level diagram illustrating the splitting of $^4\text{F}_{3/2}$, $^4\text{I}_{11/2}$, and $^4\text{I}_{9/2}$ multiplets of Nd^{3+} ions has been constructed to show features of the active optical centers with the C_2 site symmetry.

Keywords: selective laser spectroscopy; optical center; rare-earth ion



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1. Introduction

Rare-earth (RE^{3+})-doped Sc_2O_3 and Y_2O_3 sesquioxides exhibit high thermal conductivity, approximately twice that of yttrium aluminum (YAG) [1], and have a wide transparency range from 0.25 μm to 9.6 μm [2]. These materials have demonstrated excellent potential for high-power solid-state lasers [3–8], particularly in the infrared (IR) spectral region. They could serve as a viable alternative to the well-established YAG crystals. RE^{3+} -doped sesquioxide materials show strong potential for a variety of applications, including solid-state light-emitting devices [9–11], high-efficiency luminescent materials [12,13], rare-earth magnets [14,15], magneto-optical recording materials [16,17], and so on.

Both Y_2O_3 and Sc_2O_3 are categorized as a cubic bixbyite-type structure [18–22], where there are one position for the oxygen ion and two symmetrically independent positions for cations: the 8b site with C_{3u} symmetry and 24d site with C_2 symmetry. The unit cell contains three cations occupying the the C_2 site and one cation in the C_{3u} site. Two types of 6-vertex polyhedra share corners and edges to form a chessboard packing derived from the fluorite structure type [23].

Extensive research has been carried out on rare-earth dopants in Y_2O_3 crystals, revealing that RE^{3+} ions have the capability to occupy Y^{3+} sites [24–31]. However, due to inversion symmetry, the electric dipole–dipole transitions within the $4f$ -configuration are forbidden for the Kramers RE^{3+} ions (which have an odd number of $4f$ -electrons) occupying the C_{3u} sites. Consequently, all electron transitions observed in the fluorescence spectra of these ions should be assigned to electronic transitions in active optical centers located in the C_2 sites. Sc_2O_3 is also a promising host material as it exhibits a strong crystal field effect, primarily caused by the lattice distortions resulting from the substitution of Sc^{3+} for RE^{3+} ions of larger size [4,32,33]. Moreover, Tm^{3+} -doped Sc_2O_3 and Y_2O_3 have extraordinary

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