Influence of Configuration Interaction on Absorption Transition Intensities of Rare-Earth Ions in Laser Materials

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Abstract— On an example of holmium doped crystals and glasses the influence of excited configurations with a charge transfer and opposite parity configurations on oscillator strengths of absorption transitions is investigated. The deduction about the most adequate approximation for description of experimental results is made

Optical absorption and emission properties of Ho3+ doped crystals and glasses were in detail investigated experimentally [1,2]. These materials represent practical interest for making solidstate lasers. From the point of view of the intensity theory the Ho3+ doped materials are difficult objects [3]. The experimental oscillator strengths differ essentially for some transitions from calculated one by a method [4,5]. It is possible to explain by strong influence of excited configurations, which is taken into account in a method [4,5] not full enough.

In this paper for multifold study of influence of excited configurations we propose to use the effective operator of line strengths offered in [6]

\[
S_{ij}^{\text{eff}} = \frac{e^2}{4} \sum_{\gamma J', \gamma J} \left\langle \gamma'_J | U^* | \gamma J \right\rangle \left\langle \gamma L'S'| U' | \gamma L'S \right\rangle \times \\
\left| O_{\Delta \gamma} \left( \frac{\Delta_d}{\Delta_c - E_J} + \frac{\Delta_d}{\Delta_c - E_{J'}} \right) + O_{\Delta \gamma} \left( \frac{\Delta_c}{\Delta_c - E_J} + \frac{\Delta_c}{\Delta_{c} - E_{J'}} \right) \right|^2,
\]

Here the parameters \( O_{\Delta \gamma} \) and energy \( \Delta \gamma \) correspond to excited configuration of opposite parity \( 4f^{15}5d \), while parameters \( O_{\Delta \gamma} \) and energies \( \Delta \gamma \) correspond to covalent effects of excited configurations with charge transfer;

\[
\left\langle \gamma L'S'| U^* | \gamma L'S \right\rangle
\]

is the reduced matrix element of the unite tensor \( U_k, E_j \) and \( E_{J'} \) are the energies of \( \gamma J \) and \( \gamma J' \) multiplets.

The operator was obtained by us in an approximation of strong configuration interaction. From operator (1) it is possible easily to receive effective operators in other approximations, for example, approximation of weak configuration interaction [4,5].

The comparative analysis, carried out by us in various approximations, has allowed to make a deduction, that most adequate is the approximation of strong configuration interaction for description of absorption oscillator strengths of holmium doped crystals and glasses.