A brief introduction to Judd-Ofelt theory: Application to rare earth-doped silicate glass

Petr Vařák[1,2], Jan Hrabovský[3,4], Robin Kryštůfek[5,6], Artem Simoniakin[1], Pavla Nekvindová[1], Michal Kamrádek[2], and Pavel Peterka[2]

[1]*University of Chemistry & Technology, Prague, Technická 5, Praha 6, Czechia*
[2]*Institute of Photonics & Electronics of the CAS, Prague, Czech Republic*
[3]*Faculty of Mathematics and Physic, Charles University, Prague, Czech Republic*
[4]*Department of Physics, New Mexico State University, Las Cruces, NM, United States*
[5]*Institute of Organic Chemistry and Biochemistry of the CAS, Prague, Czech Republic*
[6]*Faculty of Science, Charles University, Prague, Czech Republic*

Rare-earth (RE) elements and their trivalent ions remain highly relevant in both science and industry thanks to their unique electronic, magnetic, and optical properties, especially the sharp absorption and emission lines owing to the intra 4f-4f electron transitions.

The Judd-Ofelt (J-O) theory, introduced in 1962 by B. R. Judd and G. S. Ofelt, remains a staple in the analysis of the optical properties of the 4f-4f electronic transitions in trivalent rare earth ions [1, 2]. The J-O theory starts with the free ion Hamiltonian of a 4*f* electron, which has no exact solution, and using several approximations and assumptions, arrives to a simple expression for the so-called line strength, *S*, of each transition. The analysis under the umbrella of the J-O theory allows to use measured absorption cross sections to calculate the experimental values of line strengths, and using a simple least squares method, obtain three phenomenological J-O parameters, Ω_i, where i = 2, 4 and 6 [3]. The parameters are subsequently used to calculate the transition probabilities, branching ratios, radiative lifetimes and quantum efficiency - all crucial parameters in various theoretical tasks and simulations, e.g. the calculations of emission cross sections, energy transfer coefficients, etc., making the J-O analysis one of the most important tools of materials research in photonics.

In this contribution, the main concepts and background of the rare earth ion spectroscopy are summarized, and the J-O theory is briefly introduced. We introduce the newly developed, on-line and free-to-use software LOMS.cz [4]. The Spectroscopic properties of several glass systems are measured, and the J-O analysis is conducted using the LOMS.cz software. The utility and practical application of the J-O theory are demonstrated on the results.

This work was supported by Czech Science Foundation (23-05507S). This work was co-funded by the European Union and the Czech Republic under the project LasApp CZ.02.01.01/00/22_008/0004573 and SenDiSo CZ.02.01.01/00/22008/0004596.

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