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Guokui Liu Bernard Jacquier (Eds.)

Spectroscopic Properties of Rare Earths in Optical Materials

With 194 Figures and 61 Tables

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《Spectroscopic Properties of Rare Earths in Optical Materials》

Preface

Decades of scientific research on spectroscopic properties of f-shell electrons has spawned an extensive array of applications for rare-earth activated luminescent and laser materials. From phosphors activated by Eu^{2+}, Eu^{3+} and Tb^{3+} ions for lighting and display to crystals and glasses doped with Er^{3+} and Yb^{3+} for infrared-to-visible up-conversion, rare-earths represent a large share of the lighting materials market. Currently, Nd^{3+} doped crystals such as Nd^{3+}: YAG ($Y_3Al_5O_{12}$) and Nd^{3+}: YVO_4 are the dominant laser media for high power and compact solid-state lasers, while Er^{3+} doped phosphate and silicate glasses prevalent in optical fiber amplifiers and microlasers used in optical telecommunications. Thanks also to materials science development, rare-earths will receive even wider use in the future, entering in the new world of nanotechnologies for instance. In addition to rare-earth activated phosphors and solid-state lasers, optical applications of rare-earths are already an integral part of internet and data communications and are expected to be applied to information storage and processing, and organic and biological devices.

Since the 1960s, several classic books on spectroscopy of rare-earth ions in solids have been published, including those by Wybourne (1965) and Hüfner (1978). More recent advances in spectroscopic theory and laser experiments involving rare-earth ions in solids were also reviewed, for example, in the book edited by Kaplyanskii and Macfarlane (1987). However, in the f-elements research community, we feel the need of a book that updates the information of recent progresses in the field and facilitates understanding and applications of the principles and concepts that are required in rare-earth optical materials characterization and development. The goal of this book is to provide a connection between basic research and materials science through analysis of fundamental spectroscopic properties of rare-earth activated luminescent and laser optical materials. In addition, this book will serve as an updated reference for materials research by covering a number of currently active topics in the field of rare-earth photo-physics and photo-chemistry. Fundamental topics of optical spectroscopy are addressed with an emphasis on the physical interactions that determine the primary optical properties, including energy level schemes, transitions intensities, line broadening, mechanisms of non-radiative relaxation and energy transfer. Topics of applied research are selected from recent advances in concepts and techniques that created significant opportunities for present and future applications of rare-earth optical materials.

An international collaboration, which includes contributions from authors with both experimental and theoretical expertise, enables us to offer the reader a systematic review of fundamental aspects and to provide a wide coverage on new applications that utilize the electronic transitions of rare-earth ions in solid-state materials. From free-ion and crystal-field energy level structures to transition intensities and line broadening induced by ion-ion and ion-phonon interactions, the first four chapters survey the fundamentals of f-element photo-physics and spectroscopy, and provide a theoretical framework for the subjects that are discussed in the rest of the book. From Chapter 5 onwards, each chapter is devoted to a particular area of importance in new materials characterization or technology development. From up-conversion phenomena, to materials requirements for frequency-domain and time-domain optical memory, to current progress in rare-earth laser materials and phosphors, the concepts and principles discussed in this book were taken directly from the forefront of research in rare-earth optical materials. Moreover, illustration of current progress in fundamental aspects of quantum confinement and quantum electrodynamics is also discussed. To make it easier to read, and also to avoid cluttering up Chapters 1, 2 and 3, the more theoretical derivations of these chapters are given in Appendices A and B. We hope that this book will provide useful information to researchers and students in the field of f-element spectroscopy and materials development.

Although chapters in this book are written independently by individual authors, significant efforts have been made to achieve a coherent connection and systematic balance for the book as a whole. We are grateful to all authors of this book for their excellent contributions.

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