Nonlinear-Emission Photonic Glass Fiber and Waveguide Devices

A comprehensive introduction to the design of compact and broadband fiber and waveguide devices using active-ion-doped photonic glasses. Combining cutting-edge theory with new applications, it shows how the complementarity of emission spectra of different active ions can be used in broadband fiber amplifiers and optical fiber communication, and describes how the quantum cutting of active ions can improve the match between the solar spectrum and the responsiveness of silicon cells. Mathematical modeling is used to predict the performance of photonic fiber and waveguide devices, and experimental data from glass doped with rare-earth ions is included. Offering unique insights into the state of the art of the field, this is an ideal reference for researchers and practitioners, and invaluable reading for students in optoelectronics, electrical engineering, and materials science.

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Preface

Luminescence of transition-metal ions and rare-earth ions has important applications in optoelectronic devices and systems including fiber amplifiers, fiber lasers, and fiber sources. With advances in integrated photonic devices and broadband and compact fiber-optic devices, it is necessary to make active fiber devices that have short interaction length and have broadband gain and emission spectra by using high-concentration active ion-doping and multi-active ion-doping techniques. For low-concentration doped-fiber devices, the dependence of emission intensity on excitation power generally is a linear relationship. However, in highly doped and multiply doped fiber devices, the relation is not linear and but nonlinear, due to the interaction between rare-earth ions such as upconversion, cross-relaxation, energy transfer, and so on. In this book, thus, the active fiber and waveguide devices including high concentration-doping and multi-rare-earth-doping are defined as nonlinear-emission photonic fiber and waveguide devices.

This book consists of eight parts as follows:

Chapter 1 introduces the fundamental mathematics of nonlinear-emission photonic glass fiber and waveguide devices. In the design and analysis of the photonic glass fiber and waveguide devices, one of most important tasks is to solve a multi-variable rate equation group and power-propagation equation group. The methods introduced in this chapter are Newton iteration, Runge–Kutta algorithms and their combination as well as solution of two-point boundary problem, which are effective numerical techniques for highly doped or co-doped fiber amplifiers, fiber sources, and fiber laser systems.

Chapter 2 introduces the fundamental of spectral theory of photonic glasses. In this chapter, spectral properties of rare-earth-doped glasses, including absorption and emission cross-sections, spontaneous emission transition probability, fluorescence branch ratio and quantum efficiency, and homogeneous and inhomogeneous broadening of fluorescence spectra and their calculating methods, are summarized.

Chapter 3 systematically reports the spectral properties and laser performance parameters of ytterbium-doped glass systems. Ytterbium ions can be used as sensitizers to other active ions due to simple level structure and strong absorption coefficient, ytterbium ion-doped fiber can be used as a high-power fiber laser system for industrial processing, and ytterbium ion-doped glass waveguides can be used as a spectral converter because its emission wavelength matches well with the spectral responsivity of single-crystal silicon solar cell.

Chapter 4 presents the modeling and numerical results of compact ytterbium-erbium-co-doped fiber amplifiers, which are supposed to obtain higher internal gain and higher gain per unit length in fiber amplifiers using numerical solutions of rate and evolution equations of signal, pump power, and amplified spontaneous emission.

Chapter 5 introduces the fundamentals of lasers and a numerical model of ytterbium-doped-glass fiber systems, which can be widely used in industrial processing. Nonlinear interaction between high-concentration active ions or the co-upconversion effect will degrade these system performances. Our numerical model considers the nonlinear transition in the high-concentration doped system and may be used to calculate the threshold power and output power.

Chapter 6 proposes several schemes for all-wave fiber transmission systems, including doubly doped fiber amplifiers such as erbium-thulium-co-doped and erbium-praseodymium-co-doped fiber amplifiers and triply doped fiber amplifiers such as erbium-thulium-praseodymium-co-doped fiber amplifiers, and presents their numerical models and calculates the dependence of gains at different wavelength on fiber and pump parameters.

Chapter 7 introduces the spectral conversion mechanisms of multi-rare-earth-co-doped glass waveguides including the setting up of rate-equations and power-propagation equations model of several co-doped systems. These kinds of photonic glass waveguides are simple applications of spectral downconversion and quantum cutting for enhancing performance of c-Si solar cells. The power-conversion efficiency and quantum conversion efficiency of the co-doped systems are analyzed and the enhanced performances of a sc-Si solar cell model are evaluated.

Chapter 8 establishes photonic glass waveguide systems for white-light generation and presents their numerical models. White-light generation has important applications in lighting and display areas. In this chapter, the energy level, electron transition process, and numerical models are proposed and the fluorescence intensity of the system is calculated. Optimal active concentrations are proposed to enable system to emit red, blue, and green light, which are mixed to generate white light.

Some topics in this book appear as color reprints of authors' published articles taken, with permission, from various journals, including *Journal of Solid State Chemistry*, *Journal of Luminescence*, *Material Letters*, *IEEE Journal of Quantum Electronics*, *Journal of Optics Society of America, Applied Physics B*, *IEEE Photonics Journal*, *and Applied Optics*, and so on.

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