

Semiconductor Optoelectronic Devices Bhattacharya

This book is the first to give a comprehensive description of the physics and applications of resonant tunneling diodes. The opening chapters of the book set out the basic principles of coherent tunneling theory. The authors describe in detail the effects of impurity scattering, femtosecond dynamics, non-equilibrium distribution, and intrinsic bistabilities. They review the applications of RTDs, such as in high-frequency signal generation and multi-valued data storage, and close the book with a chapter on the new field of resonant tunneling through laterally confined zero-dimensional structures. Covering all the key theoretical and experimental aspects of this active area of research, the book will be of great value to graduate students of quantum transport physics and device engineering, as well as to researchers in both these fields.

The first true introduction to semiconductor optoelectronic devices, this book provides an accessible, well-organized overview of optoelectronic devices that emphasizes basic principles. Coverage begins with an optional review of key concepts—such as properties of compound semiconductor, quantum mechanics,

semiconductor statistics, carrier transport properties, optical processes, and junction theory—then progress gradually through more advanced topics. The Second Edition has been both updated and expanded to include the recent developments in the field.

Optoelectronic devices operating in the mid-infrared wavelength range offer applications in a variety of areas from environmental gas monitoring around oil rigs to the detection of narcotics. They could also be used for free-space optical communications, thermal imaging applications and the development of "homeland security" measures. Mid-infrared Semiconductor Optoelectronics is an overview of the current status and technological development in this rapidly emerging area; the basic physics, some of the problems facing the design engineer and a comparison of possible solutions are laid out; the different lasers used as sources for mid-infrared technology are considered; recent work in detectors is reviewed; the last part of the book is concerned with applications. With a world-wide authorship of experts working in many mid-infrared-related fields this book will be an invaluable reference for researchers and graduate students drawn from physics, electronic and electrical engineering and materials science.

Designed for a senior or graduate-level course in optical communications,

Principles and Applications of Optical Communications offers comprehensive coverage of a variety of light wave technologies not often found in other texts. Taking an applied approach to the subject, this text has utility in a number of different optical communications courses and in advanced signal processing. The coverage and approach reflect Dr. Liu's background in industry. They offer students exposure to the latest technologies and give strong preparation for industry positions in optical communications.

This book brings together two broad themes that have generated a great deal of interest and excitement in the scientific and technical community in the last 100 years or so: quantum tunnelling and nonlinear dynamical systems. It applies these themes to nanostructured solid state heterostructures operating at room temperature to gain insight into novel photonic devices, systems and applications.

This is the first monograph which solely investigates the thermoelectric power in nanostructured materials under strong magnetic field (TPSM) in quantum confined nonlinear optical, III-V, II-VI, n-GaP, n-Ge, Te, Graphite, PtSb₂, zerogap, II-V, Gallium Antimonide, stressed materials, Bismuth, IV-VI, lead germanium telluride, Zinc and Cadmium diphosphides, Bi₂Te₃, Antimony and carbon nanotubes, III-V, II-VI, IV-VI and HgTe/CdTe superlattices with graded

interfaces and effective mass superlattices under magnetic quantization, the quantum wires and dots of the aforementioned superlattices by formulating the appropriate respective carrier energy spectra which in turn control the quantum processes in quantum effect devices. The TPSM in macro, quantum wire and quantum dot superlattices of optoelectronic materials in the presence of external photo-excitation have also been studied on the basis of newly formulated electron dispersion laws. This monograph contains 150 open research problems which form the very core and are useful for PhD students and researchers in the fields of materials science, solid-state sciences, computational and theoretical nanoscience and technology, nanostructured thermodynamics and condensed matter physics in general in addition to the graduate courses on modern thermoelectric materials in various academic departments of many institutes and universities.

This study explores the key properties of III-V compounds and presents the various material parameters and constants of these semiconductors for a number of research applications. The experimental and theoretical data has been summarized in tabular, graphical and functional formats.

Annotation Tiny structures measurable on the nanometer scale (one-billionth of a meter) are known as nanostructures, and nanotechnology is the emerging

application of these nanostructures into useful nanoscale devices. As we enter the 21st century, more and more professional are using nanotechnology to create semiconductors for a variety of applications, including communications, information technology, medical, and transportation devices. Written by today's best researchers of semiconductor nanostructures, this cutting-edge resource provides a snapshot of this exciting and fast-changing field. The book covers the latest advances in nanotechnology and discusses the applications of nanostructures to optoelectronics, photonics, and electronics.

Wide Bandgap Semiconductor Power Devices: Materials, Physics, Design and Applications provides readers with a single resource on why these devices are superior to existing silicon devices. The book lays the groundwork for an understanding of an array of applications and anticipated benefits in energy savings. Authored by the Founder of the Power Semiconductor Research Center at North Carolina State University (and creator of the IGBT device), Dr. B. Jayant Baliga is one of the highest regarded experts in the field. He thus leads this team who comprehensively review the materials, device physics, design considerations and relevant applications discussed. Comprehensively covers power electronic devices, including materials (both gallium nitride and silicon carbide), physics, design considerations, and the most promising applications

Addresses the key challenges towards the realization of wide bandgap power electronic devices, including materials defects, performance and reliability
Provides the benefits of wide bandgap semiconductors, including opportunities for cost reduction and social impact

A graduate textbook presenting the underlying physics behind devices that drive today's technologies. The book covers important details of structural properties, bandstructure, transport, optical and magnetic properties of semiconductor structures. Effects of low-dimensional physics and strain - two important driving forces in modern device technology - are also discussed. In addition to conventional semiconductor physics the book discusses self-assembled structures, mesoscopic structures and the developing field of spintronics. The book utilizes carefully chosen solved examples to convey important concepts and has over 250 figures and 200 homework exercises. Real-world applications are highlighted throughout the book, stressing the links between physical principles and actual devices. *Electronic and Optoelectronic Properties of Semiconductor Structures* provides engineering and physics students and practitioners with complete and coherent coverage of key modern semiconductor concepts. A solutions manual and set of viewgraphs for use in lectures are available for instructors, from solutions@cambridge.org.

Optoelectronics, first published in 2002, is a practical and self-contained textbook written for graduate students and engineers.

This updated, second edition textbook provides a thorough and accessible treatment of semiconductor lasers from a design and engineering perspective. It includes both the physics of devices as well as the engineering, designing and testing of practical lasers. The material is presented clearly with many examples provided. Readers of the book will come to understand the finer aspects of the theory, design, fabrication and test of these devices and have an excellent background for further study of optoelectronics.

This book addresses material growth, device fabrication, device application, and commercialization of energy-efficient white light-emitting diodes (LEDs), laser diodes, and power electronics devices. It begins with an overview on basics of semiconductor materials, physics, growth and characterization techniques, followed by detailed discussion of advantages, drawbacks, design issues, processing, applications, and key challenges for state of the art GaN-based devices. It includes state of the art material synthesis techniques with an overview on growth technologies for emerging bulk or free standing GaN and AlN substrates and their applications in electronics, detection, sensing, optoelectronics and photonics. Wengang (Wayne) Bi is Distinguished Chair

Professor and Associate Dean in the College of Information and Electrical Engineering at Hebei University of Technology in Tianjin, China. Hao-chung (Henry) Kuo is Distinguished Professor and Associate Director of the Photonics Center at National Chiao-Tung University, Hsin-Tsu, Taiwan, China. Pei-Cheng Ku is an associate professor in the Department of Electrical Engineering & Computer Science at the University of Michigan, Ann Arbor, USA. Bo Shen is the Cheung Kong Professor at Peking University in China.

This book captures cutting-edge research in semiconductor quantum dot devices, discussing preparation methods and properties, and providing a comprehensive overview of their optoelectronic applications. Quantum dots (QDs), with particle sizes in the nanometer range, have unique electronic and optical properties.

They have the potential to open an avenue for next-generation optoelectronic methods and devices, such as lasers, biomarker assays, field effect transistors, LEDs, photodetectors, and solar concentrators. By bringing together leaders in the various application areas, this book is both a comprehensive introduction to different kinds of QDs with unique physical properties as well as their preparation routes, and a platform for knowledge sharing and dissemination of the latest advances in a novel area of nanotechnology.

Semiconductors are at the heart of modern living. Almost everything we do, be it

work, travel, communication, or entertainment, all depend on some feature of semiconductor technology. Comprehensive Semiconductor Science and Technology captures the breadth of this important field, and presents it in a single source to the large audience who study, make, and exploit semiconductors. Previous attempts at this achievement have been abbreviated, and have omitted important topics. Written and Edited by a truly international team of experts, this work delivers an objective yet cohesive global review of the semiconductor world. The work is divided into three sections. The first section is concerned with the fundamental physics of semiconductors, showing how the electronic features and the lattice dynamics change drastically when systems vary from bulk to a low-dimensional structure and further to a nanometer size. Throughout this section there is an emphasis on the full understanding of the underlying physics. The second section deals largely with the transformation of the conceptual framework of solid state physics into devices and systems which require the growth of extremely high purity, nearly defect-free bulk and epitaxial materials. The last section is devoted to exploitation of the knowledge described in the previous sections to highlight the spectrum of devices we see all around us. Provides a comprehensive global picture of the semiconductor world Each of the work's three sections presents a complete description of one aspect of the whole Written

and Edited by a truly international team of experts

This text motivates students by striking a balance in orientation between a strong physics and a strong applications approach. The author also has a unique chapter on fabrication absent in other major books, and puts less of an emphasis on lasers and microwaves. The book de-emphasizes some difficult concepts in Quantum Mechanics as well as the complex mathematics that is used in applying these concepts. Readers are introduced to the steps in the fabrication of devices to make the operation and construction of each device more real.

This book reviews the current status of semiconductor materials for conversion of sunlight to electricity, and highlights advances in both basic science and manufacturing. Photovoltaic (PV) solar electric technology will be a significant contributor to world energy supplies when reliable, efficient PV power products are manufactured in large volumes at low cost. Expert chapters cover the full range of semiconductor materials for solar-to-electricity conversion, from crystalline silicon and amorphous silicon to cadmium telluride, copper indium gallium sulfide selenides, dye sensitized solar cells, organic solar cells, and environmentally friendly copper zinc tin sulfide selenides. The latest methods for synthesis and characterization of solar cell materials are described, together with techniques for measuring solar cell efficiency. Semiconductor Materials for Solar

Photovoltaic Cells presents the current state of the art as well as key details about future strategies to increase the efficiency and reduce costs, with particular focus on how to reduce the gap between laboratory scale efficiency and commercial module efficiency. This book will aid materials scientists and engineers in identifying research priorities to fulfill energy needs, and will also enable researchers to understand novel semiconductor materials that are emerging in the solar market. This integrated approach also gives science and engineering students a sense of the excitement and relevance of materials science in the development of novel semiconductor materials. · Provides a comprehensive introduction to solar PV cell materials · Reviews current and future status of solar cells with respect to cost and efficiency · Covers the full range of solar cell materials, from silicon and thin films to dye sensitized and organic solar cells · Offers an in-depth account of the semiconductor material strategies and directions for further research · Features detailed tables on the world leaders in efficiency demonstrations · Edited by scientists with experience in both research and industry

The second edition of Solid State Electronic Devices serves as a textbook for an introductory course on solid state electronic devices.

Developed as an introductory course, this up-to-date text discusses the major

building blocks of present-day fiber-optic systems and presents their use in communications and sensing. Starting with easy-to-understand ray propagation in optical fibers, the book progresses towards the more complex topics of wave propagation in planar and cylindrical waveguides. Special emphasis has been given to the treatment of single-mode fibers the backbone of present-day optical communication systems. It also offers a detailed treatment of the theory behind optoelectronic sources (LEDs and injection laser diodes), detectors, modulators, and optical amplifiers. Contemporary in terms of technology, it presents topics such as erbium-doped fiber amplifiers (EDFAs) and wavelength-division multiplexing (WDM) along with dense WDM. Building upon these fundamental principles, the book introduces the reader to system design considerations for analog and digital fiber-optic communications. Emphasis has also been given to fiber-optic sensors and laser-based systems along with their industrial and other applications. This student-friendly text would be very useful to undergraduate students pursuing instrumentation, electronics, and communication engineering. It would also prove to be a good text for postgraduate students of physics. Discover cutting-edge techniques for next-generation integrated circuit design, and learn how to deliver improved speed, density, power, and cost. Since its invention in 1962, the semiconductor laser has come a long way.

Advances in material purity and epitaxial growth techniques have led to a variety of semiconductor lasers covering a wide wavelength range of 0.3-100 μm . The development during the 1970s of GaAs semiconductor lasers, emitting in the near-infrared region of 0.8-0.9 μm , resulted in their use for the first generation of optical fiber communication systems. However, to take advantage of low losses in silica fibers occurring around 1.3 and 1.55 μm , the emphasis soon shifted toward long-wavelength semiconductor lasers. The material system of choice in this wavelength range has been the quaternary alloy InGaAsP. During the last five years or so, the intense development effort devoted to InGaAsP lasers has resulted in a technology mature enough that lightwave transmission systems using InGaAsP lasers are currently being deployed throughout the world. This book is intended to provide a comprehensive account of long-wavelength semiconductor lasers. Particular attention is paid to InGaAsP lasers, although we also consider semiconductor lasers operating at longer wavelengths. The objective is to provide an up-to-date understanding of semiconductor lasers while incorporating recent research results that are not yet available in the book form. Although InGaAsP lasers are often used as an example, the basic concepts discussed in this text apply to all semiconductor lasers, irrespective of their wavelengths.

Optoelectronics has become an important part of our lives. Wherever light is used to transmit information, tiny semiconductor devices are needed to transfer electrical current into optical signals and vice versa. Examples include light emitting diodes in radios and other appliances, photodetectors in elevator doors and digital cameras, and laser diodes that transmit phone calls through glass fibers. Such optoelectronic devices take advantage of sophisticated interactions between electrons and light. Nanometer scale semiconductor structures are often at the heart of modern optoelectronic devices. Their shrinking size and increasing complexity make computer simulation an important tool to design better devices that meet ever rising performance requirements. The current need to apply advanced design software in optoelectronics follows the trend observed in the 1980's with simulation software for silicon devices. Today, software for technology computer-aided design (TCAD) and electronic design automation (EDA) represents a fundamental part of the silicon industry. In optoelectronics, advanced commercial device software has emerged recently and it is expected to play an increasingly important role in the near future. This book will enable students, device engineers, and researchers to more effectively use advanced design software in optoelectronics. * Provides fundamental knowledge in semiconductor physics and in electromagnetics, while helping to understand and use advanced device simulation software * Demonstrates the combination of measurements and simulations in order to obtain realistic results and provides data on all required material parameters * Gives

deep insight into the physics of state-of-the-art devices and helps to design and analyze of modern optoelectronic devices

The first true "introduction" to semiconductor optoelectronic devices, this book provides an accessible, well-organized overview of optoelectronic devices that emphasizes basic principles. Coverage begins with an optional review of key concepts— such as properties of compound semiconductor, quantum mechanics, semiconductor statistics, carrier transport properties, optical processes, and junction theory— then progress gradually through more advanced topics. The "Second Edition" has been both updated and expanded to include the recent developments in the field.

Quantum well devices have been the objects of intensive research during the last two decades. Some of the devices have matured into commercially useful products and form part of modern electronic circuits. Some others require further development, but have the promise of being useful commercially in the near future. Study of the devices is, therefore, gradually becoming compulsory for electronics specialists. The functioning of the devices, however, involve aspects of physics which are not dealt with in the available text books on the physics of semiconductor devices. There is, therefore, a need for a book to cover all these aspects at an introductory level. The present book has been written with the aim of meeting this need. In fact, the book grew out of introductory lectures given by the author to graduate students and researchers interested in this rapidly developing area of electron devices. The book covers the

subjects of heterostructure growth techniques, band-offset theory and experiments, electron states, electron-photon interaction and related phenomena, electron transport and the operation of electronic, opto-electronic and photonic quantum well devices. The theory as well as the practical aspects of the devices are discussed at length. The aim of the book is to provide a comprehensive treatment of the physics underlying the various devices. A reader after going through the book should find himself equipped to deal with all kinds of quantum well devices.

Covers both the fundamentals and the state-of-the-art technology used for MBE Written by expert researchers working on the frontlines of the field, this book covers fundamentals of Molecular Beam Epitaxy (MBE) technology and science, as well as state-of-the-art MBE technology for electronic and optoelectronic device applications. MBE applications to magnetic semiconductor materials are also included for future magnetic and spintronic device applications. Molecular Beam Epitaxy: Materials and Applications for Electronics and Optoelectronics is presented in five parts: Fundamentals of MBE; MBE technology for electronic devices application; MBE for optoelectronic devices; Magnetic semiconductors and spintronics devices; and Challenge of MBE to new materials and new researches. The book offers chapters covering the history of MBE; principles of MBE and fundamental mechanism of MBE growth; migration enhanced epitaxy and its application; quantum dot formation and selective area growth by MBE; MBE of III-nitride semiconductors for electronic devices;

MBE for Tunnel-FETs; applications of III-V semiconductor quantum dots in optoelectronic devices; MBE of III-V and III-nitride heterostructures for optoelectronic devices with emission wavelengths from THz to ultraviolet; MBE of III-V semiconductors for mid-infrared photodetectors and solar cells; dilute magnetic semiconductor materials and ferromagnet/semiconductor heterostructures and their application to spintronic devices; applications of bismuth-containing III-V semiconductors in devices; MBE growth and device applications of Ga₂O₃; Heterovalent semiconductor structures and their device applications; and more. Includes chapters on the fundamentals of MBE. Covers new challenging researches in MBE and new technologies. Edited by two pioneers in the field of MBE with contributions from well-known MBE authors including three AI Cho MBE Award winners. Part of the Materials for Electronic and Optoelectronic Applications series. Molecular Beam Epitaxy: Materials and Applications for Electronics and Optoelectronics will appeal to graduate students, researchers in academia and industry, and others interested in the area of epitaxial growth. The updated and enlarged new edition of this book provides an introduction to and an overview of semiconductor optics from the IR through the visible to the UV. It includes coverage of linear and nonlinear optical properties, dynamics, magneto- and electrooptics, high-excitation effects, some applications, experimental techniques and group theory. The mathematics is kept as elementary as possible. The subjects covered extend from physics to materials science and optoelectronics. New or updated

chapters add coverage of current topics, while the chapters on bulk materials have been revised and updated.

This reference book provides a fully integrated novel approach to the development of high-power, single-transverse mode, edge-emitting diode lasers by addressing the complementary topics of device engineering, reliability engineering and device diagnostics in the same book, and thus closes the gap in the current book literature. Diode laser fundamentals are discussed, followed by an elaborate discussion of problem-oriented design guidelines and techniques, and by a systematic treatment of the origins of laser degradation and a thorough exploration of the engineering means to enhance the optical strength of the laser. Stability criteria of critical laser characteristics and key laser robustness factors are discussed along with clear design considerations in the context of reliability engineering approaches and models, and typical programs for reliability tests and laser product qualifications. Novel, advanced diagnostic methods are reviewed to discuss, for the first time in detail in book literature, performance- and reliability-impacting factors such as temperature, stress and material instabilities. Further key features include: practical design guidelines that consider also reliability related effects, key laser robustness factors, basic laser fabrication and packaging issues; detailed discussion of diagnostic investigations of diode lasers, the fundamentals of the applied approaches and techniques, many of them pioneered by the author to be fit-for-purpose and novel in the application; systematic insight into laser

degradation modes such as catastrophic optical damage, and a wide range of technologies to increase the optical strength of diode lasers; coverage of basic concepts and techniques of laser reliability engineering with details on a standard commercial high power laser reliability test program. Semiconductor Laser Engineering, Reliability and Diagnostics reflects the extensive expertise of the author in the diode laser field both as a top scientific researcher as well as a key developer of high-power highly reliable devices. With invaluable practical advice, this new reference book is suited to practising researchers in diode laser technologies, and to postgraduate engineering students. Dr. Peter W. Epperlein is Technology Consultant with his own semiconductor technology consulting business Pwe-PhotonicsElectronics-IssueResolution in the UK. He looks back at a thirty years career in cutting edge photonics and electronics industries with focus on emerging technologies, both in global and start-up companies, including IBM, Hewlett-Packard, Agilent Technologies, Philips/NXP, Essient Photonics and IBM/JDSU Laser Enterprise. He holds Pre-Dipl. (B.Sc.), Dipl. Phys. (M.Sc.) and Dr. rer. nat. (Ph.D.) degrees in physics, magna cum laude, from the University of Stuttgart, Germany. Dr. Epperlein is an internationally recognized expert in compound semiconductor and diode laser technologies. He has accomplished R&D in many device areas such as semiconductor lasers, LEDs, optical modulators, quantum well devices, resonant tunneling devices, FETs, and superconducting tunnel junctions and integrated circuits. His pioneering work on

sophisticated diagnostic research has led to many world's first reports and has been adopted by other researchers in academia and industry. He authored more than seventy peer-reviewed journal papers, published more than ten invention disclosures in the IBM Technical Disclosure Bulletin, has served as reviewer of numerous proposals for publication in technical journals, and has won five IBM Research Division Awards. His key achievements include the design and fabrication of high-power, highly reliable, single mode diode lasers. Book Reviews "Semiconductor L

As we approach the end of the present century, the elementary particles of light (photons) are seen to be competing increasingly with the elementary particles of charge (electrons/holes) in the task of transmitting and processing the insatiable amounts of information needed by society. The massive enhancements in electronic signal processing that have taken place since the discovery of the transistor, elegantly demonstrate how we have learned to make use of the strong interactions that exist between assemblages of electrons and holes, disposed in suitably designed geometries, and replicated on an increasingly fine scale. On the other hand, photons interact extremely weakly amongst themselves and all-photon active circuit elements, where photons control photons, are presently very difficult to realise, particularly in small volumes. Fortunately rapid developments in the design and understanding of semiconductor injection lasers coupled with newly recognized quantum phenomena, that arise when device dimensions become comparable with electronic wavelengths,

have clearly demonstrated how efficient and fast the interaction between electrons and photons can be. This latter situation has therefore provided a strong incentive to devise and study monolithic integrated circuits which involve both electrons and photons in their operation. As chapter I notes, it is barely fifteen years ago since the first demonstration of simple optoelectronic integrated circuits were realised using m-V compound semiconductors; these combined either a laser/driver or photodetector/preamplifier combination.

This book presents the Einstein Relation(ER) in two-dimensional (2-D) Heavily Doped (HD) Quantized Structures. The materials considered are quantized structures of HD non-linear optical, III-V, II-VI, Ge, Te, Platinum Antimonide, stressed materials, GaP, Gallium Antimonide, II-V, Bismuth Telluride together with various types of HD superlattices and their Quantized counterparts respectively. The ER in HD opto-electronic materials and their nanostructures is studied in the presence of strong light waves and intense electric fields on the basis of newly formulated electron dispersion laws that control the studies of such quantum effect devices. The suggestion for the experimental determination of HD 2D and 3D ERs and the importance of measurement of band gap in HD optoelectronic materials under intense built-in electric field in nanodevices and strong external photo excitation (for measuring photon induced physical

properties) are also discussed in this context. The influence of crossed electric and quantizing magnetic fields on the ER of the different 2D HD quantized structures (quantum wells, inversion and accumulation layers, quantum well HD superlattices and nipi structures) under different physical conditions is discussed in detail. This monograph contains 100 open research problems which form the integral part of the text and are useful for both Ph.D aspirants and researchers in the fields of condensed matter physics, solid-state sciences, materials science, nano-science and technology and allied fields.

Chemical Solution Synthesis for Materials Design and Thin Film Device Applications presents current research on wet chemical techniques for thin-film based devices. Sections cover the quality of thin films, types of common films used in devices, various thermodynamic properties, thin film patterning, device configuration and applications. As a whole, these topics create a roadmap for developing new materials and incorporating the results in device fabrication. This book is suitable for graduate, undergraduate, doctoral students, and researchers looking for quick guidance on material synthesis and device fabrication through wet chemical routes. Provides the different wet chemical routes for materials synthesis, along with the most relevant thin film structured materials for device applications Discusses patterning and solution processing of inorganic thin films,

along with solvent-based processing techniques Includes an overview of key processes and methods in thin film synthesis, processing and device fabrication, such as nucleation, lithography and solution processing

This unique resource explains the fundamental physics of semiconductor nanolasers, and provides detailed insights into their design, fabrication, characterization, and applications. Topics covered range from the theoretical treatment of the underlying physics of nanoscale phenomena, such as temperature dependent quantum effects and active medium selection, to practical design aspects, including the multi-physics cavity design that extends beyond pure electromagnetic consideration, thermal management and performance optimization, and nanoscale device fabrication and characterization techniques. The authors also discuss technological applications of semiconductor nanolasers in areas such as photonic integrated circuits and sensing. Providing a comprehensive overview of the field, detailed design and analysis procedures, a thorough investigation of important applications, and insights into future trends, this is essential reading for graduate students, researchers, and professionals in optoelectronics, applied photonics, physics, nanotechnology, and materials science.

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