

Chapter 4. Semiconductor Lasers: Physics and Applications

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4.1 Introduction

We are developing novel semiconductor lasers to improve the performance of communications systems. Our approach is to build an understanding of these devices that is solidly rooted in electromagnetic modeling, quantum mechanics and condensed matter physics. In the past, we have developed devices that exploit physical phenomena such as (1) Bose-Einstein condensation and coherent population transients; (2) novel fabrication processes such as wafer fusion and x-ray lithography, and (3) novel device designs such as surface-emitting microcavities and quantum cascade lasers to improve devices.

In the last year, several significant advances have been made. These include,

- the development of efficient numerical algorithms for energy band structure calculations
- the development of x-ray diffraction for characterizing the interfaces between optical thin films such as distributed Bragg reflectors
- the prediction and demonstration of low distortion signal transmission achieved by cancellation of spatial-hole burning and gain compression nonlinearities in DFB lasers, and
- the construction of an analog fiber link utilizing ultracompact surface emitting laser sources.

These are among the results discussed in the following sections. Extensive discussion will be presented in several forthcoming journal publications.

4.2 Band Structure and Optical Gain in Strained Layer Quantum Wells

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Project Staff

Farhan Rana, Professor Rajeev J. Ram

Design of high-performance semiconductor lasers requires a careful and detailed consideration of the physical processes involved. In the case of lasers operating at high modulation frequencies and high output power levels, non-equilibrium effects associated with carrier transport, carrier relaxation in quantum wells and carrier heating effects are important. Analytical models currently available to describe laser physics have little accuracy. Design of novel high-performance lasers require efficient and powerful computer simulation tools. Unlike passive devices, active optical devices have a rich variety of physics ranging from the microscopic to the macroscopic level. In order to design semiconductor lasers one needs to know the band structure of strained quantum wells, laser gain, radiative and Auger recombination rates, carrier leakage rates, non-equilibrium carrier dynamics. Careful design of optical waveguiding structures and gratings (in the case of DFB lasers) is also crucial. In addition, microwave propagation characteristics of metal contacts are also of importance especially at high frequencies. We have developed a suite of modeling tools for the accurate simulation of various laser structures:

1. **Band Structure Solver:** We have implemented an efficient finite difference technique to solve band structure of strained quantum wells using an eight-band $k \cdot p$ approach. This scheme also gives us the k -dependent wavefunctions

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Handbook of Laser Technology and Applications Chunlei Guo,Subhash Chandra Singh,2021-06-23 This comprehensive handbook gives a fully updated guide to lasers and laser systems including the complete range of their technical applications The first volume outlines the fundamental components of lasers their properties and working principles The second volume gives exhaustive coverage of all major categories of lasers from solid state and semiconductor diode to fiber waveguide gas chemical and dye lasers The third volume covers modern applications in engineering and technology including all new and updated case studies spanning telecommunications and data storage to medicine optical measurement defense and security nanomaterials processing and characterization **Handbook of Laser Technology and Applications** Colin Webb,Julian D.C. Jones,2020-09-29 The invention of the laser was one of the towering achievements of the twentieth century At the opening of the twenty first century we are witnessing the burgeoning of the myriad technical innovations to which that invention has led The Handbook of Laser Technology and Applications is a practical and long lasting reference source for scientists and engineers who work with lasers The Handbook provides a comprehensive guide to the current status of lasers and laser systems it is accessible to science or engineering graduates needing no more than standard undergraduate knowledge of optics Whilst being a self contained reference work the Handbook provides extensive references to contemporary work and is a basis for studying the professional journal literature on the subject It covers applications through detailed case studies and is therefore well suited to readers who wish to use it to solve specific problems of their own The first of the three volumes comprises an introduction to the basic scientific principles of lasers laser beams and non linear optics The second volume describes the mechanisms and operating characteristics of specific types of laser including crystalline solid state lasers semiconductor diode lasers fibre lasers gas lasers chemical lasers dye lasers and many others as well as detailing the optical and electronic components which tailor the laser s performance and beam delivery systems The third volume is devoted to case studies of applications in a wide range of subjects including materials processing optical measurement techniques medicine telecommunications data storage spectroscopy earth sciences and astronomy and plasma fusion research This vast compendium of knowledge on laser science and technology is the work of over 130 international experts many of whom are recognised as the world leaders in their respective fields Whether the reader is engaged in the science technology industrial or medical applications of lasers or is researching the subject as a manager or investor in technical enterprises they cannot fail to be informed and enlightened by the wide range of information the Handbook supplies [Handbook of Laser Technology and Applications \(Three- Volume Set\)](#) Colin Webb,Julian D. C. Jones,2003-12-01 The invention of the laser was one of the towering achievements of the twentieth century

At the opening of the twenty first century we are witnessing the burgeoning of the myriad technical innovations to which that invention has led The Handbook of Laser Technology and Applications is a practical and long lasting reference source for scientists a **Semiconductor Disk Lasers** Oleg G. Okhotnikov,2010-03-30 This timely publication presents a review of the most recent developments in the field of Semiconductor Disk Lasers Covering a wide range of key topics such as operating principles thermal management nonlinear frequency conversion semiconductor materials short pulse generation electrical pumping and laser applications the book provides readers with a comprehensive account of the fundamentals and latest advances in this rich and diverse field In so doing it brings together contributions from world experts at major collaborative research centers in Europe and the USA Each chapter includes a tutorial style introduction to the selected topic suitable for postgraduate students and scientists with a basic background in optics making it of interest to a wide range of scientists researchers engineers and physicists working and interested in this rapidly developing field It will also serve as additional reading for students in the field Optoelectronic Technology and Lightwave Communications Systems Chinlon Lin,2012-12-06 Ever since the invention of the transistor semiconductor based microelectronics has made a revolutionary impact on the information society as evident from the widespread application of microprocessor based technology in our modern society The next wave of modern information technology after transistors and microelectronics is that of lasers and micro optoelectronics Optoelectronics or optical electronics based on lasers and related modern optical technology has also become a very important field of science and technology in the past 20 years Electronics or microelectronics deals with micro electronic devices and components for generation transmission and processing of electronic signals In contrast in optoelectronics we deal with optoelectronic devices and components for the generation transmission and processing of lightwave signals It is the interaction of lightwaves photons with matter that shows the uniqueness of optoelectronic technology optical absorption and scattering optical gain and amplification material and waveguide dispersion nonlinear optical effects etc are very much dependent on the materials intrinsic properties and the lightwave propagation effects

Introduction to Laser Technology C. Breck Hitz,James J. Ewing,Jeff Hecht,2012-04-10 The only introductory text on the market today that explains the underlying physics and engineering applicable to all lasers Although lasers are becoming increasingly important in our high tech environment many of the technicians and engineers who install operate and maintain them have had little if any formal training in the field of electro optics This can result in less efficient usage of these important tools Introduction to Laser Technology Fourth Edition provides readers with a good understanding of what a laser is and what it can and cannot do The book explains what types of laser to use for different purposes and how a laser can be modified to improve its performance in a given application With a unique combination of clarity and technical depth the book explains the characteristics and important applications of commercial lasers worldwide and discusses light and optics the fundamental elements of lasers and laser modification In addition to new chapter end problems the Fourth Edition includes

new and expanded chapter material on Material and wavelength Diode Laser Arrays Quantum cascade lasers Fiber lasers Thin disk and slab lasers Ultrafast fiber lasers Raman lasers Quasi phase matching Optically pumped semiconductor lasers Introduction to Laser Technology Fourth Edition is an excellent book for students technicians engineers and other professionals seeking a fuller more formal introduction to the field of laser technology

Comprehensive Semiconductor Science and Technology, 2011-01-28 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 Six Volume Set 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

Miniaturized High-Power Solid-state Laser and Applications Zhi-Han Zhu,Zhenxu Bai,Baitao Zhang,Liyuan Chen,2023-06-07

Single Frequency Semiconductor Lasers Zujie Fang,Haiwen Cai,Gaoting Chen,Ronghui Qu,2017-07-29 This book systematically introduces the single frequency semiconductor laser which is widely used in many vital advanced technologies such as the laser cooling of atoms and atomic clock high precision measurements and spectroscopy coherent optical communications and advanced optical sensors It presents both the fundamentals and characteristics of semiconductor lasers including basic F P structure and monolithic integrated structures interprets laser noises and their measurements and explains mechanisms and technologies relating to the main aspects of single frequency lasers including external cavity lasers frequency stabilization technologies frequency sweeping optical phase locked loops and so on It paints a clear physical picture of related technologies and reviews new developments in the field as well It will be a useful reference to graduate students researchers and engineers in the field

Broadband Terahertz Communication Technologies Jianjun Yu,2021-06-28 This book highlights the comprehensive knowledge and latest progress in broadband terahertz THz technology THz communication technology is believed to be one of the major choices that succeed the fifth generation 5G communication technology With years of efforts

the author's team has created a number of world records in the generation transmission and reception of ultra wideband THz signal realizing the MIMO transmission and reception of THz communication the THz signal transmission with communication capacity of 1 Tbit/s and the optical fiber and THz integrated transmission A variety of linear and nonlinear algorithms for multi carrier and single carrier THz communication systems are developed which greatly improves the transmission performance of broadband systems The book covers in details the broadband THz signal generation long distance transmission and high sensitivity detection It is of great reference value for researchers engineers and graduate students in optical and wireless communications

Gas Lasers Masamori Endo, Robert F. Walter, 2018-10-03 Lasers with a gaseous active medium offer high flexibility wide tunability and advantages in cost beam quality and power scalability Gas lasers have tended to become overshadowed by the recent popularity and proliferation of semiconductor lasers As a result of this shift in focus details on modern developments in gas lasers are difficult to find In addition different types of gas lasers have unique properties that are not well described in other references Collecting expert contributions from authorities dealing with specific types of lasers Gas Lasers examines the fundamentals current research and applications of this important class of laser It is important to understand all types of lasers from solid state to gaseous before making a decision for any application This book fills in the gaps by discussing the definition and properties of gaseous media along with its fluid dynamics electric excitation circuits and optical resonators From this foundation the discussion launches into the basic physics characteristics applications and current research efforts for specific types of gas lasers CO lasers CO₂ lasers HF DF lasers excimer lasers iodine lasers and metal vapor lasers The final chapter discusses miscellaneous lasers not covered in the previous chapters Collecting hard to find material into a single convenient source Gas Lasers offers an encyclopedic survey that helps you approach new applications with a more complete inventory of laser options

Scientific and Technical Aerospace Reports, 1995 **Laser Technology--development and Applications** United States. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space, 1980 *Process Technology for Semiconductor Lasers* Kenichi Iga, Susumu Kinoshita, 2013-03-07 Process Technology for Semiconductor Lasers describes the design principles of semiconductor lasers mainly from the fabrication point of view A review is given of the history of semiconductor laser development and applications and of the materials used in lasing at short to long wavelengths The basic design principles for semiconductor laser devices and the epitaxy for laser production are discussed An entire chapter is devoted to the technology of liquid phase epitaxy and another one to vapor phase and beam epitaxies The characterizations of laser materials and the fabrication and characteristics of semiconductor lasers are treated Mode control techniques are presented and surface emitting lasers are introduced in the final chapter

Current Review of the Soviet Technical Press, 1964-07 **Precision Spectroscopy, Diode Lasers, and Optical Frequency Measur** Leo Hollberg, 2000 A selected set of reprints from the Optical Frequency Measurement Group of the Time and Frequency Div of

the Nat Inst of Standards and Technology and consists of work published between 1987 and 1997 The 2 programs represented are 1 development of tunable diode laser technology for scientific applications and precision measurements and 2 research toward the goal of realizing optical frequency measurements and synthesis The papers are organized in 5 categories diode laser technology tunable laser systems laser spectroscopy optical synthesis and extended wavelength coverage and multi photon interactions and optical coherence

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