

**Physics of Semiconductor  
Laser Devices**

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# Physics Of Semiconductor Laser Devices

**Ken'ichi Iga, Susumu Kinoshita**



## **Physics Of Semiconductor Laser Devices:**

**Physics of Semiconductor Laser Devices** Thompson GHB.,1980      Physics of Semiconductor Lasers B. Mroziwicz,M. Bugajski,W. Nakwaski,2017-01-31 Written for readers who have some background in solid state physics but do not necessarily possess any knowledge of semiconductor lasers this book provides a comprehensive and concise account of fundamental semiconductor laser physics technology and properties The principles of operation of these lasers are therefore discussed in detail with the interrelations between their design and optical electrical and thermal properties The relative merits of a large number of laser structures and their parameters are described to acquaint the reader with the various aspects of the semiconductor lasers and the trends in their development      **Quantum Confined Laser Devices** Peter Blood,2015-10-23 The semiconductor laser invented over 50 years ago has had an enormous impact on the digital technologies that now dominate so many applications in business commerce and the home The laser is used in all types of optical fibre communication networks that enable the operation of the internet e mail voice and skype transmission Approximately one billion are produced each year for a market valued at around 5 billion Nearly all semiconductor lasers now use extremely thin layers of light emitting materials quantum well lasers Increasingly smaller nanostructures are used in the form of quantum dots The impact of the semiconductor laser is surprising in the light of the complexity of the physical processes that determine the operation of every device This text takes the reader from the fundamental optical gain and carrier recombination processes in quantum wells and quantum dots through descriptions of common device structures to an understanding of their operating characteristics It has a consistent treatment of both quantum dot and quantum well structures taking full account of their dimensionality which provides the reader with a complete account of contemporary quantum confined laser diodes It includes plenty of illustrations from both model calculations and experimental observations There are numerous exercises many designed to give a feel for values of key parameters and experience obtaining quantitative results from equations Some challenging concepts previously the subject matter of research monographs are treated here at this level for the first time      **Process Technology for Semiconductor Lasers** Kenichi Iga,Susumu Kinoshita,2011-12-29 A description of the design principles seen mainly from the fabrication point of view Following a review of the historical development and of the materials used in lasing at short to long wavelengths the book goes on to discuss the basic design principles for semiconductor laser devices and the epitaxy for laser production One entire chapter is devoted to the technology of liquid phase epitaxy while another treats vapor phase and beam epitaxies The whole is rounded off with mode control techniques and an introduction to surface emitting lasers      *Semiconductor Lasers: Basic Physics, Technology, and Design* Heinrich Rieck,1970      Essential Semiconductor Laser Physics A F J Levi,2018-07-18 The invention of the semiconductor laser along with silica glass fiber has enabled an incredible revolution in global communication infrastructure of direct benefit to all Development of devices and system concepts that exploit the same fundamental light

matter interaction continues Researchers and technologists are pursuing a broad range of emerging applications everything from automobile collision avoidance to secure quantum key distribution This book sets out to summarize key aspects of semiconductor laser device physics and principles of laser operation It provides a convenient reference and essential knowledge to be understood before exploring more sophisticated device concepts The contents serve as a foundation for scientists and engineers without the need to invest in specialized detailed study Supplementary material in the form of MATLAB is available for numerically generated figures **Semiconductor Lasers** Govind P. Agrawal, Niloy K. Dutta, 2013-11-27 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  $\mu\text{m}$  The development during the 1970s of GaAs semiconductor lasers emitting in the near infrared region of 0.8–0.9  $\mu\text{m}$  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  $\mu\text{m}$  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 wave length semiconductor lasers Particular attention is paid to InGaAsP lasers although we also consider semiconductor lasers operating at longer wave lengths 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 **Essential Semiconductor Laser Device Physics** A. F. J. Levi, 2018-07-17 The invention of the semiconductor laser along with silica glass fiber has enabled an incredible revolution in global communication infrastructure of direct benefit to all Development of devices and system concepts that exploit the same fundamental light matter interaction continues Researchers and technologists are pursuing a broad range of emerging applications everything from automobile collision avoidance to secure quantum key distribution This book sets out to summarize key aspects of semiconductor laser device physics and principles of laser operation **Semiconductor-Laser Fundamentals** Weng W. Chow, Stephan W. Koch, 2013-03-09 Since Fall of 1993 when we completed the manuscript of our book Semiconductor Laser Physics W W Chow S W Koch and M Sargent III Springer Berlin Heidelberg 1994 many new and exciting developments have taken place in the world of semiconductor lasers Novel laser and amplifier structures were developed and others for example the VCSEL vertical cavity surface emitting laser and monolithic MOPA master oscillator power amplifier made the transition from research and development to production When investigating some of these systems we discovered instances when device performance and thus design depend critically on details of the gain medium

properties e.g. spectral shape and carrier density dependence of the gain and refractive index. New material systems were also introduced with optical emission wave lengths spanning from the mid infrared to the ultraviolet. Particularly note worthy are laser and light emitting diodes based on the wide bandgap group III nitride and II-VI compounds. These devices emit in the visible to ultra violet wavelength range which is important for the wide variety of optoelectronic applications. While these novel semiconductor laser materials show many similarities with the more conventional near infrared systems they also possess rather different material parameter combinations. These differences appear as band structure modifications and as increased importance of Coulomb effects such that e.g. excitonic signatures resulting from the attractive electron-hole interaction are generally significantly more prominent in the wide bandgap systems.

### **Semiconductor Laser Theory**

Prasanta Kumar Basu, Bratati Mukhopadhyay, Rikmantra Basu, 2015-06-17. Developed from the authors classroom tested material. Semiconductor Laser Theory takes a semiclassical approach to teaching the principles, structure and applications of semiconductor lasers. Designed for graduate students in physics, electrical engineering and materials science, the text covers many recent developments including diode lasers using quantum wells, quantum dots, quantum cascade lasers, nitride lasers, group IV lasers and transistor lasers. The first half of the book presents basic concepts such as the semiconductor physics needed to understand the operation of lasers, p-n junction theory, alloys, heterostructures, quantum nanostructures, k-p theory, waveguides, resonators, filters and optical processes. The remainder of the book describes various lasers including double heterostructure, quantum wire, quantum dot, quantum cascade, vertical cavity surface emitting, single mode and tunable nitride, group IV and transistor lasers. This textbook equips students to understand the latest progress in the research and development of semiconductor lasers, from research into the benefits of quantum wire and quantum dot lasers to the application of semiconductor lasers in fiber optic communications. Each chapter incorporates reading lists and references for further study, numerous examples to illustrate the theory and problems for hands on exploration.

### **Semiconductor Lasers II**

Eli Kapon, 1999-01-14. Judging from the impact it has on our everyday lives, the semiconductor laser has emerged as perhaps the most important laser device currently in use. This volume presents information on recent advances in materials and structures.

*Process Technology for Semiconductor Lasers* Ken'ichi Iga, Susumu Kinoshita, 1996-01-15. A description of the design principles seen mainly from the fabrication point of view. Following a review of the historical development and of the materials used in lasing at short to long wavelengths, the book goes on to discuss the basic design principles for semiconductor laser devices and the epitaxy for laser production. One entire chapter is devoted to the technology of liquid phase epitaxy while another treats vapor phase and beam epitaxies. The whole is rounded off with mode control techniques and an introduction to surface emitting lasers.

### **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

Diode Laser Materials and Devices - A Worldwide Market and Technology Overview to 2005 R. Szweda, 2001-12-20 This report examines the development of the diode laser industry over a six year period 2000 to 2005 incorporating analysis of trends in markets technologies and industry structure It is designed to provide key information to users and manufacturers of substrates epitaxial wafers epiwafers and devices The coverage includes components laser diodes and the semiconducting SC wafers and epiwafers on which most of these devices are made The geographical coverage of the report includes North America Japan and Europe which together will account for over 90% of the production and consumption of diode laser materials and devices over the next five years However many other countries have activities in this field including South East Asia Taiwan South Korea Singapore Malaysia etc China India Australia and Eastern Europe Russia Poland Hungary the Czech Republic amongst others Activities in these countries are commented on in the text where relevant but are not quantified in the market data Chapter 1 is an introduction to the market study Chapter 2 contains an executive summary Chapter 3 overviews materials markets The size quality and particularly the price of substrates and wafers are key factors in determining the ability of companies to produce competitive laser products Chapter 3 also examines trends in materials technologies for laser diodes the impact of the device markets on wafer demand and the main suppliers This chapter introduces the semiconductor materials that are presently or will likely become important to the fabrication of diode laser devices The principal distinguishing properties of these materials are explained with reference to their application Chapter 4 chapter examines the basic application sectors for laser diode devices as well as the basic commercial opportunities changes and forces acting within each sector The chapter also examines the market for the basic types of device as well as the promising newer types For each type of device market data and forecasts are provided and future prospects described The application data are presented for the following industrial groups Automotive Computers Consumer Industrial Military and Aerospace Telecommunications Others A full 5 year forecast and analysis is provided by application and region Chapter 5 is a technology overview In this chapter a background and overview of developments in the principal technological R D and production processes for devices is provided The main focus is on the most important enabling technology for the production of the present and future generations of laser diodes and related devices This process is crystal growth and involves the following sequence Bulk growth of single crystals Epitaxial growth of semiconductor single crystal layers Ion implantation

Device fabrication ie gate and contact formation etc Packaging test Chapter 6 profiles substrate suppliers epiwafers suppliers and merchant and captive producers of GaAs devices Chapter 7 lists universities and selected industrial labs involved in the areas of diode laser research Chapter 8 is a directory of suppliers Chapter 9 provides acronyms and exchange rates

**Introductory Semiconductor Device Physics** Greg Parker, 2004-09-30 Introduction to Semiconductor Device Physics is a popular and established text that offers a thorough introduction to the underlying physics of semiconductor devices It begins with a review of basic solid state physics then goes on to describe the properties of semiconductors including energy bands the concept of effective mass carrier concentr

**Semiconductor Lasers** Junji Ohtsubo, 2012-10-06 This third edition of Semiconductor Lasers Stability Instability and Chaos was significantly extended In the previous edition the dynamics and characteristics of chaos in semiconductor lasers after the introduction of the fundamental theory of laser chaos and chaotic dynamics induced by self optical feedback and optical injection was discussed Semiconductor lasers with new device structures such as vertical cavity surface emitting lasers and broad area semiconductor lasers are interesting devices from the viewpoint of chaotic dynamics since they essentially involve chaotic dynamics even in their free running oscillations These topics are also treated with respect to the new developments in the current edition Also the control of such instabilities and chaos control are critical issues for applications Another interesting and important issue of semiconductor laser chaos in this third edition is chaos synchronization between two lasers and the application to optical secure communication One of the new topics in this edition is fast physical number generation using chaotic semiconductor lasers for secure communication and development of chaos chips and their application As other new important topics the recent advance of new semiconductor laser structures is presented such as quantum dot semiconductor lasers quantum cascade semiconductor lasers vertical cavity surface emitting lasers and physical random number generation with application to quantum key distribution Stabilities instabilities and control of quantum dot semiconductor lasers and quantum cascade lasers are important topics in this field

**Reliability of Semiconductor Lasers and Optoelectronic Devices** Robert Herrick, Osamu Ueda, 2021-03-06 Reliability of Semiconductor Lasers and Optoelectronic Devices simplifies complex concepts of optoelectronics reliability with approachable introductory chapters and a focus on real world applications This book provides a brief look at the fundamentals of laser diodes introduces reliability qualification and then presents real world case studies discussing the principles of reliability and what occurs when these rules are broken Then this book comprehensively looks at optoelectronics devices and the defects that cause premature failure in them and how to control those defects Key materials and devices are reviewed including silicon photonics vertical cavity surface emitting lasers VCSELs InGaN LEDs and lasers and AlGaIn LEDs covering the majority of optoelectronic devices that we use in our everyday lives powering the Internet telecommunication solid state lighting illuminators and many other applications This book features contributions from experts in industry and academia working in these areas and includes numerous practical examples and case studies

This book is suitable for new entrants to the field of optoelectronics working in R D Includes case studies and numerous examples showing best practices and common mistakes affecting optoelectronics reliability written by experts working in the industry Features the first wide ranging and comprehensive overview of fiber optics reliability engineering covering all elements of the practice from building a reliability laboratory qualifying new products to improving reliability on mature products Provides a look at the reliability issues and failure mechanisms for silicon photonics VCSELs InGaN LEDs and lasers AlGaIn LEDs and more *Introduction to Semiconductor Lasers for Optical Communications* David J. Klotzkin, 2020-01-07

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 *Semiconductor Laser Engineering, Reliability and Diagnostics* Peter W. Epperlein, 2013-01-25

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 **Optical Feedback Aspects of Hybrid Integrated Diode Laser Systems** Nils Werner, 2024-07-24 In hybrid integrated diode laser systems diode lasers



are combined with components such as optical amplifiers or nonlinear crystals to extend their range of capabilities. However, combining optical components leads to mutual influencing as each component can be a source of optical feedback which has to be considered in detail. In this work, experimental and theoretical studies are carried out on periodically poled nonlinear crystals (PPNC), semiconductor optical amplifiers (SOA), and distributed Bragg reflector ridge waveguide lasers (DBR RWL). Periodic poling in PPNCs results in grating-like refractive index modulations that cause wavelength-dependent reflection characteristics with typical resonances. The optical feedback from PPNCs is directed to the pump laser source with reflectances from  $10^{-4}$  to  $10^{-2}$ . In SOAs, the optical feedback depends on the operating point while spontaneous emission can be a significant source. With respect to the input power, the reflectance is between  $10^{-3}$  and  $10^{-1}$ . While the reflectance can exceed unity if additional external optical feedback enters the SOA, the optical feedback from the SOA is still defined by the internal structure of the SOA and directed to the input laser source. The emission behavior of DBR RWLs subject to strong optical feedback is characterized by thermal effects and spectral mode hops that go beyond usual optical feedback considerations. Even DBR RWLs insensitive to coherence collapse can be affected for feedback reflectances higher than  $10^{-3}$ . The investigations in this thesis provide a deeper understanding of the optical feedback characteristics of components in hybrid diode laser systems. This results in starting points for further component improvements and new concepts for the realization of hybrid laser systems.

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