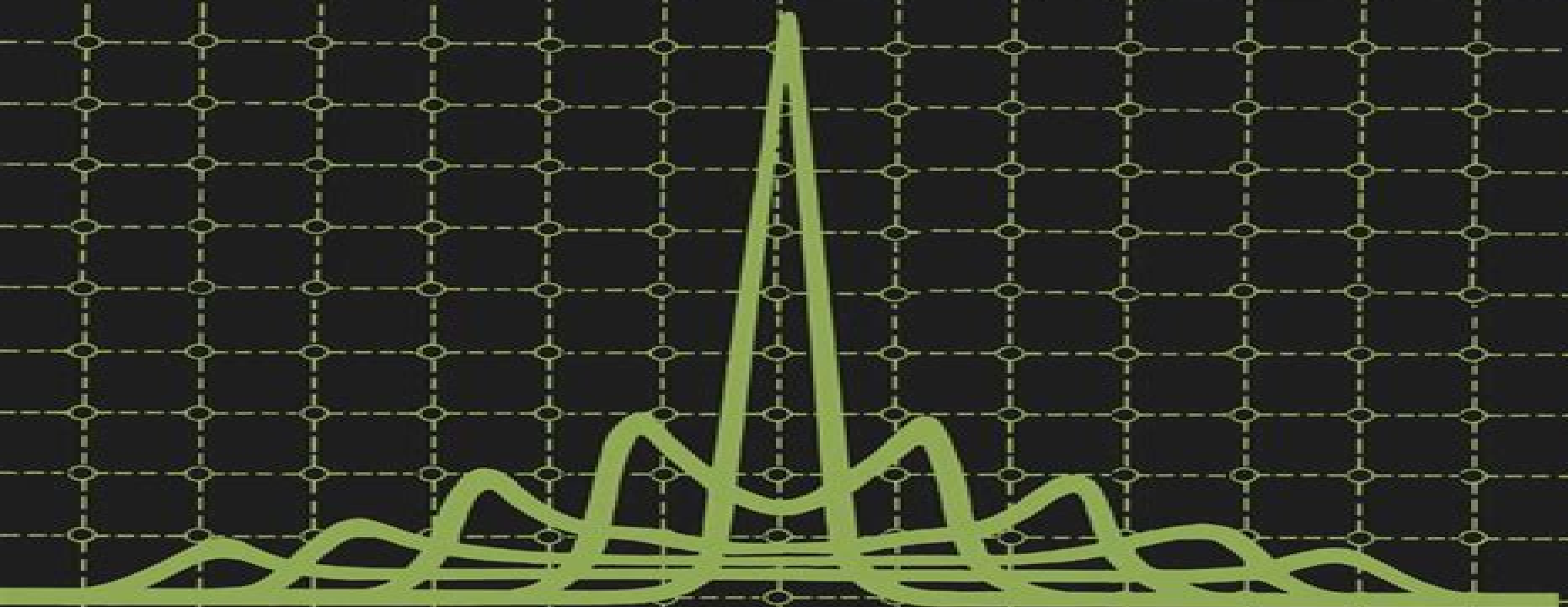


# LONG-WAVELENGTH SEMICONDUCTOR LASERS

G.P. AGRAWAL  
N.K. DUTTA



# Long Wavelength Semiconductor Lasers

**M. J. Adams**



## **Long Wavelength Semiconductor Lasers:**

*Long-Wavelength Semiconductor Lasers* Govind Agrawal, Niloy K. Dutta, 1986-12-31 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 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.

**Long-Wavelength Semiconductor Lasers** Govind Agrawal, 2014-09-12 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 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.

**Long-Wavelength Infrared Semiconductor Lasers** Hong K. Choi, 2004-03-18 Long wavelength Infrared Semiconductor Lasers provides a comprehensive review of the current status of semiconductor coherent sources emitting in the mid to far infrared spectrum and their applications. It includes three topics not covered in any previous book: far infrared

emission from photo mixers as well as from hot hole lasers and InP based lasers emitting beyond two micrometers Semiconductor lasers emitting at more than two micrometers have many applications such as in trace gas analysis environmental monitoring and industrial process control Because of very rapid progress in recent years until this book no comprehensive information beyond scattered journal articles is available at present **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 to 100  $\mu\text{m}$  The development during the 1970s of GaAs semiconductor lasers emitting in the near infrared region of 0.8 to 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 *Design and Fabrication of High Speed, Long Wavelength, Semiconductor Lasers* John Gilmary Wasserbauer, 1994 *Semiconductor Lasers for Long-wavelength Optical-fibre Communications Systems* M. J. Adams, 1987 *Using Band-filling to Understand Long-wavelength Semiconductor Lasers and Q-switching of Solid-state Lasers* Yi-jen Tsou, 1993 *InGaAsNSb* Xiaoping Yang, 2002 **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 *Long-Wavelength Infrared Semiconductor Lasers* Hong K Choi, 2004 *Long Wavelength Semiconductor Lasers Development for Infrared Heterodyne Applications* National Aeronautics and Space Administration, 2018-12-29 PbSnTe single crystals were grown in a new 3 zone furnace Molecular beam epitaxy MBE growth parameters have been established including beam flux vs temperature and growth rates and dopant vs PbTe flux ratios for the various effusion sources involved Lattice matching studies were conducted and doping studies were completed Broad area Pb 1 x Sn x Te double heterostructure lasers were fabricated with active layer compositions up to x equals 0.04 at percent Sn in the active layers Electrical and optical test data are presented Feit Zeev and Kostyk Douglas NASA CR 189243 NAS 1 26 189243 NAS5 30445 *Long Wavelength Infrared Emitters Based on Quantum Wells and Superlattices* Manfred Helm, 2000-10-31 This book

offers a thorough survey of long wavelength infrared semiconductor emitters based primarily on quantum wells and superlattices. Featuring contributions from the most prominent researchers in the field, this volume allows readers to compare different types of lasers as well as examine investigations of potential far infrared terahertz sources. This is an essential reference for researchers, engineers, and graduate students who wish to obtain comprehensive knowledge about infrared semiconductor sources and recent developments in this field. **Semiconductor Lasers** Alexei Baranov, Eric

Tournié, 2013-04-23 Semiconductor lasers have important applications in numerous fields including engineering, biology, chemistry, and medicine. They form the backbone of the optical telecommunications infrastructure supporting the internet and are used in information storage devices, bar code scanners, laser printers, and many other everyday products. Semiconductor lasers: Fundamentals and applications is a comprehensive review of this vital technology. Part one introduces the fundamentals of semiconductor lasers, beginning with key principles before going on to discuss photonic crystal lasers, high power semiconductor lasers, and laser beams, and the use of semiconductor lasers in ultrafast pulse generation. Part two then reviews applications of visible and near infrared emitting lasers. Nonpolar and semipolar GaN based lasers, advanced self assembled InAs quantum dot lasers, and vertical cavity surface emitting lasers are all considered, in addition to semiconductor disk and hybrid silicon lasers. Finally, applications of mid and far infrared emitting lasers are the focus of part three. Topics covered include GaSb based type I quantum well diode lasers, interband cascade and terahertz quantum cascade lasers, whispering gallery mode lasers, and tunable mid infrared laser absorption spectroscopy. With its distinguished editors and international team of expert contributors, Semiconductor lasers is a valuable guide for all those involved in the design, operation, and application of these important lasers, including laser and telecommunications engineers, scientists working in biology and chemistry, medical practitioners, and academics working in this field. Provides a comprehensive review of semiconductor lasers and their applications in engineering, biology, chemistry, and medicine. Discusses photonic crystal lasers, high power semiconductor lasers, and laser beams, and the use of semiconductor lasers in ultrafast pulse generation. Reviews applications of visible and near infrared emitting lasers, and mid and far infrared emitting lasers. **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. **Fundamentals of Semiconductor Lasers** Takahiro Numai, 2006-05-10 Fundamentals of Semiconductor Lasers explains the physics and fundamental characteristics of semiconductor lasers with regard to systems applications. The detailed and comprehensive presentation is unique in that it encourages the reader to consider different semiconductor lasers from different angles. Emphasis is placed on recognizing common concepts such as operating principles and structure, and solving problems based on individual situations. The treatment

is enhanced by an historical account of advances in semiconductor lasers over the years discussing both those ideas that have persisted over the years and those that have faded out The first four chapters cover the basics of semiconductors including band structures optical transitions optical waveguides and optical resonators The remaining chapters discuss operating principles and basic characteristics of semiconductor lasers and advanced topics including dynamic single mode lasers quantum well lasers and control of spontaneous emission The reader need only be familiar with undergraduate level electromagnetism and quantum mechanics After reading this book the student will be able to think critically about semiconductor lasers and be able to read and understand journal papers in the field This book will be essential to any advanced undergraduate or graduate student of semiconductor lasers and any professional physicist or engineer looking for a good overview of the subject

*Principles of Lasers* Orazio Svelto, 2010-03-16 This fifth edition of Principles of Lasers includes corrections to the previous edition as well as being the first available as an ebook Its mission remains to provide a broad unified description of laser behavior physics technology and applications

**Principles Of Semiconductor Laser Diodes And Amplifiers: Analysis And Transmission Line Laser Modeling** Hooshang Ghafouri-shiraz, 2003-12-15 Optical communications technology is growing increasingly in importance with a rapid pace of development Innovative optical devices have emerged from the integration of semiconductor laser diodes amplifiers and filters with optical waveguide technology This well researched volume traces the evolution of semiconductor laser amplifiers SLAs from these technologies Focusing on the principle applications of SLAs the author illustrates the growing importance of these functional components in the future of optical communications systems This book will provide engineering and science students with a basic understanding of laser diode and optical amplification through the analysis of the performance characteristics of these devices both in theory and application Practising device engineers wishing to consolidate their knowledge in lightwave technology will also find this book an invaluable reference a

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 wavelengths 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

### **History of Modern Optics and Optoelectronics Development in China**

Fuxi Gan, 2014 This book presents a collection of memoir papers on the development of modern and contemporary optics and optoelectronics in China from the 18th to 20th centuries The papers were written by famous scientists in China including members of the Chinese Academy of Sciences and the Chinese Academy of Engineering sharing their experience in different fields of optics and optoelectronics development This is a unique book in understanding the natural science history of optics and optoelectronics It gives you the general idea about how the western optical science spread to China in the 17th to 18th century the cradle of the contemporary optics in China Birth development and application of lasers in China high energy and high power lasers for laser antiballistic missile and laser nuclear fusion development of Chinese optical communication and optical information storage laser and infrared optics research for space science development of Chinese optical instruments etc Contents West Science vs East Gan Fuxi Optical Science and Technology in China in the First Half of 20th Century Gan Fuxi The Cradle of the Contemporary Optics in China Gan Fuxi The History of Research and Development of Optical Glass in China Gan Fuxi Birth and Early Development of Lasers in China Gan Fuxi Laser ABM OCo One of the Strategic Defense Means in Early Time Gan Fuxi Memory of the Early Days OCo Quantum Electronics Research in the Institute of Electronics Lin Fucheng Chinese Laser Research Opened to the World Gan Fuxi Breakthroughs and Development of Semiconductor Lasers in China Wang Qiming and Huang Yong Zhen Development of the Solid State Laser Materials in China Gan Fuxi Development of High Power Lasers in China Fan Dianyan Establishment of the Daheng Company OCo A Pioneering Work of Chinese Scientific and Technological System Reform Gan Fuxi National 863 High Technology Program Promoted the Development of Optoelectronics in China Gan Fuxi Open Up the Optical Information Storage Technology in China Gan Fuxi Progress of Optical Communications in China OCo Fragments of Personal Reminiscences Fang Zujie The Course of Development of Astronomical Optical Instruments Pan Junhua Infra Red Optics Research and Application in Satellite Monitoring Xue Yongqi High Speed Imaging and Monitoring Research and Development Hou Xun Research on Laser Cooling and Time Standard in Optical Wavelength Range Wang Yuzhu Industrial Development of Optical Instruments in China Zhuang Songlin Readership Students and scientists who are interested in the history of optics and optoelectronics in China

Distributed Feedback Laser Diodes and Optical Tunable Filters Dr. H. Ghafouri-Shiraz, 2004-02-06 Advances in optical fibre based communications systems have played a crucial role in the development of the information highway By offering a single mode oscillation and narrow spectral output distributed feedback DFB semiconductor laser diodes offer excellent optical light sources as well as optical filters for fibre based communications and dense wavelength division multiplexing

DWDM systems This comprehensive text focuses on the basic working principles of DFB laser diodes and optical filters and details the development of a new technique for enhanced system performance Considers the optical waveguiding characteristics and properties of semiconductor materials and the physics of DFB semiconductor lasers Presents a powerful modelling technique based on the transfer matrix method which can be used to improve the design of laser diodes optical fibres and amplifiers Examines the effect of the various corrugation shapes on the coupling coefficients and lasing characteristics of DFB laser diodes Technical advice to improve immunity against the spatial hole burning effect Extensive referencing throughout and a comprehensive glossary of symbols and abbreviations Suitable for both introductory and advanced levels This is an indispensable textbook for undergraduate and postgraduate students of electrical and electronic engineering and physics as it consolidates their knowledge in this rapidly growing field As a technical guide for the structural design of DFB laser diodes and optical filters the book will serve as an invaluable reference for researchers in optoelectronics and semiconductor device physics



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