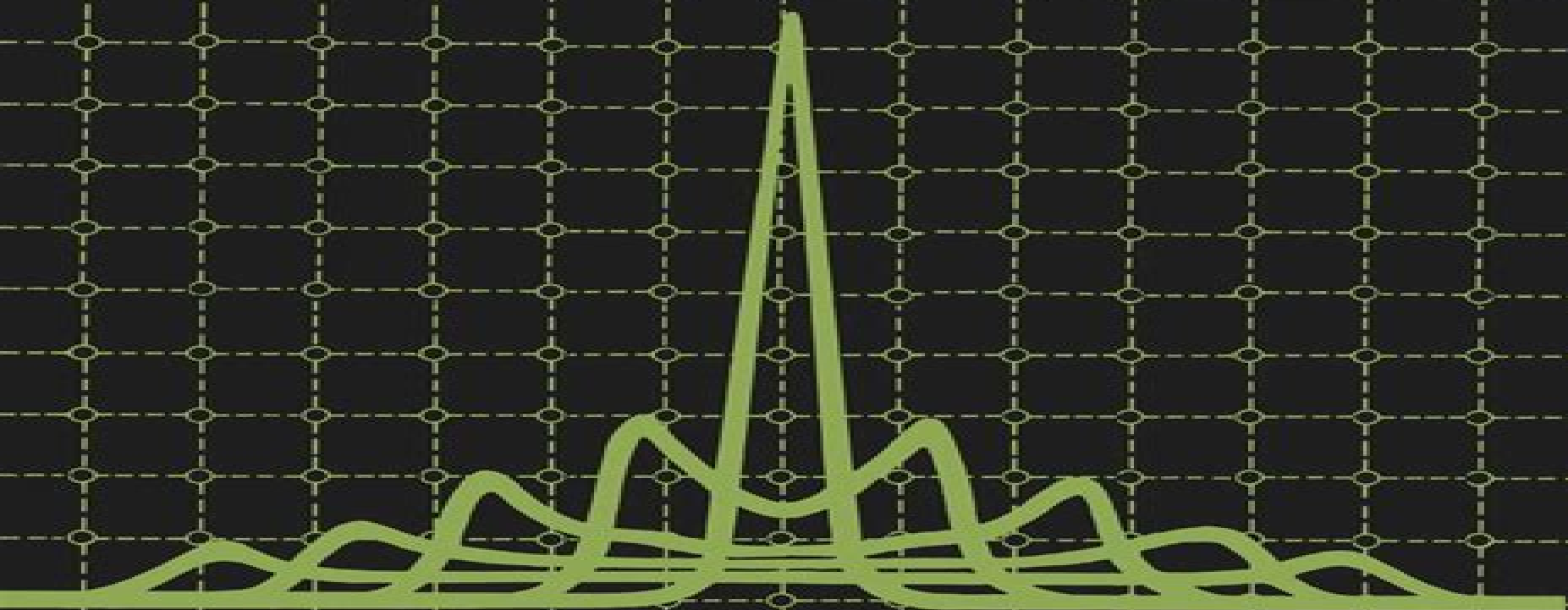


# LONG-WAVELENGTH SEMICONDUCTOR LASERS

G.P. AGRAWAL  
N.K. DUTTA



# Long Wavelength Semiconductor Lasers

**Alexei Baranov, Eric Tournié**



## **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 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.

**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 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.

**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 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.

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, 1999-01-12. This volume presents state of the art information on several important material systems and device structures employed in modern semiconductor lasers. The first two chapters discuss several III-V, II-VI and VI-VI compound semiconductor material systems employed in diode lasers whose emission spectra cover the range from the blue to the mid infrared. Subsequent chapters describe the elaboration of special laser structures designed for achieving narrow spectral linewidths and wavelength tunability as well as high power emission devices. The last chapter covers the development of surface emitting diode lasers, particularly vertical cavity structures. In all five chapters, the underlying device physics as well as the state of the art and future trends are discussed. This book introduces the non expert to the design and fabrication issues involved in the development of these important laser devices. In addition, it reviews the current status of the different material systems and cavity configurations for the benefit of readers engaged in research in this field. Useful background material related to the fundamentals of lasing in semiconductors can be found in the companion volume.

Semiconductor Lasers I Fundamentals Covers important recent advances in materials design fabrication and device structure of semiconductor lasers aspects not covered in previously existing literature Introduces the non expert to the subject Useful for professionals engaged in research and development Numerous schematic and data containing illustrations Written by leading experts in the 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     **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     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

**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

**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 u

**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 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

*Fundamentals of Phosphors* William M. Yen, Shigeo (deceased) Shionoya, Hajime Yamamoto, 2018-10-03 Drawing from the second edition of the best selling Handbook of Phosphors Fundamentals of Phosphors covers the principles and mechanisms of luminescence in detail and surveys the primary phosphor materials as well as their optical properties The book addresses cutting edge developments in phosphor science and technology including oxynitride phosphors and the impact of lanthanide level location on phosphor performance Beginning with an explanation of the physics underlying luminescence mechanisms in solids the book goes on to interpret various luminescence phenomena in inorganic and organic materials This includes the interpretation of the luminescence of recently developed low dimensional systems such as quantum wells and dots The book also discusses the excitation mechanisms by cathode ray and ionizing

radiation and by electric fields to produce electroluminescence The book classifies phosphor materials according to the type of luminescence centers employed or the class of host materials used and interprets the optical properties of these materials including their luminescence characteristics and mechanisms Placing a strong emphasis on those materials that are important from a practical point of view the coverage also includes those possessing no possibility for practical use but are important from a theoretical standpoint **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 **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

*Handbook of Laser Wavelengths* Marvin J. Weber, 2018-10-08 This volume represents the most complete up to date compilation of wavelengths of lasers in all media Divided by type solid liquid and gas and listed in order of increasing wavelength *Handbook of Laser Wavelengths* includes crystalline paramagnetic ion lasers glass lasers color center lasers

semiconductor lasers polymer lasers liquid and solid state dye lasers rare earth liquid lasers neutral atom ion and molecular gas lasers extreme ultraviolet and soft X ray lasers free electron lasers nuclear pumped lasers lasers in nature lasers without inversion Brief descriptions of each type of laser are presented followed by tables listing the laser wavelength lasing element or medium host transition and primary literature citations A special section on commercial lasers is an added featured Handbook of Laser Wavelengths singularly serves as the essential reference for scientists and engineers searching for laser sources for specific applications as well as a survey of the developments that have occurred since the advent of the laser



The book delves into Long Wavelength Semiconductor Lasers. Long Wavelength Semiconductor Lasers is an essential topic that needs to be grasped by everyone, from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Long Wavelength Semiconductor Lasers, encompassing both the fundamentals and more intricate discussions.

1. The book is structured into several chapters, namely:
  - Chapter 1: Introduction to Long Wavelength Semiconductor Lasers
  - Chapter 2: Essential Elements of Long Wavelength Semiconductor Lasers
  - Chapter 3: Long Wavelength Semiconductor Lasers in Everyday Life
  - Chapter 4: Long Wavelength Semiconductor Lasers in Specific Contexts
  - Chapter 5: Conclusion
2. In chapter 1, this book will provide an overview of Long Wavelength Semiconductor Lasers. The first chapter will explore what Long Wavelength Semiconductor Lasers is, why Long Wavelength Semiconductor Lasers is vital, and how to effectively learn about Long Wavelength Semiconductor Lasers.
3. In chapter 2, this book will delve into the foundational concepts of Long Wavelength Semiconductor Lasers. This chapter will elucidate the essential principles that must be understood to grasp Long Wavelength Semiconductor Lasers in its entirety.
4. In chapter 3, the author will examine the practical applications of Long Wavelength Semiconductor Lasers in daily life. This chapter will showcase real-world examples of how Long Wavelength Semiconductor Lasers can be effectively utilized in everyday scenarios.
5. In chapter 4, this book will scrutinize the relevance of Long Wavelength Semiconductor Lasers in specific contexts. This chapter will explore how Long Wavelength Semiconductor Lasers is applied in specialized fields, such as education, business, and technology.
6. In chapter 5, the author will draw a conclusion about Long Wavelength Semiconductor Lasers. This chapter will summarize the key points that have been discussed throughout the book.

This book is crafted in an easy-to-understand language and is complemented by engaging illustrations. It is highly recommended for anyone seeking to gain a comprehensive understanding of Long Wavelength Semiconductor Lasers.

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