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# **LONG-WAVELENGTH INFRARED SEMICONDUCTOR LASERS**

Edited by **HONG K. CHOI**

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# Long Wavelength Infrared Semiconductor Lasers

**John F. Ready**



## **Long Wavelength Infrared 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 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.

*Long-Wavelength Infrared Semiconductor Lasers* Hong K Choi, 2004      *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.

*Advances in Semiconductor Lasers* James J Coleman, A. Catrina Bryce, Chennupati Jagadish, 2012-05-02 Since its inception in 1966 the series of numbered volumes known as *Semiconductors and Semimetals* has distinguished itself through the careful selection of well known authors, editors and contributors. The Willardson and Beer Series as it is widely known has succeeded in

publishing numerous landmark volumes and chapters Not only did many of these volumes make an impact at the time of their publication but they continue to be well cited years after their original release Recently Professor Eicke R Weber of the University of California at Berkeley joined as a co editor of the series Mid-infrared Semiconductor Optoelectronics Anthony Krier,2007-05-22 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 **Industrial Applications of Lasers** John F. Ready,1997-04-25 A practical book with a variety of uses this book can help applications engineers spark problem solving techniques through the use of lasers Industrial Application of Lasers Second Edition takes the reader through laser fundamentals unusual properties of laser light types of practical lasers available and commonly used accessory equipment The book also applies this information to existing and developing applications Current uses of lasers including laser welding and cutting electronic fabrication techniques lightwave communications laser based applications in alignment surveying and metrology are all covered as well as discussing the potential for future applications such as all optical computers remote environmental monitoring and laser assisted thermonuclear fusion Explains basic laser fundamentals as well as emphasizing how lasers are used for real applications in industry Describes the importance of laser safety Discusses potentially important future applications such as remote environmental monitoring Includes rare expert lore and opinion *The Physics of Semiconductors* Marius Grundmann,2015-12-24 The 3rd edition of this successful textbook contains ample material for a comprehensive upper level undergraduate or beginning graduate course guiding readers to the point where they can choose a special topic and begin supervised research The textbook provides a balance between essential aspects of solid state and semiconductor physics on the one hand and the principles of various semiconductor devices and their applications in electronic and photonic devices on the other It highlights many practical aspects of semiconductors such as alloys strain heterostructures nanostructures that are necessary in modern semiconductor research but typically omitted in textbooks Coverage also includes additional advanced topics such as Bragg mirrors resonators polarized and magnetic semiconductors nanowires quantum dots multi junction solar cells thin film transistors carbon based nanostructures and transparent conductive oxides The text derives explicit formulas for many results to support better understanding of the topics The

Physics of Semiconductors requires little or no prior knowledge of solid state physics and evolved from a highly regarded two semester course In the third edition several topics are extended and treated in more depth including surfaces disordered materials amorphous semiconductors polarons thermopower and noise More than 1800 references guide the reader to historic and current literature including original and review papers and books

**Laser-based Mid-infrared Sources and Applications** Konstantin L. Vodopyanov, 2020-06-25 An important guide to the major techniques for generating coherent light in the mid infrared region of the spectrum Laser based Mid infrared Sources and Applications gives a comprehensive overview of the existing methods for generating coherent light in the important yet difficult to reach mid infrared region of the spectrum 2 20  $\mu\text{m}$  and their applications The book describes major approaches for mid infrared light generation including ion doped solid state lasers fiber lasers semiconductor lasers and laser sources based on nonlinear optical frequency conversion and reviews a range of applications spectral recognition of molecules and trace gas sensing biomedical and military applications high field physics and attoscience and others Every chapter starts with the fundamentals for a given technique that enables self directed study while extensive references help conduct deeper research Laser based Mid infrared Sources and Applications provides up to date information on the state of the art mid infrared sources discusses in detail the advancements made over the last two decades such as microresonators and interband cascade lasers and explores novel approaches that are currently subjects of intense research such as supercontinuum and frequency combs generation This important book Explains the fundamental principles and major techniques for coherent mid infrared light generation Discusses recent advancements and current cutting edge research in the field Highlights important biomedical environmental and military applications Written for researchers academics students and engineers from different disciplines the book helps navigate the rapidly expanding field of mid infrared laser based technologies

**Terahertz Techniques** Erik Brändermann, Heinz-Wilhelm Hübers, Maurice FitzGerald Kimmitt, 2012-04-18 Research and development in the terahertz portion of the electromagnetic spectrum has expanded very rapidly during the past fifteen years due to major advances in sources detectors and instrumentation Many scientists and engineers are entering the field and this volume offers a comprehensive and integrated treatment of all aspects of terahertz technology The three authors who have been active researchers in this region over a number of years have designed Terahertz Techniques to be both a general introduction to the subject and a definitive reference resource for all those involved in this exciting research area

**Mid-infrared Optoelectronics** Eric Tournié, Laurent Cerutti, 2019-10-19 Mid infrared Optoelectronics Materials Devices and Applications addresses the new materials devices and applications that have emerged over the last decade along with exciting areas of research Sections cover fundamentals light sources photodetectors new approaches and the application of mid IR devices with sections discussing LEDs laser diodes and quantum cascade lasers mid infrared optoelectronics emerging research areas dilute bismide and nitride alloys Group IV materials gallium nitride heterostructures and new nonlinear materials

Finally the most relevant applications of mid infrared devices are reviewed in industry gas sensing spectroscopy and imaging This book presents a key reference for materials scientists engineers and professionals working in R D in the area of semiconductors and optoelectronics Provides a comprehensive overview of mid infrared photodetectors and light sources and the latest materials and devices Reviews emerging areas of research in the field of mid infrared optoelectronics including new materials such as wide bandgap materials chalcogenides and new approaches like heterogeneous integration Includes information on the most relevant applications in industry like gas sensing spectroscopy and imaging

**Basics of Laser Physics** Karl F. Renk, 2012-02-09 Basics of Laser Physics provides an introductory presentation of the field of all types of lasers It contains a general description of the laser a theoretical treatment and a characterization of its operation as it deals with gas solid state free electron and semiconductor lasers and furthermore with a few laser related topics The different subjects are connected to each other by the central principle of the laser namely that it is a self oscillating system Special emphasis is put on a uniform treatment of gas and solid state lasers on the one hand and semiconductor lasers on the other hand The discussions and the treatment of equations are presented in a way that a reader can immediately follow The book addresses undergraduate and graduate students of science and engineering Not only should it enable instructors to prepare their lectures but it can be helpful to students for preparing for an examination

**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: Principles* Colin E. Webb, Julian D. C. Jones, 2004

Lasers and Optoelectronics Anil K. Maini, 2013-08-05 With emphasis on the physical and engineering principles this book provides a comprehensive and highly accessible treatment of modern lasers and optoelectronics Divided into four parts it explains laser fundamentals types of lasers laser electronics optoelectronics and laser applications covering each of the topics in their entirety from basic fundamentals to advanced concepts Key features include exploration of technological and application related aspects of lasers and optoelectronics detailing both existing and emerging applications in industry medical diagnostics and therapeutics scientific studies and Defence simple explanation of the concepts and essential information on electronics and circuitry related to laser systems illustration of numerous solved and unsolved problems practical examples chapter summaries self evaluation exercises and a comprehensive list of references for further reading This volume is a valuable design guide for R D engineers and scientists engaged in design and development of lasers and optoelectronics systems and technicians in their operation and maintenance The tutorial approach serves as a useful reference for under graduate and graduate students of lasers and optoelectronics also PhD students in electronics optoelectronics and physics

Handbook of Laser Technology and Applications Chunlei Guo, 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 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

*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 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.

**Handbook of Defence Electronics and Optronics** Anil K. Maini, 2018-07-23 Handbook of Defence Electronics and Optronics Anil K Maini Former Director Laser Science and Technology Centre India. First complete reference on defence electronics and optronics. Fundamentals, Technologies and Systems. This book provides a complete account of defence electronics and optronics. The content is broadly divided into three categories: topics specific to defence electronics, topics relevant to defence optronics, and topics that have both electronics and optronics counterparts. The book covers each of the topics in their entirety from fundamentals to advanced concepts, military systems in use and related technologies, thereby leading the reader logically from the operational basics of military systems to involved technologies and battlefield deployment and applications. Key features: Covers fundamentals, operational aspects, involved technologies and application potential of a large cross section of military systems. Discusses emerging technology trends and development and deployment status of next generation military systems wherever applicable in each category of military systems. Amply illustrated with approximately 1000 diagrams and photographs and around 30 tables. Includes salient features, technologies and deployment aspects of hundreds of military systems including military radios, ground and surveillance radars, laser range finder and target designators, night vision devices, EW and EO jammers, laser guided munitions and military communications equipment and satellites. Handbook of Defence Electronics and Optronics is an essential guide for graduate students, R D scientists, engineers engaged in manufacturing defence equipment and professionals handling the operation and maintenance of these systems in the Armed Forces.

*Intense Terahertz Excitation of Semiconductors* Sergey Ganichev, Willi Prettl, 2006 This work presents the first comprehensive treatment of high power terahertz applications to semiconductors and low dimensional semiconductor structures. Terahertz properties of



semiconductors are in the centre of scientific activities because of the need of high speed electronics

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