Optical Integrated Circuits

Diode Lasers and Photonic Integrated Circuits, Second Edition provides a comprehensive treatment of optical communication technology, its principles and theory, treating students as well as experienced engineers to an in-depth exploration of this field. Diode lasers are still of significant importance in the areas of optical communication, storage, and sensing. Using the the same well received theoretical foundations of the first edition, the Second Edition now introduces timely updates in the technology and in focus of the book. After 15 years of development in the field, this book will offer brand new and updated material on GaN-based and quantum-dot lasers, photonic IC technology, detectors, modulators and SOAs, DVDs and storage, eye diagrams and BER concepts, and DFB lasers. Appendices will also be expanded to include quantum-dot issues and more on the relation between spontaneous emission and gain.

Electronic integrated circuits are considered one of the most significant technological advances of the 20th century, with demonstrated impact in their ability to incorporate successively higher numbers transistors and construct electronic devices onto a single CMOS chip. Photonic integrated circuits (PICs) exist as the optical analog to integrated circuits; however, in place of transistors, PICs consist of numerous scaled optical components, including such "building-block" structures as waveguides, MMIs, lasers, and optical ring resonators. The ability to construct electronic and photonic components on a single microsystems platform offers transformative potential for the development of technologies in fields including communications, biomedical device development, autonomous navigation, and chemical and atmospheric sensing. Developing on-chip systems that provide new avenues for integration and replacement of bulk optical and electro-optic components also reduces size, weight, power and cost (SWaP-C) limitations, which are important in the selection of instrumentation for specific flight projects. The number of applications currently emerging for complex photonics systems-particularly in data communications-warrants additional investigations when considering reliability for space systems development. This Body of Knowledge document seeks to provide an overview of existing integrated photonics architectures; the current state of design, development, and fabrication ecosystems in the United States and Europe; and potential space applications, with emphasis given to associated radiation effects and reliability. Alt, Shannon Goddard Space Flight Center

*An expert guide to the new and emerging field of broadband circuitsfor optical fiber communication This exciting publication makes it easy for readers to enter intoand deepen their knowledge of the new and emerging field ofbroadband circuits for optical fiber communication. The author'sselection and organization of material have been developed, tested,and refined from his many industry courses and seminars. Five typesof broadband circuits are discussed in detail: * Transimpedance amplifiers * Limiting amplifiers * Automatic gain control (AGC) amplifiers * Lasers drivers * Modulator drivers Essential background on optical fiber, photodetectors, lasers,modulators, and receiver theory is presented to help readersunderstand the system environment in which these broadband circuitsoperate. For each circuit type, the main specifications and theirimpact on system performance are explained and illustrated withnumerical values. Next, the circuit concepts are discussed andillustrated with practical implementations. A broad range ofcircuits in MESFET, HFET, BJT, HBT, BiCMOS, and CMOS technologiesis covered. Emphasis is on circuits for digital, continuous-modetransmission in the 2.5 to 40 Gb/s range, typically used in SONET,SDH, and Gigabit Ethernet applications. Burst-mode circuits forpassive optical networks (PON) and analog circuits for hybridfiber-coax (HFC) cable-TV applications also are discussed. Learning aids are provided throughout the text to help readersgrasp and apply difficult concepts and techniques, including: * Chapter summaries that highlight the key points * Problem-and-answer sections to help readers apply their newknowledge * Research directions that point to exciting new technologicalbreakthroughs on the horizon * Product examples that show the performance of actual broadbandcircuits * Appendices that cover eye diagrams, differential circuits, Sparameters, transistors, and technologies * A bibliography that leads readers to more complete and in-depthtreatment of specialized topics This is a superior learning tool for upper-level undergraduates andgraduate-level students in circuit design and optical fibercommunication. Unlike other texts that concentrate on analogcircuits in general or mostly on optics, this text providesbalanced coverage of electronic, optic, and system issues.Professionals in the fiber optic industry will find it an excellentreference, incorporating the latest technology and discoveries inthe industry.*

Functional Photonic Integrated Circuits

Neuromorphic Photonics

Optical Integrated Circuits Theory and Design

Silicon-Organic Hybrid Platform for Photonic Integrated Circuits

InGaAsP/InP Based Photonic Integrated Circuits for Optical Switching

In Optoelectronic Integrated Circuit Design and Device Modeling, Professor Jianjun Gao introduces the fundamentals and modeling techniques of optoelectronic devices used in high-speed optical transmission systems. Gao covers electronic circuit elements such as FET, HBT, MOSFET, as well as design techniques for advanced optical transmitter and receiver front-end circuits. The book includes an overview of optical communication systems and computer-aided optoelectronic IC design before going over the basic concept of laser diodes. This is followed by modeling and parameter extraction techniques of lasers and photodiodes. Gao covers high-speed electronic semiconductor devices, optical transmitter design, and optical receiver design in the final three chapters. Addresses a gap within the rapidly growing area of transmitter and receiver modeling in OEICs Explains diode physics before device modeling, helping readers understand their equivalent circuit models Provides comprehensive explanations for E/O and O/E conversions done with laser and photodiodes Covers an extensive range of devices for high-speed applications Accessible for students new to microwaves Presentation slides available for instructor use This book is primarily aimed at practicing engineers, researchers, and post-graduates in the areas of RF, microwaves, IC design, photonics and lasers, and solid state devices. The book is also a strong supplement for senior undergraduates taking courses in RF and microwaves. Lecture materials for instructors available at www.wiley.com/go/gao

Recent developments in photonic integrated circuits (PICs) are attracting strong interest for their advances in building scalable, high-throughput, and low-cost on-chip optical communication systems. The silicon-on-insulator (SOI) platform is compatible with CMOS technologies which allow for optic-electronic interconnects in the future photonic-electronic integration. In the meantime, Silicon nitride (Si_3N_4) based PIC platforms are becoming outstanding solutions because of their relatively low optical propagation losses on a silicon CMOS compatible platform. The multilayer structure is promising for future low-loss, small-footprint, and high-density 3D PICs. The key components in this field including arrayed waveguide gratings/routers (AWG/AWGR), optical modulators, and germanium photo-detectors are forming the path to the on-chip passive optical circuits. Heterogeneous integration opens an access to realizing the integration of active components on silicon substrates as light sources of the on-chip optical systems. In addition, heterogeneous integration of various materials is adding powerful functions to the silicon photonic platform, such as the athermalization and the magneto-optical effect. This dissertation pursues the development of 2D passive photonic devices as well as 3D multilayer photonic devices, integration of III-V materials on silicon substrates, and novel materials integration on the silicon photonic platform. The investigated 2D passive photonic devices include the cascaded multimode interference (MMI) couplers, the uniform splitting star couplers, the low-loss arrayed waveguide gratings/routers (AWGs/AWGRs), and the uniform emission gratings. Heavy emphasis is the silicon nitride (Si_3N_4) multilayer platform and the 3D photonic devices, including the vertical Y-junctions and the 3D couplers with arbitrary power splitting ratio. Along with passive photonic device demonstrations, the demand of more useful platforms leads the path to heterogeneous integration. To realize the integration of functional materials on silicon substrates, we investigated direct wafer bonding and RF magnetron sputtering in this dissertation. By using the wafer bonding approach, we demonstrated the AlGaAs/GaAs multiple quantum wells (MQWs) thin film integration on silicon substrates. By using the RF magnetron sputtering approach, we demonstrated the integration of novel materials on the silicon photonic platform, such as titanium dioxide (TiO_2) for athermal applications, and bismuth-iron-garnet (BIG) for magneto-optic isolators.

This hands-on introduction to silicon photonics engineering equips students with everything they need to begin creating foundry-ready designs.

Optoelectronic Integration: Physics, Technology and Applications

Design of Integrated Circuits for Optical Communications

Silicon Photonics

Semiconductor Lasers

Flexible Silicon Photonic Integrated Circuits for Optical Interconnects and WDM Networks

This book provides the first comprehensive, up-to-date and self-contained introduction to the emergent field of Programmable Integrated Photonics (PIP). It covers both theoretical and practical aspects, ranging from basic technologies and the building of photonic component blocks, to designalternatives and principles of complex programmable photonic circuits, their limiting factors, techniques for characterization and performance monitoring/control, and their salient applications both in the classical as well as in the quantum information fields. The book concentrates and focusesmainly on the distinctive features of programmable photonics, as compared to more traditional ASPIC approaches.After some years during which the Application Specific Photonic Integrated Circuit (ASPIC) paradigm completely dominated the field of integrated optics, there has been an increasing interest in PIP. The rising interest in PIP is justified by the surge in a number of emerging applications that callfor true flexibility and reconfigurability, as well as low-cost, compact, and low-power consuming devices.Programmable Integrated Photonics is a new paradigm that aims at designing common integrated optical hardware configurations, which by suitable programming, can implement a variety of functionalities. These in turn can be exploited as basic operations in many application fields. Programmabilityenables, by means of external control signals, both chip reconfiguration for multifunction operation, as well as chip stabilization against non-ideal operations due to fluctuations in environmental conditions and fabrication errors. Programming also allows for the activation of parts of the chip,which are not essential for the implementation of a given functionality, but can be of help in reducing noise levels through the diversion of undesired reflections.

Integrated optoelectronics is becoming ever more important to communications, computer, and consumer industries. It is the enabling technology in a variety of systems, ranging from low-cost, robust optical componentsin consumer electronics to high-performance broadband information networks capable of supporting video and multimedia conferencing. The requirements for producing low-cost, highly reliable components for deployment in these new systems have created a technology challenge. Integrated optoelectronics promises to meet the performance and cost objectives of these applications by integrating both optical and electronic components in a highly functional chip. This book provides an overview of this exciting newtechnology. Integrated Optoelectronics brings together a group of acknowledged experts from both universities and industry around the world to focus on a common theme of integration. These experts have reported not only on the state-of-the-art, but also on the physics and design experience that goes into implementing integrated chips and modules. This book is a cohesive series of articles that includes a discussion of the intimate trade-offs between materials, processes, devices, functional blocks, packaging,and systems requirements in a truly integrated technology. This integration encompasses electrical, optoelectronic, and optical devices onto monolithic or hybrid chips, and into multichip modules. This volume surveys state-of-the-art research activities in integrated optoelectronics and gathers most of the important references into a single place. It outlines the major issues involved in integrating both optical and electronic components, provides an overview of design and fabrication concepts, and discusses the issues involved in bringing these new chips to the marketplace. This exciting new book: Provides a broad overview of the optoelectronic field, including materials processing, devices, and systems applications Features authors who are acknowledged research experts in this field, from both industry and universities around the world Includes new information on device fabrication, including the latest epitaxial growth and lift-off techniques to permit the mixing of dissimilar materials onto single chips Covers planar processed laser fabrication leading to wafer level automated testing Discusses optimization of devices for integration, including a detailed treatment of the vertical emitting laser and theoretical and experimental coverage of optimization of photodetectors for integration into receiver chips Describes design approaches for multifunctional chips, including photonic circuits for all-optical networks and the design of integrated optoelectronic chips with lasers, photodiodes, and electronic ICs Covers the infrastructure needed to support an integrated technology, including automated design systems which treat both optical and electrical circuits, and multichip packaging approaches for both optical and IC chips

Explains the circuit design of silicon optoelectronic integrated circuits (OEICs), which are central to advances in wireless and wired telecommunications. The essential features of optical absorption are summarized, as is the device physics of photodetectors and their integration in modern bipolar, CMOS, and BiCMOS technologies. This information provides the basis for understanding the underlying mechanisms of the OEICs described in the main part of the book. In order to cover the topic comprehensively, Silicon Optoelectronic Integrated Circuits presents detailed descriptions of many OEICs for a wide variety of applications from various optical sensors, smart sensors, 3D-cameras, and optical storage systems (DVD) to fiber receivers in deep-sub-?m CMOS. Numerous detailed illustrations help to elucidate the material.

Broadband Circuits for Optical Fiber Communication

Materials, Device Physics, Guided Wave Design

Special Topics in Information Technology

High-Speed Optical Transceivers

Optical fiber current sensor using photonic integrated circuits based on polymer waveguide

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 ~m. The development during the 1970s of GaAs semiconductor lasers, emitting in the near-infrared region of 0. 8-0. 9 ~m, resulted in their use for the first generation of optical fiber communication systems. However, to take advantage oflow losses in silica fibers occurring around 1. 3 and 1. 55 ~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 semicon ductor 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.

The growing demand for instant and reliable communication means that photonic circuits are increasingly finding applications in optical communications systems. One of the prime candidates to provide satisfactory performance at low cost in the photonic circuit is silicon. Whilst silicon photonics is less well developed as compared to some other material technologies, it is poised to make a serious impact on the telecommunications industry, as well as in many other applications, as other technologies fail to meet the yield/performance/cost trade-offs. Following a sympathetic tutorial approach, this first book on silicon photonics provides a comprehensive overview of the technology. Silicon Photonics explains the concepts of the technology, taking the reader through the introductory principles, on to more complex building blocks of the optical circuit. Starting with the basics of waveguides and the properties peculiar to silicon, the book also features: Key design issues in optical circuits. Experimental methods. Evaluation techniques. Operation of waveguide based devices. Fabrication of silicon waveguide circuits. Evaluation of silicon photonic systems. Numerous worked examples, models and case studies. Silicon Photonics is an essential tool for photonics engineers and young professionals working in the optical network, optical communications and semiconductor industries. This book is also an invaluable reference and a potential main text to senior undergraduates and postgraduate students studying fibre optics, integrated optics, or optical network technology.

This book sets out to build bridges between the domains of photonic device physics and neural networks, providing a comprehensive overview of the emerging field of "neuromorphic photonics." It includes a thorough discussion of evolution of neuromorphic photonics from the advent of fiber-optic neurons to today's state-of-the-art integrated laser neurons, which are a current focus of international research. Neuromorphic Photonics explores candidate interconnection architectures and devices for integrated neuromorphic networks, along with key functionality such as learning. It is written at a level accessible to graduate students, while also intending to serve as a comprehensive reference for experts in the field.

Principles of Photonic Integrated Circuits

Chapter 2. Semiconductor Photonic Integrated Circuit Transmitters and Receivers

Silicon Photonics for High-Performance Computing and Beyond

Optical Fiber Telecommunications VIA

An Introduction

"Silicon photonics is a promising solution to meeting the increasing bandwidth demands in future terabit-per-second data communications. It takes advantage of the ultra-wide optical bandwidth and ultrafast transmission speed of photonics, while at the same time inheriting the existing manufacturing infrastructures from the microelectronics industry. Silicon photonics has advanced rapidly in recent years, highlighted by the demonstration of various high performance passive and active silicon photonic devices. As all the necessary building blocks are individually realized on the silicon platform, the next challenge will naturally be the integration of photonic devices with electronic circuits in a single silicon chip. As previously demonstrated on the III-V semiconductor-based photonic integrated circuits (PICs), electronic-photonic integration is challenging both in physical device fabrication as well as in system and circuitry design. The device fabrication challenges lie in the development of a low-cost complementary metal-oxide-semiconductor (CMOS) compatible process that effectively integrates photonics within the limitations posed by CMOS electronics. On the system and circuit design side, electronic-photonic integrated circuits (EPICs) need to address the fundamental mismatch between the large potential bandwidth of photonics and the significantly lower speed of CMOS electronics. To overcome this challenge, many previous works use wavelength division multiplexing (WDM) to split the optical bandwidth in the wavelength domain and achieve a larger aggregated data rate. However, on-chip WDM systems are usually complicated to design and dicult to implement, including the issues of channel cross-talk, integration of a large number of source-detector pairs, clock synchronization between multiple sources, etc. We propose to time-share the optical bandwidth by applying time-interleaving circuit techniques in photonics. Time-interleaving schemes have been widely employed in high-speed electronics, which increases the overall bandwidth of the system by operating several low-speed subsystems in parallel. Applying time-interleaving techniques in high-speed EPICs would effectively relax the bandwidth requirement in each subsystem, and hence the relatively low-speed electronics can be used to achieve the large bandwidth enabled by the photonics. As an example of utilizing the time-interleaving technique in silicon photonics, this thesis presents a new EPIC concept based on microrings. In addition to their wavelength-domain properties as add-drop filters, the time-domain properties of microrings are explored. In this new microring-based optical pulse train generator (MOPTG), multiple microring add-drop filters are cascaded in a series of stages and resonate at the same wavelength, which is shifted from the input wavelength by design. The microrings are used as compact couplers to equally divide the input pulse energy. The stage outputs are then time-interleaved by the delay lines between the stages and combined at the circuit output to form an optical pulse train. The circuit can be used for optical arbitrary waveform generation (OAWG) by controlling the amplitude and timing of the output pulses. It can also be easily developed into an ultrafast optical transmitter by actively modulating the microrings. As a methodology, the transfer matrix method combined with full-wave electromagnetic (EM) simulation is developed to analyze large microring-based EPIC systems. A four-stage M-OPTG prototype is designed and fabricated on silicon-oninsulator (SOI) using e-beam lithography. Four identical pulses that are 50-ps apart duplicate the 10-ps-wide input pulse at the output, indicating a high pulse repetition rate of 20 GHz. The preliminary experimental results verify the multiply-by-4 circuit function, with pulse repetition rates of 18 GHz and 33 GHz demonstrated by two prototypes respectively. To fully utilize the filter function of microrings as well as the time-interleaving circuit technique to boost the repetition rate of the input pulse train, WDM and time division multiplexing (TDM) are combined in a new multi-wavelength M-OPTG concept. Different from the single-wavelength design, all the stages resonate at different wavelengths, and are used as WDM multiplexers to filter the wideband input spectrum and multiplex it to the output. Moreover, the multi-wavelength operation removes the power loss introduced by the "asynchronous" optical combining at the circuit output by using a single output waveguide to combine the stage outputs. A design of a 30-wavelength M-OPTG impressively demonstrates this circuit concept by multiplying the input repetition rate 30 times at the output, which can be used as a guideline for the future implementation of the circuit. A four-wavelength prototype is fabricated on SOI as an experimental demonstration of the multi-wavelength M-OPTG. To solve the microring resonant wavelength shift problem, Ti/Au heaters are implemented on top of the microrings to thermally control their resonant wavelengths. When thermal tuning is applied, the output waveform of the prototype shows four identical pulses with a pulse width of 25 ps and a timing delay of 60 ps between the adjacent pulses. The total power consumption for the thermal tuning is about 13:75 mW. The pulse repetition rate is demonstrated to be 17 GHz"--Leaves vi-viii.

In response to the continuous growth in the demand for higher speed and volume of data transmission, optical networks are evolving to become more elastic to maximize spectrum utility. This in turn is driving the development of flexible optical devices and circuits that can be reconfigured to adapt to fast changes in network conditions. Over the past decade, silicon photonics has gained widespread industry acceptance as a platform for photonic integrated circuits for optical communication, due to its low cost, potential for dense integration and compatibility with the CMOS fabrication process. In spite of its promising benefits, several important challenges remain in the development of flexible silicon photonic circuits, namely, broadband wavelength tunability, fast recon figurability, and scalability. This thesis addresses these issues through the development of flexible and scalable silicon photonic components for elastic optical networks, including a widely tunable reconfi gurable optical add-drop multiplexing (ROADM) circuit, a universal variable bandwidth optical filter, and a fast wavelength selection circuit. The ROADM circuit can provide wavelength reconfi gurability over more than 4 Tb/s data transmission bandwidth. The variable bandwidth filter is based on a novel microring-loaded Mach-Zehnder interferometer that can provide insertion loss-free bandwidth tuning by only tuning the microring resonant frequencies. The wavelength selection circuit combines the wide band tunability of thermo-optic microring filters with fast switching by free carrier injection to achieve best-case wavelength selection time of a few nanoseconds over a 32 nm wavelength range. As silicon photonic circuits grow in functionality and complexity, it also becomes necessary to monitor their performance and optical signal quality throughout the system. To address this issue, we proposed and investigated two novel methods for on-chip optical monitoring. The first method is the use of on-chip thermistors for tracking the centre wavelength and bandwidth of microring add/drop filters. The second method is the use of silicon photodetectors based on two-photon absorption for on-chip signal detection. These devices and methods can be seamlessly integrated into silicon photonic circuits for real-time monitoring of their performance.

Updates the advancements made in the level of achievable integration of optical circuits and components in the last ten years--highlighting the commercial success of particular devices as well as introducing multiple facets of integrated optics.

The State of the Art

Design of Analog CMOS Integrated Circuits

Photonic Integrated Circuits for Compact High Resolution Imaging and High Capacity Communication Utility

Silicon Photonics Design

Diode Lasers and Photonic Integrated Circuits

Principles of Photonic Integrated CircuitsMaterials, Device Physics, Guided Wave DesignSpringer Nature

This graduate-level textbook presents the principles, design methods, simulation, and materials of photonic circuits. It provides state-of-the-art examples of silicon, indium phosphide, and other materials frequently used in these circuits, and includes a thorough discussion of all major types of devices. In addition, the book discusses the integrated photonic circuits (chips) that are currently increasingly employed on the international technology market in connection with short-range and long-range data communication. Featuring references from the latest research in the field, as well as chapter-end summaries and problem sets, Principles of Photonic Integrated Circuits is ideal for any graduate-level course on integrated photonics, or optical technology and communication.

This chapter covers the field of semiconductor photonic integrated circuits (PIC) used in access, metro, long-haul, and undersea telecommunication networks. Although there are many variants to implementing optical integration; the focus is on monolithic integration where multiple semiconductor devices, up to many hundreds in some cases, are integrated onto the same substrate. Monolithic integration poses the greatest technical challenge and the biggest opportunity for bandwidth and size scaling. The PICs discussed here are based on the two most popular semiconductor material systems: Groups III–V indium phosphide-based devices and Group IV silicon-based devices. The chapter also covers the historical evolution of the technology from the decades old original proposal to the current day terabit/s class, coherent PICs.

Design and Applications

Integrated Optoelectronics

Optoelectronic Integrated Circuit Design and Device Modeling

Photonic Network-on-Chip Design

OPTICAL INTEGRATED CIRCUITS.

Optoelectronic devices and fibre optics are the basis of cutting-edge communication systems. This monograph deals with the various components of these systems, including lasers, amplifiers, modulators, converters, filters, sensors, and more.

This open access book presents thirteen outstanding doctoral dissertations in Information Technology from the Department of Electronics, Information and Bioengineering, Politecnico di Milano, Italy. Information Technology has always been highly interdisciplinary, as many aspects have to be considered in IT systems. The doctoral studies program in IT at Politecnico di Milano emphasizes this interdisciplinary nature, which is becoming more and more important in recent technological advances, in collaborative projects, and in the education of young researchers. Accordingly, the focus of advanced research is on pursuing a rigorous approach to specific research topics starting from a broad background in various areas of Information Technology, especially Computer Science and Engineering, Electronics, Systems and Control, and Telecommunications. Each year, more than 50 PhDs graduate from the program. This book gathers the outcomes of the thirteen best theses defended in 2020-21 and selected for the IT PhD Award. Each of the authors provides a chapter summarizing his/her findings, including an introduction, description of methods, main achievements and future work on the topic. Hence, the book provides a cutting-edge overview of the latest research trends in Information Technology at Politecnico di Milano, presented in an easy-to-read format that will also appeal to non-specialists.

Examines in detail the theory, fabrication techniques, and applications of the hybrid types, of optical integrated circuits, as well as explaining waveguiding theory, device design, and fabrication. Provides material on the derivation of the fundamental equations, physical explanation, numerical exa"

Integrated Photonics

Theory and Technology

Photonic Integrated Circuit (Pic) Device Structures: Background, Fabrication Ecosystem, Relevance to Space Systems Applications, and Discussion of Rel

Integrated Optics

This book provides a comprehensive synthesis of the theory and practice of photonic devices for networks-on-chip. It outlines the issues in designing photonic network-on-chip architectures for future many-core high performance chip multiprocessors. The discussion is built from the bottom up: starting with the design and implementation of key photonic devices and building blocks, reviewing networking and network-on-chip theory and existing research, and finishing with describing various architectures, their characteristics, and the impact they will have on a computing system. After acquainting the reader with all the issues in the design space, the discussion concludes with design automation techniques, supplemented by provided software.

"The increasing demand for high-speed transport of data has revitalized optical communications, leading to extensive work on high-speed device and circuit design. This book deals with the design of high-speed integrated circuits for optical communicationtransceivers.Building upon a detailed understanding of optical devices, the book describes the analysis and design of critical building blocks, such as transimpedance and limiting amplifiers, laser drivers, phase-locked loops, oscillators, clock and datarecovery circuits, and multiplexers.This second edition of this best selling textbook has been updated to provide information on the latest developments in the field"--

Integrated photonics refers to the integration of multiple photonic components on a common substrate. Examples of photonic components include waveguides, gratings, couplers, polarizers, interferometers, beam splitters, light sources, and detectors. In turn, these components can then be used as building blocks to realize more complex planar photonic circuits, capable of performing a wide range of functions with applications in optical sensors and communication systems. The development of integrated photonics is the confluence of waveguide technology and photonic disciplines, which deals with the control of light by electrons and vice versa. The optical waveguide technology is the fundamental of integrated photonics which enables light guiding, coupling, splitting, multiplexing and demultiplexing of optical signals. In the first three chapters of this dissertation, we will discuss the main characteristics of integrated photonics and show relevant aspects of material and fabrication technologies. We will also briefly describe some basic components used in integrated photonics, emphasizing the difference in their design concepts in contrast to conventional bulk optics. Some examples of photonic integrated circuits (PICs) are presented to highlight photonic integration as an elegant solution to realizing multifunctional chip-scale module. Chapter 4 discusses the arrayed waveguide grating (AWG) as another example of PIC. The AWGs are widely used as optical (de)multiplexers in wavelength division multiplexer (WDM) systems. These devices are capable of multiplexing a large number of wavelength channels into a single optical fiber, thereby increasing the aggregate transmission capacity of the single-mode fiber. We will explain the working principle of AWG devices, and then address several design techniques. Eventually, we will demonstrate a large channel spacing AWG (an 18 channel 3.3 THz channel spacing AWG centered around 1310 nm) and a high channel count AWG (a 512 channel 25 GHz channel spacing AWG centered around 1550 nm). Chapter 5 investigates the use of PICs in interferometric imaging. In astronomy, optical interferometric imaging is a technique that brings the light of many telescopes together to create images with high angular resolution. While these interferomic telescopes based on PICs achieve the same spatial resolution as the conventional telescopes, they offer much more compact and robust platforms. This chapter further proposes and demonstrates a small-scale interferometric imager based on PIC technology. The PIC interferometer has the potential to become an alternative to conventional telescope interferometer, but with significantly reduced size, weight and power consumption. Chapter 6 discusses the use of PICs in orbital angular momentum (OAM) communication system. OAM can be understood as characterizing the twist of a helical phase front of the light beam. A set of OAM mode forms an orthogonal modal basis set that can be used in a mode-division-multiplexing system, which increases the capacity of optical communication in addition to WDM and polarization division multiplexing (PDM) techniques. This chapter demonstrates the first silicon PIC that is capable of demultiplexing free-space optical beams with multiple OAM states near 1550 nm into the single-mode waveguides. The device is easily connected to high-speed telecommunication components like modulators and photodetectors and is comparable with the CMOS silicon fabrication process. Chapter 7 summarizes this dissertation and projects possible future research directions.

Integrated Optics: Theory and Technology

Programmable Integrated Photonics

Integrated Circuits Designs and Optical Devices Techniques

Optical Integrated Circuits

9-10 February 1995, San Jose, California

Silicon photonics is currently a very active and progressive area of research, as silicon optical circuits have emerged as the replacement technology for copper-based circuits in communication and broadband networks. The demand for ever improving communications and computing performance continues, and this in turn means that photonic circuits are finding ever increasing application areas. This text provides an important and timely overview of the 'hot topics' in the field, covering the various aspects of the technology that form the research area of silicon photonics. With contributions from some of the world's leading researchers in silicon photonics, this book collates the latest advances in the technology. Silicon Photonics: the State of the Art opens with a highly informative foreword, and continues to feature: the integrated photonic circuit; silicon photonic waveguides; photonic bandgap waveguides; mechanisms for optical modulation in silicon; silicon based light sources; optical detection technologies for silicon photonics; passive silicon photonic devices; photonic and electronic integration approaches; applications in communications and sensors. Silicon Photonics: the State of the Art covers the essential elements of the entire field that is silicon photonics and is therefore an invaluable text for photonics engineers and professionals working in the fields of optical networks, optical communications, and semiconductor electronics. It is also an informative reference for graduate students studying for PhD in fibre optics, integrated optics, optical networking, microelectronics, or telecommunications.

As we approach the end of the present century, the elementary particles of light (photons) are seen to be competing increasingly with the elementary particles of charge (electrons/holes) in the task of transmitting and processing the insatiable amounts of infonnation needed by society. The massive enhancements in electronic signal processing that have taken place since the discovery of the transistor, elegantly demonstrate how we have learned to make use of the strong interactions that exist between assemblages of electrons and holes, disposed in suitably designed geometries, and replicated on an increasingly fine scale. On the other hand, photons interact extremely weakly amongst themselves and all-photonic active circuit elements, where photons control photons, are presently very difficult to realise, particularly in small volumes. Fortunately rapid developments in the design and understanding of semiconductor injection lasers coupled with newly recognized quantum phenomena, that arise when device dimensions become comparable with electronic wavelengths, have clearly demonstrated how efficient and fast the interaction between electrons and photons can be. This latter situation has therefore provided a strong incentive to devise and study monolithic integrated circuits which involve both electrons and photons in their operation. As chapter I notes, it is barely fifteen years ago since the first demonstration of simple optoelectronic integrated circuits were realised using m-V compound semiconductors; these combined either a laser/driver or photodetector/preamplifier combination.

Integrated Optics: Theory and Technology provides a comprehensive and thorough treatment suitable for use both as a classroom text (practice problems are included) and as a specialist's reference. Detailed descriptions of the phenomena, devices, and technology used in optical integrated circuits and their relationship to fiber optics are presented. In this fourth edition all chapters have been completely revised.

Heterogeneous Integration and Multilayer Platform for Photonic Integrated Circuits

Integrated Optical Circuits and Components

Silicon Optoelectronic Integrated Circuits

Optical Integrated Circuits for Large-scale Quantum Networks

Fibre Optic Communication Devices

Silicon photonics is beginning to play an important role in driving innovations in communication and computation for an increasing number of applications, from health care and biomedical sensors to autonomous driving, datacenter networking, and security. In recent years, there has been a significant amount of effort in industry and academia to innovate, design, develop, analyze, optimize, and fabricate systems employing silicon photonics, shaping the future of not only Datacom and telecom technology but also high-performance computing and emerging computing paradigms, such as optical computing and artificial intelligence. Different from existing books in this area, Silicon Photonics for High-Performance Computing and Beyond presents a comprehensive overview of the current state-of-the-art technology and research achievements in applying silicon photonics for communication and computation. It focuses on various design, development, and integration challenges, reviews the latest advances spanning materials, devices, circuits, systems, and applications. Technical topics discussed in the book include: • Requirements and the latest advances in high-performance computing systems • Device- and system-level challenges and latest improvements to deploy silicon photonics in computing systems • Novel design solutions and design automation techniques for silicon photonic integrated circuits • Novel materials, devices, and photonic integrated circuits on silicon • Emerging computing technologies and applications based on silicon photonics Silicon Photonics for High-Performance Computing and Beyond presents a compilation of 19 outstanding contributions from academic and industry pioneers in the field. The selected contributions present insightful discussions and innovative approaches to understand current and future bottlenecks in high-performance computing systems and traditional computing platforms, and the promise of silicon photonics to address those challenges. It is ideal for researchers and engineers working in the photonics, electrical, and computer engineering industries as well as academic researchers and graduate students (M.S. and Ph.D.) in computer science and engineering, electronic and electrical engineering, applied physics, photonics, and optics.

Our intent in producing this book was to provide a text that would be comprehensive enough for an introductory course in integrated optics, yet concise enough in its mathematical derivations to be easily readable by a practicing engineer who desires an overview of the field. The response to the first edition has indeed been gratifying; unusually strong demand has caused it to be sold out during the initial year of publication, thus providing us with an early opportunity to produce this updated and improved second edition. This development is fortunate, because integrated optics is a very rapidly progressing field, with significant new research being regularly reported. Hence, a new chapter (Chap. 17) has been added to review recent progress and to provide numerous additional references to the relevant technical literature. Also, thirty-five new problems for practice have been included to supplement those at the ends of chapters in the first edition. Chapters l through 16 are essentially unchanged, except for brief updating revisions and corrections of typographical errors. Because of the time limitations imposed by the need to provide an uninterrupted supply of this book to those using it as a course text, it has been possible to include new references and to briefly describe recent developments only in Chapter 17. However, we hope to provide details of this continuing progress in a future edition.

Microring-based Electronic-photonic Integrated Circuits