Silicon Photonics Design From Devices To Systems

This book introduces the reader to the optical switching technology for its application to data centers. In addition, it takes a picture of the status of the technology and system architecture evolution and of the research in the area of optical switching in data center. The book is organized in four parts: the first part is focused on the system aspects of optical switching in intra-data center networking, the second part is dedicated to describing the recently demonstrated optical switching networks, the third part deals with the latest technologies developed to enable optical switching and, finally, the fourth part of the book outlines the future prospects and trends.

Integrated photonic devices are poised to play a key role in a wide variety of applications, ranging from optical interconnects and sensors to quantum computing. Design methods for photonics, however, lag far behind other areas such as digital electronics and aerospace vehicles. Photonic devices are largely designed by hand using a combination of semi-analytic theory and brute-force parameter sweeps, and as a result only a small library of devices is currently known. In this dissertation, I discuss our recent efforts to automate the design of photonic devices. In particular, we have developed an automated design method that explores the full design space of fabricable devices. This has allowed us to design devices with previously unattainable functionalities, performance, fabrication robustness, and compact footprints. Using this method, we designed, fabricated, and experimentally demonstrated a wide variety of passive silicon photonics devices. These include a wavelength splitting grating coupler, compact waveguide-coupled wavelength splitters, and a 3-way power splitter. The design methods we have introduced have the potential to both revolutionize the integrated photonics industry, and open new avenues of research for photonics.

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 the all issues in the design space, the discussion concludes with design automation techniques, supplemented by provided software.


This book focuses on recent research and developments on optical communications. The chapters present different aspects of optical communication systems, comprising high capacity transmission over long distances, coherent and intensity modulated technologies, orthogonal frequency-division multiplexing, ultrafast switching techniques, and photonic integrated devices. Digital signal processing and error correction techniques are also addressed. The content is of interest to graduate students and researchers in optical communications.

Silicon photonics is an emerging industry that aims to implement photonic systems using extensions to traditional CMOS process technologies. With silicon technologies being used to transmit light, there exists a need by designers to understand the performance of standard silicon photonics elements and the deviations that may arise in actual production. Drop-in models for silicon-based photonic structures do exist and are used to make light-based systems. However, these models do not take manufacturing variations into account and are assumed to be ideal. This thesis establishes the use of models for photonic structures that take spatial and random variations from manufacturing into account. More specifically, we demonstrate two elements of a variation-aware photonic design and analysis methodology. First, we develop first-order models of passive ring resonators and its active counterpart, the ring modulator, to simulate and predict the behavior and impact of variation in these devices on large-scale designs. Both are small footprint devices capable of selective filtering, yet often deviate considerably from expected behavior due to process deviations. Second, we explore ways to use these basic photonic elements to build a larger system that can probe process deviations over a chip. Together, these methods contribute key steps toward a design for manufacturability methodology to achieve high yield and high performance silicon photonic systems.

Recent developments in inverse design have demonstrated the power of computer algorithms for designing new and more efficient silicon photonic devices. However, most photonic design remains in human hands, because of the need for design for manufacturability and mitigate the impact of process variations, where computational tools and models have lagged behind. In this work, I investigate the viability and limitations of modeling and efficiently predicting the effects of one type of process variation, line edge roughness, using the adjoint simulation method. I then develop a robust optimization framework for designing devices that mitigate the impact of line edge roughness, using a hybrid worst-case / average-case scenario construction procedure, and demonstrate its application on the design of a Y-branch splitter. The resulting design experiences 20% less variation in the output imbalance between its two ports compared to the nominal design it started with, in addition to a decrease in insertion loss. Although the optimization algorithm suffers from overfitting as currently implemented, it remains a successful proof-of-concept and its framework is broadly applicable.

This second edition of An Engineer's Guide to Automated Testing of High-Speed Interfaces provides updates to reflect current state-of-the-art high-speed digital testing with automated test equipment technology (ATE). Featuring clear examples, this one-stop reference covers all critical aspects of automated testing, including an introduction to high-speed digital basics, a discussion of industry standards, ATE and bench instrumentation for digital applications, and test and measurement techniques for characterization and production environment. Engineers learn how to apply automated test equipment for testing high-speed digital I/O interfaces and gain a better understanding of PCI-Express 4, 100Gb Ethernet, and MIPI while exploring the correlation between phase noise and jitter. This updated resource provides expanded material on 28/32 Gbps NRZ testing and wireless testing that are becoming increasingly more pertinent for future applications. This book explores the current trend of merging high-speed digital testing within the fields of photonic and wireless testing.

The book gives an in-depth description of key devices of current and next generation fibre optic communication networks. Devices treated include semiconductor lasers, optical amplifiers, modulators, wavelength filters and other passives, detectors, all-optical switches, but relevant properties of optical fibres and network aspects are included as well. The presentations include the physical principles underlying the various devices, technologies used for their realization, typical performance characteristics and limitations, but development trends towards more advanced components are also illustrated. This new edition of a successful book was expanded and updated extensively. The new edition covers among others lasers for optical communication, optical switches, hybrid integration, monolithic integration and silicon photonics. The main focus is on Indium phosphide-based structures but silicon photonics is included as well. The book covers relevant principles, state-of-the-art implementations, status of current research as well as expected future components.
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 design alternatives 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 focuses mainly on the distinctive features of programmable photonics, as compared to more traditional ASPIC (Application Specific Photonic Integrated Circuit) 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 calibrate 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.

Programmability enables, 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. This book focuses on RFID (Radio Frequency Identification), IoT (Internet of Things), and WSN (Wireless Sensor Network). It includes contributions that discuss the security and privacy issues as well as the opportunities and applications that are tightly linked to sensitive infrastructures and strategic services. This book addresses the complete functional framework and workflow in IoT-enabled RFID systems and explores basic and high-level concepts. It is based on the latest technologies and covers the major challenges, issues, and advances in the field. It presents data acquisition and case studies related to data-intensive technologies in RFID-based IoT and includes WSN-based systems and their security. It can serve as a manual for those in the industry while also helping beginners to understand both the basic and advanced aspects of IoT-based RFID-related issues. This book can be a premier interdisciplinary platform for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered, and find solutions that have been adopted in the fields of IoT and analytics. 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.

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, data center networking, learning. 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 photonics 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 provide 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. The open access journal Micromachines invites manuscript submissions for the Special Issue “Silicon Photonics Bloom”. The past two decades have witnessed a tremendous growth of silicon photonics. Lab-scale research on simple passive component designs is now being expanded by on-chip hybrid systems architectures. With the recent injection of government and private funding, we are living the 1980s of the electronic industry, when the first merchant foundries were established. Soon, we will see more and more merchant foundries proposing well-established electronic design tools, product development kits, and mature component libraries. The open access journal Micromachines invites the submission of manuscripts in the developing area of silicon photonics. The goal of this Special Issue is to highlight the recent developments in this cutting-edge technology.]
the fully potentiality of silicon photonics. It contains a number of chapters written by engineers and scientists of the main companies, research centers and universities active in the field. It can be of use for all those persons interested to know the potentialities and the recent applications of silicon photonics both in microelectronics, telecommunication and consumer electronics market.

The book is devoted to the design, application and characterization of thin films and structures, with special emphasis on optical applications. It comprises ten papers—five featured and five regular—authored by scientists all over the world. Diverse materials are studied and their possible applications are demonstrated and discussed—transparent conductive coatings and structures from ZnO doped with Al and Ga and Ti-doped SnO2, polymers and nanosized zeolite thin films for optical sensing, TiO2 with linear and nonlinear optical properties, organic diamagnetic materials, broadband optical coatings, CrWN glass molding coatings, and silicon on insulator waveguides.

Addressing the growing demand for larger capacity in information technology, VLSI Micro- and Nanophotonics: Science, Technology, and Applications explores issues of science and technology of micro/nano-scale photonics and integration for broad-scale and chip-scale Very Large Scale Integration photonics. This book is a game-changer in the sense that it is quite possibly the first to focus on “VLSI Photonics”. Very little effort has been made to develop integration technologies for micro/nanoscale photonic devices and applications, so this reference is an important and necessary early-stage perspective on this field. New demand for VLSI photonics brings into play various technological and scientific issues, as well as evolutionary and revolutionary challenges—all of which are discussed in this book. These include topics such as miniaturization, interconnection, and integration of photonic devices at micron, submicron, and nanometer scales. With its “disruptive creativity” and unparalleled coverage of the photonics revolution in information technology, this book should greatly impact the future of micro/nano-photonics and IT as a whole. It offers a comprehensive overview of the science and engineering of micro/nanophotonics and photonic integration. Many books on micro/nanophotonics focus on understanding the properties of individual devices and their related characteristics. However, this book offers a full perspective from the point of view of integration, covering all aspects of benefits and advantages of VLSI-scale photonic integration—the key technical concept in developing a platform to make individual devices and components useful and practical for various applications.

Recently, the rapid development of radiofrequency (RF)/microwave and photonic/optical waveguide technologies has had a significant impact on the current electronic industrial, medical and information and communication technology (ICT) fields. This book is a self-contained collection of valuable scholarly papers related to waveguide design, modeling, and applications. This book contains 20 chapters that cover three main subtopics of waveguide technologies, namely RF and microwave waveguide, photonic and optical waveguide and waveguide analytical solutions. Hence, this book is particularly useful to the academics, scientists, practicing researchers and postgraduate students whose work relates to the latest waveguide technologies.

Silicon photonics, emerging from the interface of silicon technology and photonic technology, is expected to inherit the incredible integration ability of silicon technology that has boomed the microelectronic industry for half a century, as well as the unparalleled communication capability of photonic technology that has revolutionized the information industry for decades. Being a prevailing research topic in the past decade, silicon photonics has seen tremendous progresses with the successful demonstrations and commercializations of almost all of the key components, including on-chip light source, low-loss silicon waveguide, and ultrafast silicon modulators and detectors. It seems silicon photonics is ready to take off by following the successful path the microelectronic industry has been traveling through to achieve a large-scale integration of millions of photonic devices on the silicon chip with the aide of the well-established complementary metal-oxide-semiconductor (CMOS) technology. However, there remain some substantial challenges in silicon photonics, including the reliable design and fabrication of silicon photonic devices with unprecedented accuracy, and the large-scale integration of otherwise discrete silicon photonic devices. To this end, this thesis explored several examples as possible means of addressing these two challenges in silicon photonics. Two different ways of improving silicon photonic device accuracy were presented from perspectives of fabrication and device design respectively, followed by a successful integration demonstration where more than 4,000 components worked together on a silicon chip to form a functional large-scale silicon photonic system, representing the largest silicon photonic integration demonstrated to date.


“Silicon Photonics is a promising new technology for realizing efficient, high performance interconnects. There is a growing need for educating future engineers on how to design, fabricate, package and test silicon photonic circuits. Silicon photonic processing for an educational institution with i-line lithography capabilities is demonstrated and the thesis elaborates on the fabrication process used for realizing passive photonic devices and circuits (i.e. waveguides, interferometeric structures and fiber chip grating couplers). The process is realized in a CMOS compatible environment which has been in use since 1986 to teach microelectronic engineering. And is now also being used to support the AIM Photonics Academy education mission. Specifically, TM-polarized grating coupler with a ring resonator, y-branch, bidirectional coupler and three-way couplers were fabricated with a lithographic resolution of less than 400 nm on an SOI wafer. The setup time and run time required was 3 days in comparison to the long wait time in the industry. Optimization of the resolution using ARC i-CON7, diluted OIR 620 and the etch selectivity of the silicon to the 1:1 OIR 620: PGMEA is key to the student run fabrication process. Alternatives for the hard mask used for etching and other plasma etch tool alternatives were explored and is supported by the Optical microscope and SEM results. The pattern fidelity of the Y splitter was simulated using PROLITH and the design was imported into Lumerical FDTD. The test results of the photonic circuits fabricated were analyzed and compared with the Lumerical FDTD and Lumerical INTERCONNECT simulations."--Abstract.

This hands-on introduction to silicon photonics engineering equips students with everything they need to begin creating foundry-ready designs.
Silicon has become a popular platform for the integration of a large number of devices. The material property of silicon and its high contrast in refractive index with silica makes it a preferable choice for smaller devices. This thesis has a detailed analysis of two significant passive devices, namely - grating couplers and Y-branch. A grating coupler enables an efficient way of coupling light from the free space to the circuit. It is an on-chip coupling solution besides other complicated techniques such as edge coupling or butt coupling. An efficient design of grating coupler with low loss, low back reflection and high 1 dB bandwidth is efficient and easier to implement compared to other techniques as it reduces the complexity of optics. The best grating coupler design presented in this thesis has a measured insertion loss of -4.95 dB and 1 dB bandwidth of 93 nm. Using conventional techniques for designing a silicon photonic passive device at times proves to be cumbersome because converging to an optimized solution might be difficult. Therefore a robust algorithm with a better optimization technique is necessary. A method of designing efficient Y-branch using particle swarm optimization is discussed in detail in this thesis. The fabricated devices are quick to design and their performance is usually better than the conventional devices. The Y-branch designed using this technique has a 50-50 splitting over the entire wavelength range of 1500 nm - 1600 nm. The technique of using a particle swarm algorithm can further be extrapolated to other algorithms like gradient descent or machine learning for designing more complicated devices. Finally, this work also presents the design of an automated stage for testing passive devices. The stage is fully capable of aligning fibers to a passive device and perform its characterization. This system increases the efficiency of measurement by 60 times, thereby reducing the time required to couple the light and align the chip. Rapid interpolation algorithms are used to find the optimized position given an objective function. Silicon photonics has become a key solution to tackle the demands on current communication systems and information processing because the use of this platform can reduce power consumption, eliminate electrical to optical conversion and leverage mature CMOS fabrication techniques. As silicon photonic devices are introduced into system-level applications, new challenges need to be addressed. This thesis will present some solutions to these challenges. These challenges range from device design and functionality to the post-processing and testing of silicon photonic devices. First, the system-level testing of a silicon photonic switch with crosstalk using real Ethernet datastreams is presented. Next, a rapid characterization technique for processing of silicon photonic switches is shown. Finally, the functionality of barrel shifting is demonstrated in silicon photonics. The challenges and the solutions presented in this thesis are key steps to realizing the promise of system-level applications of silicon photonic devices. From design and simulation through to testing and fabrication, this hands-on introduction to silicon photonics engineering equips students with everything they need to begin creating foundry-ready designs. In-depth discussion of real-world issues and fabrication challenges ensures that students are fully equipped for careers in industry. Step-by-step tutorials, straightforward examples, and illustrative source code fragments guide students through every aspect of the design process, providing a practical framework for developing and refining key skills. Offering industry-ready expertise, the text supports existing PDKs for CMOS UV lithography foundry services (OpSiS, ePixFab, imec, LETI, IME and CMC) and the development of new kits for proprietary processes and clean-room based research. Accompanied by additional online resources to support students, this is the perfect learning package for senior undergraduate and graduate students studying silicon photonics design, and academic and industrial researchers involved in the development and manufacture of new silicon photonics systems. Silicon Photonics Design Cambridge University Press Introduction to Fiber-Optic Communications provides students with the most up-to-date, comprehensive coverage of modern optical fiber communications and applications, striking a fine balance between theory and practice that avoids excessive mathematics and derivations. Unlike other textbooks currently available, this book covers all of the important recent technologies and developments in the field, including electro-optic modulators, coherent optical systems, and silicon integrated photonic circuits. Filled with practical, relevant worked examples and exercise problems, the book presents complete coverage of the topics that optical and communications engineering students need to be successful. From principles of optical and optoelectronic components, to optical transmission system design, and from conventional optical fiber links, to more useful optical communication systems with advanced modulation formats and high-speed DSP, this book covers the necessities on the topic, even including today’s important application areas of passive optical networks, datacenters and optical interconnections. Covers fiber-optic communication system fundamentals, design rules and terminologies Provides students with an understanding of the physical principles and characteristics of passive and active fiber-optic components Teaches students how to perform fiber-optic system design, performance evaluation and troubleshooting Includes modern advances in modulation and decoding strategies 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 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. Machine learning is a potential solution to resolve bottleneck issues in VLSI via optimizing tasks in the design process. This book aims to provide the latest machine-learning–based methods, algorithms, architectures, and frameworks designed for VLSI design. The focus is on digital, analog, and mixed-signal design techniques, device modeling, physical design, hardware implementation, testability, reconfigurable design, synthesis and verification, and related areas. Chapters include case studies as well as novel research ideas in the given field. Overall, the book provides practical implementations of VLSI design, IC design, and hardware realization using machine learning techniques. Features: Provides the details of state-of-the-art machine learning methods used in VLSI design Discusses hardware implementation and device modeling pertaining to machine learning algorithms Explores machine learning for various VLSI architectures and reconfigurable
computing. Illustrates the latest techniques for device size and feature optimization. Highlights the latest case studies and reviews of the methods used for hardware implementation. This book is aimed at researchers, professionals, and graduate students in VLSI, machine learning, electrical and electronic engineering, computer engineering, and hardware systems.

Given silicon's versatile material properties, use of low-cost silicon photonics continues to move beyond light-speed data transmission through fiber-optic cables and computer chips. Its application has also evolved from the device to the integrated-system level. A timely overview of this impressive growth, Silicon Photonics for Telecommunications and Biomedicine summarizes state-of-the-art developments in a wide range of areas, including optical communications, wireless technologies, and biomedical applications of silicon photonics. With contributions from world experts, this reference guides readers through fundamental principles and focuses on crucial advances in making commercial use of silicon photonics a viable reality in the telecom and biomedical industries. Taking into account existing and anticipated industrial directions, the book balances coverage of theory and practical experimental research to explore solutions for obstacles to the viable commercialization of silicon photonics. The book's special features include: A section on silicon plasmonic waveguides. Detailed coverage of novel III-V applications. A chapter on 3D integration. Discussion of applications for energy harvesting/photovoltaics. This book reviews the most important technological trends and challenges. It presents topics involving major silicon photonics applications in telecommunications, high-power photonics, and biomedicine. It includes discussion of silicon plasmonic waveguides, piezoelectric tuning of silicon's optical properties, and applications of two-photon absorption. Expert authors with industry research experience examine the challenge of hybridizing III-V compound semiconductors on silicon to achieve monolithic light sources. They also address economic compatibility and heat dissipation issues in CMOS chips, challenges in designing electronic photonics integrated circuits, and the need for standardization in computer-aided design of industrial chips. This book gives an authoritative summary of the latest research in this emerging field, covering key topics for readers from various disciplines with an interest in integrated photonics.

Optical Fiber Telecommunications, Volume Eleven, covers the latest in optical fiber communications and their potential to penetrate and complement other forms of communication, such as wireless access, on-premises networks, interconnects and satellites. This updated edition of this classic, first published in 1979, examines opportunities for future optical fiber technology by presenting the latest advances on key topics, such as 5G wireless access, inter and intra data center communications, THz technologies, secure communications, and free space digital optical links. Topics of note include sections on foundries for widespread user access, designing photonics integrated circuits (PICs), monolithic and hybrid integration technologies, nanophotonics, and advanced and non-conventional data modulation formats. The traditional emphasis of achieving higher data rates and longer transmission distances are also addressed through chapters on space-division-multiplexing using multimode and multicore fibers, undersea cable systems, and reconfigurable networking. This book is an indispensable reference on the latest advances in key technologies for future fiber optic communications. It is suitable for university and industry researchers, graduate students, optical systems implementers, network operators, managers and investors. Updated edition presents the latest advances in optical fiber components, systems, subsystems and networks. Written by leading authorities from academia and industry. Gives self-contained overview of specific technologies, covering both the state-of-the-art and future research challenges.

All integrated optical components and devices make use of "waveguides", where light is confined by total internal reflection. The elements in such "photonic chip" are interconnected through waveguides, and also the integrated optics components themselves are fabricated using waveguide configuration, such as couplers, switches, modulators, multiplexors, amplifiers and lasers, etc. These components are integrated in a single substrate, thus resulting in a compact and robust photon device, which can be optically connected through optical fibres. With and increase in the number of integrated optical components and devices emerging from the research laboratories to the market place an up-to-date book is essential in collecting, summarizing and presenting the new developed photonic devices. This includes fundamental aspects, technical aspects (such as fabrication techniques and materials) and characterization and performance. This is an advanced text aimed at specialists in the field of photonics, but who may be new to the field of integrated photonics. The fundamental aspects have been carefully considered, and all the topics covered by the book start at a medium level, making it highly relevant for undergraduate and post-graduate students following this discipline.

Silicon photonics uses chip-making techniques to fabricate photonic circuits. The emerging technology is coming to market at a time of momentous change. The need of the Internet content providers to keep scaling their data centers is becoming increasing challenging, the chip industry is facing a future without Moore's law, while telcos must contend with a looming capacity crunch due to continual traffic growth. Each of these developments is significant in its own right. Collectively, they require new thinking in the design of chips, optical components, and systems. Such change also signals new business opportunities and disruption. Notwithstanding challenges, silicon photonics' emergence is timely because it is the future of several industries. For the optical industry, the technology will allow designs to be tackled in new ways. For the chip industry, silicon photonics will become the way of scaling post-Moore's law. New system architectures enabled by silicon photonics will improve large-scale computing and optical communications. Silicon Photonics: Fueling the Next Information Revolution outlines the history and status of silicon photonics. The book discusses the trends driving the datacom and telecom industries, the main but not the only markets for silicon photonics. In particular, developments in optical transport and the data center are discussed as are the challenges. The book details the many roles silicon photonics will play, from wide area networks down to the chip level. Silicon photonics is set to change the optical components and chip industries; this book explains how. Captures the latest research assessing silicon photonics development and prospects. Demonstrates how silicon photonics addresses the challenges of managing bandwidth over distance and within systems. Explores potential applications of SIP, including servers, datacenters, and Internet of Things. Many wireless systems could benefit from the ability to transmit and receive on the same frequency at the same time, which is known as In-Band Full-Duplex (IBFD). This technology could lead to enhanced spectral efficiency for future wireless networks, such as fifth-generation New Radio (5G NR) and beyond, and could enable capabilities and applications that were previously considered impossible, such as IBFD with phased array systems. In this exciting new book, experts from industry, academic, and federal research institutions discuss the various approaches that can be taken to suppress the inherent self-interference that is generated in IBFD systems. Both static and adaptive techniques that span across the propagation, analog and digital domains are presented. Details and measured results that encompass high-isolation antenna designs, RF, and photonic cancellation as well as signal processing approaches, which include beamforming and linear/non-linear equalization are detailed. Throughout this book, state-of-the-art IBFD systems that utilize these technologies will be provided as practical examples for various applications. Expert IBFD perspectives from multiple research organizations and companies, which would provide readers with the most accurate state-of-the-art approaches. This is the first book that dives into both the techniques that make IBFD systems possible as well as several different applications that use IBFD technology. Vollständig überarbeitete Neuausgabe des maßgeblichen Grundlagen-Lehrbuchs zur Optik und Photonik - umfassend überarbeitet.

Photonic systems are being developed with extensions to existing CMOS processes, and are growing in complexity. Silicon photonics designs are evaluated in simulation using similar methods to those used for CMOS transistor and circuit designs; simulation models for common silicon-based photonics structures and devices currently exist and are used to design larger photonic systems. However, these photonics models are often not constructed with manufacturing variations in mind. This thesis presents methods for creating simulation models for nanophotonic devices that take systematic and random variations from manufacturing into account. Factorial experiment design is used to explore the effect of process variations on photonic device performance. Corner models are constructed using the results from experiment design and capture worst-case variations. The response surface modeling method is employed to develop parameterized compact models. Example variation-aware compact models are generated using these methods for the directional coupler and the Y-branch, two passive devices widely used in silicon photonics. The use of these models is demonstrated through corner and statistical variation analyses of a simple Mach-Zehnder interferometer photonic circuit composed of the directional coupler and Y-branch devices.

Fundamentals of Photonics A complete, thoroughly updated, full-color third edition Fundamentals of Photonics, Third Edition is a self-contained and up-to-date introductory-level textbook that thoroughly surveys this rapidly expanding area of engineering and applied physics. Featuring a blend of theory and applications, coverage includes detailed accounts of the primary theories of light, including ray optics, wave optics, electromagnetic optics, and photon optics, as well as the interaction of light and matter. Presented at increasing levels of complexity, preliminary sections build toward more advanced topics, such as Fourier optics and holography, photonic-crystal optics, guided-wave and fiber optics, LEDs and lasers, acousto-optic and electro-optic devices, nonlinear optical devices, ultrafast optics, optical interconnects and switches, and optical fiber communications. The third edition features an entirely new chapter on the optics of metals and plasmonic devices. Each chapter contains highlighted equations, exercises, problems, summaries, and selected reading lists. Examples of real systems are included to emphasize the concepts governing applications of current interest. Each of the twenty-four chapters of the second edition has been thoroughly updated.

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