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Integrated Nanophotonic Devices

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The rapid advancement of integrated optoelectronics has been driven considerably by miniaturization. Following the path taken in electronics of reducing devices to their ultimately fundamental forms, for instance single-electron transistors, now optical devices have also been scaled down, creating the increasingly active research fields of integrated and coupled photonic systems. The interactions between the coupled integrated micro- and nanostructures can provide us with the fundamental understanding and engineering of complex systems for a variety of applications. This book aims to bring to the readers the latest developments in the rapidly emerging field of integrated nanophotonic resonators and devices. It compiles cutting-edge research from leading experts who form an interdisciplinary team around the world. The book also introduces the fundamental knowledge of coupled integrated photonic/electronic/mechanical micro- and nanoresonators and their interactions, as well as advanced research in the field.

From the Introduction: Nanotechnology and its underpinning sciences are progressing with unprecedented rapidity. With technical advances in a variety of nanoscale fabrication and manipulation technologies, the whole topical area is maturing into a vibrant field that is generating new scientific research and a burgeoning range of commercial applications, with an annual market already at the trillion dollar threshold. The means of fabricating and controlling matter on the nanoscale afford striking and unprecedented opportunities to exploit a variety of exotic phenomena such as quantum, nanophotonic and nanoelectromechanical effects. Moreover, researchers are elucidating new perspectives on the electronic and optical properties of matter because of the way that nanoscale materials bridge the disparate theories describing
molecules and bulk matter. Surface phenomena also gain a greatly increased significance; even the well-known link between chemical reactivity and surface-to-volume ratio becomes a major determinant of physical properties, when it operates over nanoscale dimensions. Against this background, this comprehensive work is designed to address the need for a dynamic, authoritative and readily accessible source of information, capturing the full breadth of the subject. Its six volumes, covering a broad spectrum of disciplines including material sciences, chemistry, physics and life sciences, have been written and edited by an outstanding team of international experts. Addressing an extensive, cross-disciplinary audience, each chapter aims to cover key developments in a scholarly, readable and critical style, providing an indispensable first point of entry to the literature for scientists and technologists from interdisciplinary fields. The work focuses on the major classes of nanomaterials in terms of their synthesis, structure and applications, reviewing nanomaterials and their respective technologies in well-structured and comprehensive articles with extensive cross-references. It has been a constant surprise and delight to have found, amongst the rapidly escalating number who work in nanoscience and technology, so many highly esteemed authors willing to contribute. Sharing our anticipation of a major addition to the literature, they have also captured the excitement of the field itself in each carefully crafted chapter. Along with our painstaking and meticulous volume editors, full credit for the success of this enterprise must go to these individuals, together with our thanks for (largely) adhering to the given deadlines. Lastly, we record our sincere thanks and appreciation for the skills and professionalism of the numerous Elsevier staff who have been involved in this project, notably Fiona Geraghty, Megan Palmer and Greg Harris, and especially Donna De Weerd-Wilson who has steered it through from its inception. We have greatly enjoyed working with them all, as we have with each other.

Photonics is a key technology of this century. The combination of
photonics and silicon technology is of great importance because of the potentiality of coupling electronics and optical functions on a single chip. Many experimental and theoretical studies have been performed to understand and design the photonic properties of silicon nanocrystals. Generation of light in silicon is a challenging perspective in the field; however, the issue of light-emitting devices does not limit the activity in the field. Research is also focused on light modulators, optical waveguides and interconnectors, optical amplifiers, detectors, memory elements, photonic crystals, etc. A particularly important task of silicon nanostructures is to generate electrical energy from solar light. Understanding the optical properties of silicon-based materials is central in designing photonic components. It is not possible to control the optical properties of nanoparticles without fundamental information on their microscopic structure, which explains a large number of theoretical works on this subject. Many fundamental and practical problems should be solved in order to develop this technology. In addition to open fundamental questions, it is even more difficult to develop the known experimental results towards practical realization. However, the world market for silicon photonics is expected to be huge; thus, more research activity in the field of silicon nanophotonics is expected in the future. This book describes different aspects of silicon nanophotonics, from fundamental issues to practical devices. The second edition is essentially different from the book published in 2008. Eight chapters of the first edition are not included in the new book, because the recent progress on those topics has not been large enough. Instead, seven new chapters appear. The other eight chapters are essentially modified to describe recent achievements in the field.

Optoelectronic devices are now ubiquitous in our daily lives, from light emitting diodes (LEDs) in many household appliances to solar cells for energy. This handbook shows how we can probe the underlying and highly complex physical processes using modern
mathematical models and numerical simulation for optoelectronic device design, analysis, and performance optimization. It reflects the wide availability of powerful computers and advanced commercial software, which have opened the door for non-specialists to perform sophisticated modeling and simulation tasks. The chapters comprise the know-how of more than a hundred experts from all over the world. The handbook is an ideal starting point for beginners but also gives experienced researchers the opportunity to renew and broaden their knowledge in this expanding field.

The MEMS (Micro Electro-Mechanical Systems) market returned to growth in 2010. The total MEMS market is worth about $6.5 billion, up more than 11 percent from last year and nearly as high as its historic peak in 2007. MEMS devices are used across sectors as diverse as automotive, aerospace, medical, industrial process control, instrumentation and telecommunications - forming the nerve center of products including airbag crash sensors, pressure sensors, biosensors and ink jet printer heads. Part of the MEMS cluster within the Micro & Nano Technologies Series, this book covers the fabrication techniques and applications of thick film piezoelectric micro electromechanical systems (MEMS). It includes examples of applications where the piezoelectric thick films have been used, illustrating how the fabrication process relates to the properties and performance of the resulting device. Other topics include: top-down and bottom-up fabrication of thick film MEMS, integration of thick films with other materials, effect of microstructure on properties, device performance, etc. Provides detailed guidance on the fabrication techniques and applications of thick film MEMS, for engineers and R&D groups. Written by a single author, this book provides a clear, coherently-written guide to this important emerging technology. Covers materials, fabrication and applications in one book.

The most up-to-date book available on the physics of
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photonicdevices This new edition of Physics of Photonic Devices incorporates significant advancements in the field of photonics that have occurred since publication of the first edition (Physics of Optoelectronic Devices). New topics covered include a brief history of the invention of semiconductor lasers, the Lorentz dipole method and metal plasmas, matrix optics, surface plasma waveguides, optical ring resonators, integrated electroabsorption modulator-lasers, and solar cells. It also introduces exciting new fields of research such as: surface plasmonics and micro-ring resonators; the theory of optical gain and absorption in quantum dots and quantum wires and their applications in semiconductor lasers; and novel microcavity and photonic crystal lasers, quantum-cascade lasers, and GaN blue-green lasers within the context of advanced semiconductor lasers. Physics of Photonic Devices, Second Edition presents novel information that is not yet available in book form elsewhere. Many problem sets have been updated, the answers to which are available in an all-new Solutions Manual for instructors. Comprehensive, timely, and practical, Physics of Photonic Devices is an invaluable textbook for advanced undergraduate and graduate courses in photonics and an indispensable tool for researchers working in this rapidly growing field.

Low-dimensional structures have attracted extensive research interest due to their promising applications in nanotechnology. These low-dimensional materials have the potential to make revolutionary changes in science and technology because a reduction in size not only enables a faster speed and greater computing power but also helps reduce device form factors. As such, this book examines the behaviors of oxide nanowires, group III–V compounds, and other nanowires, including basic Si nanowires, metallic wires, and complex geometrical nanowires.

Eco-efficient Materials for Reducing Cooling Needs in Buildings
and Construction: Design, Properties and Applications provides a comprehensive review on building envelope materials and technologies for reducing cooling needs in buildings. The book offers in-depth analysis of the performance of new innovative materials and technologies used in pavements, facade and roofing materials, PCMs and chromogenic smart materials. Includes practical case study examples of their applications in building and construction. The book is an essential reference resource for researchers, architects and civil engineers, city planners, product developers, manufacturers, and other professionals working in eco-efficient cooling materials and sustainable and zero-energy building design. Offers a comprehensive review of building envelope materials and technologies for reducing cooling needs Features practical case studies, which are fundamental for building design and applications Provides in-depth analysis of performance for different materials and technologies Features brand new chapters on pavements, facade and roofing materials, PCMs and chromogenic smart materials

Electronic-photonic integrated circuits (EPICs) are a promising technology for overcoming bandwidth and power-consumption bottlenecks of traditional integrated circuits. Silicon is a good candidate for building such devices, due to its high-index contrast and low propagation loss at telecom wavelengths. The current thesis presents recent advances in demonstrating discrete components built in silicon-on-insulator (SOI) platforms, around 1550 nm, that can be used as building blocks for future EPIC systems. The first part of this thesis investigates electro-optic modulators based on one-dimensional photonic crystal microcavities, with femtojoule switching energies, as well as on-chip optical interconnects using the super-collimation effect in two-dimensional photonic crystals, both in hole- and rod-based configurations. The second part focuses on microring-based structures, demonstrating wide thermal tunability and hitless operation of single-ring filters, as well as three more
advanced categories of devices suitable for wavelength-division multiplexing (WDM) applications. These are twenty-channel second-order tunable filterbanks (both in dual- and counter-propagating configurations), reconfigurable optical add-drop multiplexers (ROADMs) with telecom-grade specifications, and a dynamical slow light cell for delay lines and optical memory elements. All the devices demonstrated in this thesis can be integrated on the same chip. The small device footprints and the use of the SOI platform are ideal for integration with a standard CMOS process, enabling the fabrication of novel electronic-photonic integrated circuits. These new EPIC systems may one day play an important role in the scaling of current computing systems and taking advantage of the WDM capability to increase operational bandwidth, while keeping the power consumption at low levels.

This book gathers the lecture notes of courses given at Session CVII of the summer school in physics, entitled "Current Trends in Atomic Physics" and held in July, 2016 in Les Houches, France. Atomic physics provides a paradigm for exploring few-body quantum systems with unparalleled control. In recent years, this ability has been applied in diverse areas including condensed matter physics, high energy physics, chemistry and ultra-fast phenomena as well as foundational aspects of quantum physics. This book addresses these topics by presenting developments and current trends via a series of tutorials and lectures presented by international leading investigators.

Fundamentals and Applications of Nanophotonics includes a comprehensive discussion of the field of nanophotonics, including key enabling technologies that have the potential to drive economic growth and impact numerous application domains such as ICT, the environment, healthcare, military, transport, manufacturing, and energy. This book gives readers the theoretical underpinnings needed to understand the latest advances in the field. After an introduction to the area, chapters two and three cover the essential
topics of electrodynamics, quantum mechanics, and computation as they relate to nanophotonics. Subsequent chapters explore materials for nanophotonics, including nanoparticles, photonic crystals, nanosilicon, nanocarbon, III-V, and II-VI semiconductors. In addition, fabrication and characterization techniques are addressed, along with the importance of plasmonics, and the applications of nanophotonics in devices such as lasers, LEDs, and photodetectors. Covers electrodynamics, quantum mechanics and computation as these relate to nanophotonics Reviews materials, fabrication and characterization techniques for nanophotonics Describes applications of the technology such as lasers, LEDs and photodetectors

This much-needed text brings the treatment of optical pattern recognition up-to-date in one comprehensive resource. Optical pattern recognition, one of the first implementations of Fourier Optics, is now widely used, and this text provides an accessible introduction for readers who wish to get to grips with how holography is applied in a practical context. A wide range of devices are addressed from a user perspective and are accompanied with detailed tables enabling performance comparison, in addition to chapters exploring computer-generated holograms, optical correlator systems, and pattern matching algorithms. This book will appeal to both lecturers and research scientists in the field of electro-optic devices and systems. Features: Covers a range of new developments, including computer-generated holography and 3D image recognition Accessible without a range of prior knowledge, providing a clear exposition of technically difficult concepts Contains extensive examples throughout to reinforce learning

Nanophotonics has emerged as a major technology and applications domain, exploiting the interaction of light-emitting and light-sensing nanostructured materials. These devices are lightweight, highly efficient, low on power consumption, and are cost effective to
produce. The authors of this book have been involved in pioneering work in manufacturing photonic devices from carbon nanotube (CNT) nanowires and provide a series of practical guidelines for their design and manufacture, using processes such as nano-robotic manipulation and assembly methods. They also introduce the design and operational principles of opto-electrical sensing devices at the nano scale. Thermal annealing and packaging processes are also covered, as key elements in a scalable manufacturing process. Examples of applications of different nanowire based photonic devices are presented. These include applications in the fields of electronics (e.g. FET, CNT Schotty diode) and solar energy. Discusses opto-electronic nanomaterials, characterization and properties from an engineering perspective, enabling the commercialization of key emerging technologies. Provides scalable techniques for nanowire structure growth, manipulation and assembly (i.e. synthesis). Explores key application areas such as sensing, electronics and solar energy.

The second edition of Nanotechnology in Biology and Medicine is intended to serve as an authoritative reference source for a broad audience involved in the research, teaching, learning, and practice of nanotechnology in life sciences. This technology, which is on the scale of molecules, has enabled the development of devices smaller and more efficient than anything currently available. To understand complex biological nanosystems at the cellular level, we urgently need to develop a next-generation nanotechnology tool kit. It is believed that the new advances in genetic engineering, genomics, proteomics, medicine, and biotechnology will depend on our mastering of nanotechnology in the coming decades. The integration of nanotechnology, material sciences, molecular biology, and medicine opens the possibility of detecting and manipulating atoms and molecules using nanodevices, which have the potential for a wide variety of biological research topics and medical uses at the cellular level. This book presents the most recent scientific and
technological advances of nanotechnology for use in biology and medicine. Each chapter provides introductory material with an overview of the topic of interest; a description of methods, protocols, instrumentation, and applications; and a collection of published data with an extensive list of references for further details. The goal of this book is to provide a comprehensive overview of the most recent advances in instrumentation, methods, and applications in areas of nanobiotechnology, integrating interdisciplinary research and development of interest to scientists, engineers, manufacturers, teachers, and students.

Handbook of Nanomaterials for Industrial Applications explores the use of novel nanomaterials in the industrial arena. The book covers nanomaterials and the techniques that can play vital roles in many industrial procedures, such as increasing sensitivity, magnifying precision and improving production limits. In addition, the book stresses that these approaches tend to provide green, sustainable solutions for industrial developments. Finally, the legal, economical and toxicity aspects of nanomaterials are covered in detail, making this is a comprehensive, important resource for anyone wanting to learn more about how nanomaterials are changing the way we create products in modern industry. Demonstrates how cutting-edge developments in nanomaterials translate into real-world innovations in a range of industry sectors Explores how using nanomaterials can help engineers to create innovative consumer products Discusses the legal, economical and toxicity issues arising from the industrial applications of nanomaterials

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.

Since it was first published in 1995, Photonic Crystals has remained the definitive text for both undergraduates and researchers on photonic band-gap materials and their use in controlling the propagation of light. This newly expanded and revised edition covers the latest developments in the field, providing the most up-to-date, concise, and comprehensive book available on these novel materials and their applications. Starting from Maxwell's equations and Fourier analysis, the authors develop the theoretical tools of photonics using principles of linear algebra and symmetry, emphasizing analogies with traditional solid-state physics and quantum theory. They then investigate the unique phenomena that take place within photonic crystals at defect sites and surfaces, from one to three dimensions. This new edition includes entirely new chapters describing important hybrid structures that use band gaps or periodicity only in some directions: periodic waveguides, photonic-crystal slabs, and photonic-crystal fibers. The authors demonstrate how the capabilities of photonic crystals to localize light can be put to work in devices such as filters and splitters. A new appendix
provides an overview of computational methods for electromagnetism. Existing chapters have been considerably updated and expanded to include many new three-dimensional photonic crystals, an extensive tutorial on device design using temporal coupled-mode theory, discussions of diffraction and refraction at crystal interfaces, and more. Richly illustrated and accessibly written, Photonic Crystals is an indispensable resource for students and researchers. Extensively revised and expanded Features improved graphics throughout Includes new chapters on photonic-crystal fibers and combined index-and band-gap-guiding Provides an introduction to coupled-mode theory as a powerful tool for device design Covers many new topics, including omnidirectional reflection, anomalous refraction and diffraction, computational photonics, and much more.

Development of the computing platform of the future depends largely on high bandwidth interconnects at intra-die level. Silicon photonics, as an innately CMOS compatible technology, is a promising candidate for delivering terabit per second bandwidths through the use of wavelength division multiplex (WDM) signaling. Silicon photonic interconnects offer unmatched bandwidth, density, energy efficiency, latency and reach, compared with the electrical interconnects. WDM silicon photonic links are viewed today as a promising solution for resolving the inter/intra-chip communication bottlenecks for high performance computing systems. Towards its maturity, silicon photonic technology has to resolve the issues of waveguide propagation loss, density of device integration, thermal stability of resonant devices, heterogeneous integration of various materials and many other problems. This dissertation describes the development of integrated photonic technology on silicon and silicon nitride platforms in the increased order of device complexity, from the fabrication process of low loss waveguides and efficient off-chip coupling devices, to the die-size reconfigurable lattice filters for optical signal processing. Particular emphasis of the dissertation is
on the demonstration of CMOS-compatible, athermal silicon ring modulators that potentially hold the key to solving the thermal problem of silicon photonic devices. The development of high quality amorphous titanium dioxide films with negative thermo-optic coefficient enabled the fabrication of gigahertz-bandwidth silicon ring modulators that can be made insensitive to ambient temperature changes.

This book focuses on chemical and nanophotonic technology to be used to develop novel nano-optical devices and systems. It begins with temperature- and photo-induced phase transition of ferromagnetic materials. Further topics include: energy transfer in artificial photosynthesis, homoepitaxial multiple quantum wells in ZnO, near-field photochemical etching and nanophotonic devices based on a nonadiabatic process and optical near-field energy transfer, respectively and polarization control in the optical near-field for optical information security. Taken as a whole, this overview will be a valuable resource for engineers and scientists working in the field of nano-electro-optics.

2D Materials for Nanophotonics presents a detailed overview of the applications of 2D materials for nanophotonics, covering the photonic properties of a range of 2D materials including graphene, 2D phosphorene and MXenes, and discussing applications in lighting and energy storage. This comprehensive reference is ideal for readers seeking a detailed and critical analysis of how 2D materials are being used for a range of photonic and optical applications. Outlines the major photonic properties in a variety of 2D materials Demonstrates major applications in lighting and energy storage Explores the challenges of using 2D materials in photonics

The second edition of Nanotechnology for Microelectronics and Photonics has been thoroughly revised, expanded, and updated. The aim of the book is to present the most recent advances in the field of
nanomaterials, as well as the devices being developed for novel nanoelectronics and nanophotonic systems. It covers the many novel nanoscale applications in microelectronics and photonics that have been developed in recent years. Looking to the future, the book suggests what other applications are currently in development and may become feasible within the next few decades based on novel materials such as graphene, nanotubes, and organic semiconductors. In addition, the inclusion of new chapters and new sections to keep up with the latest developments in this rapidly-evolving field makes Nanotechnology for Microelectronics and Photonics, Second Edition an invaluable reference to research and industrial scientists looking for a guide on how nanostructured materials and nanoscale devices are used in microelectronics, optoelectronics, and photonics today and in future developments. Presents the fundamental scientific principles that explain the novel properties and applications of nanostructured materials in the quantum frontier. Offers clear and concise coverage of how nanotechnology is currently used in the areas of microelectronics, optoelectronics, and photonics, as well as future proposed devices. Includes nearly a hundred problems along with helpful hints and full solutions for more than half of them.

Presents recent developments in theoretical and experimental research of nanophotonics Discusses properties and features of nanophotonic devices, e.g. scanning near-field optical microscopy, nanofiber/nanowire based photonic devices Illustrates the most promising nanophotonic devices and instruments and their application Suits well for researchers and graduates in nanophotonics field Contents Scanning near-field optical microscopy Nanofibers/nanowires and their applications in photonic components and devices Micro/nano-optoelectronic devices based on photonic crystal

"This book shows how partnerships can be cultivated through projects, programming, funding, and extending the library's presence
through unique avenues, offering librarians a better understanding of what might be possible for their situational requirements and limitations"--Provided by publisher.

Handbook of Optoelectronics offers a self-contained reference from the basic science and light sources to devices and modern applications across the entire spectrum of disciplines utilizing optoelectronic technologies. This second edition gives a complete update of the original work with a focus on systems and applications. Volume I covers the details of optoelectronic devices and techniques including semiconductor lasers, optical detectors and receivers, optical fiber devices, modulators, amplifiers, integrated optics, LEDs, and engineered optical materials with brand new chapters on silicon photonics, nanophotonics, and graphene optoelectronics. Volume II addresses the underlying system technologies enabling state-of-the-art communications, imaging, displays, sensing, data processing, energy conversion, and actuation. Volume III is brand new to this edition, focusing on applications in infrastructure, transport, security, surveillance, environmental monitoring, military, industrial, oil and gas, energy generation and distribution, medicine, and free space. No other resource in the field comes close to its breadth and depth, with contributions from leading industrial and academic institutions around the world. Whether used as a reference, research tool, or broad-based introduction to the field, the Handbook offers everything you need to get started. John P. Dakin, PhD, is professor (emeritus) at the Optoelectronics Research Centre, University of Southampton, UK. Robert G. W. Brown, PhD, is chief executive officer of the American Institute of Physics and an adjunct full professor in the Beckman Laser Institute and Medical Clinic at the University of California, Irvine.

Silicon, which is the second element of group IV of the periodic table, forms the backbone of the semiconductor industry, similar to how carbon is the pillar of the living world. Silicon processing has
gradually become a mature technology in electronics industry. Therefore, the most economically viable way of achieving optoelectronic integration is to adopt the complementary metal oxide semiconductor (CMOS) infrastructure and use silicon technology for optical devices applications. Silicon photonics furnishes a great opportunity for reducing energy consumption in communication, at the same time resolving interconnect bandwidth density, which is becoming the performance bottleneck in integrated electronics. A variety of fascinating physical phenomena and practical devices can be implemented by manipulating light in the nanoscale, where the decrease in waveguide dimension to subwavelength scale and precise refractive index engineering enable new phenomena to emerge. However, the very first challenge of nanophotonic devices is coupling light in and out of a nanophotonic chip. Mode matched coupling devices are required to reduce the transmission losses between the optical fiber and the nanophotonic waveguides. We present a robust design for low loss, wide band grating coupler. The optimized fully etched two dimensional grating coupler can effectively couple the fundamental mode from a single mode silica optical fiber to a single mode silicon waveguide with 500-fold mode size difference. The device is fabricated through a single step E-beam lithography process on a silicon-on-insulator wafer. We characterize the mode converter device through the V-groove fiber array surface grating coupler measurement setup. The developed measurement setup and grating couplers serve as a platform to characterize optical and electro-optical integrated devices in our lab. As a solution to different challenges, photonic crystals and grating structures comprise an important part of this thesis. Photonic crystal nanocavities can strongly confine photons in a small cavity on the wavelength scale. Exciting pure symmetrical modes in nanocavities is challenging. The second part of my thesis is dedicated to designing a high extinction ratio symmetrical-mode filter based on photonic crystal nanobeam cavities. Through carefully designing the cavity mode and the distributed bragg reflectors we have achieved high
extinction ratio for the desired mode against the background transmission in the stop band region. The excitation of symmetrical modes with an even or odd symmetry is based on the design principles for a mode symmetry transforming Mach-Zender coupler. The designed device is fabricated and tested with the surface coupling setup. Beam expanders or mode converters are widely employed in matching the modes of waveguides of different widths. Here we are interested in a beam expander that can effectively couple the fundamental mode from a narrow waveguide to that of a wide waveguide in a short distance. We find that as the taper length is shorter than the final waveguide width, the insertion loss increases almost exponentially. Designing a compact beam expander with low insertion loss is challenging. In the last part of this thesis, our goal is to design an ultra-compact on-chip mode size converter. This can be achieved through incorporating a composite adiabatic and non-adiabatic structure. We have utilized an evolutionary algorithm to design a beam expander. The fabricated device is characterized with our developed surface coupling setup.

The ability to mix minute quantities of fluids is critical in a range of recent and emerging techniques in engineering, chemistry and life sciences, with applications as diverse as inkjet printing, pharmaceutical manufacturing, specialty and hazardous chemical manufacturing, DNA analysis and disease diagnosis. The multidisciplinary nature of this field – intersecting engineering, physics, chemistry, biology, microtechnology and biotechnology – means that the community of engineers and scientists now engaged in developing microfluidic devices has entered the field from a variety of different backgrounds. Micromixers is uniquely comprehensive, in that it deals not only with the problems that are directly related to fluidics as a discipline (aspects such as mass transport, molecular diffusion, electrokinetic phenomena, flow instabilities, etc.) but also with the practical issues of fabricating micomixers and building them into microsystems and lab-on-chip
assemblies. With practical applications to the design of systems vital in modern communications, medicine and industry, this book has already established itself as a key reference in an emerging and important field. The 2e includes coverage of a broader range of fabrication techniques, additional examples of fully realized devices for each type of micromixer and a substantially extended section on industrial applications, including recent and emerging applications. Introduces the design and applications of micromixers for a broad audience across chemical engineering, electronics and the life sciences, and applications as diverse as lab-on-a-chip, ink jet printing, pharmaceutical manufacturing and DNA analysis. Helps engineers and scientists to unlock the potential of micromixers by explaining both the scientific (microfluidics) aspects and the engineering involved in building and using successful microscale systems and devices with micromixers. The author's applied approach combines experience-based discussion of the challenges and pitfalls of using micromixers, with proposals for how to overcome them.

This comprehensive text collects the progress made in recent years in the fabrication, processing, and performance of organic nanophotonic materials and devices. The first part of the book addresses photonic nanofabrications in a chapter on multiphoton processes in nanofabrication and microscopy imaging. The second part of the book is focused on nanoscale light sources for integrated nanophotonic circuits, and is composed of three chapters on organic nano/microcavities, organic laser materials, and polymer light-emitting electrochemical cells (LECs). The third part is focused on the interactions between light and matter and consists in three chapters, including the propagation of light in organic nanostructures and photoswitches based on nonlinear optical polymer photonic crystals and photoresponsive molecules, respectively. The final chapter of this book introduces the integration of miniaturized photonic devices and circuits with various organic nanophotonic
elements. The practical case studies demonstrate how the latest applications actually work, while tables throughout the book summarize key information and diagrams and figures help readers to grasp complex concepts and designs. The references at the end of each chapter can be used as the gateway to the relevant literature in the field. Moreover, this book helps researchers to advance their own investigations to develop the next generation of miniaturized devices for information processing, efficient energy conversion, and highly accurate sensing. Yong Sheng Zhao, PhD, is a Professor at the Institute of Chemistry, Chinese Academy of Sciences (ICCAS), China.

This book deals with the typical equipment, materials, processes, monitoring, and control used in the practical fabrication/production of optical thin films. It focuses on the practical elements needed to actually produce optical coatings.

This book explores the role of surface effects in optical phenomena in nanoscience, from two different perspectives. When systems are reduced in volume, the ratio of surface versus volume increases. At the level of single nanostructures this translates into an enhanced role of interfacial chemistry and thermodynamics. At the level of systems of nanostructures, it translates into larger density on interfaces, which in turn leads to such intriguing collective effects as plasmonics or multiple reflection and refraction phenomena. The book highlights both perspectives presenting sample applications. Without claiming to be exhaustive, the book aims to stimulate readers in this potentially rewarding field.

Fully revised and in its second edition, this standard reference on nano-optics is ideal for graduate students and researchers alike.

Two-dimensional (2D) materials have attracted tremendous interest since the study of graphene in the early 21st century. With their
thickness in the angstrom-to-nanometer range, 2D materials, including graphene, transition metal dichalcogenides, phosphorene, silicene, and other inorganic and organic materials, can be an ideal platform to study fundamental many-body interactions because of reduced screening and can also be further engineered for nanophotonic applications. This book compiles research outcomes of leading groups in the field of 2D materials for nanophotonic physics and devices. It describes research advances of 2D materials for various nanophotonic applications, including ultrafast lasers, atomically thin optical lenses, and gratings to inelastically manipulate light propagation, their integrations with photonic nanostructures, and light–matter interactions. The book focuses on actual applications, while digging into the physics underneath. It targets advanced undergraduate- and graduate-level students of nanotechnology and researchers in nanotechnology, physics, and chemistry, especially those with an interest in 2D materials.

The Handbook of Silicon Based MEMS Materials and Technologies, Second Edition, is a comprehensive guide to MEMS materials, technologies, and manufacturing that examines the state-of-the-art with a particular emphasis on silicon as the most important starting material used in MEMS. The book explains the fundamentals, properties (mechanical, electrostatic, optical, etc.), materials selection, preparation, manufacturing, processing, system integration, measurement, and materials characterization techniques, sensors, and multi-scale modeling methods of MEMS structures, silicon crystals, and wafers, also covering micromachining technologies in MEMS and encapsulation of MEMS components. Furthermore, it provides vital packaging technologies and process knowledge for silicon direct bonding, anodic bonding, glass frit bonding, and related techniques, shows how to protect devices from the environment, and provides tactics to decrease package size for a dramatic reduction in costs. Provides vital packaging technologies and process knowledge for silicon direct bonding, anodic bonding,
glass frit bonding, and related techniques Shows how to protect devices from the environment and decrease package size for a dramatic reduction in packaging costs Discusses properties, preparation, and growth of silicon crystals and wafers Explains the many properties (mechanical, electrostatic, optical, etc.), manufacturing, processing, measuring (including focused beam techniques), and multiscale modeling methods of MEMS structures Geared towards practical applications rather than theory

Focusing on nanophotonics, which has been proposed by M. Ohtsu in 1993, this volume begins with theories for operation principles of characteristic nanophotonic devices and continues with novel optical near field phenomena for fabricating nanophotonic devices. Further topics include: unique properties of optical near fields and their applications to operating nanophotonic devices; and nanophotonic information and communications systems that can overcome the integration-density limit with ultra-low-power operation as well as unique functionalities. Taken as a whole, this overview will be a valuable resource for engineers and scientists working in the field of nano-electro-optics.

This book covers device design fundamentals and system applications in optical MEMS and nanophotonics. Expert authors showcase examples of how fusion of nanoelectromechanical (NEMS) with nanophotonic elements is creating powerful new photonic devices and systems including MEMS micromirrors, MEMS tunable filters, MEMS-based adjustable lenses and apertures, NEMS-driven variable silicon nanowire waveguide couplers, and NEMS tunable photonic crystal nanocavities. The book also addresses system applications in laser scanning displays, endoscopic systems, space telescopes, optical telecommunication systems, and biomedical implantable systems. Presents efforts to scale down mechanical and photonic elements into the nano regime for enhanced performance, faster operational speed, greater bandwidth,
and higher level of integration. Showcases the integration of MEMS and optical/photonic devices into real commercial products. Addresses applications in optical telecommunication, sensing, imaging, and biomedical systems. Prof. Vincent C. Lee is Associate Professor in the Department of Electrical and Computer Engineering, National University of Singapore. Prof. Guangya Zhou is Associate Professor in the Department of Mechanical Engineering at National University of Singapore.


Handbook of Optoelectronics offers a self-contained reference from the basic science and light sources to devices and modern applications across the entire spectrum of disciplines utilizing optoelectronic technologies. This second edition gives a complete update of the original work with a focus on systems and applications. Volume I covers the details of optoelectronic devices and techniques including semiconductor lasers, optical detectors and receivers,
optical fiber devices, modulators, amplifiers, integrated optics, LEDs, and engineered optical materials with brand new chapters on silicon photonics, nanophotonics, and graphene optoelectronics. Volume II addresses the underlying system technologies enabling state-of-the-art communications, imaging, displays, sensing, data processing, energy conversion, and actuation. Volume III is brand new to this edition, focusing on applications in infrastructure, transport, security, surveillance, environmental monitoring, military, industrial, oil and gas, energy generation and distribution, medicine, and free space. No other resource in the field comes close to its breadth and depth, with contributions from leading industrial and academic institutions around the world. Whether used as a reference, research tool, or broad-based introduction to the field, the Handbook offers everything you need to get started. (The previous edition of this title was published as Handbook of Optoelectronics, 9780750306461.) John P. Dakin, PhD, is professor (emeritus) at the Optoelectronics Research Centre, University of Southampton, UK. Robert G. W. Brown, PhD, is chief executive officer of the American Institute of Physics and an adjunct full professor in the Beckman Laser Institute and Medical Clinic at the University of California, Irvine.

This book describes the design of optical receivers that use the most economical integration technology, while enabling performance that is typically only found in very expensive devices. To achieve this, all necessary functionality, from light detection to digital output, is integrated on a single piece of silicon. All building blocks are thoroughly discussed, including photodiodes, transimpedance amplifiers, equalizers and post amplifiers.

This book shows how dispersion engineering in two dimensional dielectric photonic crystals can provide new effects for the precise control of light propagation for integrated nanophotonics. Dispersion engineering in regular and graded photonic crystals to promote
anomalous refraction effects is studied from the concepts to experimental demonstration via nanofabrication considerations. Self collimation, ultra and negative refraction, second harmonic generation, mirage and invisibility effects which lead to an unprecedented control of light propagation at the (sub-)wavelength scale for the field of integrated nanophotonics are detailed and commented upon.

Nanophotonics is a newly developing and exciting field, with two main areas of interest: imaging/computer vision and data transport. The technologies developed in the field of nanophotonics have far reaching implications with a wide range of potential applications from faster computing power to medical applications, and "smart" eyeglasses to national security. Integrated Nanophotonic Devices explores one of the key technologies emerging within nanophotonics: that of nano-integrated photonic modulation devices and sensors. The authors introduce the scientific principles of these devices and provide a practical, applications-based approach to recent developments in the design, fabrication and experimentation of integrated photonic modulation circuits. For this second edition, all chapters have been expanded and updated to reflect this rapidly advancing field, and an entirely new chapter has been added to cover liquid crystals integrated with nanostructures. Unlocks the technologies that will turn the rapidly growing research area of nanophotonics into a major area of commercial development, with applications in telecommunications, computing, security, and sensing Nano-integrated photonic modulation devices and sensors are the components that will see nanophotonics moving out of the lab into a new generation of products and services. By covering the scientific fundamentals alongside technological applications, the authors open up this important multidisciplinary subject to readers from a range of scientific backgrounds.