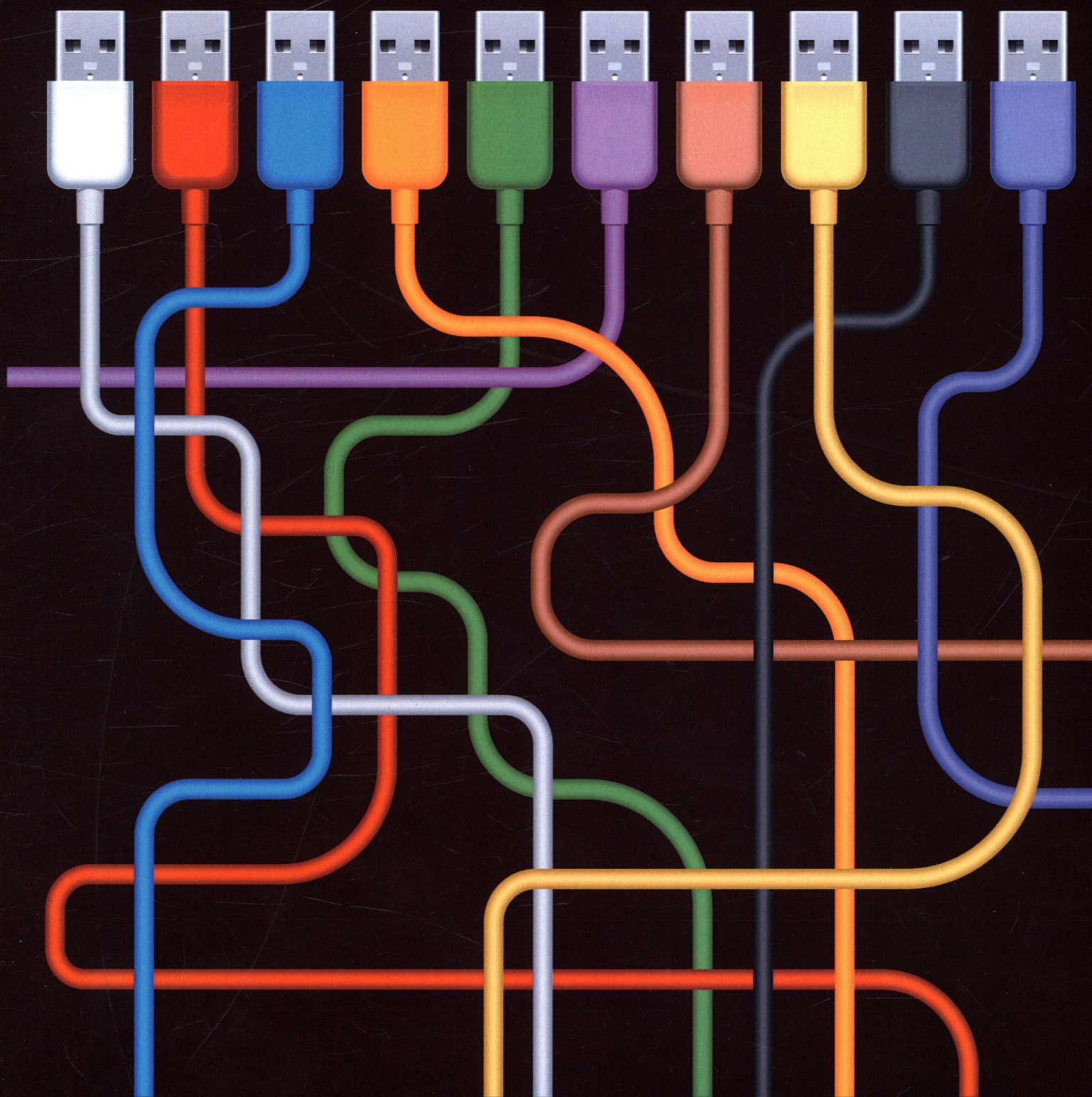


Current Trends of Optics and Photonics

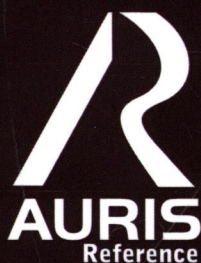
Contributors: Z. Valy Vardeny, Ajay Nahata, et al.



About the Book

Optics and photonics presents new and vibrant approaches in order to meet the challenges of the 21st century with reference to energy conservation, education, agriculture, personal health and the environment. Optical thin films and meta-materials, lasers, optical communications, light-emitting diodes, solar cells, liquid crystal technology, nanophotonics and biophotonics all play vital roles in enriching our lives. Applications of photonics are ubiquitous. Included are all areas from everyday life to the most advanced science, e.g. light detection, telecommunications, information processing, lighting, metrology, spectroscopy, holography, medicine (surgery, vision correction, endoscopy, health monitoring), military technology, laser material processing, visual art, biophotonics, agriculture, and robotics. Just as applications of electronics have expanded dramatically since the first transistor was invented in 1948, the unique applications of photonics continue to emerge. Economically important applications for semiconductor photonic devices include optical data recording, fiber optic telecommunications, laser printing (based on xerography), displays, and optical pumping of high-power lasers. The potential applications of photonics are virtually unlimited and include chemical synthesis, medical diagnostics, on-chip data communication, laser defense, and fusion energy. The science of photonics includes investigation of the emission, transmission, amplification, detection, and modulation of light. Adaptive optics (AO) is a technology used to improve the performance of optical systems by reducing the effect of wave front distortions: it aims at correcting the deformations of an incoming wave front by deforming a mirror in order to compensate for the distortion. It is used in astronomical telescopes and laser communication systems to remove the effects of atmospheric distortion, in microscopy, optical fabrication and in retinal imaging systems to reduce optical aberrations. Adaptive optics works by measuring the distortions in a wave front and compensating for them with a device that corrects those errors such as a deformable mirror or a liquid crystal array.

The book named with Current Trend of Optical and Photonic encompasses a broad range of theory and applications which are of interest for diverse classes of optical and photonic devices. Conclusively, recent successful achievements in modern optical communications and multifunctional systems have been accomplished based on composing "building blocks" of a variety of optical and photonic devices. Thus, the grasp of current trends and needs in device technology would be useful for further development of such a range of relative applications. The book is a compilation of contemporary researches and developments of various devices and structures in the area of optics and photonics. It is composed of seventeen chapters covering fundamental theory, physical operation mechanisms, fabrication and measurement techniques, and application examples. Besides, it contains comprehensive reviews of recent trends and advancements in the field.



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Mahata**

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Current Trends of Optics and Photonics

List of Contributors

Z. Valy Vardeny
Department of Physics and Astronomy, University of Utah, Salt Lake City, Utah 84112, USA

Ajay Nahata
Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, Utah 84112, USA

Amit Agrawal
Department of Electrical Engineering and Computer Science, Syracuse University, Syracuse, New York 13244, USA

Qingying Deng
Tianjin University, TEDA or King Hi-Tech CO. LTD., Tianjin, China
Beijing Moreget Creative Technology CO. LTD., Beijing, China

Hua Chen
Beijing Moreget Creative Technology CO. LTD., Beijing, China

Guohui Li
Tianjin University, TEDA or King Hi-Tech CO. LTD., Tianjin, China

Jianquan Yao
Tianjin University, TEDA or King Hi-Tech CO. LTD., Tianjin, China

Akiyoshi Mikami
Department of Electrical Engineering, Kanazawa Institute of Technology, Ishikawa, Japan

Hossam Zoweil
Advanced Technology and New Materials Research Institute, City of Scientific Research and Technology Applications, New Borg EL-Arab City, Egypt

Mehdi Hassani Keleshtery
Electronics Group, Faculty of Engineering Department, Lorestan University, Khorramabad, Iran

Hassan Kaatuzian
Photonics Research Laboratory (PRL), Electrical Engineering Department, Amirkabir University of Technology, Tehran, Iran

Ali Mir
Electronics Group, Faculty of Engineering Department, Lorestan University, Khorramabad, Iran

Yufeng Shao
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Fuping Chen
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Luo Chen
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Shilu Shen
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Anrong Wang
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Yingxiang Luo
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Zefu Tan
College of Electronic and Information Engineering, Chongqing Three Gorges University, Chongqing, China

Hassan Pakarzadeh

Department of Physics, Shiraz University of Technology, Shiraz, Iran

Zeinab Delirian

Department of Physics, Shiraz University of Technology, Shiraz, Iran

Mostafa Taghizadeh

Atomic and Molecular Group, Faculty of Physics, Yazd University, Yazd, Iran

Dilip Kumar Gayen

Department of Computer Science & Engineering, College of Engineering & Management, Kolaghat, KTPP Township, Purba Medinipur, India

W. E. Vargas

Center for Research in Science and Engineering Materials & School of Physics, University of Costa Rica, San Jose, Costa Rica
Academia Nacional de Ciencias de Costa Rica, San José, Costa Rica

M. Hernández-Jiménez

Center for Research in Science and Engineering Materials & School of Physics, University of Costa Rica, San Jose, Costa Rica

E. Libby

Center for Research in Science and Engineering Materials & School of Physics, University of Costa Rica, San Jose, Costa Rica

D. E. Azofeifa

Center for Research in Science and Engineering Materials & School of Physics, University of Costa Rica, San Jose, Costa Rica

C. Barboza

Research Center Microscopic Structures, University of Costa Rica, San Jose, Costa Rica

Á. Solís

Museo Nacional de Costa Rica, San José, Costa Rica

G. Dhanu Krishna

Department of Optoelectronics, University of Kerala, Thiruvananthapuram, India

G. Prasannan

Department of Optoelectronics, University of Kerala, Thiruvananthapuram, India

S. K. Sudheer

Department of Optoelectronics, University of Kerala, Thiruvananthapuram, India

V.P. Mahadevan Pillai

Department of Optoelectronics, University of Kerala, Thiruvananthapuram, India

T. Z. N. Sokkar

Physics Department, Faculty of Science, Mansura University, Mansura, Egypt

K. A. El-Farahaty

Physics Department, Faculty of Science, Mansura University, Mansura, Egypt

E. A. Seisa

Physics Department, Faculty of Science, Mansura University, Mansura, Egypt

E. Z. Omar

Physics Department, Faculty of Science, Mansura University, Mansura, Egypt

M. Agour

Physics Department, Faculty of Science, Aswan University, Aswan, Egypt

Physics Department, FB1: Physics and Electrical Engineering, Bremen University, Bremen, Germany

Lahcen Ez-Zariy

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

Salima Hennani

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

Hamid Nebdi

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

Abdelmajid Belafhal

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, El Jadida, Morocco

Chao Ping Chen

National Engineering Lab for TFT-LCD Materials and Technologies, Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

Yikai Su

National Engineering Lab for TFT-LCD Materials and Technologies, Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

Chul Gyu Jhun

School of Green Energy and Semiconductor Engineering, Hoseo University, Asan, Chungnam 336-795, Korea

Salima Hennani

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, Jadida, Morocco

Lahcen Ez-Zariy

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, Jadida, Morocco

Abdelmajid Belafhal

Laboratory of Nuclear, Atomic and Molecular Physics, Department of Physics, Faculty of Sciences, Chouaïb Doukkali University, Jadida, Morocco

Preface

Optics and photonics presents new and vibrant approaches in order to meet the challenges of the 21st century with reference to energy conservation, education, agriculture, personal health and the environment. Optical thin films and meta-materials, lasers, optical communications, light-emitting diodes, solar cells, liquid crystal technology, nanophotonics and biophotonics all play vital roles in enriching our lives. Applications of photonics are ubiquitous. Included are all areas from everyday life to the most advanced science, e.g. light detection, telecommunications, information processing, lighting, metrology, spectroscopy, holography, medicine (surgery, vision correction, endoscopy, health monitoring), military technology, laser material processing, visual art, biophotonics, agriculture, and robotics. Just as applications of electronics have expanded dramatically since the first transistor was invented in 1948, the unique applications of photonics continue to emerge. Economically important applications for semiconductor photonic devices include optical data recording, fiber optic telecommunications, laser printing (based on xerography), displays, and optical pumping of high-power lasers. The potential applications of photonics are virtually unlimited and include chemical synthesis, medical diagnostics, on-chip data communication, laser defense, and fusion energy. The science of photonics includes investigation of the emission, transmission, amplification, detection, and modulation of light. Adaptive optics (AO) is a technology used to improve the performance of optical systems by reducing the effect of wave front distortions: it aims at correcting the deformations of an incoming wave front by deforming a mirror in order to compensate for the distortion. It is used in astronomical telescopes and laser communication systems to remove the effects of atmospheric distortion, in microscopy, optical fabrication and in retinal imaging systems to reduce optical aberrations. Adaptive optics works by measuring the distortions in a wave front and compensating for them with a device that corrects those errors such as a deformable mirror or a liquid crystal array.

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OPTICS OF PHOTONIC QUASICRYSTALS

Z. Valy Vardeny¹, Ajay Nahata² and Amit Agrawal³

¹Department of Physics and Astronomy, University of Utah, Salt Lake City, Utah 84112, USA

²Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, Utah 84112, USA

³Department of Electrical Engineering and Computer Science, Syracuse University, Syracuse, New York 13244, USA

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ABSTRACT

The physics of periodic systems are of fundamental importance and result in various phenomena that govern wave transport and interference. However, deviations from periodicity may result in higher complexity and give rise to a number of surprising effects. One such deviation can be found in the field of optics in the realization of photonic quasicrystals, a class of structures made from building blocks that are arranged using well-designed patterns but lack translational symmetry. Nevertheless, these structures, which lie between periodic and disordered structures, still show sharp diffraction patterns that confirm the existence of wave interference resulting from their long-range order. In this Review, we discuss the beautiful physics unravelled in photonic quasicrystals of one, two and three dimensions, and describe how they can influence optical transmission and reflectivity, photoluminescence, light transport, plasmonics and laser action.

INTRODUCTION

The use of optical interference to enhance device performance is one of the most important tools in modern optics¹. Important examples include photonic crystals^{2, 3, 4}, laser action in distributed feedback resonators^{5, 6}, anomalous transmission through perforated metal films with subwavelength aperture arrays⁷, coherent backscattering enhancement^{8, 9, 10}, image reconstruction¹¹ and Anderson localization of light^{12, 13}. Overwhelmingly, periodic structures are used for applications based on optical interference, largely because it has not been widely recognized that aperiodic structures, such as quasicrystals, can also provide similar functionalities. This is particularly relevant because the large variety of aperiodic structures, when compared with their periodic counterparts, can add significant flexibility and richness when engineering the optical response of devices in ways that have yet to be realized. In this Review, we describe the optical interference phenomena that occur in quasicrystalline structures.

It has now been shown that in addition to crystalline and amorphous materials, there exists a third intermediate class known as ‘deterministic aperiodic’ structures, which can be generated by a substitution rule based on two building blocks that exhibit long-range order but lack translational symmetry. All these structures exhibit properties of self-similarity. This class of structures can be further divided into two groups: quasicrystals (group 1) and all other deterministic aperiodic structures (group 2); quasicrystals therefore represent a special class of deterministic aperiodic structures. A more precise definition of quasicrystals in group 1 with dimensionality nD ($n = 1, 2$ or 3) is that in addition to their possible generation by a substitution process, they can also be formed from a partial projection of an appropriate periodic structure in a higher dimensional space mD , where $m > n$. In contrast, structures that are part of group 2 cannot be constructed in such a manner. In one dimension (1D), quasicrystal structures include the Fibonacci sequence BABBA... and the generalized Fibonacci sequence, for example. Aperiodic structures that differ from quasicrystals and belong to group 2 include Thue–Morse^{14, 15}, Rudin–Shapiro¹⁶ and period-doubling sequences¹⁷. All structures belonging to groups 1 and 2 show discrete Fourier components, although structures in group 2 exhibit much more complex Fourier properties than those in group 1¹⁸.

The surprising discovery of quasicrystals by Shechtman et al.¹⁹ in 1984, whereby a grown solid showed a sharp X-ray diffraction pattern of ten-fold rotational symmetry, took crystallographers and theoreticians in symmetry completely by surprise. A brilliant theoretical analysis by Levine and Steinhardt²⁰ elevated the scientific discussion of the finding and established the foundation of the new field of ‘quasicrystals’, which has revolutionized solid-state physics. Consequently, the 2011 Nobel Prize in Chemistry was awarded to Shechtman for the discovery of quasicrystals, and the 2011 Buckley Prize for Physics was given to Levine and Steinhardt for their theoretical analysis. The discovery of quasicrystals in condensed matter has also initiated a new field of research in photonics. The first example of an aperiodic system that possesses long-range order in the field of optics was described by Kohmoto et al.²¹, who proposed a 1D quasicrystal structure (or photonic quasicrystal) that used dielectric multilayers to form the Fibonacci sequence (Fig. 1a). Subsequently, a broad range of photonic quasicrystals (group 1) and other deterministic aperiodic structures with long-range order (group 2) have been engineered and studied by optical means^{17, 22}. In all of these studies, interference has played a crucial role in the optical properties of each structure.

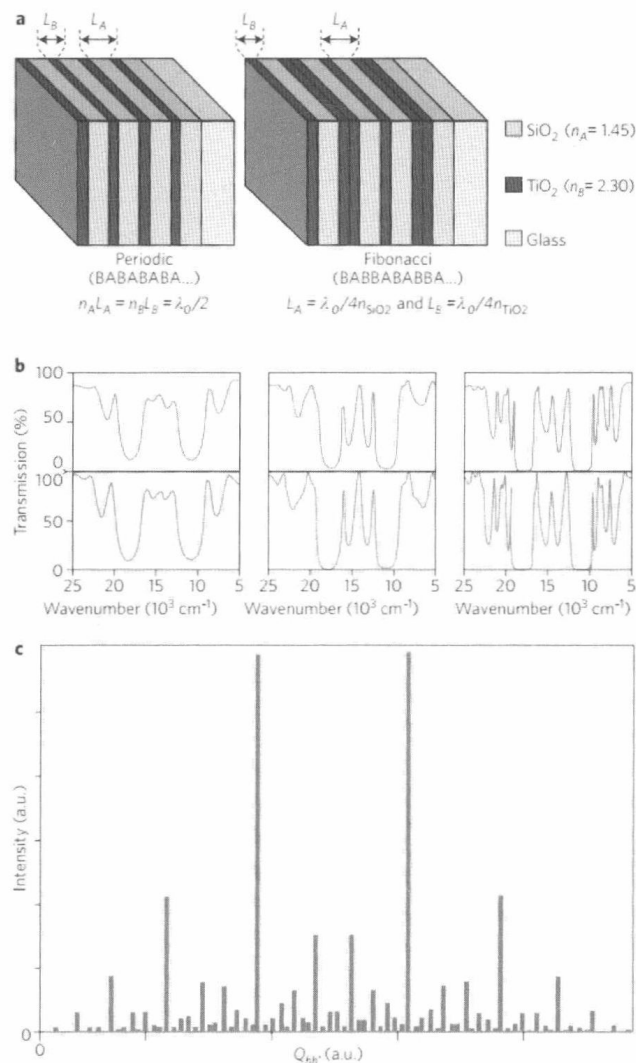


Figure 1: Non-resonant 1D Fibonacci quasicrystalline structure.