

Preface

Life comes from light and so does human civilization. In our vocabulary, the terms optics and photonics were coined to describe light. Indeed, the evolution of human civilization goes hand in hand with optics and photonics; particularly, since the invention of the laser in the last century, optics and photonics have progressed extremely rapidly and influenced human civilization significantly. Today, our daily lives as we know them wouldn't be possible without optics and photonics, a fact that has moved the United Nations (UN) to declare 2015 the International Year of Light and Light-based Technologies (IYL 2015). Hopefully, this will help the light-based technologies to be promoted even further in solving the global problems concerning energy, education, agriculture, health, environment, etc. One of the most effective ways to achieve these goals is to provide updated and reliable content on the subject to the public, which is the aim of this book.

As opposed to covering all fields of optics and photonics, instead, the book will highlight a number of currently interesting topics that might be useful for further research and development. In Part I we present the latest developments concerning optical thin films and metamaterials. Optical thin films play a vital role in optics and photonics, and without them the two fields might well not be where they are today. We introduce the theory of and manufacturing technique for a gain layer to make coatings with reflectance greater than 100 %, then describe a method for producing large useful coating areas of filters for DWDM with record-breaking uniformity, better than ± 0.003 % over an area of 50 mm in diameter. We examine the design and production of antireflective coatings with hydrophobic and hydrophilic characteristics, residual color to decorate solar cells and blackness, then illustrate the advantages of coatings with a negative refractive index layer. Monitoring is the key technique to accomplishing new designs and is extremely important in the coating process; accordingly, five advanced monitoring methods are proposed.

Metamaterials are artificial structures designed for controlling electromagnetic and acoustic waves or fields, and exhibit exceptional properties that are unexpected on the basis of their chemical constituents. These properties lead to some fascinating phenomena such as negative refraction, sub-wavelength imaging, and field

enhancement. A simple review on metamaterials research and discussion of the problems that still need to be resolved round out the second part of Part I (Chap. 2).

Since the invention of the laser in the 1960s of the last century, several kinds of lasers have been produced. A recently developed rare-earth-elements-doped fiber laser stands out for its special characteristics, such that of a movable focusing element for material process; its compact size, which makes it easy to install in a device; tunable spectrum and high output power; diffraction-limited and high-quality optical beam; low cost, etc. In this context, femtosecond Yb-doped fiber oscillators and amplifiers are the most important candidates, and their theory and development are examined in Part II (Chap. 3). Here, we demonstrate high-power femtosecond fiber lasers employing diode-pumping as well as novel mode-locking techniques for fiber-based oscillators. In fundamental mode, the ultimate fiber laser system generates a peak power of over 45 kW and burst pulse energy of 350 nJ. Its harmonics have peak powers of 6.7 kW (532 nm) and 0.6 kW (266 nm). The generation of a supercontinuum using noise-like pulses propagating through ~100 m of single-mode fiber in the normal dispersion region with a low threshold (43 nJ) and flat spectrum over 1050–1250 nm is also illustrated.

The optical free-space transmission scheme has recently been developed to provide high-speed and secure wireless connections, and visible light communication (VLC) systems in particular have proven to be a suitable candidate for delivering these wireless connections between fiber backbone networks and mobile devices. Therefore, a modern VLC communication system based on laser pointer lasers (LPL) for providing high transmission rates and long free-space links is introduced in Part III (Chap. 4). Different technical aspects of VLC, which include enhancing the transmission data rate, mitigating optical background noise, achieving a bi-directional transmission, and using AC-LED for VLC are demonstrated. In Chaps. 5–7, we subsequently propose a novel approach to nonlinear distortion compensation employing the sub-carrier-to-subcarrier intermixing interference (SSII) cancellation technique in the context of an electroabsorption modulator (EAM)-based orthogonal frequency-division multiplexing and intensity-modulation-direct-detection (OFDM-IMDD) transmission system. In order to develop the universal transmitters for the next-generation wavelength division multiplexing passive optical network (WDM-PON), the colorless weak-resonant-cavity Fabry-Perot laser diode (WRC-FPLD), which is injection-locked with the help of a highly coherent master laser is used, reducing the relative intensity noise peak at 5 GHz by 18 dB and increasing its throughput frequency response by 5 dB. This enhances the signal-to-noise ratio from 10.5 dB to 18.9 dB and the on/off extinction ratio from 10.4 dB to 11.4 dB, enabling the error-free on-off-keying (OOK) transmission at 10 Gbit/s with a requested receiving power sensitivity of -15 dBm at a bit-error-rate (BER) of 10^{-9} .

Given their energy efficiency, longer service life, comparative environmental friendliness, and compact size, the light-emitting diodes (LEDs), are now utilized in many fields, such as lighting, displays, interferometry, biophotonics, biomedical applications, agriculture, transportation, art and decoration, communication, safety, and in the military, and will eventually replace, at least partially, the traditional fluorescent lamps and high-pressure halogen lamps, making them an important

new light source. The key issues concerning LEDs for high lumen/watt efficiency are the internal quantum efficiency, light extraction, heat dissipation, and device packaging. Several techniques for addressing these issues, such as substrate pre-treatment, nano-pillar sapphire substrate, structure design with graded quantum wells, quantum dots, nano-particles and novel electron blocking layers, epitaxial technology, Joule heating minimization, transparent conductive layer patterning, and improved packaging and light extraction are described in Part IV (Chap. 8).

The depletion of fossil energy sources and dramatic change in our climate have sparked a new interest in renewable energies, with solar energy being one of the important among them. As solar cells are used to harvest solar energy and directly convert it to electricity, Part V (Chap. 9) discusses in great detail several types solar cell, including inorganic and organic variants. Recent advances are also briefly described.

Over the last few years, advances in display technology have greatly benefited people in their work and daily lives, and it would be fair to say that “displays” are among the most important and ubiquitous devices in today’s society. One of the most essential elements for display is liquid crystal technology. In addition to displays, liquid crystals are also an important component applied in many optics and photonics context, such as holographic gratings, beam steering, q-plates for shaping laser beams, photo-alignment technology, optical attenuators, bio-sensors, lenses, polarization convertors, spatial filters, lasers, etc. The physics of liquid crystals and essential device skills, as well as the emerging new type of liquid crystal displays, are described in Part VI (Chaps. 10–12). Novel applications of cutting-edge liquid crystal technology in 3D displays, non-display applications and biomedical technology are also proposed (Chaps. 13–15).

Nanophotonics have opened up a new research field and allow us to manipulate light at the nanometer scale with characteristics that may not be limited by the physical and chemical composition of natural materials or the diffraction limit of electromagnetic waves. Now that highly interesting fundamental research works have been published, scientists and engineers have started searching for potential applications. In Part VII (Chaps. 16–25) several novel applications are illustrated such as plasmonic nano-lasers, nano-structure light-emitting diodes, one-dimensional photonic crystal nanowires with small footprints and ultrahigh Q-factors, nano-structured waveguides with slow light effect, thin films with a negative refractive index, anti-reflection with nano-structures for solar cells, high-sensitivity plasmonic biosensors, etc. We hope the illustrations in Part VII will inspire people to pursue further cutting-edge breakthroughs in nanophotonics.

The principles and applications of the interactions between photons and biological samples have recently been established as a field of study and are collectively referred to as biophotonics. Many novel photonic technologies and molecular probes have now been developed, making it possible to carry out multi-modality studies with unprecedented spatial and temporal resolutions that provide not only structural, but also functional information. In Part VIII (Chaps. 26–29), we present a brief historical/chronological overview to highlight the key technological developments in four specific biophotonics techniques based on laser microscopy,

namely, Fluorescence Life-time Imaging/Foster Resonance Energy Transfer (FLIM/FRET) Microscopy; Optical Coherence Tomography (OCT); Super resolution Microscopy, and Harmonic Generation Microscopy, all of which have made tremendous strides in the last decade not only in terms of their technological development, but also in niche biological and biomedical applications.

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