

Nonlinear Optics and Applications

Edited by

**Hossin A. Abdeldayem, Ph.D.
NASA-Goddard Space Flight Center
Greenbelt, Maryland, USA**

And

**Donald O. Frazier, Ph.D.
NASA-Marshall Space Flight Center
Huntsville, Alabama, USA**

PREFACE

Nonlinear optics is the result of laser beam interaction with materials and started with the advent of lasers in the early 60's. It has already reached the level of maturity and has been proven to be an exciting field, that is growing dramatically every day and is playing a major role in the emerging photonic technology. Nonlinear optics led to countless optical devices that have become indispensable in our daily lives. Nonlinear optics played a major role in many of the optical applications such as optical signal processing, optical computers, ultrafast switches, ultra-short pulsed lasers, sensors, laser amplifiers, and many others. This special review volume on Nonlinear Optics and Applications is intended for those who want to be aware of the most recent developments in photonics and the role of nonlinear optics in photonic technology. It is also important to note that the research work in nonlinear optics, optical materials, and nonlinear optics devices in the last five years is enormous and is beyond comprehending it all in one book, which made our job extremely difficult to give a complete fair coverage of all the great published ideas. Consequently, we apologize in advance to those whose significant work was accidentally left out.

In this book, we give a survey on the recent advances of nonlinear optical applications. Emphasis will be on novel devices and materials, switching technology, optical computing, and important experimental results. We also include the recent developments in topics which are of historical interest to many researchers, and in the same time of potential to be used in the fields of all-optical communication and computing technologies. In addition, we enclosed a few new and unconventional related topics which might provoke new thinking and discussions. This review volume will be of interest for a broad range of research scientists, engineers, and graduate students in multidiscipline research areas such as optics, material science, chemistry, physics, lasers, fibers, semiconductors, computer and electrical engineering.

The book is organized as follows: Chapter 1 provides an introduction to nonlinear optics and applications particularly as related to organic π -electron materials and devices fabricated from such materials. It provides insight into the fundamental concepts and guiding principles leading to improved materials and devices. Chapter 2 provides a brief review of the nonlinear Schrodinger and associated equations that model spatio-temporal propagation in one and higher dimensions in nonlinear dispersive media. Fast adaptive numerical techniques were used to solve these equations. A unique variational approach is also outlined that helps in determining the ranges of nonlinearity and dispersion parameters. Chapter 3 is an update of the supercontinuum light source by professor Alfano, who observed the phenomenon first time in 1970. The phase change induced by an intense ultrashort laser pulse propagating through a medium causes a frequency sweep within the pulse envelope, resulting in a well-defined temporal chirp. A look into the nonlinear mechanisms involved in producing such system and its potential applications are presented. Chapter 4 demonstrated wideband ultrashort pulse fiber laser sources using optical fibers and ultrashort pulse fiber lasers and a wavelength tuning range from 0.78 to 2.0 μm . The generation process and characteristics have been analyzed both experimentally and numerically. Chapter 5 provided an overview of experimental demonstration and theoretical understanding of lattice fabrication (including 1D lattices, 2D square lattices and ring lattices, and lattices with structured defects), as well as their linear and nonlinear light guiding properties. Discrete diffraction and self-trapping are

demonstrated in a variety of settings, including fundamental discrete solitons, discrete vector solitons, discrete dipole solitons, discrete vortex solitons, and necklace-like solitons. In addition, the formation of 1D and 2D lattices with single-site negative defects, and linear bandgap guidance in these structures were demonstrate. Chapter 6 discussed the second-order EO effect (Pockels), the third-order (Kerr) and thermo-optical effects in optical waveguides and their applications in optical communication. Chapter 7 presents a theoretical study and experimental data of beam combination using Stimulated Brillouin Scattering in improving upon the beam quality in optical fiber. The study includes both coherent and incoherent combination as well as two-beam phasing using the unique polarization characteristics of stimulated Brillouin scattering. Chapter 8 demonstrates a theoretical and experimental results of a double-functional interferometer, using holographic recording of a dynamic grating in CdTe:V crystal. The mechanisms involved were attributed to a slow electro-optical effect and a fast free-carrier grating. Chapter 9 represents the poling process on optical polymers to induce second and third order nonlinear optical effects. The chapter attributes the electro-optic effect in polymers to the presence of chromophore in the polymer matrix and explains the different approaches of incorporating the chromophore into the polymer matrix. It also explains the different poling methods and the poling mechanisms. Chapter 10 treats the effect of magnetic field and its role in nonlinear optics. It presents a set of experimental results, which prompt a reconsideration the role of magnetization in optics and predictions of optical magnetic resonance, negative permeability, and magnetic birefringence at optical frequencies. Chapter 11 describes the observations of Stokes and anti-Stokes emission of gold nano-particles as a three step process involving single-photon or three-photon excitation of electron-hole pairs, relaxation of excited electrons and holes, and emission from the electron-hole recombination. It also presents quantitative analysis of the experimental data. Chapter 12 explores the use of linear optics and the reliance on detection to design a number of optical logic gates that perform operations in the complex domain of linear optics and are converted to Boolean operations by the act of detection. These logic have no energy cost and the bandwidth is strictly limited by the electronic modulation and demodulation rate and can be integrated on chips with the electronics. Chapter 13 presents an answer to the important question: can the electric field of a light wave be assigned a definite polarity? In other words, can an optical field vector be more up than down? It also describes physical experiments and devices where this polar asymmetry is generated and detected and also connects the answer to the independently developed, Nobel Prize-winning technique of generating stabilized combs of mode-locked frequency components of light. Chapter 14 presents an excellent review of the chalcopyrite materials and their potential as compact highly sensitive nonlinear optical sensors, of potential for many remote sensing devices. The chapter also touches on the integration of miniaturized photonic nonlinear bandgap structures, which enhances the nonlinearity and minimize problems associated with walk-off effects and outlines a theoretical analysis of nonlinear propagation in these structures. Chapter 15 presents the status of the ultimate device that can be attained in this 21st century through the photonic technology which is optical computing. The chapter lists the different components that might the optical computer will consist of and lists the most recent advances achieved and the substantial list of the recent literature on each component. It concludes with the obstacles to be overcome to build the system.

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Philip A Sullivan and Larry R. Dalton

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Hossin Abdeldayem and Donald O. Frazier

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