

Preface

Nonlinear Optics is one of subdisciplines of Modern Optics, it has an important academic status in the Modern Optics as same as the Laser Physics.

Laser Physics studies on the principle of laser devices and properties of laser, the main research contents include the stimulated radiation theory, optical resonant cavity theory, laser propagation theory, laser coherence theory, laser frequency spectrum, laser spatial mode, and laser power property.

Nonlinear Optics studies on various kinds of nonlinear effects in the interaction between laser and matter. The research contents include two aspects: one is studying in the laser how to change the macroscopic parameters of matter (susceptibility, dielectric coefficient, refractive index, absorption coefficient, etc.) and the microscopic structure of matter, thereby to realize “controlling matter by laser”; other one is studying in the pump laser induced matter change how to effect the parameters of the signal light propagating in the matter (frequency, power, wave vector, phase, pulse width, frequency spectrum, group velocity, propagation direction, etc.), thereby to realize “controlling light with light.”

In short, Laser Physics studies the laser generation method; and Nonlinear Optics studies the laser controlling method, the two courses are basics of laser application. Therefore, the optics specialized graduate students must study Nonlinear Optics, besides study Laser Physics.

Nonlinear optics was established soon after the invention of laser in 1960. It has half a century of development history; its research field has been continuously developed in depth and breadth. Now the nonlinear optics has gained extensive applications. For example, it has been widely used in laser technology in order to change the frequency of the laser, compress the pulse width of laser, and achieve the tunable power and frequency of laser; the nonlinear optics has been used to make various optoelectronic devices, such as laser, optical amplifier, optical modulator, optical storage, optical display, and optical switches, which are widely used in the optoelectronic technology and photonic technology; the nonlinear optics has made important contribution to the development of optical fiber communication, space optical communication, and nonlinear optical communications (optical

soliton communication, optical chaotic communication, and optical quantum communication, etc.); the nonlinear optics has been used to study the optical logic, optical router, optical switching, optical interconnection, optical wavelength conversion, wavelength division multiplexing, and time division multiplexing technology and to promote the digital optical information processing, the all-optical computer, and the all-optical network technology; in addition, the nonlinear optics has been used to make the nonlinear optical fiber sensors to promote the development of the optical sensing technology; using the phase conjugation principle for the compensation of the waveform distortion of light; using the nonlinear optical limiting technology to against the blinding laser weapons; using the nonlinear optical principle to develop the spectral analysis technology with high spatial resolution and high temporal resolution, which has been applied to the analysis of material composition and hyperfine energy level structure of atom and molecule; using the multiphoton absorption effect for high-precision laser processing of nanoscale materials and devices; and the nonlinear optics is a powerful tool for study of new materials, such as surface, interface and low dimension materials, nano materials, and chiral materials; it is a necessary tool for measuring the nonlinear optical parameters of materials. Therefore, to master the basic knowledge of the nonlinear optics is necessary for scientists and engineers working in the field of the optoelectronic technology, the photonic technology, and the optical information technology.

Up to now, the published books on nonlinear optics have many versions in the world. These books have made important contributions to the related research and teaching works. But due to historical reasons, most of the existing books on nonlinear optics are old in the content, too deep in the theory, too many mathematical formulas, less actual application, or the unit and symbol are confusing, the readability is not good, and they are not suitable to directly use as short-term teaching materials.

This book attempts using “light wave” and “photon” the two kinds of physical images, clearly, deeply, and systematically to expound the basic principles of nonlinear optics. On the one hand, using the first order nonlinear wave equations in frequency domain and in “slowly variation amplitude” approximation and the classical polarization model in interaction between light and electric dipoles; on the other hand, using the rate equation theory based on photon excited energy-level transition in molecular system, as well as the photonic energy conservation and momentum conservation principle, to explain various nonlinear optical effects. The book uses the practical unit system, achieving the unity of symbol and unit. In the book, the author gives the strict mathematical derivation to basic theory, in the same time, pays attention to the experimental verification and the practical application. The book tries to reflect the latest progress in the research of nonlinear optics.

In order to make this book more refined, in the treatment of the second-order nonlinear optical effects, the author uses approximate method to transfer the problem of anisotropic medium into the problem of isotropic medium, avoiding the tedious description of crystal optics and complex tensor operation. Then all of the second-order nonlinear optical effects can be condensed into one chapter,

in order to have more space to focus on the third-order nonlinear optical effects. In this way, the teachers may finish the course teaching in 60 class hours, and the readers mastered certain optics and mathematics knowledge may study the book himself.

The author has been engaged in the research of nonlinear optics for more than 30 years, published about 300 academic papers and 5 books in the field of nonlinear optics. This book contains the author's achievements in research of nonlinear optics, for example, the optical bistability and optical instability in Chap. 8; the excited-state nonlinear optics and optical limiting in Chap. 7; the all-optical switches in Chap. 10; the spatial self-phase modulation in Chap. 5; the spatial optical soliton in Chap. 9; and the measurements of nonlinear optical parameters (such as Z-scan) in some chapters. So this book is also a review of author's research works.

The author engaged in the teaching graduate-student course "nonlinear optics" for many years. The writing of this book is based on his teaching material for course. The author hopes that the book can be a popular textbook for graduate students studying on the optics professional, but also can be used as a reference book for scientific and technical personnel working in the field of optoelectronic technology, photonic technology, optical information technology, and nonlinear optical material technology.

I sincerely thank my original Ph.D. graduate students and Master graduate students who did many contributions to this book. Heartfelt thank to the professors and colleagues who gave me support and encouragement in my research and teaching works. I am also thankful to the teachers and readers who use this book and would like to offer the valuable comments to me for modifying the book in the near future.

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