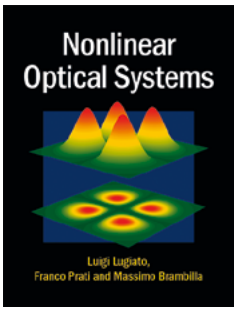
RECENSIONI



L. Lugiato, F. Prati, M. Brambilla

Nonlinear Optical Systems

Cambridge University Press, Cambridge UK, 2015

pp. XIV + 454; £ 55.00
ISBN 9781107062672

This book by Luigi Lugiato and his long time collaborators Francesco Prati and Massimo Brambilla contains an original presentation of several topics of laser dynamics and nonlinear optics. It covers a large spectrum of processes, starting from the basic equations for the laser operation to the dynamics for the spatial pattern of the laser intracavity intensity. Three different parts, whose level of complexity keeps increasing and with the final chapters appropriate for specialized lectures, compose the book.

The present textbook contains a very original character as compared to the several well established textbooks. It combines within a simple, clear and unifying theoretical framework basic concepts and complex processes, these last ones owing to their difficulties often restricted to very specialized publications. The long time personal experience by the authors with all the treated topics places them in a strategic position for a novel presentation approach. The theoretical treatment is mainly semiclassical, and therefore the quantum phenomena at the level of the single photon (today a very hot research topic!) are not examined. Nevertheless the variety of optical processes treated here is impressive. Today the study of nonlinear dynamics in optical devices and systems is relevant to several practical technological applications such as laser arrays, compact disk players, fiber optic communications, and optical switching devices. It should be mentioned here the use of chaotic lasers for encoding and decoding information-carrying signals. At the same time, the nonlinear optical dynamics observed in those devices and systems requires a careful exam from a fundamental perspective, and there this book gives an important contribution.

The book title itself deserves some attention, because it emphasizes the role of nonlinearity within the optical processes. In fact the nonlinearity, and more precisely the controlled nonlinearity associated to the optical components, has placed optics as the main element of the present information/communication society. The book is a tribute to those optical nonlinear systems, and the level of the treated nonlinearity complexity increases while progressing with the book chapters.

Seventeen chapters compose the book's first part, each of them not too long, around ten pages. It contains some basic principles of the semiclassical interaction between a quantum discrete system and electromagnetic fields, as the transition probabilities, the density matrix, the Bloch equations, the processes of amplification and absorption, the optical nonlinear response, and so on. However this introductory part presents in simple terms not standard processes as self-induced transparency, superfluorescence and superradiance, laser without inversion. In addition it presents also very precise derivations of the nonlinear optical generation, and phase-conjugation, while most textbooks limit the presentation to the basic principles. The relation between the electric field amplitudes of a beam splitter is also presented, an important phase-connection for the electric field often discarded by laser physicists.

The second part reports detailed analyses for the dynamical phenomena, temporal instabilities and chaotic behavior of the intensity or frequency associated to laser systems. The laser community has greatly contributed to the development and to the formalization of this broad topic, as evidenced by the long analysis and the extended reference list within this book. At the right beginning in the nineneteen-eighties the observations of instabilities and chaos in lasers was a very pleasant surprise. However it was very soon realized that the lasers could represent very flexible and simple systems where to test the Lorenz model for atmospheric chaos, later denominated as Lorenz-Haken model because of the important connection with the laser physics. Within today language in 1980-1990 laser and electronic systems have performed "quantum simulations" of chaos. The chapters composing Part II describe within a common frame the mathematical approaches required to interpret the different lasers commonly classified within three different classes, A, B, and C. This last classification, formally based on the characteristics of the differential equations describing the laser, corresponds in practice to a quite different nonlinear dynamics. Besides introducing the reader to general aspects of nonlinear dynamics and of chaos, the chapters present, within a general mathematical framework, the single and multimode instabilities corresponding to the different classes evidencing the richness associated to the nonlinear optical dynamics. Several important experimental results are mentioned or reported as examples of observed nonlinear optical phenomena.

The appendices connected to this second part of the book introduce the mathematical tools for the determination of the temporal laser instabilities. The same tools are essential for the study of spatial instabilities, denoted as transverse optical patterns, covered by the third part of the book. As pointed out within the introduction to that part, historically the interest in optical pattern formation emerged as a natural evolution of the temporal instabilities, mainly when proper detection tools were available to probe and record the spatial distribution of laser intensities. If initially this area named as optical morphogenesis was greatly inspired by the analogies with hydrodynamics, soon it turned out that, as for the case of the temporal instabilities, the great flexibility associated to the laser operations has allowed the optical exploration of a large variety of original processes. In addition optical spatial patterns lend themselves naturally to applications in communication and information technologies, also in the quantum optics domain. The organization of this third part follows the scheme of previous chapters with detailed and well-planned presentation of the different spatial structures produced by the optical nonlinearities. The authors have made a special effort to place within a common theoretical framework results obtained by a large number of authors. A large number of phase diagrams and several plots of temporal or spatial laser intensities complete the theoretical analysis. In addition the last few chapters contain also the reproduction of several key experimental results.

An important common character to all the book parts is the complete mathematical analysis, with all the intermediates steps and the validity of the final equations precisely detailed. This approach makes the book a very useful source for a very large community of students and researchers. In addition it represents an excellent reference for specialists exploring new quantum-optics temporal-spatial instabilities. The first body of chapters represents the appropriate material for an introductory teaching of laser physics. However for that purpose the very theoretically oriented text should be completed by an experimental textbook in order to transmit to the student the strict connection between theory and experiments that makes this topic of nonlinearity in optical systems so fascinating.

Ennio Arimondo
Università di Pisa