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ORAZIO SVELTO

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Front cover photograph: The propagation of an ultraintense pulse in air results in self-trapping of the laser beam. The rich spectrum of colors produced is the result of the high intensity ($\approx 10^{14}$ W/cm^2) within the self-focused filament, producing nonlinear phenomena such as self-phase modulation, parametric interactions, ionization, and conical emission due to the beam collapse. The rainbowlike display with its sequenced color is due to diffraction of the different colors (copyright 1998 William Pelletier, Photo Services, Inc.).

Back cover photograph: Interaction of an ultraintense ($\approx 10^{20}$ W/cm^2) laser pulse with a target consisting of plastic and aluminum layers. The 450-fs pulse, with peak power of 1200 TW, is produced by the petawatt laser at the Lawrence Livermore National Laboratory. Numerous nonlinear and relativistic phenomena are observable including copious second harmonic generation (green light in photo) (courtesy of M. D. Perry, Lawrence Livermore National Laboratory).

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影印版前言

这是一部介绍激光基本原理的堪称经典的著作。作者是在激光物理前沿从事多年研究并做出了一些先驱性工作的意大利物理学家斯维尔托。该书的第一版出版于 1976 年（其中译本《激光原理》由科学出版社于 1983 年出版），其后于 1982 和 1989 年经过两次改版，这里推荐的是 1998 年出版的第四版。鉴于该书的前几版受到了物理学界的普遍欢迎以及考虑到激光技术蓬勃发展的需要，在这一版中作者对 1989 年出版的第三版做了大量的补充和修订，篇幅扩大了几近一倍。基于现代理论的发展，该书对于激光器的三大组成部分，即激活物质、泵浦系统与谐振腔的基本概念和基本理论的表述给出了许多更新；大大增加了对各类激光器，特别是最新发展起来的一些激光器的详细的介绍；进一步深入地阐述了激光束的各种特性和各种可能的变换方法。除了内容的大量更新之外，在这一版中还补充了许多散见于文献以及从作者本人所作的实验中抽取出来的实际的数值实例，添加了一些实用的数据表和一些数学附录。实际上这一版已经完全可以看作是一部新书。但是作者认为，尽管有如此大的变动，该书的写作初衷并没有改变，全书的逻辑思路以及组织结构仍然与前面几版相同，体现作者力图统一描述激光的特性以及其在物理和技术方面的广泛的应用，坚持强调物理的理解而不是详细的数学处理的一贯宗旨。

该书内容非常广泛，涵盖了与激光物理与技术相关的一切必要的概念、原理和最新的应用的详细介绍，注重了理论与实验的密切结合，同时也给出了为理解这一不断发展的学科所必需的基本数学框架。每一章都包含有大量习题，书末给出了部分解答。掌握该书的内容将会为尽快进入相关的前沿研究领域奠定很好的基础。因此，它很适合作为高等院校相关专业的高年级学生或研究生学习激光原理课程的教材。同时，该书的自容性以及易读性使它无论对于初学者还是该领域的专家都是一本很有价值的参考书。

丁亦兵
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2007 年 10 月 25 日

Preface to the Fourth Edition

This book is motivated by the very favorable reception given to the previous editions as well as by the considerable range of new developments in the laser field since the publication of the third edition in 1989. These new developments include, among others, quantum-well and multiple-quantum-well lasers, diode-pumped solid-state lasers, new concepts for both stable and unstable resonators, femtosecond lasers, ultra-high-brightness lasers, etc. This edition thus represents a radically revised version of the preceding edition, amounting essentially to a *new book* in its own right. However, the basic aim has remained the same, namely to provide a *broad* and *unified description* of laser behavior at the simplest level which is compatible with a correct physical understanding. The book is therefore intended as a textbook for a senior-level or first-year graduate course and/or as a reference book.

The most relevant *additions* or *changes* to this edition can be summarized as follows:

1. A much-more detailed description of Amplified Spontaneous Emission has been given (Chapter 2) and a novel simplified treatment of this phenomenon, both for homogeneous and inhomogeneous lines, has been introduced (Appendix C).
2. A major fraction of a new chapter (Chapter 3) is dedicated to the interaction of radiation with semiconductor media, either in a bulk form or in a quantum-confined structure (quantum-well, quantum-wire and quantum dot).
3. A modern theory of stable and unstable resonators is introduced, where a more extensive use is made of the ABCD matrix formalism and where the most recent topics of dynamically stable resonators as well as unstable resonators, with mirrors having Gaussian or super-Gaussian transverse reflectivity profiles, are considered (Chapter 5).
4. Diode-pumping of solid-state lasers, both in longitudinal and transverse pumping configurations, are introduced in a unified way and a comparison is made with corresponding lamp-pumping configurations (Chapter 6).
5. Spatially dependent rate equations are introduced for both four-level and quasi-three-level lasers and their implications, for longitudinal and transverse pumping, are also discussed (Chapter 7).

6. Laser mode-locking is considered at much greater length to account for, e.g., new mode-locking methods, such as Kerr-lens mode locking. The effects produced by second-order and third-order dispersion of the laser cavity and the problem of dispersion compensation, to achieve the shortest pulse-durations, are also discussed at some length (Chapter 8).
7. New tunable solid-state lasers, such as Ti: sapphire and Cr: LiSAF, as well as new rare-earth lasers such as Yb^{3+}, Er^{3+}, and Ho^{3+} are also considered in detail (Chapter 9).
8. Semiconductor lasers and their performance are discussed at much greater length (Chapter 9).
9. The divergence properties of a multimode laser beam as well as its propagation through an optical system are considered in terms of the M^2 factor and in terms of the embedded Gaussian beam (Chapters 11 and 12).
10. The production of ultra-high peak intensity laser beams by the technique of chirped-pulse-amplification and the related techniques of pulse expansion and pulse compression are also considered in detail (Chapter 12).

Besides these major additions, the contents of the book have also been greatly *enriched* by numerous examples, treated in detail, as well as several new tables and several new appendixes. The examples either refer to real situations, as found in the literature or encountered through my own laboratory experience, or describe a significant advance in a particular topic. The tables provide data on optical, spectroscopic, and nonlinear-optical properties of laser materials, the data being useful for developing a more quantitative context as well as for solving the problems. The appendixes are introduced to consider some specific topics in more mathematical detail. A great deal of effort has also been devoted to the *logical organization* of the book so as to make its content even more accessible. Lastly, a large fraction of the problems has also been changed to reflect the new topics introduced and the overall shift in emphasis within the laser field.

However, despite these profound changes, the basic philosophy and the basic organization of the book have remained the same. The *basic philosophy* is to resort, wherever appropriate, to an intuitive picture rather than to a detailed mathematical description of the phenomena under consideration. Simple mathematical descriptions, when useful for a better understanding of the physical picture, are included in the text while the discussion of more elaborate analytical models is deferred to the appendixes. The *basic organization* starts from the observation that a laser can be considered to consist of three elements, namely the active medium, the resonator, and the pumping system. Accordingly, after an introductory chapter, Chapters 2–3, 4–5, and 6 describe the most relevant features of these elements, separately. With the combined knowledge about these constituent elements, Chapters 7 and 8 then allow a discussion of continuous-wave and transient laser behavior, respectively. Chapters 9 and 10 then describe the most relevant types of laser exploiting high-density and low-density media, respectively. Lastly, Chapters 11 and 12 consider a laser beam from the user's viewpoint, examining the properties of the output beam as well as some relevant laser beam transformations, such as amplification, frequency conversion, pulse expansion or compression.

The inevitable price paid by the addition of so many new topics, examples, tables, and appendixes has been a considerable increase in book size. Thus, it is clear that the entire

content of the book could not be covered in just a one semester-course. However, the organization of the book allows several different learning paths. For instance, one may be more interested in learning the *Principles of Laser Physics*. The emphasis of the study should then be concentrated on the first section of the book (Chapters 2–8 and Chapter 11). If, on the other hand, the reader is more interested in the *Principles of Laser Engineering*, effort should mostly be concentrated on the second part of the book (Chapters 5–12). The *level of understanding* of a given topic may also be suitably *modulated* by, e.g., considering, in more or less detail, the numerous examples, which often represent an extension of a given topic, as well as the numerous appendixes.

Writing a book, albeit a satisfying cultural experience, represents a heavy intellectual and physical effort. This effort has, however, been gladly sustained in the hope that this completely new edition can now better serve the pressing need for a general introductory course to the laser field.

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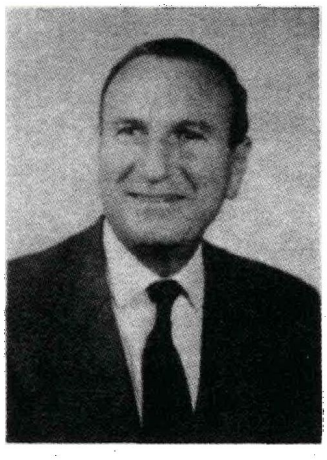
Milan Orazio Svelto



Orazio Svelto is professor of Quantum Electronics at the Polytechnic Institute of Milan and Director of the Quantum Electronics Center of the Italian National Research Council. His research has covered a wide range of activity in the field of laser physics and quantum electronics, starting from the very beginning of these disciplines. This activity includes ultrashort-pulse generation and applications, development of laser resonators and mode-selection techniques, laser applications in biology and medicine, and development of solid-state lasers. Professor Svelto is the author of more than 150 scientific papers and his researches have been the subject of more than 50 invited papers at international conferences. He has served as a program chair of the IX International Quantum Electronics Conference (1976), as a chair of the European program committee for CLEO '85 and CLEO '90, and he was general co-chair for the first CLEO–Europe Conference (1994). He is an elected member of the Italian "Accademia dei XL" and a Fellow of the IEEE.

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