



MASERS & LASERS

AN HISTORICAL APPROACH

Second Edition

Mario Bertolotti



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MASERS & LASERS

Second Edition

Foreword to the First Edition

Masers, and especially lasers, are by now familiar devices that are very widely used in many fields of science and technology. To a few, lasers seem to offer fulfilment of one of mankind's oldest dreams of technological power, an all-destroying energy ray. That may be the basis for the ancient, probably apocryphal, legend that Archimedes was able to set enemy ships on fire by using large mirrors to reflect and focus sunlight. The English novelist H.G. Wells, in his 1898 story *War of the Worlds*, had Martians nearly conquering the Earth with a heat ray. In the 1920s, the Soviet novelist Alexei Tolstoi wrote *The Hyperboloid of Engineer Gorin*, which device also was described as producing an intense light beam. Newspaper comic strips such as *Buck Rogers* in the 1930s made "disintegrator guns" familiar ideas.

Yet as scientists learned more about how light is produced and absorbed, these novelists' dreams seemed all the more unlikely. Thermal emitters of light, which were all we had, seemed to absorb the light that they emitted, if we tried to make them thicker to get more intensity. Yet it turned out that this and many other apparent difficulties could be overcome. Indeed, when the first lasers were operated, I and other scientists close to the research were surprised at how easy it turned out to be. We had assumed that, since lasers had never been made, it must be very difficult. But once you knew how, it was not at all difficult. Mostly what had been lacking were ideas and concepts.

This book blazes a new trail, in retracing the history and expounding the theory and experiments as they were discovered. This is a complex task, as there is no earlier book of comparable scope to use as starting point. Inevitably, there are many points in the discussion which I would state differently, and some which I would have to dispute. But Professor Bertolotti's long experience in this field, to which his research contributed much, has enabled him to produce a sound outline of the way things developed.

The treatment could serve very well as an introduction to the theory of masers and lasers, since these matters are thoroughly discussed in a sequence appropriate to the historical presentation.

Arthur L. Schawlow
Department of Physics
Stanford University
October 1982

Foreword to the Second Edition

After the explosion in the last 20 years in the number of books with the word “laser” in their title, I found myself muttering “what—yet another book?...” when I learned about Mario Bertolotti’s second edition of *Masers and Lasers*. Upon reading it, however, I was left with an altogether different reaction to the book, which I can only describe as—a great story, well told.

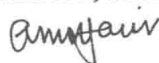
There is little doubt that the laser is shaping up as one of the great technological and scientific inventions of the twentieth century, and its practical and theoretical ramifications are reshaping our lives. A book that manages to clearly grasp and convey the human historical background of this invention (with names like Townes, Bloembergen, Basov, Glauber, plus many others, and their individual stories), as well as the chronology and significance of the key development in the field, is a major social document.

This need is excellently served by *Masers and Lasers*, and I would like to congratulate Mario Bertolotti on this major endeavor, and on the elegant and entertaining telling of the story. I found myself learning some new facts, for example, the early pre-laser period where concepts such as “negative absorption” by inverted population of atomic levels and contributions by scientists such as Einstein and Ladenburg were but a step away from proposing optical amplification and then oscillation.

I also found that some parts of the book could serve as a good introduction to the topic even in graduate level courses. One such example is Chapter 10, “On the statistical properties of light,” which is obviously a topic close to the author’s area of research.

In conclusion, I found the book highly instructive and enjoyed as well the personal/historical background material. I will make it a “Highly Recommended” reference for my future classes in quantum electronics and nonlinear optics.

December 9, 2014



Amnon Yariv, PhD

Martin and Eileen Summerfield

Professor of Applied Physics and Professor of Electrical Engineering
California Institute of Technology

Preface

Preface to the Second Edition

This second edition takes advantage of the many recollections that the first protagonists of the initial development of lasers have written. It was also necessary to update some developments. In particular, a general survey of the development of nonlinear optics and how lasers have evolved in the last 40 years has been included. Several arguments that were omitted in the first edition have been added, together with some new developments, such as micro-masers, lasers without inversion, nano-lasers, spasers, and so on. Lasers and their applications have experienced an exponential growth both in interest and development. I have, therefore, been obliged to compress the materials into a synthetic presentation considering the most important advances, adding references to more in-depth discussions that are now available, focused on single cases. I believe this revised edition is a reasonable good start for more extended study. In any case, I apologize for any omission and will be grateful to readers who provide me with additions and suggestions.

A special acknowledgment goes to my wife who allowed me to spend all my time on this work. I would also like to thank the Taylor & Francis editorial staff, Luna Han, Robert Sims, and Karthick Parthasarathy from Techset Composition, for help in publication and editing the manuscript.

Mario Bertolotti

Roma

June 2014

Preface to the First Edition

Nowadays masers and especially lasers are very popular devices. When masers were invented in 1951, they offered a completely new and revolutionary method of producing microwaves. The theoretical foundations necessary to understand the way they work and actually to build them, however, had already been well established in the 1930s. It took people 20 years to get rid of

Preface

the old traditional schemes of producing electromagnetic waves and to find a completely revolutionary path of achieving them and, as often occurs in these cases, at the moment the time was ripe and the same idea occurred to many scientists almost simultaneously.

Lasers were the natural extension of this idea to light. Mostly popularized, invented even before they actually worked by science fiction writers as the “death ray” and other similar names, lasers were for some time ironically defined as a “solution in search of a problem.”

Nowadays, there is scarcely any physical laboratory which does not own at least one. More applications are discovered every day. In fact, lasers have not been fully exploited yet, and probably their best applications are to come. I think it both interesting and instructive to trace out the history of how these devices developed since the first basic principles at their origin were established. And now let me say, as Agamemnon does in *Troilus and Cressida* by William Shakespeare (Act I, Scene II):

*Speak, Prince of Ithaca; and be't of less expect,
That matter needless, of importless burden
Divide thy lips, than we are confident,
When rank Thersites opens his mastiff jaws,
We shall hear music, wit, and oracle.*

Before starting, let me first acknowledge help from many people who provided me with documentation and discussion. Notably Professors N Bloembergen, B Crosignani, P Di Porto, H Gamo, R J Glauber, S F Jacobs, B A Lengyel, V S Letokhov, S I Nishira, A M Prokhorov, M Sargent, A L Schawlow, C P Slichter, C H Townes, and V Vavilov.

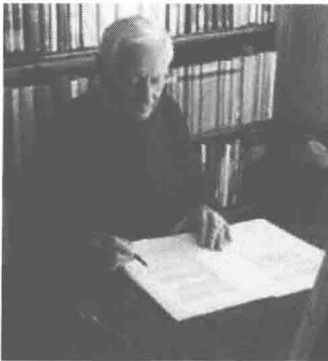
Special thanks are due to Dr. Roy Pike who kindly turned my Anglo-Italian into English, to Miss A De Cresce who, with great patience and ability, typed the manuscript and to Mrs F Medici and C Sanipoli for preparing drawings and diagrams.

Mario Bertolotti

Roma

October 1982

Author



Mario Bertolotti received his degree in physics from the University of Roma, Italy, and has been full professor of physics and optics at the Engineering Faculty of the University of Roma La Sapienza from 1970 until 2008. He is the author of more than 500 peer-reviewed publications. A major part of his research has been in lasers and their applications, as well as non-linear optics and nano-optics. He is an elected Fellow of the Institute of Physics, Optical Society of America (OSA), and European Optical Society (EOS), of the Italian Physical

Society (SIF) and the Italian Optics and Photonic Society (SIOF) of which he was the president.

He is currently enjoying his retirement with his wife, Romana de Angelis (an archeologist and a writer). They have two children, Alessandro, a television director and writer, and Elena, who died too soon. His inspiring cat Einstein passed on at the ripe age of 21, although the spirit of his illustrious homonymous Albert Einstein pervades this entire book.

Contents

Foreword to the First Edition	xiii
Foreword to the Second Edition	xv
Preface	xvii
Author	xix

CHAPTER 1	Introduction	1
1.1	Principle of Operation	1
1.2	The Devices	2
1.2.1	Masers	3
1.2.2	Lasers	4
1.3	Applications	4
1.4	Development	6
	Note	6

CHAPTER 2	Stimulated Emission: Could the Laser Have Been Built More than 80 Years Ago?	7
2.1	Stimulated Emission	7
2.2	Role of Stimulated Emission in the Theory of Light Dispersion	11
2.3	Experimental Proofs of Negative Dispersion	24
2.4	More on Negative Absorption	28
	Notes	30

CHAPTER 3	Intermezzo: Magnetic Resonance and Optical Pumping	35
3.1	Introduction	35
3.2	The Resonance Method with Molecular Beams	36
3.3	Magnetic Relaxation Phenomena in Solids	40
3.4	Magnetic Resonance: Bloch, Purcell, and Zavoisky	41
3.5	Bloch Equations	45
3.6	Experimental Proof of Population Inversion	51
3.7	The Concept of Negative Temperature.....	55
3.8	The Overhauser Effect.....	57
3.9	Spin Echo	61
3.10	Medical Application of Nuclear Magnetic Resonance (NMR).....	64
3.11	Electronic Paramagnetic Resonance.....	66
3.12	Atomic Clocks	66
3.13	Optical Pumping.....	71
	Notes	80
CHAPTER 4	The Maser	87
4.1	Introduction	87
4.2	Weber's Maser	89
4.3	Townes and the First Ammonia Maser	91
4.4	Basov and Prokhorov and the Soviet Approach to the Maser	100

4.5	The Three-Level Solid-State Maser	106
4.6	Optically Pumped Masers	113
4.7	The Hydrogen Maser	114
4.8	The Ancestor of the Free-Electron Laser	115
4.9	The Electron Cyclotron Maser	117
4.10	The Rydberg or Single-Photon Maser (Micromaser)	118
4.11	Two-Photon Maser	124
4.12	Maser Action in Nature	125
	Notes	131

CHAPTER 5 The Laser 141

5.1	Introduction	141
5.2	The Townes and Schawlow Proposal	141
5.3	Townes' and Schawlow's Idea	144
5.4	The Gordon Gould Story	148
5.5	The Dicke Coherence-Brightened Laser	154
5.6	Soviet Research	156
	Notes	159

CHAPTER 6 The First Lasers..... 163

6.1	Introduction	163
6.2	The Ruby Laser	163
6.3	The Four-Level Laser	175
6.4	The Neodymium Laser	178

Contents

6.5	The Gas Laser	181
6.6	The Cesium Laser.....	190
6.7	Laser Cavities	192
6.8	Further Progress in Gaseous Lasers	203
6.8.1	Neutral Atom Lasers	203
6.8.2	Ion Gas Lasers	205
6.8.3	Molecular Lasers.....	207
6.8.4	Excimer Lasers	210
6.9	The Liquid Laser: Dye and Chelate Lasers.....	211
6.10	The Chemical Laser	215
6.11	The Semiconductor Laser	217
6.12	Vertical-Cavity Surface-Emitting Laser Diodes (VCSELs)	231
6.13	Quantum Cascade Lasers.....	231
6.14	The Free-Electron Laser	233
6.15	Does the Laser Exist in Nature?	236
	Notes	238

CHAPTER 7	Laser Properties and Progresses in Novel Lasers.....	253
7.1	Introduction	253
7.2	Q-Switching	254
7.3	Modes in the He-Ne Laser	256
7.4	Mode Locking	258
7.5	Lamb's Theory	262
7.6	Mode Selection and Frequency and Amplitude Stabilization	266