

The Biomedical Laser: Technology and Clinical Applications

Edited by

Leon Goldman

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Director, Laser Laboratory
University of Cincinnati Medical Center

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Leon Goldman, M.D.
Director, Laser Laboratory
University of Cincinnati Medical Center
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Preface

The laser's range of application is extraordinary. Arthur Schawlow says, "What instrument can shuck a bucket of oysters, correct typing errors, fuse atoms, lay a straight line for a garden bed, repair detached retinas, and drill holes in diamonds?"^{*} The laser's specifically biomedical uses cover a similarly broad and interesting spectrum. In this book, I have endeavored to convey some of the fascination that the laser has long held for me. It is my hope that both clinicians and researchers in the various medical and surgical specialties will find the book a useful introduction. Biologists, particularly molecular biologists, should also find a great deal of relevant information herein.

This volume's distinguished contributors provide admirably lucid discussions of laser principles, instrumentation, and current practice in their respective specialties. Safety, design, capabilities, and costs of various lasers are also reviewed. We have aimed to create a practical text that is comprehensive but not exhaustive. Our emphasis on the practical, rather than the esoteric, is dictated not only by the short history of biomedical laser use, but by the extent of the community to which this information will appeal.

Because of its unique properties and the diversity of its uses, one is apt to forget that the laser employs a special form of light. In studying the laser as a medical, surgical, or biological tool, some understanding of light and its electric effects is required. This is particularly important in surgery, where for the first time the physician has an instrument that does not touch the tissue it cuts. The laser operates with lower hemorrhage rates than the traditional scalpel, the high-frequency electrosurgical unit, the plasma torch, or cryosurgery. Indeed, one type of laser can coagulate bleeding vessels 3–4 mm in diameter. Therefore, appropriate discussion

^{*}Personal communication, 1978.

has been included of the special properties of laser light and its effects on living tissue. Although much is known, many challenges remain in developing the laser's full potential in these areas. Investigations in molecular biology, immunobiology, analytical spectroscopy, phototherapy, photochemotherapy, imaging, laser surgery, and the biomedical aspects of laser communication and information handling are all progressing rapidly, while laser dentistry and laser veterinary medicine are developing more slowly. This book will serve to orient us as we look ahead to new technological developments and to refinements in surgical, diagnostic, and therapeutic techniques.

Leon Goldman

Contributors

Alessandra M. Andreoni, Ph.D., Professor of Physical Technology, University of Milan; Researcher, National Research Council, Istituto di Fisica del Politecnico, 32-20133 Milano, Italy, *Chapter 7*

Billie L. Aronoff, M.D., Director of Surgical Oncology, Charles A. Sammons Cancer Center; Professor of Surgery (Clinical), Southwestern Medical School, University of Texas, Dallas, Texas 75246, U.S.A., *Chapter 19*

Peter Wolf Ascher, M.D., Universitäts Dozent, Neurochirurgische Klinik, Karl Franzens Universität Graz; Director, Neurochirurgischen Universitäts Klinik, Graz, Austria, *Chapter 17*

Michael W. Berns, Ph.D., Professor of Biological Sciences, Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

Sari Brenner, M.S., Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

Janis Burt, Ph.D., Graduate student, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

L. Karen Chong, B.S., Department of Developmental and Cell Biology, University of California, Irvine, California, 92717, U.S.A., *Chapter 6*

Richard M. Dwyer, M.D., Assistant Clinical Professor of Medicine, UCLA/Harbor General Hospital; Senior Research Scientist, Center for Laser Studies, School of

xii *Contributors*

Engineering, University of Southern California, Los Angeles, California 90007, U.S.A., *Chapter 20*

Gilbert T. Feke, Ph.D., Associate Scientist, Eye Research Institute of Retina Foundation, 20 Staniford Street, Boston, Massachusetts 02114, U.S.A., *Chapter 13*

James P. Fidler, M.D., Associate Professor of Surgery, College of Medicine, University of Cincinnati, Cincinnati, Ohio 45267, U.S.A., *Chapter 16*

Nikolai F. Gamaleya, Ph.D., Professor of Biophysics; Chief, Department of Laser Biology, Kavetski Institute for Oncology Problems, Kiev, U.S.S.R., *Chapter 21*

John A. Goldman, M.D., Associate Professor, Rheumatology and Immunology, Emory School of Medicine, Atlanta, Georgia 39303, U.S.A., *Chapter 23*

Leon-Goldman, M.D., Director, Laser Laboratory, University of Cincinnati Medical Center, 231 Bethesda Ave., Cincinnati, Ohio 45267, U.S.A., *Chapters 1, 2, 4, 8, 18, 25*

David B. Greenberg, Ph.D., Head, Department of Chemical & Nuclear Engineering, College of Engineering, University of Cincinnati, Cincinnati, Ohio 45221, U.S.A., *Chapter 22*

Marie J. Hammer-Wilson, M.S., Staff Research Associate III, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

F. Heppner, M.D., Clinical Professor of Neurosurgery, School of Medicine, University of Graz, Graz, Austria, *Chapter 17*

Geza J. Jako, M.D., Research Professor of Otolaryngology, Boston University School of Medicine, Boston, Massachusetts 02118, U.S.A., *Chapter 15*

Isaac Kaplan, M.D., Professor of Surgery, Medical School, Tel Aviv University; Head, Department of Plastic Surgery, Beilinson Hospital, Petah-Tiqwa, Israel, *Chapter 9*

Margarita C. Kitzes, Ph.D., Associate Specialist, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

Maurice B. Landers, III, M.D., Professor of Ophthalmology, Duke University Medical Center, Durham, North Carolina 27710, U.S.A., *Chapter 12*

Lih-Huei L. Liaw, M.S., Staff Research Associate, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

- A. Longoni, Ph.D., Professor of Electronics, Istituto di Fisica del Politecnico, 32-20133 Milano, Italy, *Chapter 7*
- Byron J. Masterson, M.D., Professor and Chief, Section Gynecologic Oncology, The University of Kansas College of Health Sciences; Director, Section Gynecologic Oncology, Truman Medical Center, Kansas City, Missouri 66103, U.S.A., *Chapter 11*
- Patricia A. McNeill, Ph.D., Lecturer, Department of Developmental and Cell Biology, University of California, Irvine, California, U.S.A., *Chapter 6*
- Myron C. Muckerheide, Vice President, Research, Mark Laser Systems, Inc., Wausau, Wisconsin 54401, U.S.A., *Chapter 24*
- Edward Perry, Engineer and Safety Officer, Laser Laboratory, College of Medicine, University of Cincinnati, Cincinnati, Ohio 45267, U.S.A., *Chapter 8*
- Scott P. Peterson, Ph.D., Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*
- Joshua Raif, M.Sc., Vice President Research & Development, Laser Industries Ltd., Tel-Aviv, Israel, *Chapter 9*
- Jerome B. Rattner, Ph.D., Researcher, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*
- Charles E. Riva, D.Sc., Associate Professor of Ophthalmology, Biochemistry and Biophysics, University of Pennsylvania, Philadelphia, Pennsylvania 19104, U.S.A., *Chapter 13*
- C. A. Sacchi, Ph.D., Professor of Physics, Istituto di Fisica Politecnico, 32-20133 Milano, Italy, *Chapter 7*
- Gary C. Salzman, Ph.D., Biophysics Group, University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87545, U.S.A., *Chapter 5*
- Helmut Schellhas, M.D., Associate Professor of Obstetrics and Gynecology and Radiation Oncology; Director, Gynecologic Oncology, University of Cincinnati Medical Center, Cincinnati, Ohio 45267, U.S.A., *Chapter 10*
- Ann Siemens, B.S., Staff Research Associate, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*
- David H. Sliney, M.Sc., Instructor, Department of Military Medicine and History, Uniformed Services University of the Health Sciences; Chief, Laser Branch, Laser Microwave Division, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland 21010, U.S.A., *Chapter 3*

Kenneth Strahs, Ph.D., Postdoctoral Researcher, Department of Developmental and Cell Biology, University of California, Irvine, California 92717, U.S.A., *Chapter 6*

Orazio Svelto, Ph.D., Professor of Quantum Electronics, Istituto di Fisica del Politecnico, 32-20133 Milano, Italy, *Chapter 7*

Michael D. Tribbe, Project Engineer, Procter & Gamble Co., Cincinnati, Ohio 45267, U.S.A., *Chapter 22*

Rene C. J. Verschueren, M.D., Ph.D., Department of Surgical Oncology, University Hospital Groningen, 9700 RB Groningen, The Netherlands, *Chapter 14*

Myron L. Wolbarsht, Ph.D., Professor of Ophthalmology and Biomedical Engineering, Duke University Medical Center, Durham, North Carolina 27710, U.S.A., *Chapter 12*

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Introduction to the Laser in Medicine

Leon Goldman

THE NEED FOR THE DEVELOPMENT OF SPECIAL INSTRUMENTS FOR THE LASER IN MEDICINE

The central problem confronting the laser researcher today in clinical medicine is laser safety. To enhance safety for both the patient and the operator, the flexibility of the laser beam must be increased. All forms of optics have been tested: prisms, lenses, windows, rods, and more recently, fiber optics. Optical fibers of quartz, capable of transmitting laser beams through internal reflection (Fig. 1.1), are proving to be useful in medicine. Quartz fibers are widely used in laser communications, information handling, and computer technology. Current developments include fiber-optics systems for the far-infrared CO₂ laser (Fig. 1.2). Other new combinations of special fibers, lens systems, mirrors, and prisms will extend the flexibility of fiber-optic transmission to new areas of treatment.

The safety of the laser for surgical use can also be enhanced by improving its coagulation capabilities. Quartz and sapphire cutting scalpels and transmission probes use transparent blades, with the laser coagulating blood as the incision is made. The optic wave is omitted near the cutting edge of the blade surface, increasing coagulation. For this blade, the argon laser is usually the source of laser radiation because its wavelengths are absorbed by red hemoglobin (Fig. 1.3). A type of photocoagulating scalpel has been developed by Auth (personal communication).

Reductions in the sizes and weights of the operating probes and precision focusing all make for more precise instruments. For lasers in the infrared spectrum, a beam of low-output HeNe laser is often used to outline target areas because

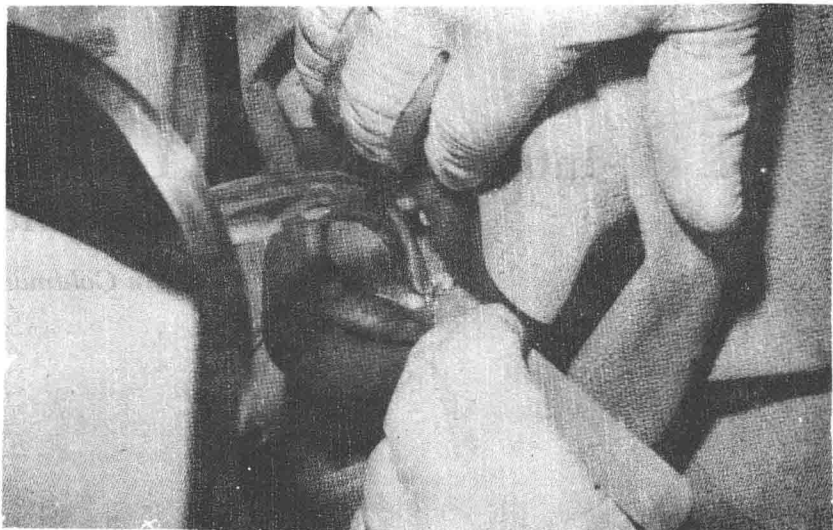


Fig. 1.1. Transmission of pulsed ruby laser through tapered quartz rod for treatment of dental caries.

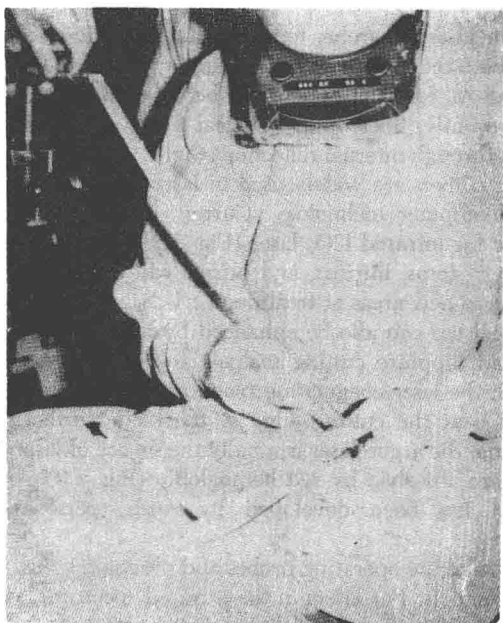


Fig. 1.2. Effective treatment of skin cancer of the toe by means of CW Nd laser, 300 W output, transmitted through Nath quartz fiber.

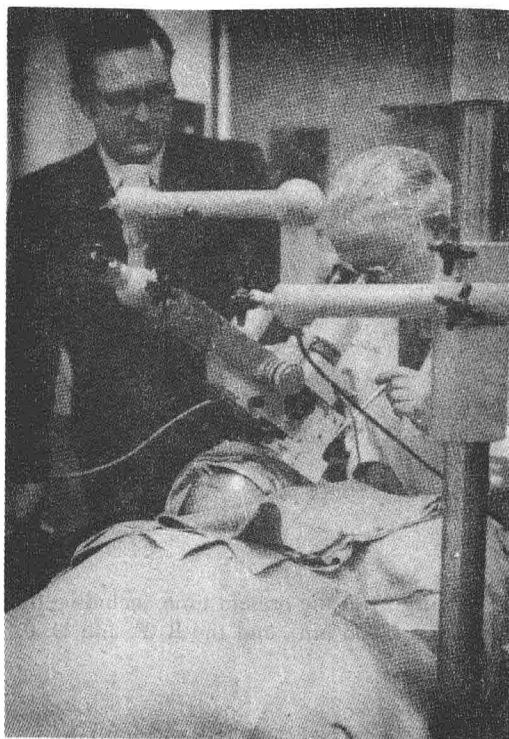


Fig. 1.3. Microirradiation with argon laser for small areas residual after laser treatment of vascular lesions of the face. The laser was attached with fiber-optics transmission to an operating microscope.

infrared is invisible, making targeting difficult. Self-contained water cooling will also make the CO_2 laser unit more flexible.

PARAMETERS FOR THE MEASUREMENT OF THE LASER BEAM

For laser scientists to communicate, precise characteristics of each beam must be known. These standard terms will be used frequently in the following chapters:

1. Wavelength, in nanometers
2. Total pulse duration—duration of burst of energy
3. Energy and power densities in joules per square centimeter
4. Irradiance—watts per square centimeter
5. Beam divergence—spread of beam
6. Mode content—single or multiple

The pulse duration of the laser may be expressed in terms of continuous wave (CW); normal mode in milliseconds, or Q-switched. The term Q is carried over

from radio- and microwave terminology and identifies the so-called quality factor of a resonating system. It is expressed in nanoseconds.

TYPES OF LASERS

Ten lasers are now in use in medicine, surgery, and biology (specific details will be described elsewhere):

1. Helium-neon (HeNe) (632.3 nm)
2. Ruby (694.3 nm)
3. Argon (476.5–514.5 nm)
4. Krypton ion (476.1–647 nm)
5. Neodymium (Nd) (near infrared 1060 nm)
6. Neodymium and yttrium aluminum garnet (YAG) (1060 nm)
7. Carbon dioxide (CO_2) (10,600 nm infrared)
8. Helium cadmium (325–441.6 nm)
9. Nitrogen (337 nm)
10. Dye

New lasers are being investigated for surgery at the present time, including the carbon monoxide (CO) laser, the holmium (2065 nm), and the R. F. and D. C. wave guide CO_2 .

LASER SAFETY

The operator of lasers has a great responsibility for laser safety. Detailed information on laser measurement devices should be consulted by those responsible for controlling output of laser radiation. The American National Standards Institute (ANSI) has a special committee on laser radiation measurement, and the data are available from them. Measuring instruments are available to measure the output of laser equipment. These devices are essentially absorbent devices that convert the laser beam into heat and measure the change produced. Special devices are available for ultra-fast measurements, such as the 2-photon-absorption fluorescence devices. When continuous wave power measurement is needed, thermal power collimators may be used. Power densities are also measured. Power density is the time rate by which energy is emitted and is usually measured in watts or joules per second. For pulsed lasers, the capacity is measured as joules per centimeter squared of the output of the laser.

A Special Note of Caution

The American National Standards Institute has issued the following warning in regard to laser measurements.

Measurements should only be attempted by persons trained or experienced in laser technology and radiometry. Routine survey measurements of lasers or laser systems are neither required nor advisable when laser classifications are known and the appropriate control measures implemented. (ANSI, 1979)

SUMMARY

Developments in the use of the laser beam are proceeding rapidly. New approaches to medical and surgical care with the laser are a major part of this advancement. Although these developments are welcome, improvements in instrumentation, increased knowledge on the part of the user, and extreme caution are highly essential to assure the safety of both the patients and of those who use the equipment.

REFERENCE

American National Standards Institute Inc (ANSI). Committee on the Safe Use of Lasers. Z136.1—1979, New York.