The Biomedical Laser: Technology and Clinical Applications

Edited by

Leon Goldman

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Director, Laser Laboratory
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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

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Contents

The Laser: A Revolution in Medical Care

Laser Uses in Biology

1

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 CO_2 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

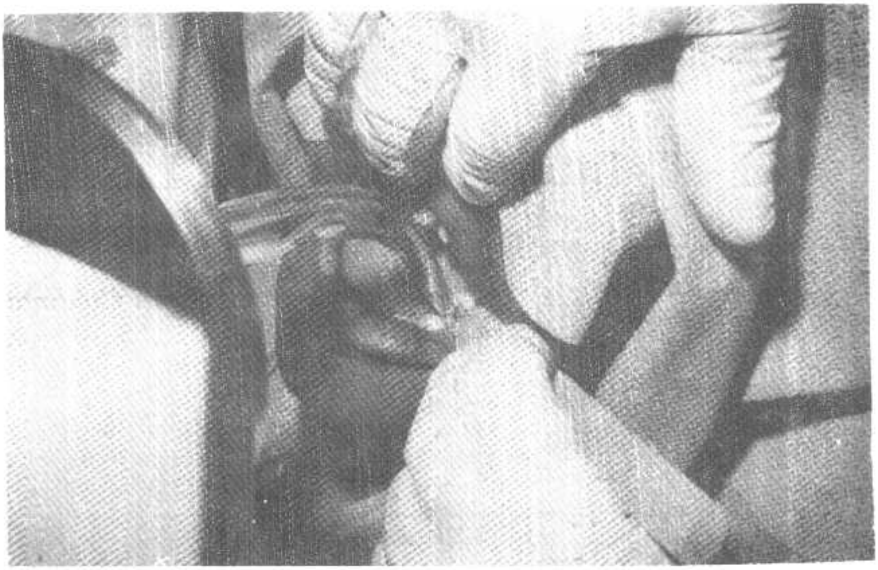

Fig. 1.1. Transmission of pulsed ruby laser through tapered quartz rod for treatment of dental caries.

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.

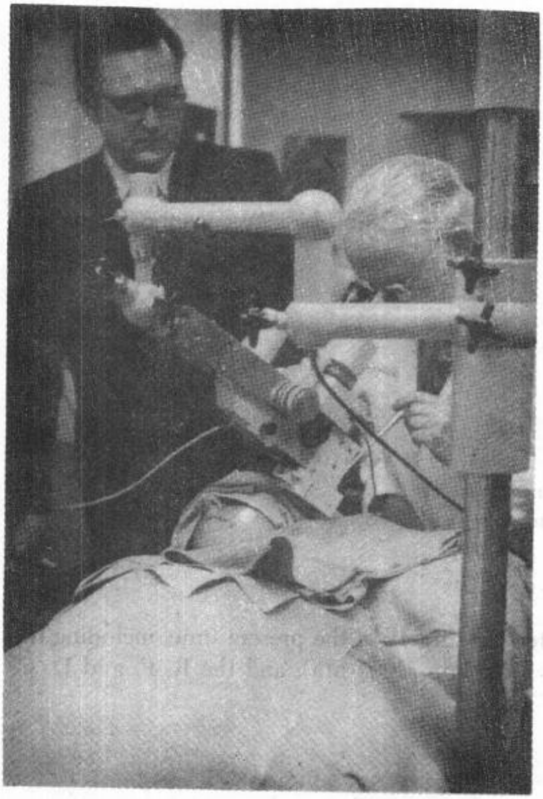

Fig. 1.3. Microirradiation with argon laser for small areas residual after laser treatment of vascular lesions of the face. The laser was attached with fiberoptics transmission to an operating microscope.

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 . 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.