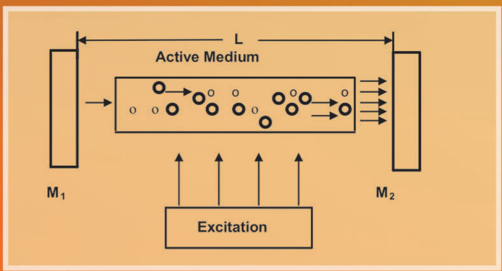
LASER IN BIOSCIENCE, INDUSTRY, AND DEFENCE

NARAIN MANSHARAMANI



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Preface

The objective of writing this monograph is to highlight laser in bioscience, industry, and defence and its futuristic development and uses exclusively for scientists, engineers, and students. The applications of laser in bioscience are diagnosis, testing, biosimulation, photocoagulation, photodynamic therapy, and surgery. The applications of laser in industry are in various materials processing starting with testing, cutting, marking, polishing, welding, drilling, annealing, aligning, and measurement. The applications of laser in semiconductors are lithography, repair, and manufacturing processes like sputtering and cladding. In defence, starting with training aids, laser is used for ranging, viewing, imaging, guidance, navigation, communication, and safety; and as weapon and for countermeasure. Lasers are widely used in entertainment, computer, consumer equipment, construction, atmospheric study, meteorology, agriculture, forestry, basic science, sensors for pollution control, early warning against land slide or earthquake, and communication. It is very difficult to cover all applications of laser, however, this monograph covers most important and cost-effective applications where other tools or methods are not as effective as lasers. For more details, references of books, journals, and conference proceedings are given.

This monograph comprises nine chapters. *Fundamental of Light and Laser Basics* provides a historical account of lasers starting from Newton's Corpuscular's theory of light and interaction of light with matter to how Charles Townes arrived in developing theory of lasers. *Propagation of Laser Beam in Atmosphere* describes scattering, molecular absorption, and various optical effects of lasers that are useful for ranging and remote detections. *Laser Sources* dwells upon various types of laser sources useful in the field of bioscience, industry, and defence. *Systems, Devices, and Components* provides an account of components like detectors, focusing, and beam delivery devices. *Laser in Bioscience* describes the use of lasers in eye surgery, photocoagulation, photodynamic for early cancer diagnosis, distorting cancerous cells, tuberculosis and burn, and bioscience study. *Laser in Industry* explains various applications like welding, cutting, polishing annealing, etc.; and different manufacture procedures, diamond cutting and polishing, semiconductors manufacturing, ultraviolet laser lithography, engraving and testing, and quality assurance. *Laser in Defence* describes various applications like weapon simulation, ranging remote detection of explosive and biological warfare agents, etc. *Futuristic Developments/Applications* provides an overview of future of diode-pumped ceramic disc laser, high power laser diode, and quantum cascade lasers in bioscience, industry, and defence.

Laser Safety provides an account of possible laser hazard/laser beam hazards and gives a comprehensive account of precautions against laser and first-aid.

Good source of information for lasers and applications are *Applied Optics* (USA), *IEEE Journal of Quantum Electronics*, *Laser Focus World*, *Photonics Spectra*, *Optics Letters*, *Photonics News*, Proceedings of SPIE, and *Applied Physics Letters*.

I am grateful to Shri SS Sundaram, Director, IRDE for giving permission to use the library facilities at IRDE.

In the end, I would like to thank my son Shri Rohit Mansharamani, for presenting a laptop to me on father's day. This has made my writing work easier. This book could not have been written without the encouragement, patience, and support of my wife Smt Sarla.

June 2012 Narain Mansharamani

Dehradun

Chapter 1

Fundamentals of Light and Laser Basics

1.1 HISTORY OF THEORY OF LIGHT

In 1666, Sir Isaac Newton, after his famous experiment on prismatic decomposition of white light into its component colours, elaborated on what is known as Corpuscular theory of light. According to Corpuscular theory, light is regarded as flight of material particles emitted by a source, the sensation of light being produced by their mechanical action upon the retina. The rectilinear propagation followed once from the second law of motion. He explained reflection, refraction, and colour in thin film by putting rays of light into fits, i.e., corpuscles being supposed to arrive at the surface in different phase, i.e., fits of easy reflection and easy transmission. Small bodies have attractive powers or some other force by which they stir up vibrations in which they act, vibration being swifter than the rays, overtakes successfully, and agitate them, increase and decrease their velocities thereby put them into these fits.

In 1676, Romer demonstrated that light requires a finite time for its propagation, travelling across space with a velocity, which he estimated at 3,08,995 km/s. The impact of corpuscles moving at such high speed might well expect to exert a pressure. Although, optical pressure could not be detected at that time, due to corpuscular striking surface. Huygens considering Wave theory, explained reflection, refraction, and double refraction in unaxial crystal by Wave theory. But Newton clung to the idea of corpuscles, presumably, as he could not visualise strong medium, which could be defined, if Wave theory was given. Later, discovery of polarisation of light was a blow to Huygens Longitudinal Wave theory. Frensel gave concept for transverse wave and explained interference of light. He had to define elastic solid medium ether, which can sustain waves at high speed with no obstruction to material bodies, but millions of times rigid than steel. Although no evidence of longitudinal disturbance was observed in ether, since transverse one in elastic ether medium must be associated with longitudinal disturbances.

In 1821, HC Osterd observed magnetic effect of current, and Michael Faraday's conception of electric and magnetic force and their interrelation expressed in terms of lines of force were founded. Faradays laws of electromagnetic induction were established in 1831. From this, James Clerk Maxwell developed the equation that underlines all modern theories of electromagnetic waves.

In 1860, Maxwell showed that the propagation of light could be regarded as an electromagnetic phenomenon; the wave consists of an advance of coupled electric and magnetic forces. If an electric field is varied periodically, a periodical magnetic field is obtained, which in turn generates a varying electric field and the disturbance is passed on in the form of a wave which is called as electromagnetic wave. Maxwell's theory predicated the speed at which these electromagnetic waves would travel from measurements of the magnetic field of electric current, the velocity of propagation being the ratio of the electromagnetic to the electrostatic unit. This ratio, determined, from electric and magnetic measurements, turned out to be the velocity of light, and indicated that light was essentially an electromagnetic phenomenon. Hertz discovered the wave predicated by Maxwell in 1892, which produced electric oscillation in a pair of conductors between which sparks were passed. The conductor radiates waves that could be detected by another pair of similar conductors, which oscillates in resonance with the first pair, causing the passage of minute's sparks between these conductors. Maxwell theory, like the electric solid theory requires ether, but not a mechanical one in which material displacement took place but, an electromagnetic one, in which displacement of current and magnetic field could occur. The periodic disturbances, which are supposed to constitute these waves, were called displaced current by Maxwell. These displaced currents can occur in free ether, or in a dielectric, i.e., in non-conductor of electricity. Maxwell theory told nothing about the nature of this electric displacement, so that in one sense, about the real nature of luminous disturbances were much vaguer than the wave 50 years earlier, when the elastic solid theory was generally accepted. For in the motion of a solid, we are dealing with perfectly definite physical process. As Schusler remark in the preface of his work on Optics ‘So long as the character of the displacement, which constitute the waves, remain undefined, we cannot pretend to have established a theory of light[1-3].

1.2 LORENTZ THEORY OF LIGHT SOURCES

Maxwell theory identified light as an electromagnetic disturbance, HA Lorentz advanced this idea that the atoms and molecules contained electrons, but are capable of vibration under the influence of a restoring force, when displaced. The bound electrons execute damped vibration under the influence of a restoring force, when displaced. The bound electrons, executing damped vibration were supposed to be the source of the luminous disturbances, or it might act as an absorber of radiation energy, when its natural frequency of vibration was in agreement with that of the radiation[2,3,4]. This theory accounted for many of the newly discovered effects of magnetism on light, as well as the older phenomena of refraction, dispersion, etc.

1.3 BLACK BODY

Kirchhoff established that at a given temperature, the ratio between the emission ε and absorption power A for a given wavelength is same for all bodies.

$$\varepsilon/A = constant \tag{1.1}$$

For all bodies at the same temperature, the more powerfully a body absorbs, the more powerfully it will emit when heated, i.e., black body will give more light when heated. A black body absorbs all electromagnetic radiations that fall on it; such an object if heated would be a perfect radiator, producing radiation which is called black

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About the Book

This monograph covers laser basics, laser beam propagation, and most important cost-effective laser applications in bioscience, industry, and defence. Its use in bioscience is described for painless refractive and general surgery, highly effective coagulation for internal and external bleeding, and detection and curing diseases. It also highlights future applications of laser in preventing infectious and virus diseases for which there is no effective medicine. In industry, besides cutting and welding, laser finds importance in marking, cladding, ultraviolet lithography, and diamond processing. The future applications in deep hole drilling with compact high power fibre and ceramic laser that will be economical for oil exploration are discussed. In defence, laser will find more use in underwater application and uranium enrichment with efficient infrared lasers and possible clean energy by controlled nuclear fusion. The concept of ultra high power laser development using upper atmosphere as amplifying medium to deflect/disintegrate large asteroid hit earth has been discussed.

About the Author

Shri Narain Mansharamani obtained postgraduate degree in physics in 1960 and electronics technology in 1962 from Rajasthan University. After working as Assistant Physicist (Instruments) at Indian Agricultural Research Institute (IARI), New Delhi, he joined Instruments Research and Development Establishment (IRDE), Dehradun in 1965. After creating facilities in lasers, he developed laser range finders (LRF) using Ruby and Nd:Glass in early seventies. He was on deputation at the Royal Signal and Radar Establishment (RSRE), Great Malvern, UK during 1976–77. After working on low level detection for compact LRF and doing research on thermal imaging and electronic materials, he worked on the development of LRF for various service roles at IRDE. Some of these LRF accepted by Services, were manufactured at IRDE, and BEL engineers were trained for production for bulk supply to services. After retirement from IRDE, he delivered lectures in educational institutes and training centres. He has published 28 research papers and guided students for postgraduate thesis. He has published three monographs in LRF and lidar techniques.

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