Chapter 1

Introduction to LASER

History
Physics
Types
Hazards and Safety

The term **LASER** is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. LASER light is usually spatially coherent, which means that the light is emitted in a narrow, low-divergence beam, or can be converted into one wavelength with the help of optical components such as lenses(Gilberson 2004).

History of Medical LASER:

Light Amplification by the Stimulated Emission of Radiation was originally described as a theoretical concept by Albert Einstein in 1917, but it was not until 1954 that the first stimulated emissions of microwave radiation (MASER) were generated by J.P. Gordon and C.H. Townes at Bell Laboratories at 1954. The first LASER was built in 1960 by Dr. T.H. Maiman at Hughes Aircraft Company, using a synthetic ruby rod stimulated by high intensity flash lamps, which generated millisecond pulses of coherent 694nm ruby laser (red) light . Shortly afterwards, 1060nm (near-infrared) laser light was generated by stimulating glass rods doped with Neodymium (Nd:Glass Laser)(Clarke et al 2002).

Within a year, pioneers such as Dr. Leon Goldman in 1961 began research on the interaction of LASER light on biologic systems, including early clinical studies on humans. Interest in medical applications was intense, but the difficulty controlling the power output and delivery of LASER energy, and the relatively poor absorption of these red and infrared wavelengths led to inconsistent and disappointing results in early experiments. The exception was the application of the ruby LASER in retinal surgery in the mid-60's. In 1964, the argon ion laser was developed. This continuous wave 488nm (blue-green) gas LASER was easy to control, and it's high absorption by hemoglobin made it well suited to retinal surgery, and clinical systems for treatment of retinal diseases were soon available(Clarke et al 2002).

In 1964, the Nd:YAG (Neodymium: Yttrium Aluminum Garnet) LASER and CO2 (Carbon Dioxide) LASER were developed at Bell Laboratories. The CO2 laser is a continuous wave gas LASER, and emitted infrared light at 10600nm in an easily manipulated, focused beam that was well absorbed by water. Because soft tissue consists mostly of water, researchers found that a CO_2 laser beam could cut tissue like a scalpel, but with minimal blood loss. The surgical uses of this laser were investigated extensively from 1967-1970 by pioneers such as Dr. Thomas Polanyi and Geza Jako, and in the early 70's, use of the CO_2 LASER in ENT and gynecologic surgery became well established, but was limited to academic and teaching hospitals(Stellar et al 2003).

Dye LASERs became available in 1969, and excimer lasers in 1975. Since that, many other different LASER systems have become available for industrial scientific, telecommunication, as well as medical use. In the early 1980's, smaller but more powerful lasers became available, and were soon appearing in community hospitals and even physician's offices. Most of these systems were CO_2 lasers used for cutting and vaporizing, and Argon LASERs for ophthalmic use. Nd:YAG and KTP LASER systems were used by larger hospitals for the new field of laparoscopic surgery. These second generation LASERs were all continuous wave, which tend to cause non-selective heat injury, and proper use required a long learning time and experienced LASER surgeons(Hall et al 2003).

The single most significant advance in the use of medical LASERs was the concept of pulsing the LASER beam, which allowed selective destruction of abnormal or undesired tissue, while leaving surrounding normal tissue undisturbed. The first LASERs act by the principal of "selective thermolysis" were the Pulsed Dye Lasers introduced in the late 1980s for the treatment of port wine stains and strawberry marks in children, and shortly after, the first Q-switched lasers for the treatment of tattoos. Another major advance was the introduction of scanning devices in the early 1990s, enabling precision computerized control of laser beams. Scanned, pulsed lasers are now widely used in plastic and cosmetic surgeries(Westra et al 2005).

Medical LASERs have made it possible to treat conditions which previously were untreatable, or difficult to treat. Patients benefit by improved results and less cost. In the last few years, the main focus of research and development of medical LASERs has been on LASER hair removal , the treatment of vascular lesions including leg veins, and vision correction. The current research is directed towards non-ablative LASER resurfacing, no-touch computerized vision correction, and improved photodynamic therapy for treatment of skin cancer and for hair removal(Russell et al 2002).

How LASER work ?

The gain medium of a LASER is a material of controlled purity, size, concentration, and shape, which amplifies the beam by the process of stimulated emission. It can be of any state: gas, liquid, solid or plasma. The gain medium absorbs pump energy, which raises some electrons into higher-energy (excited) states. Particles can interact with light both by absorbing photons or by emitting photons. Emission can be spontaneous or stimulated. In the latter case, the photon is emitted in the same direction as the light that is passing by. When the number of particles in one excited state exceeds the number of particles in some lower-energy state, population inversion is achieved and the amount of stimulated emission due to light that passes through is larger than the amount of absorption. Hence, the light is amplified. By itself, this makes an optical amplifier. When an optical amplifier is placed inside a resonant optical cavity, one obtains a LASER. The light generated by stimulated emission is very similar to the input signal in terms of wavelength, phase, and polarization. This gives laser light its characteristic coherence, and allows it to maintain the uniform polarization and often monochromaticity established by the optical cavity design(Stellar et al 2003).

The optical cavity, contains a coherent beam of light between reflective surfaces so that the light passes through the gain medium more than once before it is emitted from the output aperture. As light circulates through the cavity, passing through the gain medium many times by means of reflection, thus the light is amplified many times. (Needham & Jones 2004).

Properties of LASER beam :-

In most cases, a laser emits light in the form of a laser beam. This means that the light dominantly propagates in a certain direction, typically with most of the optical power concentrated to a small area of the order of a square millimeter. The variation of beam size can be very small with large width or very fast beams. Generally, LASER beams exhibit a high degree of spatial coherence, which is related to a high beam quality. As a result, such