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THE LASER—25 YEARS OF DEVELOPMENT

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If there is, in the length and breadth of science and technology, an innovation unparalled by any other, that has permeated and brought about revolutionary changes in almost all facets in research and day to day life and is now in the forefront of the ever so important high-tech industry, it is the Optical Maser, which evolved in the spring time of the space age as a result of ardous and meticulous research into basic phenomena in Physics. In effect, this device which is presently called the Laser represents one of the most spectacular scientific and technical milestones of the 20th century.

When the history of the laser is written, it will probably—begin with that day in July 1960 when T. H. Maiman of the Hughes Aircraft Co. in California carried out an experiment, that was remarkably simple in concept, where a deep red beam of light, possessing an extremely high degree of coherence, was generated from a synthetic Ruby rod. As the very term Laser—an acronym for light amplification by stimulated emission of radiation, itself reflects, its roots however goes deeper, to the principle of stimulated emission presented by Albert Einstein in the year 1917. Due recognition should also be given to its Pioneers Charles Townes and Arthur Schawlow of the Columbia University, Weber of the Maryland University and the two Russians Basov and Prokhorov who proposed the use of this concept for microwave amplification in the years 1953 and 1954. Their intensive theoretical and experimental research efforts brought the scientists to the very brink of developing the laser by the end of the 1950's and Maiman was the first to report the success. The Laser thus born was an unusual source of light which was in many ways incomparably brighter than the sun, its salient features—the monochromaticity and tuning of wavelength, high intensity and variable pulse duration, good directionality and controllable polarization and the most striking of all the high degree of coherence, exciting the imagination of the scientists.

The appearance of the Ruby Laser heralded the laser age in optics and aroused a flurry of activity in this field. By the fall of 1960 coherent radiation was also generated from a gas discharge consisting of Helium and Neon at the Bell Telephone Laboratories in Holmdel, New Jersy, by Ali Javan and his co-workers. Once the concept was established literally hundreds of new laser materials including crystals, glass, plastics, liquids, gases, and even plasmas were discovered, the emitted radiation stretching from the far infra-red through the visible to the mid ultra-violet. Of these the near infra-red semiconductor lasers, developed simultaneously in several laboratories in the U.S.A. and the U.S.S.R. in the years 1962 and 63, were unlike their large predecessors, minute in size ; their dimensions being in the millimeter range. Among the most powerful and the efficient are the highly stable infra-red molecular CO_2 lasers invented by C. K. N. Patel again of the Bell Telephone Laboratory in 1964. These versatile devices that have been studied in great detail can operate both in the CW and the pulsed mode emitting a broad spectrum of out put powers ranging from a few watts to ten's of Terra Watts in sub—picosecond pulses.

When it comes to versatility and cost-effectiveness the lasers made from organic dyes that produce radiation in the visible region of the spectrum easily stands out. A useful quality of this liquid state device, first discovered by Peter Sorokin at the IBM's research centre, Yorktown Heights, is its sharp spectral output. The rare gas halide or the excimer lasers that operate in the ultra violet and the vacuum ultraviolet of the spectral regions are in a class of their own. This is principally because they are the first lasers outside the infra-red region that appear to be scalable to high single pulse energies with nigh average power and efficiency. Since the first demonstration, nearly a decade ago, they have experienced a very rapid and a successful growth. But the most exciting of all seems to be the free electron laser, somewhat a baby in the laser family. Its tunability extends theoretically from the extreme ultra violet through the visible and the infra-red out to the millimeter region. However, this is a machine only a few have seen, let alone used, that still needs considerable development. It requires access to high energy accelerator and thus is a rarity even in the research environments.

Within a very short span of time the significance of the laser as an exemplary scientific development was acknowledged and the American Physicist Charles Townes—unequivocally the generating force behind the laser, along with A.M. Prokhorov and N. Basov were awarded the Noble Prize in the year 1964, showing the high regard of the world's scientific fraternity for this work. Seven years later, Denis Gabor was conferred the Nobel Prize for his notable and creative contributions to holography, a discipline that matured into a serious scientific and technological field with the advent of the laser. Then in the year 1981, this most prestigious award was bestowed on Nicholass Bloembergen and Arthur Schawlow for their impressive and untiring work in the field of non—linear optics—a fledgling until the arrival of the laser.

For a short while, this young brash off-spring of high technology was a solution looking for a problem. Now one can speak of problems looking for the right laser solution. Attesting to such acceptance of lasers is their development from a scientific curiosity to a billion dollar industry. Today it has become a permanent piece of equipment in the laboratory and in most industries, its applications ranging from destructive weaponry in the form of death rays to the healing arts probing blood, sweat and tears. They ring up prices in super markets and are used in industry for cutting cloth and welding steel. In the field of entertainment finely focussed laser beams are employed to play back video and audio programmes from pre-recored discs. Easily over a million personnel are involved in laser research and its related trade and many a governments have adopted vast laser programmes.

In scientific research its applicatons are innumerable; tbe unique properties of laser light being instrumental in achieving very important breakthroughs. The coherence of the laser has made possible accurate measurements of length over long distances. One of the most dramatic experiments was carried out in 1973, where the distance to the moon was measured to an accuracy of six inches. It has also been used to measure the speed of light with very high precision ; the new value being a thousand times more accurate than the older accepted value. Interaction of laser light with matter has produced results that has led to existing ideas and theories to be refined to a far higher degree than hitherto possible while spectroscopic studies have realisep new dimensions.

Tunable lasers have proved to be of immense value to the Photochemists. Of particular interest are those selective processes applicable to laser isotope separation, where an intense laser beam tuned to a specific resonance cause only one kind of isotope to react leaving all other isotopes inert. It also provides the most precise and controllable means available for studying the nature of molecular bonds as ultrashort laser pulses can be employed to break particular bonds in large molecules. Two other technologies that are worth mentioning are the chemical synthesis by laser initiated chain reaction and laser synthesis of very pure substances. But it will probably be at least a decade before acceptable results are achieved and the technique is accepted.

Laser systems covering a wide frequency spectrum of varying out put power capabilities are already in the market. Industrial laboratories the world over, are working on high energy devices for applications involving drilling, cutting, scribbing, welding and semi-conductor manufacturing. Each of these applications have unique parameters in terms of power, energy, wavelength, the beam profile and the like and its the 10 Um Carbon Dioxide Laser that dominates as the widely used system. Its solid state counterpare is the Nd YAG laser generating 1.06 ηm light. This shorter wavelength it more readily absorbed by metals making it more desirable in electronic sols—dering, spot—welding and micro-hole burning. As the technology improves laser machinery zap the price barrier, the trend being towards easier maintenance, compactness and low cost. For instance, laser printers once rarely seen due to their astronomical price tags are now competing with the lowly priced conventional devices.

A machine that may well invade the industrial establishments is the laser robot combination—the Combo, that is still in the experimetal stage. It represents the best of two new technologies mixed to gain the spatial flexibility and the accuracy of a robot and the process flexibility of a laser.

In the field of communications it is so firmly entrenched that when the space systems of the future are launched they will probably talk to us over laser beams. Its unique features presenting many challenges to the conventional micro-wave systems. First there is capacity. This can be attributed to the wide bandwidth available in laser light and thus it appears feasible to carry the enormous amounts of data generated by deep space probes. Then there is security, as the highly collimated laser beams provide inherent protection from eavesdropping and jamming. Another technical advantage is the vast transmission distance it offers—due to the directionality of the laser beam. In the land based laser communication systems, already installed, several thousands of different messages are transmitted simultaneously over the same pathway ; the distance extending over 100's of kilometers. The use of repeaters or boosters is minimal in these systems that also employ the latest of fibre optic technology and is therefore particularly desirable for under sea cables as the problem of overhauling failed components in the deep sea does not arise. Of the several candidates tried out, the tiny semicondutor diode laser has been found to be the most appropriate for these systems.

While the scientists are still looking for new laser materials instruments consisting of highly stable laser oscillators are used by surgeons in practically every aspect of the healing arts, one of the earliest applications being that of dealing with detached retinas of the human eye. Reattachment is effected by means of a low energy ruby laser, where the retina is spot welded back in place while leaving tissues unaffected only a few cell widths away. This has now been replaced by the Nd YAG systems whose wavelength is much more effective on all types of tissues in the eye and the green light emitting Argon Krypton laser also seems to be a strong contender. It is envisaged that before long the use of lasers in opthalmology would become routine and its applications will be extended to glaucoma and cataract treatments as well.

In the operating theatre, the laser has proved its worth as a bloodless scalpel and at present it is one of the most effective means of dealing with delicate surgery involving tumours in the brain and in the spinal cord. The intensity available in the laser produce the required incisions while the heating effect of the beam cauterizes the blood vessels. In the process, as no contact is made with instruments sterilization is not necessary and as the procedure takes only a short while the misery of deep anaesthetic is no longer needed. In fact, its potential for such complex internal operations without major surgery is very high. Among the lasers used its the one employing CO_2 which is in the forefront. The high power emitted from these lasers makes it possible to vapourise or to rapidly cut through any tissue and are highly preferable for resection of densely fibrous and calcified tumours. Their high efficiency also leads to convenient and portable systems, the only disadvantage being the lack of suitable optical fibres for the efficient transmission of the invisible CO_2 laser light. For coagulation the Argon ion laser seems to be the best and since it can be accurately pinpointed the ion laser gets the highest grade in micro-surgical precision. Recent research however, indicates that once the free electron laser is developed it will replace almost all lasers presently being used in surgery, as it provides an ideal source for blood coagulation and for cutting tissues.

The laser is now fast becoming the treatment of choice for a broad range of malignancies. It is less damaging than all other forms of therapy and has recorded near total successes in almost all cases treated. The process termed photoradiation, combines laser light with a cancer tissue sensitizer, the sensitizer producing highly reactive chemicals to destroy the host cancer cells when exposed to red Argon laser light. The technique also has applications in the diagnosis of cancer where a different fluorescent dye and a blue light emitting Krypton laser scanner are employed. The healing light of the laser has also been felt in gynaecology, dermatology, ENT, orthopedics, acupuncture, paralysis and in many other specialities.

Essentially the most unproductive of all seems to be the use of this fascinating device in the defense systems of the super powers, where several billions of dollars are spent on laser weapons. Within the military, from the land based offensive weapons in battlefield conditions and airborne laser guided missiles to the utility of lasers in defending naval fleets against missile attacks, it has a broad range of tactical applications. Obviously its most publicized programme, involves the star wars scenario, where the ultimate goal is to develop the X -ray laser, a means of rendering enemy nuclear missiles and spy satellites impotent.

Associated with the military are also the laser radar programmes, that have been around for many years, the systems developing from simple range finders to more complex devices consisting of military target detection, weapons guidance, navigation, obstacle avoidance by aircraft, etc. Though the performance of the short wavelength Nd YAG and GaAs lasers is much superior in clear weather the use of the highly popular CO_2 laser ensures complete exploitation of the atmospheric window in the 8—12 ηm region. Further, its emitted radiation experiences very low attenuation even in smoke, dust and haze the very elements that a battlefield produce.

The world' largest laser facilities are installed in the American National Laboratories—the Lawrence Livermore and the Los Alamos. Though nutured mainly under military sponsorship for weapons research they would also bring the world closer to an era of cheap and safe production of electricity. The method employed is called inertial confinement fusion, where nuclei of two light atoms in the form of a fuel pellet is compressed by means of several high power laser beams directed simultaneously from all sides. This causes the pellet to implode, the density and temperature rising to values comparable to those in the centre of the sun and sufficient to fuse the nuclei. The heat energy generated in the process can be used to produce electricity.

"Shiva", the first of these laser systems built in 1977 at Livermore, has been named after the Hindu God of destruction. It was a Neodymium laser emitting 25 terra watts of power in the ultra short pulsed mode. "Nova" the upgraded version of Shiva, unveiled in April 85, generate a power that is two hundred thousand times greater than the power produced by the entire electrical generating capacity in Sri Lanka. The twenty arm laser, the largest to be built, occupies four rooms, the largest as long as a football field and the tallest as high as a five storeyed building. The high power laser systems at Los Alamos employ CO_2 of which the "Helios" that delivers 20 TW in one nanosecond pulses was the first to be built. Its upgraded version "Antares" containing 24 arms is the world's largest CO_2 laser system and became operational in November 1983.

As the 25th year of development draws to an end speculations on what the future holds in the way of further laser developments and applications become more bizzare . The most optimistic visions conjuring up communications with intelligent life elsewhere in the universe, airborne X-ray lasers shooting down hostile ICBM's to the more realistic 3-dimensional holographic television. But such speculations about the laser technology of the future are hazardous. Too often wild projections are made in some areas while being overly conservative in others and failing to foresee significant advances in them. Thus it is best to leave the job of predictions to the psychics and the astrologers. There is however, one predication that can be made with assurance; since its birth the laser has come a long way and can only add to its lustre in the years to come.