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# THE 50th ANNIVERSARY OF LASER

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**Abstract:** The year 2010 will mark the 50th anniversary of the invention of laser – one of the greatest technical achievements of humankind during the last century. This paper reviews the role and impact of laser in contemporary life, and its wide range of application in science, education, industry, medical and military practice, agriculture, archeology, information transfer, control and diagnostics of ready made goods, etc.

**Keywords:** Laser, Application, Nanotechnology.

> "The laser has a great future. It is difficult to predict where and how it will find application, however, I think that it is a whole age of technology."
>
> *Louis Braille*

## INTRODUCTION

Deliberating upon the question which innovation has changed the world, many scientists would answer that it was the laser. Soon after its invention in 1960, it attracted the attention of many scientists from all over the world. Soon, this new type of light turned into a symbol of our way towards future. A number of American dailies hailed the emergence of this novel invention calling it the "light of hope"– Reader's Digest; whereas the "New York Times" saw in the laser a revolutionary invention which might illuminate our future. The "Time" magazine called it the greatest discovery in the realm of solid body physics, second only to the development of transistors. The development of the transistor revolutionized electronic science thus paving the way for a new type of industry – the semi conductor. As was the case with many great inventions, it was no sooner than the laser was invented that they began to look for possible ways to harness its power for military purposes. Mass media were eager to announce the new weapon called the "Deadly beams". Back in 1962, the then defense secretary was quoted by "Aviation Week and Space Technology" as granting USD 1.5 million for funding laser development and its related technologies. For the newborn laser industry, this money was of a crucial importance.

However, the reality of laser application on our planet has proven to be far more pragmatic and relevant. The predictions of laser pioneers about its possible applications were greatly outdone. Today, lasers are not just another fancy toy in the hands of researchers but have acquired a status of indispensable part of our daily life

## PRESENTATION

### The beginnings

Back in 1917, Albert Einstein [1] set the first milestones on the way of laser development by introducing his first theoretical formulations on stimulated emission.

In 1939, during his work on the dissertation, the Soviet physicist V. B. Fabricant proved the possibility to utilize light emission for the purpose of pumping given media which, in turn, would create the opportunity to intensify light passing through it. During the World War II (1941-1945) research was discontinued and resumed in 1951 when professor Fabricant, along with his assistants M Vudinsky and F. Butaeva, claimed an invention whereby they propose "a way of intensifying electromagnetic radiation based on the utilization of stimulated emission". This method allows implementation of intensification of electromagnetic waves from the ultra violet, the visible and infra-red frequency range, as well as the radio frequency range. As it is often the case with all significant discoveries and inventions, the board of evaluators declared this particular invention inappli-

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cable. Eight years later, however, the patent experts had to reconsider their former decision and the inventors were awarded their due certificates of authorship with an earlier date: that of June 18, 1951. [2].

Three years later, the Soviet and American researchers obtained,independently from each other, a stimulated high frequency electromagnetic emission. The Soviet scientists referred to it as molecular generator, whereas Americans called it maser (Microwave Amplification by Stimulated Emission of Radiation). This unit was capable of emitting waves within the micro-wave range of the electromagnetic spectrum.

In 1953, the world of science saw a new stage in the development of maser by Charles Townes, James Gordon and Herbert Zeiger [3] fig.1.

The race for developing the first laser started in 1958 when the December issue of the American journal „Physical Review" published the article "Infra-red and Optical Masers", authored by physicists from the Bell laboratories: Charles H. Townes and Arthur L. Schawlow [4]. This signaled the theoretical beginning of the race for developing the optical maser, later on referred to as laser fig.2.

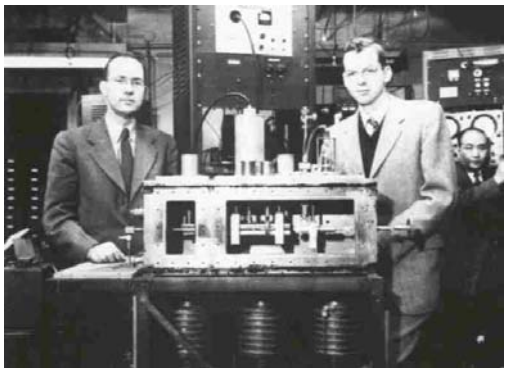

*Figure 1. In 1955 г. Charles H. Townes (left) and James P. Gordon presented their development: MASER (Microwave Amplifcation by Stimulated Emission of Radiation) which later evolved into present day laser*

*Figure 2. Arthur L. Schawlow during his laboratory investigations in 1960. He and Charles Townes developed in 1958 the concept which underlies the theoretical fundamentals of laser.*

In the applied research, it is a common practice to have different scientists working on the same scientific problem, but only one of them is the first to get to the right solution. This was the case with the first laser. Unlike his predecessors, Theodore H. Maimans was the first to reach the long cherished goal by using an active medium of ruby crystal ($Al_2O_3$ with $Cr^{+3}$ ions) that was largely ignored by the other contemporary researchers (fig.3). Although his work at the Hughest Research could not enjoy the funding of his competitors working in the laboratories of IBM, Siemens, Bell etc, and though he himself was not regarded as a potential rival of their research, in the long run, he has actually won the race by creating the laser.

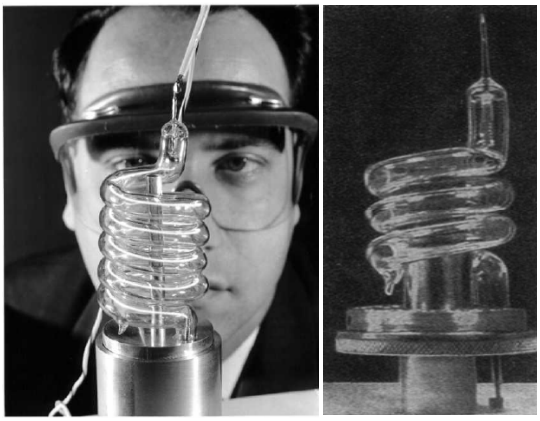

*Figure 3. Theodore H. Maimans and his ruby laser that marked the beginning of a new era in the sphere of science and technology*

The achievement of Maimans was so unexpected and surprising that his request to make a publication in Physical Review Letters was rejected.

However, on 3 August 1960, the journal "Electronic Design" published the following note: "If he has what he thinks he has, he most certainly has a laser."

Confident in his success, he took the next step which was quite untypical for an American: Maimans decided to publish the results of his research in the British journal "Nature" (the issue from 6 August 1960) [5]. On the seventh of July 1960, the Hughest Reserch Company announced, at the special briefing, the invention of laser. The results obtained by Maimans paved the way to the triumphant entry of lasers into the realm of science and technology. The later years would see the rapid development of laser technologies which continues with the same momentum in our 21st century.

Despite its ground-breaking essence, Maimans' invention was not given the appropriate credit and the Nobel Prize for 1964 was awarded to his contemporary scientists Townes, Prohorov and Bas-

sov (fig.4) for their theoretical investigations in the field of quantum electronics, which brought about to the development of masers and lasers [6]. Another contemporary scientist, Schawlow, was awarded the Nobel Prize for 1981 for his research in the area of laser spectroscopy [7].Thus Maimans remained empty-handed. Underrated by his fellow academicians, this scientist managed to offer his exquisite solution in terms of technology and application and gave the world a new type of light source that revolutionized science and technology.

*Figure 4. The 1964 Nobel prize winners for physics : left to right Alekander Prokhorov, Charles H. Townes and Nikolay Basov,*

Yet what is behind the word "LASER"?

It is an acronym which comes out of the initial letters of the words contained in its description: "*L*ight *A*mplification by *S*timulated *E*mission *R*adiation", in other words, the laser amplifies light – the electromagnetic wave. With some types of laser, this amplification may reach incredibly high values; for example, rated power of 1 PW (petawatt) = $10^{15}$ W. This power is equal 300 times the capacity of all power plants operating on our planet.

The radiation of this new source of electromagnetic emission features absolutely new properties, which are not found in the nature:

- Extremely high intensity;
- Monochrome substance;
- Coherence;
- Possibility to be focused on a spot of small diameter;
- Very short pulses.

The impact

At the dawn of the laser technology, the French physicist Louis des Brailles said: "The laser has a great future. It is difficult to predict where and how it will find its application, however, I think that it is a whole new age of technology".

Since their invention and until today lasers have impacted various fields of science and technology. Within the time of just one generation, new technical trends have emerged such are holography, non-linear and integrated optics, laser technologies, laser chemistry, utilization of lasers in nuclear fusion control and other tasks in power engineering and energy science. Over the past five years, the average annual growth in utilizing the laser systems has varied between 12 and 15%.

Further in this paper, I will refer to some concrete examples that will illustrate the fact that utilization of lasers and their unique properties offers novel applied research solutions.

Featuring high monochrome substance and coherence of radiation, lasers guarantee their successful application in spectroscopy, initiation of certain chemical reactions, splitting of isotopes; systems for measuring linear and angular velocities, instruments built on the basis of interference phenomenon, systems for optical communication. Special emphasis is to be laid on the new trend of holography which could not have found its existence had it not been for the invention of lasers. (In 1964 Emmet Leith and Uris Upatnieks from Michigan Institute of Technology, created the first 3D holograph image which can be seen without using special specs.)

High energy density and power of laser radiation in the focused spot of the laser beam are the prerequisite for the development of a numerous new technologies such are laser cutting, welding, boring, surface hardening, marking and etching, as well as the systems for nuclear fusion control.

High accuracy of direction and low dissipation of laser radiation are the prerequisite for various applications of laser in civil engineering, geodesy, mapping, target marking and measuring of distances to satellites as well as in the systems for space and submarine communication

The development of non-linear optics was given a great impetus with the emergence of laser and a definite progress was witnessed in the investigation and application of such phenomena as generation of harmonics, self-focusing of light beams; multi-photon absorption, various types of light dissipation etc. Scientific investigations have indicated that utilizing lasers as light source in many conventional optical instruments opens a wide range of possibilities for development of entirely new devices featuring incredible technical characteristics

such are brightness amplifiers, quantum hydro-meters, fast operating optical systems ,etc.

Lasers have found a successful application in medicine, dental practice and biology: in surgery (including eye surgery), in the therapy of certain illnesses and in biological experimentation where fine focusing allows for selective work on the individual cells or their constituent parts.

A large number of the above examples has evolved into individual trends in the science and technology. The purpose of quoting them is to better illustrate the great impact lasers have had on the overall development of science and technology and the society in general.

Historical review of the development of the laser technology and equipment in Bulgaria

At the dawn of the laser technology development, Bulgarian science gave its highest credit to the significant discovery of Maimans. The first investigations began in 1963 and, a year later, the research fellow Vasil Stefanov, from the Institute of Electronics at the Bulgarian Academy of Sciences, started the first Bulgarian ruby laser. The following years saw the appearance of the first Bulgarian helium-neon laser (1965) and, in 1967, the first lasers, having operated with carbon dioxide, emerged.

The related research was not confined to the institutes of the Academy of Sciences alone, but was carried out on the university level as well. For example, at the Clement Ohridsky University in Sofia there was developed a large number of lasers, optical frequency converters and injection lasers with active media of GaAs.

Development of laser sources went in tandem with active research of laser technologies and their industrial applications. In 1980, a team of researchers at the National University in Sofia developed the first industrial laser installation and called it LIR-1. It was designed to cut out sections from the coating of graphite electrodes in electric arc furnaces and to control the quality of the coating. In many countries the application of this particular type of coating is done under the patent of the Bulgarian engineer Alexander Valchev.

During the early 80s of the last century, the semiconductor industry in Bulgaria was rapidly developing. To meet its demands, the scientists and research workers from the School of Physics at the National University in Sofia, headed by the Assoc. Prof. Konstantin Stamenov, designed and developed a laser unit which was to be used to adjust the thin-film and thick-film resistors, correction of photo masks, quartz resonators and filters. This laser unit was awarded a gold medal prize at the exhibition of the International Trade Fair in Plovdiv in 1981.

In 1982, the 38th International Trade Fair in Plovdiv displayed a novel laser development; "ZEFIR", designed and produced by the Research Institute in Optics – Sofia. The device was intended for use in treatment of various types of cancer and for enhanced cure of wounds. Another development of this Institute was the laser interferometer, designed to perform a highly accurate measurements in metal cutting machines engineering. The accuracy featured by this unit is 1 micrometer and the result of measurement is read on a digital display.

Four years later, in 1986, another promising laser unit (winner of the gold medal award) was shown at the exhibition of the 42nd Trade Fair in Plovdiv. This was a laser based manufacturing system equipped with Nd:YAG plotter type laser designed to inscribe letters, symbols and graphs upon metal or dielectric materials. The system was developed at the Higher Institute of Mechanical and Electrical Engineering in Gabrovo, Bulgaria. Lead by the physicist, Lyubomir Lazov, this team of developers designed the system by incorporating into it Bulgarian modules: Nd:YAG – laser; a plotter featuring drawing surface of 300 x 400 мм and computer control by 16-bit PC. It found its industrial application in machine manufacturing companies, tool manufacturers and measuring instruments.

In 1987, the first Ph.D thesis on the laser technologies in Bulgaria was defended with the topic "Investigation in the Process of marking with Nd:YAG laser on materials used in mechanical engineering and electronics' [8].

## CONCLUSION

On 16 May 2010, one of the most significant achievements of technology – the laser, celebrated its 50th anniversary. For some years this invention of crucial importance was in the process of seeking its own ground. A brilliant young engineer perceived the right direction for the decisive experiment and generated the first laser beam. Today we can say that laser has found its application in a multitude of engineering and scientific activities such are manufacture, medicine and biology, digital and domestic equipment and appliances, communications, environmental protection etc.

Einstein and Maimans could hardly have thought that the application of laser could touch such aspects of human life as tattoo drawing or light shows performed at the concerts of rock stars. Nevertheless, the invention of laser is a typical object lesson illustrating the point that a complex physical theory could be turned, by means of a hard work,

dedicated efforts, perseverance and, of course – money, into a tangible fact materialized in so broad a range of applications.

The first of its kind "laser relay" around our planet Earth was organized in 2005 in commemoration of the 100th year anniversary of the Relativity Theory of Einstein. Actually this "relay" turned out to be a worldwide show of the laser beam. It started from Princeton, the place where Einstein worked during his last years, and, following the speed of our planet orbiting, made a full circle around it. This way the scientists reminded the world of the fundamental role of the physics science in the history of the human race. This world-renowned event was possible due to a good organization, management and, last but not the least, the awe inspiring achievements in the realm of laser physics and technology.

The sun also rises every day and shines over our common home. Human genius has created its own little sun in the substance of the laser beam which likewise could be controlled and used in service to people, helping them to reach new summits in their development.

## HIGHLIGHTS OF RETROSPECTION

1917 – Albert Einstein introduces the concept of stimulated emission.

1940 – V. Fabrikant indicates the possibility to utilize stimulated emission in amplification of electromagnetic waves.

1952–54 – N.Basov, A. Prohorov and independent from them. Ch. Townes employ stimulated emission in developing micro-wave generator of radio waves with wave length of 1,27см – the maser.

1960 .– Maimans developed the first laser – the ruby laser

1960 – Ali Javan (Mitte) Donald Herriott (vorn) und William R. Bennett jr. Ignite their Helium-Neon-Laser a little after the ruby laser of Theodore H. Maimans.

1961 – Nd: YAG is developed;

1962 – a semiconductor laser was created

1963 – Basov, Prohorov and Townes become the Nobel prize winners for physics. Their theretical works lay the foundation for development of laser.

1964 – the $CO_2$ laser was developed

1965.– the first industrial application of lasers is performed in a serial boring of diamonds

1969 – boring of holes in bearings and stones for axles in clockworks

1970 – adjustment of resistances by means of lasers

1978 – First industrial application of laser cutting

1980 - first application of laser welding

1982 – laser diodes were developed

1984 – application of 2D laser cutting

1985 – first industrial application of laser welding (Tassenstößel)

1988 – first implementation of diode pumping of Nd:YAG laser

1990 –compared to other related technologies laser cutting is most competitive in terms of quality and economy for small and medium batches

1992 – implementation of powerful kilowatt Nd:YAG laser, and radiation transfer along optic fibers

1993 – implementation of powerful diode pumped kilowatt Nd:YAG laser and radiation transport along optical fibers

1994 – emergence of first diode lasers

1998 – implementation of kilowatt diode lasers

2001 – development of fiber laser

2002 – development of disc laser

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ПЕДЕСЕТА ГОДИШЊИЦА ЛАСЕРА

**Сажетак:** Године 2010. обиљежава се 50. годишњица изума ласера – једног од највећих техничких достигнућа човјечанства у току посљедњег вијека. Овај рад даје преглед улоге и утицаја ласера у модерном животу и широки спектар његове примјене у науци, образовању, индустрији, медицинској и војној пракси, пољопривреди, археологији, преносу информација, контроли и дијагностици произведене робе, итд.

**Кључне ријечи:** ласер, примјена, нанотехнологија