The Laser- Fifty Years

From Curiosity to Everybody's Property

The laser theory is described by Albert Einstein in 1917, and since then imaginative versions have been used in Star Wars movies for several decades, but the first functional model was demonstrated at Hughes Research Laboratories in 1960. The first version was built mainly for verification of the theory, but five decades of further research and developing gained the laser entry in nearly all fields of modern society.

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The History

The theoretical platform for the instrument was established by Albert Einstein in 1917 through the paper "Zur Quantentheorie der Stralung". That was a re-derivation of Max Planck's law of radiation and a confirmation of the theory he described was carried out by independent scientists in 1939. However, it was not until the fifties the research around the phenomena shot ahead and the first laboratory model was demonstrated.

From then on and until now the development has shot incredibly ahead and all types of lasers can be found in nearly all fields of our daily life, not only within research industry and other more industrial areas, but also for daily use in the private homes.

Charles H. Townes and two graduate students produced the first microwave amplifier already in 1953, a device operating on similar principles as the laser, but amplifying microwave radiation, not in the visible area. The device was called MASER, an abbreviation of Microwave Amplification by Simulated Emission of Radiation. As a curiosity, back then, this was opposed by several academic colleagues, among them the Dane, Niels Bohr, arguing that the MASER was theoretically impossible.

The first instrument based on visible light been the first time called "optical Maser". However, at a conference in 1959, Gordon Gould from the Columbia University published the terms LASER in the paper "The LASER, Light Amplification by Simulated Emission of Radiation". The laser was born.

Laser Applications

The first lasers were only scientific instruments, but quickly many found

The following articles are compiled and edited of

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Classical spectagular laser effects. Photo credit: Wikipedia.

the theory very suitable for commercial products. The first application for the general population was the supermarket bar code scanner, an instrument that revolutionized the product handling both for the market and for the customer. In people's homes the first laser equipped device was the disc player, introduced in 1978 and ready for the first consumers in the beginning of 1982, followed shortly by the laser printer and other products. Today lasers for ordinary people's usage are found in different products everywhere.

LASER is now a well functioning application with regard to the following fields;

Medicine: Bloodless surgery, laser healing, surgical treatment, kidney stone treatment, eye treatment, dentistry.

Industry: Cutting, welding, material heat treatment, marking parts.

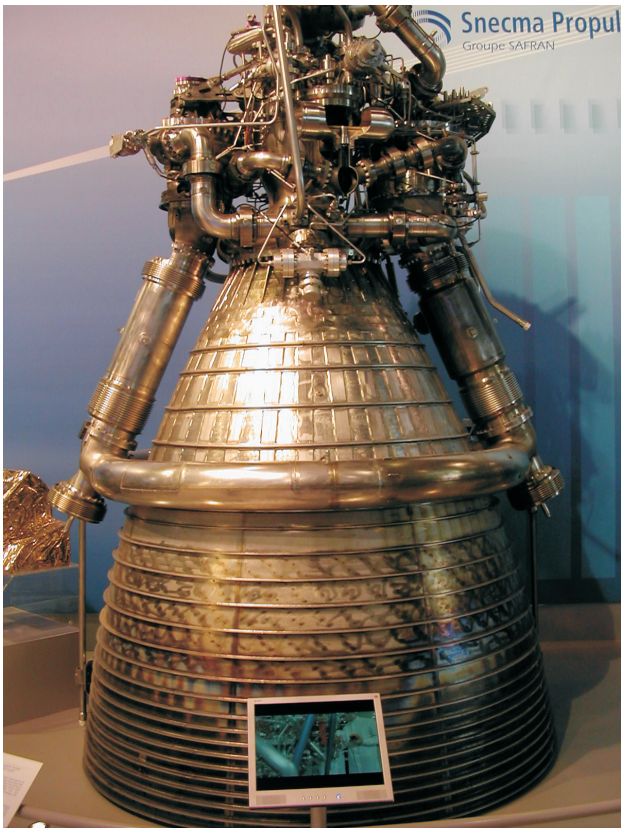
Defence: Marking targets, guiding missiles, missile defence, electro-optical countermeasures and with regards to blinding enemy troops.

Research: Spectroscopy, laser ablation, laser annealing, laser scattering, laser interferometry, LIDAR.

Commercial product development: Laser printers, CDs, bar code scanners, thermometer, holograms, bubble grams.

Laser lightning displays: Laser light shows.

Cosmetic skin treatments: Acne treatment, cellulite and mole reduction, hair removal.



Industrial lasers for production of launcher nozzles increase the efficiency in production of the next generation Vulcain engine.

Photo Credit: NordicSpace

The power consumption is for obvious reasons very different from the different types of lasers. A simple laser pointer uses less than 1 mW, a DVD player 5-10 mW, the majority of commercially available solid-state lasers used for micromachining 1-20 W while lasers used in industrial cutting can have a power consumption up to 3000W.

Laser Safety

Already in the beginning the device was characterised as dangerous. It is not difficult to understand, models of the device can cut steel plates without problems. Today it is accepted that even low power lasers with only few milliwatt of outputs can be hazardous to human eyesight when the beam from such a laser hits the eye directly or after reflection from a shiny surface. For that reason, warnings for proper usages are formulated and different classes of lasers based on their effect on people's health have been established as well for security measures. The least dangerous are machines such as CD players etc. where the laser is encapsulated and cannot be seen. This type is placed in the dangerous class 1. Pointers with an effect of around 1 mW power are harmless with normal use, but harmful when pointing directly in the eye. This would be considered class 2, while class 4 contains mainly lasers used for industrial and scientific tasks. This can burn skin, and in some cases, even scattered light can cause eye damages and lead to skin damages.

The Nanolaser.

A further development of laser is to develop the nanolaser. The Nanolaser is a tiny laser which emits a coherent beam of light through vibration of a single electron, rather than the traditional – and space-consuming- optical pumping process of a traditional laser. The concept

for a nanolaser was developed in 2003 at Georgia State University. The theory was that an electron that vibrated in a regular pattern will emit light that was in phase (or coherent) just as the excited electrons in a traditional laser emit coherent light. A traditional laser can fit on a computer chip, but these nanolasers could be a thousandth of that. A device based on the theory has not been built yet, but three different research teams have announced success with the new principal. If the technique will result in an even greater commercial interest, the nanolasers could among others increase the speed, and decrease the size, of computers even more.

The LIDAR

The LIght Detection And Ranging (LIDAR) device is an optical remote sensing technology that measures characteristics of shattered light to find range and other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. Like the similar Radar technology, that uses radio waves, the range to an object is determined by the time delay between transmission of a pulse and detection of the reflected signal. Very useful applications are remote measurements from satellites.

The primary difference to the radar is that lidar uses much shorter wavelengths of the electromagnetic spectrum, typically in the ultraviolet, visible or near infrared range. Thus Lidar is highly sensitive to aerosols and cloud particles and has many applications in atmospheric research and meteorology.

An object needs to produce a dielectric discontinuity to reflect the transmitted wave. Metal objects produce a significant reflection. However, non-metallic objects produce weaker reflections and can hardly or impossibly, be detected with radar pulses. Lasers provide one solution to these problems. The beams densities and coherency are excellent. Moreover the wavelengths are much smaller than can be achieved with radio systems, and range from about 10 micrometers to the UV at about 250 nanometers can be used. At such wavelengths, the waves been reflected very well from small objects. This type of reflection is called backscattering. Different types of scattering are used for different lidar applications, most common are Rayleigh scattering, Mie scattering as well as fluorescence and based on the different kinds of backscattering the lidar can be called Rayligh LIDAR, Mie LIDAR and so on. The wavelength is ideal for making measurements of smoke and other airborne particles aerosols and air molecules.

That characteristic has been used extensively for space physic, atmospheric research and for meteorology. With introduction of the Global Monitoring System (GPS) in the eighties precision positioning became possible and downward looking instruments at aircraft and satellites could give data accurately positioned. Lidars for space research in the middle and high atmosphere is through the instruments 'ability to differentiate between different types of charged particles. The Alomar laboratory in the Northern Norway and the Lidar with the Swedish Institute of Space Physics are such examples.

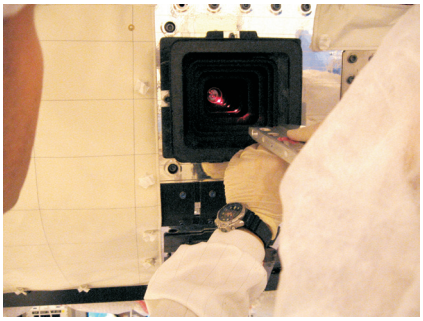
Meteorology and Atmospheric Environment

The first lidars were used for studies of atmospheric composition, structure, clouds and aerosols. Initially based on ruby lasers LIDAR's for meteorological applications were constructed shortly after the invention of the laser and represented one of the first applications for the laser technology. Several types of LIDARs are used for the meteorological tasks and mentioned can be:

Elastic backscatter LIDAR is the simplest type of lidar and is typical used for studies of aerosols and clouds.

Differential Absorption LIDAR (DIAL) is typical for measuring concentration of gases as ozone, carbon dioxide or water vapour in the atmosphere. Raman LIDAR can be used for measuring the concentration of atmospheric gases.

Doppler LIDAR is a type is to measure wind speed along the speed by measuring the frequency shift in the backscattered light. Synthetic array LIDAR allows imaging LIDAR without the need for an array detector and can be used for Doppler velocimetry, ultra-fast frame imaging etc.



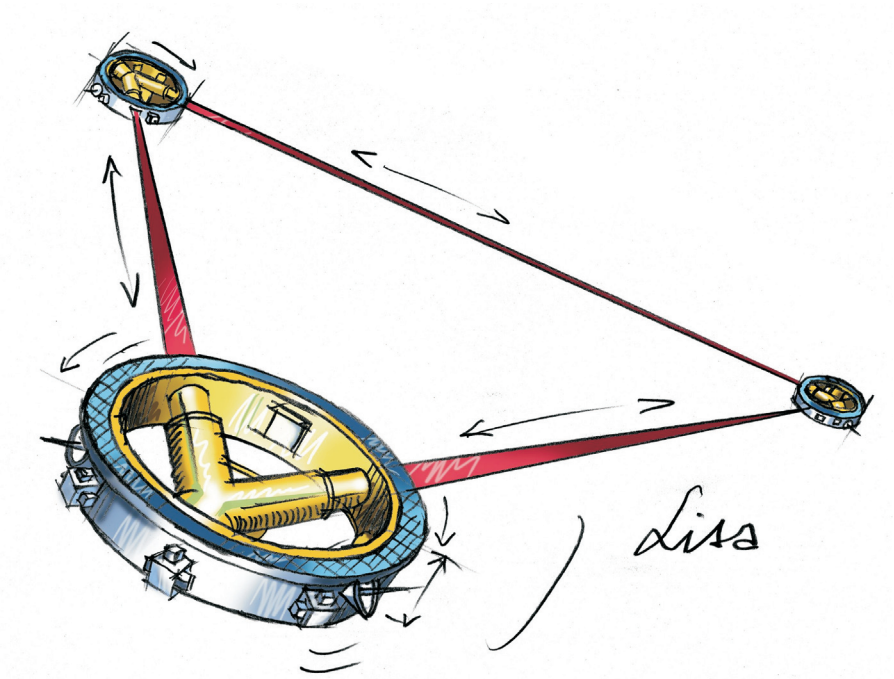
Checing star tracker baffles for alignment. Phot credir: ESA

Space Research, Astronomy and Physics

Lidars are now well known instruments on satellites and space probes. MOLA, the Mars Orbiting Laser Altimeter, used a LIDAR instrument at NASA's Mars Orbiter to produce precise global topographic surveys of the planet and in 2008 a LIDAR at the American Phoenix detected snow in the Mars atmosphere.

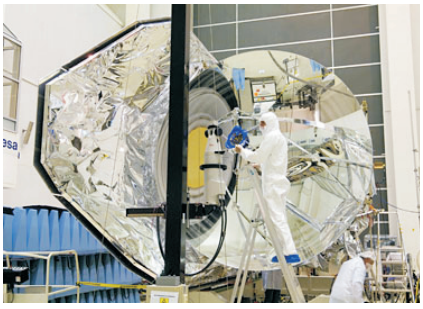
Lasers can also been used to look for life on planets, however, until now, only from samples that have been returned to Earth, because the instrument is to heavy to be sent to a planet. The method is based on a technique called laser desorption mass spectroscopy. By focussing a laser beam on a spot less than one-hundred of with of a pencil point, the researchers can knock microscopic fragments off the mineral and look for chemical signatures of molecules.

The American Lunar Reconnaissance Orbiter (LRO), that now orbits the Moon, uses the Lunar Orbiting Laser Altimeter (LOLA) to map the topography at the surface. Pulses were sent to the surface, and with measuring the reflection time the topography is measured very accurately, to the centimetre. As an example at the sensitivity, the instrument was turned off when the satellite passes areas where the previous moon astronauts have left behind instruments and reflectors. That is because the reflection may destroy the instrument. Laser based instruments on Earth measures the correct distance to the Moon and can also detect the Moon's receding from Earth (3.8 centimetres per year) and variations in the rotation of the Moon. The distance is measured with accuracy within ten centimetres, while the microwave measuring only has an accuracy of about twenty meters.

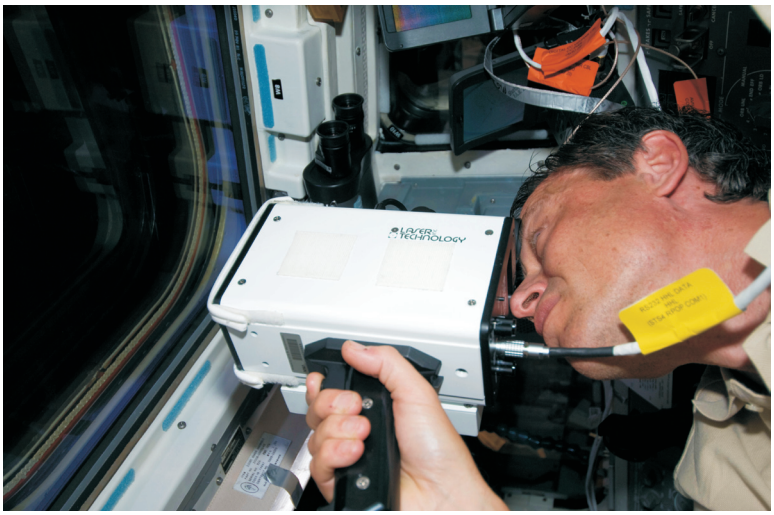


The measuring principle for the Lisa mission. Drawing credit: ESA

A future European project LISA (Laser Interferometer Space Antenna) will use the laser technology to detect and observe gravitational waves that are emitted during the most powerful events in the universe. ESA and NASA will in a common project try to detect the waves and with that confirm a theory that is an integrated part of Einstein's general theory of relativity. To possibly detect the waves three identical satellites placed in equilateral triangle with arm length of about 5 million kilometres will be developed. Each of the three LISA spacecraft will carry two telescopes with associated lasers and optical system. The distance between the different spacecrafts is monitored using highly accurate laser-based techniques. In this manner, it is possible to detect minute changes caused by passing gravitational waves.



Herschel spacecraft during distance measurments between primary and secondary mirrors. Photo credit: ESA



The Swedish astronaut Christer Fuglesang uses handheld laser ranging device after undocking of Discovery from ISS. Photo credit. ESA

To Reach the Space

Lasers are not only used for space missions, but they have also been used to build the necessary satellite and launchers for several tasks, especially with regard to welding components for the launchers. The Swedish Volvo Aero, that produced the nozzle for Ariane 5, has developed a unique laser welding technology that makes the production process both more rational, more reliable and gives the engine higher output. The production process is based on the use of a powerful laser beam that melts the material in two different plates together, one of them with open channels. The two plates together give a nozzle with integrated channels in order to cool down the nozzle during the launch.