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LASER TECHNIQUE IN GEODESY

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Abstract

The paper presents a review of methods for the use of laser techniques in the solving of various geodetic tasks. The basic principle of laser operation and the advantages of laser light in comparison with normal light sources are described.
Keywords: laser, interferometry

1 INTRODUCTION

Over the past two decades, lasers have become very important light sources which can be used in very different technical fields owing to their specific properties. They are used in the military, mechanical engineering, electronics, civil engineering, medicine and other areas. In geodesy, the use of lasers enables very successful solving of problems for certain tasks. In comparison with normal light sources, lasers have certain very useful properties which enable considerable time savings and contribute to the cost-efficiency of the execution of certain tasks.

2 BASIC PROPERTIES OF LASER LIGHT

Lasers are usually constructed as follows (Figure 1): Energy is delivered to a laser material placed between two mirrors, of which one is semi-permeable. This energy excites the photons in the laser material and brings the atoms into an excited state. The atoms then spontaneously pass into their basic state by emitting photons of light-energy. This light is reflected between the two mirrors and creates a standing wave of light of a certain wavelength. Each time light passes through the laser material, it is amplified by the stimulated emission. Successive reflection of light with parallel mirrors eliminates beams which do not run in the direction perpendicular to the mirrors and amplifies rays of a certain wavelength which are parallel to the mirrors. The light coming out of the semi-permeable mirror is parallel, single-colour and coherent; a laser beam. Using a collecting lens, such waves can be focused to an extremely small area in which an extremely high density of energy flow appears.

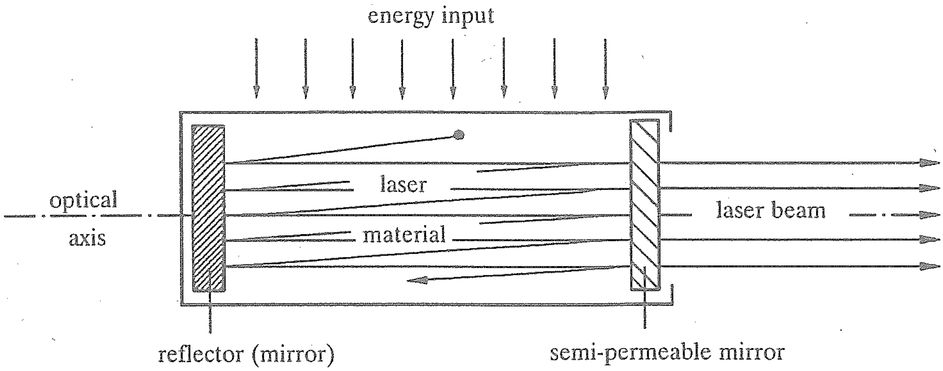

Figure 1: Basic principle of laser operation

In comparison with normal light sources, laser beams have the following characteristic properties which can be successfully used in technical measurement:

1) The monochromatic light obtained from a laser has a constant wavelength. In helium-neon lasers which are most often used in measuring instruments, this is 632,8 nm.

2) Laser light is coherent in time and space. Time coherence means that the phases of waves emitted from the same point at two successive time intervals correlate. Spatial coherence means that the phases of two waves emitted at the same time from two different points of a light source also correlate.

3) The angle of divergence is very small. This means that the density of energy of a laser beam remains large even at greater distances. Using an optical system it is possible to ensure that the laser beam cluster remains parallel over greater distances and that the diameter of the laser beam remains almost constant (even at several hundred meters).

The first two properties are above all important for interferometric measurement of distances or displacements. They enable the measurement of lengths or differences in length at an accuracy of a few microns from a distance of 20 m, or in extreme cases up to 50 m. The third property enables the use of a laser beam as an active target in centering, orientation, and measurement of differences in height, as well as a source of high energy densities for the measurement of lengths without reflectors and for marking targets in the use of remote measurement methods. The advantage of the active axis is that with the use of a target or a photoelectric detector, displacement can be measured at any point along the laser beam, without requiring the presence of a person behind the measuring instrument.

3 DIFFERENT WAYS OF USING LASERS

3.1 Laser as a light source for an active axis

Lasers have a wide range of applications in measurements for construction. They are used as a light source in instruments for determining surfaces or directions

(Figure 2). The manufacturers of this kind of equipment mainly produce instruments which perform both functions at the same time. By adding a rotating prism, the beam can be directed so as to describe a plane during its rotation. In addition, it is possible to set the laser beam to any direction or any plane.

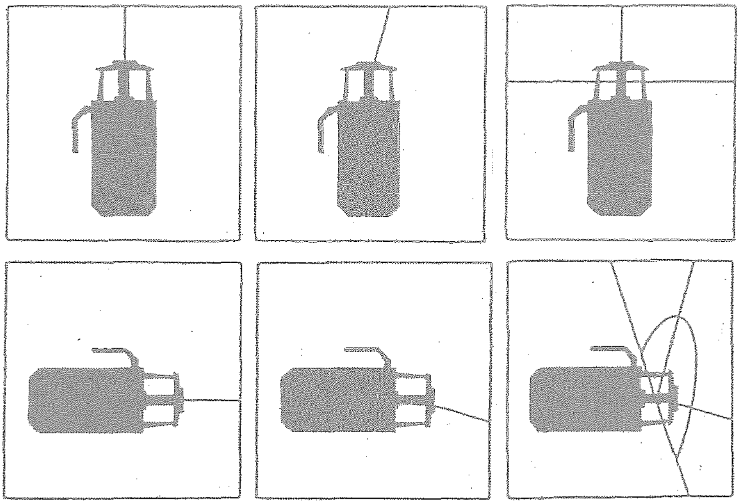

Figure 2: *Different possibilities for the use of a laser beam as an active axis*

At the end of the eighties, an electronic laser level was developed in which it is not necessary to move the detector manually along the staff, since electronic detectors are installed along its entire length. The reading in the place where the laser beam hits the staff is displayed on the screen in digital form. The level enables direct reading of height from the heel of the level or the determination of height difference with regard to a previously measured reference point.

Modern laser techniques enable cost-efficient execution of measurement when laying pipelines and directing machines for digging tunnels. In laying pipelines, the laser is positioned with special stands set directly into the pipe. The direction of the laser beam is set at the planned inclination and the pipeline is set such that the desired reading is obtained at the end of the pipeline. Laser equipment used in such work is usually sturdy and not sensitive to weather conditions (e.g. waterproof). Handling the laser device is simple. The instrument is levelled with a spherical level, while the final levelling is performed by the instrument itself using a compensator.

3.2 Measurement of distances without a prism

Due to high energy density of a laser beam it is possible to measure distances with instruments which have a laser light source without a reflector at the target. This is because enough laser light is reflected from straight hard surfaces, as well as from liquid surfaces, for the instrument to register and evaluate. In this method of measurement, the instrument operates in pulse mode. The instrument calculates the distance on the basis of the measured time interval for the travelling of impulse from the instrument to the target and back and the speed of the waves. This measuring method can be used to solve tasks which cannot be solved (or involve large costs and effort) with the use of standard distance measuring devices which require a prism at the target point. These tasks above all include:

- measurement of displacements of inaccessible points: in quarries, surface mining, in areas prone to landslides
- measurements inside buildings
- measurements of profiles in large caves
- remote method for the measurement of the volume of liquid in large vessels
- measurement of the distance to surfaces onto which a prism cannot be placed (polished surfaces or liquid metals).

Quite a few distance meters are available in the market, in different versions:

- manual distance meters which are hand-held during measurement
- distance meters set on a tripod
- instruments which are set on theodolites.

The measurement of distances without a prism is limited to 1 000 m and the range of measurement depends on the following parameters: surface roughness, colour and structure of the surface, position of the surface with regard to the squareness of the measuring beam. Manufacturer's declarations of the accuracy of laser distance meters range between 5 and 20 mm. The divergence angle of the laser beam is also important, and they range between 1 mrad and 2,4 mrad (3,5"-8,2") which means that at 100 m, the width of a laser beam cluster is 100 to 250 mm. Laser distance meters can also be used with prisms, which considerably increases their range.

3.3 Interferometers

The monochromaticity and coherence of laser beams is exploited in interferometric distance measurement. The basic structure of a Michelson interferometer is presented in Figure 3.

A laser beam is split on a reference prism in such a way that one part of the beam falls directly onto the detector, while the other, the measuring beam, runs to the measuring prism and turns towards the detector after being reflected. Overlapping of light and dark interference bands occurs, which represents a displacement of one half of the wavelength. The meter at the outlet of the detector counts the number of minimum and maximum intensities, and the distance travelled by a measuring laser beam can be determined at a very high accuracy. With the use of a two-frequency laser and the Doppler effect, measurement accuracy of a few nanometers can be achieved.

Interferometers constructed in this way are used for the calibration of comparators. It is important here that the frequency and the wavelength of the laser beam are stable; this in turn means that the atmospheric conditions along the path of the laser beam must be stable and registered as accurately as possible. The most important factor which influences the achieved accuracy of measurement with the use of an interferometer is the accuracy of obtaining data on atmospheric conditions along the path of the laser beam. In connection with various additional devices, interferometers enable the measurement of straightness, squareness, speed, etc. Laser interferometry enables the monitoring of periodic oscillations. A reflector is attached onto an oscillating object, e.g. a church bell tower, the bell of which causes oscillations, and an interferometer is placed on a stable base is used to register the oscillations of the bell tower. The influence of atmospheric conditions is less important in this case, since only small amplitudes are measured. Difficulties may appear due to the influence of atmospheric turbulence, but this problem can be solved by protecting the laser beam with a special pipe.

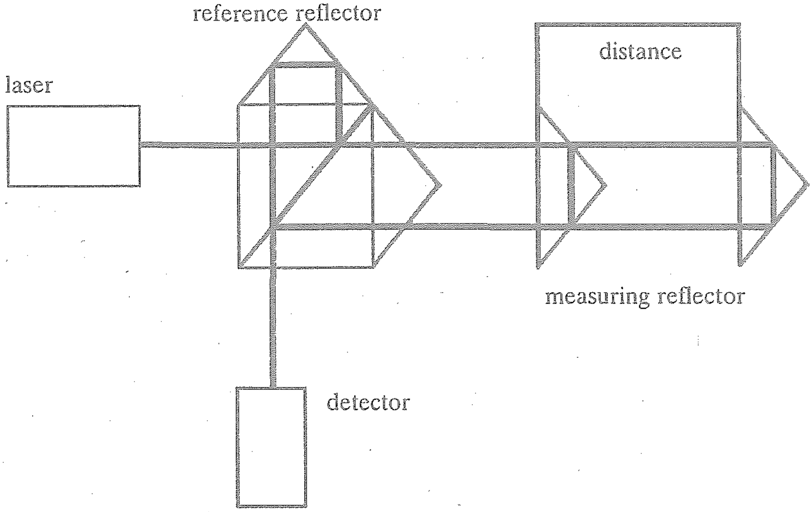

Figure 3: Michelson interferometer

3.4 Other methods for the use of lasers

Lasers are widely applied in industrial measurements, in so-called laser-optical triangulation. The use of laser beams in industrial measurement systems should be mentioned. One of two theodolites is equipped with a laser ocular such that the laser beam forms a line of sight. This beam forms a spot of light on the measured object which serves as a target point for the second theodolite. In this way, remote measurement of sensitive surfaces can be performed. In automatic industrial systems, the laser spot is a great advantage, since it enables automatic control of the entire measuring system.

4 CONCLUSION

As can be seen from the above examples of the use of lasers, laser light enables a more cost-efficient performance of a number of geodetic tasks, above all in the field of engineering geodesy. While the emphasis in tasks from the field of interferometry is on measurement accuracy, the cost-efficiency of the performance of geodetic measurements is important for other tasks. The fact that lasers enable the automation of measurement is significant. In certain cases, measuring systems can be used even without operators behind the instruments.

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