1970 - First Laser Ranging in Czechoslovakia

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Abstract

The first Czechoslovak laser ranging experiment was conducted on 1970. The setup and main characteristics of used instruments are presented. The conclusions of the experiment and transfer of experiences are mentioned.

Introduction

The observations of artificial satellites of the Earth begin in 50th years of 20 century. They were used for determination of the satellite orbit and the observing station positions. The determination of direction from station to the satellite using photography was used in 60th years. At the end of 60th years was erected the idea about determination of distance between station and satellite using pulses of light from LASER - Light Amplification by Stimulated Emission of Radiation.

There were some institutions performing satellite observations in the Czechoslovakia in 60th years. One of them was Research Institute of Geodesy, Topography and Cartography which use observations of satellites namely for determination of position on the Earth. Second one was Astronomical Institute of Czechoslovak Academy of Science which used observations of satellites for determination of satellite orbit and their changes due to gravitational effects.

Other group was erected at the Czech technical University in Prague – Faculty of Nuclear Sciences and Physical Engineering. This group performs research in the field of LASERs – pulse generators, detectors, signal processing.

Basic facts about Experiment

Determination of distance from station to the satellite by pulse of light is based on measurement of time which needs the pulse of light to travel distance between station to satellite and back to station.

The mixed group of specialists was formed for first experimental determination of distance using LASER pulse in the Czechoslovakia. Four peoples were main leaders of experiment: **Pavel Navara** from Research Institute of Geodesy, Topography and Cartography and **Karel Hamal**, **Tomas Daricek** and **Antonin Novotny** from Czech Technical University in Prague

– Faculty of Nuclear Sciences and Physical Engineering.

The experiment was performed in close cooperation of three institutions:

- **Czech Technical University in Prague, Faculty of Nuclear Science and Physical Engineering**, Department of Physical Electronics, which was responsible for all developed instruments: laser of laboratory construction, detection package with photomultiplier, measurement time of flight and for organization of experiment.
- **Research Institute of Geodesy, Topography and Cartography**, Geodetic Observatory Pecny, which was responsible for station issues: SBG camera and their pointing to satellite.
- **Astronomical Institute of Czechoslovak Academy of Science**, which was responsible for ephemerides of satellite and for computing time at the Minsk 22 computer and mechanical workshop for special mechanics.

Many other collaborating organizations from Czechoslovakia were included in development of parts of used instruments. Some of them were: Association for Chemical and Metallurgical Production, Usti nad Labem, Monokrystaly Turnov, Preciosa Turnov, Dioptra Turnov, Meopta Prerov, Mechanical workshop of Astronomical Institute Czechoslovak Academy of Sciences.

The experiment was performed at National Satellite Station Ondrejov/Skalka, Czech Republic managed by Research Institute of Geodesy, Topography and Cartography in nights in August and September 1970. The distances from the station Skalka to the GEOS B geodetic satellite was determined in the experiment.

The technical description of experiment is in next paragraphs.

Mount

The Satellitenbeobachtungsgerät (SBG) – camera for photographic observations of satellites produced by Carl Zeiss Jena, Democratic Republic of Germany – was used for pointing of laser pulse generator and detectors to the satellites. The SBG was installed at spring 1968 at National Satellite Station Ondrejov, Skalka, Czechoslovakia. The mount has 4-axis. First, second and fourth axes are manually controlled, third axis is used for steering of satellite orbit velocity and it is controlled by engine. Rotation velocity around third axis is controlled by previously prepared program for each pass of satellite. Initial pointing accuracy is 1 deg, better accuracy is achieved by small manual corrections performed by observer based on visual satellite monitoring in tracking telescope. So, only observations during night are possible.

Transmit path

The transmit path was composited from laser generator and transmit telescope.

The ruby laser was used in the laser generator. It was laboratory product of Faculty of Nuclear Science and Physical Engineering, Czech Technical University in Prague with some good aspects for using outside the laboratory. The laser contained two ruby rods 150 x 15 mm with both ends cut at Brewster angle. Producer of the rods was Association for Chemical and Metallurgical Production (Czechoslovakia). Rods of oscillator and amplifier were placed in common focus of double elliptical pumping cavity. Two xenon flashlamps used for pumping were placed in second focus. The prism (with reflexivity R=100%) and BK7 plate (reflexivity R=10%) were used as optical resonator. Q-switching was performed by rotating prism with rotation frequency 200 Hz. The laser generator was cooled by water. The construction had benefit in simple arrangement, no precise adjustments needed. The laser generator was connected with collimator (Galileo telescope with ratio 1:5) on the SBG camera (Fig. 1).

Fig 1: SBG camera with laser head and collimator installed, laser power and cooling electronic on the right side

Laser pulse had wavelength 694,3 nm, length 18-23 ns, repetition rate 0,08 Hz (period 12 sec i.e. 5 pulses per minute) and output energy 3-4,5 J. Beam diameter after collimation was 7,5 mm and divergence at laser output was 3 mrad, collimation can change the divergence of pulse to 0,6-6 mrad.

Receiving path

The receiving path was assembled from receiving telescope, detection package and instruments of measurement time of pulse flight.

The SBG camera was used as receiving telescope. It is Schmidt telescope with focal length 760 mm and input aperture diameter 420 mm which is given by correction plate. It has planar focal plane which was originally used for location of photographic plates.

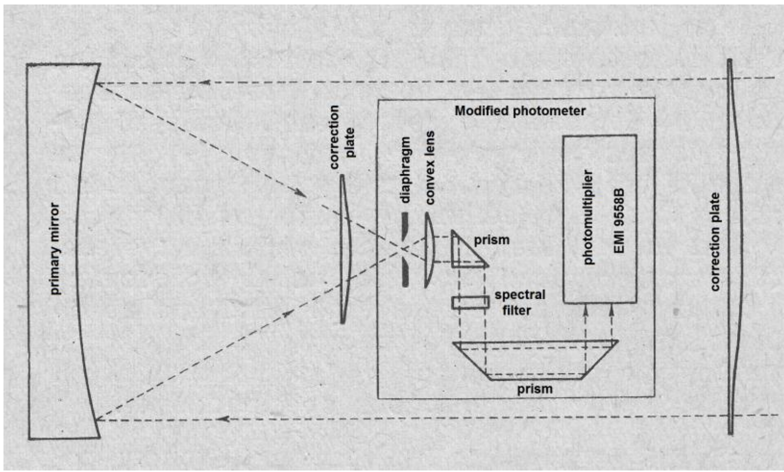

Fig 2: Scheme of detection package – modified photometer – installed in focal plane of SBG camera (from [3])

Detection package – modified photometer – was placed in focal plane (Fig. 2). The diaphragm was used as the spatial filter. Used spectral filter with bandwidth 4 nm and transmission 45% was produced by Meopta Prerov (Czechoslovakia). For the detection of receiving pulses the photomultiplier EMI 9558B was used. It was produced by EMI electronics, which was also for many years an internationally respected manufacturer of photomultipliers. This part of the business was transferred to Thorn as part of Thorn/EMI, then later became the independent concern Electron Tubes Ltd, now ET Enterprises Limited.

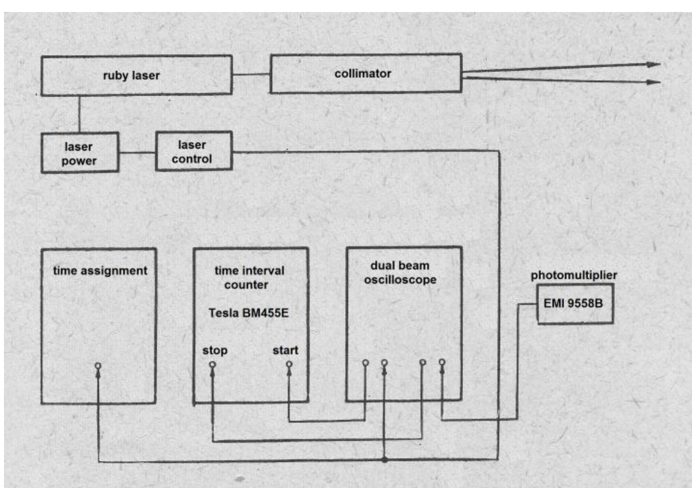

Fig 3: Signal scheme of experiment (from [3])

The time interval counter Tesla BM455E (Czechoslovakia) was used for measurement of time of flight. It was accuracy 1 μsec which **limited precision of results** to distance accuracy about 350 m. Other used part was dual beam oscilloscope. The signal processing was performed in some consecutive steps (see scheme at Fig. 3): laser firing pulse started the dual beam oscilloscope and also the time interval counter, received pulse from photomultiplier stopped the time interval counter and it draw second beam at oscilloscope. The oscilloscope display was equipped with photo camera for taking pictures of beams. Time of laser firing was determined manually by recording of voice on magnetic tape. The used instruments are at Fig. 4.

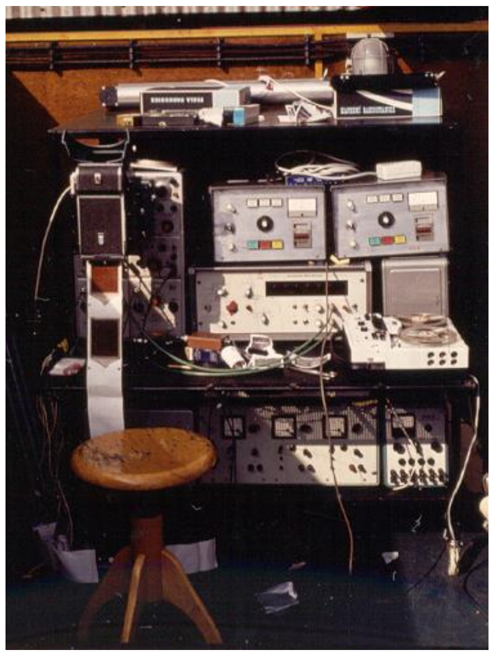

Fig 4: Detection electronic. In the middle from left to right: dual-beam oscilloscope with photographic recording, time interval counter, magnetic tape recorder for voice recording

Conclusions from the experiment

The laser ranging experiment in Czechoslovakia was fourth in the world (after USA [5], France [6] and Japan [7]). The distance to GOES B satellite was measured – it was in good agreement with ephemerides with precision 350 m due to time interval counter accuracy. The experiences with laser generator in the field condition were obtained. The spectral filter meets needs for this application. Tests with detection of clouds were used late for LIDAR construction. Information about hazard of pulse laser beam was received by making photo of laser beam at 5 km distance.

The results from this first experiment gave base for development of satellite laser radars in the Czechoslovakia – in the frame of INTERCOSMOS project. The obtained experiences were used for building some parts for the SLR stations in the world for next 20 years:

- Ondrejov, Czechoslovakia (now Czech Republic)

- Hradec Kralove, Czechoslovakia (now Czech Republic)
- Riga, Soviet Union (now Latvia)
- Helwan, Egypt
- Borowiec, Poland
- Zvenigorod, Soviet Union (now Russia Federation)
- Potsdam, Germany
- Uzhorod, Soviet Union (now Ukraine)
- Katzively, Crimea, Soviet Union (now Ukraine/Russia Federation)
- Penc, Hungary
- La Paz, Bolivia
- Kavalur, India
- Santiago de Cuba, Cuba
- Quito, Ecuador
- Nha Trang, Vietnam

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References

[1] Hamal K., Daricek T., Navara P., Novotny A.: Experimental Satellite Laser Radar at Ondrejov Observatory. Czech. J. Phys., B21, 1971, p. 1118.

[2] Daricek T., Hamal K., Navara P., Novotny A.: Laser Ranging on Ondrejov Observatory. Bull. Astronom. Inst. Czech., Vol. 22, 1971, No. 3, p. 124.

[3] Navara P., Daricek T., Hamal K., Novotny A.: Laser Satellite Radar (in Czech), Geodeticky a kartograficky obzor, Vol. 17/59, No. 9/1971, pp. 220-223.

[4] Novotny A.: The Network of satellite laser radars developed at Faculty of Nuclear Science and Physical Engineering Czech Technical University under leading by Prof. Karel Hamal (in Czech). In: 50 let kosmonautiky – vyroci startu prvni umele druzice Zeme. Prague, 2007.

[5] (USA) Johnson T. S., et al.: IEE Journal, vol. QE-3, pp. 435-439.

[6] (France) Bivas M. R.: Space Res. VIII, pp. 58-63.

[7] (Japan) Takenouchi, T., et al.: Hitachi Rev., vol. 19, No. 4, pp. 153-164.