

Requirements on SLR System for Participation in European Laser Timing and in Future Laser Time Transfer Experiments

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Abstract. *We are summarizing the hardware requirements put on SLR system for its participation in the European Laser Timing (ELT) experiment. The procedure of calibration of related epoch timing delays will be described also. The determined calibration value is equal to time correction of acquired laser fire epoch versus a time, when the laser pulse is crossing the SLR system invariant point. Calibration campaigns related to the ELT project is under preparation by European Space Agency. It is expected that selected European and several overseas and non-European SLR stations will be characterized by this procedure. Obviously the calibration value acquired may be applied in a number of other experiments of laser time transfer, asynchronous laser transponder and one way ranging in a future.*

Introduction

The overall objective of the project is to establish an instrumental and procedure background for the European Laser Timing (ELT) system calibration. The correct calibration of all the participating ground SLR systems is a prerequisite of a correct operation of the entire ELT experiment. The “twin” of the ELT detector package flying hardware has been built. Its detection delay has been compared to the flying unit. Together with the dedicated timing device and cabling they are forming the “Calibration Tool” – a reference for the worldwide network of cooperating laser stations. In addition to the ELT project, the measured results – calibration constants related to individual SLR ground stations – may be used also in other SLR related measurements, in which the accurate epoch of laser pulse transmission is critical. These measurements are: laser time transfer ground to space, one way laser ranging to space objects, asynchronous laser transponder and similar.

Calibration Device Principle

To characterize the ground segment, namely to measure the systematic delays in a laser time transfer ground segment, this approach to calibration of system delays was developed. The method is based on a presumption, that all the ground stations participating in the European Laser Time transfer experiment will be calibrated versus a dedicated set consisting of the photon counting detector identical to the satellite one, epoch timing system and signal cable. These components form an ELT Calibration Device. The calibration principle is plotted in Figure 1.

The *Detector* in Figure 1 is a twin of a photon counting detector used in space segment. Its photon to electrical signal delay Dd was determined with accuracy better than 15 ps. Both the Event Timers (ETS and ETG) are referred to the common time scale and clock frequency. One common signal cable for “*Ipps*” has to be used to synchronize the Event Timers *ETG* and *ETS* consecutively. In

addition equal values of trigger slope and level regarding the “1pps” signals have to be set on both timing systems. The timing unit of the Calibration Device is constructed in such a way, that all the possible triggering configurations used on various SLR ground stations may be configured on it. The calibration constant B for ELT related to the particular ground station can be evaluated as

$$B = (ES - EG) - L/c \quad (1)$$

where B is the calibration constant, L is a separation of reference points, c is a group speed of light, ES and EG are the epoch readings of Even Timers of the ground and space segment respectively.

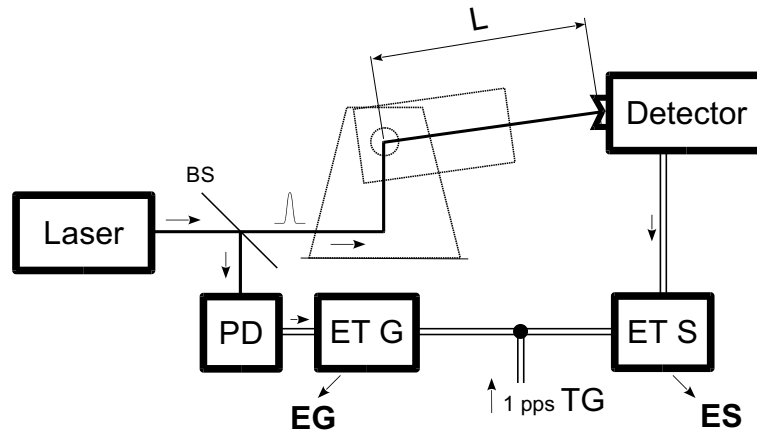


Figure 1. Block scheme of calibration of the laser time transfer ground segment using ELT Calibration Device. The left part represents the SLR system, the right one the calibration Device.

To determine the absolute delay C related to a particular ground system the additional information is needed – namely the detection delay of the detector Dd and a delay of the signal cable Dc interconnecting these two devices forming the ELT Calibration Device.

$$C = B - (Dd + Dc) \quad (2)$$

The delay constants Dd and Dc were determined in a Calibration Device assembly phase with the accuracy of ± 15 ps typically. The calibration constant C is expressing a difference between the laser fire epoch reading ETG and epoch, when the laser pulse center of mass is crossing the system invariant point.

Requirements on SLR System

The calibration procedure is expected to be performed at the SLR station, which is ready for participation in ELT-ACES project or other laser time transfer missions and similar ones. The calibration procedure will demonstrate, among others, the SLR station capabilities to participate in ELT measurements.

The minimum requirements on the SLR systems are as follows:

- Capability to perform routinely SLR of space targets on low (ISS) orbits.
- Capability to perform laser ranging with several mm single shot precision and mm system stability.
- Capability to time tag the laser fire epochs with a resolution not worse than 20 ps.
- Capability to generate the results data file in a standard ASCII form, where the first column is an integer second of a day and a second column is a fractional part of a day.
- Capability to fire the laser at a frequency of 5, 10, 20 or 100 Hz and optionally 1 kHz in pre-defined epochs on a shot-by-shot basis in order to deliver the laser pulse to a detector in space in a desired epoch with accuracy not worse than 100 ns

- The ability to fire SLR laser in pre-calculated epochs differs in real measurement and calibration mission. While observing ACES requires laser fire in computed epochs based on available predictions, the calibration requires to fire with SLR laser in constant time delay to “1 pps” time marker. This time delay will be established during calibration mission and must be easy to change by SLR operator.
- Time reference of SLR event timing unit in a form of “1pps” pulse, response to a well defined slope and trigger level. Both positive and negative levels and slopes may be used.
- The signal cable distributing the “1pps” signal must be long enough to be connected alternatively to the SLR timing system and to the ELT Calibration Device.
- The available space in front of the SLR system telescope to install and operate the ELT Calibration Device.
- The local time scale reference frequency source must be common for both SLR and ELT Calibration Device. It means the SLR system must provide the clock frequency. The frequencies of 5 MHz, 10 MHz, 100 MHz, or 200 MHz may be accepted by the ELT Calibration Device. The suitable clock signal amplitude is within a range of 0.2 to 2 Volts peak to peak on 50 Ohms.
- The laser transmitter output energy of the SLR system must be reduced to provide on its output the energy density of the order of $1 \mu\text{J}/\text{m}^2$ on the transmitting telescope output aperture. This reduction may be accomplished or by adjusting the final amplifier(s) of the laser or by inserting additional ND filters into the output laser beam. The attenuation procedure applied depends on a SLR system configuration. The attenuation procedure must enable fine adjustment of output energy density.

Installation requirements on the SLR site – Installation of the detector package

The ELT Calibration Device detector package has to be installed in front of the SLR system telescope. The location must fulfill the following requirements:

- The installation of device should not restrict normal operation of SLR system,
- flat horizontal surface of minimal dimensions of 200×200 mm in front of the telescope for the detector unit,
- it should be located in an elevation close to the elevation of SLR system invariant point (horizontal axis of the telescope mount) with acceptable tolerance of ± 100 mm,
- mechanical pin having a diameter of 6 mm and 10–15 mm long has to be installed close to the surface edge as a mechanical and geometrical reference,
- distance of the device from the SLR should be as small as possible, distance shorter than 5 meters is recommended to simplify the survey of distance(s),
- the detector will be oriented in a horizontal plane in such a way that the laser beam from the SLR system under test will hit its input optics under the angle of 45 degrees.

The example of installation of the device at the SLR station in Graz is in Figure 2.

Installation requirements on the SLR site – Installation of the timing electr. and control PC

- Flat horizontal surface of minimal size 400×600 mm in a distance shorter than 1 meter from the detector unit for installation of timing electronics,
- available working space for a control PC,
- installation of devices should not restrict normal operation of SLR system,
- AC power (90...240 V, 50–60 Hz, 100 VA) must be available,
- signal “1pps” via coaxial cable common for both SLR and ELT timing systems consecutive synchronization must be available,

- clock signal common for both SLR and ELT timing systems, frequencies of 5 MHz, 10 MHz, 100 MHz, or 200 MHz, amplitude within a range of 0.2 to 2 Volts peak to peak on 50 Ohms must be available.



Figure 2. ELT Calibration Device installed in a dome in front of the Graz SLR system. SLR system telescope (right top), ELT detector (black, top center), ELT calibration Timing (top, left), process control and data acquisition PC (low left).

Conclusion

We have briefly described the principle of the calibration of a SLR system for its participation in European Laser Timing experiment. The requirements put of the SLR systems were defined along with additional requirements on calibration process. The resulting calibration constant is equal to time correction of acquired laser fire epoch versus a time, when the laser pulse is crossing the SLR system invariant point. Calibration campaigns related to the ELT project is under preparation by European Space Agency. It is expected that selected European and several overseas and non-European SLR stations will be characterized by this procedure. Obviously the calibration value acquired may be applied in a number of other experiments of laser time transfer, asynchronous laser transponder and one way laser ranging. Its value will be also applicable in data processing of bi- and multi-static space debris laser tracking.

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References

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