On the Horizon: New ESA Laser Ranging Station (ELRS) with Debris Tracking Capabilities

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ABSTRACT

A new, mostly COTS based "Laser Ranging Station for Cooperative Targets" is being built for the European Space Agency (ESA) by a consortium of European companies and institutes (D, A, CH, LV) under the lead of DiGOS Potsdam GmbH.

The objective of the ELRS is to establish a flexible and economical basis for various optical applications. Starting with laser ranging to cooperative targets and demonstrating passive-optical debris tracking, the system provides the adaptability for future applications to be integrated including laser ranging to non-cooperative targets/debris, space-to-ground laser communication, and for serving as a general test bed for optical technologies.

We will present the multi-purpose concept and the flexibilities of the ELRS design with a focus on current and future debris tracking capabilities which are being strongly advanced together with the scientific partners IWF and AIUB.

1 INTRODUCTION

Satellite Laser Ranging (SLR) is an established method for precise observation of cooperative targets with an accuracy of a few millimetres. These targets are satellites which are equipped with retro-reflectors to allow a stable and precise observation with precise reflection areas. From the beginning, the new ESA Laser Ranging Station (ELRS) will perform such observations and additional passive-optical debris tracking with a camera.

2 SITE & ATMOSPHERIC CONDITIONS

The planned installation site is at Observatorio del Teide on Tenerife, Spain and located 2.300 metres above mean sea level. The site has very good seeing and atmospheric conditions.

So far more than 20 telescopes are installed at the observatory. To minimise conflicts between laser and astronomical observation, SLR operations at night will be limited to near-infrared (1064nm) whereas during daytime both supported wavelengths (1064nm and 532nm) can be used.

Fig. 1 shows the two-way transmission for 1064nm wavelength at different visibilities. Due to the high altitude of the site, atmospheric transmission is exceptional good and well suited for laser ranging.

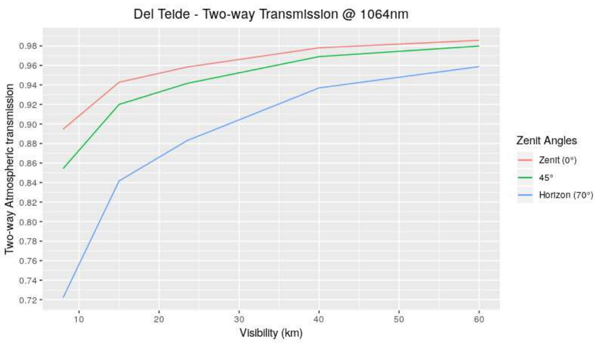

Figure 1. Two-way atmospheric transmission for 1064nm vs. visibility at Teide observatory

3 DESIGN OVERVIEW

The design of the ELRS comprises mostly commercial-off-the-shelf (COTS) based elements. The telescope system is originally designed for astronomical applications and will receive some slight adaptations for the laser ranging application. The telescope is of a Ritchey-Chrétien design with an 80cm main mirror providing two Nasmyth (through the elevation axis) and two folded Cassegrain foci (top and bottom of main mirror cell). The tracking mount is a fork type Alt-Az mount.

For the SLR application a small state-of-the-art picosecond laser with a repetition rate of 400Hz and switchable wavelength (532nm or 1064nm) is used. The corresponding detector package supports both wavelengths and will be mounted to one of the Nasmyth foci. Laser and detector package designs are based on proven SP-DART design which has been used by IWF for SLR performance verification and problem identification at other SLR stations [1].

Proc. 1st NEO and Debris Detection Conference, Darmstadt, Germany, 22-24 January 2019, published by the ESA Space Safety Programme Office Ed. T. Flohrer, R. Jehn, F. Schmitz (http://neo-sst-conference.sdo.esoc.esa.int, January 2019)

Other essential elements comprise off-the-shelf components like event timer, range gate generator, meteorological sensors and ADS-B receiver for aircraft detection.

A space debris camera for optical observation will be mounted to one the folded Cassegrain foci.

The ELRS will be controlled, monitored and operated by the SLR Control and Operation software (SCOPE) running on a Linux platform. SCOPE is also integrated at the SLR stations in Potsdam in Germany and Metsähovi in Finland [2]. The software core is stable and tested, and only interface adaptations will be implemented as required.

The complete ELRS will be housed in a two-story station building with a rotatable slit-type dome on top (Fig. 2) providing easy, weather independent access during hardware upgrades, modifications, experiments, etc.

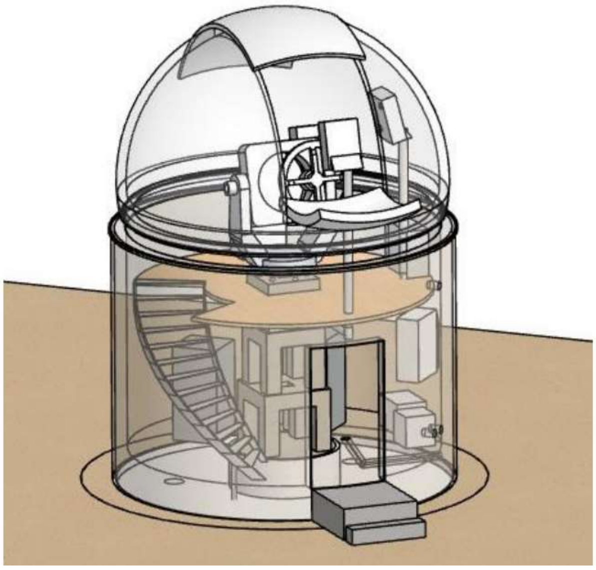

Figure 2. ELRS station building with main components

3.1 Laser Package

In contrast to most today's SLR stations, the telescope system will not have a complex and expensive Coudé path to route the laser light from a laser laboratory to the transmitting telescope. Instead the laser will be directly attached to the telescope system which becomes feasible as picosecond lasers are getting lighter and smaller in size during the last years.

For the ELRS, the laser head unit, a transmit telescope for each wavelength and some additional optical elements will be integrated into a single compact laser package (Fig. 3) which then will be mounted piggyback onto the telescope.

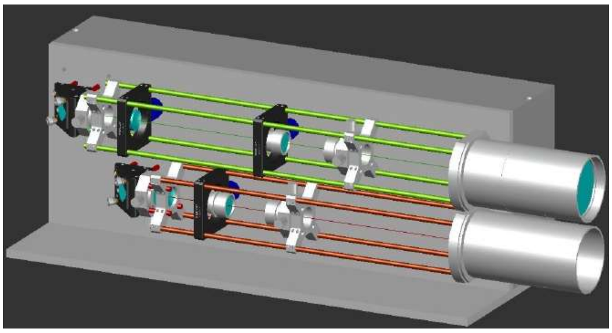

Figure 3. Laser package with two transmit telescopes

3.2 Detector Package

The detector package will comprise detectors for both wavelengths (532 nm and 1064 nm), a tracking camera, various other optical elements as well as a placeholder for a light curve detector (Fig. 4).

Moreover, additional electronics for power supply, environmental monitoring and communication will be included in the package that is mounted to one side of the telescope mount/fork.

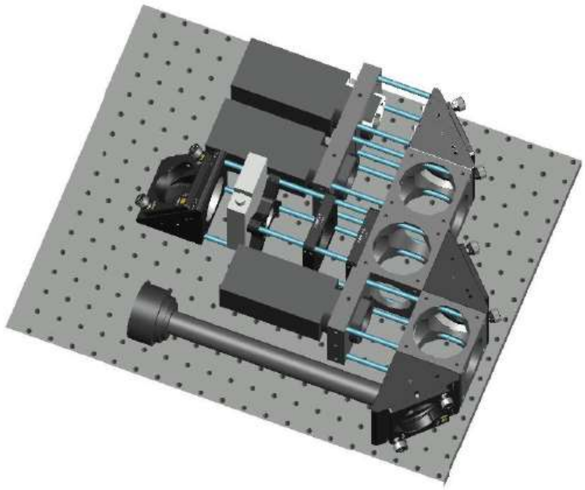

Figure 4. Detector package for two wavelengths, light curve detector (prepared) and tracking camera

4 ESTIMATED PERFORMANCE

The link budget calculation shows a good performance in terms of received photons for both wavelengths with different elevations and site visibilities (Fig. 5 and Fig. 6).

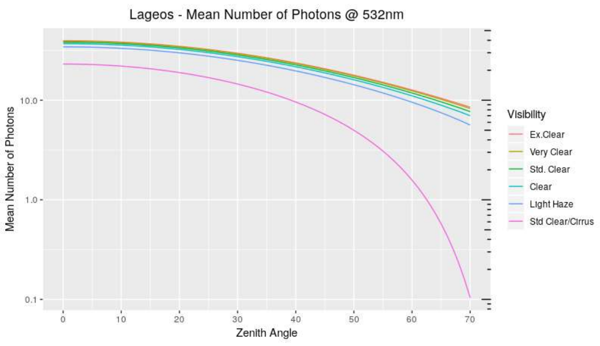

Figure 5. Calculated performance for LAGEOS observation at 532 nm with different visibilities

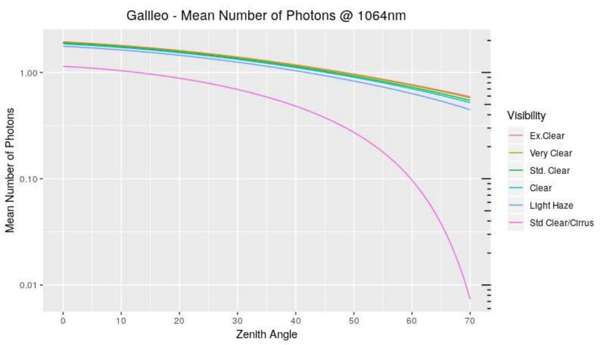

Figure 6. Calculated performance for Galileo observation at 1064 nm with different visibilities

5 SPACE DEBRIS TRACKING CAPABILITIES

The ELRS is designed to support tracking or observation of space debris / non-cooperative target with different methods. Two methods will be available with the commissioning of the station:

1. Passive-optical space debris observation [3] will be demonstrated with a high-performance camera whose pictures will be post-processed by available AIUB software.
2. Multi-static space debris tracking in passive mode [4] is supported by SCOPE. In this mode, ELRS synchronizes to the fire sequence of another SLR station equipped with a high-power “space debris” laser and detects the diffusely reflected photons from the debris target. Using such quasi-simultaneous laser ranging should result in more accurate orbit determination.

The ELRS is prepared to support future space debris observation methods by hardware and partially software extensions:

1. Active space debris tracking [5] can be implemented with a high-power laser which must also be mountable onto the telescope. Additionally, an improved, dedicated “space debris detector” can be used to optimize the performance of this observation method. This extension is still experimental and has been used only during night time.
2. An additional light curve detector [6] can be used to characterise e.g. the rotation of non-cooperative targets [7].

6 REFERENCES

1. Kirchner, G., Steindorfer M.A., Koidl F. & Wang P. (2015). SP-DART: Single-Photon Detection, Alignment and Reference Tool. In *Proc. 2015 ILRS Technical Workshop*, Matera, Italy

2. Kloth A., Steinborn J., Näränen J. & Raja-Halli A. (2014). Development of a full SLR software stack based on real-time Linux and a new version of the Potsdam Range Gate. In *Proc. 19th International Workshop on Laser Ranging*, Annapolis, USA

3. Silha, J., Schildknech T., Hinze A., Flohrer T. & Vananti A. (2017). An optical survey for space debris on highly eccentric and inclined MEO orbits, Advances in Space Research, 59, Issue 1, 1 January 2017, Pages 181-192.

4. Kirchner G., Koidl F. & Ploner M. et al (2013). Multi-static laser ranging to space debris targets: tests and results. In *Proc. 18th International Workshop on Laser Ranging*, Fujiyoshida, Japan

5. Kirchner G., Koidl F., Friederich F., Buske I., Völker U. & Riede W. (2013). Laser Measurements to Space Debris from Graz SLR Station. Advances in Space Research, Volume 51, Issue 1, 1. January 2013, pg 21.-24

6. Kirchner, G., Steindorfer M., Koidl F. & Wang P. (2015). Light Curve Measurements with Single Photon Counters at Graz SLR. In *Proc. 2015 ILRS Technical Workshop*, Matera, Italy

7. Šilha, Jiří, J.-N. Pittet, T. Schildknecht, M. Hamara, Apparent rotation properties of space debris extracted from photometric measurements, Advances in Space Research, 61, Issue 3, 1 February 2018, Pages 844-861. https://doi.org/10.1016/j.asr.2017.10.048