Field maintenance of the SLR telescope at TIGO

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Abstract

We report a major maintenance service of the laser telescope at the Transportable Integrated Geodetic Observatory (TIGO), in Concepción, Chile, which has been carried out under field conditions in August and September 2008. The purpose of this work was to improve the transmission properties of the 50 cm refracting telescope, whose optical path is folded by four Coudé prisms. The coatings of these critical components had degraded over several years of continuous operation. The implementation of the repair service, carried out on site in absence of service infrastructure and buildings, involved the replacement of these prisms and their mounts within the hermetically sealed optical Coudé train. Quasi clean-room conditions were established by constructing two tents around the site with air conditioning and filtering devices. The entire telescope structure had to be lifted to access and replace the critical components, requiring a complete re-alignment and survey of the instrument. This paper documents the practical implementation of the on-site maintenance, which significantly improved the transmission properties and overall performance of the SLR system.

Introduction

In March 2006, the TIGO SLR unit was upgraded by a passively (SESAM) mode-locked oscillator and diode pumped amplifiers. Since then, the modernized system operating at 100 Hz repetition rate has proved to operate significantly more stable than its forerunner. This enabled a strong increase of TIGO's SLR data productivity at its fundamental wavelength 847 nm. However, the two-color ranging capability of CONL, currently the only operative Ti:Saph system of the ILRS network, has continuously declined. Fig. 1 shows the number of observations per normal point at the second harmonic (423.5 nm) obtained in 2002 and 2003. The plot shows that return rates at the blue wavelength have continuously decreased since the installation of TIGO in Concepción. By the end of 2006 two-color ranging was stopped completely to yield the entire pulse energy to the fundamental (IR) wavelength. But even with this setup, the station's capability to track HEO missions at has been limited to night time.

The likely main reason for the declining transmission properties of the SLR system are damages of optical components along the transmit and detection path, which have deteriorated over six years of continuous operation. The mobile SLR unit of TIGO features a 50 cm refracting Coudé telescope, whose cross section is depicted in Fig. 2. The instrument is protected by a waterproof cart with a removable dome and is supported on the platform by three adjustable feet. The optical path is folded by four AR-coated prisms, indicated in Fig. 2. The outgoing beam from the Ti:Saph laser located inside the operation unit (container) is coupled into the telescope through a hermetically sealed tunnel (indicated in the lower left part of Fig. 2). Slight overpressure and a constant flow of dry and clean air pumped through the tunnel prevents dust and humidity from entering the optical path. The outgoing beam is reflected into the azimuth axis by prism FP7, folded over 110° by FP4 and FP2 and reflected into the elevation axis by FP1. The beam is subsequently expanded by an adjustable triplet lens, and folded over two large flat mirrors before being recollimated by the front lens.

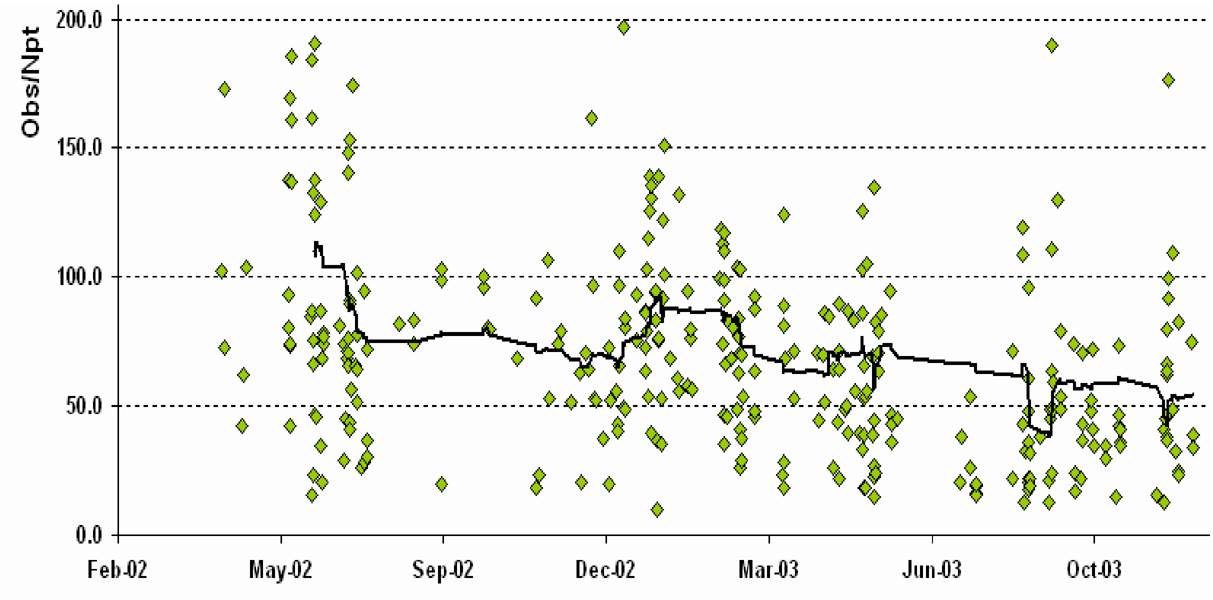

Figure 1. Number of observations per normal point at 423.5 nm during TIGO's first two years of operation. The return rate has fallen by approx. 50 % in less than two years, presumably due to the degradation of optical components.

After inspections confirmed significant damages on all four prisms in the Coudé path, it was decided to replace them in a single maintenance effort. As optical workshops were not available the delicate work had to be carried out under field conditions at the TIGO site, moreover during the rough rain season to minimize the loss of data, while at the same time maintaining a clean and dry environment to protect the optics. This paper briefly documents the implementation of the prism replacement and the re-alignment of the telescope.

Setting up an optical workshop in the field

Due to TIGO‘s design as a transportable geodetic observatory, its laser telescope is located on an open air platform, only protected by a cart structure with a small dome. It is connected to the laser system through a hermetically sealed tunnel. One challenge was to provide dry and clean conditions for installation and adjustment of delicate optical components in absence of a service building. Dust particles entering the Coudé path during several days of maintenance while the beam tunnel was to be opened were likely to remain in the optical path, settle on the new prisms' surfaces and subsequently cause new damages on the AR-coatings.

In order to prevent this, we set up a protective construction around the telescope module consisting of two tents, depicted in Fig. 3: First a large stable pavilion tent was erected, which was provided by a catering company. This external tent provided rain and wind protection during the intensive rain season in Southern Chile on a 12x12 m area around the telescope. The smaller second tent was built inside the external one and enclosed the telescope cart in a 6x6 m area. Inside this internal tent, we installed an air filtering and conditioning system, hourly pumping 3400 m^3 of clean and dry air (> 99 % filer ting efficiency for 5 µm particle size and < 20% rel. humidity) from the pre-heated external into the internal structure. By injection through a tube system a constant dry air circulation and overpressure inside the internal tent were obtained, pushing dust particles outside the internal tent. With this setup, "quasi clean room conditions" were established, allowing for the replacement of the optical components in the field.

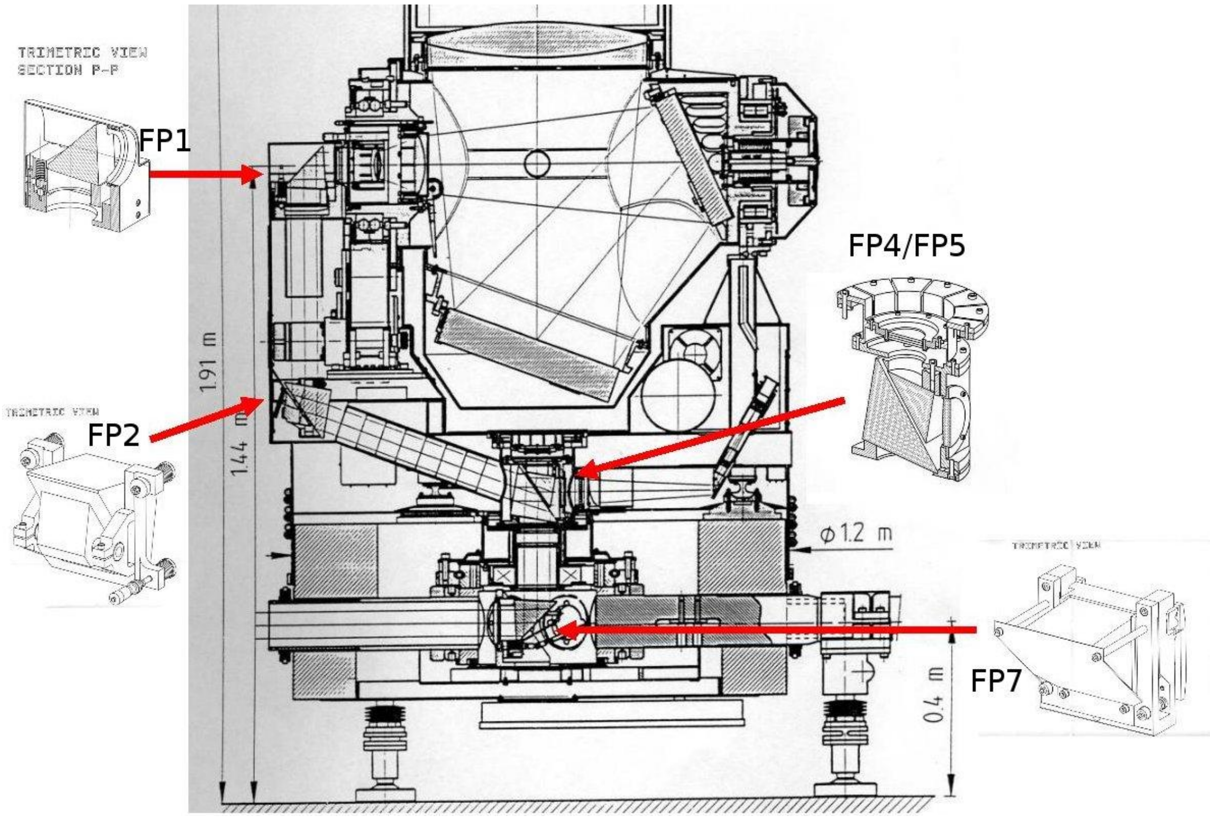

Figure 2. Cross section of the TIGO SLR telescope. The positions of the replaced prisms and their mounts are indicated.

Prism replacement

The moving part of the telescope, which rotates about the azimuth axis, is mounted on three flat air bearings floating on a monolithic granite bench, indicated by the shaded areas in Fig. 2. In order to access the lowest prism FP7 (reflecting the beam into the azimuth axis) the entire mechanical structure including the granite bench, with a total weight of about 2000 kg, had to be lifted by about 40 cm, which was done by a built-in manually operated mechanism. After disassembling various mechanical parts of the telescope FP7 and the other Coudé prisms were removed together with their mounts. The prisms of size 115 x 98 mm are cemented into their individual mounts by a high-performance flexible epoxy (3M Scotch-Weld 2216B/A). At it is difficult to remove the cemented optics from the mounts without damage, we decided to re-build the four complex and individually different mounts. This work, as well as the installation of the new prisms (manufactured by Laser Components, Munich) was performed at an opto-mechanical workshop in Santiago de Chile, run by European Southern Observatory (ESO) staff. Due to differences in the dimension of the spare parts, slight modifications of the mechanical mounts had to be designed.

Figure 3. Construction of two interleaved tents to provide clean work conditions.

Re-installation and alignment

Three weeks after its disassembly the telescope was lifted again and the new prism mounts were installed. Due to the modifications of mechanical and optical components a complete re-alignment of the telescope optics had to be done. Several new alignment procedures were applied to ensure that the transmitted beam was exactly centered and aligned with respect to both the azimuth and vertical axis. After replacing FP7 a flat mirror was positioned in place of the FP4/FP5 combination and precisely levelled in order to reflect the beam back into the spatial beam splitter (perforated mirror for separation of transmission and reception beam) inside the SLR container. For this adjustment over a distance of about 8 meters through the beam tunnel the second harmonic (423.5 nm) of the attenuated pulsed laser beam was used, and precisely centered in the azimuth axis. Similar techniques, using calibration mirrors and a HeNe auxiliary laser (620 nm) were used for the re-alignment of the parallel axis (between FP2 and FP1) as well as the elevation axis. Some mechanical modifications to the prism mounts allowed for a more accurate adjustment of the parallelism between the transmission, reception and pointing reference (cross-line) axes. For example the surfaces of prisms FP4 and FP5, the latter projecting the reference cross-line into the field of view (see Fig. 2), had to be positioned highly parallel w.r.t. each other. In absence of the required optical alignment tools (goniometer bench) this could be achieved by making FP5 adjustable and using an MCP camera inside the container unit to manually align the cross-hair reference with the transmission beam.

Since the telescope and with it the system invariant point had been moved several times as the cart structure was lifted and re-installed during the maintenance process, the eccentricity w.r.t. the reference point had to be redetermined. Table 1 shows the results of the post-maintenance survey as well as the previous coordinates relative to SRP.

Figure 4. Access to the prisms required working underneath the mechanical structure supporting the telescope. Great care was taken to prevent dust from entering the open Coudé path.

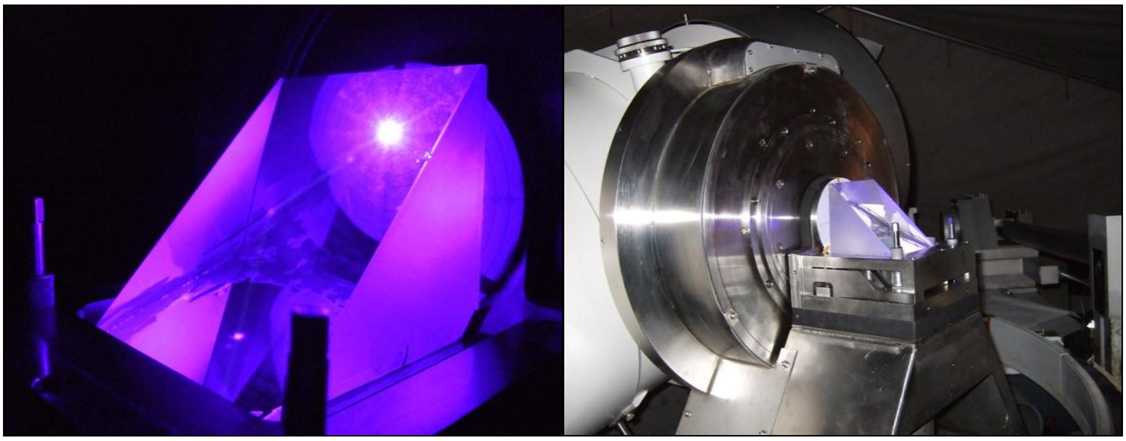

Figure 5. The blue (423.5 nm) second harmonic of the transmitted beam was used to re-align the optics, utilizing various improvised alignment tools.

Table 1. Changes of eccentricity vector from system invariant point to SRP

Component	Old ecc. Values [m]	New ecc. Values [m]
	valid UNTIL 08-10-2008	valid SINCE 08-10-2008
North	0.1956±0.0007	0.1996±0.0007
East	0.0008±0.0007	0.0085±0.0007
Up	1.4667±0.0006	1.4627±0.0006

Summary

We have carried out an optical maintenance service under field conditions for a complex mobile telescope system. Quasi clean room conditions were established around the telescope at the SLR site and the critical optical components folding the Coudé path were removed. The new prisms were cemented into improved mounts and a complete re-alignment was performed using dedicated alignment strategies. As a result of the prism replacement TIGO-SLR (CONL) is now fully capable of daylight tracking GNSS satellites (GPS, GIOVE, GLONASS and COMPASS), which had been difficult before. The improved tracking performance is also reflected in the station´s GNSS observation statistics, as can be seen in Fig. 6. The chart shows that TIGO's tracking performance for high targets has more than tripled since the successful telescope maintenance. After upgrading its detector system it is expected that CONL will resume two-color operation in April 2009.

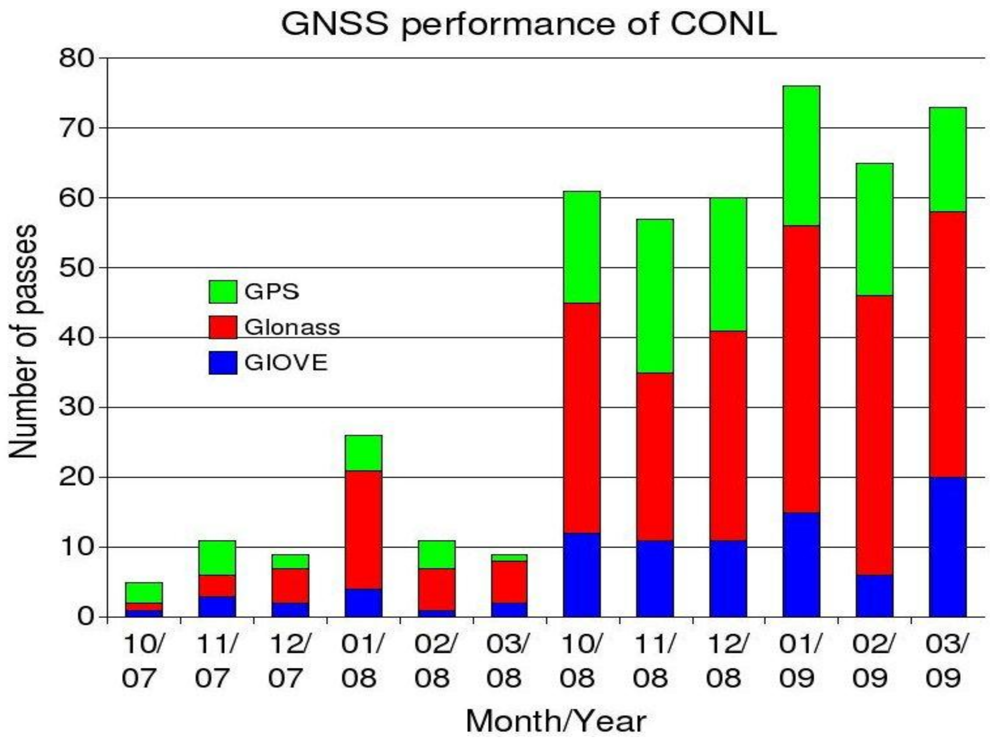

Figure 6. GNSS observation statistics for CONL: 6 month of data after the maintenance are plotted (Sept. 2008-March 2009) along with the corresponding period of the previous year. The strong increase of HEO passes per month is a result of the improved system transmission after the telescope upgrade.