# HISTORY OF THE LASER OBSERVATIONS AT ZIMMERWALD

M. Ploner, P. Lauber, M. Prohaska, P. Ruzek, T. Schildknecht, A. Verdun, A. Jaeggi

Astronomical Institute, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland, martin.ploner@aiub.unibe.ch

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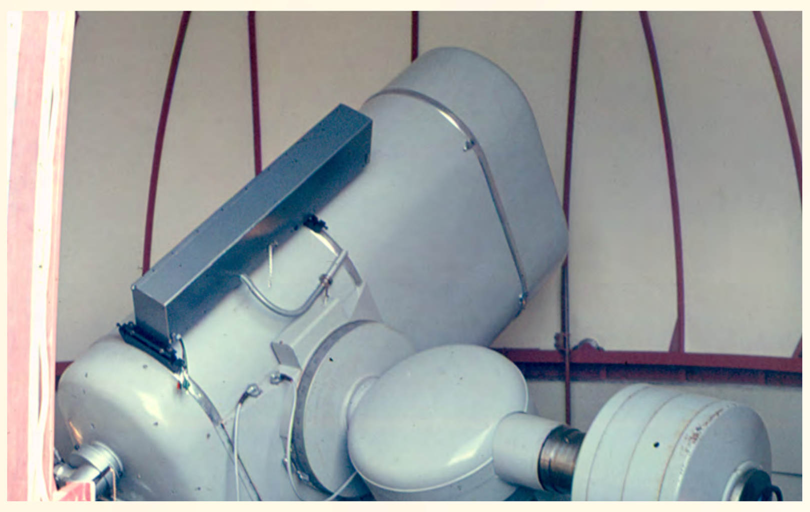
## The observatory Zimmerwald

It was built 1955/1956. In the first three years optical observations were performed using a small Schmidt Camera (25 cm aperture, 104 cm focal length). Since 1959 the larger Schmidt Camera (40 cm aperture, 104 cm focal length) as well as a Cassegrain telescope (60 cm aperture, 13 m focal length), both fixed to the same equatorial mount, were at disposal.

First optical observations of active and passive geodetic satellites (GEOS, Explorer, Pageos and Echo) were performed with the Schmidt Camera in 1965. Due to the extremely time-consuming evaluation of the photographic plates the photographic observation technique was abandoned and a new observation technique was introduced: The satellite laser ranging (SLR).

## 60cm Cassegrain/Schmidt Telescope

1971-1972: In 1971 first tests with a ruby laser built by the Institute of Applied Physics (IAP) of the University of Bern mounted along the tube of the astronomical telescope, using the Cassegrain telescope as receiver, were performed. The success was very limited, but first instrumental experience in the field of SLR observations during the ISAGEX campaign could be acquired. D1D, BEC, D1C and GEO2 were the most important targets.



60 cm Cassegrain/Schmidt Telescope with Ruby laser

## 50 cm Cassegrain Telescope

1974-1983: The satellite observatory Zimmerwald (an annex to the existing observatory with a new dome) was constructed in collaboration with the IAP. The telescope was designed and mostly built in-house. It consisted of a Cassegrain receiving telescope of 50 cm aperture and a separate transmitting Galilei telescope. 2 laser systems were installed, a Ruby laser for SLR purposes and a Rhodamin laser for the illumination of satellites in case of optical observations. In autumn 1978 first successful ranging with the ruby laser was carried out, about 120 echos in 8 passages of GEOS 1 and GEOS 3 could be measured. In 1979, the first major upgrade of the telescope control took place. The former manual control of the telescope was replaced by a computer-controlled system using a PDP 11/40 system.

1983-1995: Starting in 1983, the ruby giant pulse laser system was replaced by a new 10 Hz Neodyme:YAG laser system. Optics, electronic components, software and ranging accuracy were significantly improved. The upgrade of the laser system provided the possibility to range the satellites on a routine basis. On 15th May 1984, the first successful ranges to LAGEOS were obtained. Due to difficult and unstable axis alignments between the transmitting and receiving telescope and the limited tracking accuracy it was not possible to narrow the field of view enough for daylight tracking. The energy budget of the whole system did not allow ranging to high-orbit targets such as GPS and GLONASS satellites. In May 1995 the old satellite laser ranging telescope and its dome were dismounted, the Nd:YAG laser system and much of the control electronics removed.

50 cm Cassegrain Telescope with Ruby Laser and PMT

50 cm Cassegrain Telescope with Nd:Yag Laser

| Laser | 1978-1983 | 1983-1995 |
|---|---|---|
| Type | Ruby | Nd:YAG, passive mode locking<br>Since 1987: active/passive mode locking |
| Manufacturer / Model | IAP | Quantel 402 DP |
| Wavelength | 694 nm | 532 nm |
| Frequency | 1 Hz | 10 Hz |
| Pulse Energy | 3 – 5 J | 125 mJ @ 532 nm |
| Pulse Width | 15 -20 nsec | 160 ps |

| Echo detection | 1978-1983 | 1983-1995 |
|---|---|---|
| Type | PMT (RCA 7265) | PMT (EMI GENCOM D341B)<br>MCP (Hamamatsu R1244)<br>MCP (Hamamatsu R1249J) |
| Time of Flight | Interval (Eldorado 796) | Interval (since1986 HP5370A) |
| Epoch Timing | Quartz controlled by HGB (similar to DCF77) | Quartz controlled by LORAN-C, Since 1991 by GPS |
| Ranging accuracy | 60 – 100 cm | < 10 cm |

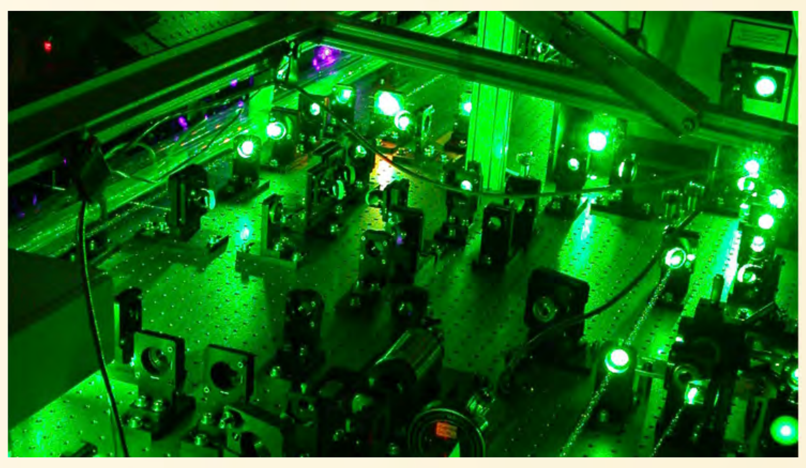
Laser systems used at the 50cm Cassegrain Telescope (1978 – 1995)

## 1 m ZIMLAT Telescope

1995 – 2008: In July the installation of the new 1-meter Zimmerwald Laser and Astrometry Telescope (ZIMLAT) was started. The telescope has been built by Telas, a joint venture of Aerospatiale Cannes and Framatome, France. For the first time a Titanium-Sapphire laser was introduced into an SLR tracking system. Day- and nighttime observations to all LEO and MEO satellites equipped with retroreflectors (including the GPS and GLONASS navigation satellites) were now possible and routinely performed. On 19th December 1996, first ranges to LAGEOS could be collected, the regular SLR observations started by mid-1997. The first ranges to a GPS satellite (GPS-35) could be measured on 16th July 1997. On 14th August 2002, the first two color ranging measurements were delivered to the analysis centers of the Inter national Laser Ranging Service (ILRS).

1 m ZIMLAT Telescope

Since 2008: In spring 2008 the Titanium-Sapphire laser was replaced by a new 100 Hz Neodyme:YAG laser system. On 7th April 2008 first successful ranging to LAGEOS was carried out, since 19th April the system operates on a routine basis 365 days per year and 24 hours per day in case of good weather conditions. On 20th July 2009, Zimmerwald was the first European station which successfully sent laser pulses to the Lunar Reconnaissance Orbiter (LRO). 5 years later another remarkable success was reported by the ILRS, namely the first simultaneous ranging to LRO between a European (Zimmerwald) and American station (Greenbelt) on 15th September 2014.



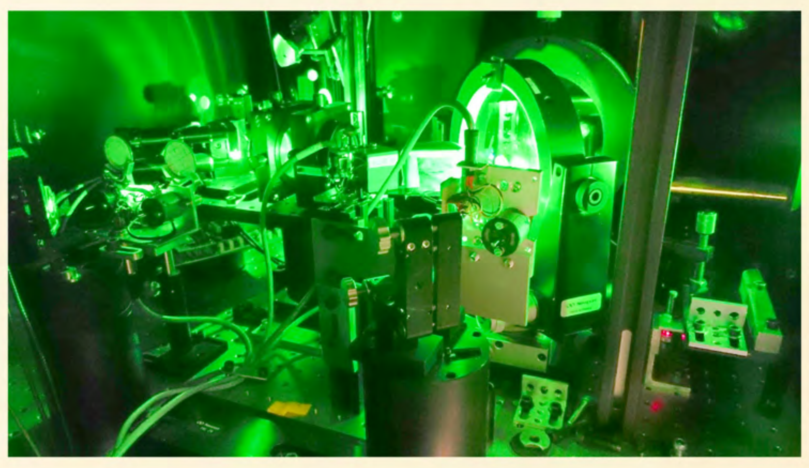
Titanium - Sapphire Laser 1996 - 2008

| Laser | 1996-2008 | Since 2008 |
|---|---|---|
| Type | Titanium-Sapphire | Nd:YAG |
| Manufacturer / Model | Thales | Thales |
| Wavelength | 423 & 846 nm | 532 nm |
| Frequency | 10 Hz | 100 Hz |
| Pulse Energy | 100 mJ @ 846 nm<br>40 mJ @ 423 nm | 24 mJ @ 1064 nm<br>10 mJ @ 532 nm |
| Pulse Width | 100 ps @ 423 nm | 58 ps @ 532 nm |

| Echo detection | 1996-2008 | Since 2008 |
|---|---|---|
| Type | PMT / CSPAD | CSPAD |
| Time of Flight | Interval counter (Stanford) | Event timer (Riga) |
| Epoch Timing | Quartz controlled by GPS | Quartz controlled by GPS |

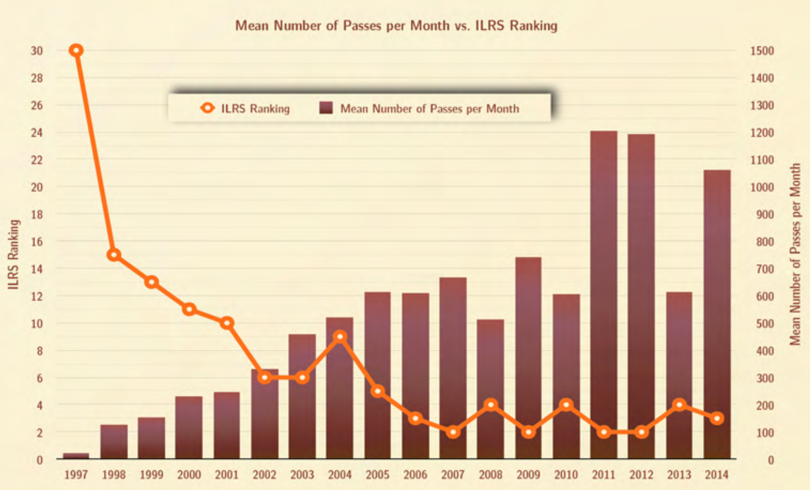
Laser systems used at the 1 m ZIMLAT Telescope (since 1996)

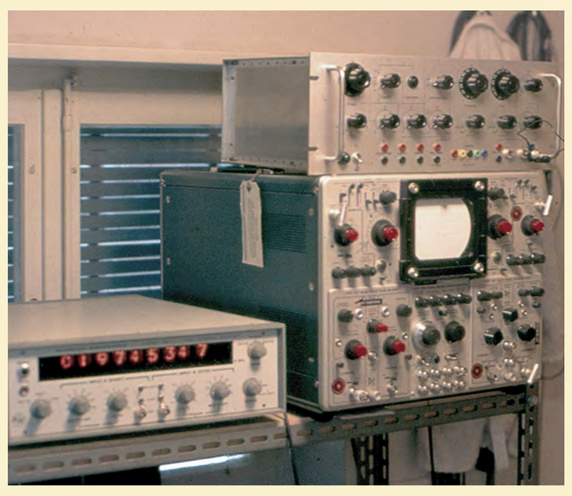
Since summer 2010 the complete GLONASS constellation is ranged from Zimmerwald. On March 2012 the Graz and Zimmerwald SLR stations successfully conducted the first ever so called ‘bistatic’ laser ranging to a non-cooperative target. On 28th March 2012 the Zimmerwald SLR station for the very first time successfully detected and time-tagged photons sent by a powerful laser at the Graz SLR station and diffusely reflected by the body of the European ENVISAT spacecraft. About one year later (18th June 2013) photons reflected on a space debris object (upper stage CZ-2C) with a considerably smaller cross section than ENVISAT could be detected.



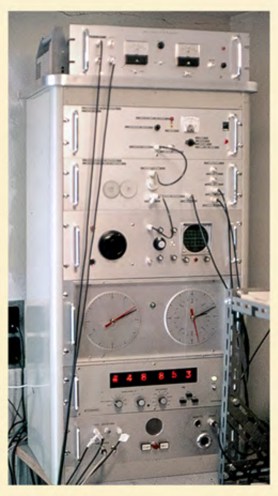
Transmit / Receive Switch of the current Nd:YAG Laser

Since 2006 Zimmerwald is one of the 4 most productive stations worldwide in terms of number of observed satellite passes and delivered normal points. Thanks to the steadily increasing automation of the observations the number of passes raised from about 100 passes per month in 1998 up to more than 1000 passes in 2014. The large increase of the number of delivered passes in 2011 can be explained by the continuous ranging of all GNSS satellites since 2010. Installation of the new laser system (2008) and replacement of laser components (2010 and 2013) can be clearly seen in the statistics.



Epoch registration 1971 - 1972

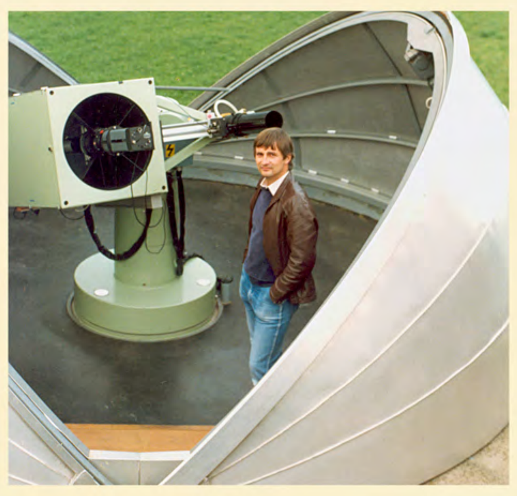


Timing system 1971 -1972

Nd:YAG Laser 1983 - 1995

PDP 11/40 1979 - 1987

PDP 11/40 1979 - 1987



50 cm Cassegrain Telescope 1976 - 1995