MeO: The new French lunar laser station

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Abstract

Since the beginning of the year 2004 a new organization focused on the Lunar Laser Ranging (LLR) and the mobile laser stations has been set up at OCA. In 2005 the LLR station was stopped in order to make some important modifications. The LLR station is now renamed MeO for "Metrology and Optics". Data acquisitions on low Earth altitude satellites, that were performed until now by the SLR station, will be done by MeO.
Since 2005, many developments was done:

Telescope: high speed motorisation, high accuracy pointing Dome: new guiding device
Building: offices, focus laboratory
Optics: optical benches for experimental research, optical path
Operational telemetry: lasers, high speed laser commutation, photo-detection
Software.

First echoes in the new configuration scheme on both low and high altitude satellite has been obtained in July 2008.

1. Introduction

In the past, the activities around the French Lunar laser ranging station [1] was primarily based on the observations of the moon and high altitude satellites. Since 2004, we have renovated the instrument in order to enlarge the program of the station:
- New facilities to make some instrumental research (new optical links, time transfer, astronomy)
- New performances to track some low altitude satellites or very distant targets

The instrument is now called MeO.

We have at OCA 4 instrumental projects based on the laser thematic:
- MeO station
    - Lunar laser ranging
    - Low and high altitude satellites laser ranging
    - Time transfer
    - Research

- FTLRS « French Transportable Laser Ranging System» [2]
    - Low altitude satellites laser ranging (up to lageos)
    - Altimetry calibration
    - Time transfer
- Time and frequency laboratory
    - Time Scale
    - Local time and frequency distribution
    - Time Transfer comparison: T2L2, TWSTFT, GPS
- Time transfer by laser link [3] [4],
    - Very high resolution Time transfer
    - One way laser ranging demonstration
    - Optical and microwave link Time transfer comparison

2. MeO Project overview

The station is based on a 1.5 meter Cassegrain telescope installed on an Alt-Az mount. The total weight of the mobile elements of the instrument is roughly 20 tons. The diameter of the dome is 9 meters with a total weight of 14 tons. The station use a Nd:YAG laser @ 10 Hz and a common optic (the main telescope) for both the laser emission and reception.

The renovation is divided in 4 themes:
- Motorization - Dome
    - Increase the maximum speed of the telescope at 5°/s with an acceleration of $1°/s^{-2}$
    - Increase the pointing accuracy below 1 arcsec.
- Coudé, focal laboratories
    - Operational laser ranging observation with a dedicated laboratory for that purpose.
    - Instrumental research with some dedicated optical benches directly connected to the optical flux of the telescope.
- Software
    - Upgrade the software for both laser ranging observation and research activities.
- Renovation of the monument
    - Renovation of the existing surface.
    - Construction of new surface.

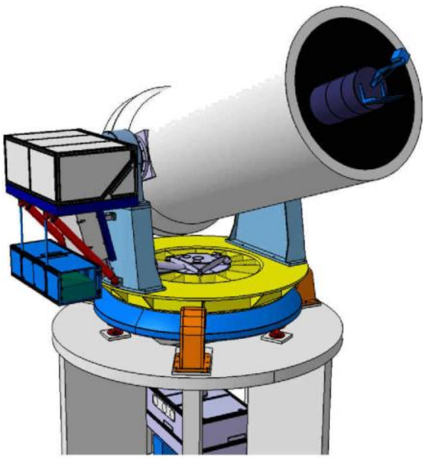

Figure 1. Overview of the MeO station. Telescope diameter: 1.5 m.
In the real configuration, there is a floor in the plan of the Yellow disk

3. Focal Laboratories

There are 2 laboratories (Fig. 2): one for research and development, the other for operational laser ranging.

The first one is based on a 60 m^2 circular room located under the telescope and centred on the azimuth axis of the telescope. There are in this lab 4 optical benches for the projects. A fifth one, in the middle of the room is devoted for the flux distribution. This bench is equipped with a fold mirror on a rotation stage that permits to send the light form the telescope to one of the other optical benches.

The second one is 6 m apart from the azimuth axis. It has a surface of 45 m^2. All the instrumentation for laser ranging is located in this lab. It is built around a single large optical bench for both laser and reception unit. This architecture permits to have the same optical path in the Coudé for both emission and reception. The laser has 2 cavities, one for the Moon (200 ps 300 mJ), the other one for the satellites (20 ps, 50 mJ). Currently, the detection unit is located on the Nasmyth bench. It will be installed in the final operational lab by the end of the year 2009.

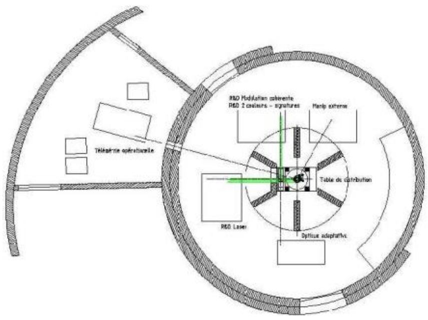

Figure 2. Focal laboratories. The circular shape is the wall supporting the dome.

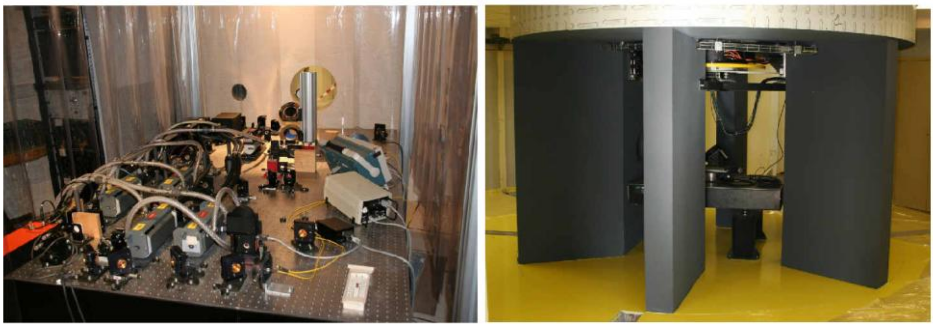

Figure 3. On the left, photography of the laser ranging optical bench.
On the right, the pillar of the telescope in the focal laboratory

4. Coudé

The coudé permits to manipulate the optical beacon coming either from the laser or the telescope. It is made with some large 200 mm flat fold mirror. These mirrors are made in Zerodur with some dielectric layers. The layers are organized in order to obtain a very large bandwidth between 350 to 1200 nm. In the band 400-1100 nm, the reflection factor is higher than 98 % for both s and p polarizations. The damage threshold is greater than 10 J/cm^2 for ns pulses. The diameter of the mirrors was chosen to obtain a field of view of 5 arcmin on the distribution bench and 2 arcmin on the laser ranging bench.

Figure 4. 200 mm high energy Fold mirrors; distribution bench on the left.

5. Motorization

As compared to the previous design (based on a worm wheel), the objective was to increase both the speed and the acceleration by one order of magnitude to get: 5^o/S for the speed and $1^o/s^{-2}$ for the acceleration. It has been achieved with some direct drive motors and some direct encoders (Fig. 5).

The motors are made by Etel. The main characteristics are:
- Torque: 1000 kg.m
- Diameter 800 mm and 1000 mm
- Drive by a DSPC2 drive made by Etel

The encoders are made by Heidenhain. The main characteristics are:
- Absolute for the elevation axis ; incremental for Azimuth
- Linearity < 1 arcsec
- Precision: 0.01 arcsec

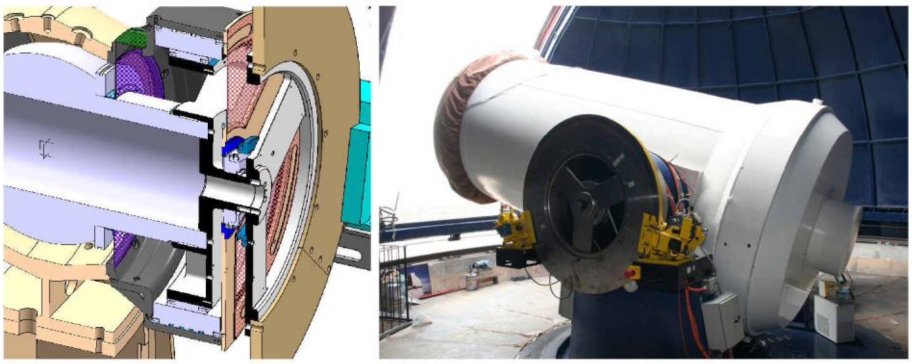

Figure 5. Motorization of the Elevation axis. The disk on the first plane is the brake.
On the left view, the rotor and stator can be seen just after the disk.
The absolute encoder is at the end of the axis.

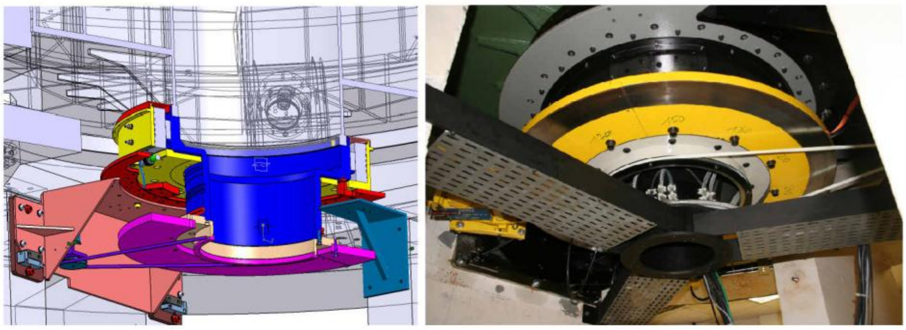

Figure 6. Motorization of the azimuth axis.

The pointing precision for both axis are 0.015 arcsec rms. The accuracy is corrected through a calibration process using position of stars. This calibration is based on a 6 order harmonic decomposition model. With a table built through 48 starts, one obtains an absolute accuracy better than +/- 2 arcsec. Two inclinometers have been attached to the pillar of the telescope to improve (in the next future) this absolute accuracy. They will permit to correct in real time the pillar tilt which is currently the main inaccuracy source.

6. Dome

The dome was redesigned for the same reasons: increase the speed and the acceleration of the dome in order to get the same performances: 5°/s. It has been achieved with a circular rail attached on the wall, and 10 guiding modules maintained by some springs for both the vertical axis and the radial axis (Fig. 7). The motorization is made with an asynchronous motor drives in frequency.

Figure 7. Guiding module of the dome. The rotation is obtained with a 30 meters chain and an asynchronous motor located downstairs

7. Software

The new software is based on an architecture with several PC machines.
- Telescope:
    - Generation of tables giving the prediction positions of the targets as a function of time.
    - Coudé steering
    - Communication with Etel's drives through a dedicated machine

- Security of the telescope
- Smart interface

- Laser ranging
  - Rotating mirror, neutral density, filters,
  - Computation of the real time residuals
  - Event timers interface

In the future, another PC machine will control the whole instrumentation through an unique interface.

8. Results

The first light of the telescope in the new configuration was obtained in May 2008, the first echoes (Etalon) in July 2008 and the continuous observation by the end of October. The observations on the Moon restarted in April 2009, but up to now, one doesn't get any echoes (some fine adjustment are still necessary in the laser).

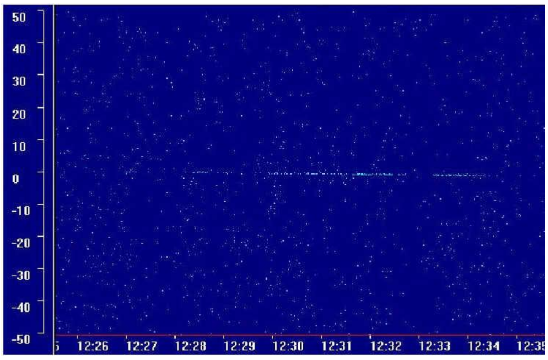

Figure 8. Echoes on Lageos

9. Conclusions

The capability of the station is now extended from low altitude satellite to the moon. The Moon will continue to be a major objective for the station together with Time transfer and high altitude satellite. The new configuration of the station will permit to perform both laser ranging and experimental research.

Reference

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