

# **LASSO EXPERIMENT INTERCALIBRATION TRIP FOR THE TWO LASSO RANGING STATIONS**

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## **Abstract**

*In order to achieve the accuracy of the LASSO time transfer between OCA, Grasse, France and McDonald Observatory, Texas, USA, an intercalibration of the two Laser Ranging Stations was made.*

*At the same stations, GPS receivers were set up and the GPS to Laser epoch differences were also monitored.*

*In addition to the principle and the results of the measurements, the cause of the difficulties met during the campaign will be described.*

## **INTRODUCTION**

After a successful LASSO Ranging Campaign by the two Lunar Laser Ranging (LLR) Stations, University of Texas at Mc Donald and Observatoire de la Côte d'Azur in Grasse, which took place from April 1992 to January 1993, an intercalibration trip for the participating stations has been set up.

The principle of this intercalibration (Fig. 1) is to use a common vector on both sites, in order to determine the emission delay difference. The common vector is a specially designed laser ranging station, transportable and able to be set up close to each telescope. The range limit of such a station is of a few kilometers on simple ground targets (corner cube).

## **CONFIGURATIONS**

At each site two configurations were scheduled:

- emission by the LLR local station and reception by both LLR local station and calibration station (Fig.2).
- emission by the calibration station and reception by both stations (Fig. 3). These configurations allow to write a set of redundant relations from which we can derive the difference of the emission delays. This difference is called the LASSO calibration. For the LASSO calibration to be valid, it is necessary that the delays of the calibration station and the cables for the 5 MHz and the 1 Hz remain stable. A special design of the calibration station allows to monitor any change in the internal delays and the cables being considered as part of the equipment thereof. The same set of cables will be used at every site.

Outside of the LASSO calibration, another calibration is needed in the Lasso synchronization relations. It is the ranging calibration of each LLR Station.

This is routinely surveyed by the ranging teams and could be also determined from the two way flight time of the laser beam of the calibration station.

## CALIBRATION TRIP

The calibration started in April 1993 at LLR OCA Station. The transportation of the calibration station was easy since a van had been purchased for that purpose. Setting the station near the LLR telescope was quite easy, we only had to solve a Radio Frequency Interference, probably caused by the iron sheet cover of the dome of the LLR station. In June of the same year, we moved the station to the LLR station at McDonald. The transportation of the calibration station was done by air, from Nice to Houston, then by truck, from Houston to El Paso and finally by car, from El Paso to the Observatory.

At the station our equipment had to be set up outside as the shelter of the LLR station was already quite crowded. This occurred to be somewhat of a problem as the weather was unusually bad (heavy rain and wind) for such an area as Texas at that time of the year. After some hardware adjustments (laser, telescope focus) the calibration station was ready to work in less than two days in what we would call an expected nominal mode. However, because we did not have any oscilloscope that we could use, we were unable to control the level of the discriminators and actually for some reason they were not set as they were for the calibration at OCA.

We have to mention here that we encountered some problems, which are not unusual when you carry material to different countries. The ATA Carnet, for example is not commonly used in some areas as El Paso, and of course it can be of a risk to go through customs on an official Holiday.

## CALIBRATION SESSIONS

- The LLR OCA station was designed with LASSO in mind, therefore outside of the Radio Frequency Interference problem, no other difficulties appeared. The data files are very

stable for successive and close together sessions, but not for day to day sessions with a noise around 150 ps up to 300 ps (Fig. 4).

- The LLR McDonald station, in spite of some difficulties saved the LASSO experiment, as it was the only other station ready and in position to make LASSO sessions at that time.

The station had been designed with only the goal of ranging and later on adapted for LASSO observations.

Consequently we have encountered some limitations at McDonald station:

1. Processing the data in real time was impossible, as a preprocessing of the data at University of Texas at Austin was absolutely necessary to make the files readable. This led to the impossibility of scheduling any other session in case that something would fail. An example is that we could not discover that a range gate had been adjusted in the wrong way, rejecting the real data and recording the adjacent noise (Fig. 5).
2. The design of the equipment is such that the same interpolator is used for both the emission and the reception. Ranging the Moon or satellites is very efficient in this way, as any variation in the interpolator slope cancels. For LASSO the emission delay, relying on a single path in the interpolator, may and actually does change from day to day (estimated to up 5 ns). For calibration sessions, ranging on a close target is impossible, because the dead time of the interpolator is far too large (Fig. 6). As the system is computer driven in a synchronous mode, the LLR station is then also unable to record emissions from the calibration station (Fig. 7).

Back to OCA LLR station we discovered that the calibration equipment delay had changed during the trip, most likely during the hardware tuning at McDonald station and because we did not have a oscilloscope, we could not readjust the constant fraction discriminator at the ideal level. This adds an uncertainty of 1 ns. Taking into account the previous remarks, the data files recorded at McDonald station have the same discrepancy than the ones of OCA. The short term stability is rather good (1 to 3 hours) but the values drift from session to session.

The overall calibration is computed at 136,999 ps. It is obvious that this is meaningless due to the long term instability of a part of the Lunar Laser Ranging station equipment at McDonald, which was not fully designed for LASSO experiment.

The estimated discrepancy could be up to  $\pm 2.5$  ns.

## CONCLUSION

Considering what we have learned during this first intercalibration trip, we think that the equipment as it is designed, could provide a value with an accuracy of a few hundreds picoseconds (200 to 300 ps).

It has to be noticed that the stations willing to participate in such campaigns have to be designed for time transfer and need event timers reaching at least the same accuracy.

With some changes, such as fast photodetectors, a new event timer and new discriminates, the level of 30 to 10 picoseconds could be reached.

## REFERENCE

J. Gaignebet et al., "*LASSO Experiment: Intercalibration of the LASSO Ranging Stations*", Proceedings 25th Annual Precise Time and Time Interval Applications and Planning Meeting, December 1993.

## INTERCALIBRATION LASSO CONFIGURATION GENERALE

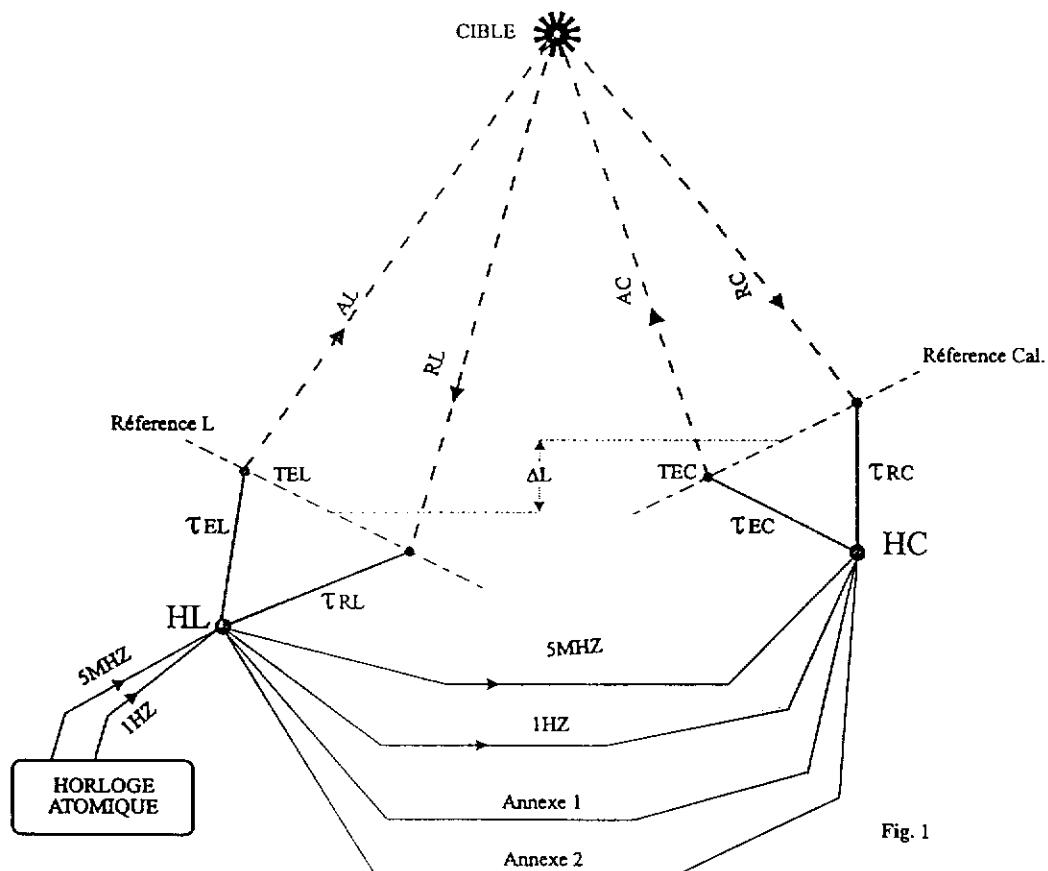


Fig. 1

### STATION LASER LUNE :

HL = Dateur Laser Lune  
 Ref.L = Référence station Laser Lune  
 TEL = Heure passage laser au point de ref.  
 AL = Temps aller Ref.L / cible  
 RL = Temps retour cible / Ref.L.  
 $\tau_{EL}$  = Ecart Réf.L / Dateur HL  
 $\tau_{RL}$  = Ecart Dateur HL / Réf.L.  
 CCLL =  $\tau_{EL} + \tau_{RL}$  (Constante de calibration LL)  
 AL = RL

5MHZ, 1HZ, Annexe 1, Annexe 2 = Cables coaxiaux

### STATION DE CALIBRATION :

HC = Dateur station de calibration  
 Réf.Cal. = Référence stat. de Calib.  
 TEC = Heure au point de Réf.  
 AC = Temps aller Réf.Cal/cible  
 RC = Temps retour cible/Réf.Cal.  
 $\tau_{EC}$  = Dateur Réf.Cal. / Dateur HC  
 $\tau_{RC}$  = Ecart Dateur HC / Réf.Cal.  
 $\tau_{EC} = \tau_{RC} = \tau_C$   
 AC = RC

## INTERCALIBRATION LASSO CONFIGURATION PHASE1 GRASSE

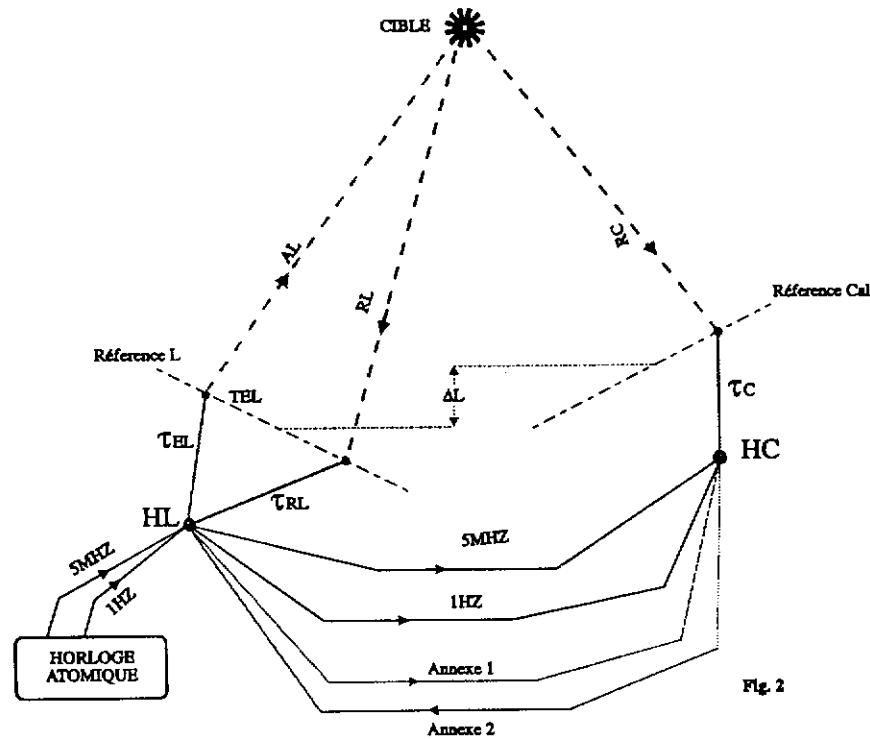


Fig. 2

## INTERCALIBRATION LASSO CONFIGURATION PHASE2 GRASSE

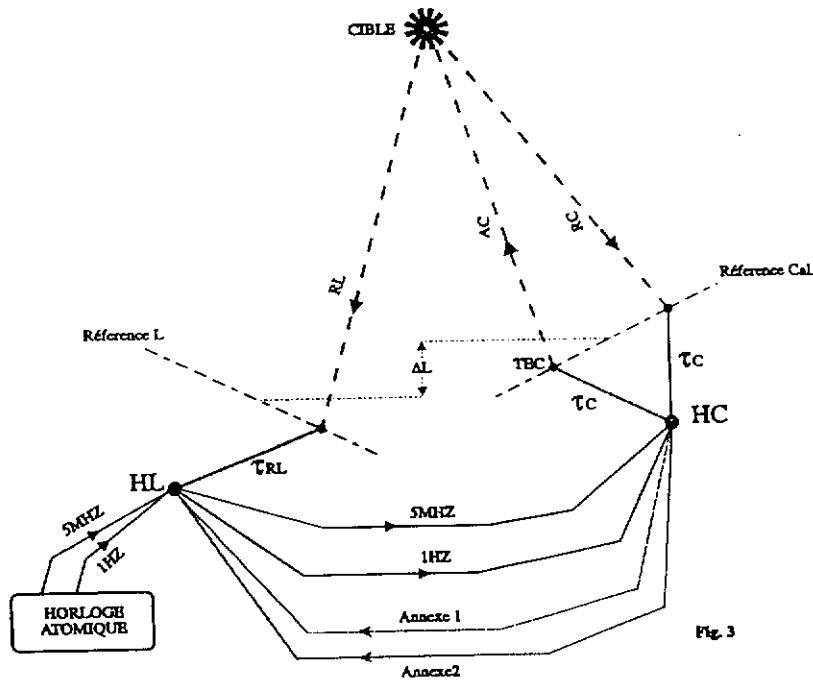


Fig. 3

## LASSO INTERCALIBRATION PHASE 1 GRASSE

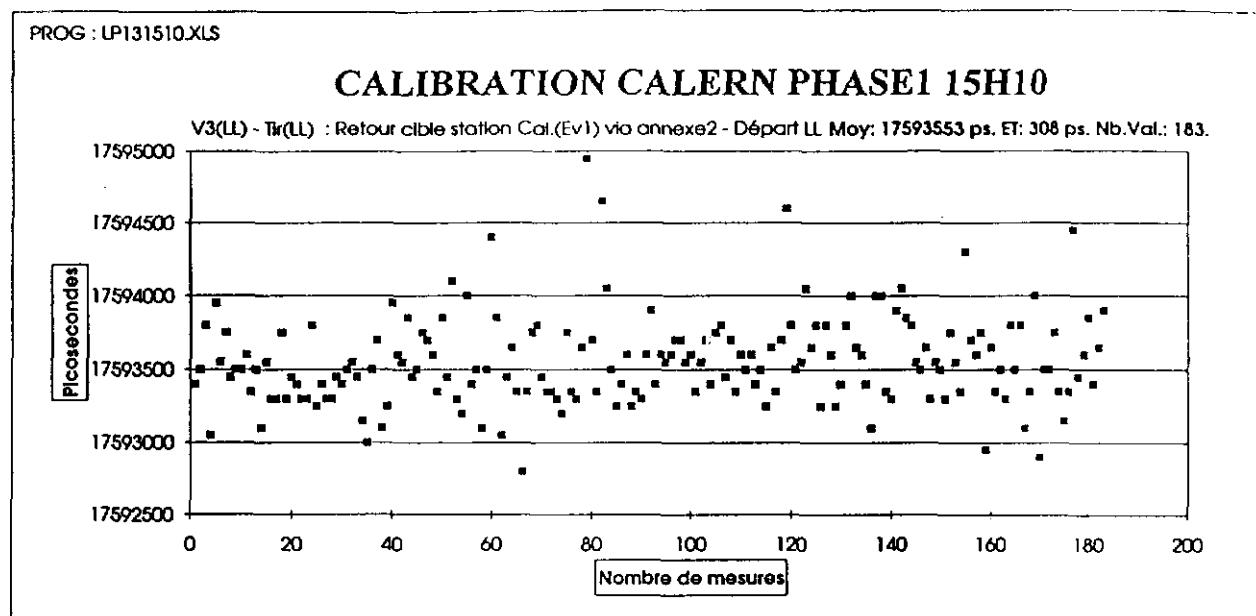


Fig. 4

## LASSO INTERCALIBRATION PHASE2 TEXAS

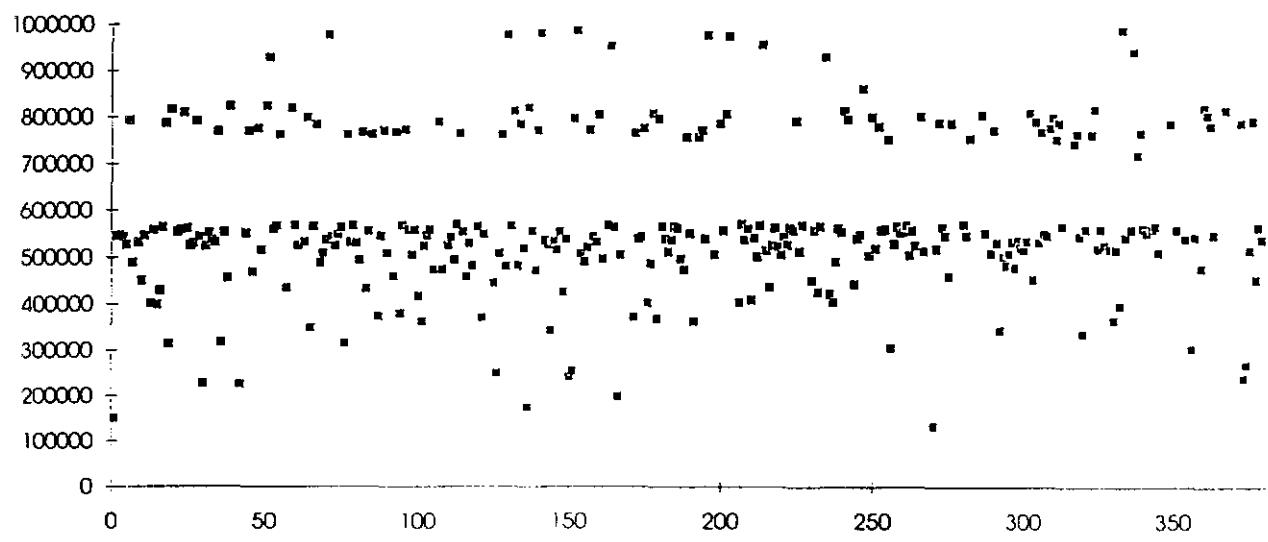


Fig. 5

## INTERCALIBRATION LASSO CONFIGURATION PHASE1 TEXAS

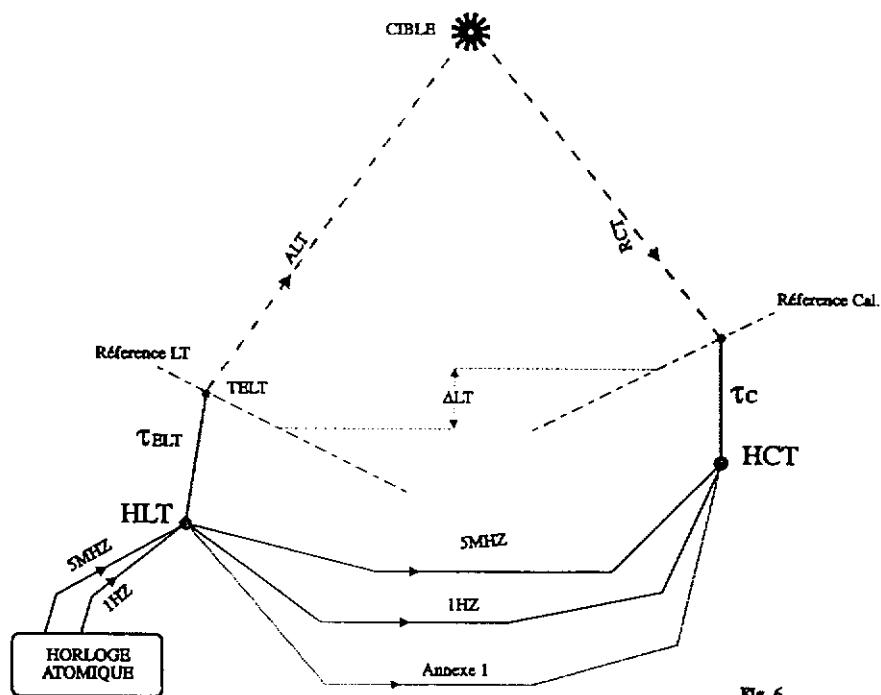


Fig. 6

## INTERCALIBRATION LASSO CONFIGURATION PHASE2 TEXAS

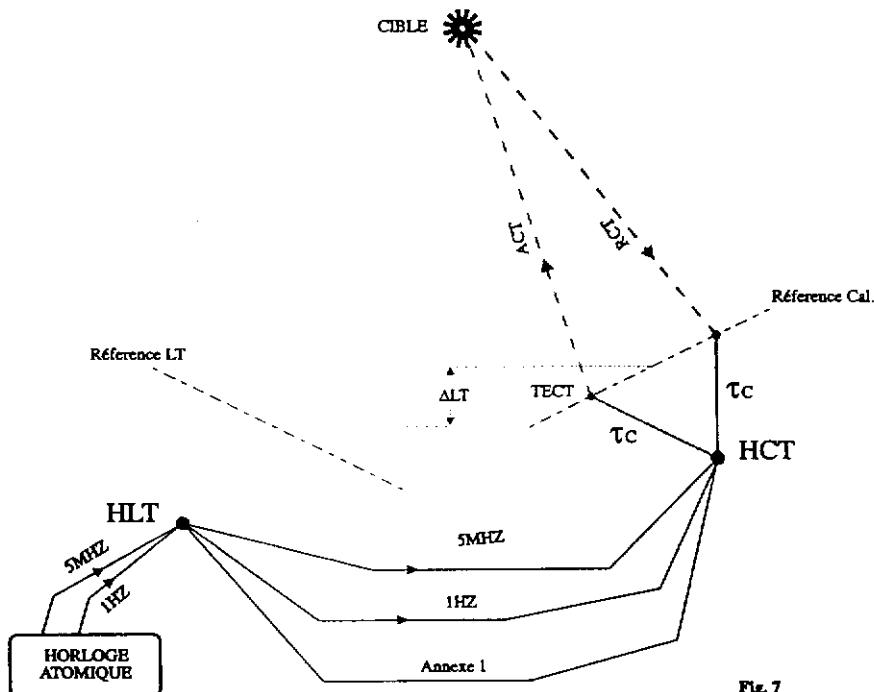


Fig. 7