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Results of the MTLRS-1 Upgrade

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Abstract. In this report the results of the upgrade of the German Modular Transportable Laser Ranging System MTLRS#1 are summarized. A short description of the new components and their influence on the system accuracy is given. It is shown, that the single shot accuracy of the MTLRS#1 has been improved from 5 cm to 1 cm.

1. Introduction

The German Modular Transportable Laser Ranging System MTLRS#1 has been operated successfully since 1984. From 1985 to 1990 the system was employed in the Central and Eastern Mediterranean area and in the U.S.A., contributing to the WEGENER-Medlas and the NASA Crustal Dynamics project.

In order to improve the system reliability and the ranging accuracy from 5 cm to 1 cm a major system upgrade was performed from December 1990 to July 1991.

This upgrade was planned and carried out in five steps:

- Exchange of the Laser
- Exchange of the Start Detector
- Exchange of the Receiving System
- Exchange of the Single Photon Detector
- Improvements in Periphery and Software

In this paper we will summarize the technical specifications of the new systems and show first tracking results.

2. Technical description of the upgrade

2.1. The Laser

The duration and the energy of the emitted laser pulses are critical elements in the determination of the accuracy and the number of returns produced by a satellite laser ranging system. To improve this two points, we exchanged the original Nd:YAP Laser (Pulseduration: 370 ps; Pulseenergy at 536 nm: 10 mJ) for a new Nd:YAG Laser (Pulseduration: 30 ps, Pulseenergy at 532 nm: 30 mJ). To ensure a good reliability of the laser in field, we made use of the self filtering unstable resonator (SFUR), described by R. Bianchi et.al. and K. Hamal et.al, which has a very simple optical layout.

This setup has three major advantages:

- insensitive to inaccurate adjustment
- homogenous spatial energy distribution
- very high pulse energy in the resonator.

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The realisation of the optical setup of the laser delivered by Laser Valvivre is shown in Fig. 1. To save place, the resonator M1 - M2 is folded over the prism PR. The laser is cavity dumped through a pockelscell PC and a polarizer PO. An active-passive configuration (acousto-optic modelocker ML and dye cell with Kodak 9860 in 1,2-Dichlorethan) is used to generate picosecond pulses.

In the SFUR configuration, the energy of the pulses in the resonator is already reasonable high, therefore a Single Pass Amplifier (AMP) is sufficient to generate a pulseenergy of about 100 mJ in the infrared which gives about 30-40 mJ in the Second Harmonic.

Due to the good isolation of the laser head and the power electronic to environmental influences and due to remote control facilities in the laser head, we are able to operate the laser over long period without opening the shielding.

2.2. The Start Detector

To take full advantage of the short laser pulses it is necessary to use a start diode with very fast risetime to generate the start signal for the counter. As each component between diode and counter gives some additional jitter we were looking for a solution with a very simple electrical layout. Mainly we tried to find a way where it was no longer necessary to use a constant fraction discriminator to compensate the amplitude fluctuations of the diode signal.

Therefore we integrated an optically triggered avalanche diode (I. Prochazka et.al.) as start detector. This diode generates an electrical signal, which is independent from the energy fluctuations of the laser pulses. This signal is directly used as start signal for the counter.

The signal has a risetime of 300-400 ps (Fig. 2), the jitter between laserpulse and electrical pulse is less than 20 ps.

To obtain high stability and to have also the possibility to vary the pulse energy during tracking the new start diode is placed before the amplifier to detect the infrared signal. In the previous design the diode detected the green light after the second harmonic generation.

2.3. Receiving Package

In contrast to other SLR System the MTLRS is using an echelle grating for the spectral filtering of the received light. Compared to the common used interference filters this has the advantage to be insensitive to environmental influences. Unfortunately an echelle grating generates a time spread of a pulse due to the different light paths over the grating.

In the old grating this was compensated with an accuracy of about 1 cm by sending the diverse parts of the beam to different mirrors. Due to this splitting of one pulse into several beams, the outgoing beam has not the high optical quality which is necessary for focusing on the small active area ($100\mu\text{m}$) of an avalanche diode.

In the new package a second echelle grating in opposite position is used to make full compensation. The excellent optical quality of this configuration results in a very homogeneous beam which is necessary to generate small focal spots.

Additionally a remote controled field-of-view pinhole and a better isolation against straylight is installed in the new package. The sketch of the whole receiver is seen in Fig. 3. (H. Visser)

At the input the beam coming from the telescope is directed by a prism to an optical package in which a rotating shutter and some small prism are used for filtering and guiding of the beam. The light has to travel through the rotating shutter and is directed to an echelle grating. After that the pulse is spread in time and frequency. An adjustable pinhole is used for the field of view filtering and for selection of the correct wavelength. To compensate the time spread the beam now

propagates a second time to the echelle grating before two lenses form a parallel, 8 mm diameter output beam.

2.4. Single Photon Detector

A major improvement in the accuracy of the time interval measurement was achieved by the exchange of the photomultiplier for a single photon avalanche diode (SPAD) (I. Prochazka et.al., G. Kirchner).

The signal out of the SPAD is independent of the signal strength, so the use of a constant fraction discriminator is not necessary.

A description of the technical details is given in Sperber et.al.

3. System Accuracy

The main reason for the upgrade of the MTLRS was the demand to improve the system accuracy from 5 cm to about 1 cm single shot r.m.s.

In Fig. 4 the development of the accuracy during each step of the upgrade is depicted. The main influence to the accuracy came from the exchange of the laser and the single photon detector. The start detector has minor effect and the importance of the new receiver package can be seen in the good optical quality which finally allows the usage of the SPAD.

The contribution of each single component of the system to the system accuracy is shown in Fig. 5 for the old and the new configuration. The r.m.s of all components has now about the same size. Further improvements are probably possible at the laser (10 ps) and at the counter. More accurate start and stop detectors are not available at the moment.

The plot of a typical pass before and after the upgrade is given in Fig. 6. Here the significant decrease of the system r.m.s is conspicuous.

All this data are showing, that the single shot accuracy of the MTLRS#1 is now 1 cm or less, if all components (mainly start diode, SPAD and laser) are optimally adjusted.

Under field conditions we demonstrated (P. Sperber, H. Hauck) a system accuracy of 1 cm - 1.5 cm and a normalpoint accuracy of a few mm.

3. Perspectives into the next years

The receiving and transmitting part of MTLRS#1 is now again state of the art. To bring the whole system to a status comparable with modern SLR systems two additional upgrade steps are under discussion.

- Installation of a new control electronic and software, designed for future demands to Laser Ranging Systems. IfAG has decided to develop such a control system based on a transputer network in cooperation with MTLRS#2 (OSG Kootwijk). The integration in the MTLRS#1/2 is scheduled for 1993 (E. Vermaat et. al.)
- The Laser and the Receiving system are now prepared to make two color ranging. Only the telescope does not meet the specifications for two color ranging as the reflecting mirrors are optimized only for a wavelength of 532 nm. A further upgrade for two color ranging capability depends strongly on the demand of the international SLR community for two color ranging data.

5. Summary

After the upgrade of MTLRS#1 performed from December 1990 to Juli 1991 a system with the following modified specifications is now available.

- 30 ps laser pulse-width with 30 mJ/pulse at 532 nm
- Optically triggered avalanche diode to start the time interval counter
- Compensated echelle grating filter
- Single Photon Avalanche Diode
- In field normal point generation

As a result of these modifications MTLRS#1 is now capable of tracking high and low satellites day and night with a single shot r.m.s. of about 1 cm.

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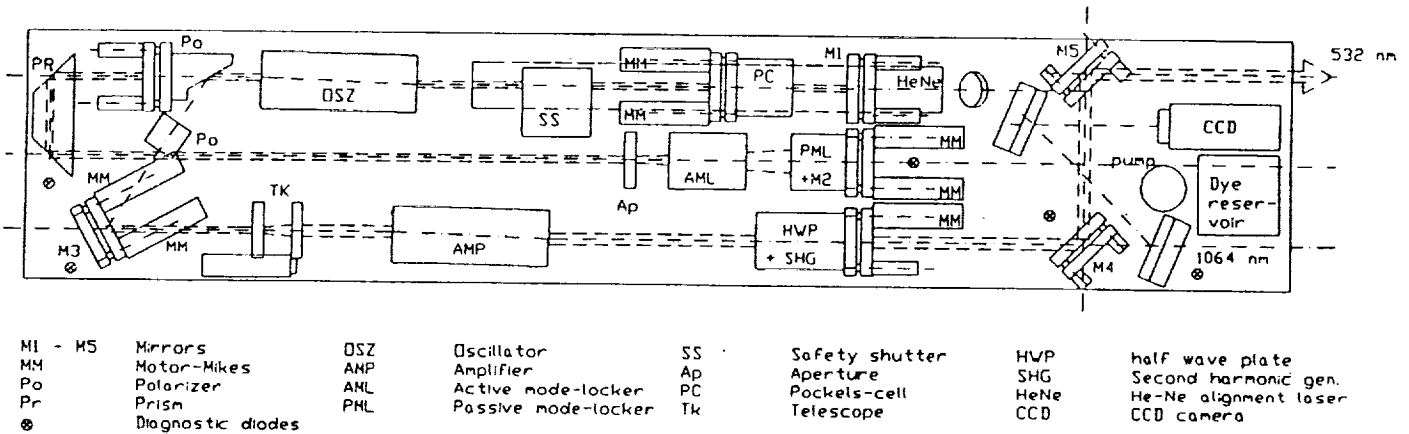


Fig. 1 - Schematic of Laser Head

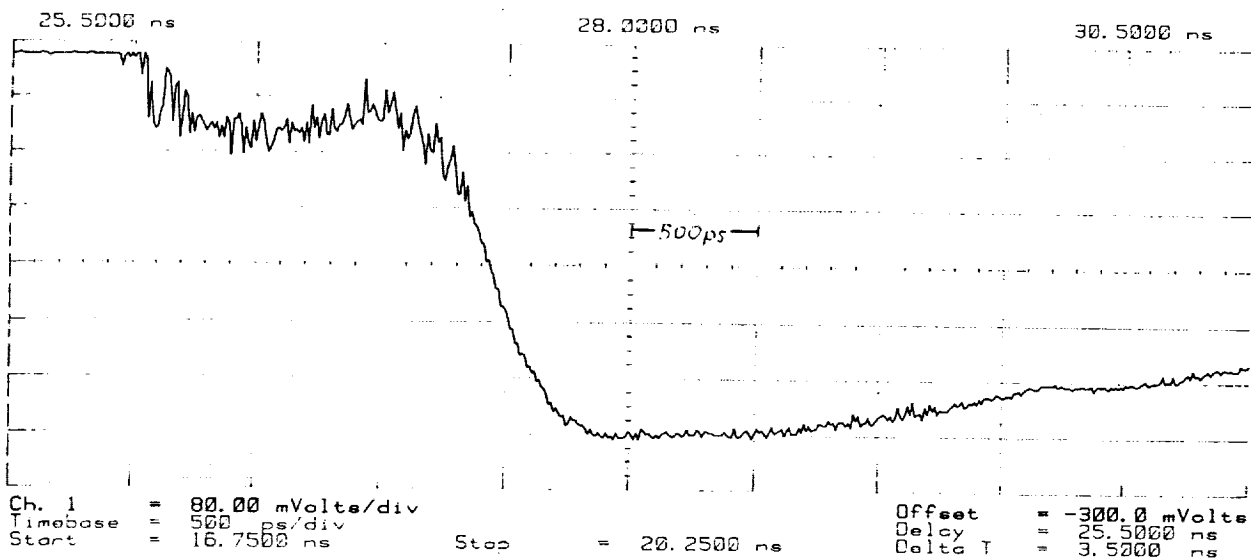


Fig. 2 - Signal of the Start Diode

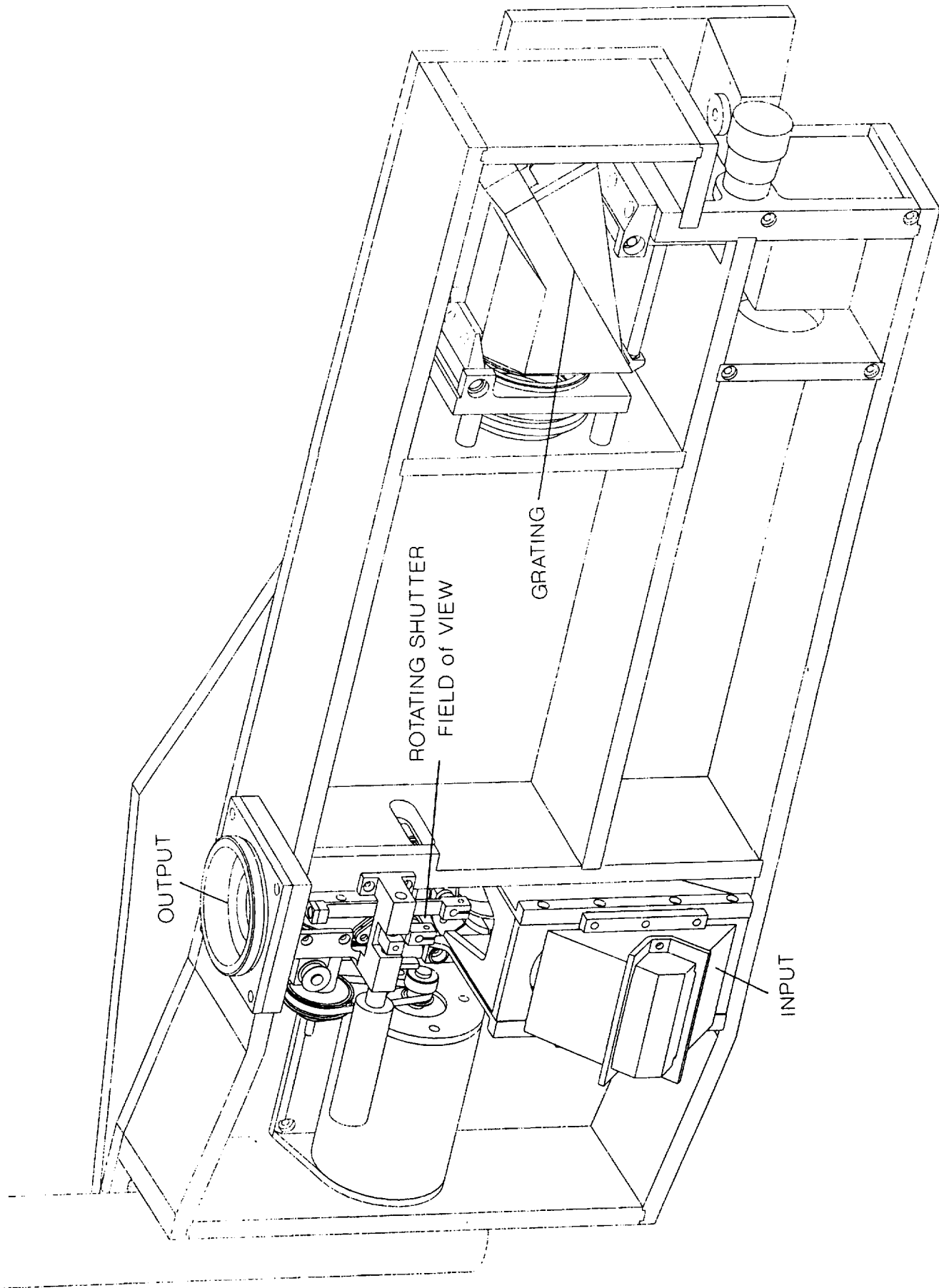


Fig. 3 Mechanical Layout of the MTLRS#1 Receiver Package

Decrease of MTLRS#1 r.m.s

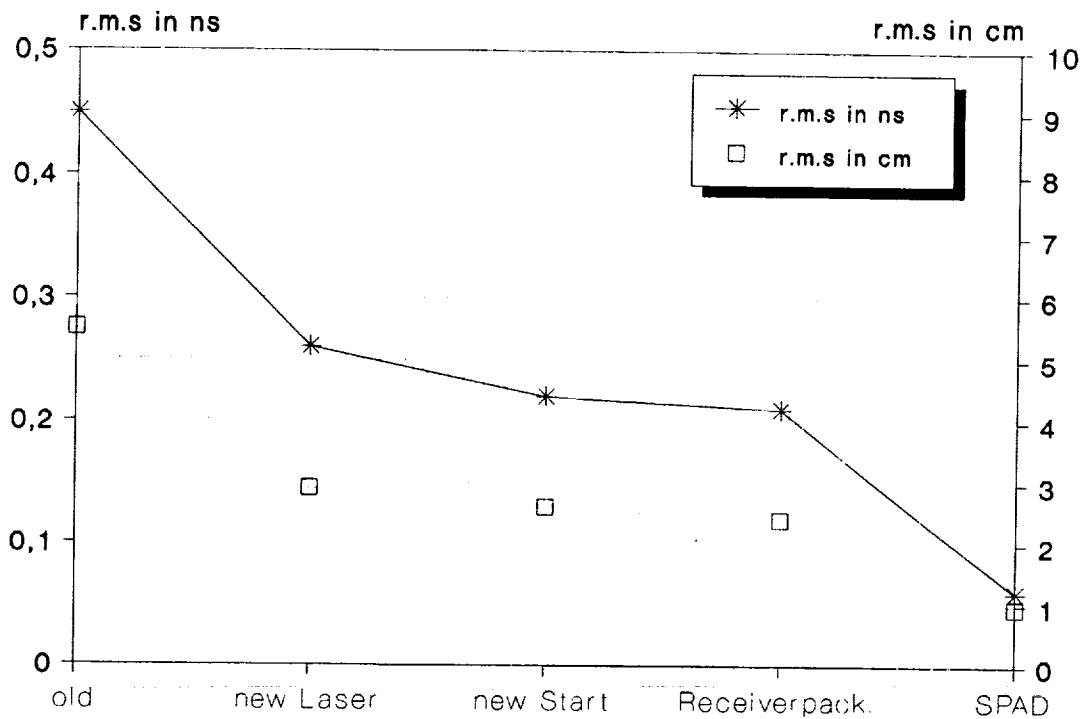


Fig. 4: Decrease of the single shot r.m.s. during upgrade

R.M.S. of MTLRS#1 Components

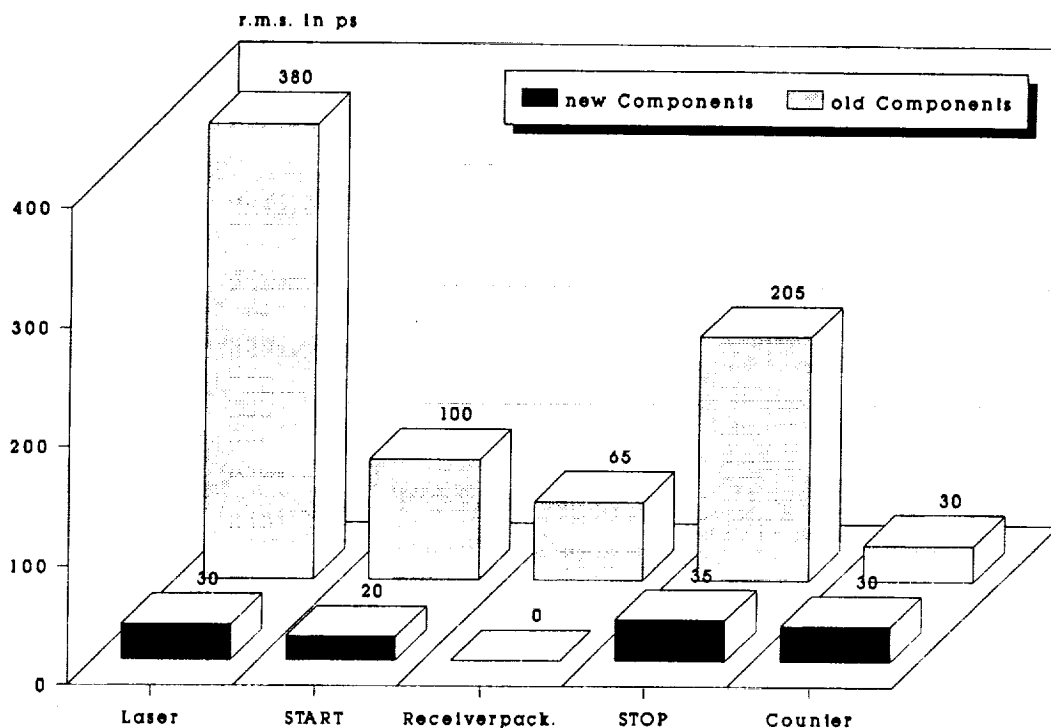


Fig. 5: Single shot r.m.s before and after upgrading

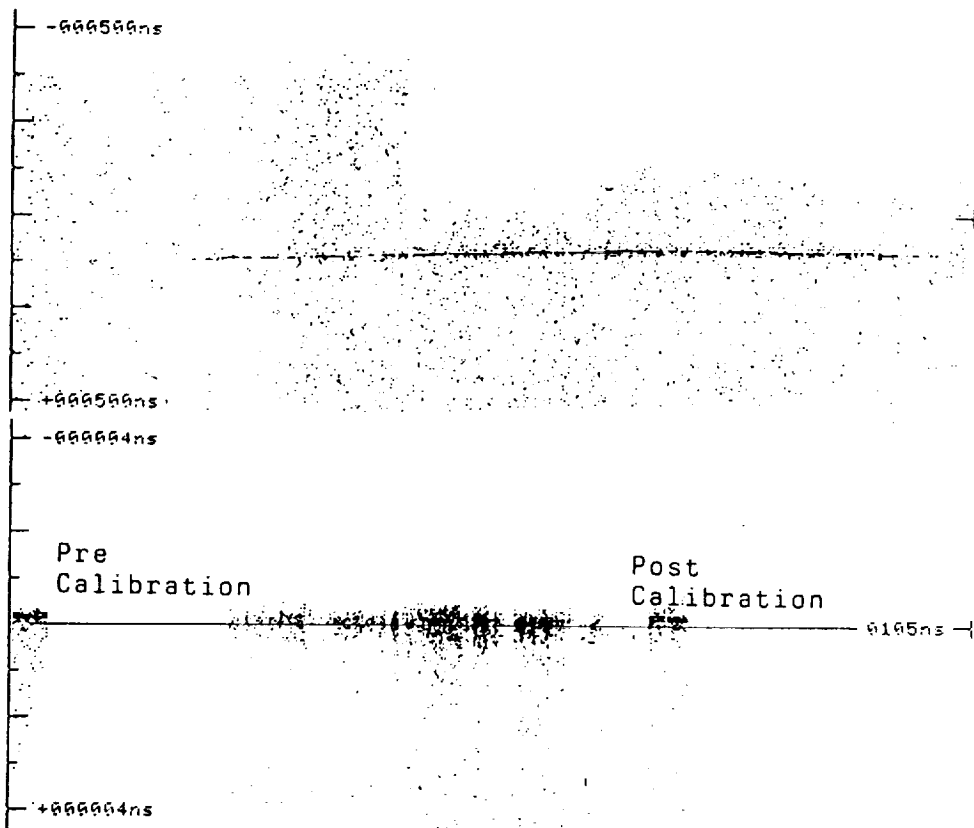
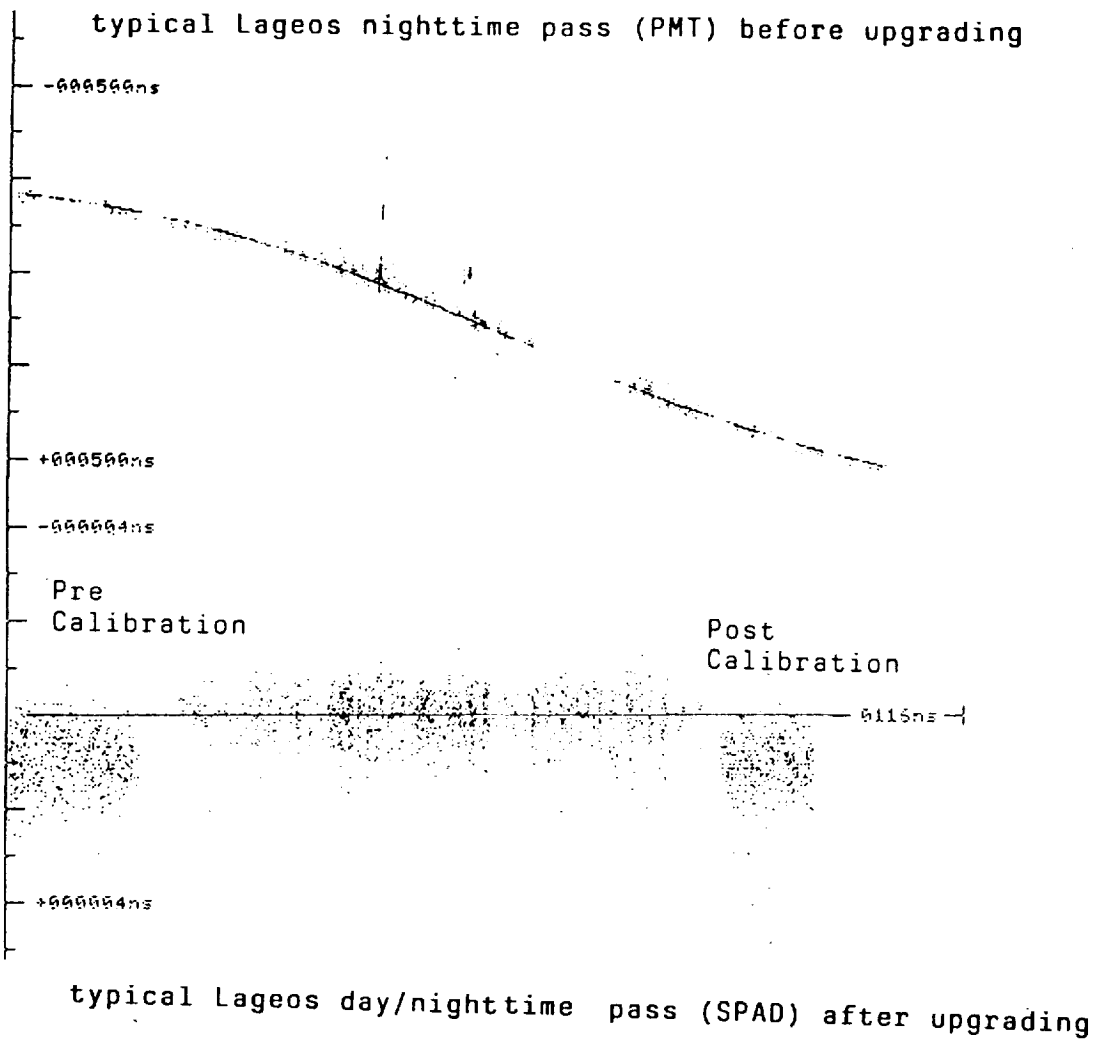


Fig. 6 - Lageos Pass before and after upgrading