One Way System Calibration Techniques

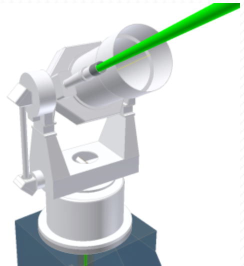
Toby Shoobridge
David Benham

NERC Space Geodesy Facility
Herstmonceux, UK

Email: tooo@nerc.ac.uk

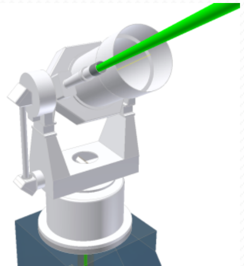
Aim

- To measure the delay in various components of our SLR two-way calibration
- Understand the Transmit-side delay



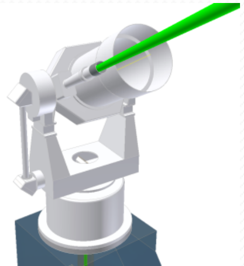
Necessity

- It has always been necessary to make a calibration to account for the two-way delays in an SLR system
- The Proposed work in T2L2 and LRO requires as accurate an epoch as possible for the laser pulse as it passes the system reference point



Current System Calibration Technique

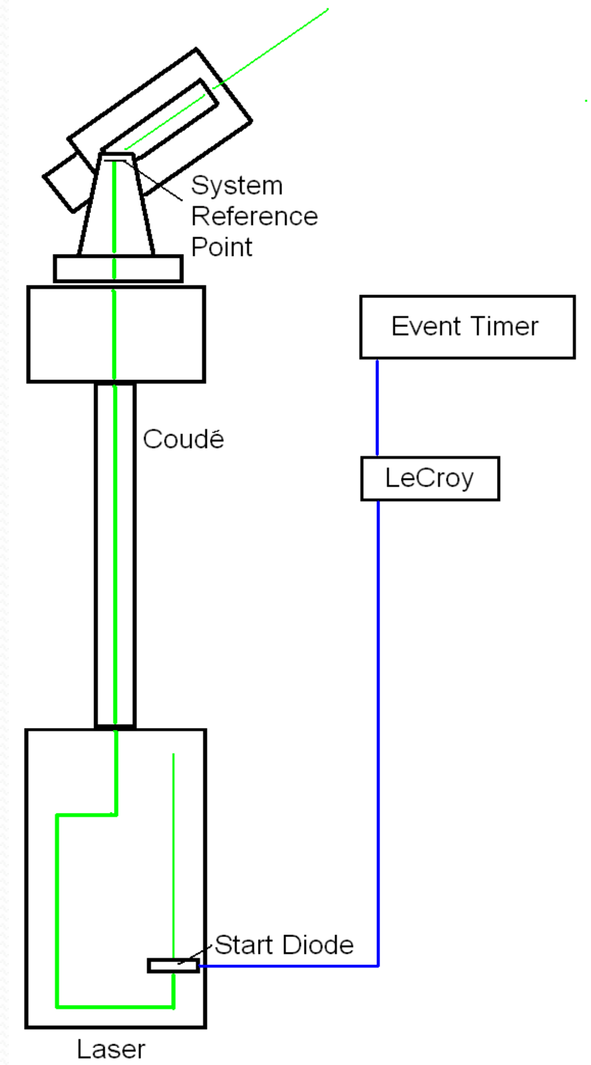
- We range to a fixed ground target of a known distance to give us our calibration value
- This accounts for both Transmit-side and Receive-side delays as a whole
- Unfortunately this cannot simply be split into the two parts we're interested in

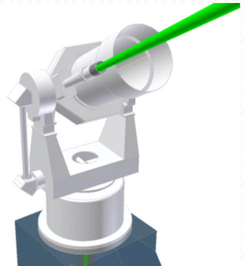


Transmit-side Delay

Comprised of:

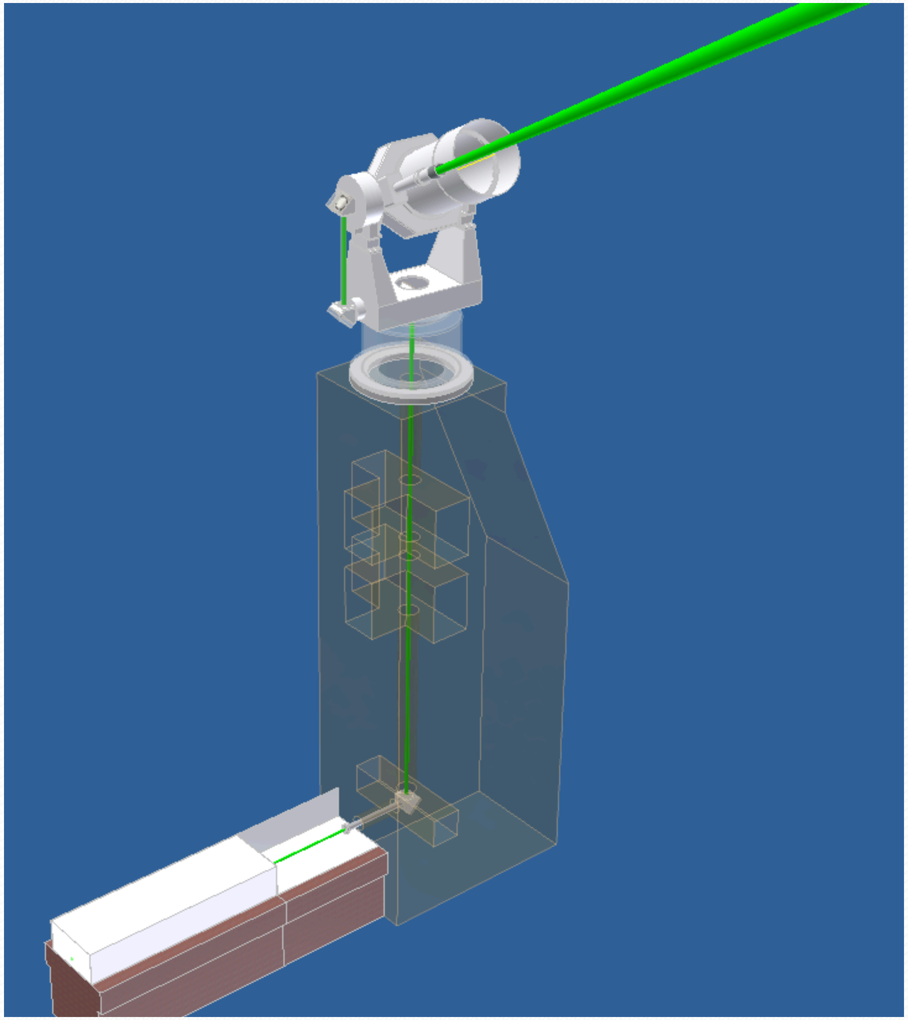
- Laser Path from Start Diode to System Reference Point
- Delay in cables and electronic equipment from the Start Diode to Event Timer





Transmit-side Delay

Laser Path



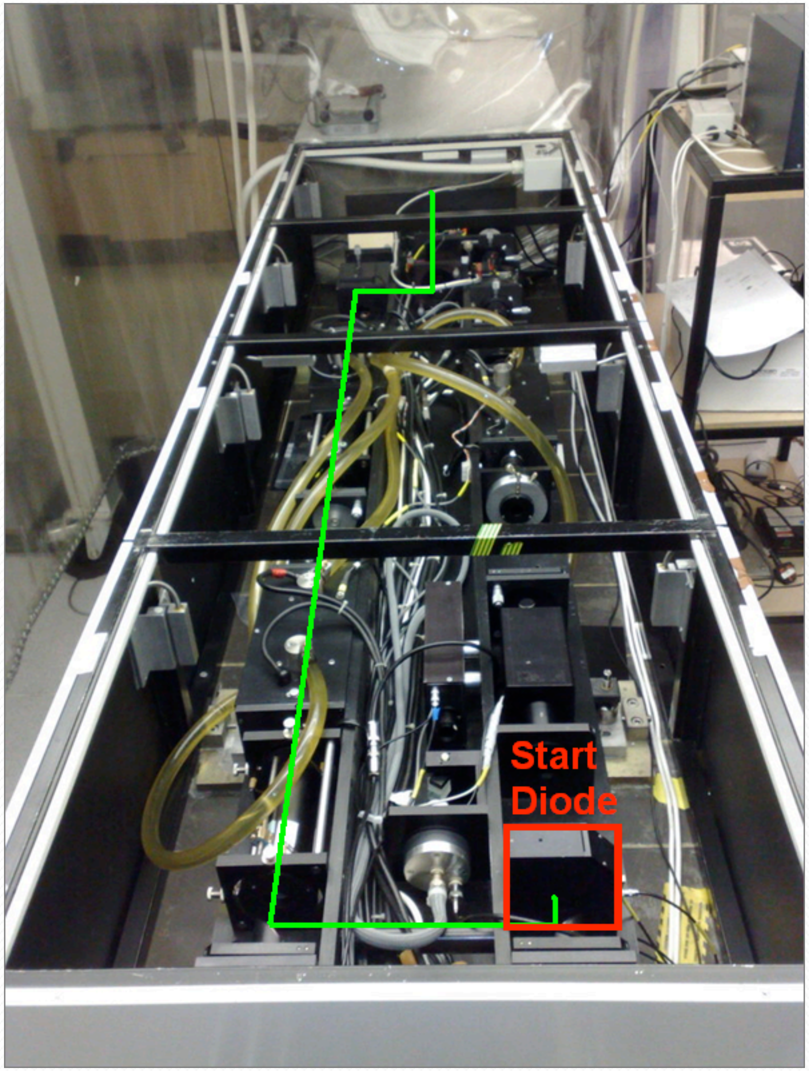
Need to know the time taken for the laser pulse to travel from the Start Diode to the System Reference Point.

We measured this as two components:

- Laser bed including propagation effects of optics
- Coudé path length

Laser Path

Laser Bed Measurements



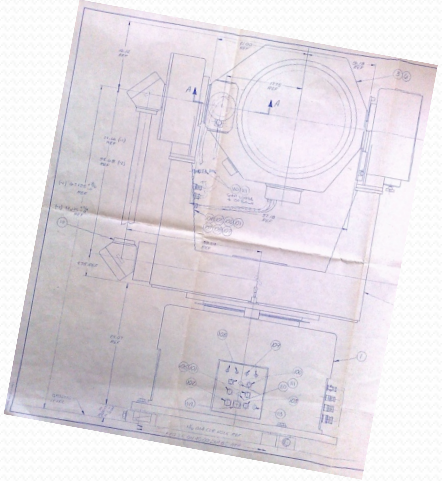
Physical Measurements were made with a rule along the Laser Path. We also calculated the Effective increase in Path Length due to the Refractive Indices of Laser components.

- Beam Splitters
- Beam Expanders
- Amplifiers
- Quarts Rotator
- Doubler Crystal

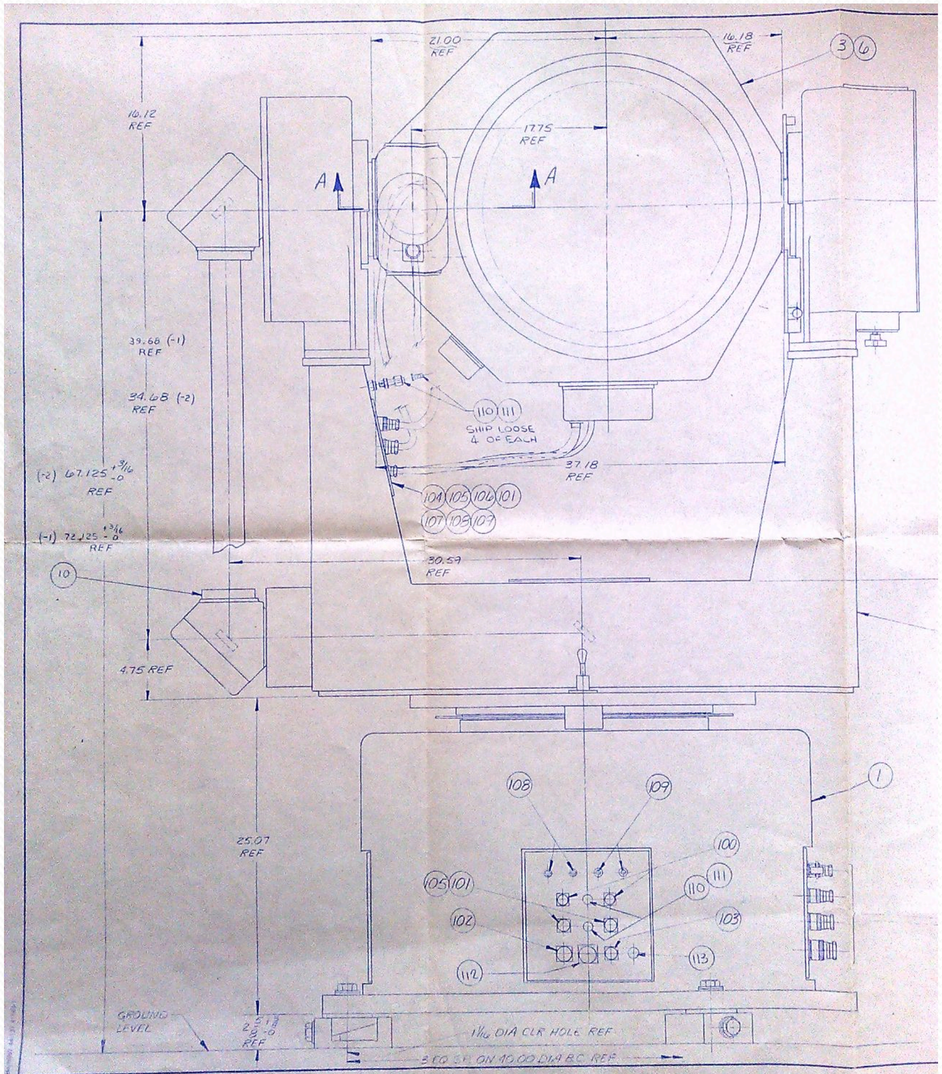
Laser Path

Three methods employed to measure Coudé Path:

- Physical Measurements and Technical Drawings provided by manufacturers
- Reflected 10-Hz Laser Pulse
- Bosch Laser Rangefinder



Laser Path
Coudé



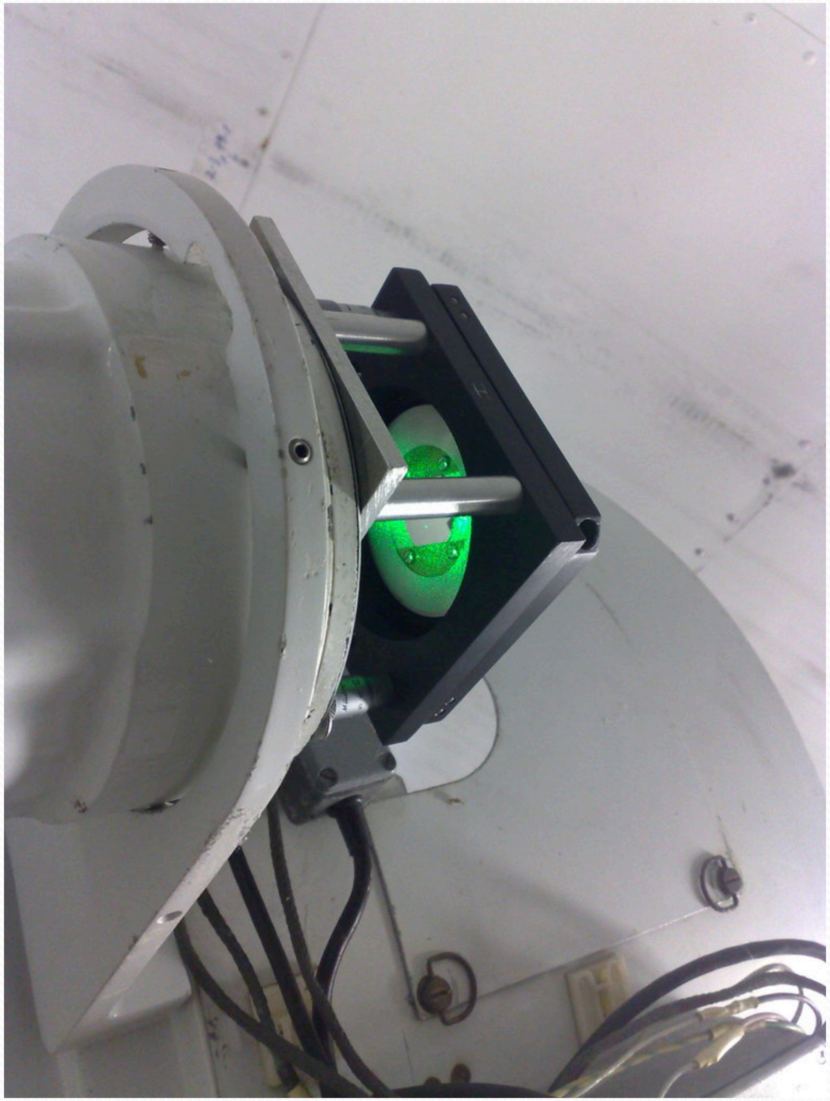
1 - Physical Measurements and Technical Drawings

- Drawings of Telescope, provided by manufacturer, were used to calculate coudé path from Telescope Base to System Reference Point
- Telescope Base down to Coudé Entrance was simply measured using a Tape Measure
- Physical Measurements not very accurate but useful as a comparison for other methods results

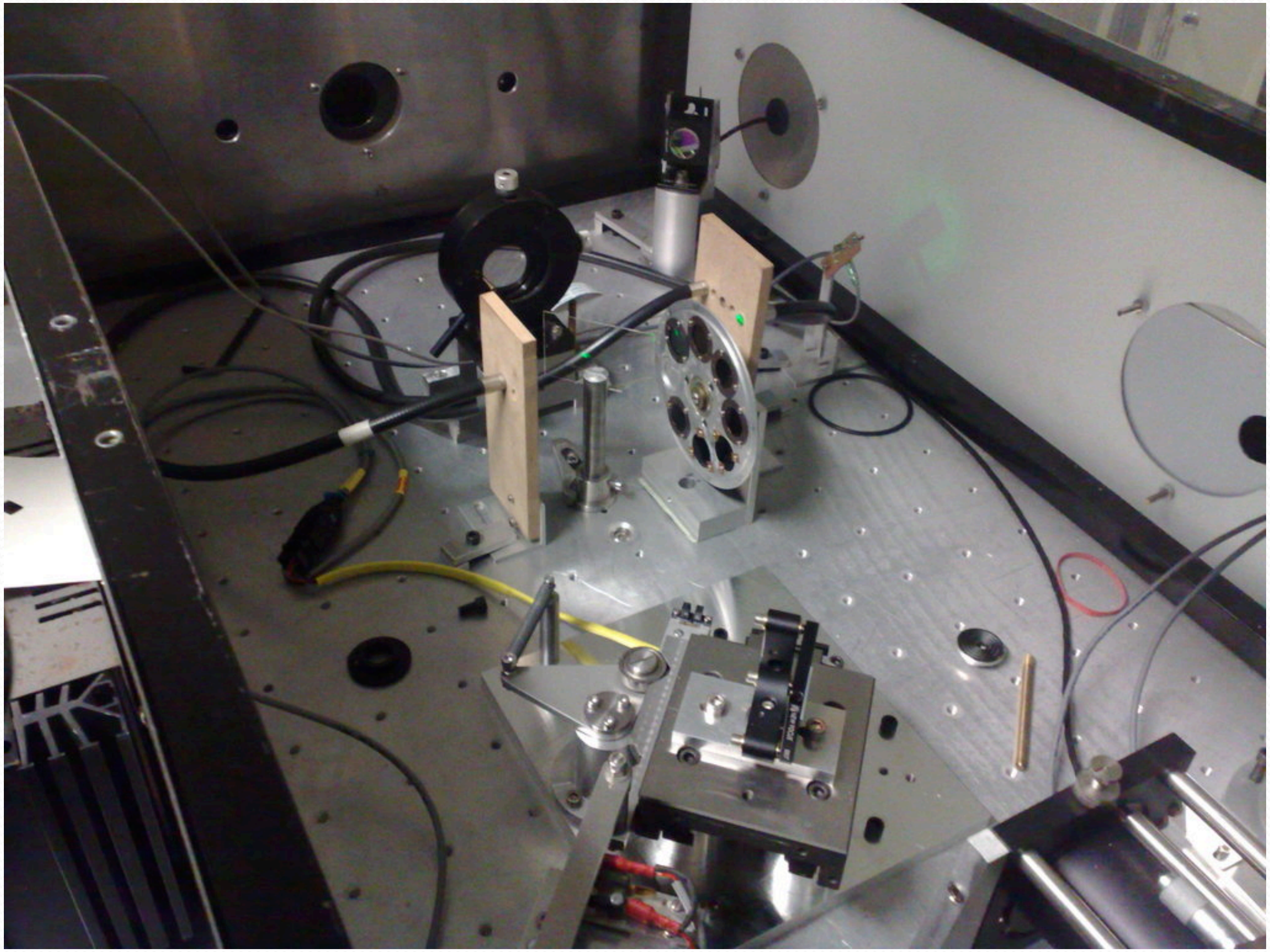
Laser Path
Coudé

2 - Reflected 10-Hz Laser Pulse

- Fired the 10-Hz Laser through the coudé reflecting it back via a mirror on the Emitter



Laser Path
Coudé

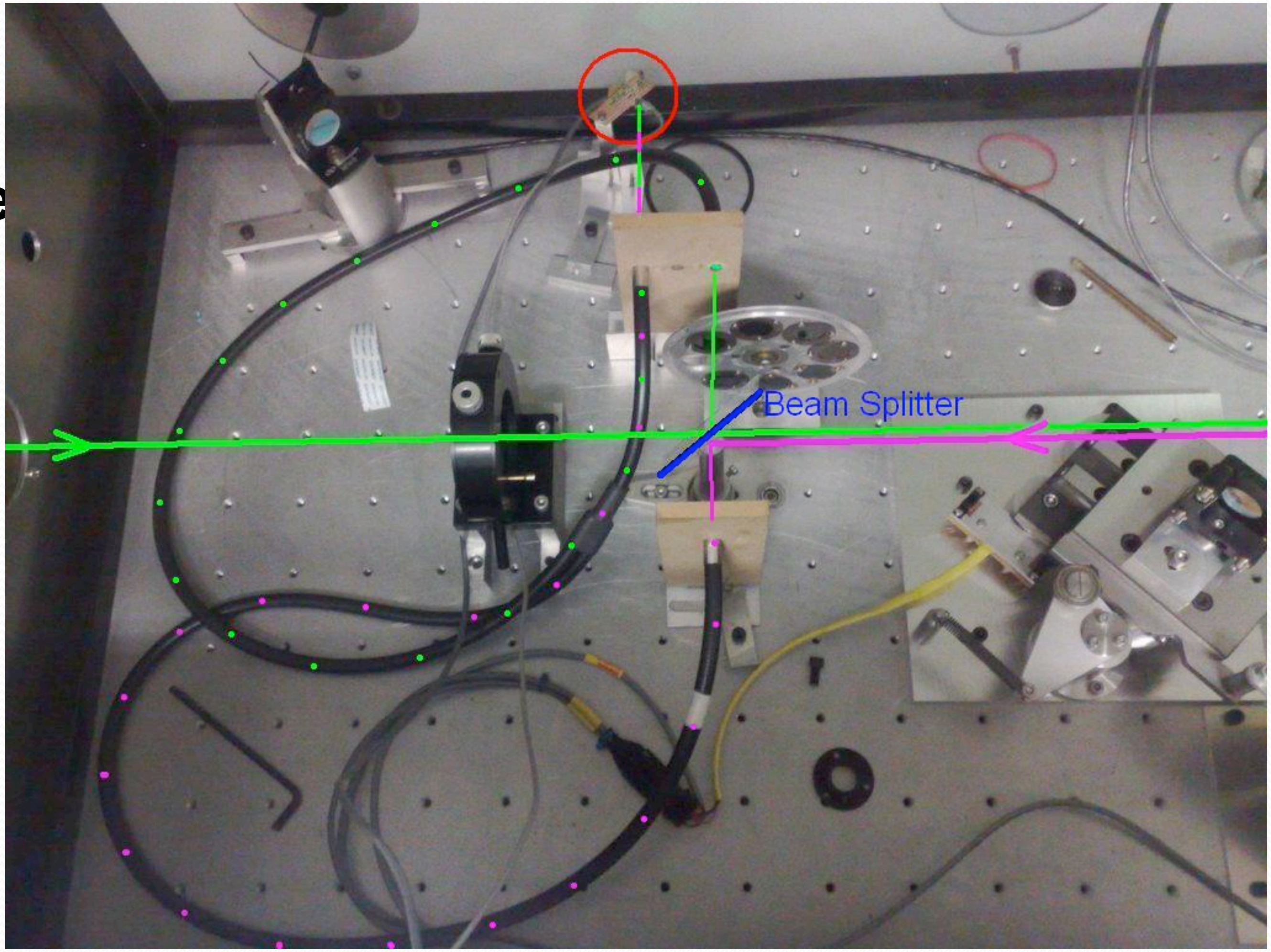


2 - Reflected 10-Hz Laser Pulse

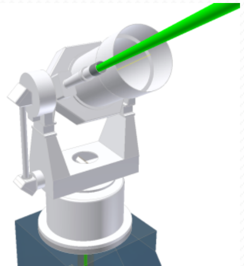
- Setup Placed before Coudé Entrance

Laser Path
Coudé

2 - Reflected 10-Hz Laser Pulse



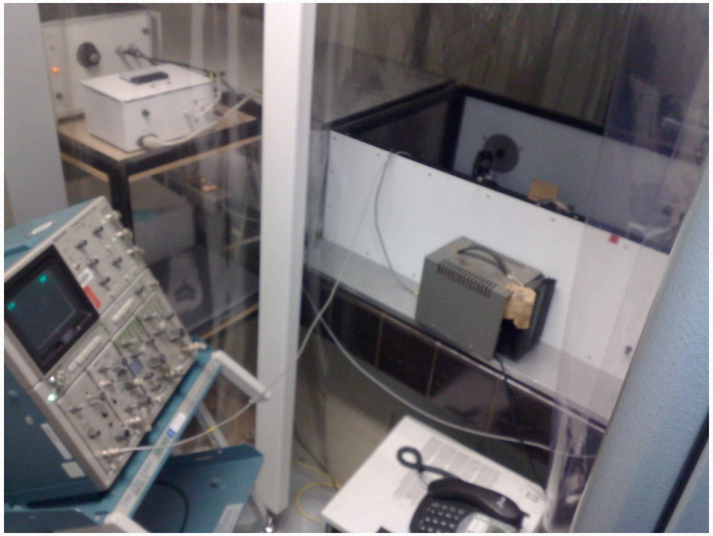
- Beam Splitter
- Two into One Fibre Optic
- Light Sensitive Diode
- Oscilloscope



Laser Path
Coudé

2 - Reflected 10-Hz Laser Pulse

- Oscilloscope shows Outgoing and Returning Semi train.
- Time difference between two pulses gives twice distance

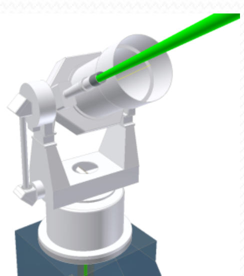


Laser Path

Coudé

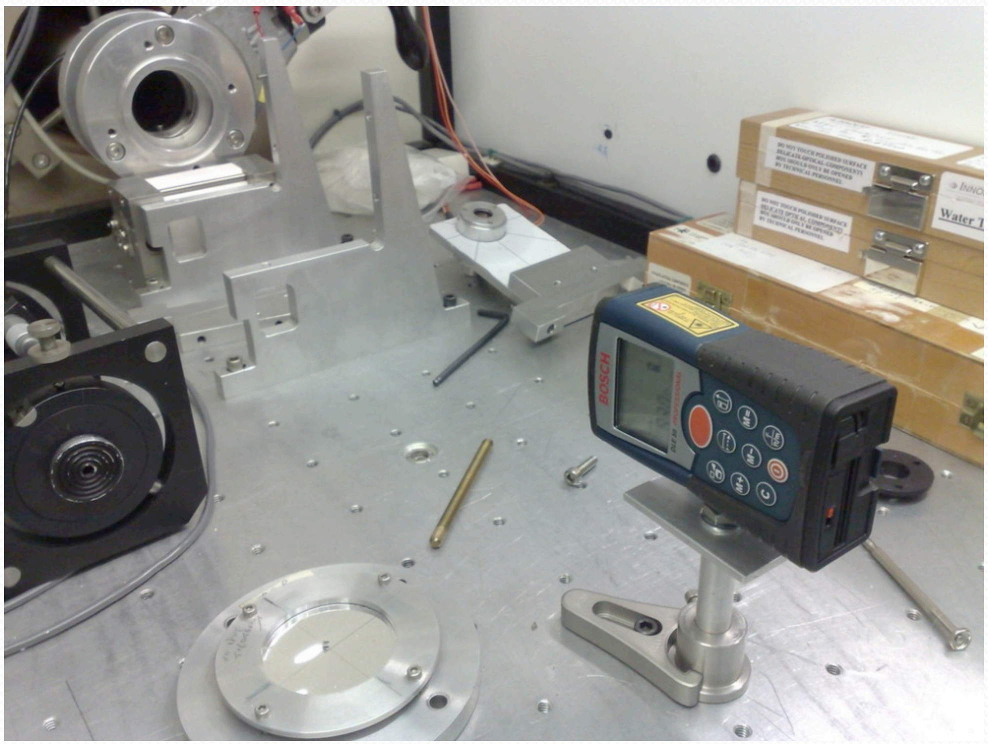
3 - Bosch Laser Rangefinder

- More commonly used as a building surveying tool
- Manufacturers state typical accuracy of ±1.5mm over 30m distance



Laser Path
Coudé

3 - Bosch Laser Rangefinder



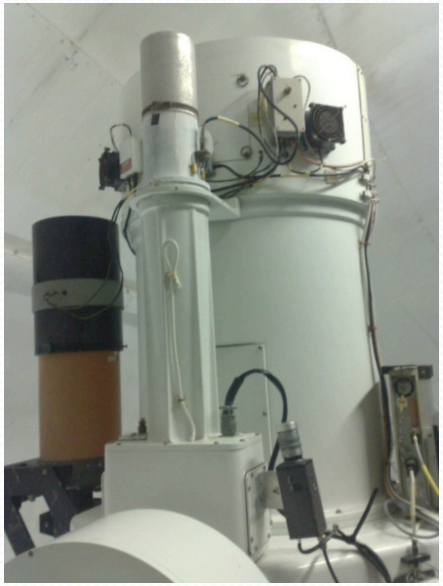
Rangefinder was aligned to ensure it measured directly up coudé

- Rangefinder laser is visible so was aligned to a target at the coudé entrance and on the emitter
- Very sensitive so required good alignment or it could take a reflection anywhere up the coudé path

Laser Path

Coudé

3 - Bosch Laser Rangefinder



- Emitter could then be removed and replaced with a flat surface for the Rangefinder to measure to
- Measurements were taken with telescope in different Azimuth positions
- Alignment and measurement process was repeated giving very good repeatability in results

Laser Path

Coudé Results

1 - Physical Measurements and Technical Drawings

8.411 m Error ± 20 mm

- Difficulty in Physical Measurement of Coudé below Telescope

2 - Reflected 10-Hz Laser

8.388 m Error ± 30 mm

- Limited by accuracy in interpreting the Oscilloscope display
- Research more accurate ways of measuring timing between outgoing and returning pulses

3 - Bosch Laser Rangefinder

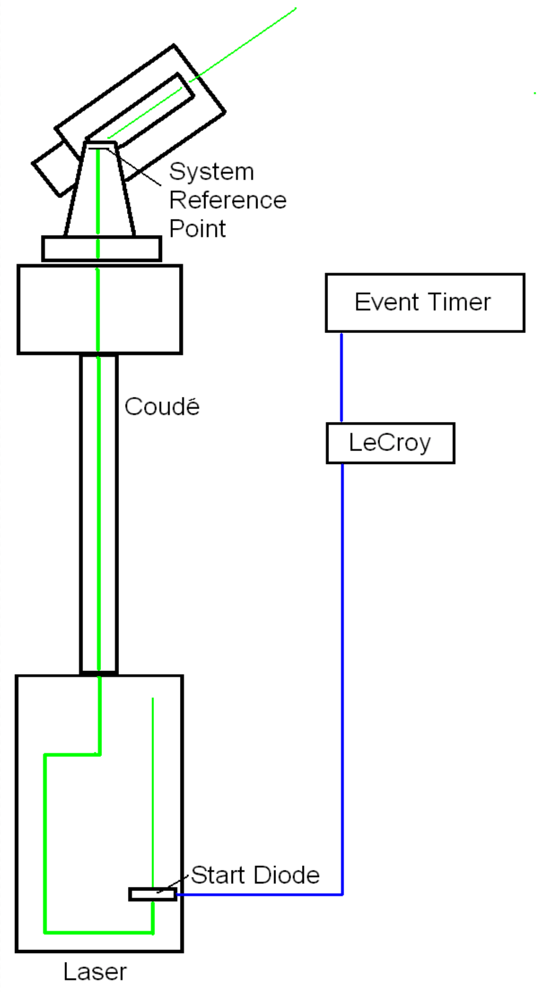
8.398 m Error ± 1.5 mm

- Most accurate and repeatable method

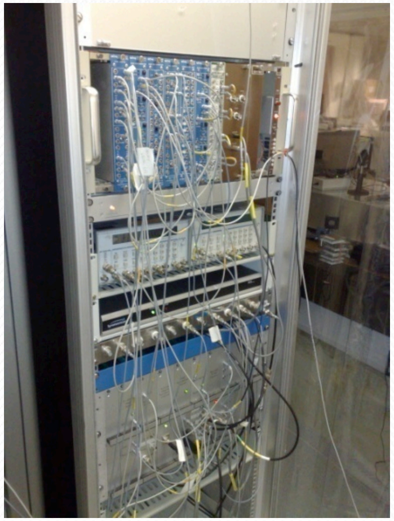
All agree within 25mm.

Transmit-side Delay

Cables and Electronic Equipment



- Start Diode
- LeCroy Discriminator
- Event Timer
- Cables



Cables and Electronic Equipment

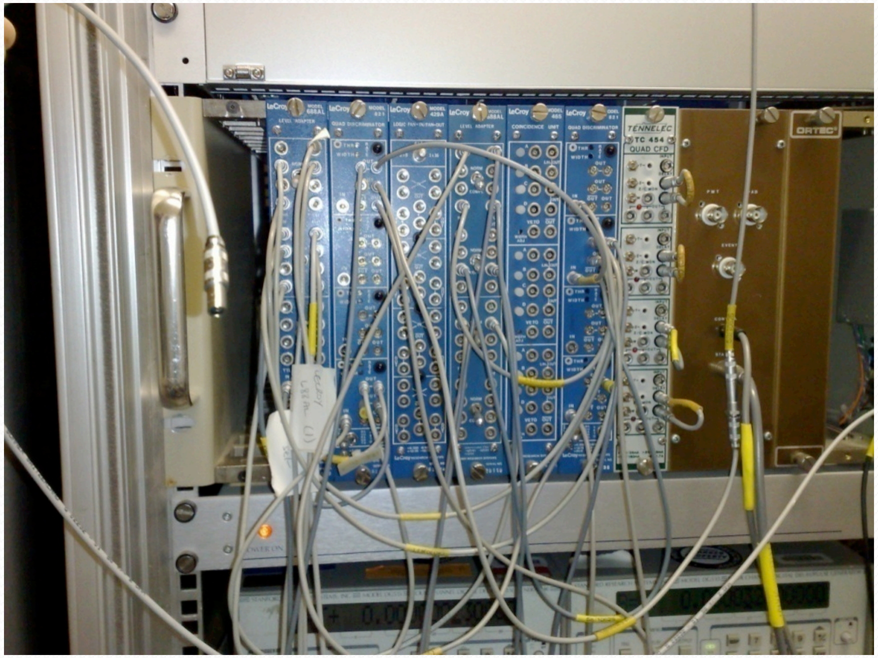
Start Diode

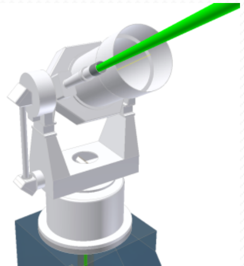
- Beam Splitter used to direct pulse to Diode
- Diode mounted 25.5 mm from Beam Splitter
- Delay in Diode Components - To be Determined

Cables and Electronic Equipment

Cables and LeCroy Measurement

- Series of Calibrations using kHz Laser
- Compare Calibration results with Cables/LeCroy in and out of the chain between Start Diode and ET
- Change in Ranged Distance to Fixed Target gives delay in particular Cable/Device added





Cables and Electronic Equipment

Event Timer

- Internal Delay from external socket to when timer is triggered is to be determined / unknown

Cables and Electronic Equipment

Total Delay between Start Diode and ET

Start Diode

- To be Determined
- Beam Splitter to Diode 0.027 m

Cables

- Diode to LeCroy: 13.34973 m
- LeCroy to ET: 2.7909 m

LeCroy

- LeCroy currently in use: 3.60853 m

Event Timer

- To be Determined

Total: 19.77617 m

Cables and Electronic Equipment

Useful comparison for the Delay found in the Coaxial Cable used

- Signal propagation through cable can be expressed as a percentage of speed of light
- Approximate figure found for the type of coaxial cable we measured would be 66%

This would tend to agree with results found for the cables tested. As with the Start Diode to LeCroy Cable for example:

Physical Length	8.868 m
Effective Length at 66% light speed	13.436 m
Effective Length using calibration method	13.349 m

Transmit-side Delay

Difference between the time the laser passes through the System Reference Point and ET is triggered

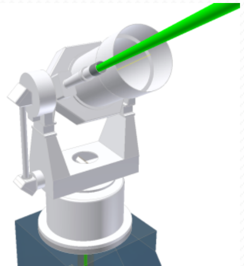
Subtract Laser Path Delay from Cable and Electronic Equipment Delay

19.77617 m - 13.49233 m

= 6.28383 m

= 20.946 ns Error Estimate <1ns

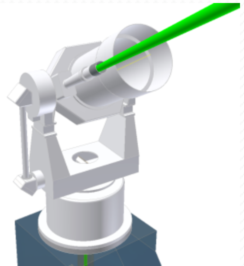
So the Laser Pulse passes through the System Reference Point 21 ns before the Event Timer is triggered



Using Electronic Delay results so far and Coudé path measurements with Bosch Laser Rangefinder

Transmit-side Delay
Further work

- More Tests on LeCroys and Cables
- Event Timer Delay
- Start Diode Delay
- Measure all Receive-side delays to close the loop and compare against our standard two-way calibration result
- Setup to enable measurement of Transmit-side delay as one measurement

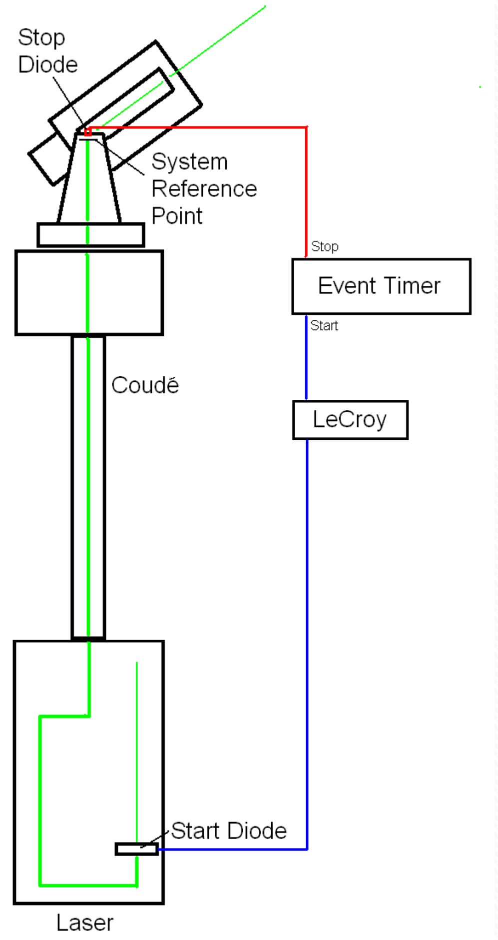


Transmit-side Delay
Further work

Measuring Transmit-side delay as one measurement

Run a Calibration similar to our two-way calibration/ ranging setup

- Place a Diode on or near the System reference point in the laser path
- Feed pulse from the Diode to ET stop instead of the SPAD pulse
- This requires good understanding of the delay in only Diode and Cable
- Can be used to calibrate regularly and when any changes occur in Transmit-side of SLR system



Conclusion

We are heading towards providing an epoch for the time the laser pulse passes the System Reference Point necessary for LRO and T2L2

Current measurements give a 21ns correction with an accuracy better than 1 ns. Still to include ET and Start Diode.