Identification and calibration of one - way biases in SLR system

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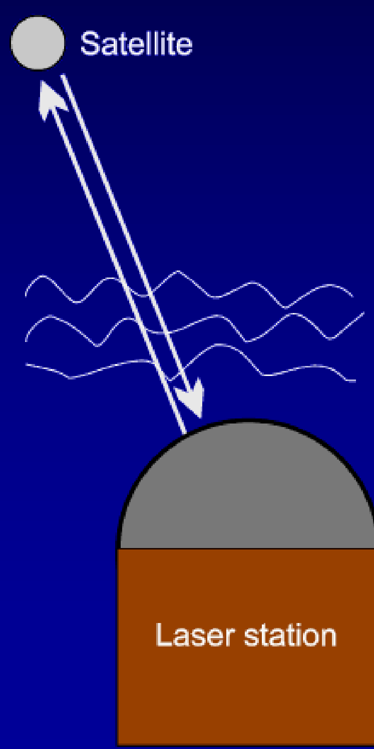
OUTLINE



- Why should we do it ?
- New SLR application.
- Measurement scheme
- Calibration Standard device
- Calibration experiments results
- Conclusion

Why should we do it ?

- As a standard for 50 years the SLR system is calibrated by a laser ranging to a ground target of a precisely known distance.

- It works OK down to ~ ps / mm level.

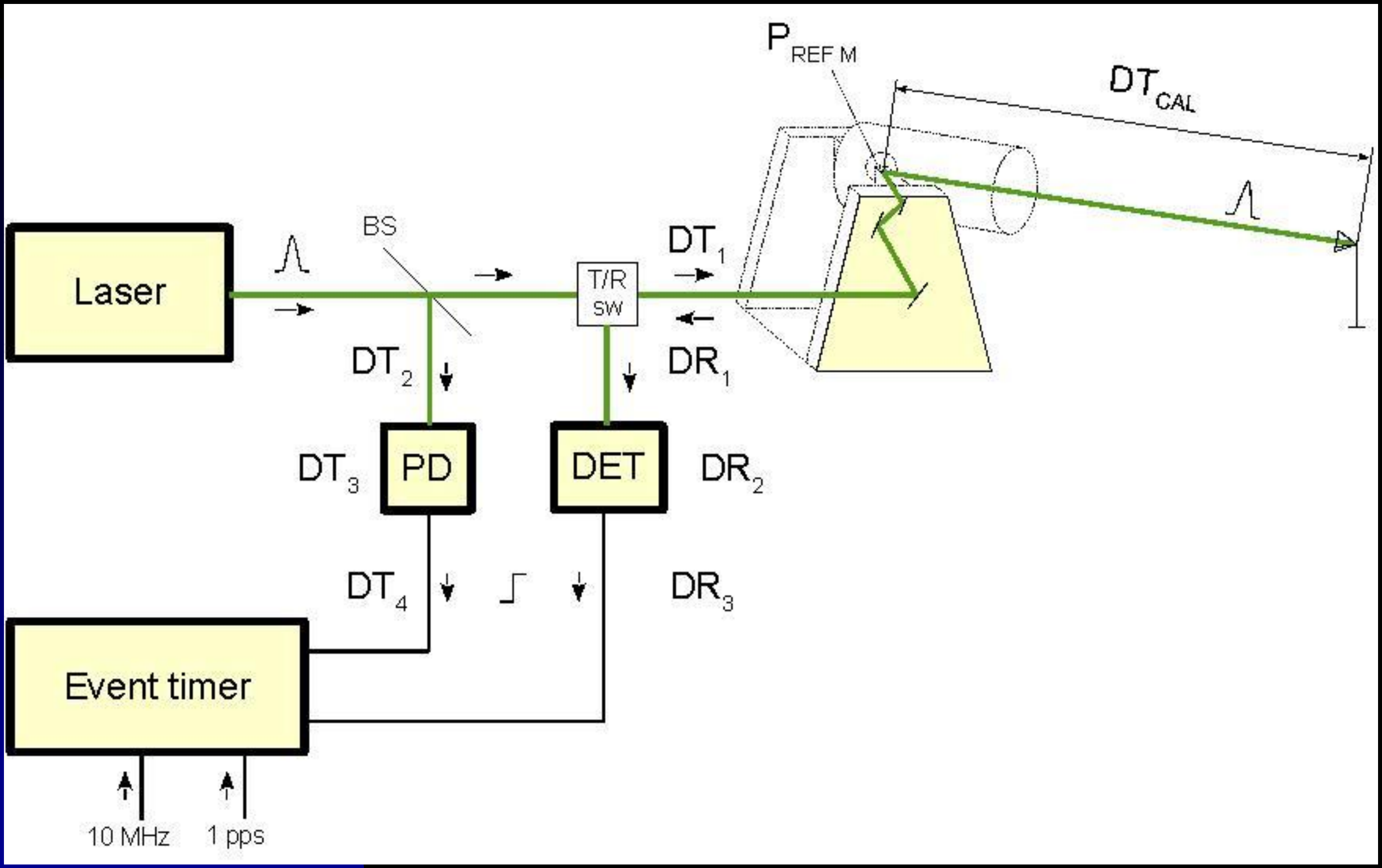
- The laser fire epoch is recorded within 100 ns versus UTC

- New SLR applications:
  - Laser Time Transfer (LTT)
  - one-way laser ranging
  - bi- and multi-static laser ranging of space debris

  require identification and calibration of one-way T / R biases

- In addition the T / R epochs must be referred to UTC < 1 ns

SLR system delays - simplified



Although the individual contributors ***DTi*** and ***DRi*** might be identified and measured (Herstmonceux..) the resulting accuracies of T and R calibration constants would be low using such a measurement scheme.

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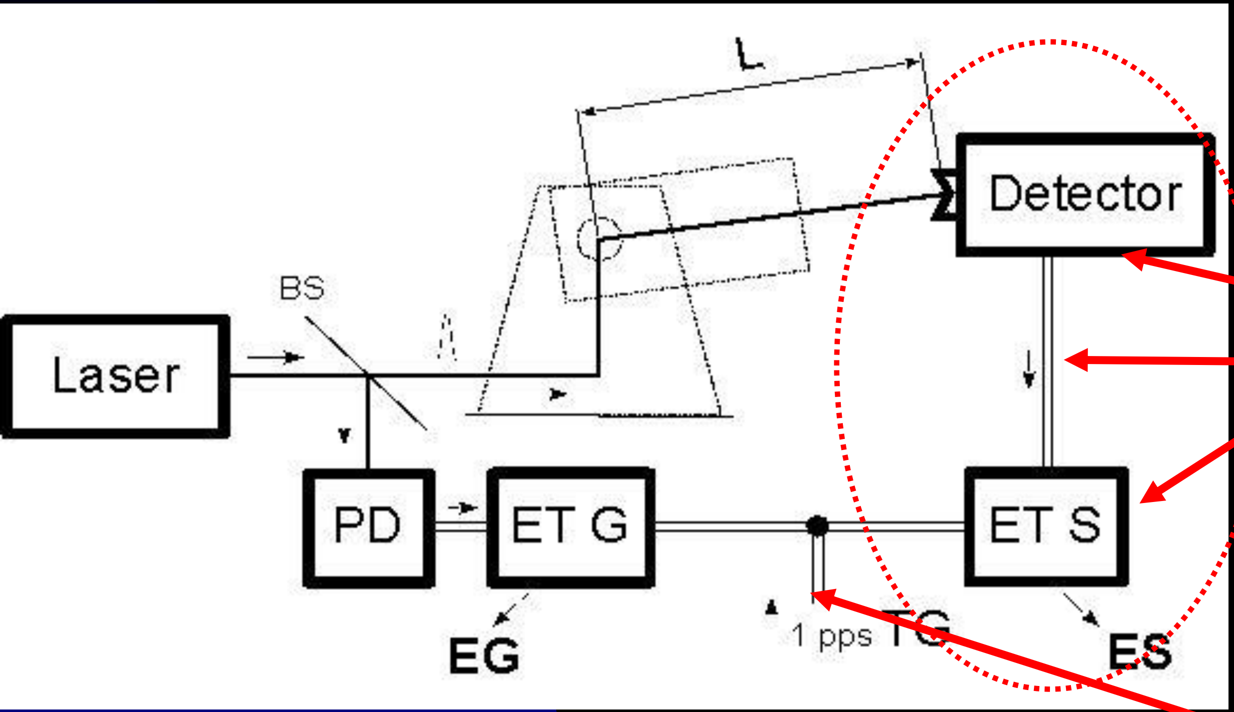
Transmit delay measurements
Scheme developed for European Laser Timing



Calibration Device

Detector SPAD

Cable

NPET epoch timing

Common epoch “1pps”;
identical cable
common clock frequency

- The epoch is referred to the “1pps” inputs of epoch timing devices
- The Calibration Device delays may be determined with ~ 20ps accuracy
- Considering the Calibration Device delays and a real distance ***L*** the transmit delay related to “1pps” input may be determined with the same accuracy

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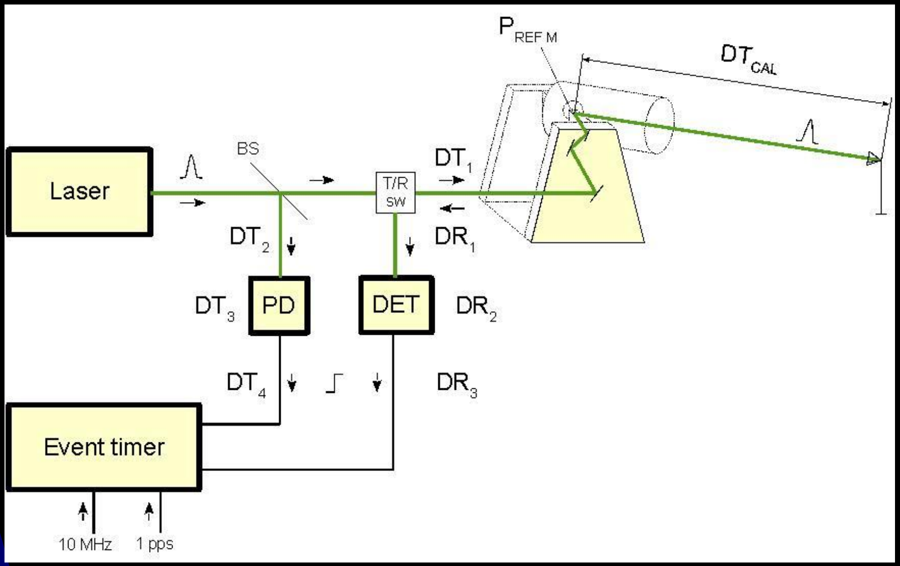
Receive delay determination

Scheme developed for bi- and multi-static space debris ranging



- Considering the principle of ground target calibration ***G*** and the two one-way parts, one can conclude that ***G* = *T* + *R***
- It means that the receiving part one-way calibration ***R*** may be simply calculated from standard ground target calibration ***G*** and transmit part bias ***T***.

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Calibration Device

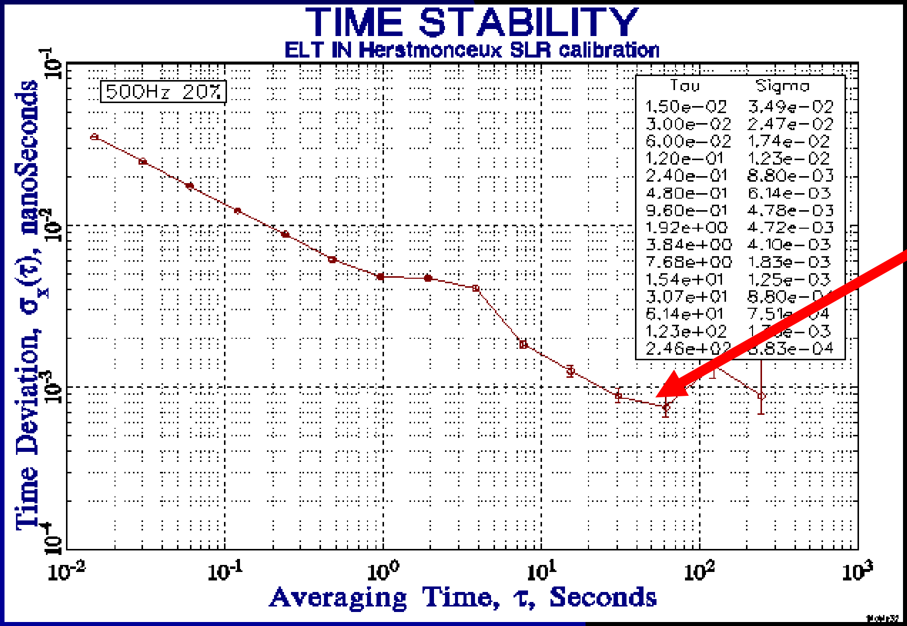
- The ELT Calibration Device was developed for ACES – ELT
- Similar device was prepared for SSA activities of ESA
- certified transportation container, loss and damage insurance coverage, ATA Carnet custom proc. for non-EU missions
- The Calibration Devices are available for field use

ELT Calibration Mission at SLR Herstmonceux UK
May 23 -27, 2016

Completed May 23-27, 2016

Single ~ 26 ps rms

ELT Calibration constant Transmit
T =   − 1.57 ± 0.03 ns.



TDEV < 1 ps @ 25s

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Calibration Missions at SLR Graz
August 2015 and August 2016

ELT Cal. Campaign Graz, August 19-21, 2015

ELT Calibration constant (Transmit)
T = 94.33 +/- 0.02 ns

SSA Cal. Campaign Graz August 18-20, 2016

Transmit   Receive
T = 94.60 +/- 0.20 ns   R = 17.66 +/- 0.20 ns

- Higher **T** spread explained by different epoch timing “1pps” input settings.
  The 18 ps accuracy may be reproduced in a future.

CONCLUSION

- The technique to identify and calibrate T and R biases in SLR system was developed
- It enables to relate the epochs of T and R pulses versus system invariant point with an accuracy of ~ 20 ps.
- The applications include Laser Time Transfer, one-way laser ranging, orbiting space debris laser ranging
- Surprisingly, quite different values were determined for similar systems Graz, and Herstmonceux
  + 94.3 ns versus - 1.6 ns resp.
- The support of ESA project 4000112447/14/D/SR appreciated