The European Laser Timing (ELT) experiment on-board ACES

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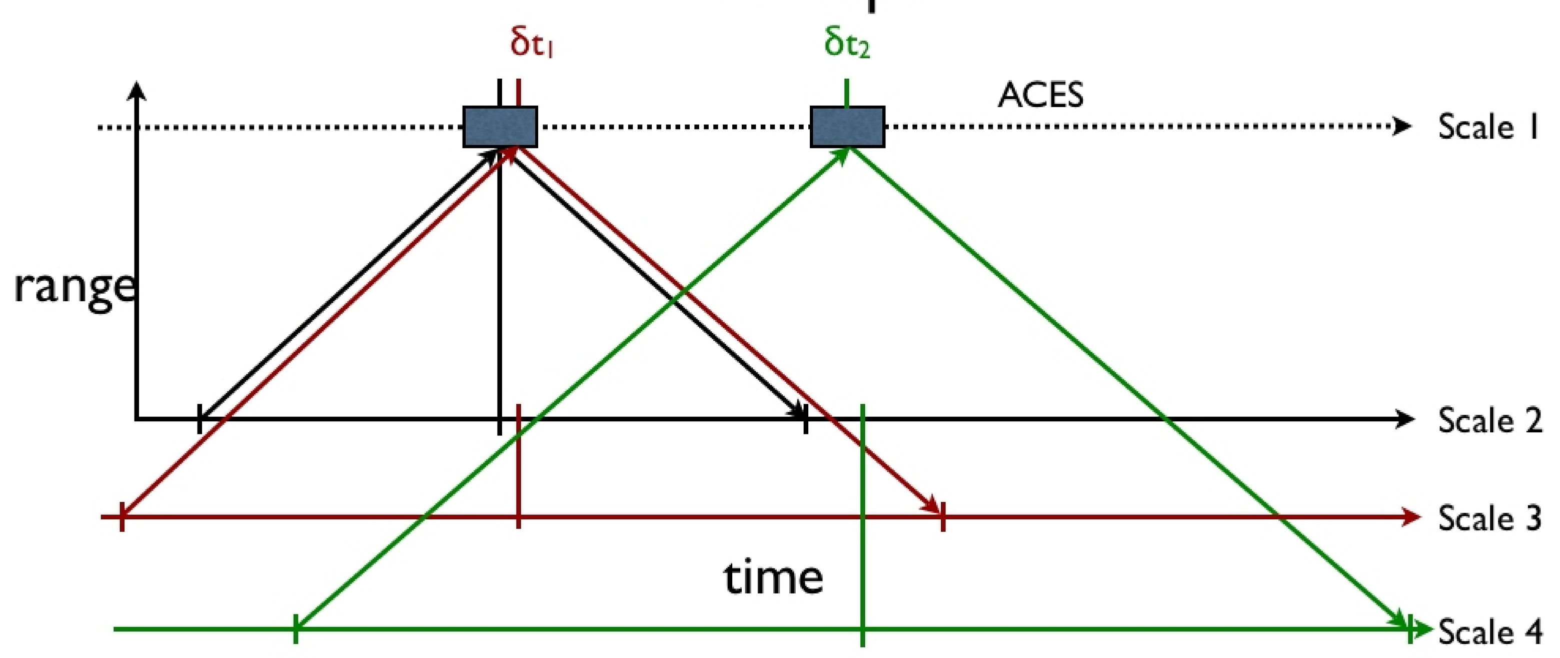
0. Motivation

Satellite Laser Ranging, based on the measurement of the time of travel of very short laser pulses between a ground station and a satellite is a suitable technique for precise clock comparison at the sub-ns level. The combination of the time tagging of 1-way and 2-way laser pulses allows the transfer of an epoch independent of the range.

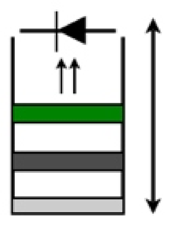
ELT (European Laser Timing) is an optical link presently under study in the frame of the ESA mission "Atomic Clock Ensemble in Space". The on-board hardware consists of a corner cube retro-reflector (CCR), a single-photon avalanche diode (SPAD), and an event timer board connected to the ACES time scale. Light pulses fired towards ACES by a laser ranging station will be detected by the SPAD diode and time tagged in the ACES time scale. At the same time, the CCR will re-direct the laser pulse towards the ground station providing ranging information.

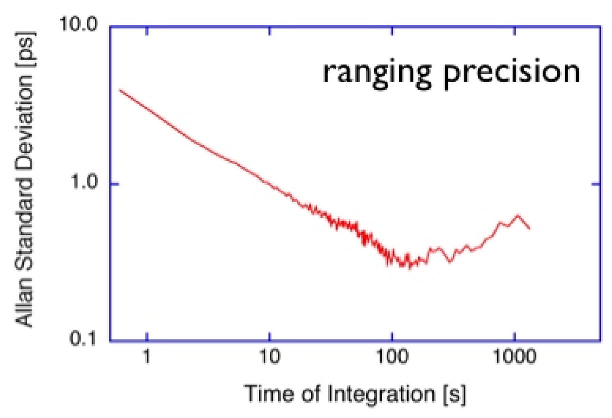
I. Concept



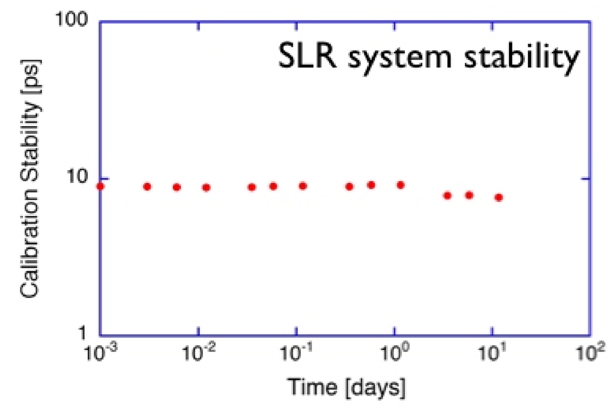
1. SLR establishes the time of arrival at the ACES payload (timescale 1) relative to timescale 2
2. Common view observations between two ground stations establish the offsets between timescale 2 and 3 relative to timescale 1
3. Laser Ranging from yet another observatory at a later time (non common view) establish the offset between timescale 4 and timescale 1. Because of the stable ACES clocks this also provides the offsets between timescale 4 and timescale 2 and 3.

II. Detection Scheme and Properties

a)  b) 



c)

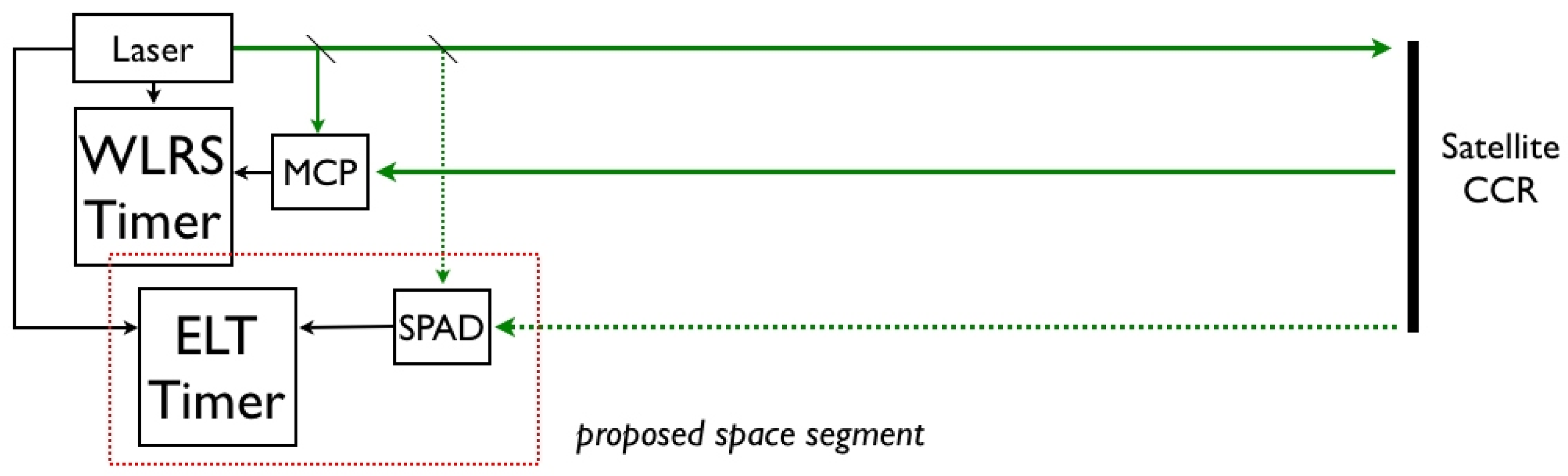


The onboard optical subsystem consists of a corner cube reflector and a photo-detector. Incoming laser pulses are both reflected back to the ground station and also timed on the satellite clock.

The application of an avalanche photo-diode (SPAD) operated at single photon light levels provides the highest precision, because biases from amplitude fluctuations are avoided.

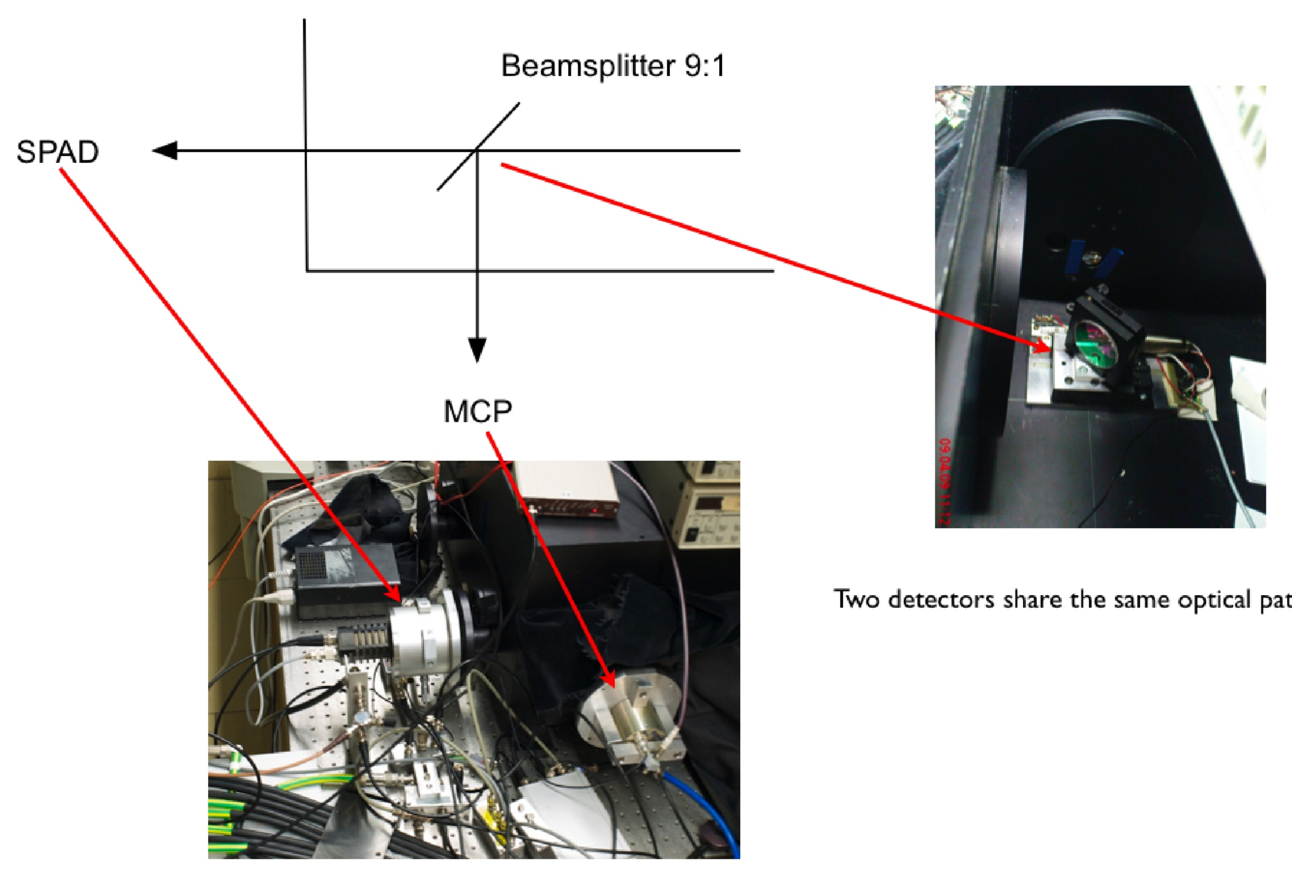
A neutral density filter and a diffusor plate in addition to a narrowband spectral filter attenuate the light level at the SPAD into the single photon regime (a). The detector is mounted in the center of the corner cube array (b). Ranging performance as obtained at the Geodetic Observatory Wettzell is indicated on the right (c).

III. Wettzell Experiment



In order to investigate the timing performance a dedicated test experiment has been carried out. The proposed onboard laser detection hardware is sharing the receive path with the SLR system on the ground. The return signal is timed on two independent detectors, the SPAD with the ELT timer and the microchannel-plate with the operational SLR timing device. The objective of this experiment is the evaluation of the laser link, the characterization of the ELT timer and the SPAD detector verification.

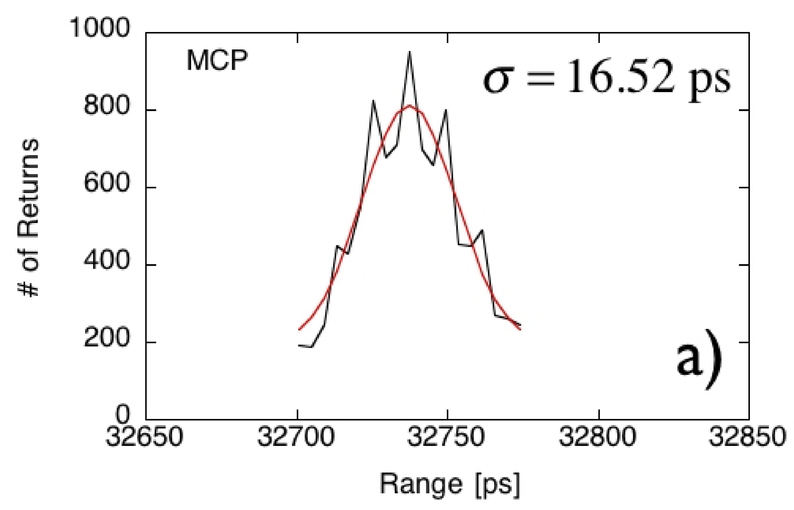
IV. Wettzell Experiment

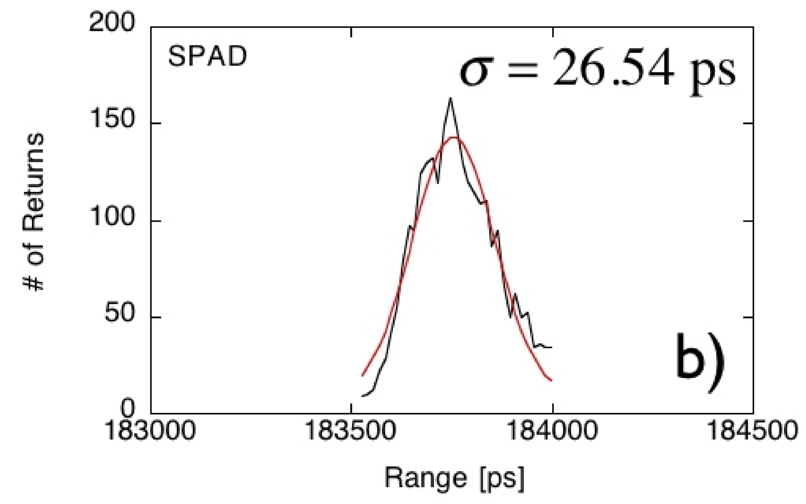


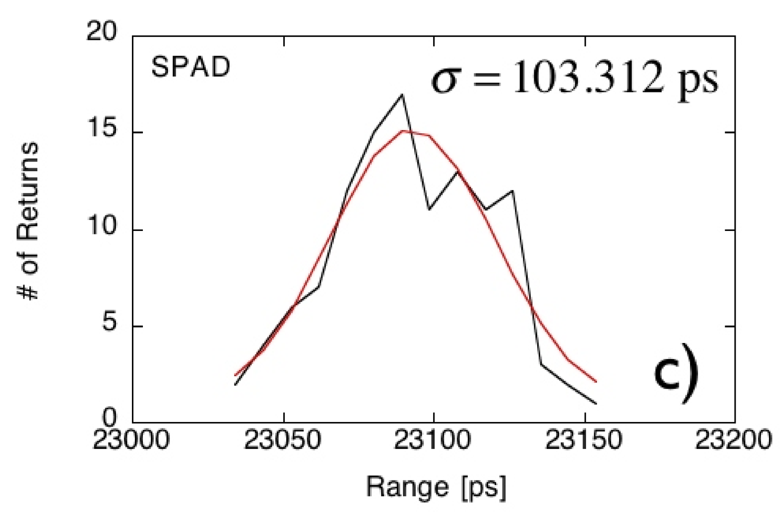
Two detectors share the same optical path.

V. Preliminary Results

a) MCP Multiphoton Calibration
b) SPAD Pulser Calibration (Width: 20 ps)
c) SPAD Single Photon Cal. (Width: >100 ps)

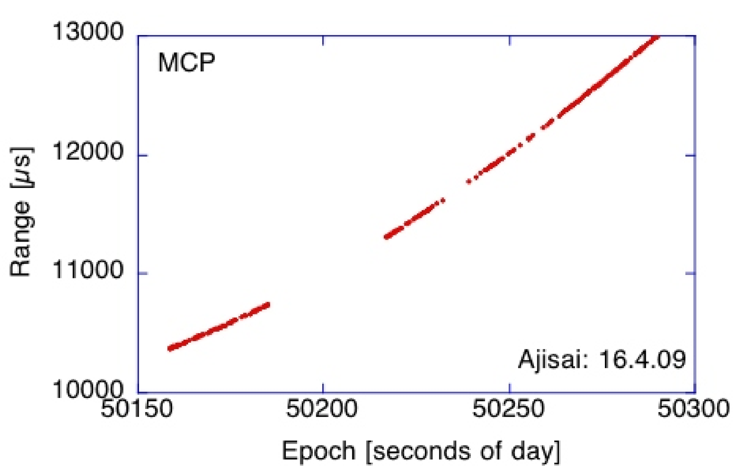


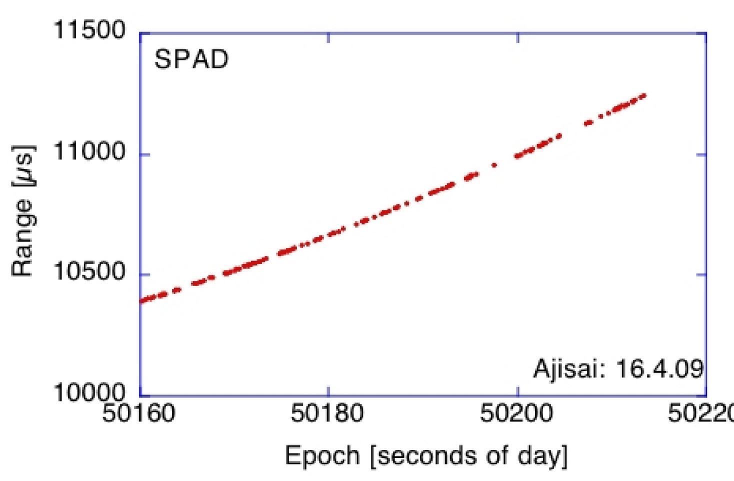




The MCP calibration on the rising edge in multiphoton mode shows low jitter (a), but is highly dependent on amplitude fluctuation. The SPAD calibration with a narrow pulse-width of 20 ps at the single-photon level provides a suitable precision for time transfer (b). The results are consistent with the WLRS measurements, where the laser pulse-width is > 100 ps.

VI. Dual System Satellite Pass





Several satellite passes have been observed with this dual-detector arrangement. An example of satellite returns from Ajisai is displayed above. The MCP shows a higher detection rate because of the much stronger signal level.

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