Construction Progress in the Photon Counting Detector for the European Laser Timing Experiment

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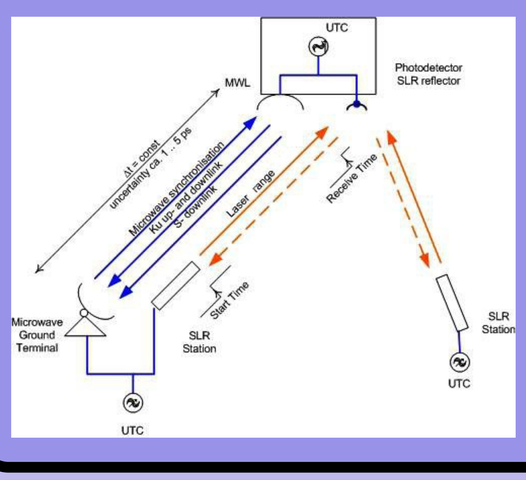
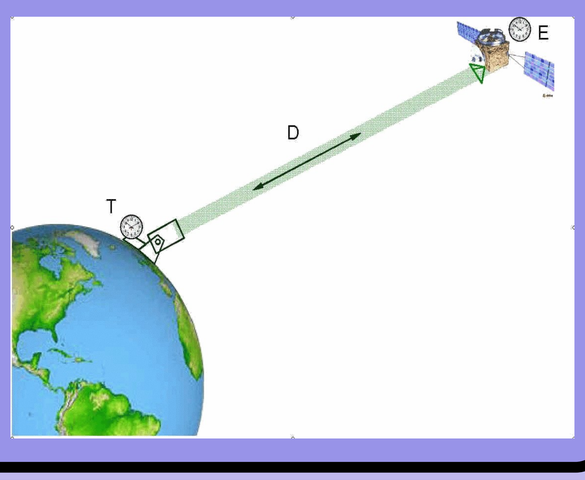
ABSTRACT

We are presenting a progress in a construction and indoor tests of the photon counting detector for the European Laser Timing (ELT) experiment [1]. ELT is an optical link prepared in the frame of the ESA mission "Atomic Clock Ensemble in Space" (ACES). *The objective of this laser time transfer is the synchronization of the ground based clocks and the clock on board the space station with precision of the order of units of picoseconds and the accuracy of 50 picoseconds. The requirements put on the detector package are quite high – temperature stability of the delay better than 20 ps peak to peak within one satellite orbit, operation within a broad temperature range of -20 to +55 degrees Celsius, absolute calibration of the photon to electrical signal delay with precision 25 ps and others. Although the signal photon flux at the satellite orbit is of the order of 10^{13}photons per square meter per one laser shot and multi-photon signal strength may be obtained, the photon counting approach to the optical signal detection has been selected in order to reduce the systematic biases as much as possible*.

OPERATING PRINCIPLE

The satellite range D is measured by laser ranging technique, the laser emission time T is recorded with ground clock, the arrival time of the laser pulse to the satellite E is recorded by on-board clock and the recorded time tags are transmitted to ground via satellite telemetry channel. Combining the laser pulse emission times, propagation and instrumental delays and satellite arrival times, the space clock and the station clock may be compared.

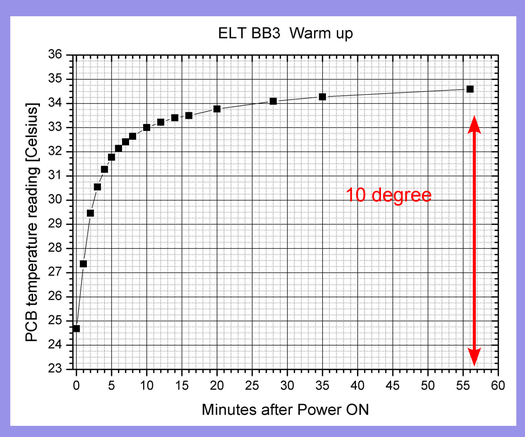


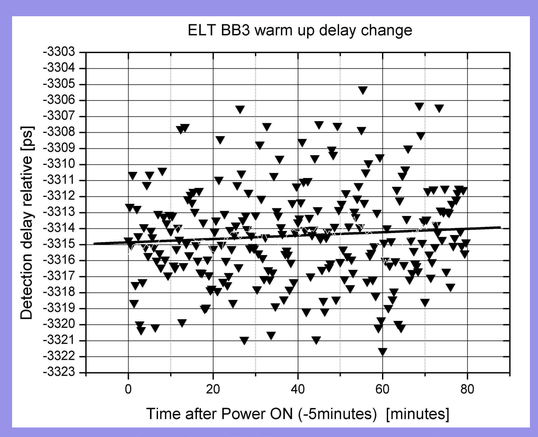


CONSTRUCTION

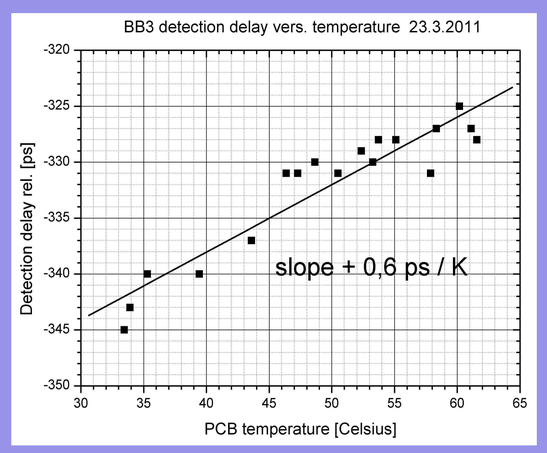
The ELT detector package – engineering model (left), detector bread board version assembly in CTU in Prague laboratory (right).

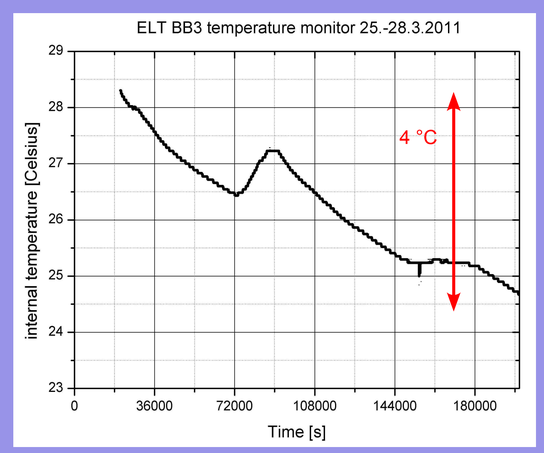
TEMPERATURE CHARACTERISTICS



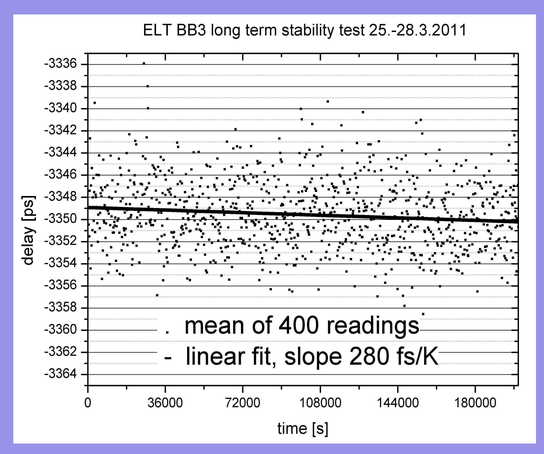


The warm up charakteristics - temperature increase inside the ELT detector package after power on. After the first 5 minutes the temperature raised only by 2.5 degrees (left). The detection delay - changed by 1 ps in 80 minutes after 5 minutes after Power ON (right).



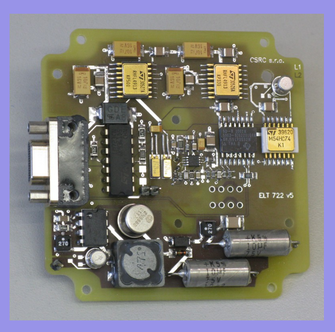


Up - the detection delay temperature dependance, room temperature up to 60 °C. The detection delay coefficient is 0.6 ps/°C.

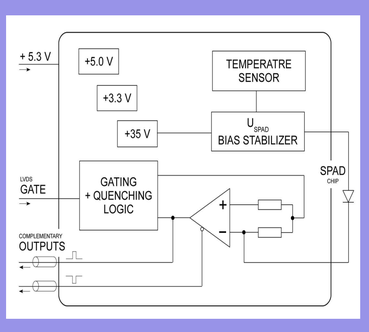


Detection delay long term stability test, The Time Correlated Photon Counting (TCPC) experiment was carried out during the weekend, temperature changed by -4 °C, see the graph above. The detection delay change has slope 280 fs/°C.

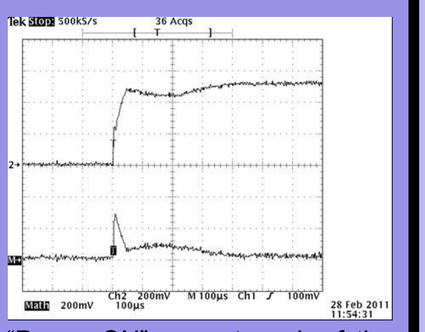
ELT ELETRONICS AND OUTPUT PULSES



Bread board version of the active quenching and gating circuit. Entire components are space qualified or their military specified pin to pin compatible versions.

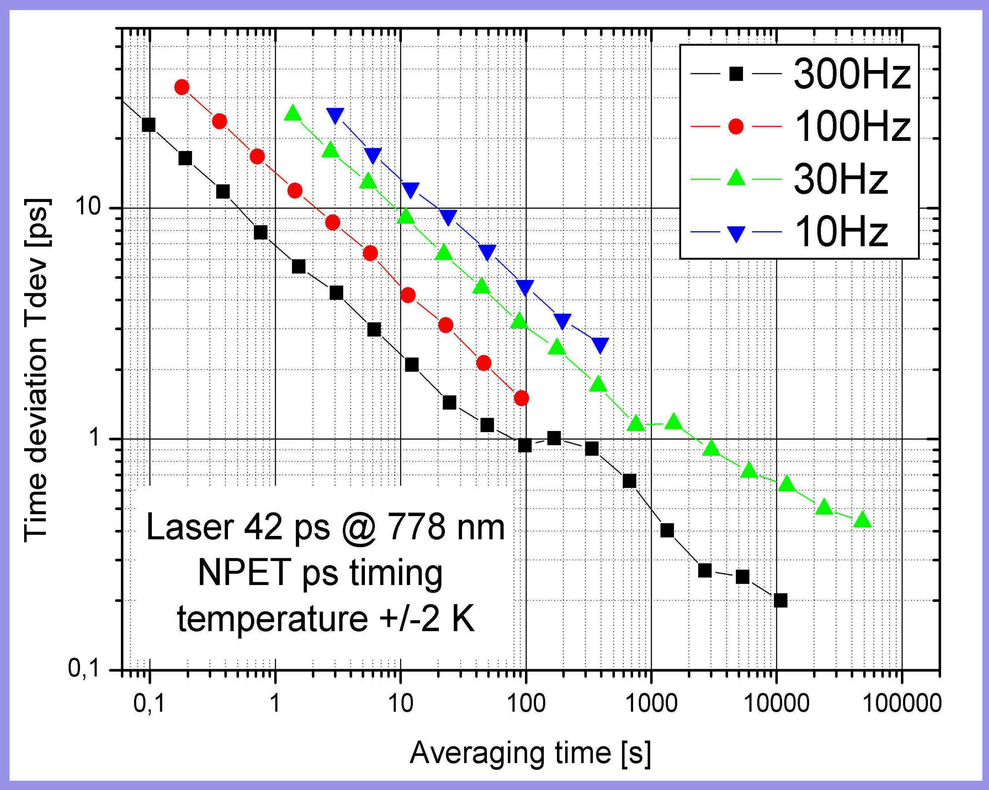


Detector block diagram. The SPAD bias voltage is temperature compensated.



"Power ON" current peak of the detector package, the probe 10x were used. The upper trace marks the bias on the detector package input 2 V / div, the lower trace is the current - 1.33 A / div.

TIMING STABILITY



The ELT detector package timing delay stability. The standard TCPC experiment setup was used. The optical pulses 42 ps @778 nm, the sub-picoseconds timing system by CTU [2]. The data rate was 6 - 10 %, the single shot timing jitter was 23 ps rms. The T_{dev} algorith Stable32 was used. The operating temperature changed ±2 K.

CONCLUSION

We have developed and constructed a photon counting receiver, which is prepared for the European Laser Timing (ELT) experi-ment in space. The photon detection probability > 20 % at 532 nm wavelength, timing resolution better than 25 ps rms and the detection delay long term stability better than 1 ps were achived. The detector package is capable to operate within a temperature range of -20 °C up to +55 °C, the detection delay change with the temperature is +0.6 ps/K. The delay between the event of photon absorption and the appearance of the electrical pulse on the detector output was determined. The newly developed experimental technique permits to determine this detection delay within accuracy of 12 ps. The new configuration of the optical receiver should maintain uniform sensitivity over a wide field of view of ± 5 to 60 degrees from nadir. Several radiation tests according ESA and ASTRIUM specifications were completed. The detector passed the ESA Critical Design Review, receantly the engineering modude is under construction.

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REFERENCES

[1] Schreiber U., Procházka I., Lauber P., et al. Ground Based Demonstration Of The European Laser Timing (ELT) Experiment; IEEE Trans. on Ultras. Ferroel. and Freq.Cont., ISBN 978-1-4244-3511-1, 594-599, 2009
[2] Pánek, P.; Procházka, I.: Time interval measurement device based on surface acoustic wave filter excitation, providing 1 ps precision and stability. Review of Scientific Instruments, vol. 78, no. 9, Sep 2007.

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