

Upgrade of SLR Station 7841 Potsdam

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Abstract. *The SLR station 7841 was upgraded to kHz operation in 2011. Laser repetition rates of 2 or 4 kHz are feasible. The range gate generator is based on an ARM-7 microprocessor with a clock frequency of 60 MHz. A Hamamatsu 5320 PMT tube or alternatively a 100 μm (non-compensated) MPD SPAD is used for signal detection. The system is operated in strict single photoelectron mode under both day and night conditions with return rates not exceeding few per cent. The tracking software is based on a RT Linux system [Steinborn et al. 2013.].*

Introduction

The SLR system 7841 Potsdam has been operating since 2002 as a typical 3rd generation system with 10 Hz laser repetition rate and a single shot accuracy of about 1-2 cm. Following the international trend towards higher repetition rates and shorter laser pulses, adequate modifications were performed in 2011. These concerned both hard- and software.

The main system parameters after the upgrade are summarized in Table 1 below.

Table 1. Parameters of SLR system 7841 Potsdam

Laser Type	picoREGEN™ (HighQ Inc.)
Repetition Rate	2 or 4 kHz (selectable)
Pulse Energy	400 μJ @ 532.15 nm
Pulse Width	12 ps @ 532 nm
Event Timer	A032-ET (University of Riga)
Single Shot Accuracy of ET	7 ps

The Range Gate Generator

The in-house build Range Gate Generator (RGG) is based on the widely used ARM-7 micro processor running on an internal clock frequency of 60 MHz. This allows for a timing resolution of 16.7 ns which is considered sufficient for both range gate and laser firing control. The GPS clock of the station delivers a 1 PPS signal and a 10 MHz clock frequency. The tracking PC provides once per second the predicted time of flight, the applied gate open time and the satellite time bias. The processor software (written in C++) uses the internal counters and match registers of the ARM-7 to derive the gate-open pulse, the laser trigger signal (including a shift in firing epoch in case of detected overlap between outgoing and incoming laser signals) and a gate-close pulse in case of no return signal. The gating signal for the SPAD detector is applied by the RGG about 100 ns before the expected arrival of the return signal.

Different from other RGG solutions, the recorded epoch of laser firing is not read-out to derive the gate-open time. Instead the RGG relies entirely on the well-known time delay between commanding the laser ON and the appearance of the light pulse at the laser output. With an internal clock frequency of 80 MHz for the seeder generator within the laser, the uncertainty of this epoch is ± 12.5 ns and thus sufficiently accurate considering the 16.7 ns resolution of the RGG.

The laser trigger pulses can be provided by the RGG at selectable frequencies between 2 and 10 kHz. Rates of 2 and 4 kHz were tested so far. No transmit-receive switch is required as the system 7841 Potsdam uses separate telescopes for signal transmission and reception (cf. Figure 5).

The Detector Package

Two selectable detectors are used: a conventional PMT and a non-compensated SPAD as shown in Figure 1 and their main parameters are summarized in Table 2 below.

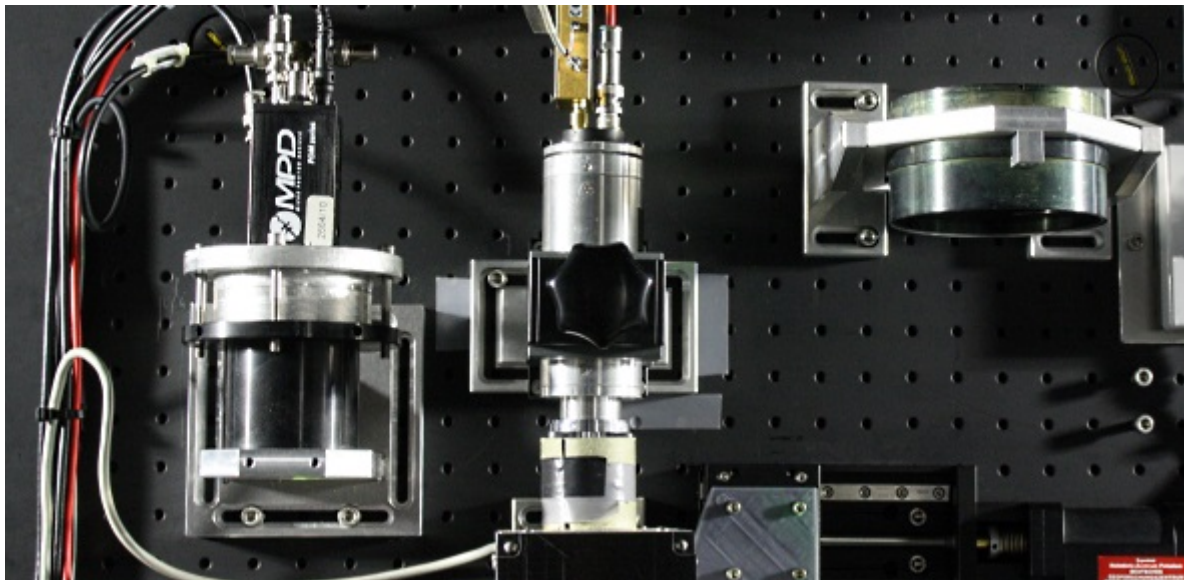


Figure 1. Detector package (left side: SPAD, right side: PMT) on the optical bench of the receiver

Table 2. Main parameters of detectors

Detector	MPD-1CTC (uncompensated SPAD)	Hamamatsu H5320 PMT
Quantum efficiency	40% @ 532 nm	8% @ 532 nm
Active area	100 μm	5 mm
Jitter of target response	20 ps (2.2 σ editing)	50 ps (2.5 σ editing)
Distribution of residuals	Non-symmetric	Symmetric

The PMT has the advantage of a large active area which results in a large field of view and is thus uncritical in alignment. The low quantum efficiency makes it mainly suitable for tracking of LEO satellites where there is sufficient return signal available.

The SPAD offers superior quantum efficiency and timing resolution but is critical to align due to its small active area. The largely non-symmetric distribution of ranging residuals (which is typical for many semiconductor-based detectors) requires stronger editing of the raw data as compared to the PMT which shows a fairly symmetric distribution as illustrated in Figure 2.

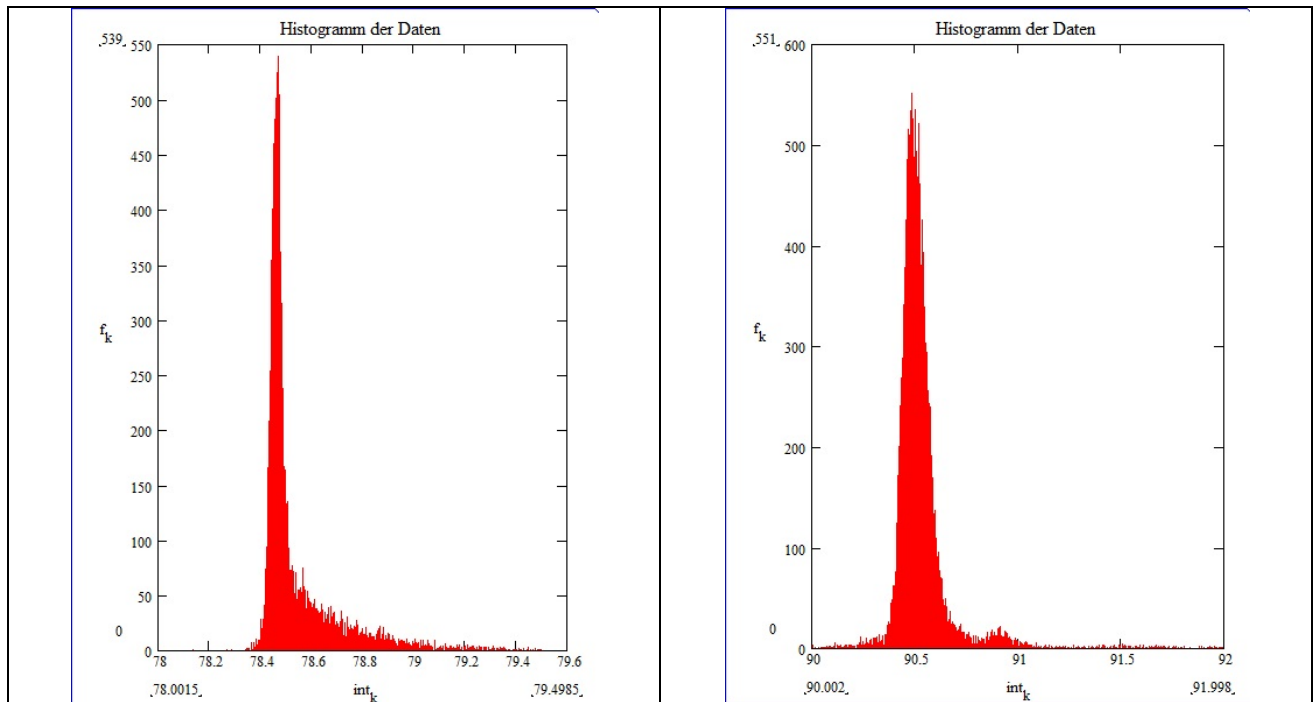


Figure 2. Distribution of range residuals for SPAD (left) and PMT (right) at single photon level (target response)

Both detectors show a very low noise frequency. For the SPAD this is mainly achieved by the use of a two-stage Peltier cooler, the PMT requires no cooling at all.

The SLR system 7841 Potsdam is operated in strict single-photon regime in order to improve the stability and minimize possible range biases. Single-photon regime is controlled by limiting the return rate to few per cent. In case of satellites with a very high optical link budget, the divergence of the transmit beam is widened until the required signal attenuation is achieved.

Upgrade of further Components

A blocked narrowband spectral filter (0.4 nm bandwidth, 42% peak transmission) is used for daylight tracking. In order to improve the return rate and to take advantage of the dark night skies, a wideband filter (3 nm, 97% peak transmission) is automatically selected by the tracking PC under nighttime conditions. The selection is made on the sun angle below the horizon and can be overrun by the observer in case of need. Both daylight and nighttime filter are mounted on a motorized stage (cf. Figure 3). While the daylight filter has to be ovenized to control the center bandwidth, this is not required for the nighttime filter due to its fairly large transmission bandwidth.

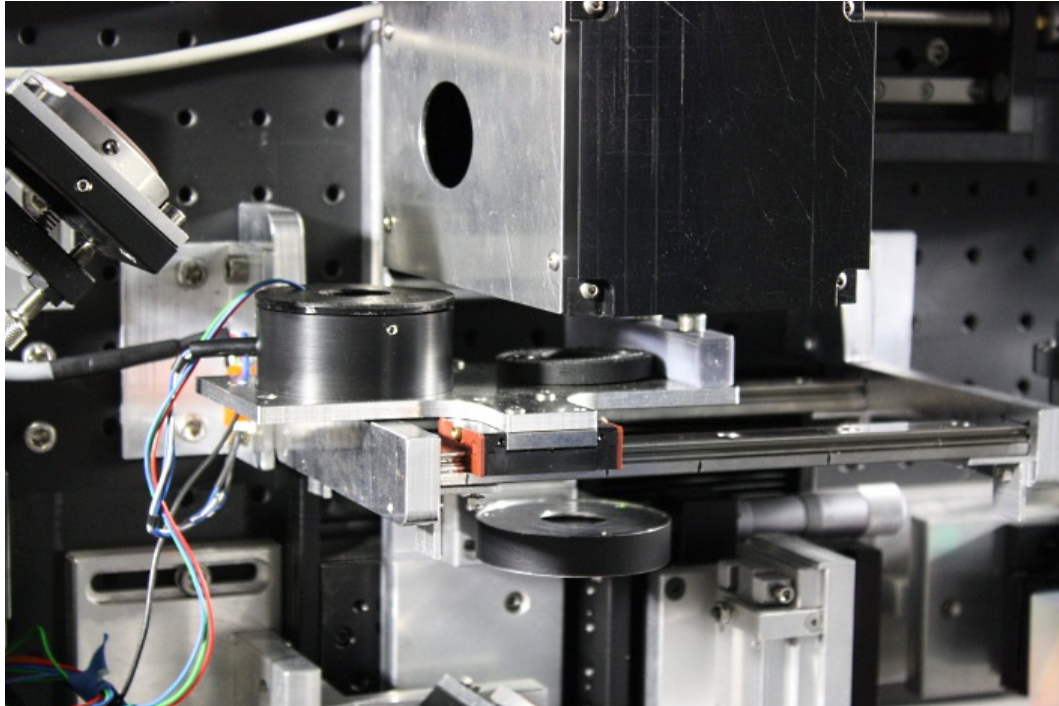


Figure 3. Daylight filter (ovenized, left) and nighttime spectral filter on a motorized linear stage

TV cameras are used on the transmit telescope for purposes of sky surveillance in addition to the ADS-B aircraft safety receiver (AirNav RadarBox 3D). These cameras serve now mainly for the detection of clouds or haze which limit the detection efficiency. In order to improve the sensitivity at night time, a stacked B&W CCD camera was mounted in parallel to the color CCD which is used in daylight (cf. Figure 4). When the integration time is set to about half a second, stars down to magnitude 5-6 are still visible.



Figure 4. Sky surveillance cameras (stacked B&W and color CCD) on the transmit telescope



Figure 5. SLR system 7841 Potsdam with separate telescopes for signal transmission and reception

Software Upgrade

Since the start of operation in 2002, the tracking software had been running on distributed PCs with the time-critical components still programmed under a DOS environment. In 2012 there was performed a major system upgrade. The time-critical parts of the tracking software were moved to a quad-core PC under a real-time Linux environment [Steinborn et al. 2013]. This PC allows for all tracking operations including session planning, tracking, system calibration, star field observation for mount model computation and more. Main emphasis was put on flexibility in order to be prepared for future ILRS tasks.

Operations of system components which are not time-critical (like setting of diaphragm, beam divergence, meteorological sensor readout or laser parameter control) were concentrated on a single PC running under Windows™. The same PC controls the aircraft safety hardware and reports the SLR system status via FTP to the EUROLAS server for worldwide distribution.

Reference

Steinborn, J., Kloth, A., Grunwaldt, L., *SLR Station Potsdam software upgrade based on a Linux real time system*, Paper 13-Po39, these Proceedings, Fujiyoshida 2013.