The upgrading of the Borowiec SLR station

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Abstract

The paper reports on the modernisation of the Borowiec SLR station (7811) carried out in 2007 and 2008. The modernisation was necessary for improvement of the quality and efficiency of measurements and for extension of the range of observations. In 2007 the measures included renovation of the laser pavilion, especially the operator room and the laser room with a new air-conditioning, and installation of the new optical elements of the telescope. The most important change in 2008 was installation of the microchannel plate photomultiplier tube with 30% QE. Preliminary results of calibration with the new MCP-PMT are presented. The results indicate improved stability of the calibration system but a little worse single shot RMS. The main changes in the electronics include installation of a new gating system of the accuracy of 1 ns for the time interval counter and the photomultiplier photocathode. Significant changes were introduced in the real time programs. The plans for 2009 include installation of the Event Timer and the indoor calibration system.

1. Introduction

The Borowiec SLR station has carried out observations since 1993 with no significant breaks. New objectives of the station such as an increase in the number of observations (daytime observations), improvement in the accuracy of measurements up to a few mm, observations of high satellites, one-way measurements (time transfer, lunar satellite) induced the necessity of significant changes in the laser system. At the first stage the laser pavilion was renovated (Fig. 1) to ensure better conditions of work for the apparatuses (precise air-conditioning). The work was realised from November 2006 to March 2007. At the second stage the transmitting – receiving optical system of the telescope was modernised, the main and the secondary mirrors of the telescope were covered with new coating, a new transmitting telescope was installed, the prisms in the Coude system were replaced by dielectric mirrors, a new receiving package with new filters and a CCD camera was installed. At the third stage the software of the system was upgraded, new controlling computers and a new gating system were introduced. All these tasks were realised in 2007 and 2008 and their realisation significantly restricted or even sometimes prevented regular observations. The partial results of the modernisation were presented at the ILRS Fall Workshop at Grasse 25-28.09.2007 (Schillak, 2008).

2. The aim of modernisation

The main aim of modernisation is to ensure the possibility of continuation of SLR station observations at a level of the requirements (quantity and quality) of ILRS. The Borowiec SLR system was outdated and needed essential changes. The main objectives were:
- improvement of single shot RMS and the accuracy of observations,
- increase in the effectiveness of observations,

- regular observations of high satellites including Galileo,
- participation in the project Time Transfer by Laser Link (T2L2) and participation in the one-way measurements to the lunar satellite in the LRO project.

Figure 1. SLR pavilion in Borowiec.

3. Changes in the system in the years 2007-2008

3.1 Modernisation of the optical elements of the telescope

The earlier used optical elements were considerably worn out and needed to be replaced. The most important change was coating of the main mirror (65 cm in diameter) and secondary mirror (20 cm in diameter) of the receiving telescope. Another important improvement was the replacement of the five prisms of the Coude path by dielectric mirrors and the replacement of their regulation systems by new ones permitting more precise regulation of the mirrors positions (Fig. 2). After these measures, a new model of errors of the telescope was determined and the Coude path was precisely adjusted. As a result the effectiveness and the range of observations were improved (Schillak, 2008). A new transmitting telescope was made of the 10 cm in diameter with regulation of the laser beam divergence. Unfortunately, the hitherto tests of this telescope have not brought satisfactory results. The earlier used transmitting telescope of the 20 cm diameter is also tested. The exchange of the receiving package has not been completed yet. The package contains a new interference filter of the spectral width of 0.3 nm or 1.0 nm, a regulated space filter, a CCD camera for control of the position of the laser beam on the day.

3.2 New MCP-PMT detector

To extend the range, to improve the effectiveness and precision of observations a microchannel plate photomultiplier tube Hamamatsu R5916U-64-3MCP with quantum efficiency 30% (Fig. 3) was installed. The parameters of the photomultiplier are given in Table 1.

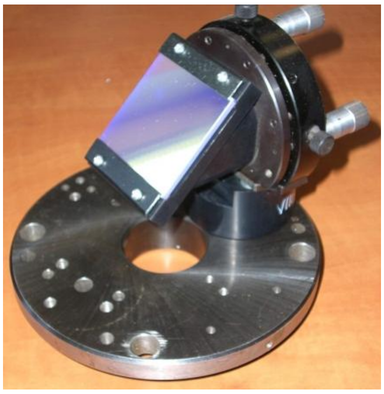

Figure 2. The dielectric mirror with the regulation system in the Coude path.

Table 1. Parameters MCP-PMT HAMAMATSU R5916U–64–3MCP.

Average Current Gain at -3600V	1.5 x 10^6
Average Dark Current	0.33 nA
Quantum Efficiency at 532 nm	30%
Rise Time	182 ps
Transit Time Spread	110 ps
Gate Rise Time	687 ps
Max. voltage supply	-4200V
Ambient Temperature in Operation	-50+50 C deg.

High efficiency of the photomultiplier (QE=30%, gain 1.5x10^6 at 532 nm) and small Transit Time Spread (TTS) should guarantee satisfaction of the above-mentioned objectives. The first observations with the new photomultiplier were performed on May 29th, 2008. However, a too small number of the hitherto observations related to realisation of the other tasks did not permit a comprehensive evaluation of the new detector. Preliminary data indicated a too great dependence of single shot RMS on the signal strength, both for calibration and satellite observation. For weak signals RMS exceeds 20 mm, which is a considerable deterioration in comparison to the 15 mm reached with the earlier used photomultiplier (Hamamatsu H5023). For strong signals the results are somewhat better (Fig. 5c). In Fig. 5a particular colours correspond to the neutral filters from the strongest 616 adjusted to the number of photons expected from high satellites to the weakest 602 adjusted to low satellites. The strength of the signal is determined by the percent of good calibration results and the number of the neutral filter. The signal strength versus the power supply of the photomultiplier is shown in Fig. 5a. A calibration stability determined by the dependence of delay on the signal strength is within 50 ps (Fig. 5b), which is much better than for the earlier used photomultiplier. Further works require tests at different levels of the constant fraction discriminator and increased power supply of the photomultiplier up to 4200V.

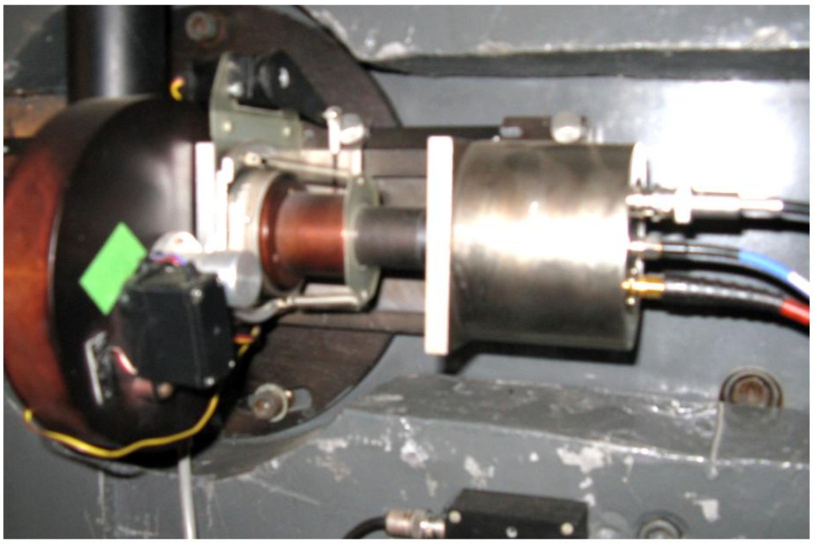

Figure 3. MCP-PMT (right) and neutral filters wheel (left).

Figure 4. Generator of the gate window (above) and the power supply of MCP-PMT (below).

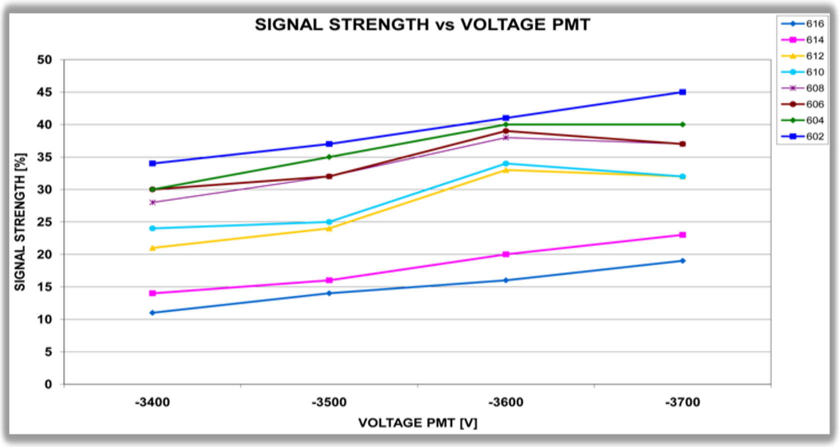

Figure 5a. Signal strength versus the photomultiplier voltage.

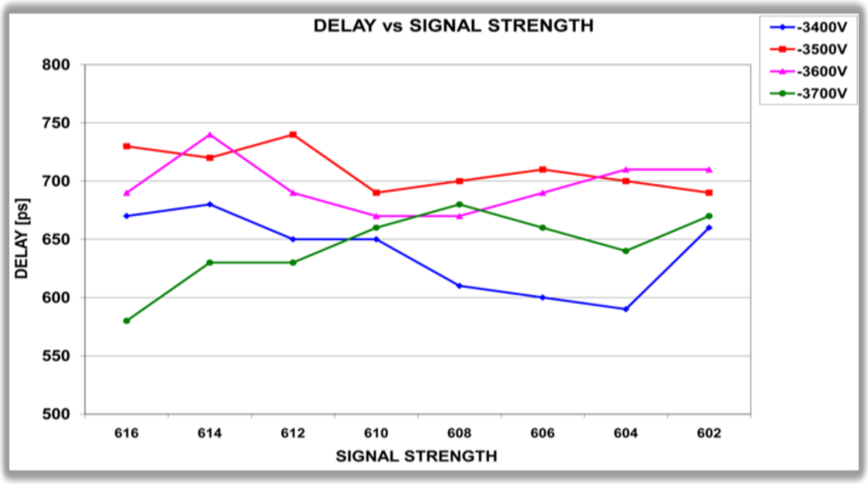

Figure 5b. Delay versus signal strength.

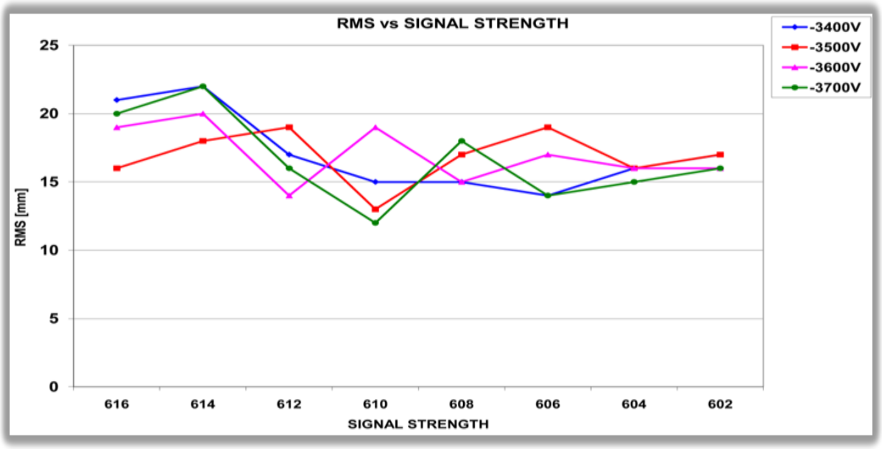

Figure 5c. Single shot RMS versus signal strength.

3.3 Software upgrading

The earlier used real time software in the DOS operational system installed at two linked computers; MASTER (real-time control program) and SLAVE (input/output programs) did not ensure correct work of the system. Two new and faster computers were introduced but they worked with the same basic software but with the possibility of gradual change into the Linux operational system. Additional loading influencing the speed of the programs realisation was introduction of a gate generator Stanford DG-535, necessary for gating the time interval counter and the photocathode of the photomultiplier. For the photocathode gating a regulated gate window was introduced in the range from 10 mcs to 10 ns (Fig. 4). The changes in the software did not increase the speed of the programs, while the delay introduced by the new gating system and the transmission between the computers led to essential problems and mistakes in their execution. At present efforts are made to eliminate these problems. An additional task is to adapt the software to work with the Event Timer.

4. Conclusions and future work

The schedule of Borowiec SLR modernisation has been much delayed because of the engagement of the SLR staff in organisation of the 16th Workshop, staff reduction and too many changes introduced simultaneously. The wintertime 2008/2009 is not suitable for testing because of the weather. The work concentrated on the measures ensuring the station full activity, in particular on more effective use of MCP-PMT, on testing the two transmitting telescopes in reaching the high satellites and on adaptation of the software to the changes in the system. An important task is the implementation of the Event Timer A032-ET and a new CRD format needed to participate in the project of laser time scale comparison T2L2.

Further work will concentrate on exchange of the outdated system of telescope control, including the engines and angle encoders, which is expected to permit more accurate tracking and realisation of daytime observations. Installation of the indoor calibration system is underway.

Unfortunately, the modernisation efforts have led to reduced activity of the station. It is expected that the effects of the modernisation will already in 2009 bring about a significant improvement in the quality of results of the Borowiec SLR. The far-ranging plans aimed at ensuring high quality of the station work are the installation of a new telescope, a kHz laser and new driving software in the Linux system working on the FPGA processor.

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Reference

Schillak S., 2008, Upgrading of the Borowiec SLR station in 2006/2007, Proceedings ILRS Fall 2007 Workshop, Grasse, 25– 28 September 2007, 9.1, CD.