The progress of Satellite Laser Ranging at Shanghai Observatory

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Abstract

Based on technology upgrades, the performance of SLR system at Shanghai Astronomical Observatory (SHAO) has been enhanced persistently in recent years. Both of SLR data quality and quantity have been improved greatly, which have reached ILRS guidelines (1996) at the field of long-term and short-term stability since 2015 and the efforts for further improving SLR data stability are still carried out.

Through updating the civil 1kHz laser system, designing control system, the SLR system with 4kHz repetition rate has been established and used in the routine SLR measurement. The results showed its advantages of increasing the amount of laser data, decreasing the precision of normal points, and more helpful for measuring the spin parameters of spherical satellites , laser time transfer and debris laser ranging.

Picosecond laser have been successfully applied in DLR by us, which boost the RMS of debris measurement from decimeter to centimeter level. Using a 532nm laser with power of 3.2w and pulse width of 50ps, DLR system with aperture of 60cm have obtained laser ranging data from several debris targets in clear nights, and the RMS is better than 8cm.

For further making a breakthrough of SLR performance, a novel method of multi-telescopes receiving and a new instrument of Superconducting Nanowire Single Photon Detector with good performance have been proposed and verified in our SLR system for increasing detection ability of SLR, which will be helpful for laser ranging with weak echoes.

1. Satellite Laser Ranging with kHz repetition rate

1.1 Performance of routine kHz SLR

Through minimizing the difference between satellite measurement and calibration measurement such as optical path, echo strength and temperature, holding the key devices constant temperature, and optimizing the working process, the quantity and quality of SLR data at SHAO have been improved in recent years. The short term stability and long term stability is 10 ~ 15mm (three months) and 6 ~ 7mm (one year) respectively, which have meet the guidelines of data quality standards (1996) as showed in Fig.1. The RMS of Lageos satellite is about 7mm ,which ranked 4th in all the stations (Fig2.)

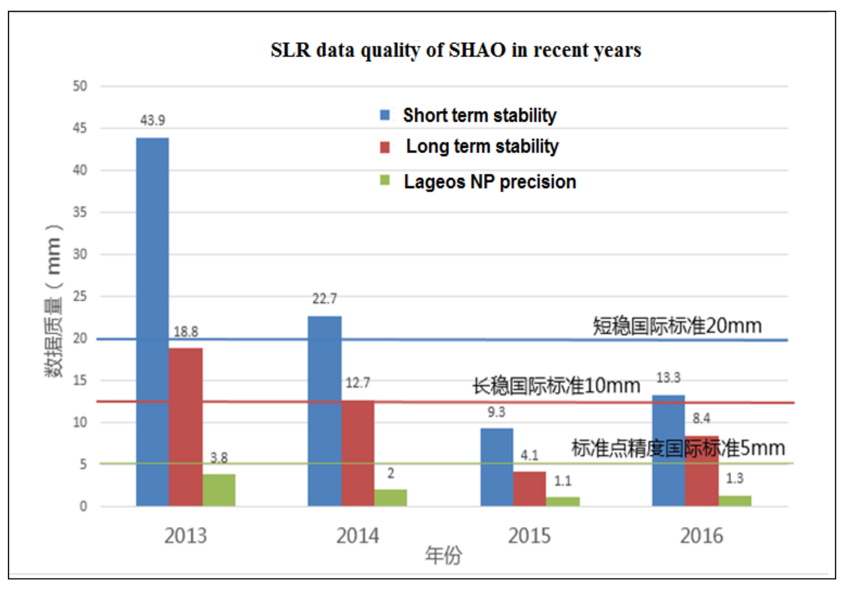


Fig.1 Data quality from 2013 to 2016

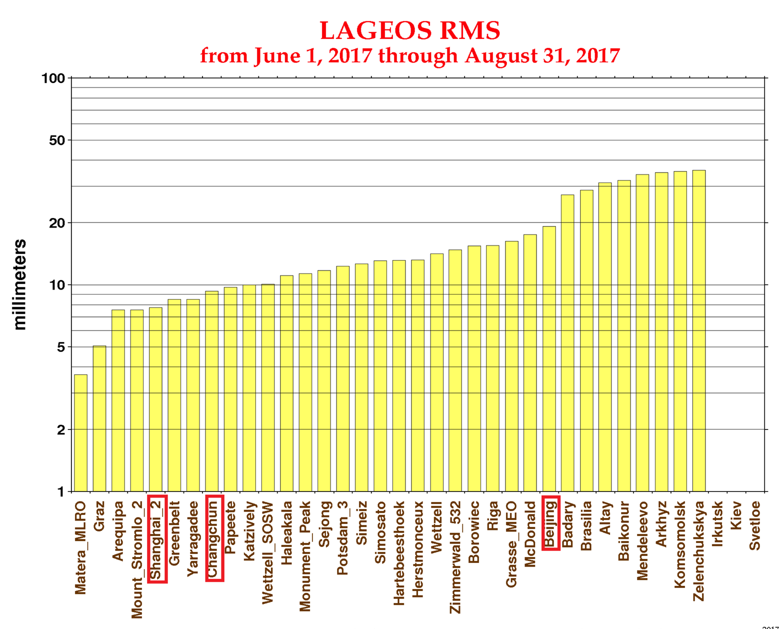


Fig.2 Lageos RMS of last quarter in this year

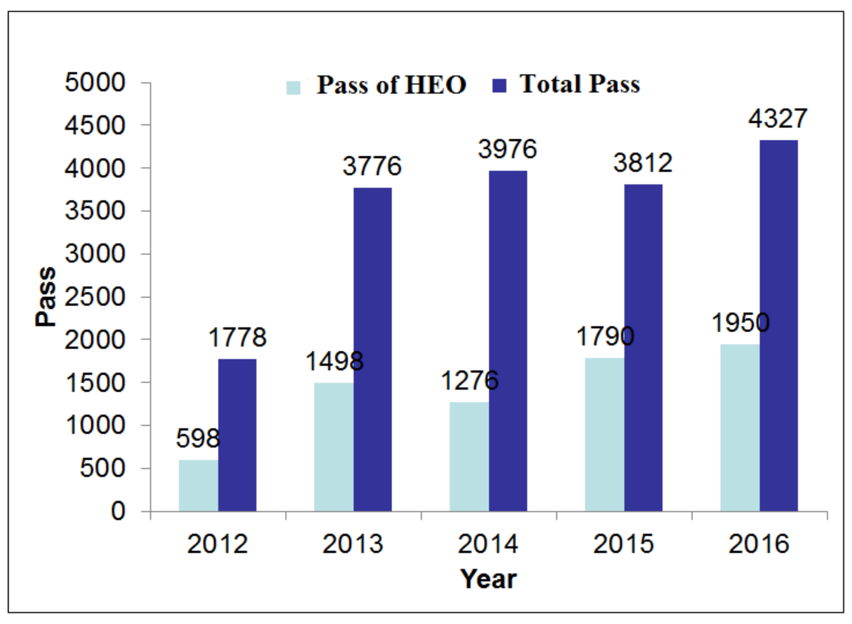


Fig.3 Satellite passes from 2012 to 2016

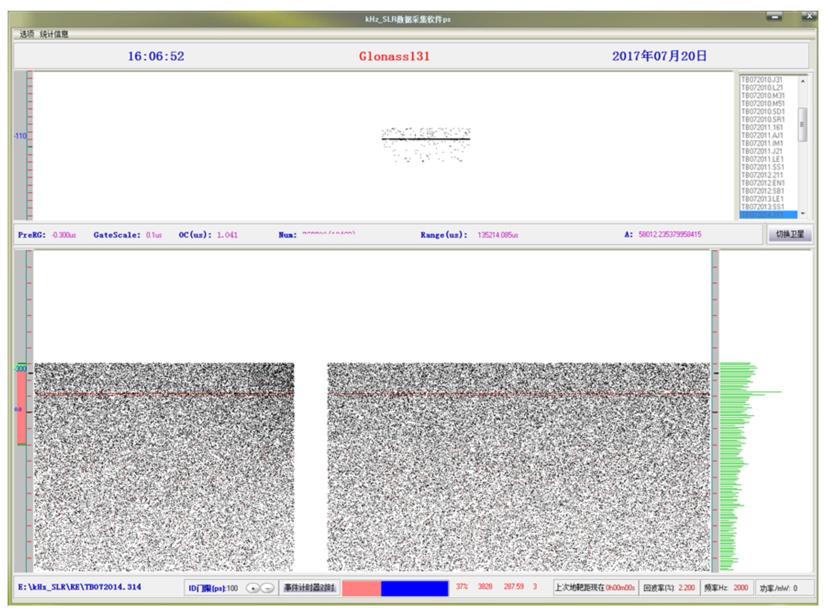


Fig.4 Interface for 4kHz SLR measurement

The obtained total satellite passes and HEO passes per year have been increased gradually from 2012 to 2016 (Fig3), and rate of HEO passes now is up to 45% . Until to 31st of August, SHAO have got over 3600 satellite passes , and the expected satellite passes in this year will be over 5000 passes.

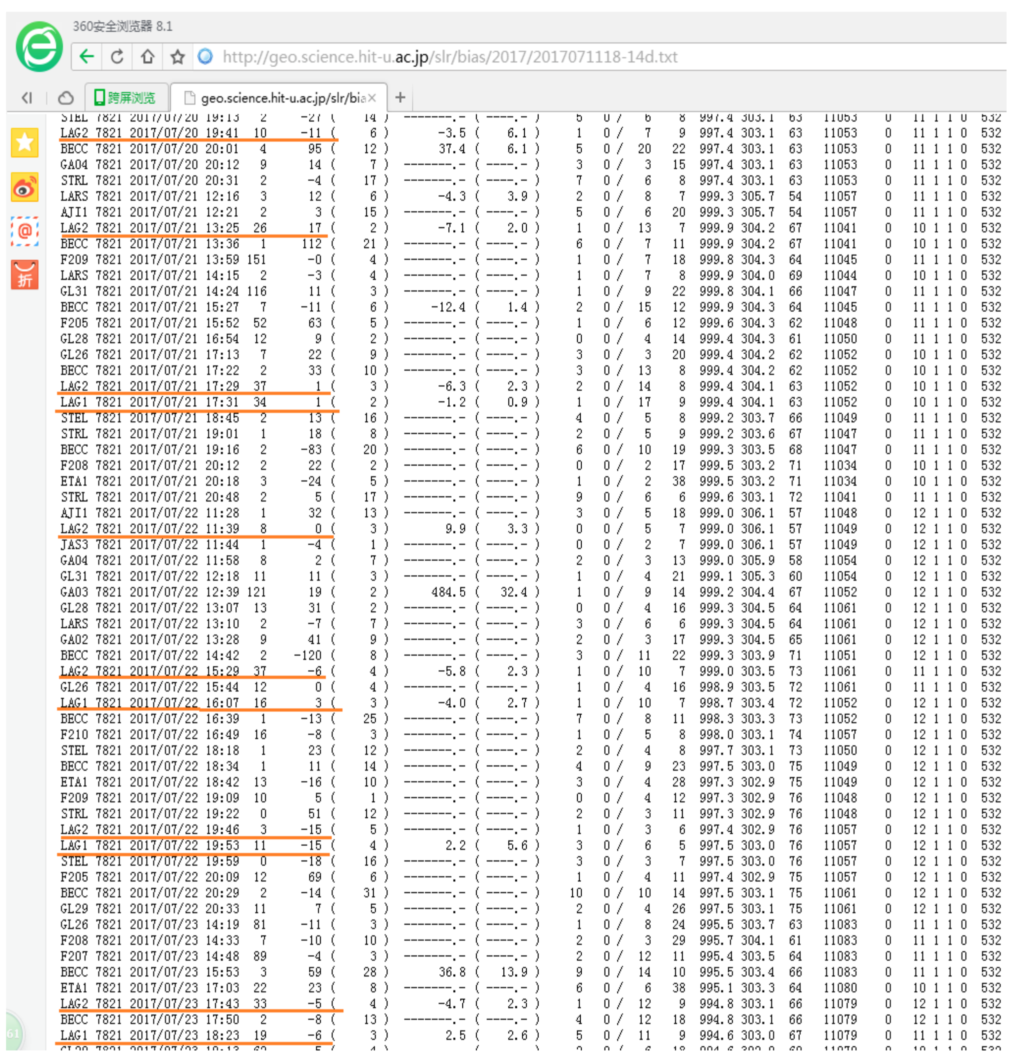


Fig.5 Range Bias of 4kHz SLR data

1.2 4kHz SLR system

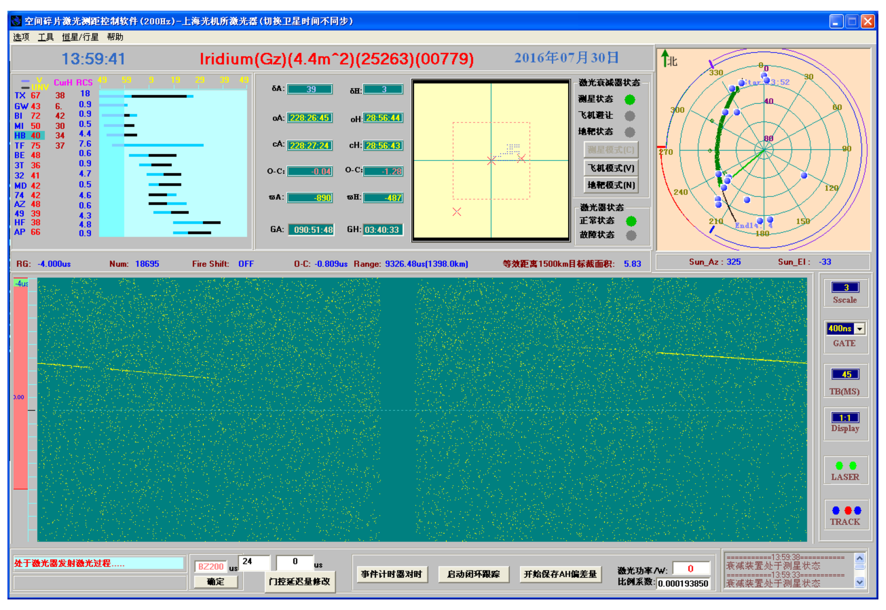
SLR system with kHz repetition rate had been established and routinized since Oct. 2009, which can range to GEO satellites with range of ～40000km in daytime tracking in Aug. 2010. For further improving the performance of SLR system, we firstly took a breakthrough of the 10kHz SLR technology in 2013.

Thanks to improvement of domestic laser technology, now we have set up a SLR system with 4kHz repetition rate by civil laser which has the power of 2.5 watts and ～50ps pulse width, and going to be used in the routine measurement (Fig.4 , Fig 5).

The experimental results showed its advantages of increasing the amount of laser data, decreasing the precision of normal points, and it is also more helpful for measuring the spin parameters of spherical satellites and make it possible to laser time transfer between two stations via Ajisai.

2. Debris Laser Ranging

2.1 Routine DLR with nanosecond laser



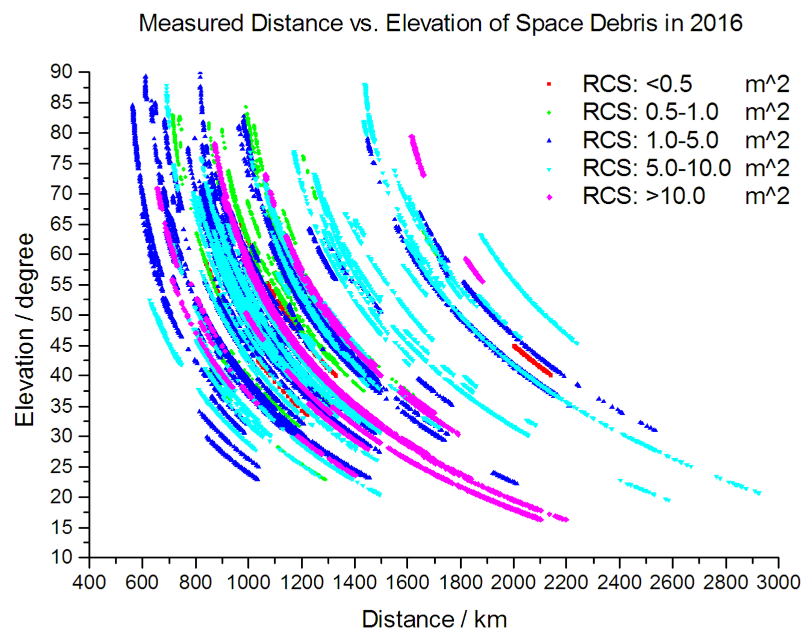


Fig.6 Measurement interface of space debris Fig.7 Range, Elevation and RCS of debris measured

By using a domestic laser with power of 60watts in 532nm and pulse width of 5～6ns, and applying HQE detector with detection efficiency of >50% in 532nm, the routine of laser ranging to space debris has been realized to precisely measure debris targets.

More than 300 passes of laser data from space debris were obtained per year ,the most 40 passes one night obtained and the longest distance is more than 2900km and the min. cross section (RCS) is 0.3 m^2 and measurement success rate >80%.

2.2 DLR experiment with picosecond laser

For boosting the measurement RMS of laser ranging to space debris, a picosecond laser with power of 3.2watts in 532nm and pulse width of 30 ps was used in our DLR system and the working frequency is 1kHz.

Based on the updating DLR system, the experiment for measuring debris was carried out and some Rocket body had been measured in clear nights. The RMS, for Satellite of compassi5, which was 37,000 kilometers far from the earth, and space debris with RCS of about 5m＾2 , is <20mm and <10cm respectively. (70.3 mm showed in Fig 9)

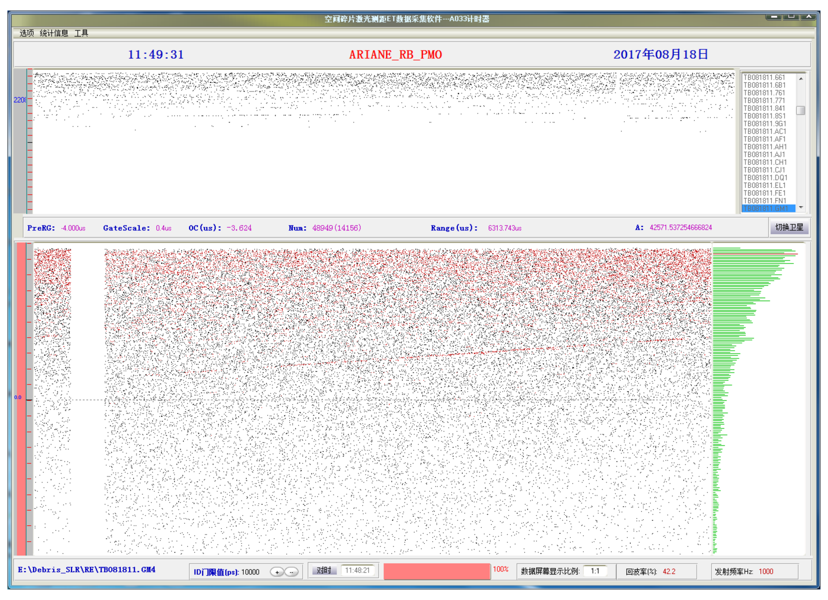


Fig.8 Laser ranging to ARIANE_RB

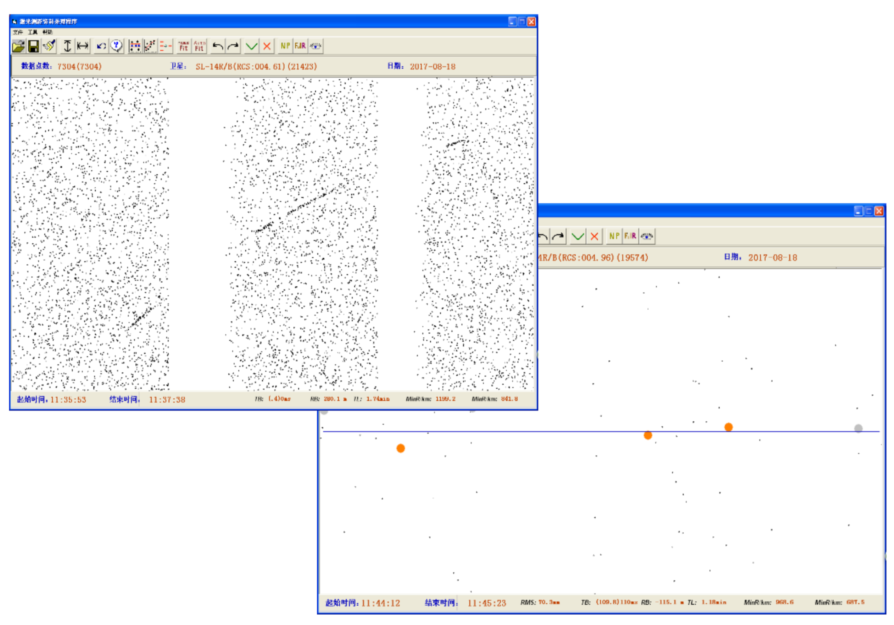


Fig.9 Laser ranging to SL-14R/B

2.3 Other progress

For further improving SLR detection capability, we proposed and developed a new SLR measurement method, the multi-telescope receiving technology, which has some advantages of robust, flexible and low cost comparing to a telescope with big aperture. Based on two nearby telescopes located in SHAO as showed in Fig.10, we have successfully range to GEO satellites and space debris, which verified feasibility of multi-receiving telescopes in laser ranging for increasing measuring ability of weak signals.

Fig.10 SLR system based on two-telescopes receiving

The SNSPD is a potential, excellence detector for SLR measurements with weak signal because it has extremely low dark count rate, high detection efficiency and low timing jitter. The successful experiment of laser ranging to satellite with 532nm laser are performed for the first time in China in 2015 which showed that SNSPD is suitable for SLR measurement with good performance.