

# Progress in kHz SLR and laser ranging to un-cooperative space targets at Shanghai Station

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## Abstract

From October 2009, Shanghai SLR station implemented routinely kHz repetition SLR by using kHz repetition laser with picosecond pulse-width and high-precision Event Timer, designing nanosecond accuracy of Range Gate Generator with event mode and back-scattering avoiding circuit, developing real-time control software and data pre-processing software. The paper presents the progress in KHz SLR at Shanghai station, including ranging to the low-Earth and high-Earth orbit satellites at nighttime and daylight laser ranging for low-Earth orbit satellites, tracking geostationary orbit satellite. In addition, some new measuring results and progresses of un-cooperative space targets laser ranging are also showed in this paper.

## 1 Introduction

Shanghai Observatory has investigated the key technologies of kHz repetition SLR since 2006. In 2008 some experimental results was obtained and Zhang reported the measuring results at Last workshop in Poznan (2008), named “the Experiment of kHz Laser Ranging with Nanosecond Pulses at Shanghai SLR station”. It presented Shanghai SLR station had the capability to track satellites up to Lageos with 1-2 kHz laser. Yang also reported “Preliminary Results of Laser Ranging to Un-cooperative Targets at Shanghai SLR Station”. It means that Shanghai SLR station have solved some key technologies of un-cooperative targets laser ranging. Recent years Shanghai Observatory got some supports from national projects to develop kHz repetition SLR and un-cooperative targets laser ranging technology. This report will introduce the new progresses on the above two fields.

## 2 Advance of kHz SLR

The major technical upgrading for the kHz SLR is following: 1) Adopt new kHz Laser with 15-20ps pulse width, 3mj energy made by PI company of USA, instead of the experimental laser with 50ns pulse width borrowed from NCRIEO (North China Research Institute of Electro-optics); 2) Develop our KHz Range Gate Generator (RGG) with 5ns resolution; 3) Improve and perfect KHz software system by ourselves.

### 2.1 New kHz Laser

In 2009, Shanghai SLR station imported the new kHz repetition laser from PI Company. The main performances of this laser are following: 1k~2kHz repetition rate; 1-2mJ per shot; 532nm wavelength; 15~20ps pulse-width; 0.5mrad diverge. Figure 1 show the inner optic principle and view of new kHz laser. According to the results of measuring near target on ground, the measuring precision is 5~8mm.

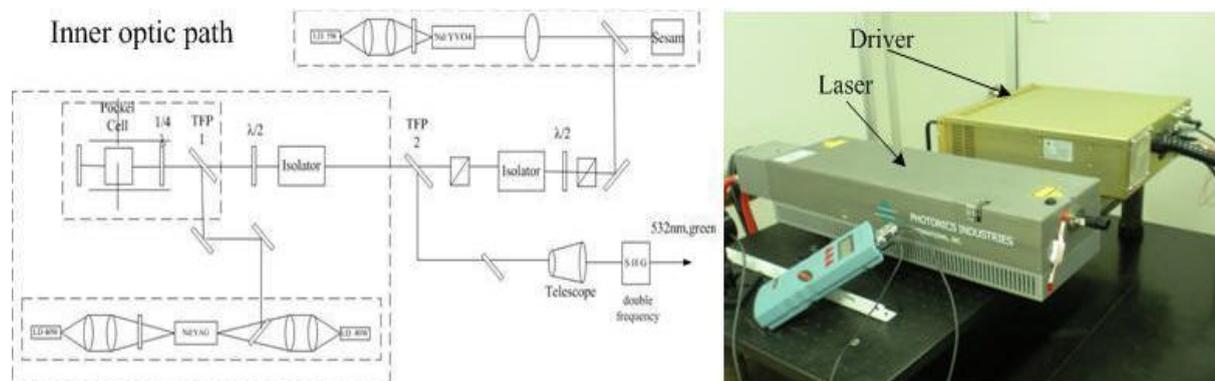


Figure 1 New kHz Laser from PI of USA

### 2.2 kHz Range Gate Generator

The kHz Range Gate Generator (RGG) is designed by our group based on FPGA and consists of four modules: serial port control module, real-time clock module, comparator module, enhanced parallel port (EPP) control module and laser firing module. Figure 5 shows the diagram of kHz RGG. The serial port control module receives the 1PPS epoch time from GPS to

make the real-time clock module synchronized UTC. The PC calculates the return time of laser signal according to the prediction and sends the timing data to the FIFO of kHz RGG. The comparator module reads the times from real-time clock module and the FIFO respectively and compares to each other. If the time from the real-time clock is equal to the one from the FIFO and then generates the range gate signal to open the photo-detector. The laser firing module is responsible for generating laser fire signal and backscatter avoiding. The main characteristics of kHz RGG are following: 5ns resolution, 1024 buffers and EPP interface.

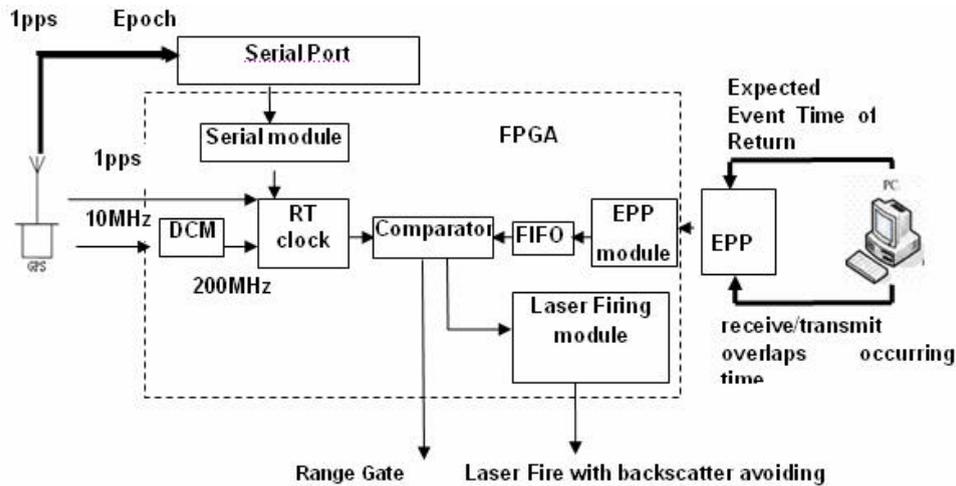


Figure 2 the diagram of kHz RGG

### 2.3 Some kHz measuring results

After finishing the kHz laser, RGG, the control software, Shanghai SLR station has been the routine kHz SLR measurement since Oct. 2009 and got 2990 passes in 2010. In Aug. 2010, Shanghai station successfully ranged to geostationary orbit satellite (GEO) by using laser with 1.8mJ@1kHz. Figure 3 show the kHz SLR measuring results for compass M1 and GEO satellites. Comparing with low repetition rate laser ranging, the returns and data density per normal points are greatly increased.

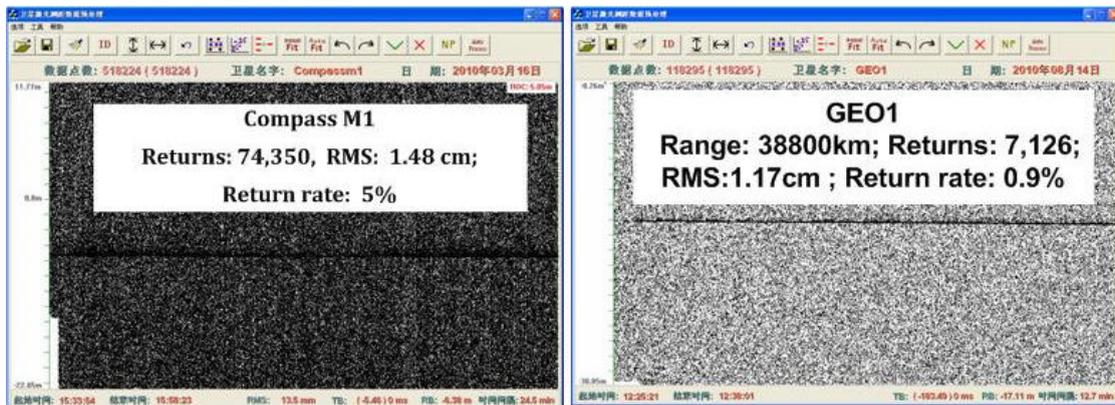


Figure 3 kHz repetition rate SLR measuring results

### 2.4 KHz SLR daylight tracking

Based on the routine kHz SLR repetition at nighttime, some key technologies of daylight laser tracking are adopted: 1) Space filter: receiving field of view of 30?- 45?; 2) Spectrum filter: Narrower filter with 0.15nm band width; 3) Transparency of central wavelength of over 50%; 4) Parallelism of transmitting and receiving paths with better than 5?; 5) Real-time return detection; 6) Measurement of telescope sighting error; 7) Increasing tracking and pointing accuracy of telescope mount. Shanghai SLR station has got returns from the LEO satellites at daylight Since Aug. 2010. Figure 4 show some passes of daylight SLR measuring results from Low Earth Satellites (LEO).

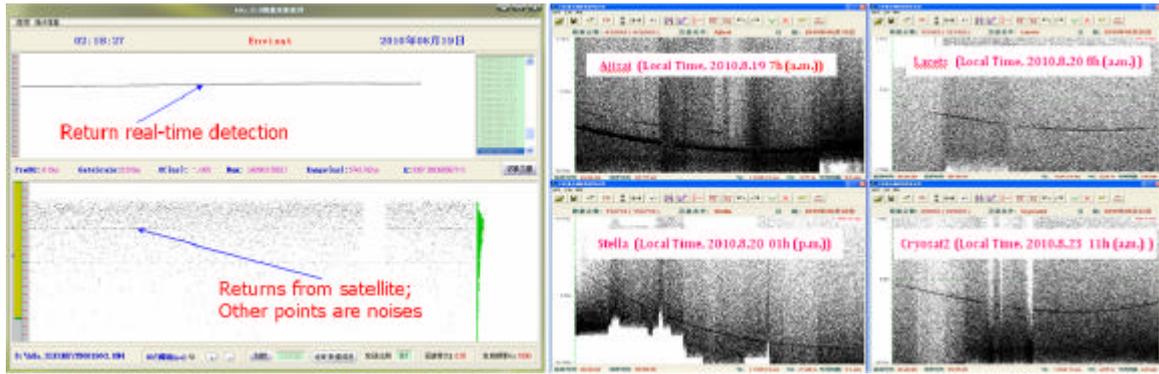


Figure 4 Daylight SLR measuring results for LEO satellites

### 3 Advance of Un-cooperative space target laser ranging

In July 2008, Shanghai SLR station successfully ranged to un-cooperative space targets by borrowing high power laser with 2J@20Hz from NCRIEO. For further studying un-cooperative space targets ranging technology, we have been upgrading the experimental system in 2010, including 1) adopting stable high power laser; 2) improving the capability of servo-tracking system; 3) adjusting Multi step range-gate automatically; 4) adopting Two Line Elements (TLE) predict.

#### 3.1 10W High power Laser

Due to the stability of the 40W laser borrowed from NCRIEO is very poor, so we imported a set of high stable 10W laser from the Spectra physics, Inc of USA and continuous working time is more than 1 hour. The main performances of high power laser are following: 10Hz repetition rate; 1J per shot; 8ns pulse-width; 532nm wavelength; 0.5 micrad diverge.



Figure 5 The view of 10W power laser

#### 3.2 Tracking ability of servo control system

The tracking precision of telescope mount plays an important role in laser ranging to the un-cooperative targets. So we adopted the high accuracy optical RESM angle encoders that offer high speed, reliable operation and open, non-contact performance with excellent immunity to dirt and electrical noise with the resolution to 0.02 arc second. At the same time, the high efficient driver system was installed to insure the ability of telescope tracking. Figure 6 shows the tracking precision of telescope mount and the tracking precision is less than 1 arc second.

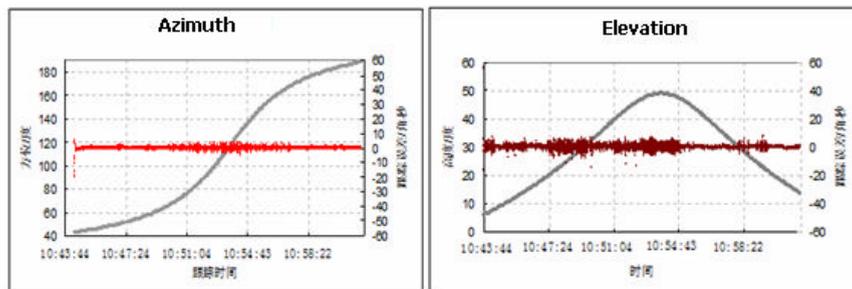


Figure 6 Tracking capability of telescope mount

### 3.3 Other upgrading

In our un-cooperative target laser ranging experimental system there are other upgrading, such as close loop tracking mode, multi range gate adjust, two line element (TLE) predict. Through the above upgrading, the measuring efficiency of laser range system is obviously increased.

### 3.4 Measuring results

In 2010, the performances of un-cooperative target laser ranging system were improved and several passes of un-cooperative laser ranging were obtained. Figure 7 shows some measuring results of un-cooperative targets. The ranging precision is about 50~80cm and the max range is up to 1200Km.

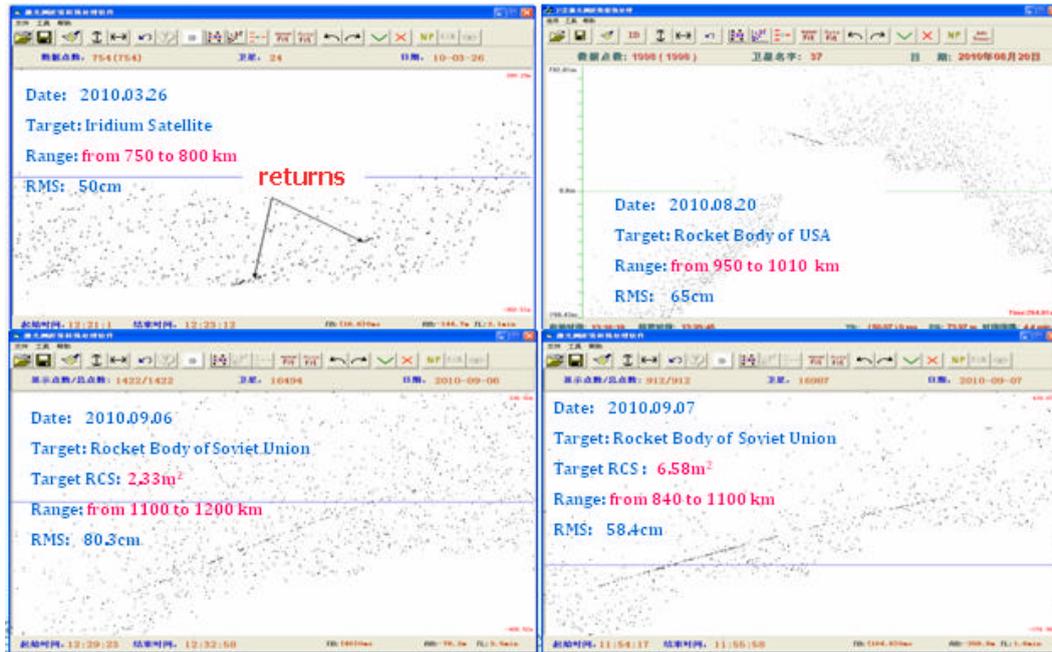


Figure 7 some results of un-cooperative target laser ranging

## 4 Summary

Shanghai SLR station has been the ability of routine kHz SLR at night-time and realized daylight laser ranging. Next stage we will improve our kHz SLR system and track to HEO satellite at daylight. For un-cooperative target laser ranging, some technologies will be implemented in the future: 1) Increasing the laser power (40W-50W); 2) Improving orbit predicting precision for un-cooperative target; 3) Adopting closed loop tracking mode; 4) Identifying laser beam automatically.

## Reference

- Zhang Zhongping, 2008: *The Experiment of kHz Laser Ranging with Nanosecond Pulses at Shanghai SLR*, Proceedings of the 16th International Workshop on Laser Ranging
- Yang Fumin, 2008: *Preliminary Results of Laser Ranging to Un-cooperative Targets at Shanghai SLR Station*, Proceedings of the 16th International Workshop on Laser Ranging

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