Laser tracking to space debris with low power of ps laser/1 kHz based on the 1.2-meter telescope at Mid-West China

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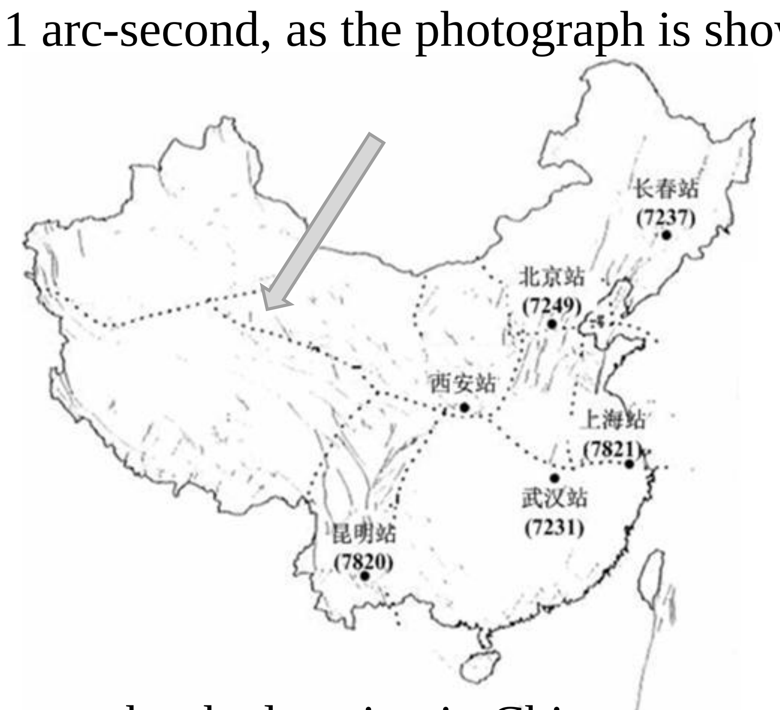
Abstract

The high power nanosecond lasers have been commonly used to space debris laser ranging (DLR) at satellite laser ranging (SLR) stations. In this paper, the feasibility of picosecond laser for DLR with low power is researched at the Shanghai Observatory (SHAO) and Purple Mountain Observatory (PMO). There was an aperture of 1.2 m telescope for laser quantum communication,which is located in mid-west of China with an altitude of 3200 m, with the seeing of about 1 arc-second. Both SHAO and PMO have upgraded it for SLR measurements, and also the picosecond laser in wavelength of 532nm was installed, **which the average power is 1.2 W @ 1 kHz**. Firstly, the ILRS satellites were successfully measured. Then, a high efficiency avalanche photodiode(APD) and a large field of view (FOV) telescope were used for DLR and also with a narrow spectral filter was applied with the line width of 2 nm. Using the TLE predictions, the DLR was successfully performed. A total of more than 60 debris targets were measured in a week. Among them, the farthest range was about 1620 km with the RCS of 2.41 m^2, and the equivalent RCS at the 1000 km range was 0.35 m^2. In addition, the ranging precision was 10.6 cm, better than that from the nanosecond lasers.

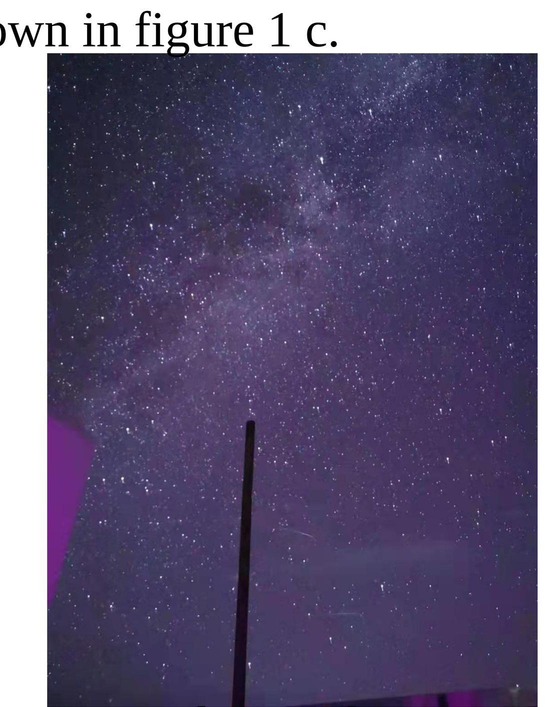
1. Introduction and laser ranging system

A quantum communication network covering the world could be realized through satellite, the world's first quantum science experiment satellite of Micius Satellite has achieved high-precision docking between the satellite and earth, and it has achieved high-speed quantum key distribution between stars and earth for the first time in the world, quantum entanglement distribution experiments, which the distance is over 1200km, and intercontinental quantum key distribution and intercontinental quantum confidential video call demonstration was achieved. The optical receiving system is an aperture of 1.2 m telescope optical ground station telescope (figure 1 a). The tele scope adopts the form of R-C structure, and it has the imaging quality near the diffraction limit. In order to suppress the ups and downs of the angle of arrival and achieve micro-radian tracking accuracy, the telescope adopts a composite axis tracking control strategy to achieve high-precision and high-bandwidth tracking. And it is located at the Qinghai Observatory of PMO in Delingha City, Qinghai Province, China. It is located at North latitude of 37°22'44.43'and East longitude of 97° 43'37.01',and its sea level is about 3200 m, as shown in figure 1b. There is a good seeing, which is about 1 arc-second, as the photograph is shown in figure 1 c.

a. the telescope



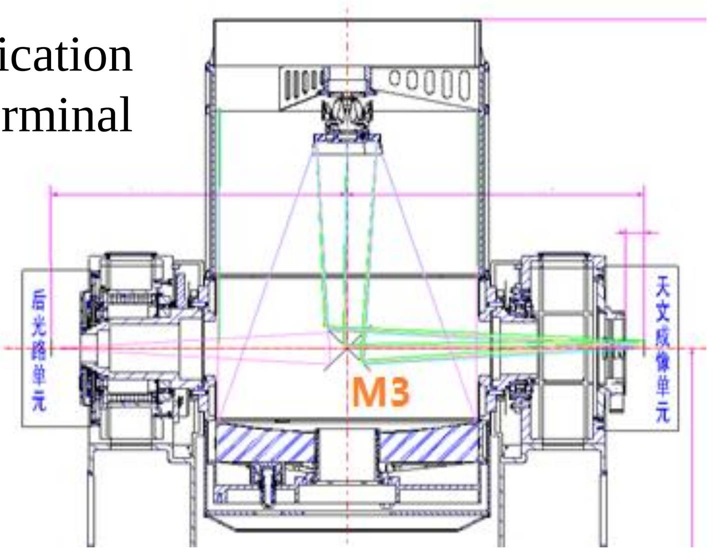
b. the location in China

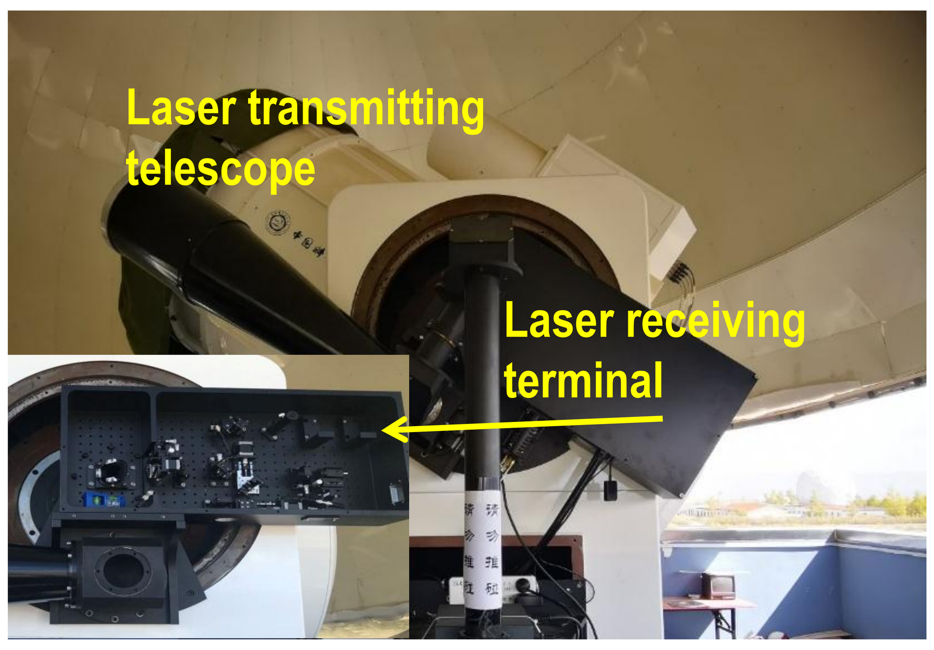


c. the good seeing

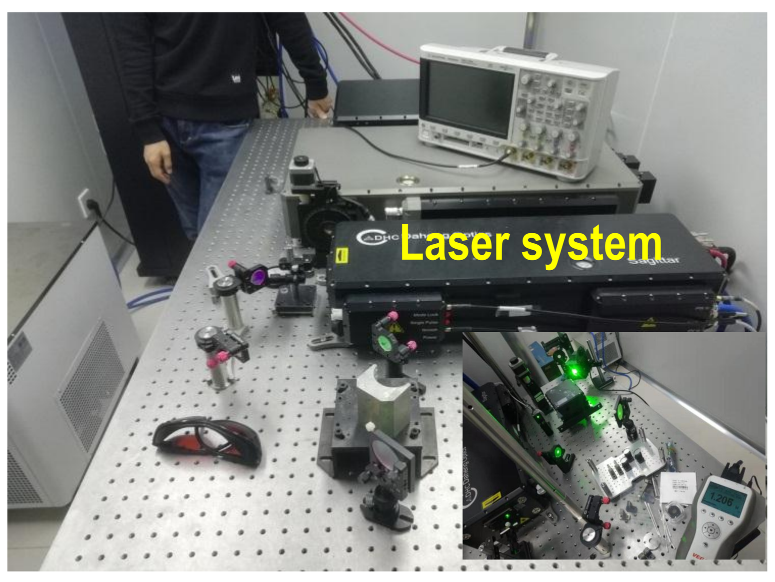
Figure 1 the aperture of 1.2 m telescope location and seeing

- Two working focus: quantum communication terminal and astronomical observation terminal through switching **M3** mirror.
- Upgrading the laser receiving terminal and laser transmitting telescope at the focus of astronomical observation terminal.





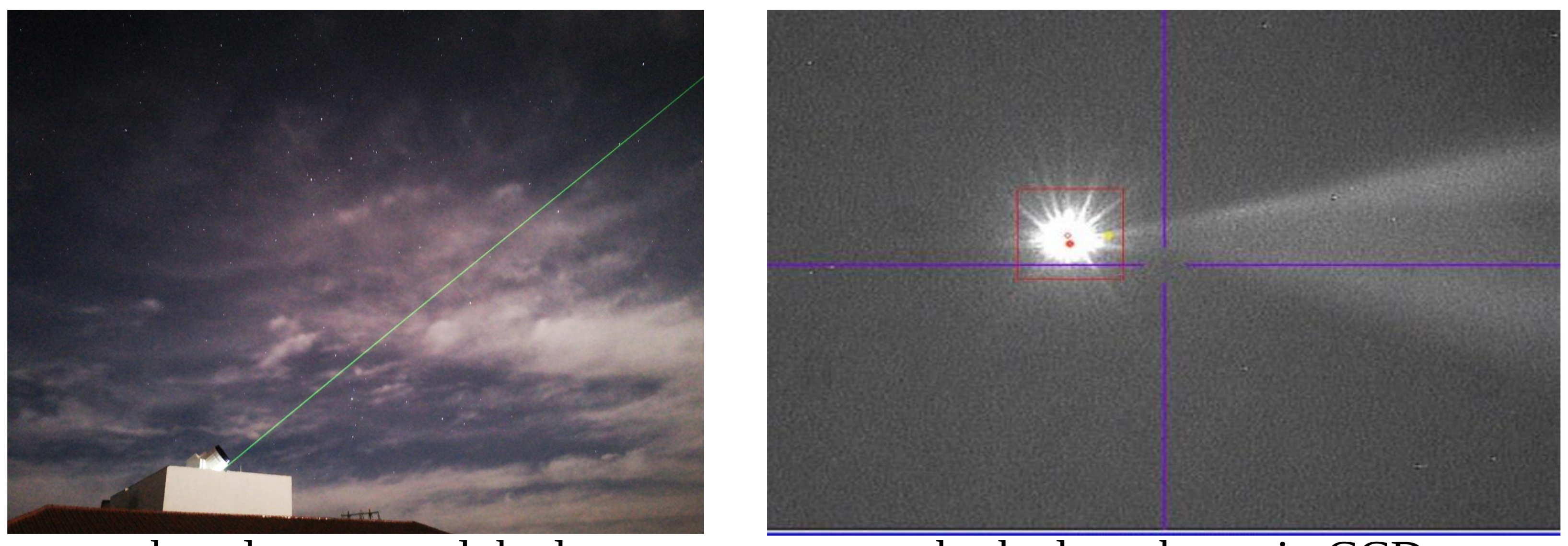
- Installation of pico-laser system: 1kHz, 532nm,1.2W power, 45ps.



Updated SLR system

2. Experiment and results

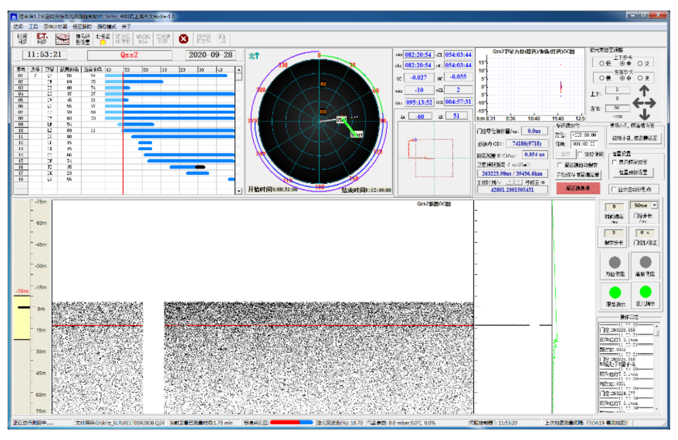
The ILRS satellites and space debris were tracked. The prediction of satellite and space debris were processed by the servo system to track the targets. The position of the target in the CCD field of view was observed , and the tracking correction is fine-tuned to make the target in the CCD field of view. At this time, a picosecond laser was emitted by a 6-fold emission telescope (figure 3 a). The beam was shown in figure 3 b, and the tip of the beam was very sharp.



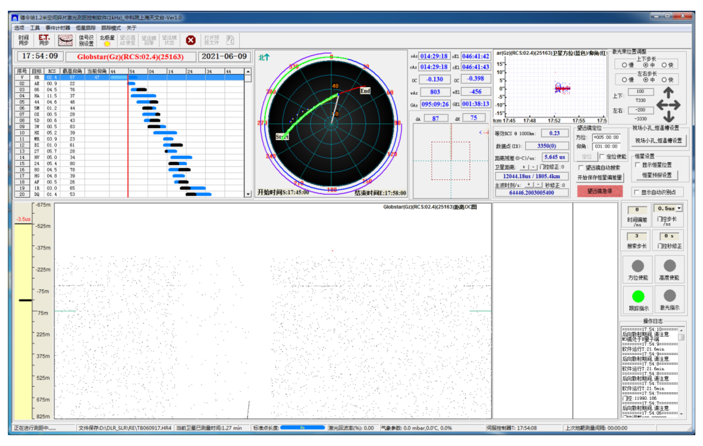
a the telescope and the laser b the laser beam in CCD

Figure 3 The real-time SLR measurements

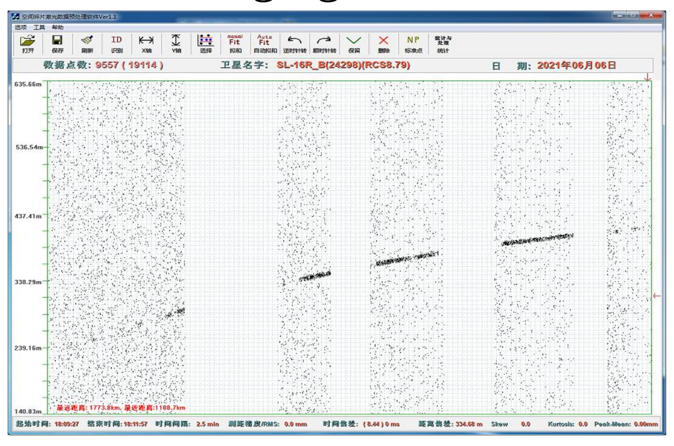
The LEO, HEO, and GEO satellites were measurements and as shown in figure 4 a, the ranging accuracy was better than 2 cm, and space debris targets were also detected by using the same laser system. The real-time measurement and data processing was shown in figure 4 b,c,d. The line with a certain radian at the dense point in the figure 4 b and c were laser echos from the space debris.



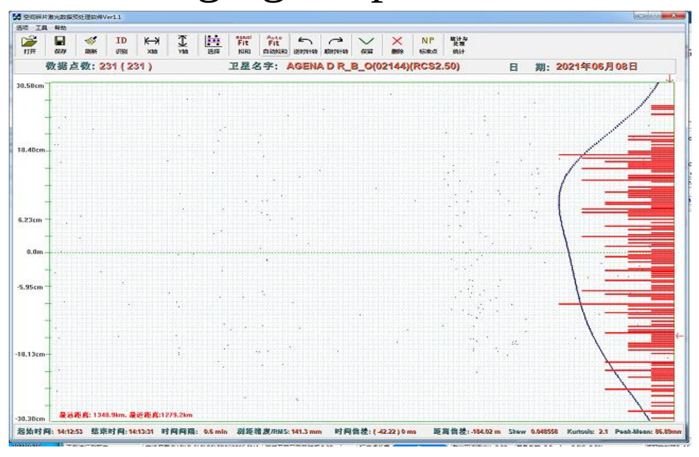
a laser ranging to satellites



b laser ranging to space debris



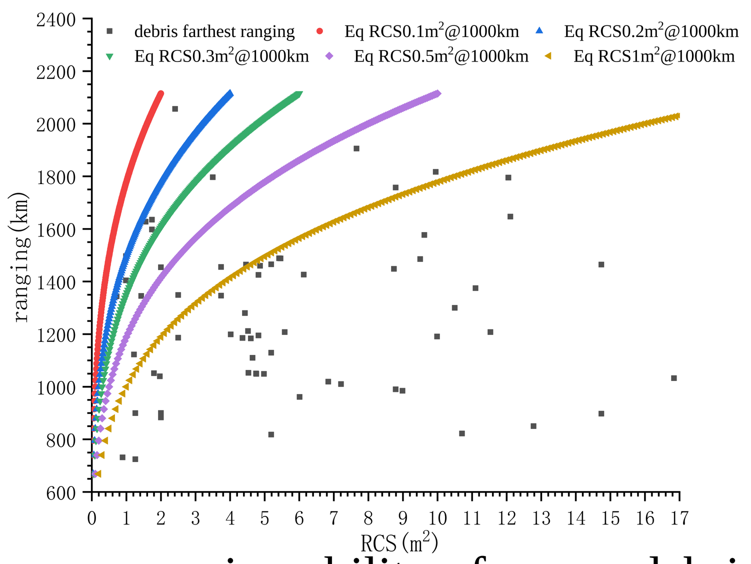
c data processing for space debris



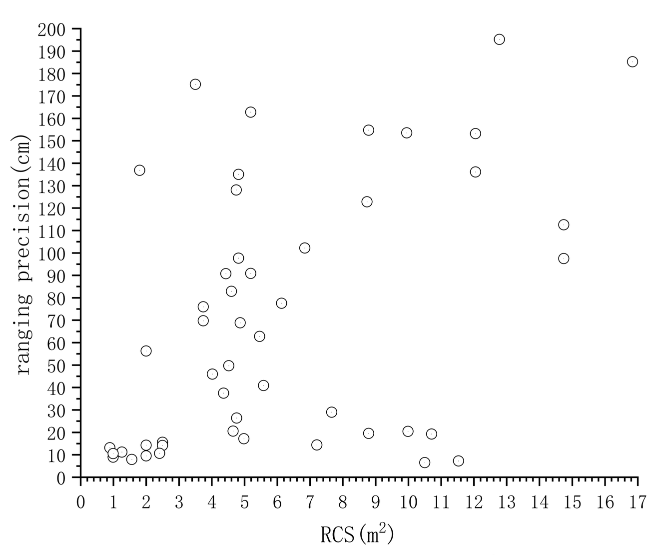
d ranging precision

Figure 4 the laser ranging results for satellite and space debris

There is about sixty passes of space debris with the 1.2m telescope laser ranging sys-tem shown in figure 5 a. There was a equivalent smallest space debris with RCS of 0.13m^2 at the distance of 1000km. For RCS of less than 2 m^2, the ranging accuracy was about ~10cm, as shown in figure 5 b.



a. measuring ability of space debris



b. ranging precision of space debris

Figure 5 The results of DLR measurements

3 Summary and discussion

A single pulse energy of 1.2 mJ picosecond laser was successfully used to track space debris and the ranging accuracy of space debris can reach ~10cm with RCS of less than 2m^2. This experiments exceed the traditional thought for laser tracking space debris with high power laser. We are seeking the possible reasons of measuring to space debris with low pulse energy, **such as larger receiving aperture? good seeing? Interaction effect of picosecond laser with atmosphere? others?** We hope more station with such good seeing try to track space debris by using the routine SLR system to pursue the potential of laser tracking to space debris.

4 Reference

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