Laser measurement to space targets by using dual-receiving telescopes and one transmitted system

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Abstract: For SLR measurement adopting large aperture of telescope will help to increase the ability of detecting laser echoes. According to laser link equation the number of laser echoes received by one large aperture of telescope can be equivalently achieved by using multi-relative small aperture of telescopes. Through updating the receiving system for laser measurement at 1.56m aperture of astronomical telescope about 50m far from 60cm SLR station in Shanghai, the demonstrated experimental system based on 1.56m/60cm dual-receiving telescopes is established to provide the platform for studying on the technology of multi-telescopes receiving laser echoes to verify the feasibility of the equivalent receiving ability produced by one large telescope.

Introduction

For SLR measurement system, one set of receiving telescope is commonly used and the receiving ability of laser ranging system is relative to the aperture of telescope. It is very helpful for receiving weak photon signals from the far and small size space targets by using large aperture of telescope which can collect the large number of laser echoes. As all know, for large aperture of telescope, the difficulty of technical development and system complexity limit its flexible applications in laser ranging system.

For cooperative space targets, the scatter of laser echoes from laser retro-reflector will be within the certain divergence angle and the patter of laser echoes will cover the some area on the ground which is relative to the divergence of reflector and distance of targets. For uncooperative space targets, due to laser diffuse reflection, the scatter of laser echoes from targets will be very widely. So if several telescopes with the independent laser echo receiving system and timing system are located nearby the laser transmitting telescope, the laser echo within the certain area on the ground can be collected at the same time. Thus the number of laser echoes for the primary measurement system will be increased when together with laser echoes from all receiving telescopes.

The multi-telescopes to receive laser echoes is put forward in order to realize the equivalent receiving ability produced by one large aperture of telescope. The demonstrated experimental system based on the 60cm SLR station (Site ID 7821) and 1.56m astronomical telescope in Shanghai with distance of about 50m is established to provide the platform for studying on the technology of multi-telescopes receiving laser echoes. The experiments of laser ranging to space targets with dual receiving telescopes and the laser transmitter on the 60cm SLR system were successfully performed to verify the technical feasibility.

Principle

The laser ranging link equation is the foundation of analyzing measurement ability of laser ranging system. According to laser link equation, the measuring ability of laser ranging system is proportional to the receiving area of telescope (tagged by A_r).

$$n_0 = \frac{\eta_q}{h\nu} \times \frac{E_t A_r \sigma}{4\pi\theta_t^2 R^4} \times T^2 \times T_t \times T_r \times \alpha$$

Theoretically speaking, the number of laser echoes (tagged by n_0) received by using the number of N telescopes with d in diameter can be equivalently achieved by the one telescope with the aperture of $SQRT(N) \times d$. In other words, the equivalent receiving ability produced by one large aperture of telescope can be realized through applying the multi-receiving telescopes.

For multi-receiving telescopes with the independent mount derived by respective servo systems to track the same targets, the technical advantages are 1) Better agility of system and number of receiving telescopes can be controlled(adding and cutting); 2) Robustness of system at the aspect of running and maintenance; 3) Distribution of receiving telescopes according to the measuring requirements; 4) Favorable feasibility for future technical development and application in laser measurement to space targets.

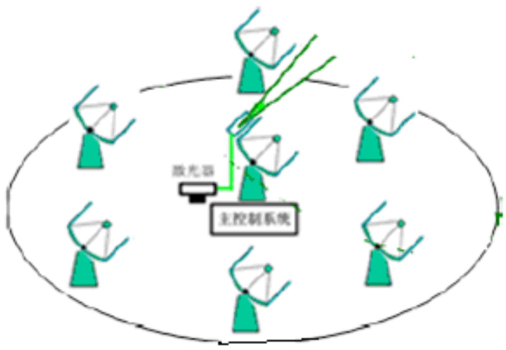

Fig.1 The multi-receiving telescopes with independent mounts to receiving laser echoes

The diameter of scatter of laser echoes on ground depends on the distance of space targets and divergence of reflector for cooperative space targets. Table 2 gives the probable diameter of scatter of laser echoes from the retro-reflector on LOW, MEO, GEO satellites and MOON.

Table 1 The probable diameter of scatter of laser echoes with the different distance and divergence

	Distance/km	Divergence of Reflector / ″	Diameter of scatter of laser echoes/ m
LEO	600-1500	18-24	< 174
MEO	19000-22000	10-12	< 1279
GEO	36000-38000	6-8	< 1473
MOON	~380000	3-4	<7369

For uncooperative space targets, the scatter of laser echoes will be more widely because of laser diffuse reflection.

The Demonstrating experimental system with two receiving telescopes

For validating the technology of laser measurement to space targets with the multi-receiving telescopes, the demonstrating experimental system based on 60cm SLR system and 1.56 astronomical telescopes at the distance of ~50m was established as the simplest form of multi-receiving telescopes. Both of them the laser transmitter is on the 60cm SLR system and the two telescopes track the same space targets to receive laser echoes. From the results in the table 1, the 60cm and 1.56m telescope will be within the scatters of laser echoes from all the cooperative space targets and can receive laser signal at the same time.

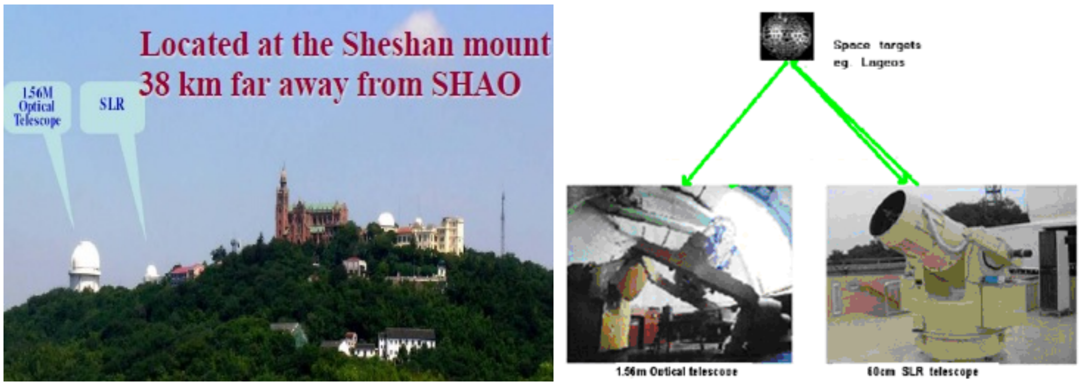

Fig.2 The setup of laser measurement to space targets by using two receiving telescopes

The main parameters of two telescopes are shown in the following table.

Table 2 The main parameters of two telescopes

1.56m Telescope	60cm Telescope
1. Optical system: R-C mode	1. Optical system: R-C mode
2. Equatorial mount	2. AZ-EL mount
3. Focus length: 15 meter	3. Focus length: 4 meter
4. Optical efficiency:70% @532nm	4. Optical efficiency:60% @532nm
5. Tracking performance: <3″	5. Tracking performace: <1″
	6. Aperture of laser transmitting telescope: 21cm

The primary mission of 1.56m astronomical telescopes is not dedicated to laser measurement. For establishing the experimental system, some improvements for 1.56m telescope have been performed, such as laser echoes receiving terminal, laser measurement control system, data communications network link and so on.The 60cm SLR system is as the primary terminal to control the 1.56m telescope measurement system. The laser echoes received by the detector on 1.56m telescope are tagged by its timing system and sent to the 60cm SLR system through network link for real-time data processing.

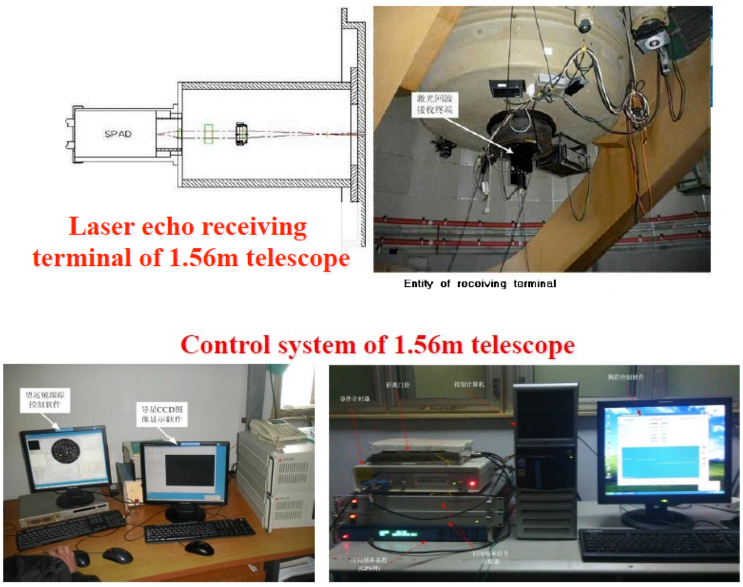

Fig.3 The improvement for 1.56m telescope system for SLR

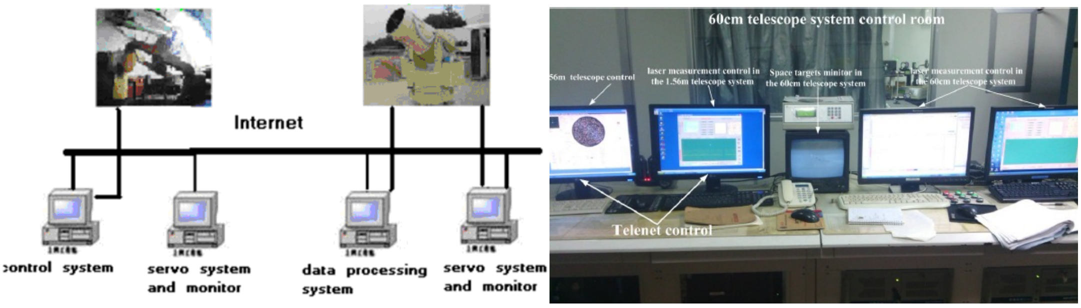

Fig.4 The data communication through network link between 1.56m telescope and 60cm telescope

Laser measurement results from two receiving telescopes and data analyses

Based on the experimental system of laser measurement to space targets with 1.56/60cm receiving telescopes, laser ranging to satellites with retro-reflector were successfully carried out from December of 2013 to January of 2014. The 1 kHz repetition rate laser signals with the pulse energy of ~1mJ is emitted from the 21cm aperture of telescope at the 60cm SLR system and 1.56m/60cm aperture of telescope track the same satellite and receive laser echoes by using respective photon detector.

Several passes of laser data from different satellites at the orbit altitude of 6000km to 36000km were obtained acquired for 1.56m/60cm aperture of telescope. Fig.5 shows the laser echoes from Glonass and Lageos satellites at the 1.56m aperture of telescope and the data post-process with the laser start pulse recorded by timer at the 60cm SLR system and table 3 gives the list of measured data by 1.56m aperture of telescope.

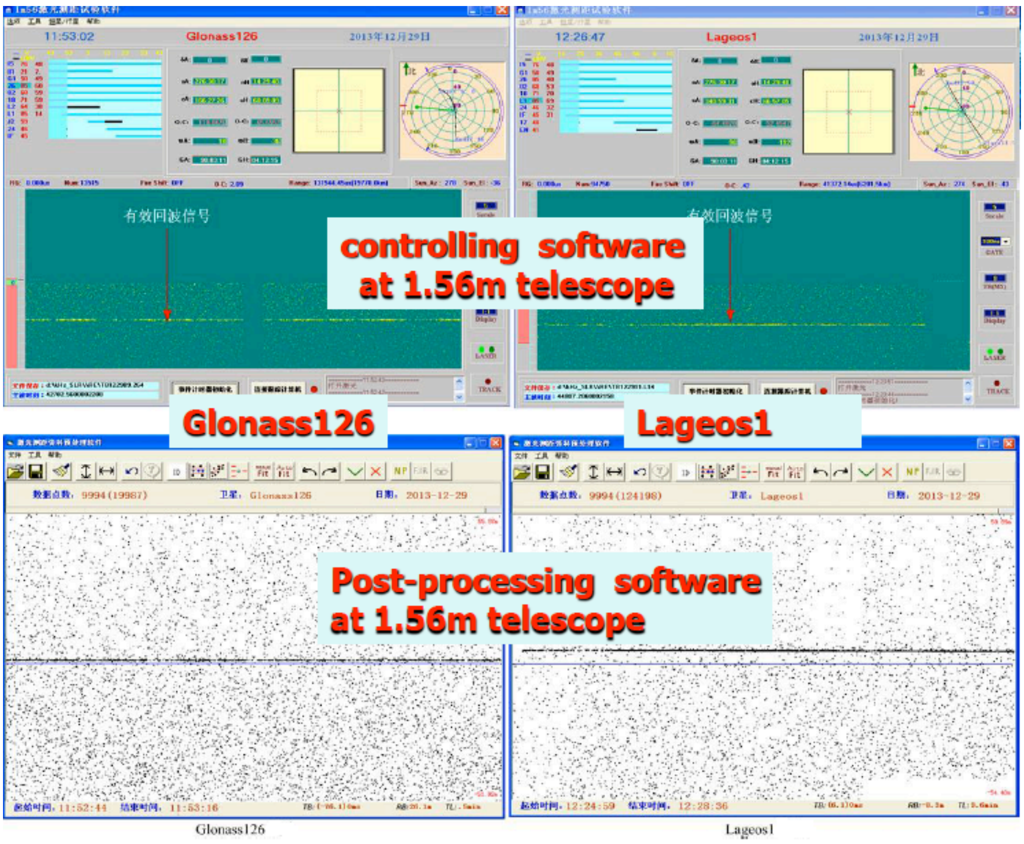

Fig.5 The laser echoes from Glonass and Lageos satellites received by 1.56m telescope

Table 3 the laser measurement to satellite by 1.56m aperture of telescope

NO	Date	Start time (UTC)	Arc length /min	Returns	precision /mm	Satellite Name	Altitude/km
1	2013-12-29	12:25:39	2.9	48663	18.5	Lageos1	6000
2	2013-12-29	12:58:59	1.4	3516	16.7	Compassg1	36000
3	2013-12-29	12:39:49	4.9	18616	28.3	Glonass102	20000
4	2013-12-29	11:48:10	5.3	8957	23.7	Glonass126	20000
5	2013-12-31	12:18:37	3.3	8235	17.8	Glonass129	20000
6	2013-12-31	12:57:24	6.3	49197	18.6	Lageos1	6000
7	2013-12-31	12:05:11	4.7	49529	20.0	Lageos2	6000
8	2014-01-02	11:50:16	4.2	5942	21.4	Lageos2	6000
9	2014-01-06	13:55:44	27.2	21772	29.7	Glonass124	20000

For comparison of laser echoes between 1.56m telescopes and 60cm telescope, one pass of laser data from Glonass124 on January 6, 2014 are selected and analyzed. The statistic of laser echoes per 20 seconds for 60cm telescope and 1.56m/60cm dual telescopes is performed and the results can be seen from Fig.6. It is shown that the number of laser echoes from 1.56m/60cm dual telescopes is higher several times than that from 60cm telescope, and it can be equivalent to the single telescope with aperture of 1.67m. Due to scatter of noise data and regular distribution of laser echoes as the number of laser echoes per second is increased, the ability of identification of laser signal is also enhanced. That will help to observe the targets with the weak laser signal. If more telescopes are applied to receive laser echoes at the same time, the number of laser echoes per second will be increased more. Through this way, the receiving ability produced by one large aperture of telescope can be equivalently realized by using multi-receiving telescopes.

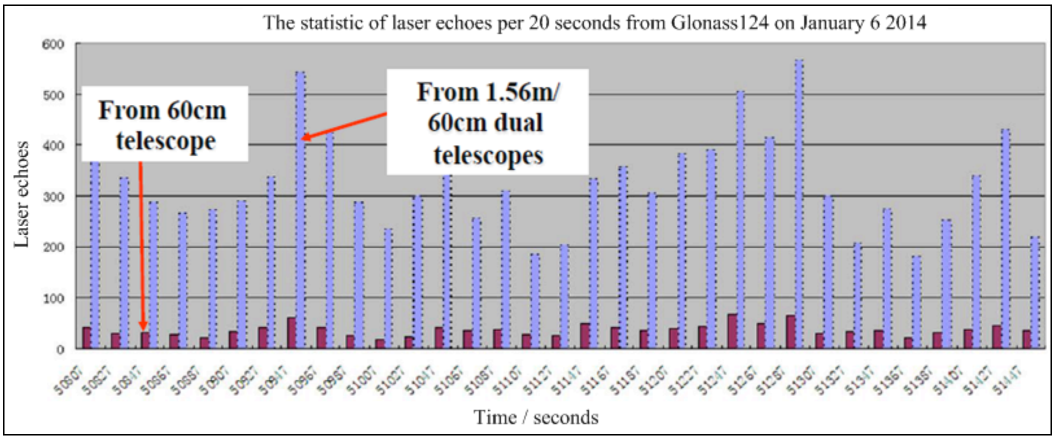

Fig. 6 The statistic of laser echoes per 20 seconds by 60m telescope and 1.56m/60cm telescopes

Based on the laser measurement to uncooperative space targets, through updating the performance of tracking servo system at 1.56m telescope, the preliminary experiments of receiving laser echoes from uncooperative targets have been performed in 2014. Further laser ranging to uncooperative targets at the 1.56m telescope to receive laser echoes is underway in order to observe the far and small size of space targets.

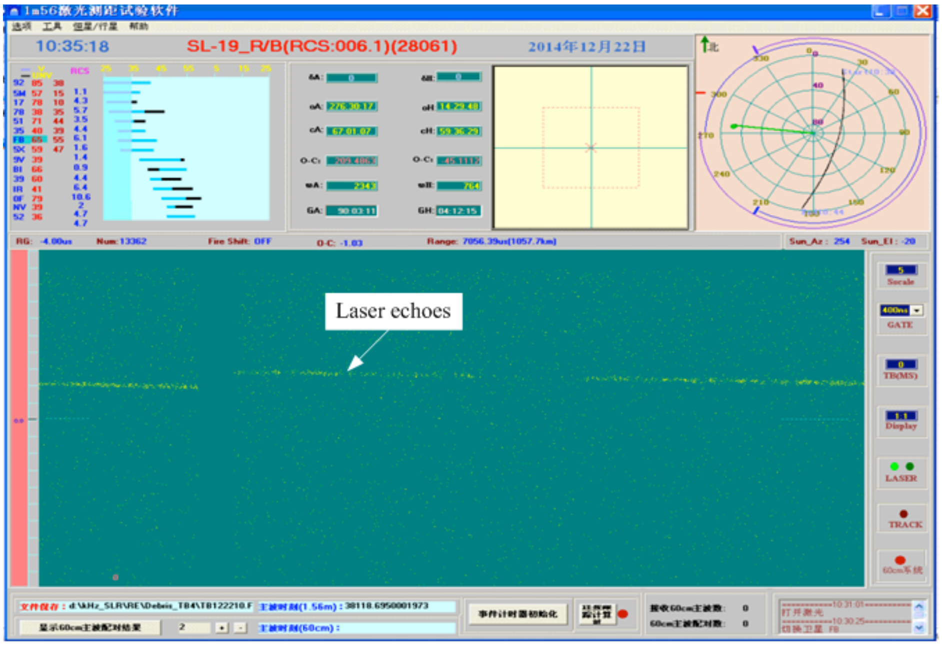

Fig.7 The laser echoes from uncooperative space targets at 1.56m aperture of telescope

Conclusion

For SLR measurement system, the number of received laser echoes is proportional to the receiving area of telescope and the difficulties of development, high cost and system maintenance for one large aperture of telescope limit the widely application in field of laser measurement to space targets. Multi-relative small receiving telescopes to receive laser echoes is put forward to improve detection capability of laser ranging to space targets produced by one large aperture of telescope. Demonstrating experimental system with 1.56/60cm dual-receiving telescope is established at Shanghai SLR station to assess the technical feasibility. The laser measurement results validate the effect of laser measuring system to increase the ability of laser echoes detection. It is expected to be the effective way to improve the ability of laser ranging to space targets with weak laser signals. The preliminary experiments of receiving laser echoes from uncooperative space targets at 1.56m aperture of telescope have been successfully performed and further research on observing far and small size of space targets is underway through applying the multi-receiving telescopes.

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