

Research on Technology of 1064nm SLR and Preliminary Measurement Experiment

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Abstract

The laser system with well performances of large pulse energy, high power, and beam quality is indispensable to perform laser measurement to uncooperative space targets especially for far distance and small size targets. Laser signal of 1064nm wavelength has advantages over 532nm wavelength because of its good performances at the aspects of laser power, number of laser echoes, less atmospheric attenuation and it will produce the technical advantages on the observation to uncooperative space targets. The researches on 1064nm wavelength laser ranging technology are performed and the relevant key techniques for building up the 1064nm wavelength SLR system are also put forward. Through upgrading the transmitting-receiving optical path for 1064nm laser signal on the aperture of 60cm SLR system, the preliminary laser measurement experiments to several ILRS satellites with 1064nm wavelength are successfully implemented to validate the technical feasibility and give supports for establishing laser ranging system with 1064nm wavelength, exploring the new laser ranging technology and promoting the technique development of laser measurement to uncooperative space target in future.

Introduction

Satellite Laser Ranging (SLR) is one kind of measuring technology famous for its high precision by recording the round trip time of flight of short laser pulses from satellite to ground station. Currently the laser system with wavelength of 532nm derived from fundamental wavelength of 1064nm through SHG is commonly used in the global laser measurement campaign. Comparison with laser signal with the wavelength of 532nm, laser system working at the frequency of 1064nm has several technological advantages as following:

- 1) Higher power
- 2) Less atmospheric attenuation
- 3) Double number of photons per pulse energy

All these characteristics above are beneficial for laser echo detection and also important factors for increasing the ability of SLR measurement system.

However, some techniques should be investigated in the actual laser measurement with 1064nm wavelength, such as:

- 1) Invisibility light for eyes, complication and danger while adjusting the optical system
- 2) Application of 1064nm laser signal detectors with single photons.
- 3) Weaker backscattering than 532nm light to cause the difficulty of monitoring laser beam for guiding and adjustment of divergence.

Based on the existed 532nm wavelength SLR system, researches on the technology of 1064nm

wavelength SLR and preliminary laser measurement to satellites have been performed to develop this technology.

Methods

Some essential modifications had been made on the aperture of 60cm SLR system with 532nm wavelength. After updating laser measurement system, it could work at the both 532nm and 1064nm wavelength laser signal.

1) Recoating primary and secondary mirror

The primary and secondary mirrors in the 60cm telescope were recoated with the high reflectivity at the both 1064nm and 532nm in order to receive 532nm and 1064nm laser signal. Figure 1 shows the installation and adjustment of the primary and secondary mirrors after recoating.



Fig.1 Installation of the recoated primary and secondary mirror

Figure 2 gives the reflectivity of the recoated primary and secondary mirror. The reflective efficiency for 1064nm wavelength light is $>85\%$ and $>95\%$ for 532nm. The other related mirror in the receiving terminal and COUDE optical system are also recoated with the same characteristics. Those performances of optical system meet the requirements of 1064nm SLR experiments while 532nm SLR measurement could also be implemented.

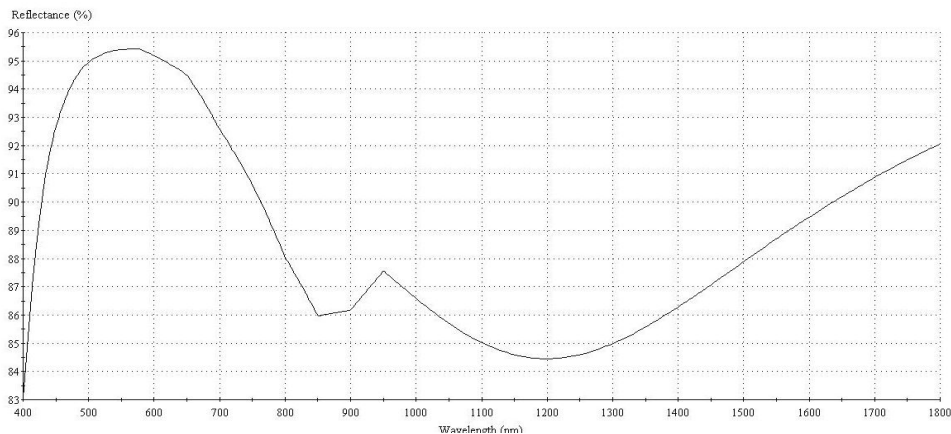


Fig.2. The reflectivity curve of the recoated primary and secondary mirror

2) The way of 1064nm laser beam aiming to satellites

For 532nm SLR measurement, the laser beam aiming to satellites can be performed through monitoring laser backscattering signal from sky by CCD with the wavelength of 450-900nm. However, 1064nm wavelength laser with less strength of backscattering is too hard to be observed because of low laser power in the experimental system. The method of 1064nm laser signal transmitted paralleled with 532nm laser is used for guiding 1064nm laser beam to aim to satellites

through monitor 532nm wavelength light. Firstly 532nm and 1064nm light are emitted from the two independent lasers and then they are coupled into the same transmitting optical path with high parallelism. The principle of superposition of both 532nm and 1064nm light is shown in Figure 3 and 532nm/1064nm laser signal were well parallel to almost several arc seconds through COUDE optical path.

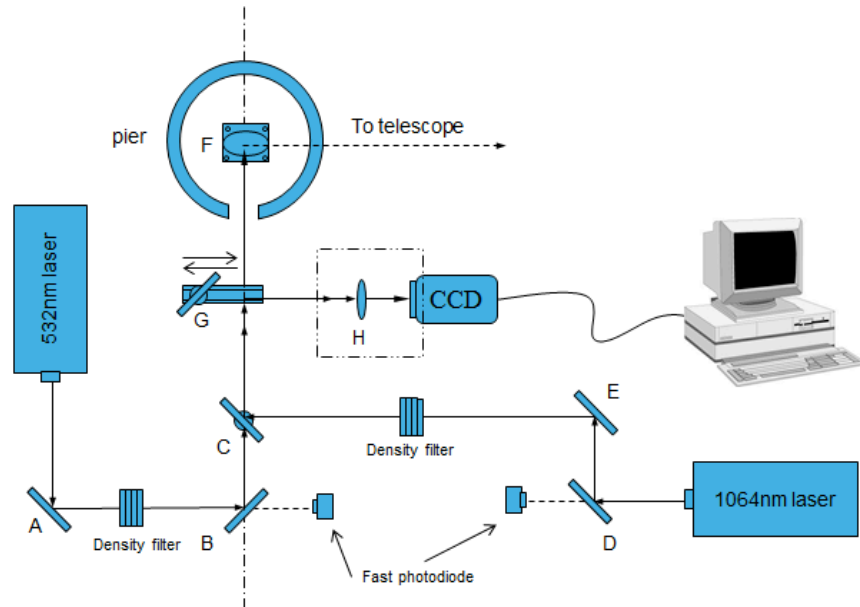


Fig.3. The principle of adjustment of parallelism of 532nm/1064nm laser

To adjust divergence angle of 1064nm laser beam, the method of utilizing the hartman mask in front of laser transmitting telescope to generate far field diffraction pattern is used to minimize the divergence by comparing the distance of different far field pattern to the corresponding holes in hartman mask. When the distance between different patterns and corresponding different holes is near, the divergence angle of laser beam can be considered to be optimized. The method has been tested by using 532nm light and verified its feasibility.

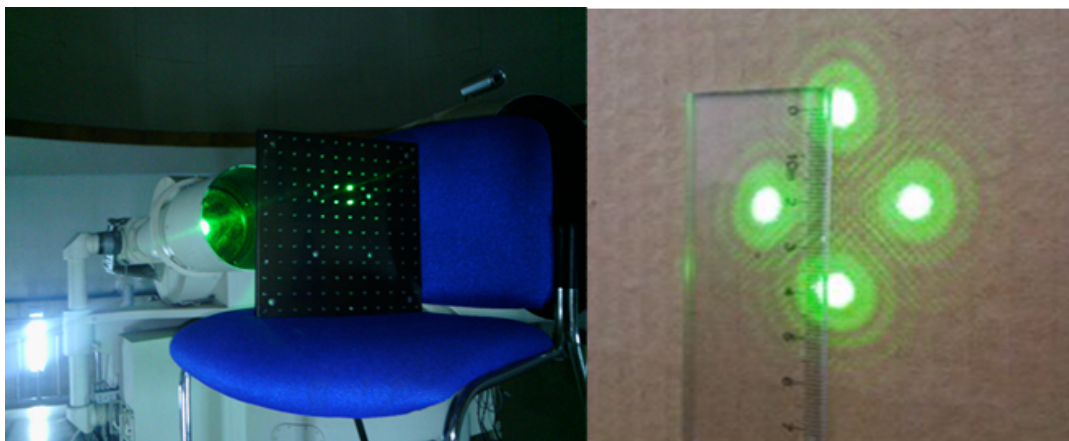


Fig.4. The 532nm laser far field diffraction pattern from hartman mask

3) Laser echo detector

A set of laser echo detector, Silicon Avalanche Photo Diode (Si-APD) with the quantum efficiency of about 3% at 1064nm wavelength was applied in the measuring experiments. And an InGaAs-APD detector with 20% efficiency is under construction and will be used in the future.



Fig.5.The Si- APD detector for detecting laser echoes

Measuring Experiments

Through updating the 60cm SLR measurement system, two laser systems are used, one for producing 1064nm light and another one for guiding 1064nm light by output 532nm light. The main parameters of 1064nm laser system are as following:

- 1) Wavelength: 1064nm
- 2) Power: 1.2W
- 3) Repetition rate: 1 kHz
- 4) Pulse width: 40~60ps

After that, measuring experiments of 1064nm wavelength to range satellites were successfully carried out, several LEO satellites (GraceA, GraceB, Jason2, etc) measured on February 22, 2014. And the measuring precision of laser data is less than 5cm, lower than that of 532nm because of precision of laser detector.

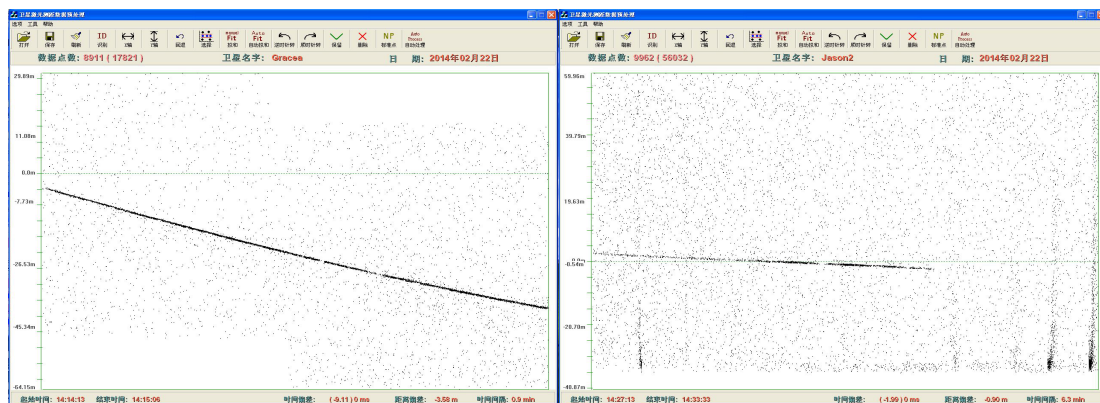


Fig.6 Range residual from Graceb and Jason2 satellites with 1064nm laser signal

Due to low efficiency of laser detector and larger divergence angle of laser signal, the success rate of laser measurement to satellites is not high and the advantages of 1064nm SLR technology do not also appears while applied in SLR measurement. It can be foreseen that after application of InGaA- APD with higher quantum efficiency and some improvements of measuring system, the

great incensement on the number of laser echoes and technical advantages of 1064nm SLR system will be made in the future.

Summary

The advantages of 1064nm wavelength laser signal are over than that of 532nm light. Based on the aperture of 60cm SLR telescope and updating system, the researches on 1064nm SLR technology and preliminary experiments have been performed and the techniques for implementing 1064nm SLR measurement are also verified. Considering the insufficiency of the current experiment system with 1064nm wavelength, more tests should be implemented and higher QE detector should be used in the laser echo detecting system. The further improvements of SLR system should also be performed to further develop 1064nm wavelength SLR technology, and make it to be beneficial to laser tracking of space debris with the requirements of high power laser system and even interplanetary laser ranging with the high performances of laser system in space.

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