Preliminary Results of Laser Ranging to Un-cooperative Targets at Shanghai SLR Station

Yang Fumin (1)**, Zhang Zhongping** (1)**, Chen Juping** (1)**,**
Chen Wanzhen (1)**, Wu Zhibo** (1)**, Zhang Haifeng** (1)**, Ivan Prochazka** (2)

(1) Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
(2) Czech Technical University in Prague, Czech Republic

yangfm@shao.ac.cn /Fax: +86-21-64696290

Abstract

The laser returns from the un-cooperative targets have been obtained at the Shanghai SLR station in July 2008. These targets are the discarded Soviet and US rockets with the ID 1987-38B and 2007-006G respectively. The return signals from the targets with the range of 900 km were quite strong. The performance of the laser used for the experiment was introduced on the Canberra Workshop in 2006.

Introduction

The specification of the experimental laser ranging system for un-cooperative targets at the Shanghai station was introduced on the Laser Ranging Workshop in Canberra in 2006[1] . The major goal of the system is to develop the key techniques for laser ranging to un-cooperative targets. After some testing and upgrading, we have obtained some laser returns from the discarded Soviet and US rockets in July 2008 respectively. The preliminary results and analysis are given in the paper.

Performance of the laser ranging system

The high power laser used for the experiment was built by the North China Research Institute of Electro-Optics (NCRIEO) in Beijing. The output of the laser is as follows: 2J in 532 nm, 10ns pulse width, 0.6 mrad divergence, 20Hz repetition rate, 40W mean power in green. Fig. 1 shows the block diagram of the 40W Nd:YAG laser.

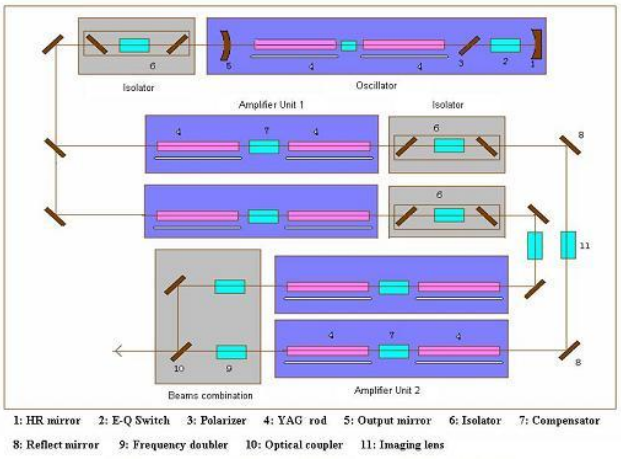

Figure 1. Diagram of the 40W laser (2J in 532nm, 20Hz)

There are 10 Nd:YAG rods in total in the laser system. The output of the oscillator which two rod are inside is divided into two beams, and then go to the amplifier unit 1 and the amplifier unit 2 in turn. The output from the amplifier unit 2 passes the frequency doublers, and then combine into on beam for ranging. Fig. 2 shows the photo of the laser. Fig. 3 shows the inner view of the laser. Fig. 4 shows the laser firing through the new 210mm aperture transmitter to the sky.

Figure 2. Photo of the laser

Figure 3. Inner view of the laser

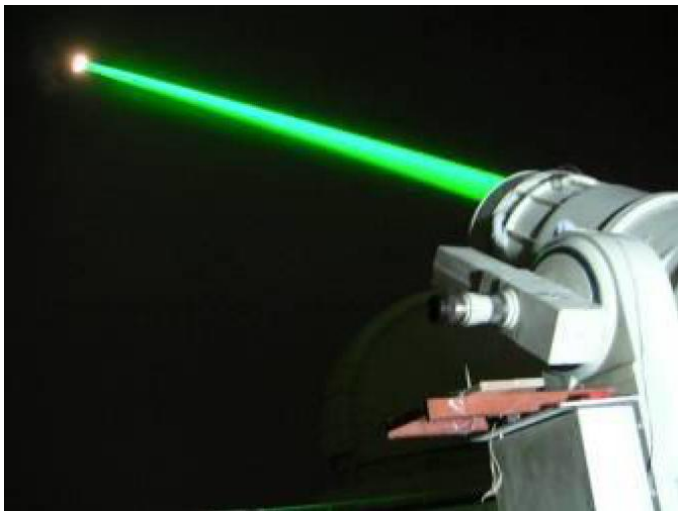

Figure 4. Laser firing

The C-SPAD detector and the Riga event timer were used for the experiment.
The returned signal strength expected from a 2-meter diameter target located 800 km away can be estimated by the following equation:

$$n_0 = \frac{\lambda \eta_q}{hc} \times \frac{E_t A_r \rho S \cos(\theta)}{\pi \theta_t^2 R^4} \times T^2 \times K_t \times K_r \times \alpha$$

Where

- n_0: Average number of photoelectrons received by detector
- λ: Wavelength of laser, 532nm
- η_q: Quantum efficiency of the detector, 0.2

h: Planck constant, 6.624×10^{-34} J·s
c: Light speed, 2.998×10^{8} m/s
E_t: Energy of laser pulse, 2J
Ar: Effective area of receive telescope, 0.245m^2
ρ: Reflectivity of the target's surface, 0.16
r: Equivalent radius of the target, 1m
cos(θ):Suppose the targets are spherical, cos(θ)=1
θ_t: Divergence of laser beam from telescope, 12 arcsec
R: Range of the targets, 800km
T: Atmospheric transmission, T^2=0.6
Kt: Eff. of transmitting optics, 0.60
Kr: Eff. of receiving optics, 0.60
α: Attenuation factor, 13dB

We have,

$$n_0 = 0.20 \text{ (Photoelectrons)}$$

The probability of detection by the C-SPAD detector with single photon sensitivity can be estimated by

$$P = 1 - e^{-n_0} = 1 - e^{-0.20} = 0.18$$

So we might get 18 returns in 5 seconds with the 20 Hz laser.

Preliminary Observational Results from the Un-cooperative Targets at Shanghai

After the installation of the new laser, we built the control and ranging interfaces and software for the experiment. Because the weather problem in Shanghai and some problems with the laser power supply, until July 2008, we have obtained some laser returns from the un-cooperative targets which are the discarded Soviet and US rockets with the ID 1987-38B (639×611 km) and 2007-006G (541×499 km) respectively. The residuals (O-C) for three passes are shown in Fig. 5-7, and the range variations for each pass are shown in Fig. 8-10. The maximum range obtained is 936 km.
Fig. 11 shows the statistics of the laser returns in 5 seconds bin from the ID 1987-38B on July 7, 2008. It is shown that 10-14 returns in 5 seconds were obtained when the telescope tracking were well, and it is roughly coincide with the estimation of the returned signal strength.

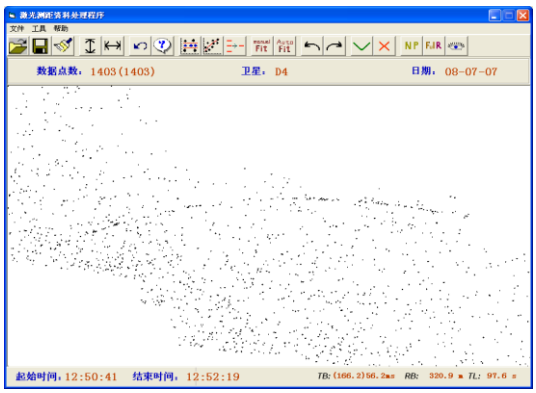

Figure 5. Returns from the discarded Soviet rocket (ID 1987-38B) on July 7, 2008

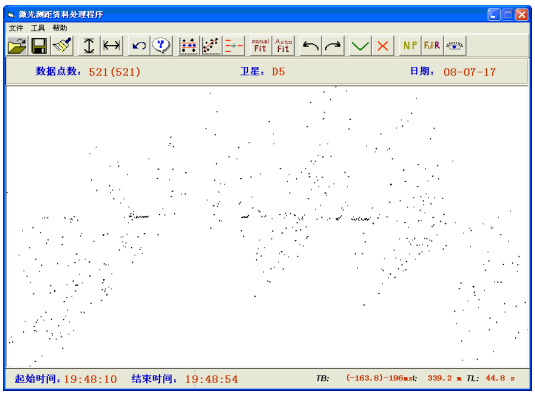

Figure 6. Returns from the discarded US rocket (ID 2007-006G) on July 17, 2008

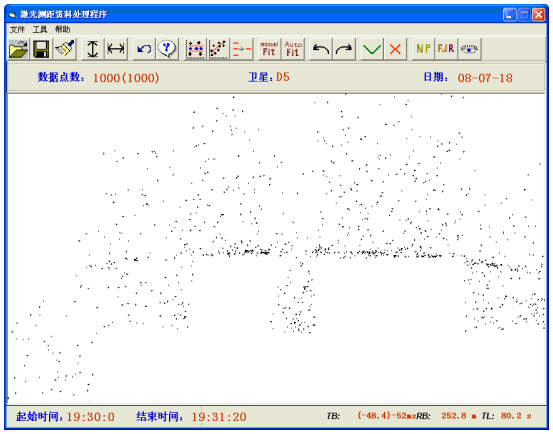

Figure 7. Returns from the discarded US rocket (ID 2007-006G) on July 18, 2008

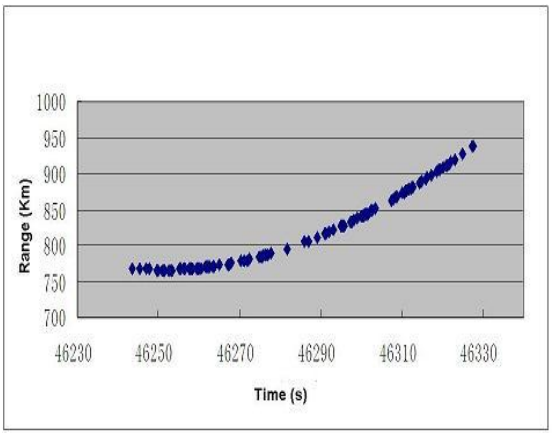

Figure 8. Ranging data of ID 1987-38B on July 7, 2008

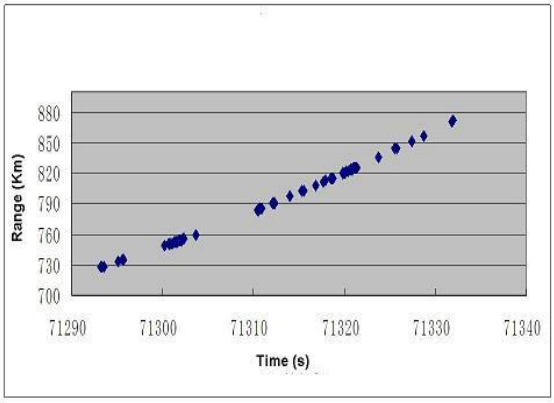

Figure 9. Ranging data of ID 2007-006G on July 17, 2008

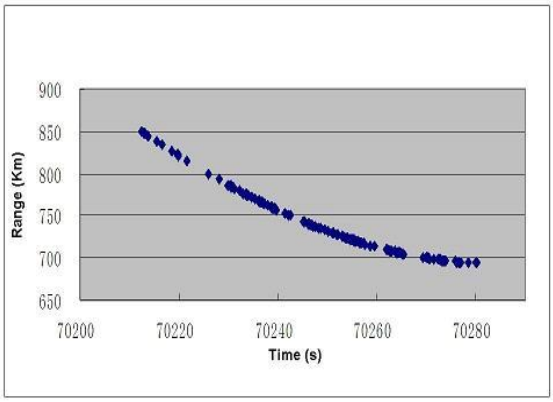

Figure 10. Ranging data of ID 2007-006G on July 18, 2008

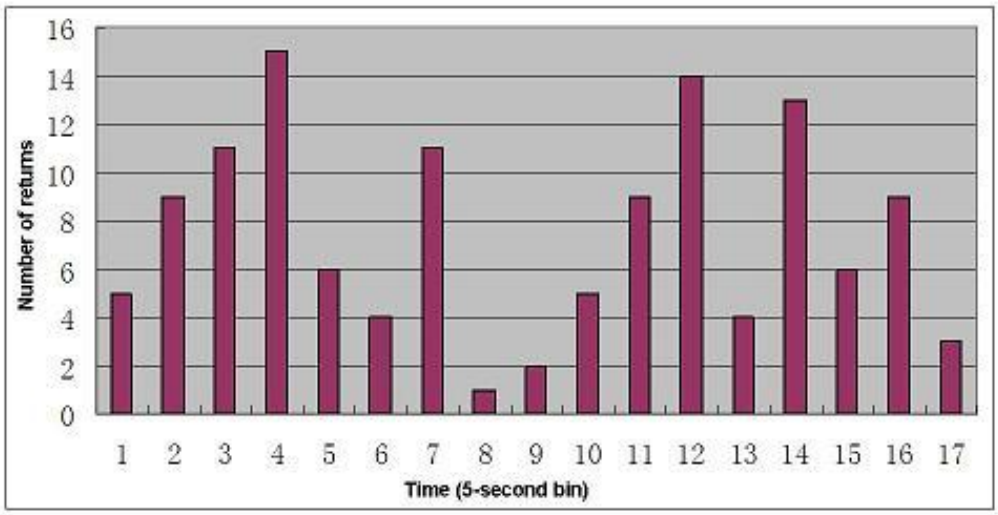

Figure 11. Statistics of returns (5-second bin) on July 7, 2008

Summary

The laser returns from the un-cooperative targets have been obtained at the Shanghai SLR station in July 2008. These targets are the discarded Soviet and US rockets with the ID 1987-38B and 2007-006G respectively. It is shown from the experiment that the return signals from the targets with the range of 900 km were quite strong. Further experiment for more distant and smaller targets is under way.

References

[1] Yang Fumin, Chen Wanzhen, Zhang Zhongping, Chen Juping, Wang Yuanming, K. Hamal, I. Prochazka, The Experimental Laser Ranging System for Space Debris at Shanghai, Proceedings of the 15th International Workshop on Laser Ranging, Volume 2, p.473—478, Canberra, Australia , 2006.