Time synchronization for Multi-static Laser Ranging via Fiber-based Time and Frequency Transfer

Zhang Haifeng, Long Mingliang, Deng Huarong, Li Pu, Zhang Zhongping
Shanghai Astronomical Observatory of Chinese Academy of Sciences
Email: hfzhang@shao.ac.cn

No.13

IWLR2018, 5-9 November, John Curtin School of Medical Research, Canberra, Australia

Abstract

Laser echoes can be obviously increased through using multi-telescopes passively receiving the signal while one active station transmits laser, called multi-static laser ranging. The precision of time and frequency synchronization will directly cause the error of laser data for the multi telescopes to detect and record the laser echo signal. Frequency synchronization for multi-telescopes laser ranging is described based on fiber-optic time-frequency transfer. **The performance of fiber-optic time-frequency transfer is measured with the the precision of 62ps and the linear slope of 4ps/day**. The experiments of laser ranging to satellites are performed by establishing the fiber-based time and frequency transfer link for dual-telescopes receiving echo signal. **Comparison of the measured range with the calculated ones from the precise orbit, the error of range data measured by the passively receiving telescope is less than 6cm**, meeting the requirements of satellite orbit determination with the decimeter-level laser ranging to space debris. It is indicated that the feasibility of the fiber-optic time-frequency transfer link are verified in the multi-static telescopes laser ranging.

1. Introduction

SLR has been widely used in the field of Satellite orbit determination, Global Earth Reference Framework, Realization of high-precision time transfer. The types of the tracking targets extend from reflector-targets to non-cooperative targets (diffusely reflections). The laser echo signal from space targets will cover the wide area on ground and so if the multiple telescopes are arranged in this area, the receiving and timing laser echo signal can be simultaneously performed by multi-receiving telescopes. Thus, the number of received laser echoes will be increased significantly and it can be equal to realizing the reception of laser echo signals by the large-aperture of receiving telescope.

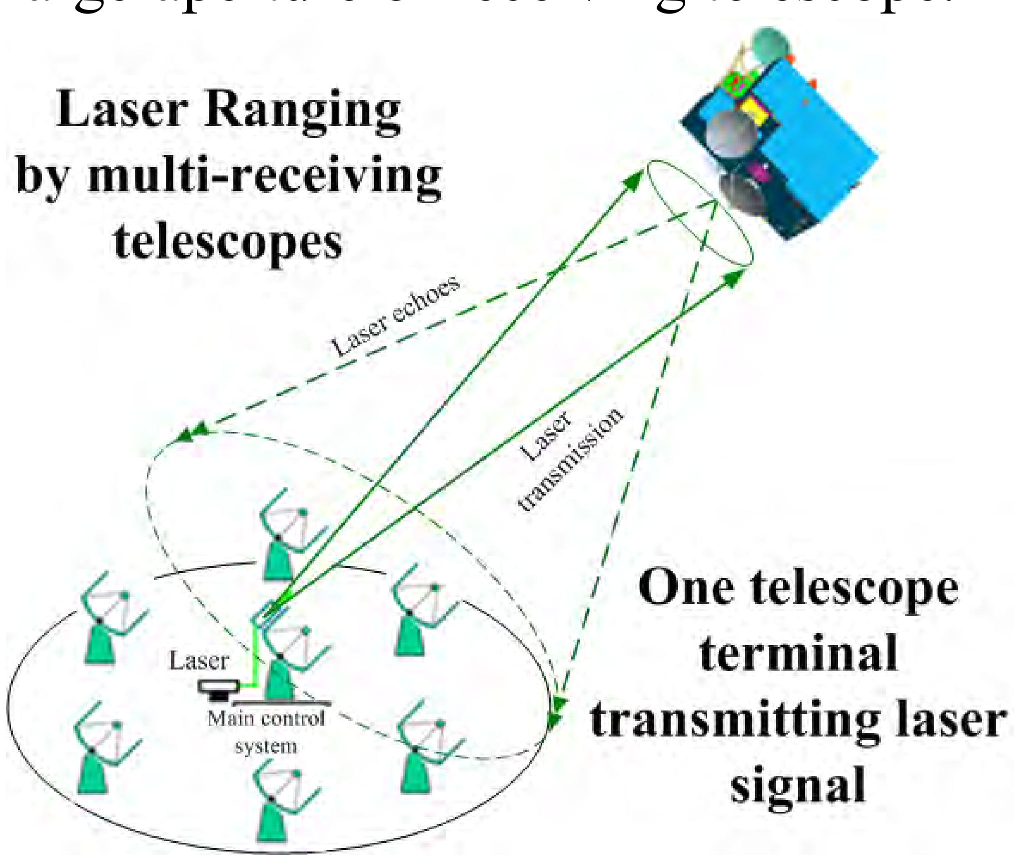

Fig.1 The one telescope terminal transmitting and multiple telescopes receiving laser signal

Time synchronization among the telescopes will cause the range bias for the receiving telescopes.

2. Time synchronization method based on fiber time frequency transmission

A high precise fiber-based time and frequency dissemination technology have been considered to be an alternative choice of global position system (GPS) method with the characteristic of fast developments. One set of fiber optic time-frequency transmission link system is established at the Shanghai Astronomical Observatory.

The principle of the fiber-based time and frequency transfer link is given in the Figure 2. The left one is the local terminal and right one is the remote terminal. The two-way transmission of a 1 GHz sinusoidal signal is implemented via a single-fiber cable and the optical transfer link delay can be adjusted according to the phase change between the local 1 GHz signal and the remote returned 1 GHz signal. The local 1PPS and 10MHz signal are modulated onto the 1 GHz signal by the local terminal to transmit to the remote terminal in the same optical fiber. Based on this way, the delay of the 1PPS and 10MHz signal transmission link will be relatively stable. The remote terminal will give the demodulation of 1 GHz signal to produce 1PPS and 10MHz signal.

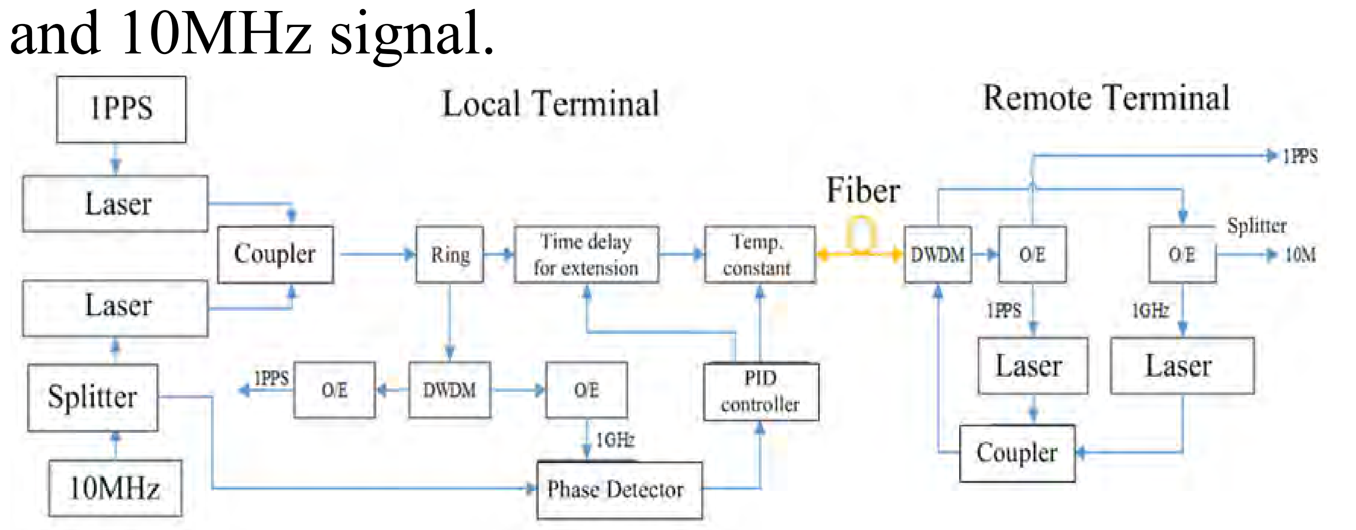

Fig.2 The principle of fiber-optic time-frequency transfer

Figure 2 shows the stability of optical fiber link between the local and remote terminal through the measuring the jitter of time interval of the local and remote returned 1PPS by the SR620 counter.

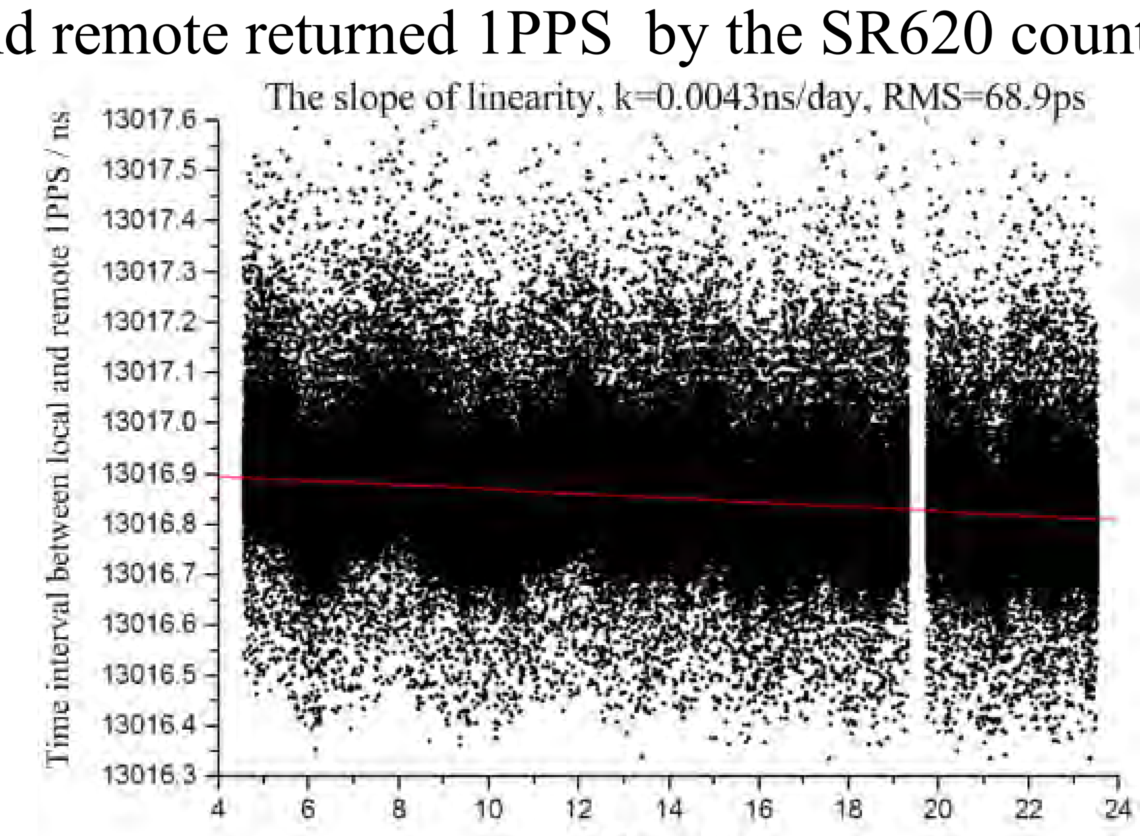

Fig.3 The stability of fiber transfer link between local terminal and remote terminal

During the test period of nearly 20 days, the slop of the change of time interval is about 4.3ps/day, and the jitter of the link delay (RMS) is 68.9ps. Due to the jitter of the measuring device (SR620, ~30ps), the fiber-based time and frequency transmission link time synchronization accuracy is about 62ps.

3. Fiber optic time-frequency transfer link applied in laser ranging with the dual-telescope systems and data analysis

The Shanghai Observatory has two optical telescopes with the aperture of 60cm and 1.56m at the distance of ~60m. Table 1 shows the main parameters of the two telescopes system.

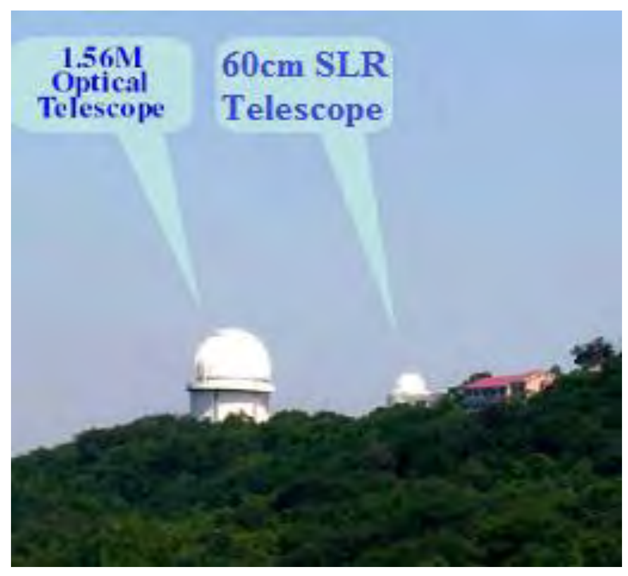

Table1 The specifications of 1.56m and 60cm optical telescopes

Items	1.56m telescope	60cm telescope
Type of receiving telescope	R-C system	R-C system
Tracking mount	Equatorial	Alt-Azimuth
Efficiency of receiving optical system	~50% @532nm	~60% @532nm
Efficiency of laser detector	C-SPAD, 20%@532nm	C-SPAD, 20%@532nm
Tracking precision (RMS)	~2″	~1″
Timing system	A033 Event Timer	A033 Event Timer
Time and Frequency source	EndRun	Symmetricom
Efficiency of laser transmitting	none	~65% @532nm
Laser system	none	1W@1kHz
Divergence of laser signal	none	8~10″

Using an independent GPS time-frequency system in the two telescopes, the error of time synchronization is tens of nanoseconds, which cannot meet the requirements of high-precision satellite ranging. One set of the fiber optic time frequency transmission link is built between the dual-telescopes system, as shown in Fig. 3. The left one (a) is the remote device in 1.56m telescope system, and the right one (b) is the local device in 60cm telescope system. The 1PPS and 10MHz signals produced by 60cm telescope system are transferred to the 1.56m telescope system to achieve the time and frequency synchronization with the error of sub-hundred picoseconds.

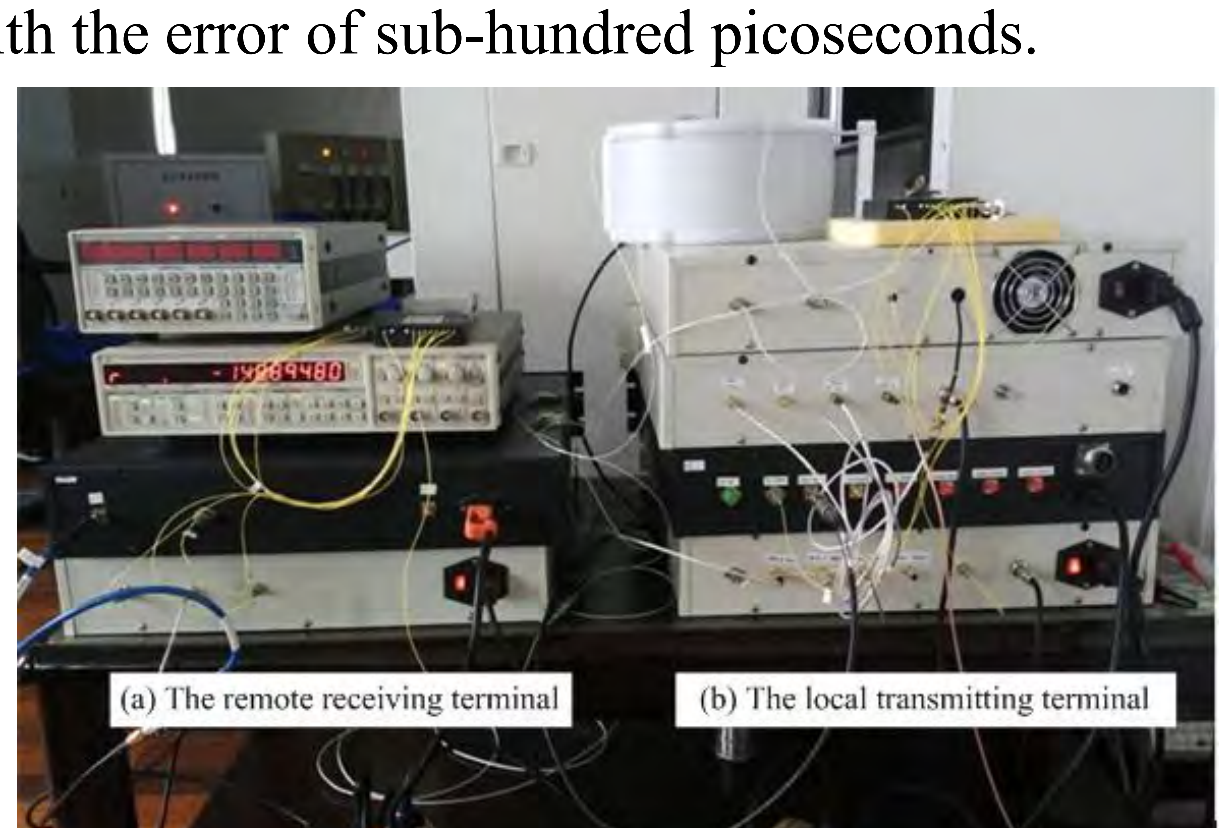

Fig.3 The device of fiber-optic time-frequency transfer

The satellites of Ajisai, Lageos2, Etalon1, Glonass, IGSO3 and IGSO5 were measured by laser transmitting in 60cm telescope system.

When tracking Glonass 128, the source of 10MHz signal in 1.56m telescope system is switched to the optical fiber transmission to the internal clock and then switched back to the optical fiber transmission. The range residual was changed significantly after using different 10MHz signal, as shown in the figure 5 (a) (b) (c). Among them, (a) and (c) are that 10MHz signal in 1.56m telescope system is from the optical fiber; (b) is from the independent GPS clock in the 1.56m telescope system.

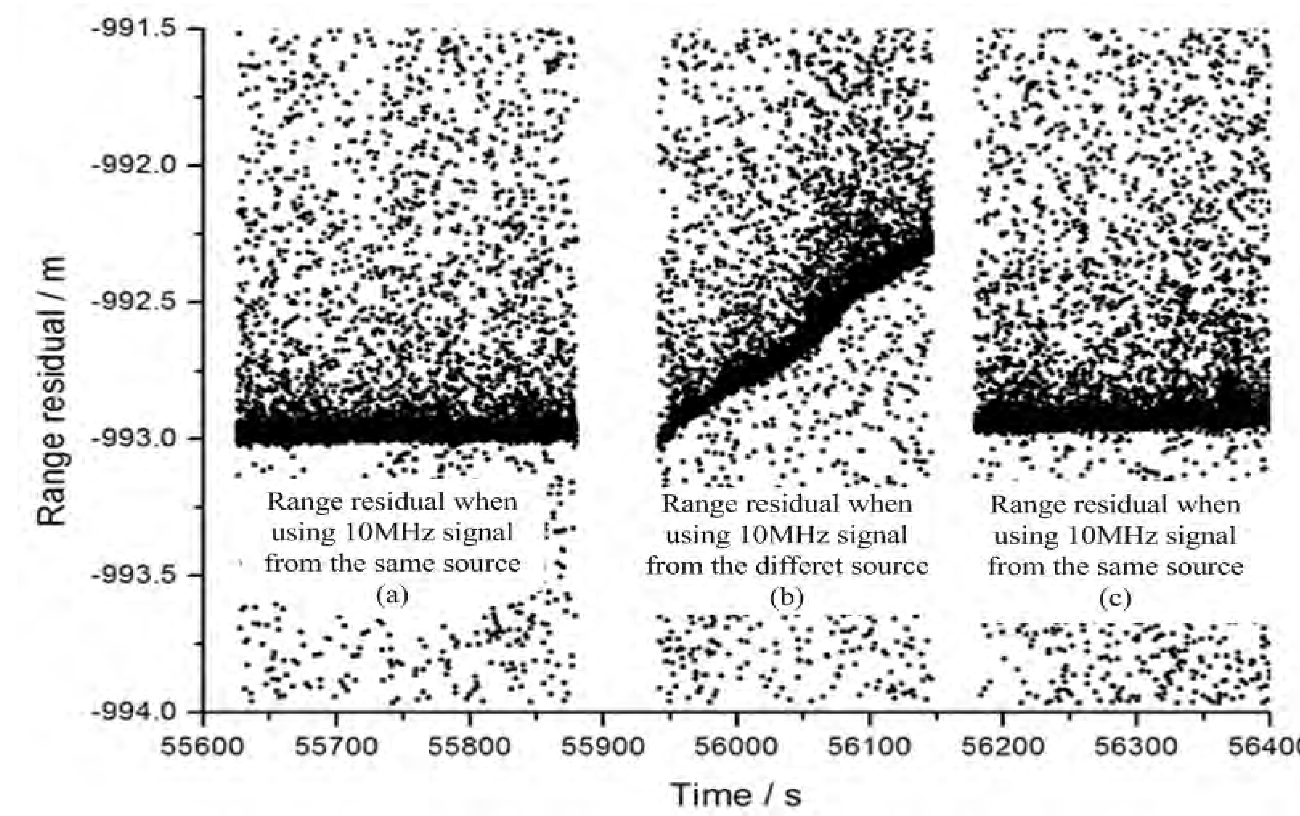

Fig.4 The range residual of Glonass128 from 1.56m telescope

Comparing the observation range after calibration with the precise orbit of satellites, the range bias of data from the 1.56m telescope was less than 6cm in figure 5, allowing for satellite orbit determination.

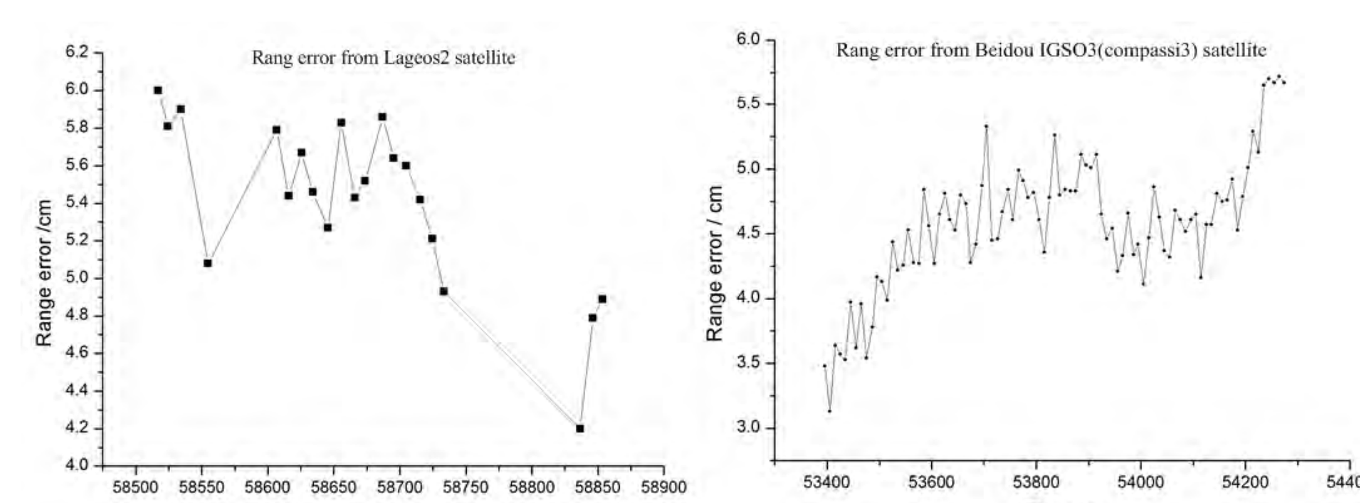

Fig.5 The range error of Lageos2 and IGSO3 satellites from 1.56m telescope system

4. Summary

A single telescope laser transmitting and dual-receiving telescopes system was built at Shanghai Observatory and the fiber optic time-frequency transfer device was applied, which the 10MHz and 1PPS produced from 60cm telescope system was transmitted to the 1.56m telescope system, enabling time and frequency synchronization of the double-telescopes measuring system.The time synchronization accuracy of the double-telescopes system is about 62ps, the changing rate of synchronization is about 4ps/day. Through the double-telescopes system for satellite measuring experiments, the range bias of data is less than 6cm.The measuring results show that the fiber time-frequency transmission is feasible in the multi-telescopes laser ranging, which play the foundation for the subsequent multi-telescope measurement systems in the application of detecting the defuse reflective laser signals from space debris.