Applications of Riga Event Timer at Shanghai SLR Station

Zhang Zhongping (1)**, Zhang Haifeng** (1)**, Yang Fumin** (1)**, Wu Zhibo** (1)**, Chen Juping** (1)**, Yu. Artyukh** (2)

(1) Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
(2) Institute of Electronics and Computer Science, Riga, Latvia

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

Abstract

The Shanghai SLR station is the first one in China which has chosen Riga Event Timer A032-ET in view of its advanced performance and reasonable price. Thereupon several LSR stations in China also began using this event timer. The paper presents the applications of A032-ET to routine SLR, high repetition rate SLR and Laser Time Transfer experiment. The advanced performance of A032-ET is also described.

Introduction

Since 2006, Shanghai SLR station commenced researching the kHz SLR. As known, the event timer is an indispensable timing device for kHz SLR. Since Riga event timers have the advanced performance and reasonable price, we have chosen one of them (the model A032-ET) for developing kHz SLR. That is for the first time used in China.

A032-ET can be easily utilized by users. Specifically, we successfully applied this Event Timer for the Routine SLR, 1KHz repetition rate SLR and Laser Time Transfer (LTT) at Shanghai SLR station. According to the applications of A032-ET at Shanghai SLR station, several SLR stations in China, such as Changchun, Beijing and so on, use the same Event Timer for kHz SLR and as advanced test equipment.

Performance of Riga Event Timer A032-ET

There are some A032-ET performance characteristics, like precision temperature stability and non-linearity, that are important for the applications at Shanghai SLR station and were not specially noted early.

RMS resolution vs. ambient-temperature

One of important parameters of Event Timer is stability of RMS resolution vs. ambient temperature. The matter is that A032-ET supports the best RMS resolution about 7-8 ps after calibration under condition that the operating temperature does not noticeably vary during following measurements. There are some test results (Bespal'ko et al., 2006) that the RMS resilution temperature stability is about 0.1 ps/^{o}C. This parameters defines ability of the A032-ET to support acceptable resolution without recalibration under time-varying operating conditions.

Effect of non-linearity

There are two basic kinds of A032-ET non-lineary: a systematic error for time-interval measurement between two adjacent events (so called interval non-linearity) and a systematic error in single event measurement over epoch time (so called integral non-linearity). Figure 1

shows the A032-ET integral non-linearity error. As can be seen, such non-linearity does not exceed 1.0 ps for greater than 100 ns time intervals.

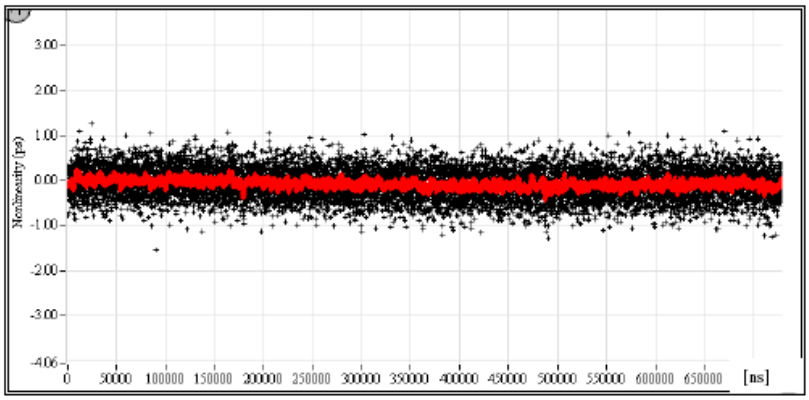

Figure 1. Interval non-linearity vs. time interval

Figure 2 and Figure 3 show the integral non-linearity over the input frequency period 100 ns (10MHz) and the internal clock period 10 ns (100MHz) respectively.

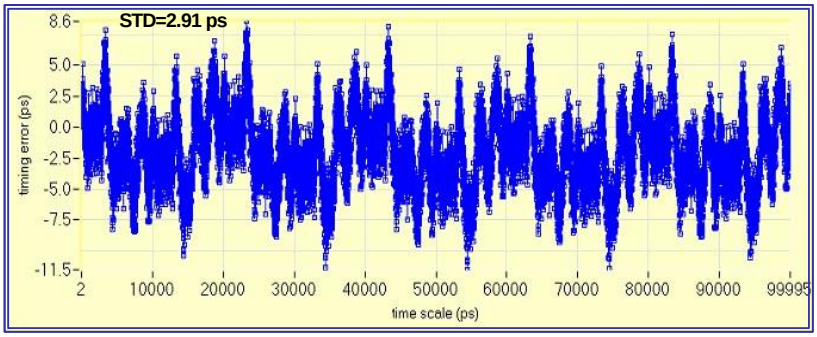

Figure 2. Integral non-linearity over input frequency period 100 ns

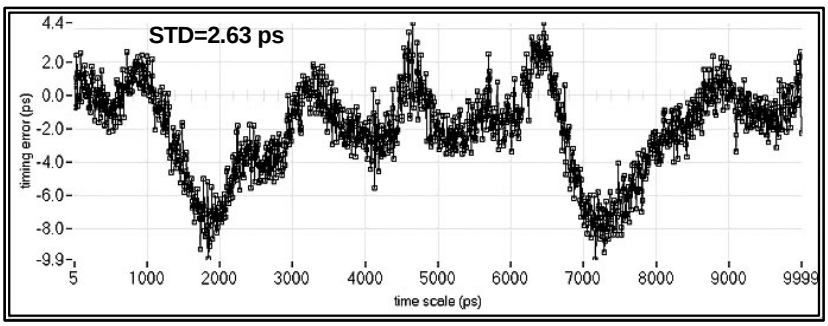

Figure 3. Integral non-linearity over internal clock period 10 ns

As can be seen in Figure 2, the maximum integral non-linearity error (peak-to-peak) does not exceed 20 ps. The non-linearity error over internal clock period is only a little less. This confirms the fact that the internal frequency multiplier (10 MHz to 100 MHz) does not add noticeable error into common integral non-linearity.

Applications at Shanghai SLR station

Routine SLR

A032-ET performs its measurement functions partly by hardware means and partly by software means. Figure 4 shows the schematic control diagram for A032-ET comprehended by us according to the principle of operating this event timer.

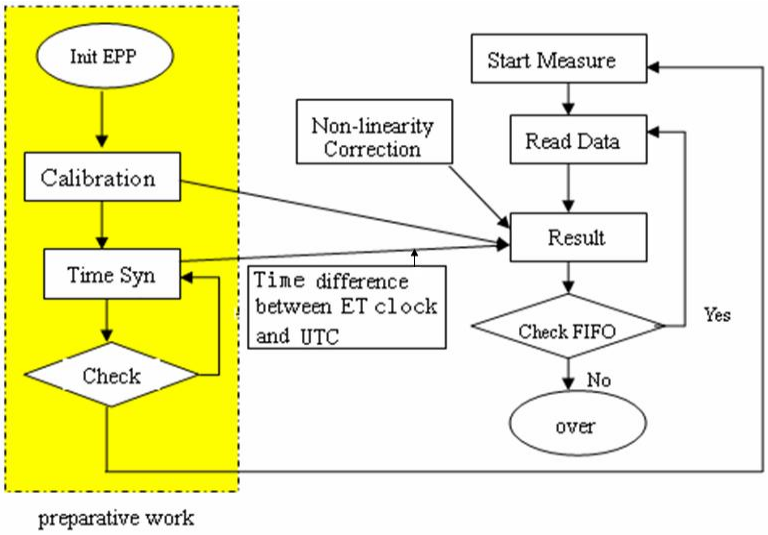

Figure 4. The schematic control diagram of A032-ET

There are two interfacing modes of measurement for users developing program.

- **TCP/IP mode.** Based on the well-known "Client/Server" network, Client (application software) connects to the A032-ET Server via TCP/IP network to receive measurement data for further processing and system control. What the users need to do is to develop own Client applications. This mode is convenient for users needing remote interaction with A032-ET. But due to the uncertain delays of network, this mode is basically fitted to low-rate data acquisition.
- **EPP mode.** In this mode the measurement data is obtained directly from the A032-ET hardware by user-made software via EPP. It is easy for users to create own timing measurement system based on library functions which defines device-specific functions to interact with A032-ET hardware. EPP mode is a way to high-rate data acquisition and avoids the uncertain delays caused by network.

In Shanghai routine SLR (10 Hz), we use TCP/IP mode to get measurement data from A032-ET. Figure 5 shows the interface of main and client applications of Shanghai routine SLR.

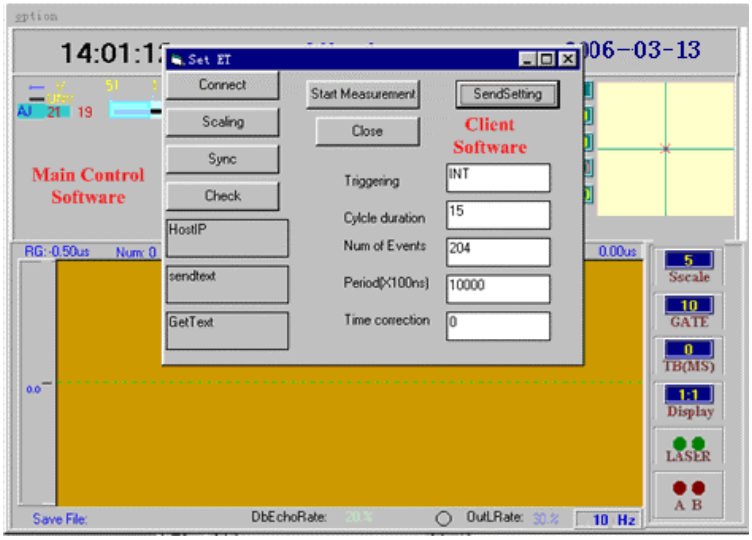

Figure 5. The interface of main and client applications

After adopting A032-ET and developing the corresponding software, Shanghai SLR station can range kinds of satellites with 10 Hz repetition rate (limitation to laser of 10Hz output rate). With the increase of ranging repetition rate, more returns and passes are got.

1 kHz repetition rate SLR

Shanghai SLR station gets the support from National Natural Science Foundation of China to research and develop the key technology of kHz SLR in 2006. Event Timer is one of the key technologies and it is a necessary timing device in kHz SLR.

Due to the huge amounts of measurement data for kHz SLR, it requires high speed of data reading (Kirchner et al, 2004). For kHz SLR, the EPP mode for A032-ET was chosen in order to make the maximum available reading speed. A032-ET has a 12000 time-tags buffer (FIFO). This is very good for data reading and allows avoiding any measurement data lost. Figure 6 is the interface of main control application at EPP mode.

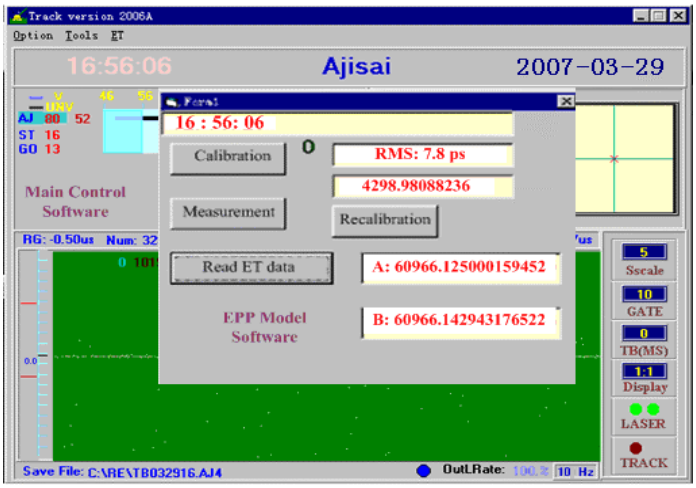

Figure 6. EPP mode for A032-ET

For Shanghai 1kHz SLR, two computers are used. One of them is to get measurement data from Event Timer, identifying start event and stop event, showing range, saving data and so on. Figure 7 is the interface of application executing the above mentioned functions.

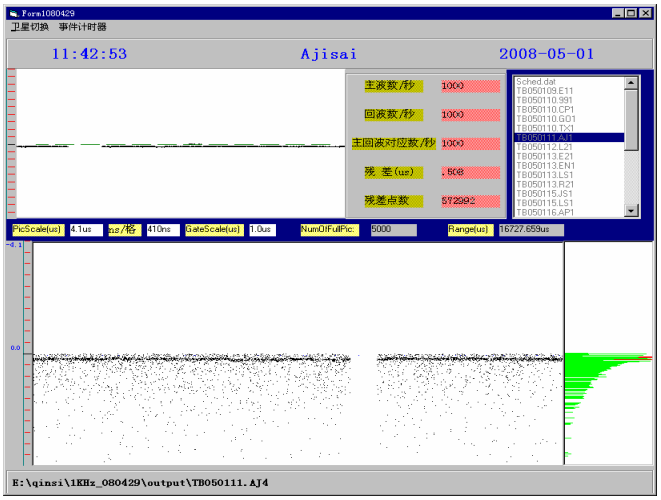

Figure 7. The real-time interface of 1 kHz SLR

Shanghai 1kHz SLR shows that EPP mode of A032-ET operation meets the demand for high speed of measurement data reading.

Laser Time Transfer (LTT)

Shanghai Astronomy Observatory carried out Laser Time Transfer in July, 2007 - March, 2008 at Changchun SLR station. The LTT payload is onboard the Chinese experimental navigation satellite, MEO orbit, altitude 21500km. The ground laser output rate is 20 Hz.

Laser Time Transfer is a high precision time measuring technology (Fumin et al., 2006). The timing precision and stability of timing device play an important role in LTT. Figure 8 is the principle of Laser Time Transfer.

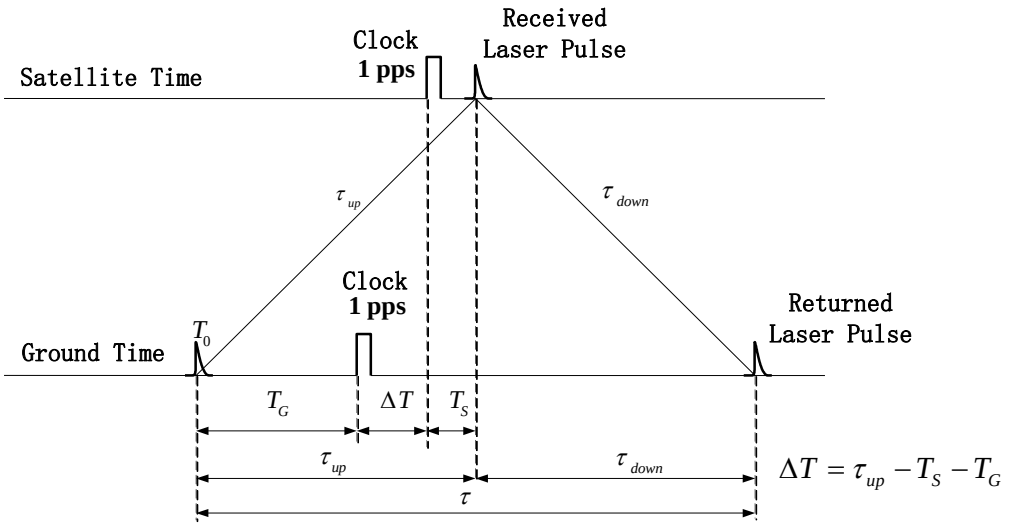

Figure 8. The principle of Laser Time Transfer, where:

ΔT - clock difference between satellite and ground clocks

T_G - time interval between the transmitting laser pulse and 1PPS of the ground clock

T_S - time interval between the received laser pulse and 1PPS of the satellite clock
τ - laser pulse flight time for ground-satellite-ground
τ_{up} - laser pulse flight time for ground-satellite
τ_{down} - laser pulse flight time for satellite-ground

For LTT experiment, two Event Timers must be used on the ground. Figure 9 shows the application of two Event Timers: Event Timer 1 and Event Timer 2. Event Timer 1 is applied to measure start and stop events for high precision SLR. Through identifying corresponding Start-and-Stop events, the laser pulse flight time for ground-satellite-ground τ is obtained. After considering the correction of the Earth rotation (Sagnac effect), the laser pulse flight time for ground-satellite τ_{up} is to be calculated. Event Timer 2 measures the time interval T_G between start event and 1PPS on the ground clock. According to the principle of LTT, the precision of measured τ_{up} and T_G directly affects that of clock difference between satellite and ground.

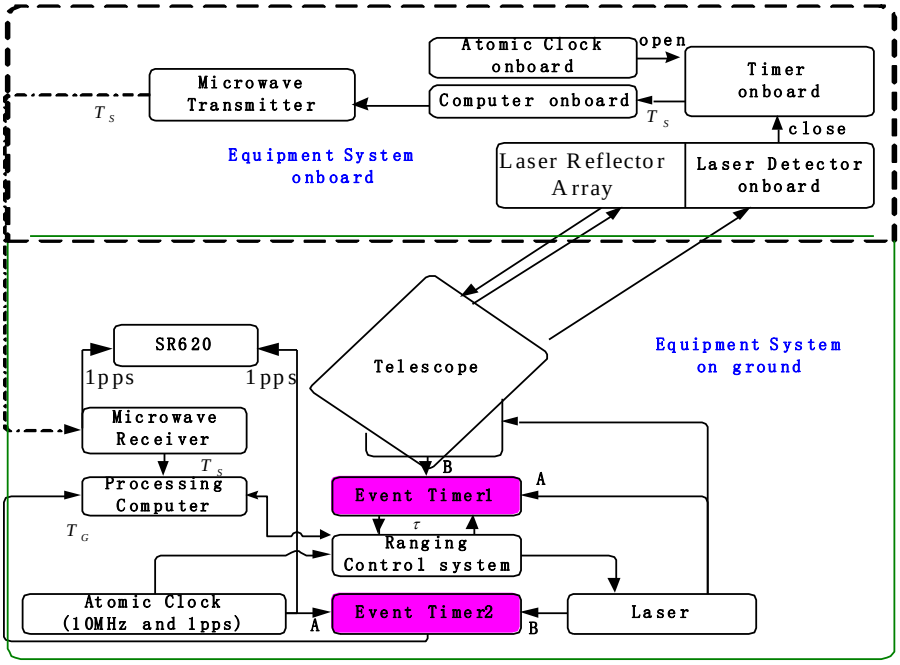

Figure 9. Diagram of LTT

From the results of LTT experiment, it can be concluded that A032-ET provides necessary performance characteristics to achieve the anticipated measurement level. Thus, A032-ET could act as high-precision timing device in LTT experiments.

Summary

Shanghai SLR station is the first one from the China SLR stations which, in collaboration with Riga Institute of Electronics and Computer Science, began using of Riga Event Timer A032-ET for SLR and the related applications. After integration of A032-ET into specific event timer systems, it has been successfully applied to SLR and LTT experiment. The analysis of the obtained measurement data showed that the performance characteristics of Riga Event Timer (such as RMS resolution, stability, non-linearity, etc.) satisfy the

requirements of high precision SLR and LTT. Following to the A032-ET applications at Shanghai SLR station, it is also adopted by several SLR stations in China for developing kHz SLR and as advanced test equipment.

References

G. Kirchner, F. Koid, *Graz KHz SLR System: Design, Experiences and Results*, 14th International Workshop on Laser Ranging, San Fernando, Spain, 7-11 June, 2004.

V. Bespal'ko, E. Boole, V. Vedin, *The Model A032-ET of Riga Event Timers*, 15th International Workshop on Laser Ranging, Canberra, Australia, 15-20 October, 2006.

Yang Fumin, Huang Peicheng, Chen Wanzhen, Zhang Zhongping, Chen Juping etc, *Progress on Laser Time Transfer Project*, 15th International Workshop on Laser Ranging, Canberra, Australia, 15-20 October, 2006.