

TIME TRANSFER BY LASER PULSES BETWEEN GROUND STATIONS

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1. Introduction

The first author of this paper with his colleagues at the Shanghai Observatory had carried out an experiment of time transfer by laser pulses between the headquarter of observatory and the old SLR station during 1981-1982^[1]. The distance between the two sites is 25.2 km. A Q-switched ruby laser with 15-20 ns pulse width, 3 sets of timer with resolution of 100ps, 2 sets of rubidium clock and PMTs with rise time of 2 ns were adopted for the experiment. The standard deviation of the mean of the rubidium clock differences is 1.3ns for a 120 sec interval.

After 21 years, we try to do the experiment with more accurate timing devices again. The purpose of the experiment is to verify the precision of time transfer by laser pulses and preparation for future global time transfer experiments.

2. Principle and configuration of the system

There were two stations: A and B. Station A was equipped with a SFUR mode-locked Nd:YAG laser and ranging system. Station B was equipped with a retro-reflector and a receiving optics and timing system. The principle of the experiment is shown in Fig. 1

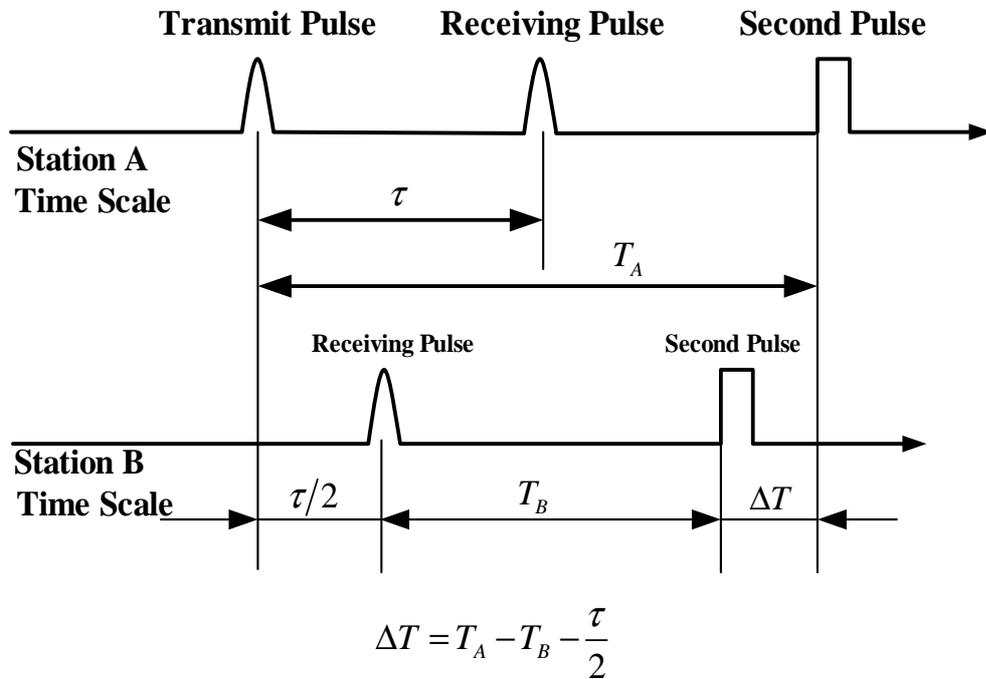


Fig. 1. Principle of experiment

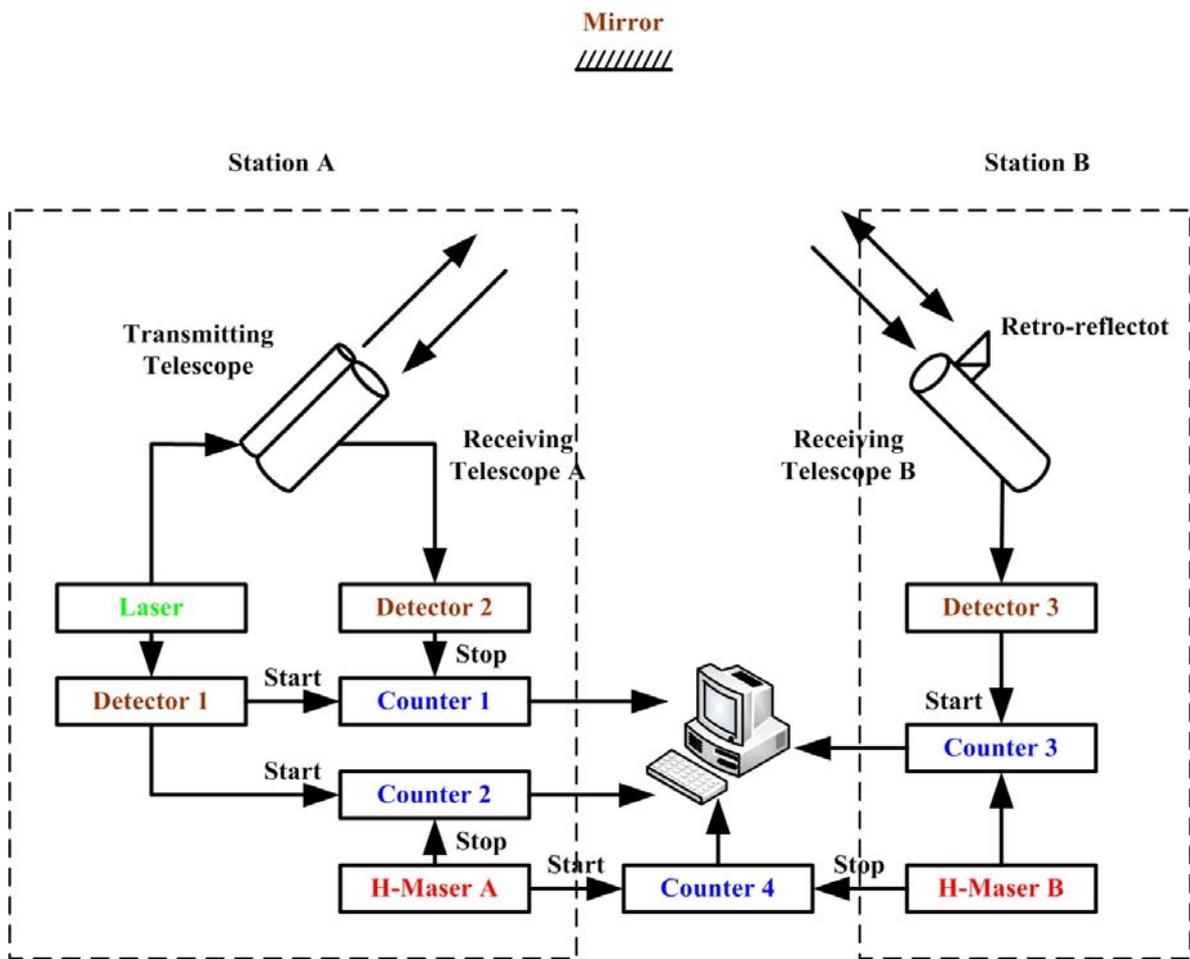


Fig. 2. Block scheme of local time transfer by laser pulses

The block scheme of the experiment is as Fig. 2

Actually, two stations (A and B) were located in a same room in the headquarter of Shanghai Observatory in the city. A 300mm diameter mirror for reflecting laser beams was set up at 250 meters away. Both stations were equipped with hydrogen masers made by the Shanghai Observatory and the two masters were directly compared with a SR-620 timer continuously.

The Characteristics of the time transfer system was as follows:

- Laser: Nd:YAG SFUR, 2mj,30ps,1-10pps
- Receiver: 3 sets of Si-PIN diode Corner cubes
- Mirror: Dia 300mm
- Timer: 4 sets of SR620
- Clock: 2 sets of hydrogen maser
- Discriminator: TC454
- Computer: 1 set for data acquirement of 4 timers

3. Experiment and result

The period of experiment was during May-June of 2003. Fig. 3 shows the hydrogen masers (right side), 4 sets of SR620 timer (left side) and computer. Fig.4 shows the station A (right table), on the table, are the SFUR laser (front), receiving telescope and PIN detectors, and the station B is at the left table and the corner cubes and the PIN detector are on it.



Fig. 3. Hydrogen masers, SR-620 timers and PC

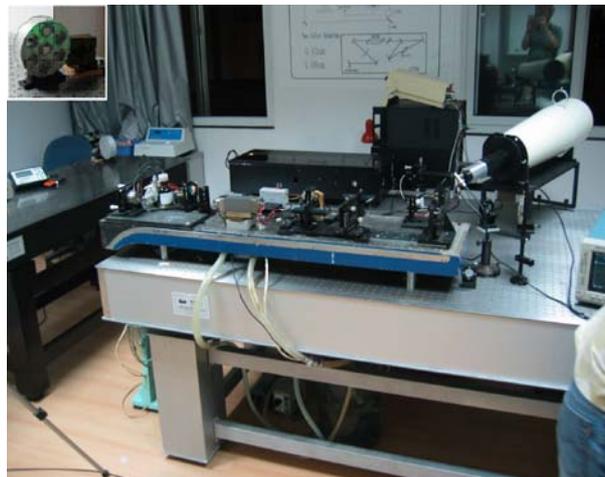


Fig.4 Station A (right table: SFUR laser, optics and detectors) and Station B (left table: corner cubes and detector)

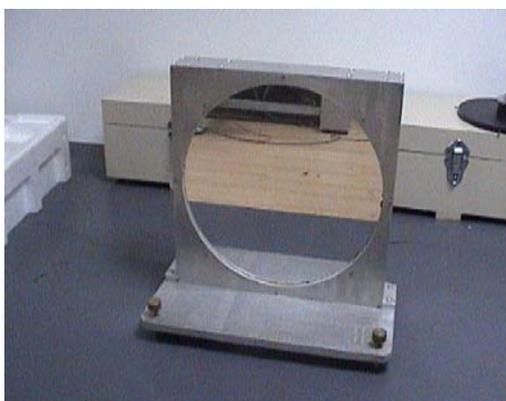


Fig. 5 The diameter 300mm reflector

The result of the experiment on June 13, 2003 is listed in Table 1, and is shown in Fig.6.

It is shown in the experiment that the Standard deviation of the mean of the clock differences determined by laser pulses is 24.1ps(rms) for a 100sec interval. The relative stability of frequency for two masers is $1.8 \times 10^{-13} / 200\text{sec}$ (Allen Deviation), due to without temperature control. The uncertainty of measurement for the relative frequency differences by laser link for two masers is 4×10^{-15} during 6000 sec. In Fig. 6, the Line 1 is the result of clock differences by the timer directly,

and its slope rate is 5.77×10^{-13} . the Line 2 is by the laser link, and its slope rate is 5.82×10^{-13} . The comparison result by laser link is very coincident with the direct timing method. Therefore, the clock comparison via laser pulses is feasible and reliable.

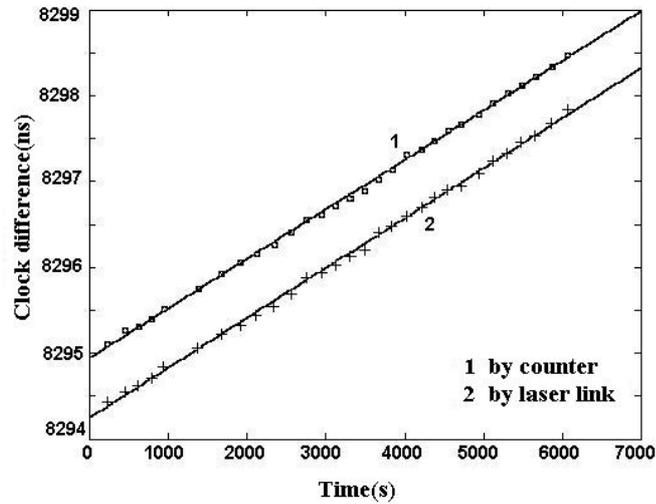


Fig. 6 Local time transfer result by laser pulses

4. FUTURE PLANS

4.1 Upgrade of Performance of Clocks

- Keep the Hydrogen masers in a special clock room, variation of temperature $\pm 0.2^\circ\text{C}$
- Better rise time of the second pulses of masers: 4 ns

4.2 Upgrade of Accuracy of Time Comparison

- Systematic biases measurement
Time delays by PIN diode, discriminator, timer...
- Systematic errors analysis

4.3 SPAD application

2 sets of for better sensitivity SPAD will be adopted to replace the PIN diodes as the detectors for better sensitivity

4.4 Time comparison with high repetition rate

- 1 KHz time comparison with 1 KHz laser, and 10 ps pulse
- Clock difference measurement within one second
- Frequency difference measurement within 5-10 minutes

Reference

- [1] Yang Fumin, Zhuang Qixiang, Su Jinyuan et al. Time comparison experiment via laser pulses, KEXUE TONGBAO (Science Bulletin in China), V.29, P.207, 1984.

Table 1. Result of clock differences by laser pulses

Set	Clock diff. by laser				Clock diff. by timer			Laser ranging data		
	Point	Mean (ns)	Single shot precision (ps)	Precision of mean (ps)	Mean(ns)	Single shot precision (ps)	Precision of mean (ps)	Mean(ns)	Single shot precision (ps)	Precision of mean (ps)
1	79	8294.4361	192.2	21.6	8295.1076	176.5	18.8	3410.967	62.7	6.7
2	85	8294.5456	208.7	22.6	8295.2665	195.2	20.8	3410.9641	51.2	5.6
3	64	8294.6283	191.1	20.7	8295.3145	181.3	18.7	3410.9718	65.1	7.8
4	81	8294.7095	268.7	29.9	8295.3963	248.2	25.2	3410.9478	56.9	6.6
5	68	8294.839	274.8	33.3	8295.5156	199.1	20.9	3410.9661	46.8	5.9
6	75	8295.0386	275.6	31.8	8295.7367	204.7	21.2	3410.9683	89.4	10.0
7	73	8295.2236	231.9	27.1	8295.9195	168.8	17.6	3410.9681	65.9	7.7
8	74	8295.3337	213.5	24.8	8296.0501	195.3	19.9	3410.9656	51.5	6.2
9	80	8295.4334	188.0	21.0	8296.1541	148.7	15.8	3410.9712	59.4	6.8
10	80	8295.5426	189.8	21.2	8296.2565	185.5	18.7	3410.9747	62.2	7.0
11	78	8295.6821	187.3	21.2	8296.4044	195.3	20.1	3410.9857	58.8	6.7
12	84	8295.8746	209.9	22.9	8296.5451	190.8	19.7	3410.989	52.2	5.9
13	83	8295.9377	222.2	24.4	8296.6086	178.4	18.6	3410.9913	55.9	6.3
14	81	8296.0246	202.6	22.5	8296.7145	175.8	18.5	3410.9869	58.4	6.2
15	82	8296.1201	255.9	28.3	8296.8100	194.9	20.0	3410.9638	33.2	4.1

16	79	8296.1997	249.9	28.1	8296.8903	206.8	21.2	3410.9642	60.6	7.1
17	71	8296.3962	152.7	18.1	8297.0179	151.0	15.7	3410.9535	50.0	5.9
18	78	8296.4827	235.5	26.7	8297.1384	174.1	18.2	3410.9533	56.2	6.3
19	79	8296.5954	204.4	23.0	8297.3161	133.1	14.3	3410.9443	71.7	8.0
20	82	8296.6873	167.7	18.5	8297.3709	168.3	17.4	3410.9319	48.1	5.6
21	74	8296.8184	214.6	24.9	8297.4782	208.4	21.7	3410.9338	62.8	8.0
22	83	8296.9122	245.7	27.0	8297.591	140.8	15.0	3410.9367	51.2	6.5
23	70	8296.9442	202.6	24.2	8297.666	208.6	21.2	3410.9433	63.1	7.8
24	74	8297.0934	180.4	21.0	8297.7887	162.9	17.0	3410.9164	50.1	6.4
25	84	8297.2371	205.8	22.5	8297.9168	186.4	19.3	3410.9599	64.9	7.5
26	73	8297.33	195.1	22.8	8298.0334	186.5	19.2	3410.9301	40.3	4.8
27	78	8297.4598	178.2	20.2	8298.1223	159.7	16.5	3410.943	56.1	7.1
28	73	8297.5217	208	24.3	8298.2232	177.7	18.0	3410.9406	55.5	6.8
29	85	8297.6806	238.5	25.9	8298.3354	184.4	19.7	3410.9534	58.9	7.4
30	83	8297.8418	213.9	23.5	8298.4751	176.7	19.4	3410.9652	44.8	5.6
Ave- rage			213.5	24.1		182.1	19.0		56.8	6.7