The achievements of the dedicated Compass SLR system with 1m aperture telescope: GEO satellite daylight tracking and Laser Time Transfer (LTT)

Zhang Zhongping (1) , Yang Fumin (1) , Zhang Haifeng (1)
Meng Wendong (1) , Wu Zhibo (1) , Chen Wenzhen (1)
Chen Juping (1) ,Ivan Prochazka (2)

(1) . Shanghai Observatory, Chinese Academy of Sciences
(2) . Czech tcchnical University

1 meter Laser Ranging System

- Shanghai observatory has been building the 1 meter laser ranging system for the Chinese regional satellite navigation system in Beijing since 2008.
- In Jan. 2009, 1m aperture telescope laser ranging system was installed.
- In March 2009, laser ranging is successful for Lageos, GPS36, Glonass, Giove at night-time.
- In April 2009, measuring data is got firstly from COMPASS GEO2 satellite at night-time and the range is about 3,8800km at the precision of about 2cm.

Main performances:

- Receiving telescope : 1000mm
- Transmitting telescope: 300mm
- Nd:YAG laser: 150mJ@532nm, 250ps pulse width, 20Hz
- Targets：GEO/IGSO/MEO, 20000km-40000km
- Ranging precision :2~3cm
- Daylight tracking ability
- Laser Time Transfer (LTT)

1 Meter SLR telescope made by Shanghai station in the assembly shop

This report introduces the following two achievements of Compass SLR system in Beijing:

- **GEO/IGSO satellite daylight tracking**
- **Laser Time Transfer for IGSO satellite**

GEO/IGSO satellites daylight tracking

Technologies solved for daylight tracking:

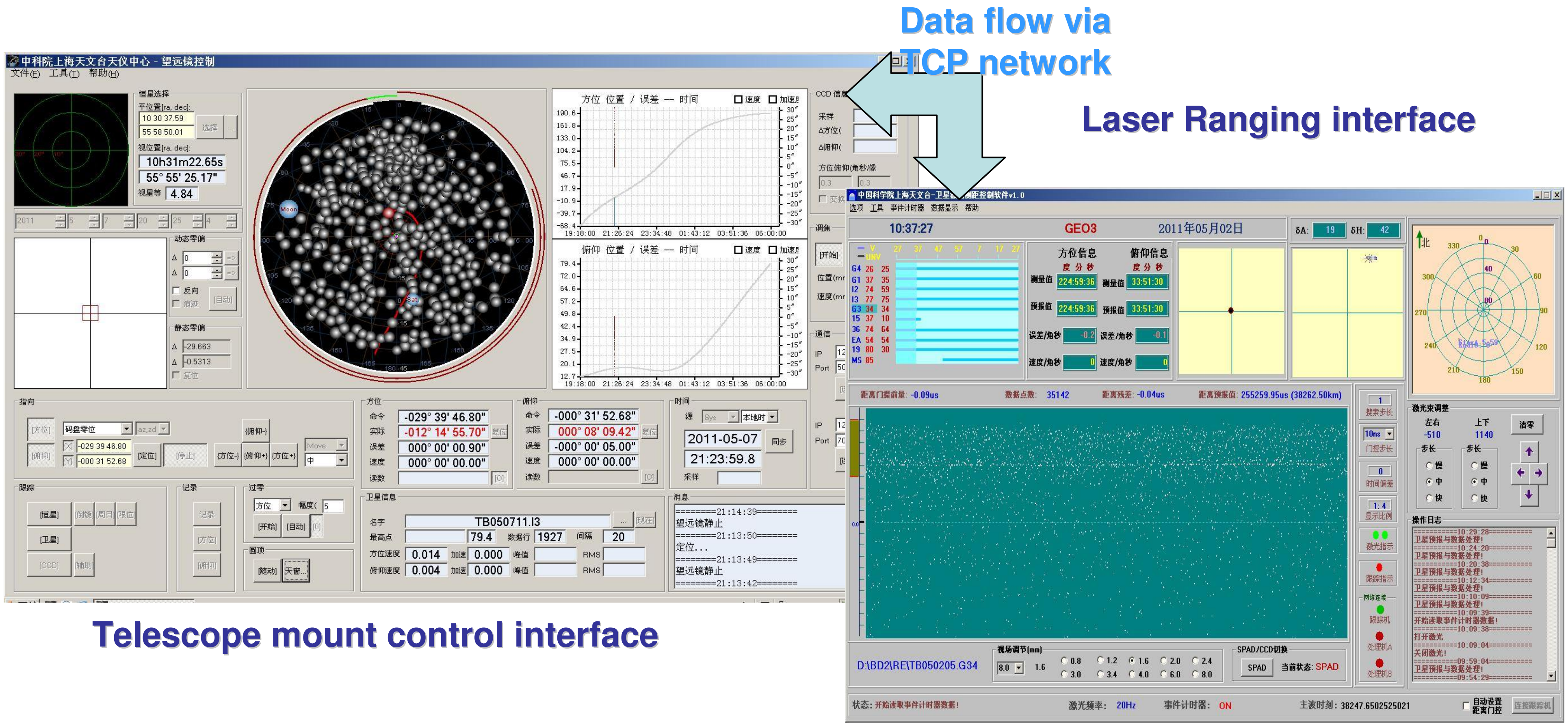
- *Performances of tracking and pointing of telescope mount*
- *Space filter: receiving filed of view is 24″~ 45″ , adjustable*
- *Spectrum filter:*

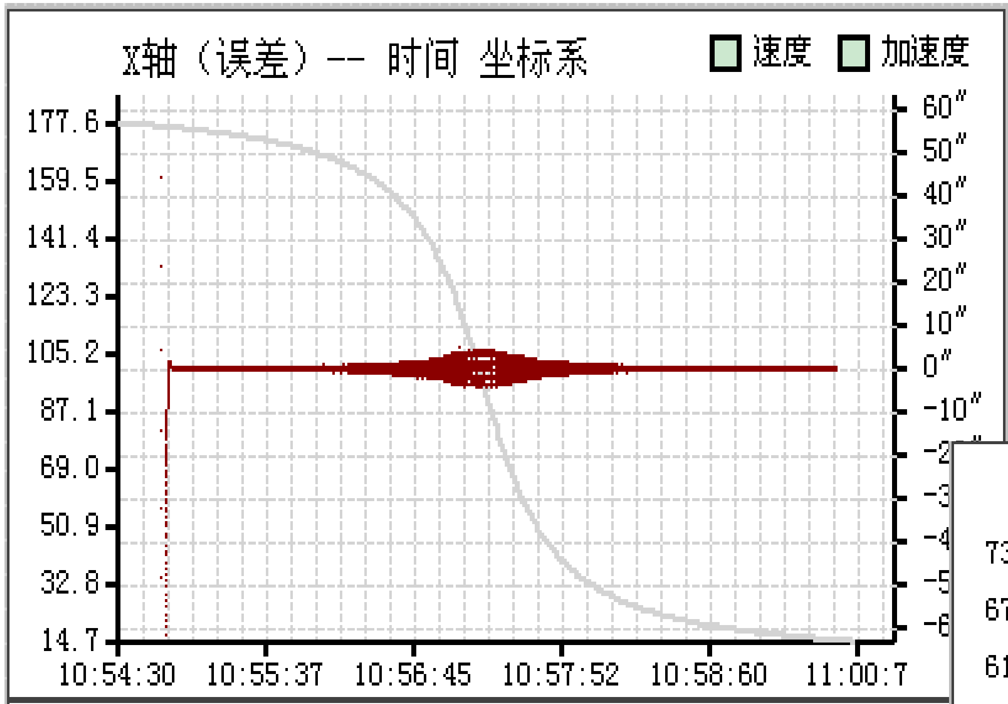
  Narrower filter with 0.15nm band width

  Transparency of central wavelength is over 50%
- *Parallelism of transmitting and receiving paths is better than 5"*
- *Daylight Laser beam monitor*
- *Return detection*

The two computers control mode:

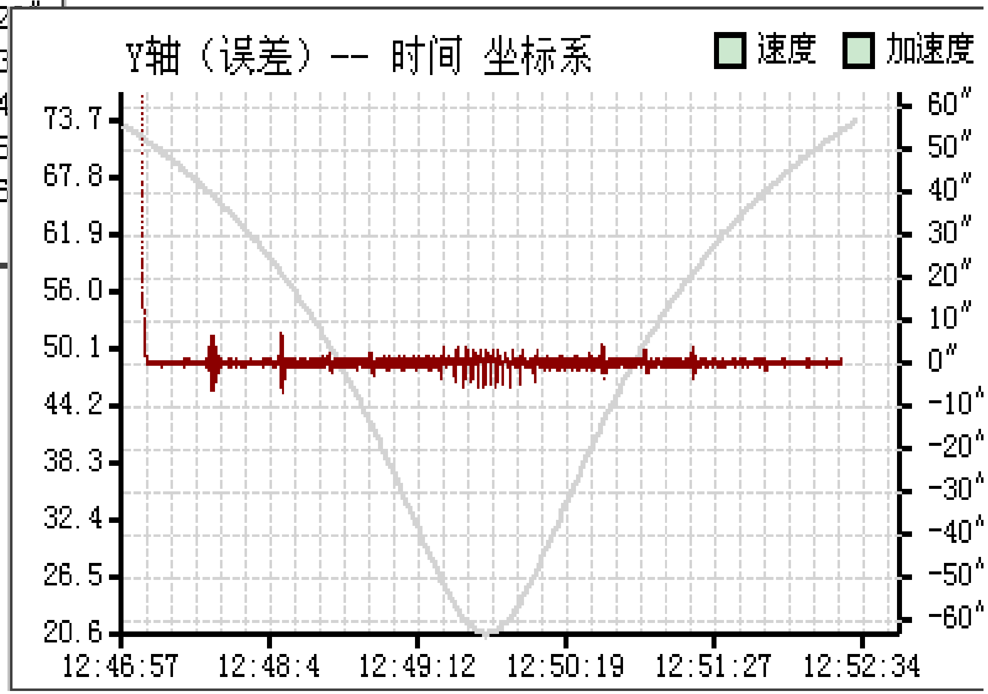
- For increasing the stability of tracking and pointing of 1m telescope mount, a computer for telescope control to track satellites and stars is adopted. Another computer is used for Laser Ranging operation.
- Tracking accuracy is less than 1 arc second.
- Pointing accuracy after star calibration is better than 3 arc second.





azimuth

(P-V 4.487″ RMS 0.731″)

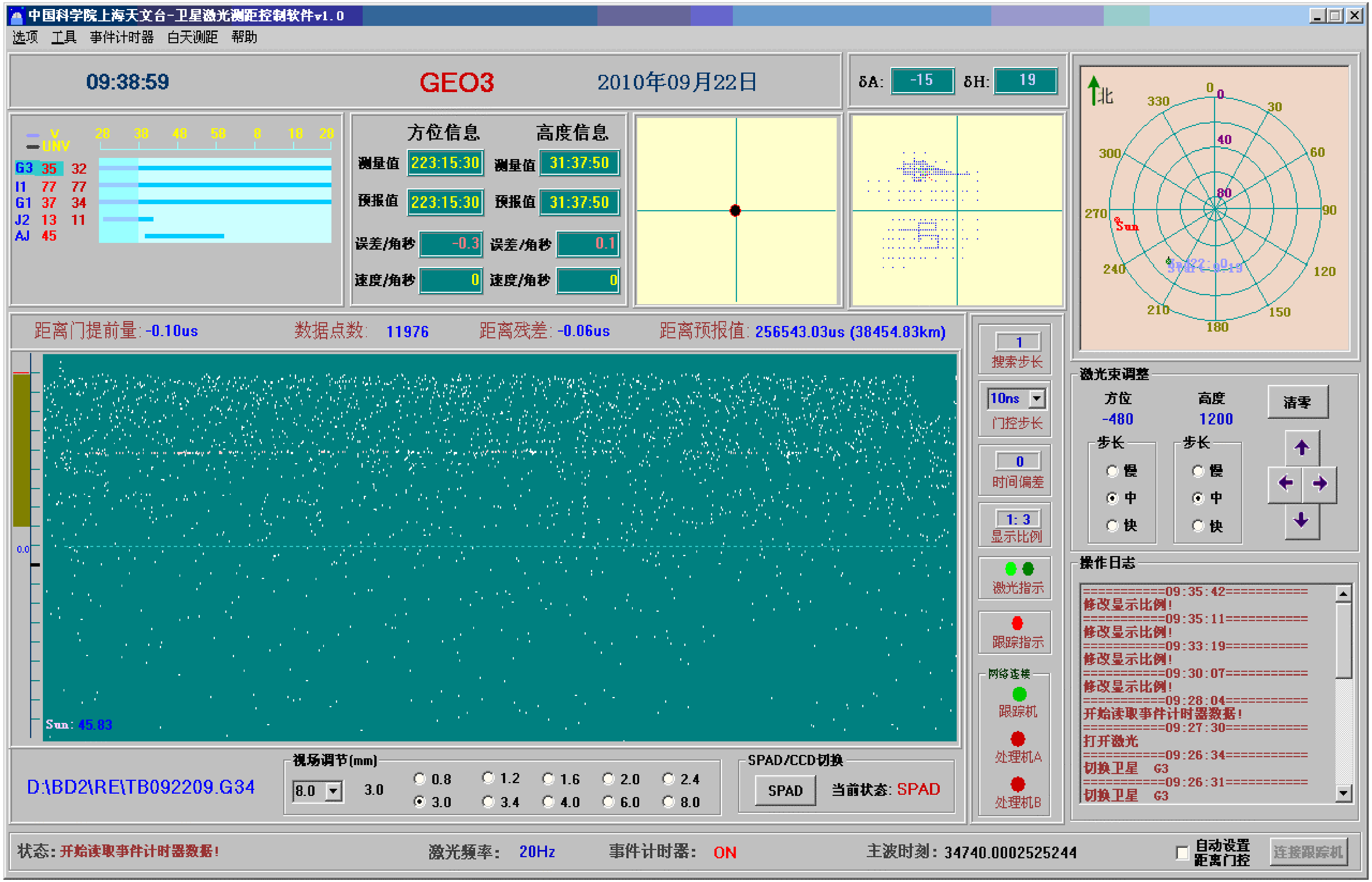


elevation

(P-V 5.37″ RMS 0.646″)

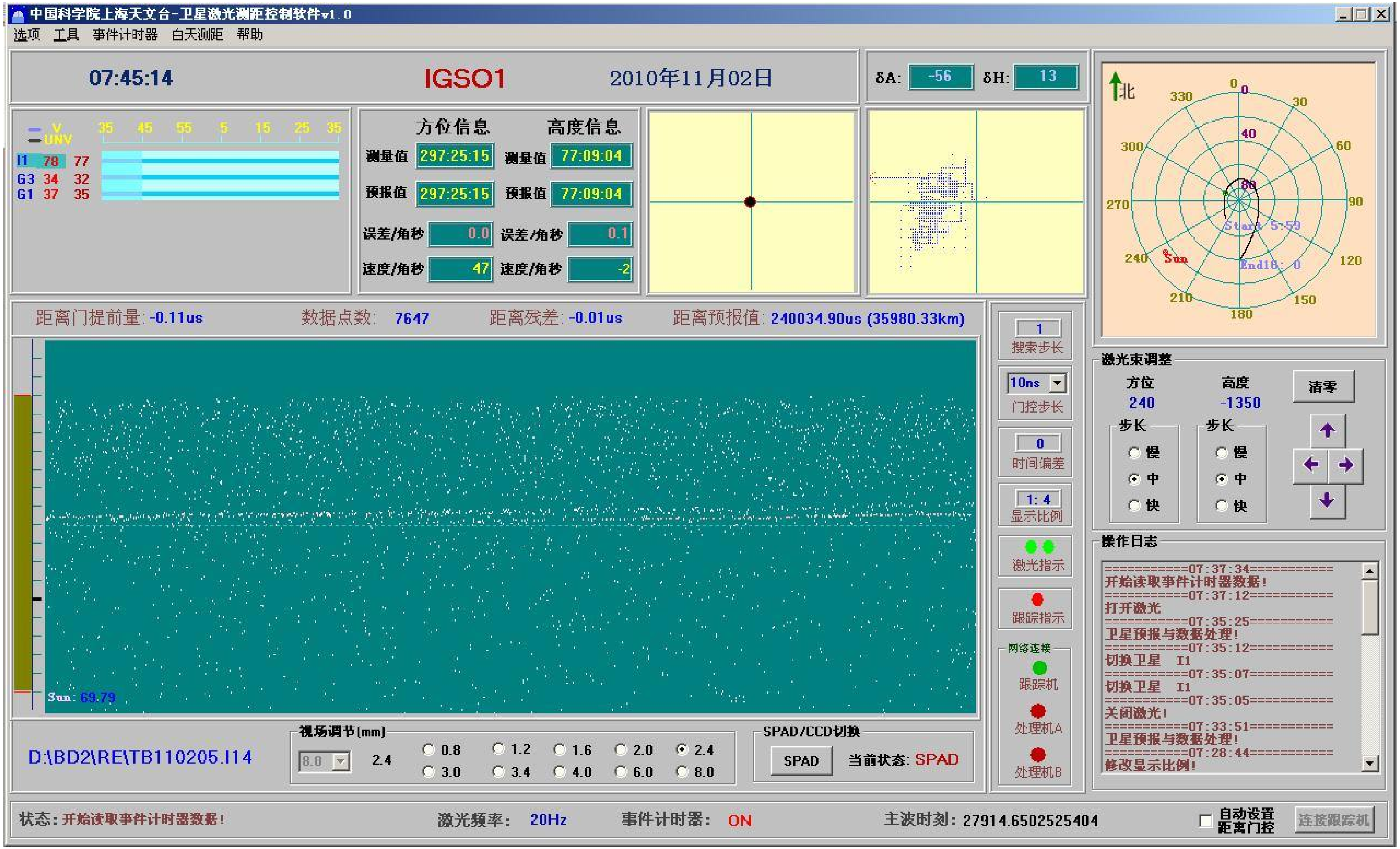
Daylight tracking real-time ranging interface for GEO3

Local time 2010.09.22 5h p.m.



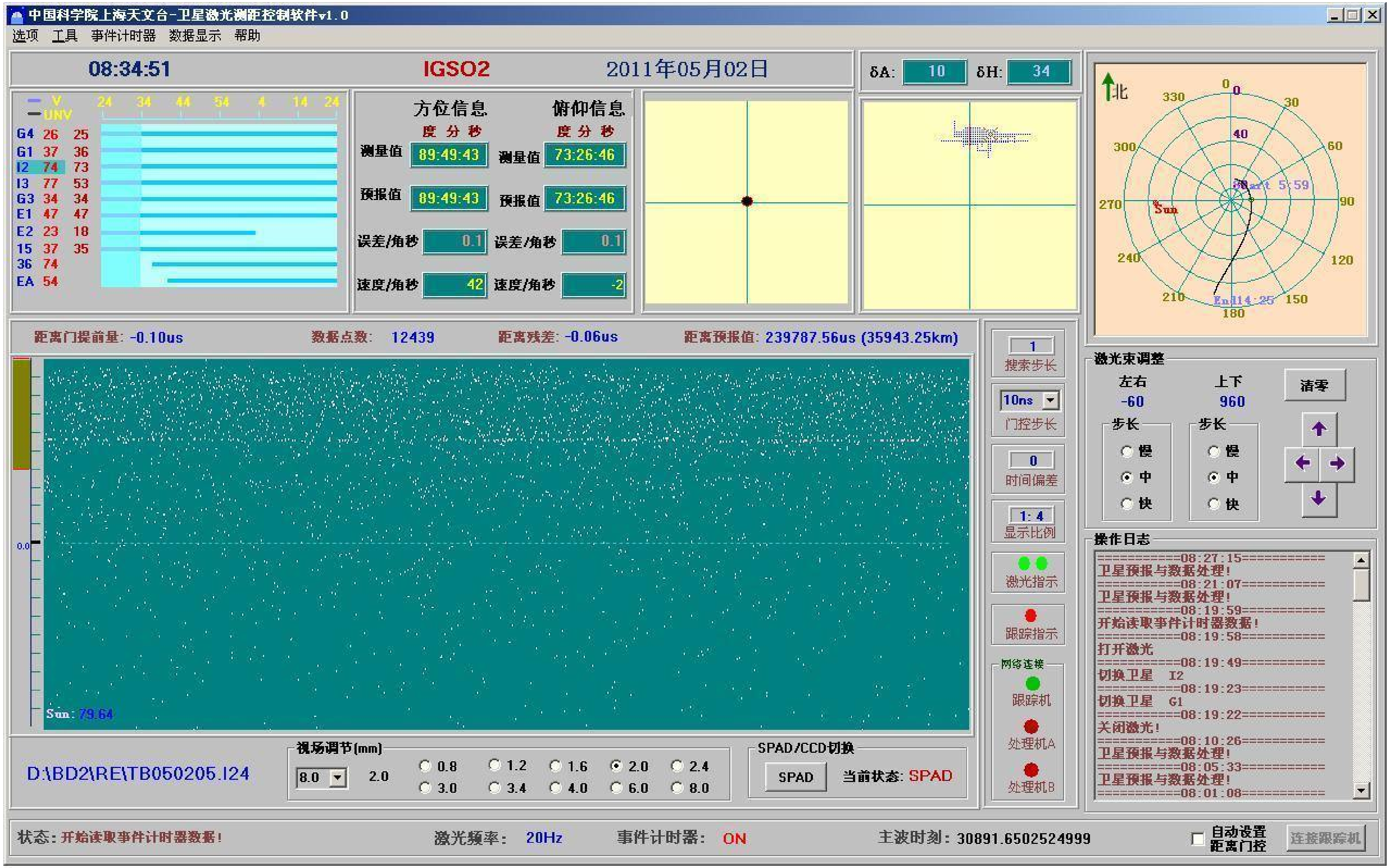
Daylight tracking real-time ranging interface for IGSO1

Local time 2010.11.02 3h p.m.



Daylight tracking real-time ranging interface for IGSO2

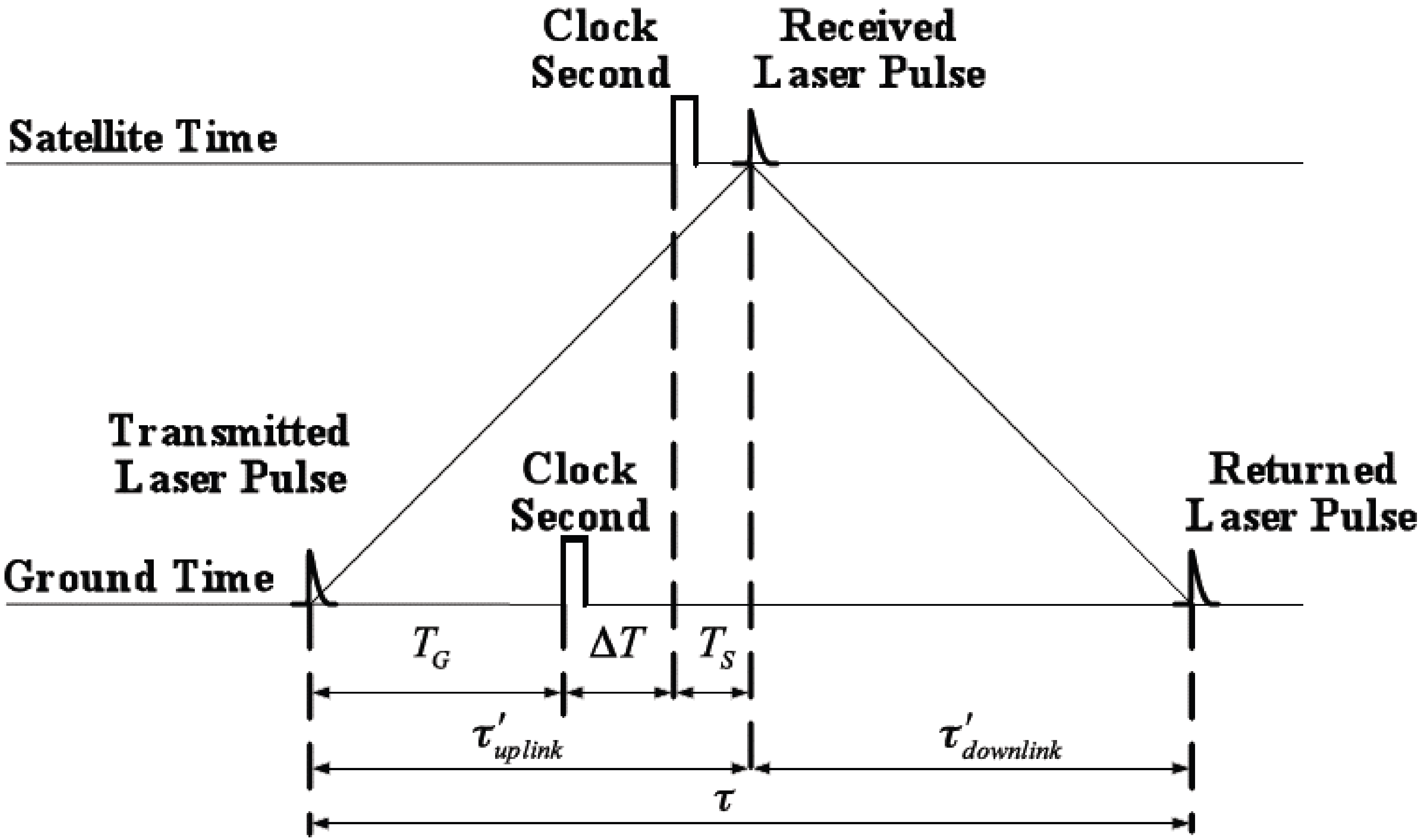
Local time 2011.05.02 4h p.m.



Laser Time Transfer for IGSO satellites

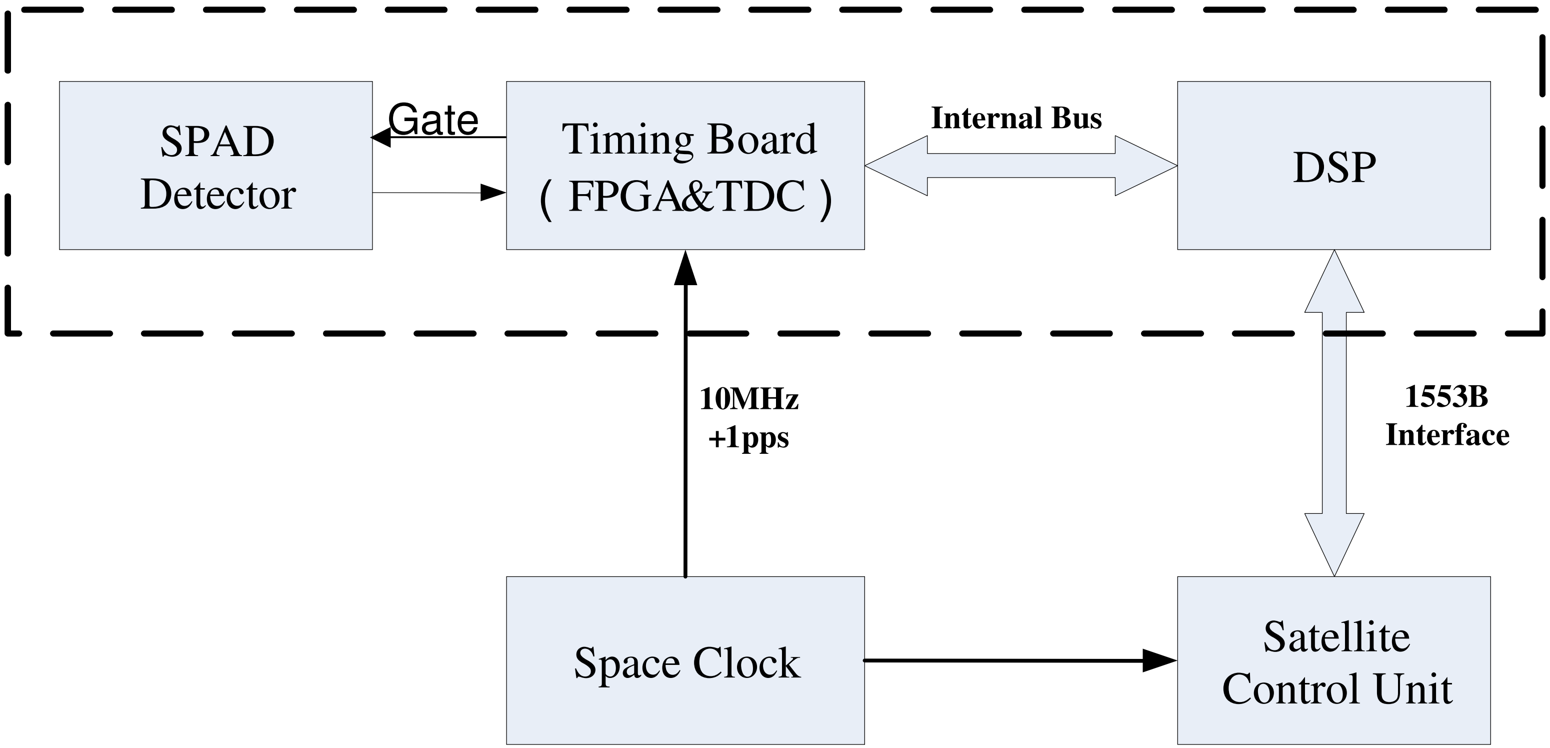
- In Dec. 2007, Shanghai Observatory have successfully actualized Laser Time Transfer (LTT) experiment at Changchun SLR station (60 centimeter aperture telescope) for CompassM1 satellite (altitude 21,500km).
- Based on above experiment, some improved technologies is applied, such as gate mode adopted, two different FOV used, narrower filter etc.
- At the end of August last year, we first got LTT measuring data by using 1 meter aperture laser ranging system, after the Compass IGSO1 satellite (altitude 36,000km) with improved LTT payload was launched..
- Compared to LTT experiment of CompassM1 satellite, the performances of the new LTT payload on Compass IGSO1 and Laser Ranging system on ground are more advanced. And measurement is also performed easily.

Principle of Laser Time Transfer

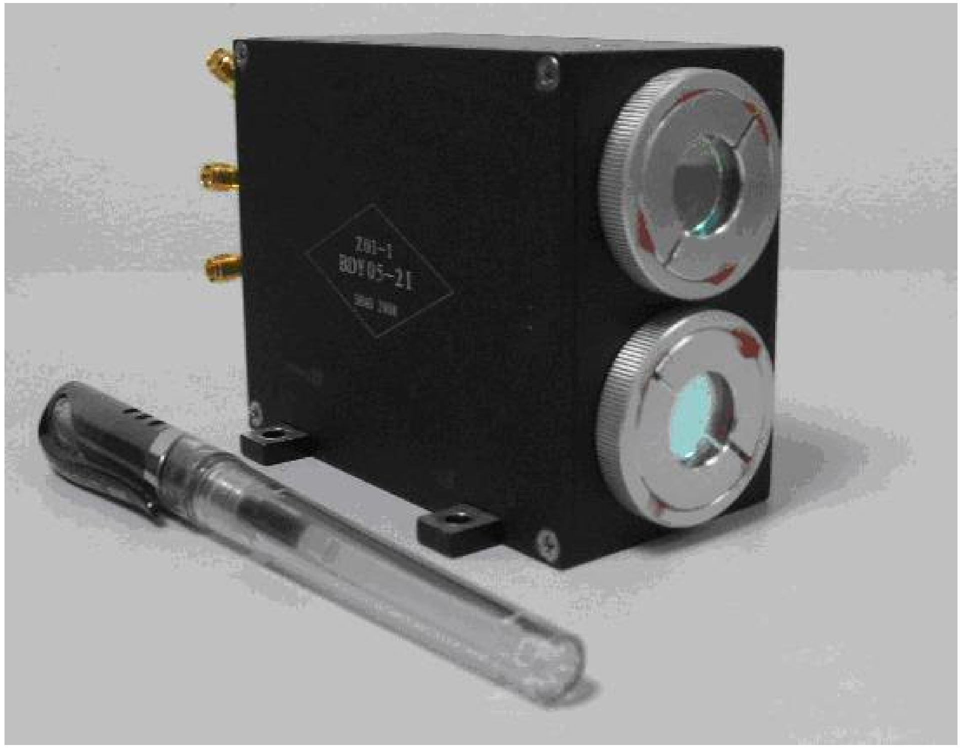


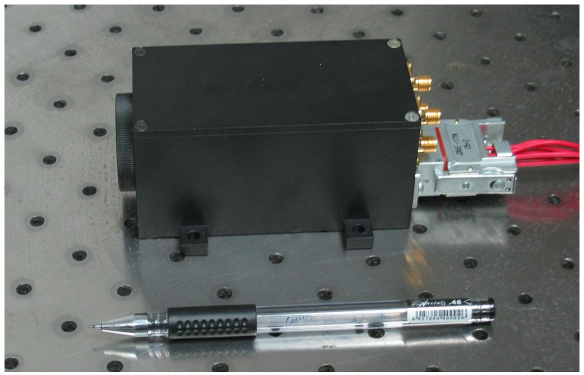
$$\Delta T = \tau'_{uplink} - T_G - T_S$$

Block Diagram of New LTT payload



New LTT Detector





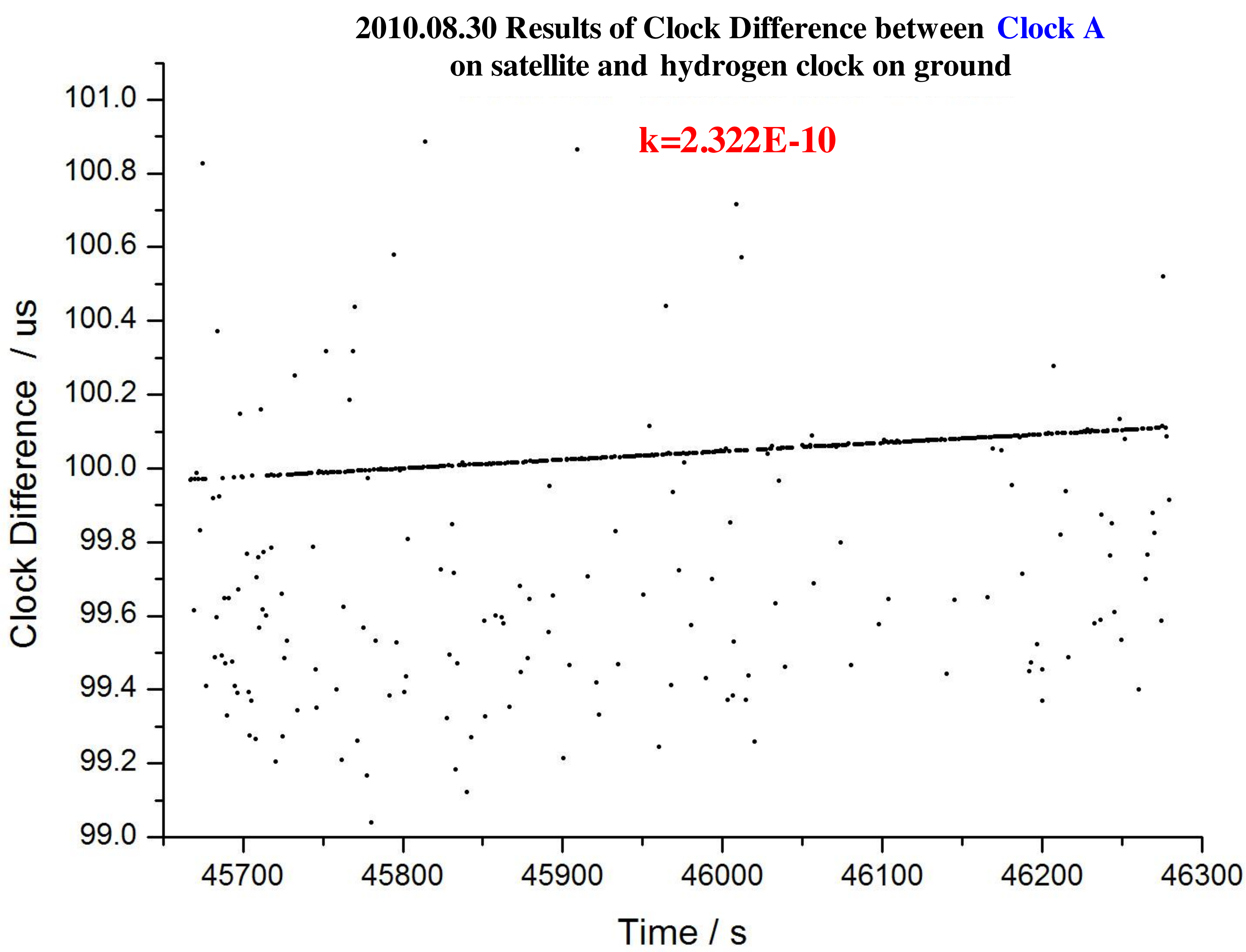
- Dual-SPAD detector
- 500g, <2W, 105×70×80mm
- Two Field of View: 15°/11° for different background noise
- Bandwidth filter: 4nm
- Gate/Un-gate mode
- Two Channels

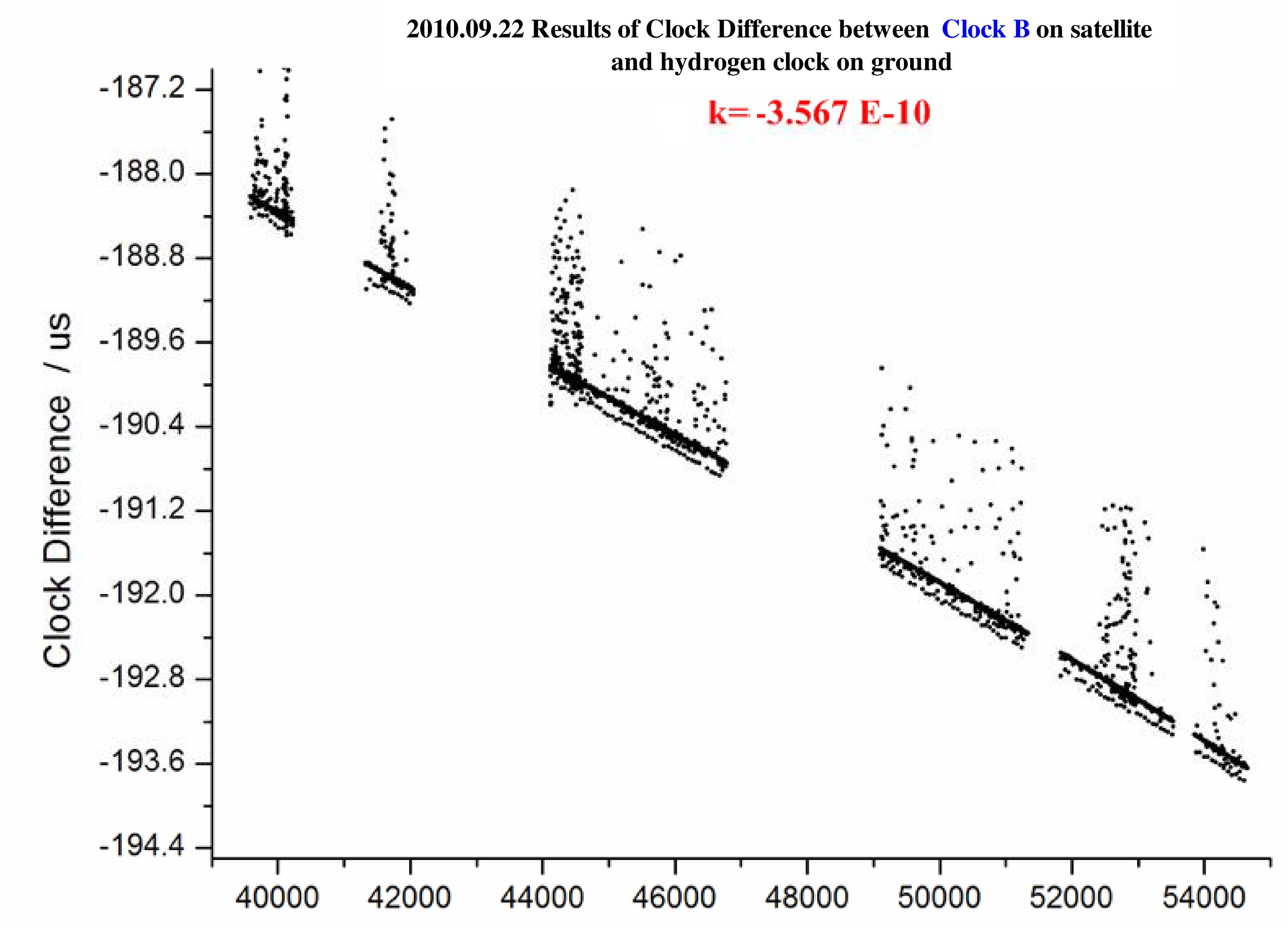
Laser fire time control

- For simplifying the design of LTT payload on satellite, the gate mode for detector is different from the one in routinely SLR, adopting a fixed range gate (about 70ns after start pulse).
- To reduce the effect of noises, we must accurately calculated/ controled laser fire time on ground according to laser pulse flight time, predicted clock difference between space and ground, system delays, etc. Let the laser pulse arrive at the detector on onboard, just after the gate pulse of detector.
- For strictly controlling laser fire time, the laser on ground should be actively switched, and laser with passive or passive-active switched cannot be used.
- The firing jitter of the new laser in this system is about 10ns.

LTT Results

Date	Points	Pass/min	Precision/ps	Slope of Clock Difference
2010.08.30	**315**	**10.1**	**283.1**	**2.322E-10**
2010.09.21	**2672**	**156.2**	**311.5**	**-3.636E-10**
2010.09.22	**4830**	**251.0**	**315.1**	**-3.567 E-10**
2010.11.01	**4345**	**47.6**	**296.6**	**-3.572E-10**
2010.11.02	**7396**	**59.2**	**299.82**	**-3.571E-10**


2010.08.30 Results of Clock Difference between Clock A
on satellite and hydrogen clock on ground
k=2.322E-10
Clock Difference / us
101.0
100.8
100.6
100.4
100.2
100.0
99.8
99.6
99.4
99.2
99.0
45700
45800
45900
46000
46100
46200
46300
Time / s


2010.09.22 Results of Clock Difference between Clock B on satellite
and hydrogen clock on ground
k= -3.567 E-10
Clock Difference / us
-187.2
-188.0
-188.8
-189.6
-190.4
-191.2
-192.0
-192.8
-193.6
-194.4
40000
42000
44000
46000
48000
50000
52000
54000

Conclusion

- The dedicated Compass SLR system has being played an important role in tracking Compass satellites (nighttime and daylight) for the precise orbit determination of satellites and LTT experiment.
- It is the first time to implement LTT experiment on IGOS1 satellite (altitude 36,000km) at the precision of about 300ps. The drift and stability of frequency onboard are about 10E-10 and 10E-13 respectively.
- Compass IGSO3 with LTT payload same to the one in IGSO1 satellite was launched and the LTT experiment was successful with the precision of 280ps last week.
- Through LTT between satellite and ground, time synchronization for different stations on ground in the Chinese regions or beyond China will be carried out in the future.

Thank you!