

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

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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)



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:

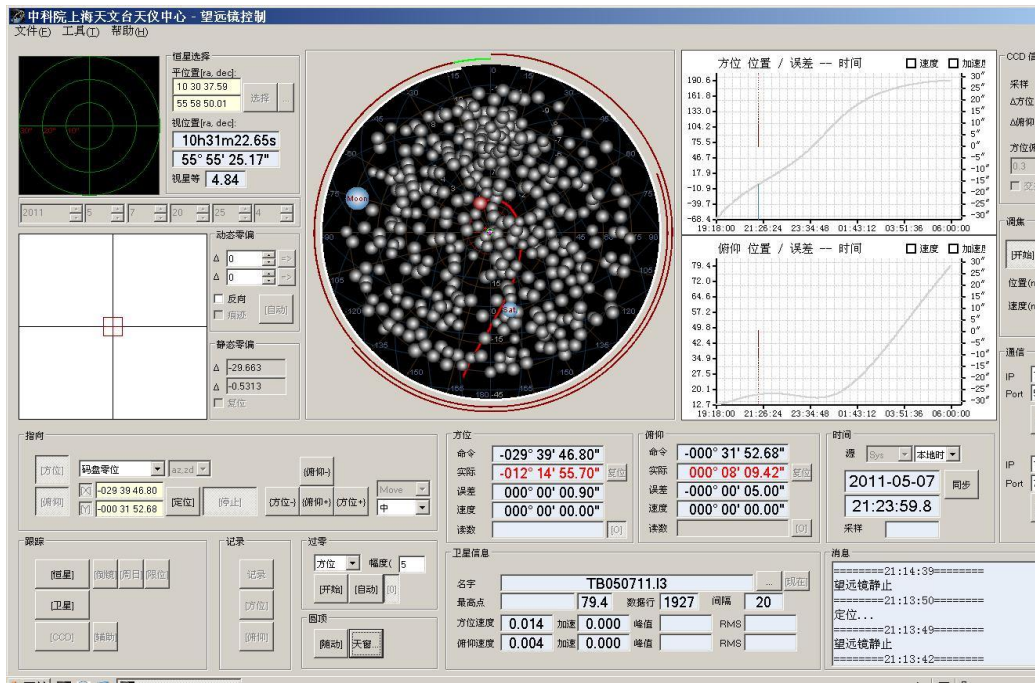
- *Performances of tracking and pointing of telescope mount*
- *Space filter: receiving field of view is 24"~ 45" , adjustable*
- *Spectrum filter:*
 - Narrower filter with 0.15nm band width*
 - Transparency of central wavelength is over 50%*
- *Parallelism of transmitting and receiving paths is better than 5"*
- *Daylight Laser beam monitor*
- *Return detection*

The two computers control mode:

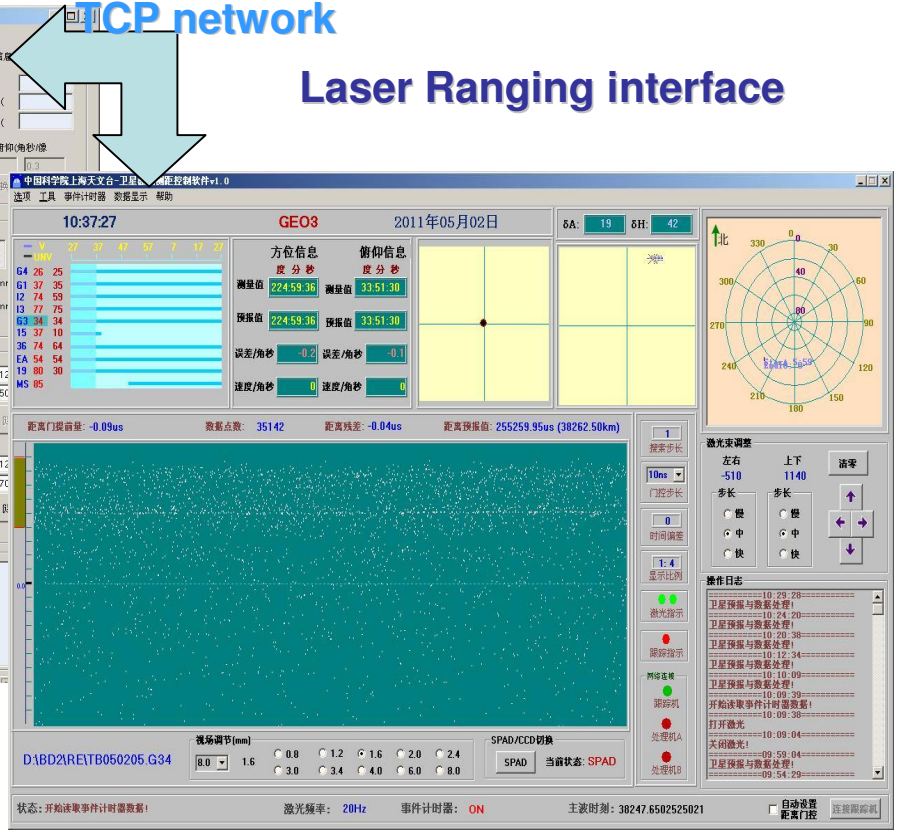
- For increasing the stability of tracking and pointing of 1m telescope mount, a computer for telescope control **to track satellites and stars** is adopted. Another computer is used for **Laser Ranging operation**.
- Tracking accuracy is **less than 1 arc second**.
- Pointing accuracy after star calibration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

Data flow via TCP network

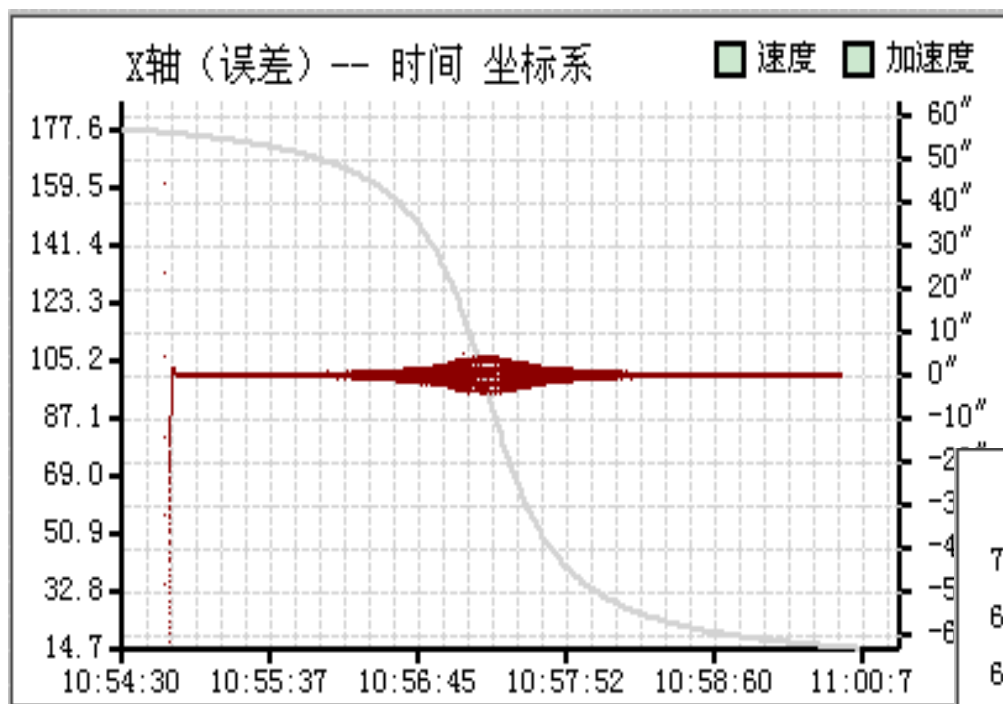
Laser Ranging interface



Telescope mount control interface

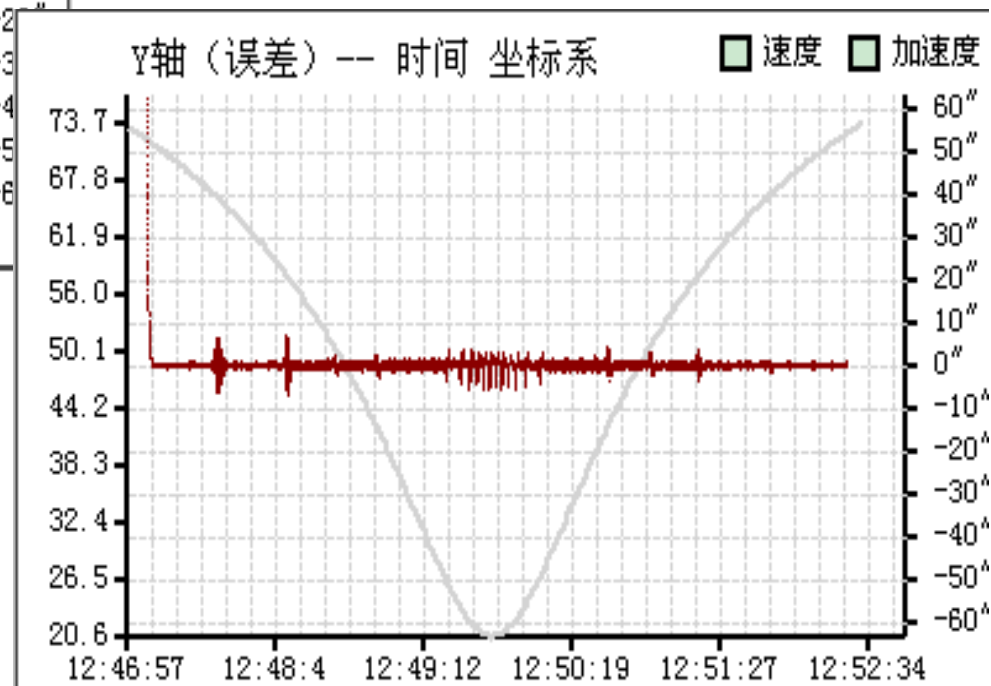


状态: 开始读取事件计时数据! 激光频率: 20Hz 事件计时器: ON 主波时刻: 30247.650252021



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.

中国科学院上海天文台-卫星激光测距控制软件v1.0
选项 工具 事件计时器 白天测距 帮助

09:38:59 **GEO3** 2010年09月22日 δA : -15 δH : 19

V	20	30	40	50	6	10	20
UVV							
G3	35	32					
I1	77	77					
G1	37	34					
J2	13	11					
AJ	45						

方位信息 **高度信息**

测量值: 223:15:30 测量值: 31:37:50
预报值: 223:15:30 预报值: 31:37:50

误差/角秒: -0.3 误差/角秒: 0.1
速度/角秒: 0 速度/角秒: 0

距离门提前量: -0.10us 数据点数: 11976 距离残差: -0.06us 距离预报值: 256543.03us (38454.83km)

搜索步长: 1
门控步长: 10ns
时间偏差: 0
显示比例: 1:3

激光束调整

方位: -480 高度: 1200 清零
步长: 慢 步长: 慢
 中 步长: 中
 快 步长: 快

操作日志

- ====09:35:42====
- 修改显示比例!
- ====09:35:11====
- 修改显示比例!
- ====09:33:19====
- 修改显示比例!
- ====09:30:07====
- 修改显示比例!
- ====09:28:04====
- 开始读取事件计时器数据!
- ====09:27:30====
- 打开激光
- ====09:26:34====
- 切换卫星 G3
- ====09:26:31====
- 切换卫星 G3

网络连接: 跟踪机, 处理机A, 处理机B

视场调节(mm): 8.0, 3.0, 0.8, 1.2, 1.6, 2.0, 2.4, 3.0, 3.4, 4.0, 6.0, 8.0

SPAD/CCD切换: SPAD 当前状态: SPAD

状态: 开始读取事件计时器数据! 激光频率: 20Hz 事件计时器: ON 主波时刻: 34740.0002525244 自动设置 距离门控 连接跟踪机

Daylight tracking real-time ranging interface for IGSO1

Local time 2010.11.02 3h p.m.

中国科学院上海天文台-卫星激光测距控制软件v1.0
选项 工具 事件计时器 白天测距 帮助

07:45:14 IGSO1 2010年11月02日 δA : -56 δH : 13

V	35	45	55	5	15	25	35
I1	78	77					
G3	34	32					
G1	37	35					

方位信息 测量值: 297:25:15 预报值: 297:25:15 误差/角秒: 0.0 速度/角秒: 47
高度信息 测量值: 77:09:04 预报值: 77:09:04 误差/角秒: 0.1 速度/角秒: -2

距离门提前量: -0.11us 数据点数: 7647 距离残差: -0.01us 距离预报值: 240034.90us (35980.33km)

搜索步长: 1 10ns 门控步长: 0 时间偏差: 1:4 显示比例

激光束调整: 方位: 240 高度: -1350 步长: 慢 中 快 跟踪指示: 慢 中 快

操作日志:
-----07:37:34-----
开始读取事件计时器数据!
-----07:37:12-----
打开激光
-----07:35:25-----
卫星预报与数据处理!
-----07:35:12-----
切换卫星 I1
-----07:35:07-----
切换卫星 I1
-----07:35:05-----
关闭激光!
-----07:33:51-----
卫星预报与数据处理!
-----07:28:44-----
修改显示比例!

D:\BD2\RE\TB110205.I14 视场调节(mm): 8.0 2.4 0.8 1.2 1.6 2.0 2.4 3.0 3.4 4.0 6.0 8.0 SPAD/CCD切换: SPAD 当前状态: SPAD

状态: 开始读取事件计时器数据! 激光频率: 20Hz 事件计时器: ON 主波时刻: 27914.6502525404 自动设置 距离门控 连接跟踪机

Daylight tracking real-time ranging interface for IGSO2

Local time 2011.05.02 4h p.m.

中国科学院上海天文台-卫星激光测距控制软件v1.0
选项 工具 事件计时器 数据显示 帮助

08:34:51 IGSO2 2011年05月02日 $\delta A:$ 10 $\delta H:$ 34

卫星	方位 (度分秒)	俯仰 (度分秒)
G4	26 25	
G1	37 36	
I2	74 73	
I3	77 53	
G3	34 34	
E1	47 47	
E2	23 18	
15	37 35	
36	74	
EA	54	

方位信息: 测量值 89:49:43 俯仰信息: 测量值 73:26:46
预报值 89:49:43 预报值 73:26:46
误差/角秒: 0.1 误差/角秒: 0.1
速度/角秒: 42 速度/角秒: -2

距离门提前量: -0.10us 数据点数: 12439 距离残差: -0.06us 距离预报值: 239787.56us (35943.25km)

激光束调整: 左右 -60 上下 960 步长 慢 中 快

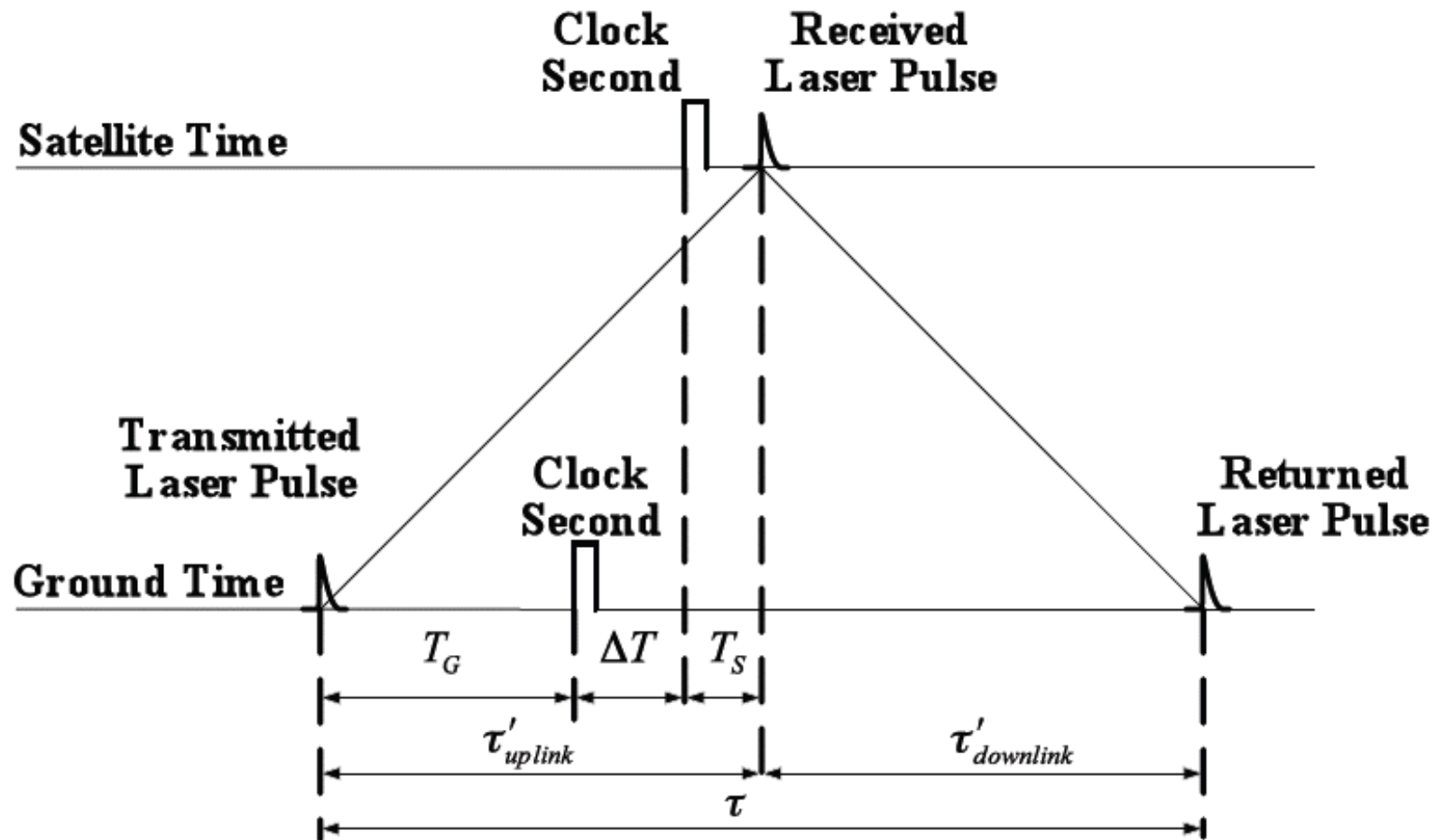
操作日志:
08:27:15 卫星预报与数据处理!
08:21:07 卫星预报与数据处理!
08:19:59 开始读取事件计时器数据!
08:19:58 打开激光
08:19:49 切换卫星 I2
08:19:23 切换卫星 G1
08:19:22 关闭激光!
08:10:26 卫星预报与数据处理!
08:05:33 卫星预报与数据处理!
08:01:08 卫星预报与数据处理!

状态: 开始读取事件计时器数据! 激光频率: 20Hz 事件计时器: ON 主波时刻: 30891.6502524999

Laser Time Transfer for IGSO satellites

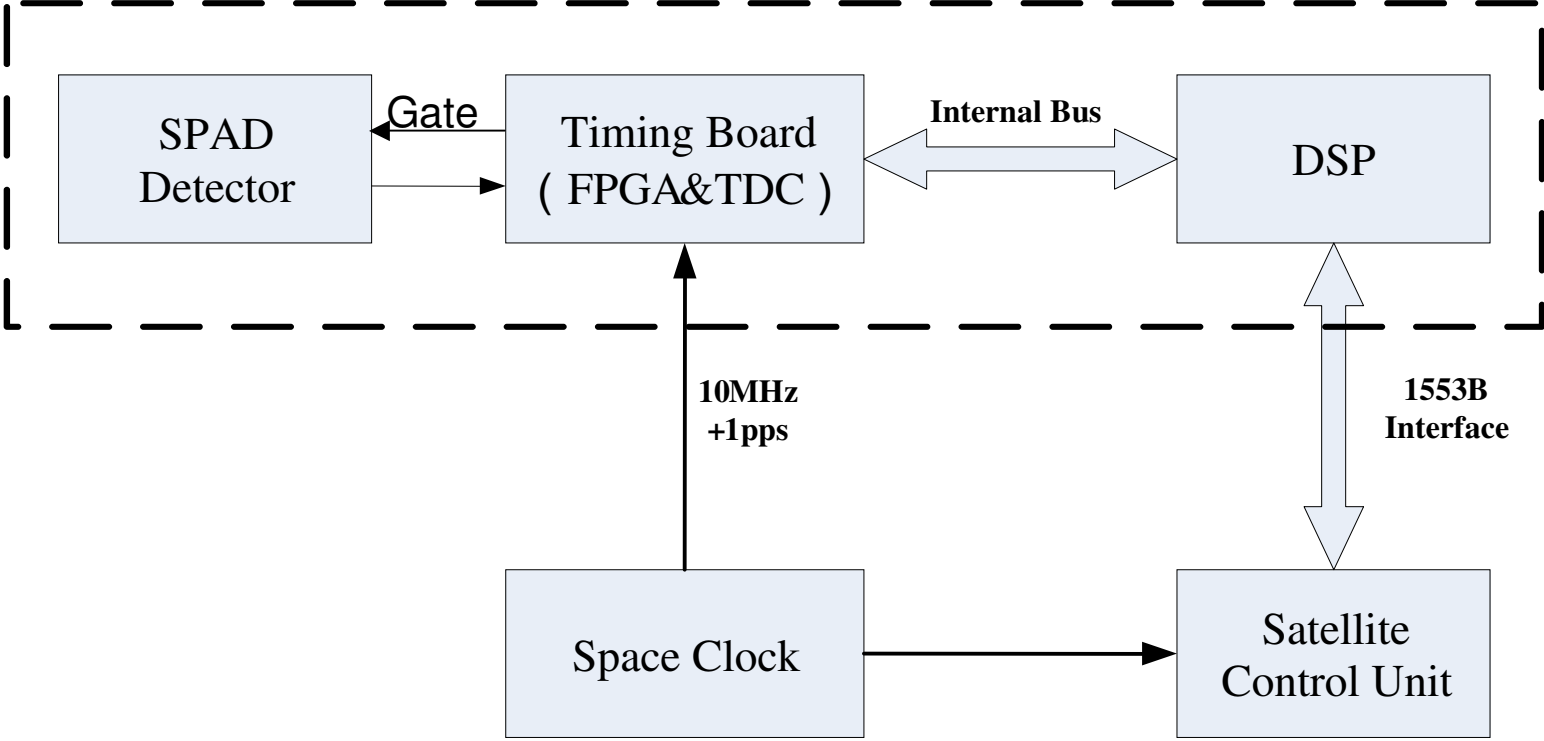
- In Dec. 2007, Shanghai Observatory have successfully actualized Laser Time Transfer (LTT) experiment at Changchun SLR station (60 centimeter aperture telescope) for **CompassM1 satellite (altitude 21,500km)**.
- Based on above experiment, some improved technologies is applied, such as **gate mode adopted, 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

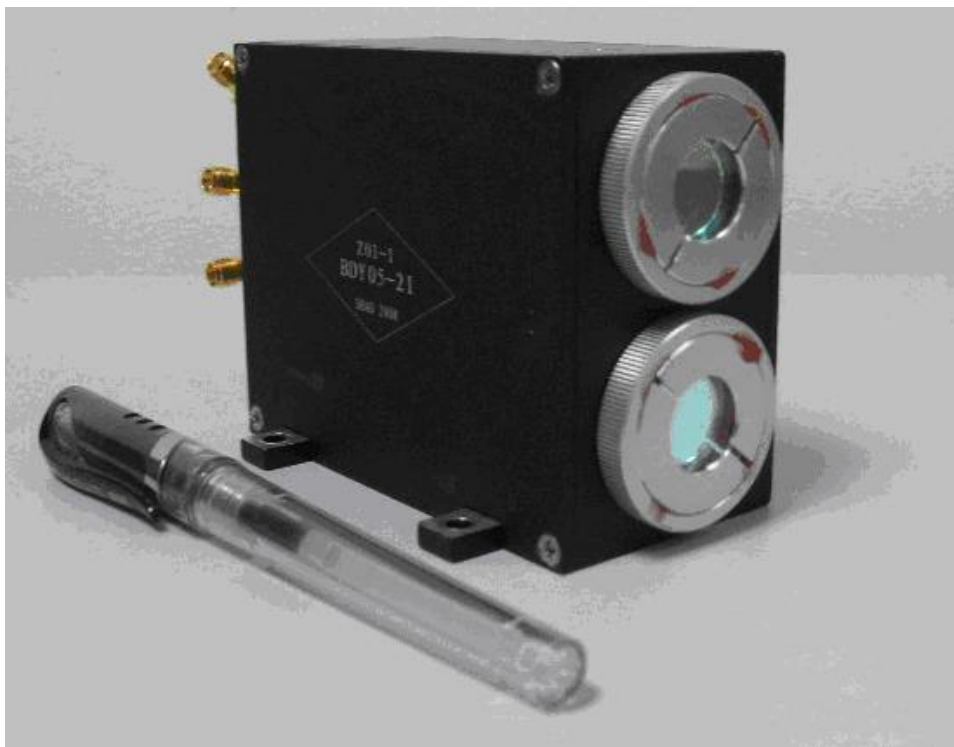


$$\Delta T = \tau'_{uplink} - T_G - T_S$$

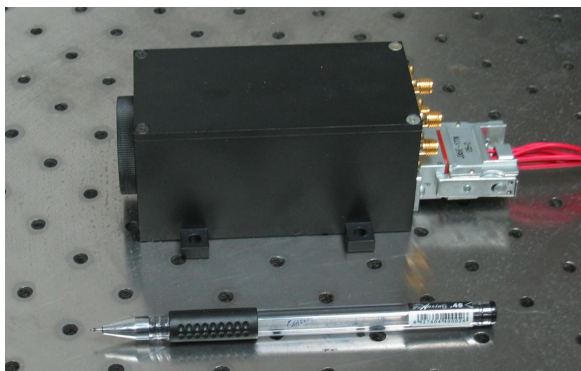
Block Diagram of New LTT payload



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



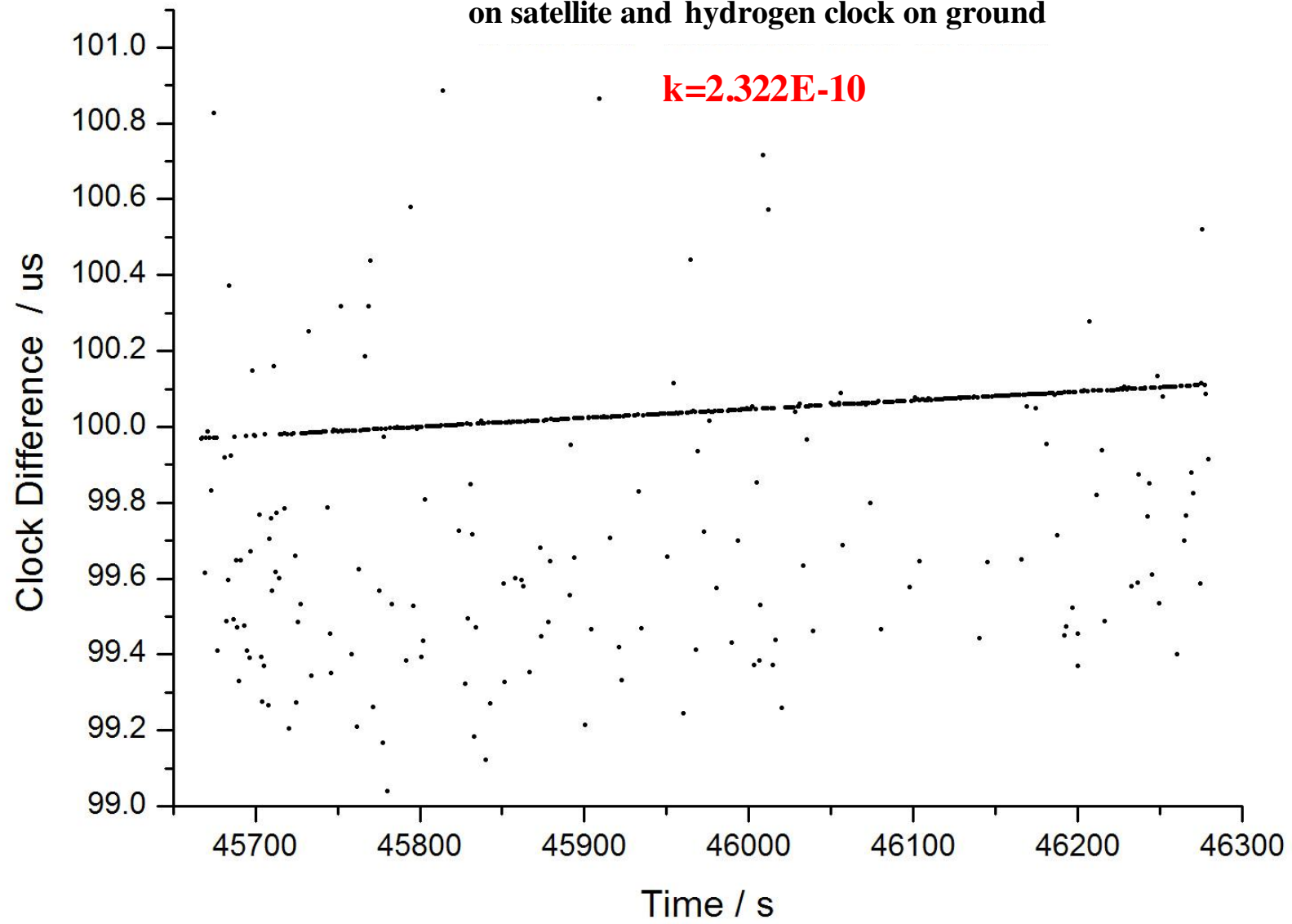
Laser fire time control

- 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/controlled 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.

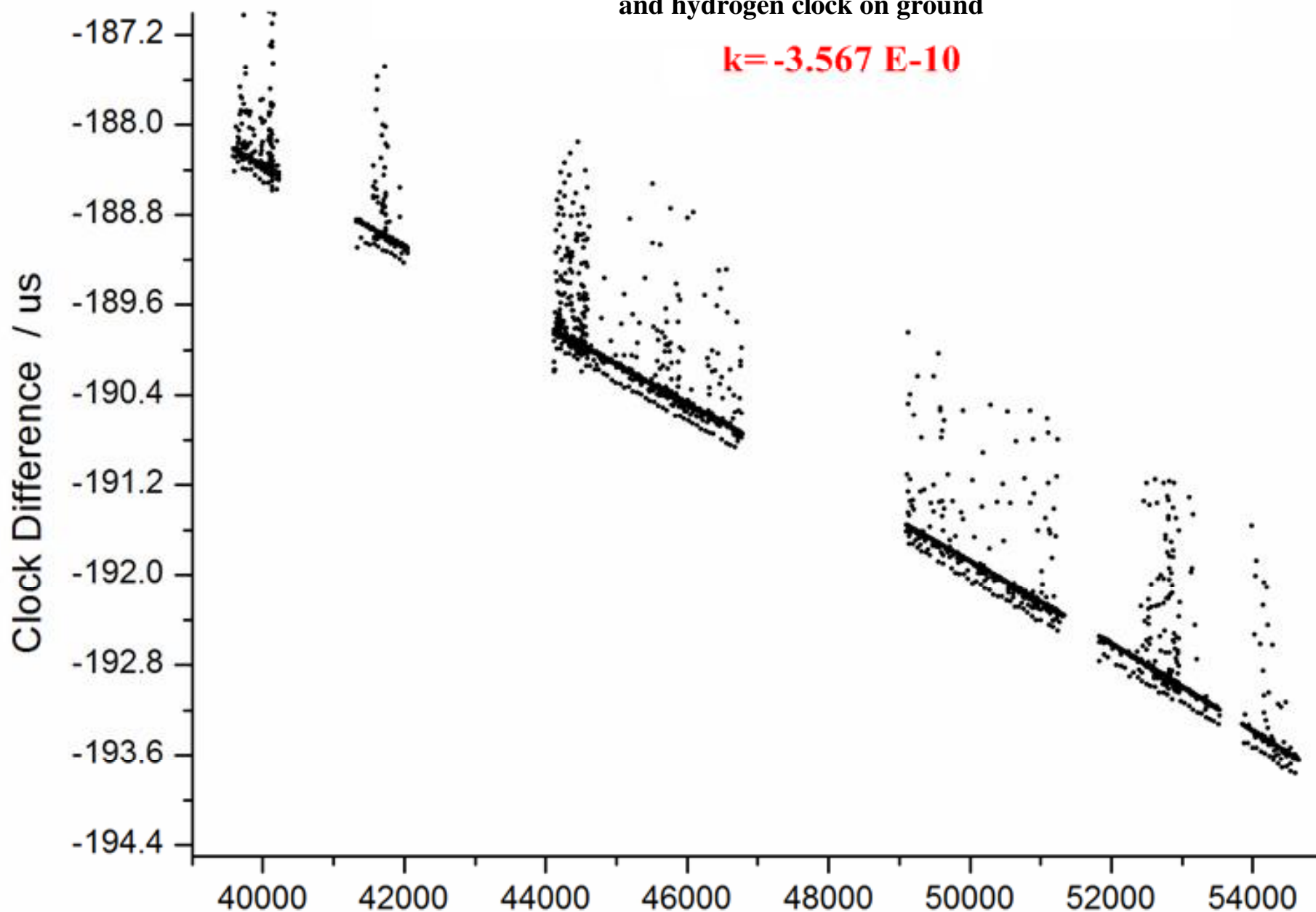
LTT Results

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



2010.09.22 Results of Clock Difference between **Clock B** on satellite
and hydrogen clock on ground



Conclusion

- The dedicated Compass SLR system has been playing 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!