Improvement and New Results of the Laser Time Transfer on MEO satellites

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Goals of Laser Time Transfer (LTT)

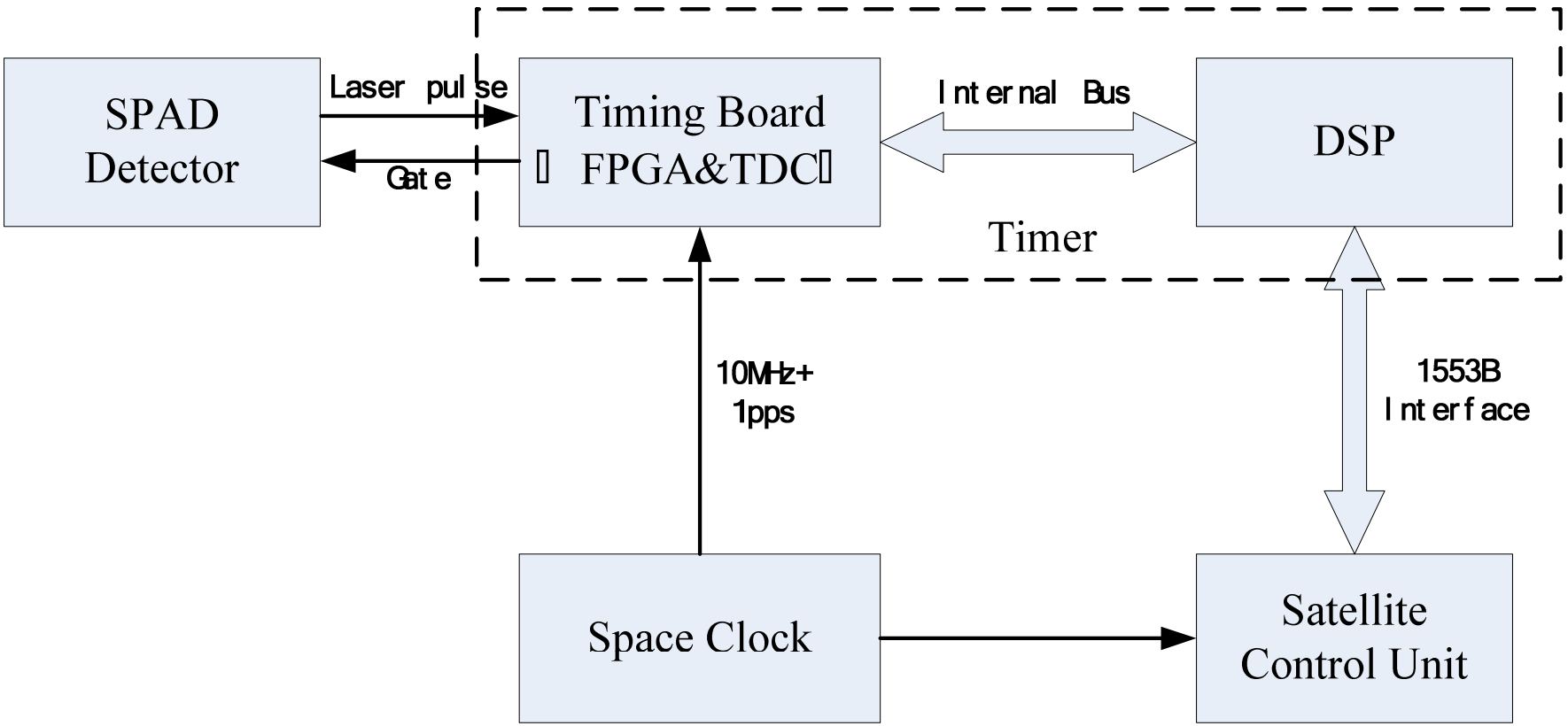
- **Evaluate the performance of the space rubidium clocks with respective to the ground hydrogen maser, dedicated for the Compass system**
- **Testing of the Relativity theory**

LTT Payloads onboard Chinese Navigation satellites

- **April 13, 2007** The first LTT payload onboard the COMPASS-MEO (altitude 21500km) was launched, and LTT experiment started.
- **Aug 1, 2010** The second new LTT payload onboard the COMPASS-IGSO1(altitude 36,000km) was launched, and obtained the LTT data at the first attempt
- **April 10, 2011** The third LTT payload onboard COMPASS-IGSO3 was launched
- **April 30, 2012** The fourth LTT payload onboard COMPASS-MEO3 was launched (altitude 21500km)

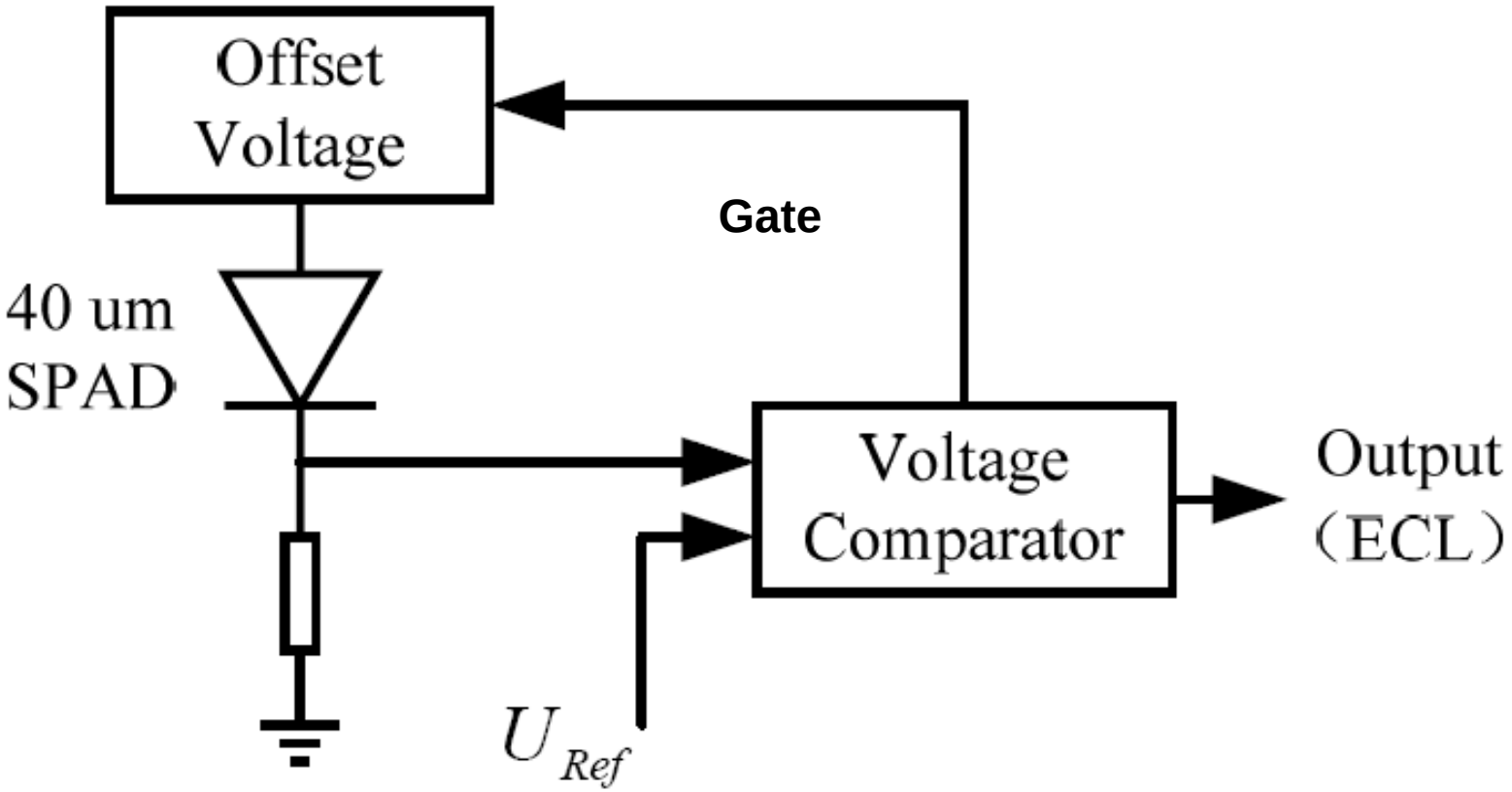
Design of New LTT Payload

- **Detector LTT payload design**
  - Simply designed
  - Single photon sensitive
  - Radiation resist
  - Cold and hot vacuum environment
  - Low noise
- **Improvement**
  - Gate/Un-gate Mode
  - Two Channel
  - Two FOV
  - Narrow bandwidth filter



Block Diagram of LTT Module

Diagram of Laser Detector

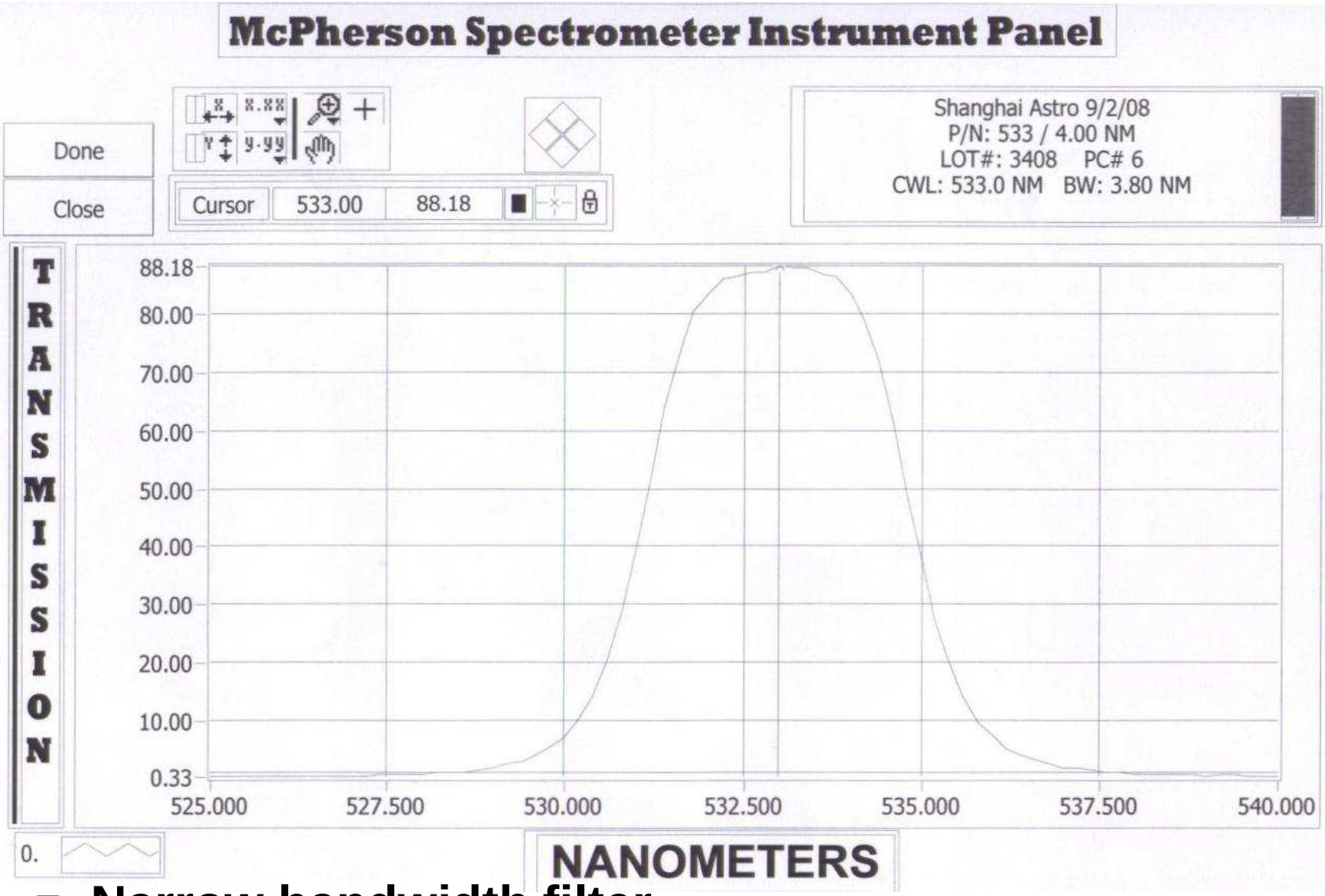


Silicon K14 SPAD (QE 20-30%, radiation resist)
Gate/Un-gate circuit -- to reduce the effect of the dead time of SPAD when the noises are strong.

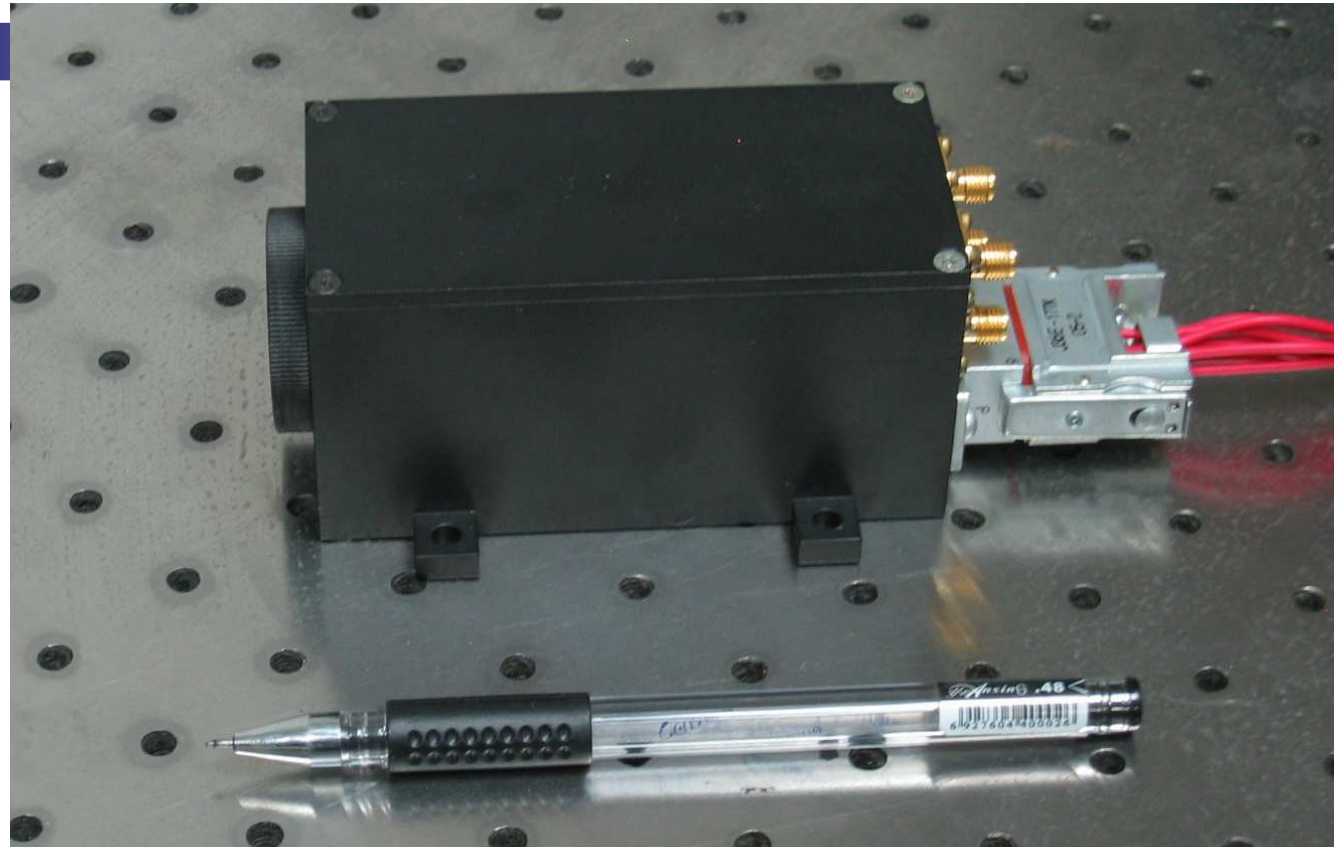
Design of New Detector

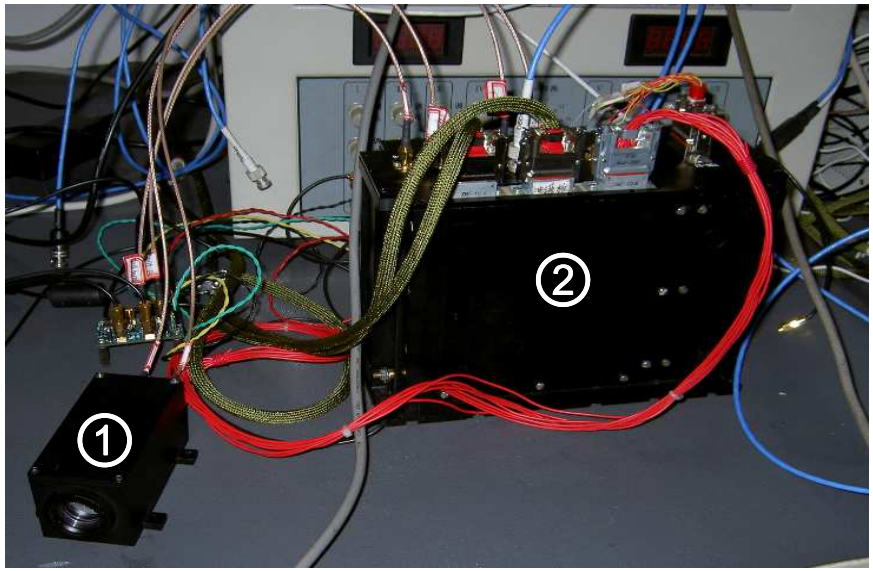
- **Field of view**
  - **MEO3 23°/17°**
  - **The OLD MEO 28°**
  - **The bigger one is for nighttime (low noise) experiment, the smaller is for daytime (high noise) experiment (but to be restricted to *laser track* IGSO satellites in daytime).**

	IGSO			MEO		
Altitude (°)	90	50	30	90	50	30
Incidence angle (°)	0	5.55	7.48	0	8.45	11.42
Slant range (km)	36000	37264	38837	21500	22686	24129



- **Narrow bandwidth filter**
  - **BARR Associates, Inc. -- Diameter 25mm**
  - **Bandwidth 3.8nm --Transmittance >75% at 532nm**
  - **The OLD MEO Bandwidth 8nm**



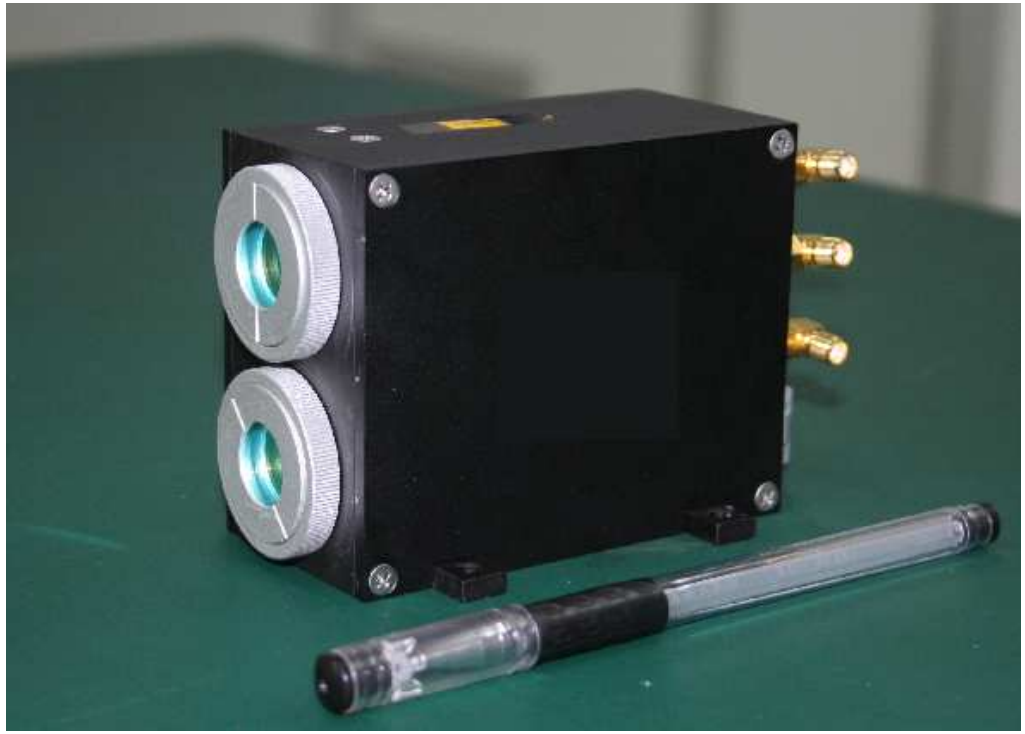


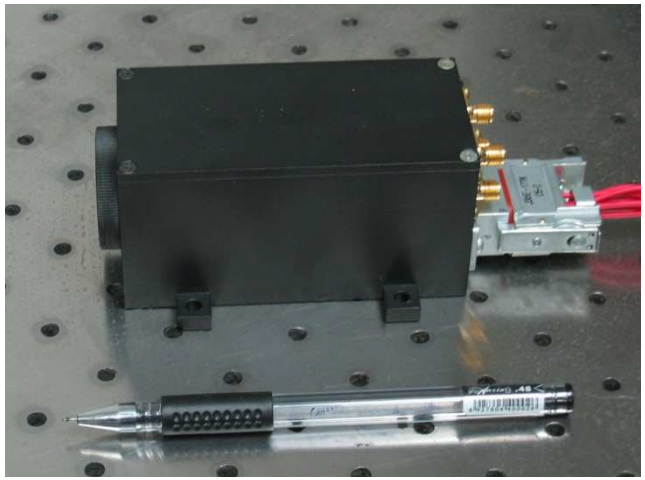
Dual-SPAD detector

(for COMPASS-MEO):

300g, <1W, 105×70×50mm

Field of View: 28°, 8.8nm bandwidth filter





New LTT Detector

- **New Dual-SPAD detector**

(for IGSO1/IGSO3/MEO3)

500g, <2W,105×70×80mm

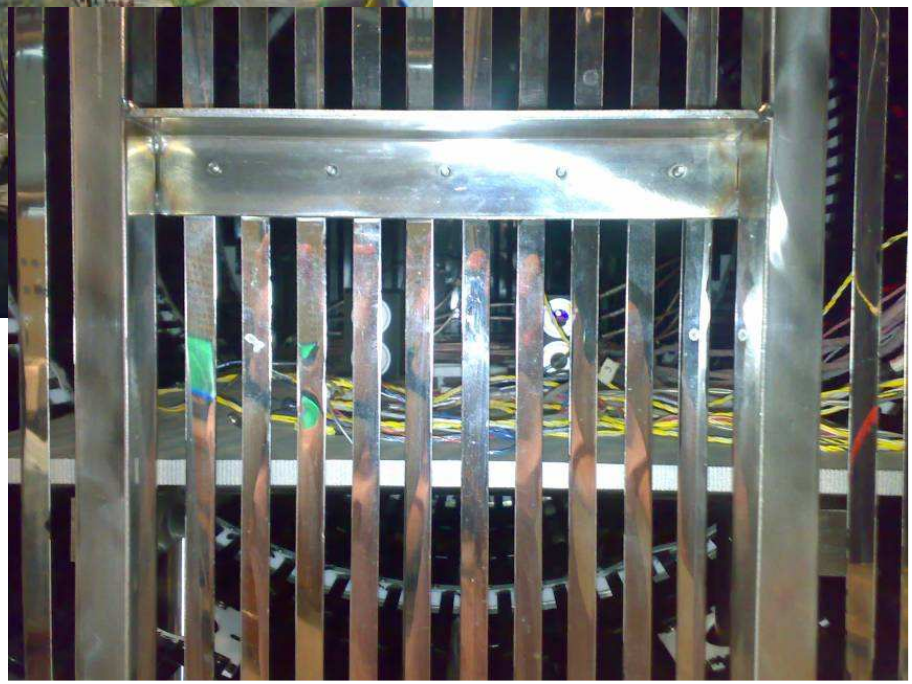
Two Field of View:

15°/ 11°for IGSO,

23°/17°for MEO,

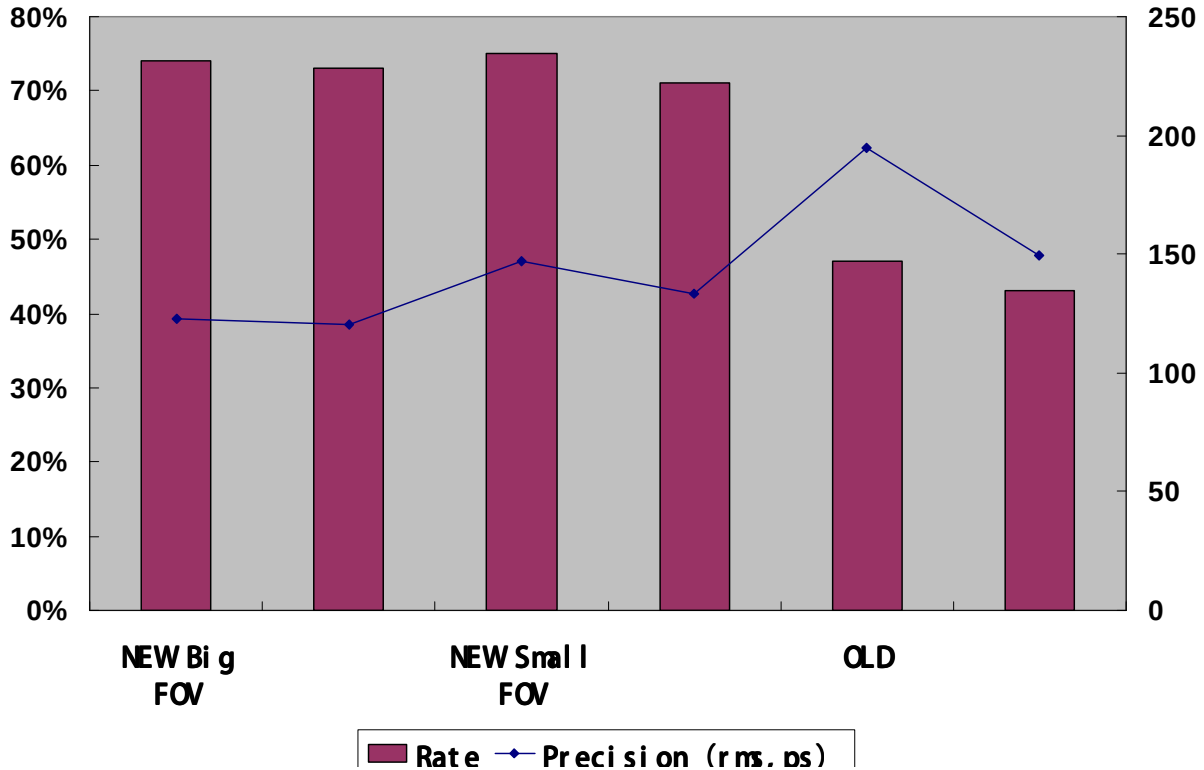
4nm bandwidth filter

Gate/Un-gate mode



vacuum experiment

Detector	Precision (rms,ps)	points	Rate
NEW Big FOV	123.1	458	74%
	120.2	437	73%
NEW Small FOV	147.2	389	75%
	133.1	409	71%
OLD	194.7	442	47%
	149.5	667	43%



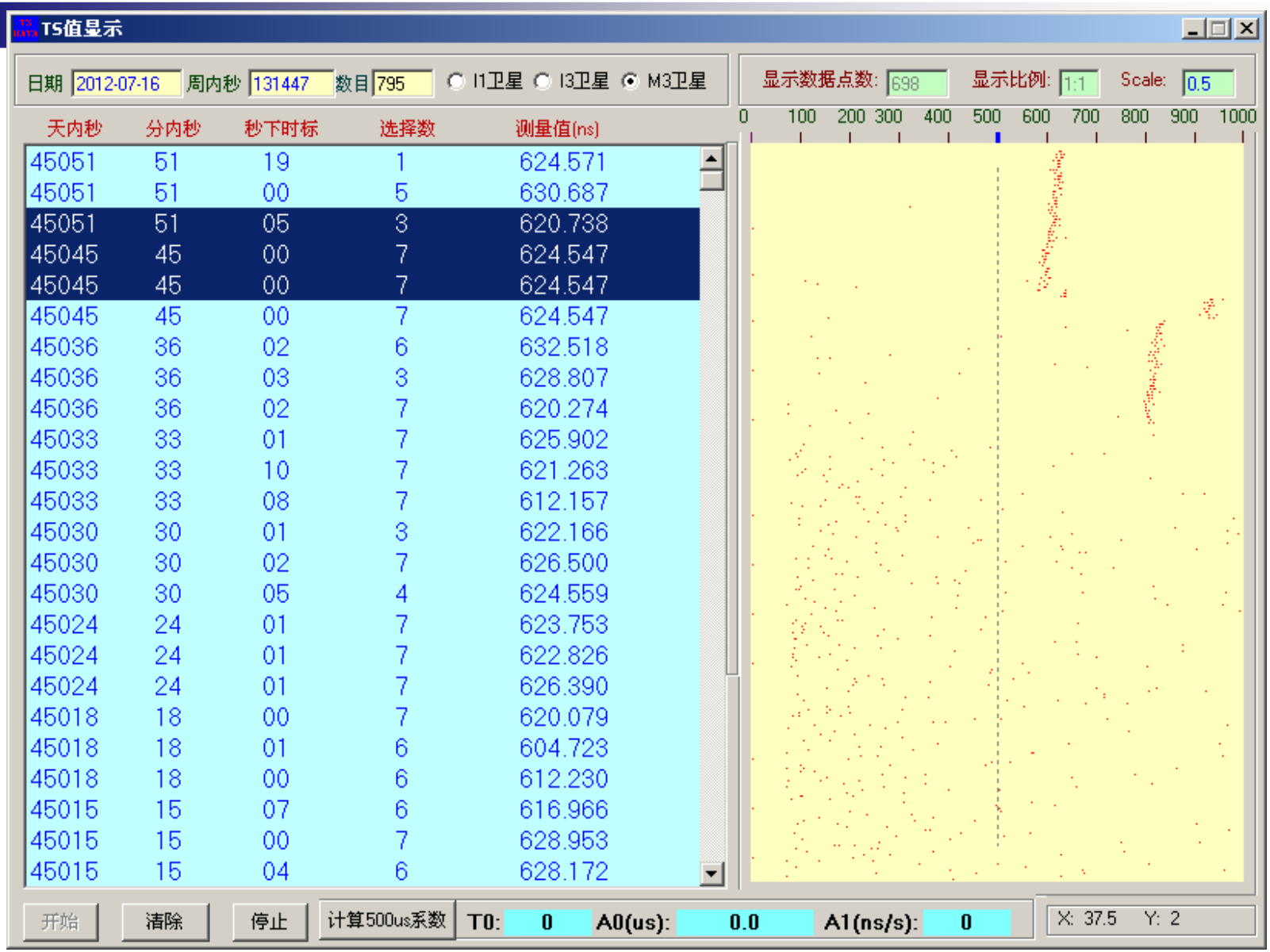
Specifications of Compass Dedicated SLR Station

- **Receiving telescope : 1000mm**
- **Transmitting telescope: 300mm**
- **Active-active mode-locked Nd:YAG laser: 150mJ@532nm, 250ps pulse width; 20Hz**
- **Targets：GEO/IGSO/MEO, 20000km-40000km**
- **Ranging precision :2~3cm**
- **Daylight tracking capability, up to GEO orbit**
- **Used for Laser Time Transfer**

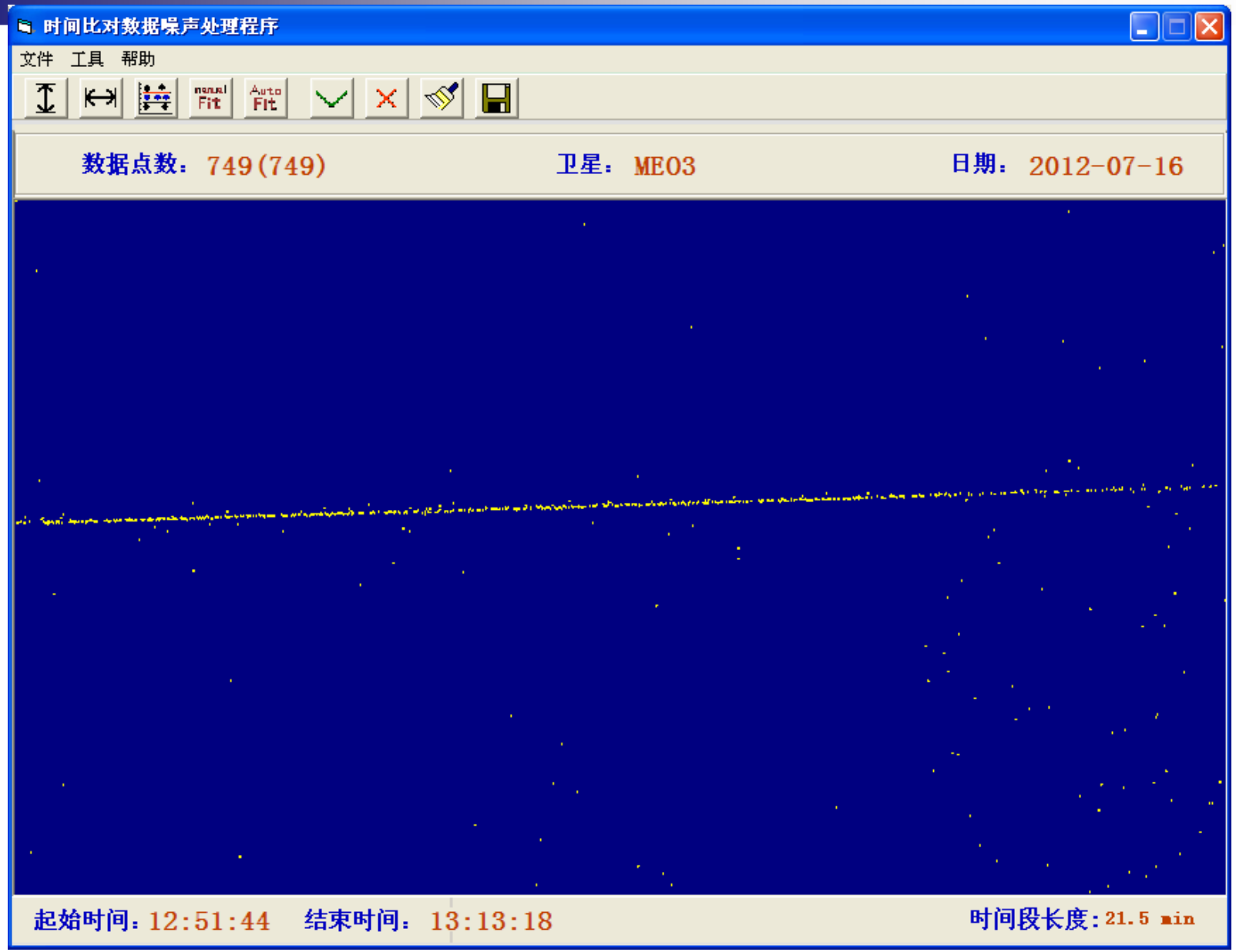
Designed and built by the SHAO during 2006-2009

1 Meter SLR telescope made by Shanghai Observatory

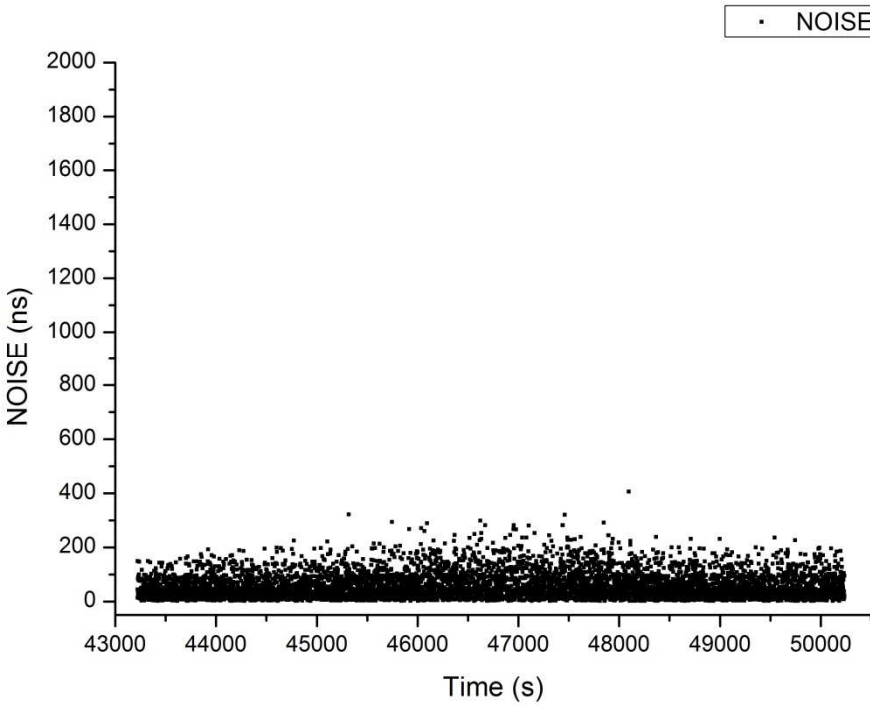
SLR Real-time tracking interface for IGSO1 (2010.09.21)

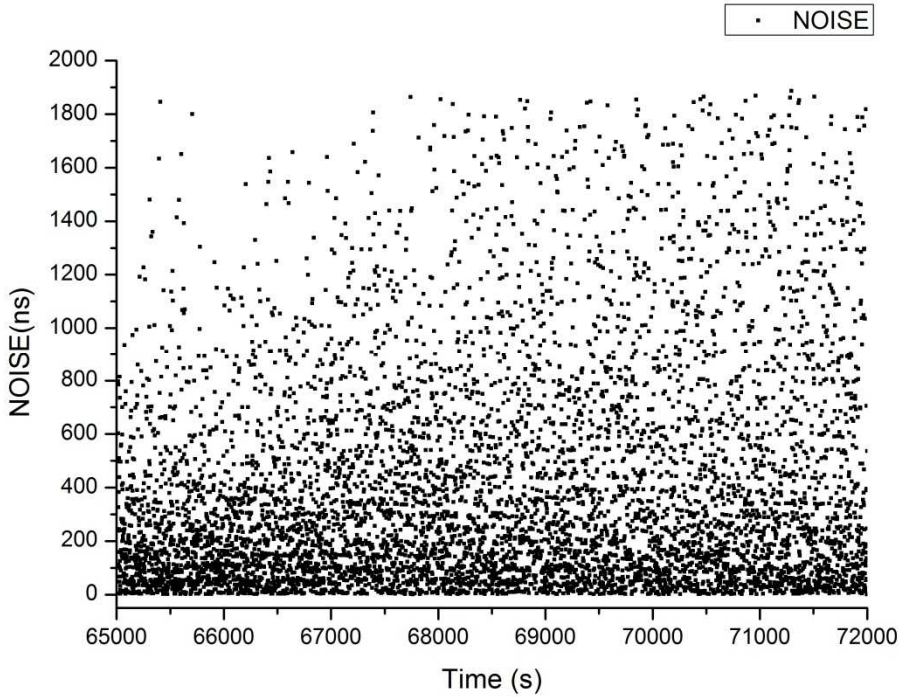


The real time LTT data processing for COMPASS-MEO3

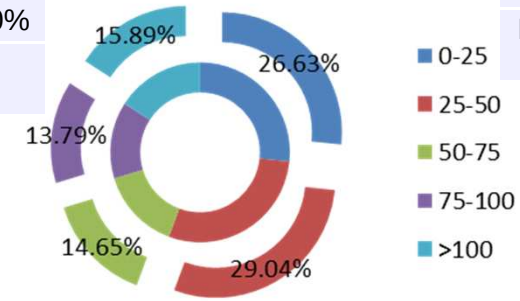


The primary LTT data processing for COMPASS-MEO3



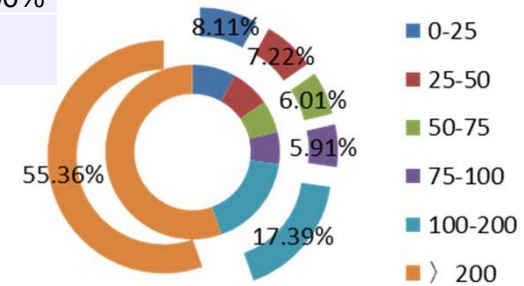


Noise(ns)	Points	Rate
0-25	1805	26.63%
25-50	1968	29.04%
50-75	993	14.65%
75-100	935	13.79%
>100	1077	15.89%
total	6778	100.00%
Mean of noise	58.65ns	



Noise of Compass-MEO

Noise(ns)	Points	Rate
0-25	935	8.11%
25-50	832	7.22%
50-75	693	6.01%
75-100	682	5.91%
100-200	2005	17.39%
〉200	6384	55.36%
total	11531	100.00%
Mean of noise	396.58ns	

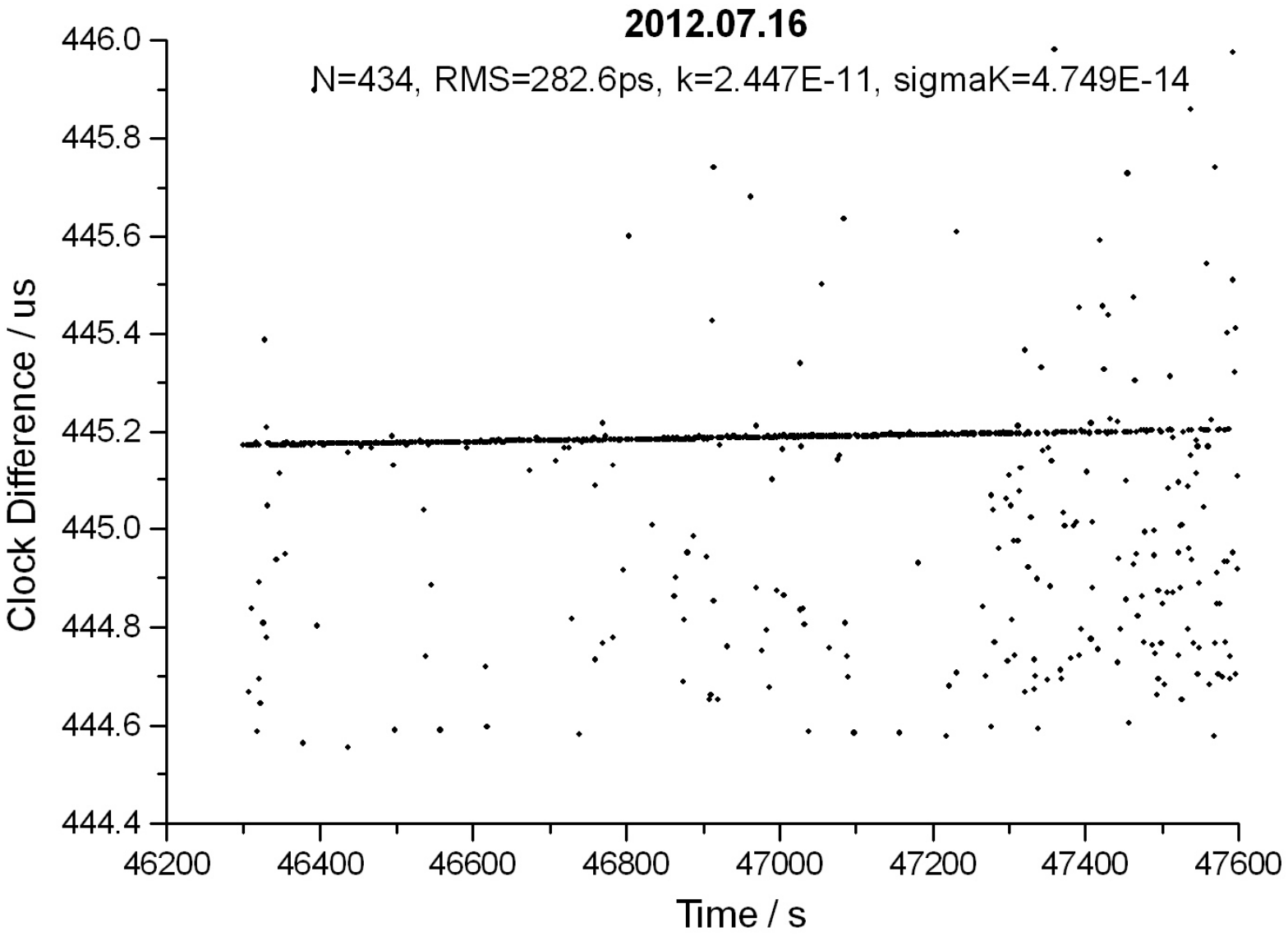


Noise of Compass-MEO3

The comparison of the LTT experiments' results

Satellite	Date	Time(minutes)	Points	Rate	Situation
COMPASS-MEO	2008-1-10	31	827	44.46%	Inside the Earth's shadow
	2008-1-10	88	326	6.17%	Outside the Earth's shadow
COMPASS-MEO3	2012-7-16	21	434	34.04%	Outside the Earth's shadow

Results of LTT Experiment (Compass-MEO3)

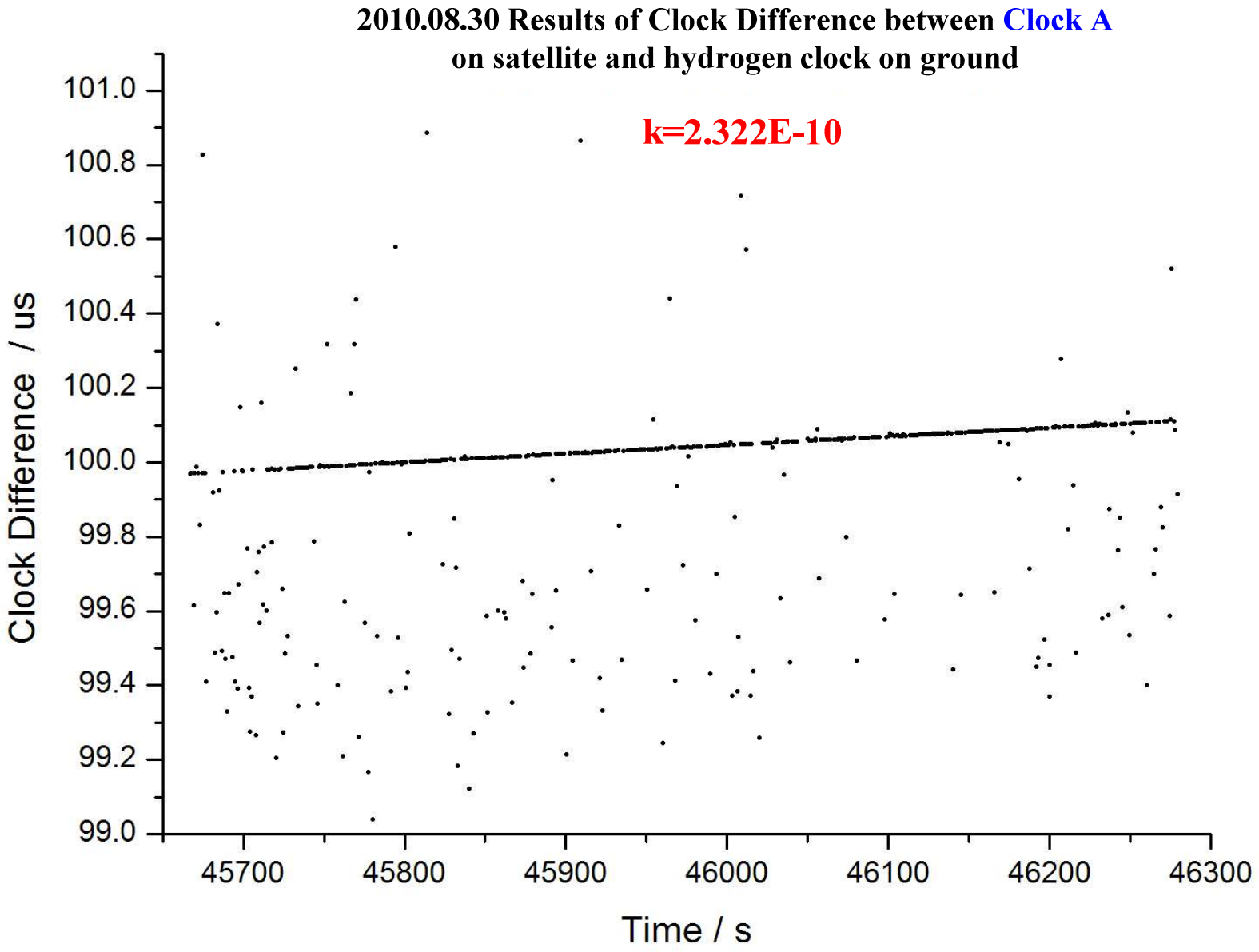


Summary

- Some improvements were made for new LTT Detector , such as gate mode increased , two different FOV used, etc.
- LTT experiment on Compass MEO3 was successful carried out at the precision of better than 300ps. The frequency drift and stability are about 2.447E-11 and 4.749E-14 respectively.
- The LTT design improvement makes the noise much lower, the detection rate much bigger, and the experiment much efficiency.
- 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

Results of LTT Experiment (Compass-IGSO1)



Results of LTT Experiment (Compass-IGSO3)