Shanghai Astronomical Observatory
Chinese Academy of Sciences

Developments of Chinese SLR network and future plans

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Outline:

1. Introduction

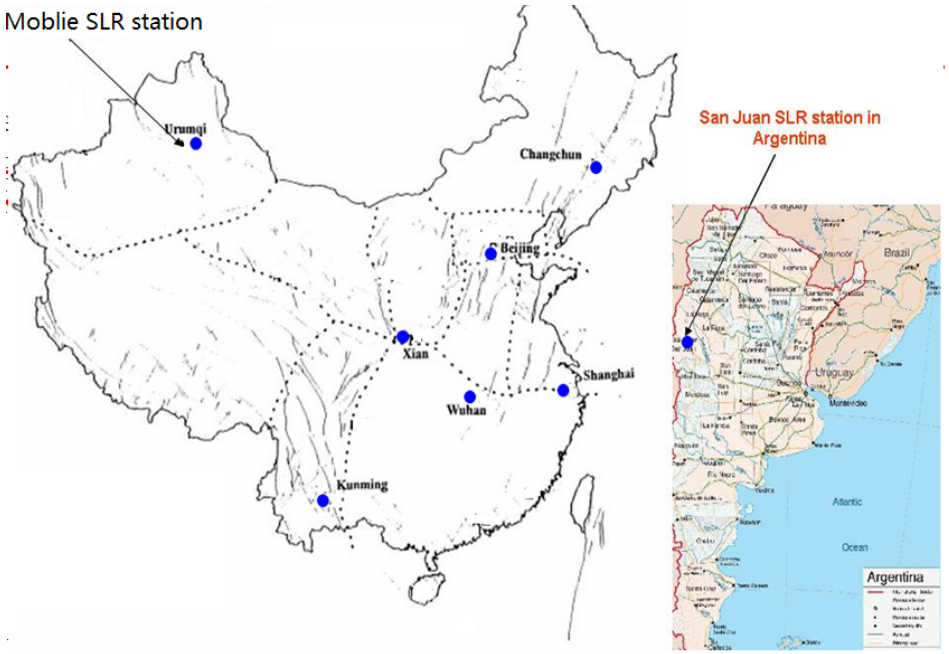
2. Updating SLR systems of Chinese SLR network

3. Developments of SLR technologies

4. Future plans

1. Introduction

- Chinese SLR network includes **Shanghai**, **Beijing**, **Changchun**, **Kunming, Wuhan**, **SanJuan** and **a mobile site.**



- Shanghai, Beijing, Changchun **with 0.6 m aperture receiving telescope**, Wuhan **with 1 m telescopes replacing the 0.6m** one and Kunming **with a 0.5 m telescope, replacing the 1.2 m one**.

- SanJuan station was installed **with 0.6m telescope** in Argentina in 2005 as part of a cooperative effort between the two countries.
  - ➢ This station makes the good distribution for Chinese SLR network and also ILRS network.

1. Introduction

1. Introduction

- Since 2009, a national project had been initiated and the Chinese SLR network were obtained strong supports, equipped with 1 kHz, 1 mJ 532nm, ps-lasers, C-SPAD detector and Event Timer for 1 kHz routine SLR, replacing the 10Hz repetition rate one.
- The performances (ranging precision, passes of data, measuring ability, etc) of Chinese SLR network were significantly increased after updating system.
- And one set of a mobile SLR system with the 1m aperture was built and operated by Institute of Seismology, CEA.

Mobile TROS1000 SLR system with 1m telescope

Outline:

1. Introduction

2. Updating 2kHz SLR in Chinese network

3. Developments of SLR technologies

4. Future plans

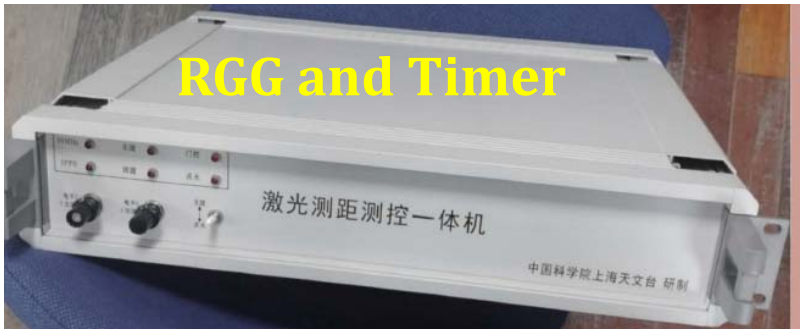
2. Updating 2kHz SLR in Chinese network

- Obtaining the supports from the national project, the upgrading Chinese SLR network are being made.
- The main goal is to achieve to 2kHz day-night SLR and the better performance, such normal point RMS of Lageos, short term and long term stability, will be also realized.
- In this project, one cabin-based SLR system with 1m receiving telescope is being built and operated by Chinese Academy of Surveying & Mapping.

Cabin-based SLR system with 1m telescope

2. Updating 2kHz SLR in Chinese network

- The specifications of laser unit:
  - Pulse energy: 2mJ@532nm
  - Frequency rate: 2kHz
  - Beam quality(M2): ＜1.2
  - Pulse width: ＜50ps



Daylight camera

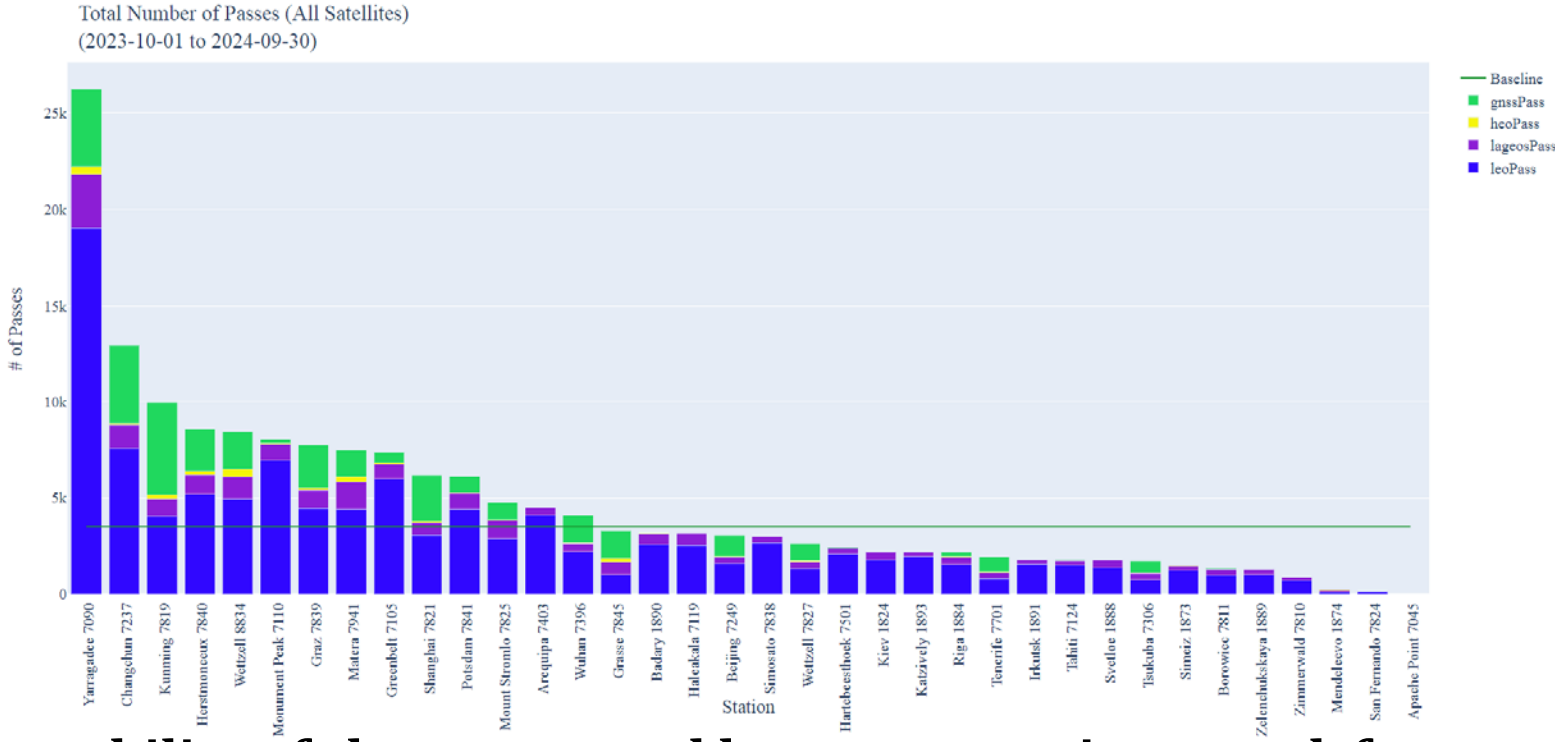
- RGG: self-developed by FPGA
- Detector: C-SPAD or APD (200um)
- Daylight packages: 0.2nm filter, sCMOS for daylight beam
- High quality of signal cable for decreasing the variable of system delay.

2. Updating 2kHz SLR in Chinese network

- **Shanghai and Changchun stations have realized 2kHz routine day-night SLR measurements.**
- **The total passes of observations from Kunming and Wuhan are significantly increased after the updating system.**
- **At the end of this year, all stations will accomplish the upgrading goals.**
- **SanJuan station is also in the process of being upgraded with the support of the Changchun station.**

2. Updating 2kHz SLR in Chinese network

- The total passes of Changchun and Kunming site are ranked at second and third in the global network in past one year.



- The NP RMS of Lageos, stability of short term and long term are improved, from ＞2mm , ＞16mm , ＞ 10mm to <1.5mm , ＜15mm , ＜ 8mm.

- Further improving works, such as the calibration, stability of equipment, data process etc. will be still done in order to get better performances.

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3. Developments of SLR technologies

The major technologies of Chinese SLR network are focusing on:

1) Developing higher repetition rate SLR system.

2) High precision Laser Timer Transfer (LTT) for CSS.

3) Lunar Laser Ranging and Laser Ranging/LTT to lunar satellites.

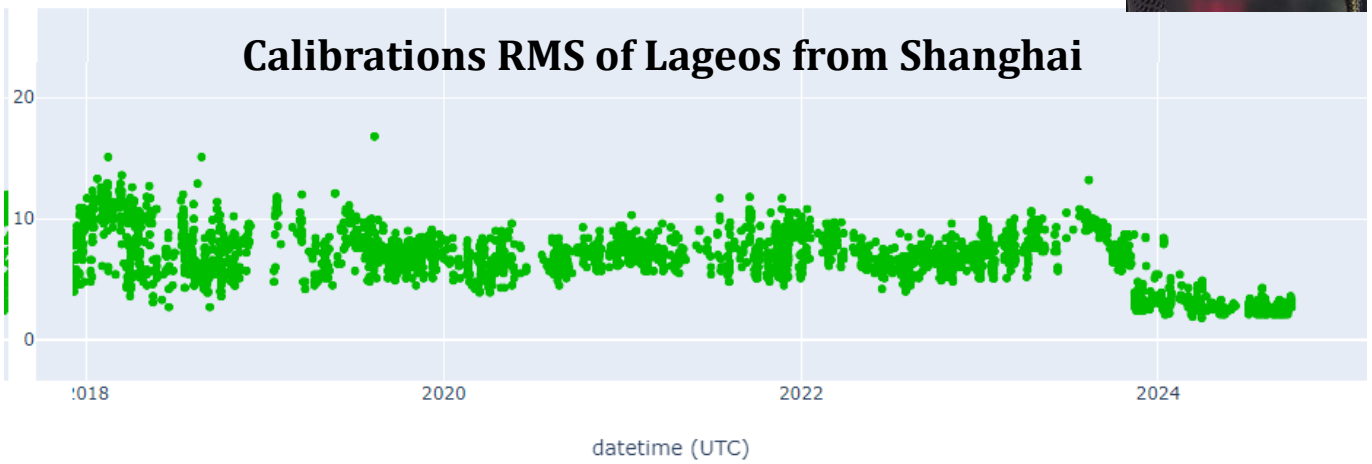
4) Developments of DLR in daylight.

3. Developments of SLR technologies

1) Developments of high repetition rate SLR system

- **Shanghai station updates SLR system for 5kHz routine measurements since Nov. 2023.**
  - **Laser unit is made by the homemade company, 5kHz repetition rate,532nm wavelength, 1mJ pulse energy, 18ps pulse width.**
  - **APD detector with chip size of 200um is used, time jitter of＜50ps, low dark counts.**
  - **Software updating for fast data processing.**

- **Calibration RMS: 2~3 mm;**
- **Ranging precision of satellites are also increased.**

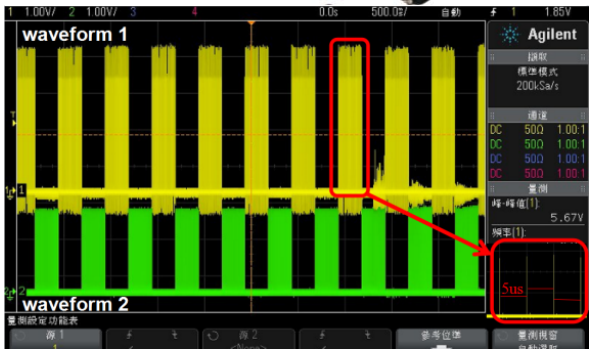


3. Developments of SLR technologies

1) Developments of high repetition rate SLR system

- **100kHz SLR system is being developed in 2024 at Shanghai station with the goal of routine observations.**

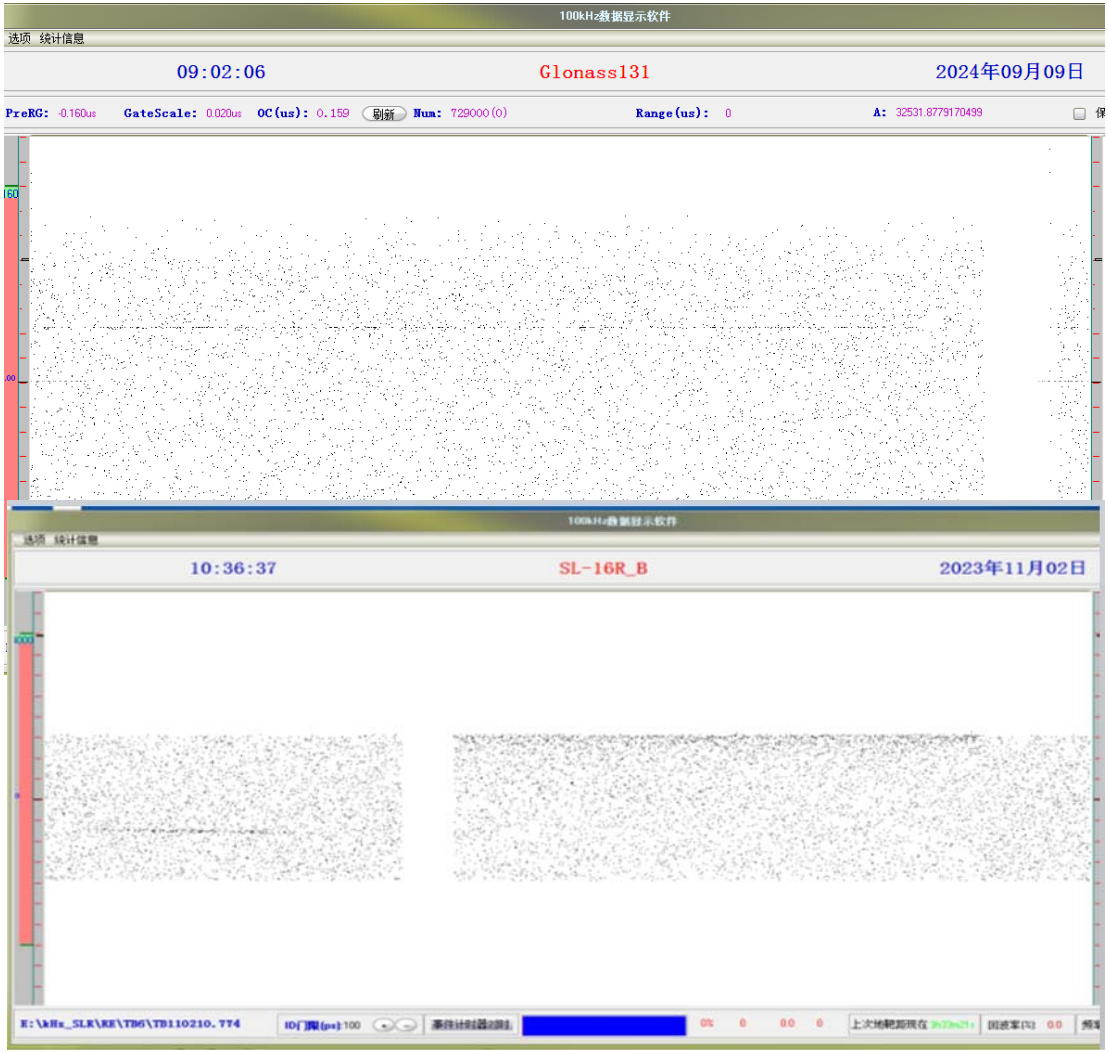
  - **The industrial level Laser unit is also used with the advantages of running stability, good price, easy of operation; 100-300kHz, 532nm, pulse energy of 0.38mJ, pulse width of 15ps.**
  - **MPD detector with the low dark count rate(1 cps), high detection efficiency(49%) is used wth the mode of free running within gate width.**
  - **FPGA gate generator is developed to switch the fire and gate signal according to the range of satellites.**



  - **Updating software at the aspects of fast processing of start and stop echoes, real-time residual display, post-processing, etc.**

3. Developments of SLR technologies

- **SLR measurement(100kHz):**
  - **LEO, Lageos, MEO, GEO satellites, day and night.**
  - **The amount of laser data is over 10 millions for LEO.**
- **DLR measurements(100kHz):**
  - **Distance of more than 1000km, RCS of ＞5 m^2, ranging precision of sub-meters.**
- **Through using this laser unit, one system has the good performance of SLR, DLR and laser frequency of kHz to hundred's kHz.**

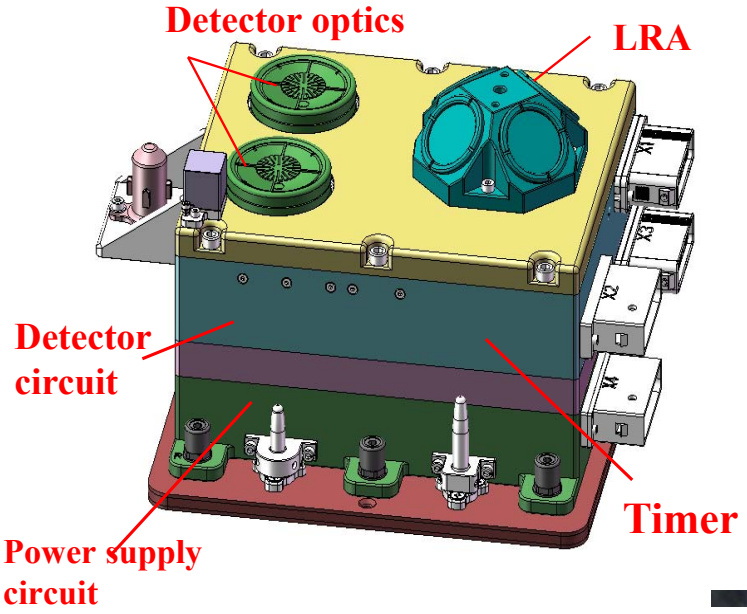


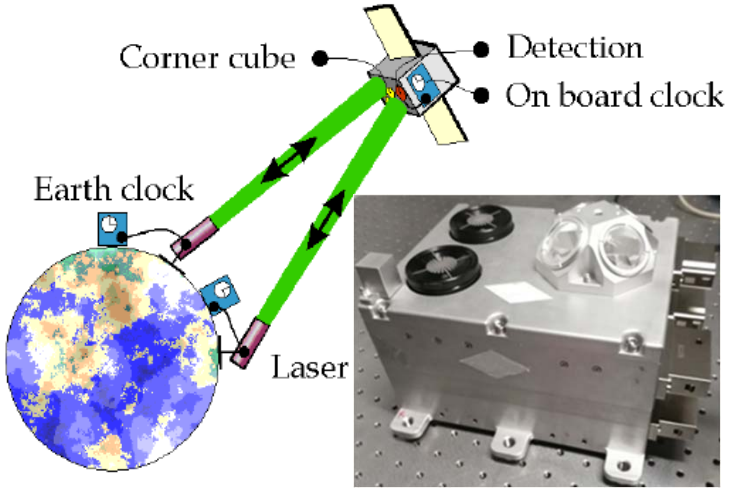
3. Developments of SLR technologies

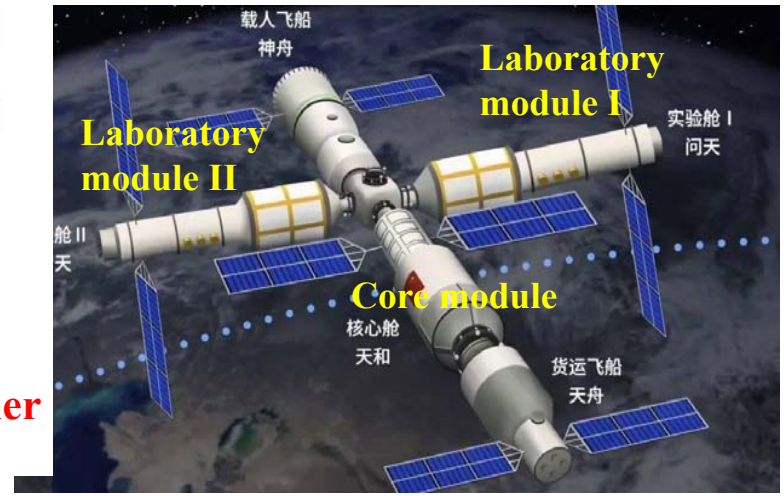
2) High precise LTT measurements of CSS

A LTT payload was developed by SHAO for CSS (Laboratory module I)

- FOV : ~120° (elevation of 20~80 degree)
- Clock reference: 200MHz
- Gate mode: synchronized with 1pps from GNSS receiver.
- Size: 230*190*170mm
- Weight: ~ 6 kg.
- Launched on Oct.30 2023





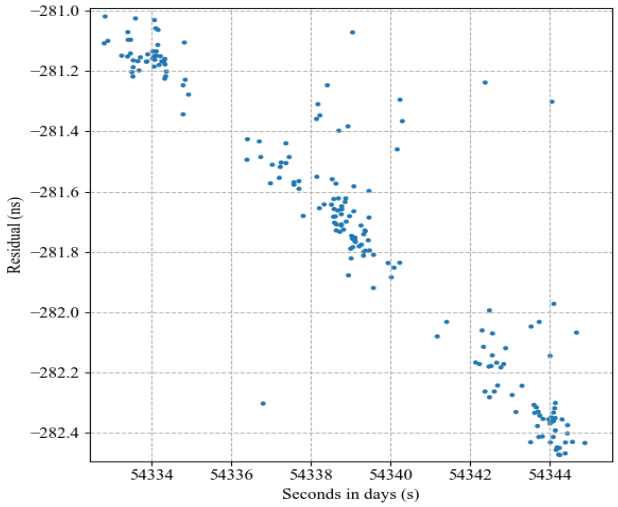


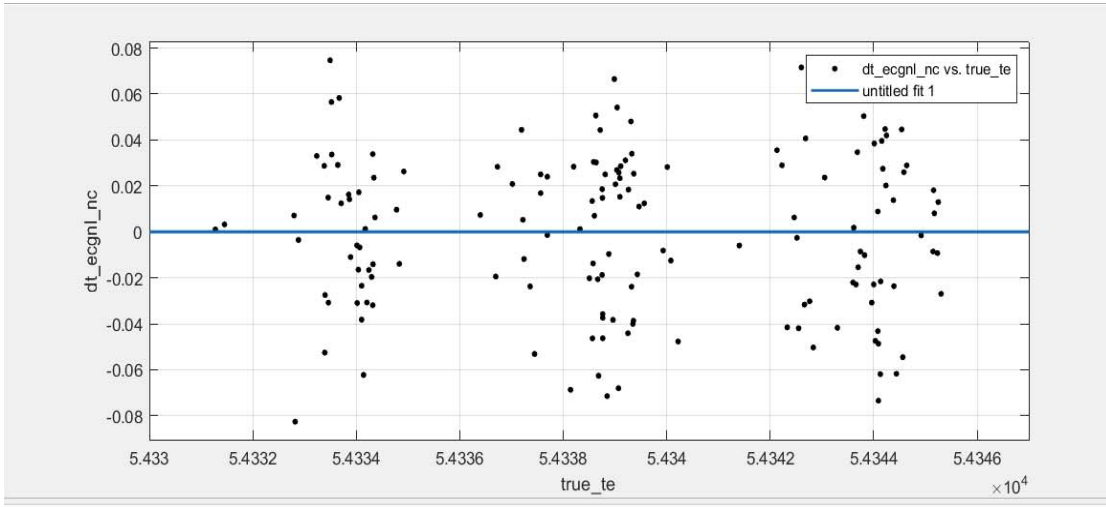
3. Developments of SLR technologies

2) High precise LTT measurements

- LTT measurements at Shanghai station (10kHz, 532nm, 3W, 45ps) on March 13, 2024.
- Measuring precision (RMS) of ~ 35ps between onboard clock and ground GNSS clock.

- The Chinese SLR stations will plan to perform LTT measurements.

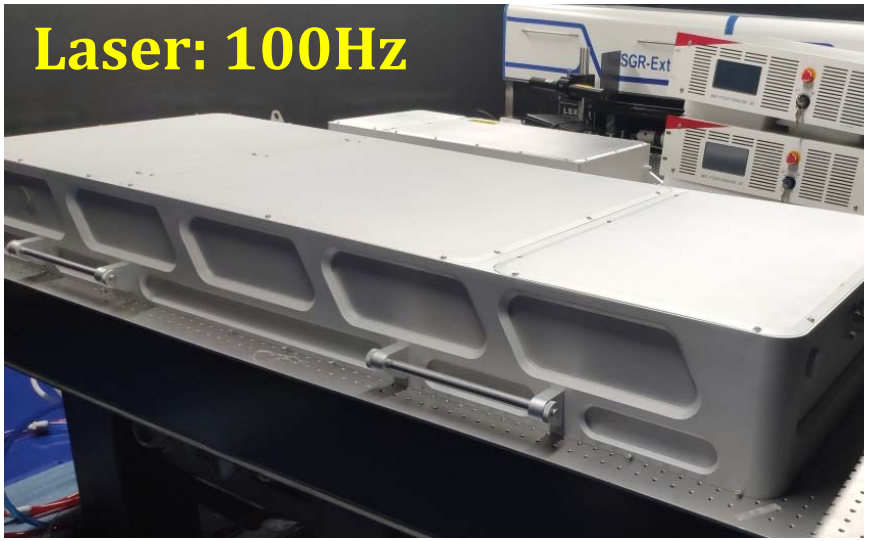


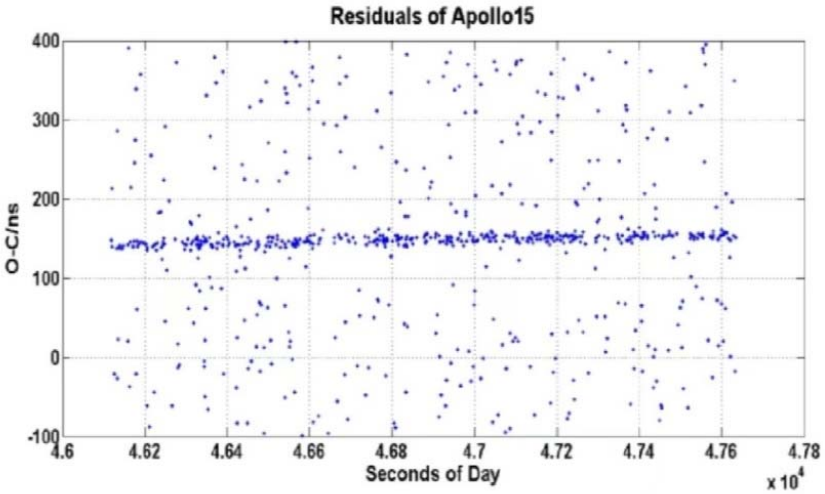


3. Developments of SLR technologies

3) Lunar Laser Ranging(LLR)

- **Kunming station has firstly realized the LLR measurements in 2018 in China by using 1.2m telescope by the laser unit with 10Hz, 3J, 532nm, ns pulse width**
- **And 5 Moon-LRAs were successfully measured.**





- **The new laser with 200mJ@1064nm, 100Hz, 80ps is updated, made by Aerospace Information Research Institute(AIRI), CAS.**

3. Developments of SLR technologies

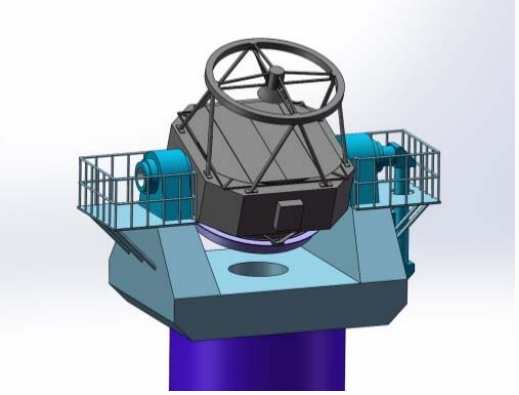
3) Lunar Laser Ranging(LLR)

In addition,

- **Sun Yat-Sen university, collaborating with Yunnan Observatory, built a LLR system (laser unit made by AIRI) with1.2m telescope in 2019 in Zhuhai city and 5 Moon-LRAs were measured.**

- **National Astronomical Observatory (NAO) is developing LLR system with 2.5m receiving telescope in the north-eastern China, collaborating with Changchun station.**

- **Purple Mountain Observatory (PMO) is also developing LLR system with 2.5m telescope, collaborating with Shanghai Observatory and Nanjing astronomical instruments company, and will be finished at the end of 2025, located in the site of west China at the altitude of 4300m.**



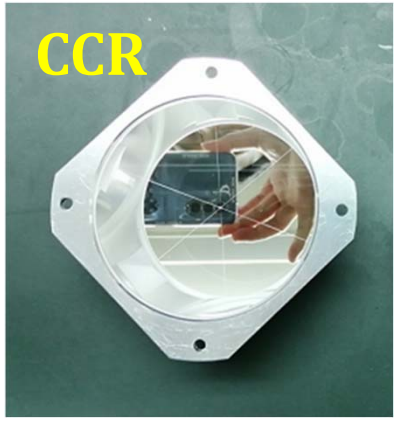
PMO, 2.5m telescope

3. Developments of SLR technologies

3) Laser ranging / LTT to lunar satellites

- 100mm CCR by SHAO for Tiandu-1 lunar satellite launched in March of 2024.
- CAS-1 lunar satellite with the same LRA and LTT payload also by SHAO was launched in March of 2024.

  - LRA with the aperture of 100mm
  - LTT payload with two channels of 532nm / 1064nm, the total weight of 2.2kg, and the power consumption of less than 22W.



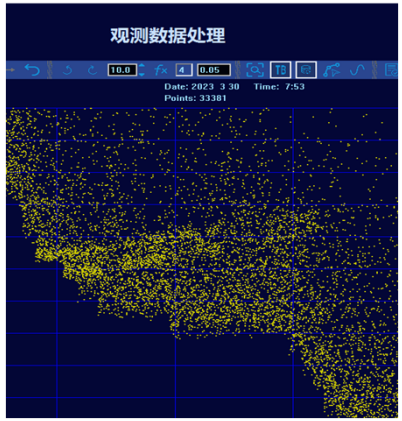
- Kunming station and Zhuhai station will perform two-way laser ranging and one-way LTT.
- Shanghai station and others will perform one-way LTT.

3. Developments of SLR technologies

4) Developments of Debris Laser Ranging(DLR)

- **Ps-laser tracking debris:** Shanghai station implemented DLR by using ps-laser unit with 1.2W power and 1.2m telescope at the altitude of 3200m.

➡ Validation of ability of ps-laser tracking debris and sub-decimeter precision .



- **Daylight DLR: Changchun station** developed a 1064nm detector for DLR and has the test results in daylight by using 1.2m telescope.

- **Tracking small size of debris:** Kunming station has realized the observation of debris with RCS of 0.046m^2@1000km (SNSPD detector).

- Wuhan and Beijing stations are developing DLR technology to enhance the regional DLR network.

3. Developments of SLR technologies

5) The dedicated SLR systems

- **Collaborated with the Chinese SLR stations, the dedicated SLR system were developed.**

➢ **National Time Services Center, CAS, built two sets of dedicated LTT system with 0.4m telescope and one set of SLR system with 1.05m telescope, collaborated with Shanghai station.**

➢ **Will join in the Chinese SLR network.**

- **The dedicated SLR system for tracking Beidou satellites**

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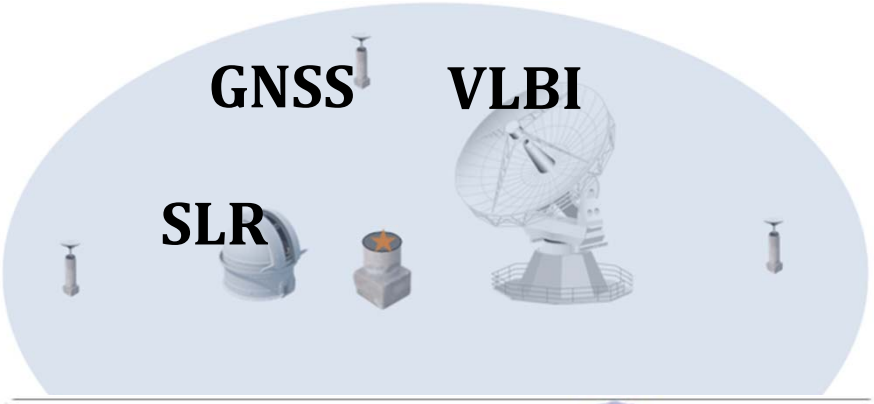
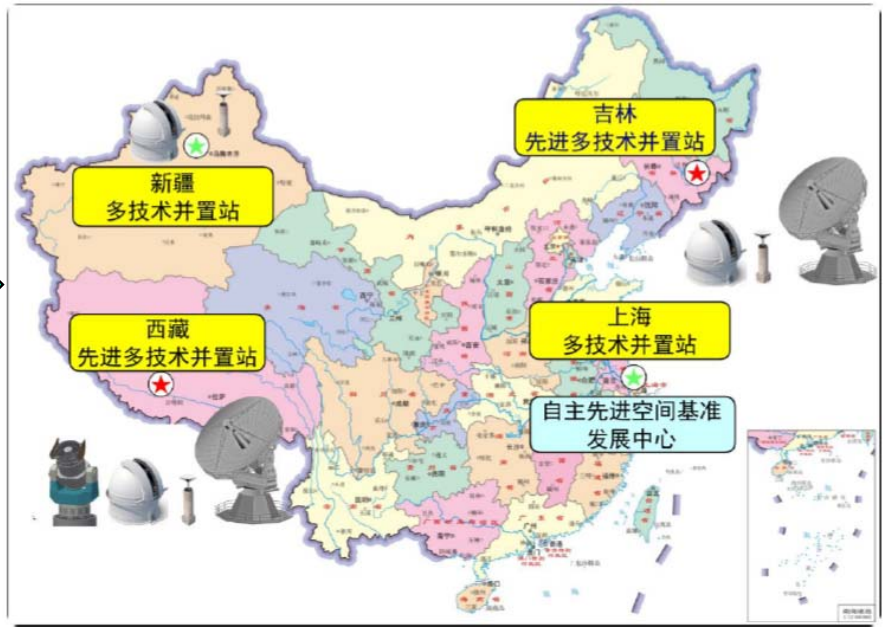
1) New SLR stations

- Shanghai Observatory has a project of supporting to build three co-location sites of geodesic observation system (VLBI, SLR and GNSS).
- One set of 1.5m telescope and two sets of 0.6m telescopes located at the southwest, northeast and northwest region of China in 2026.
- For 1.5m telescope, the LLR will also be developed at the altitude of 4000m.

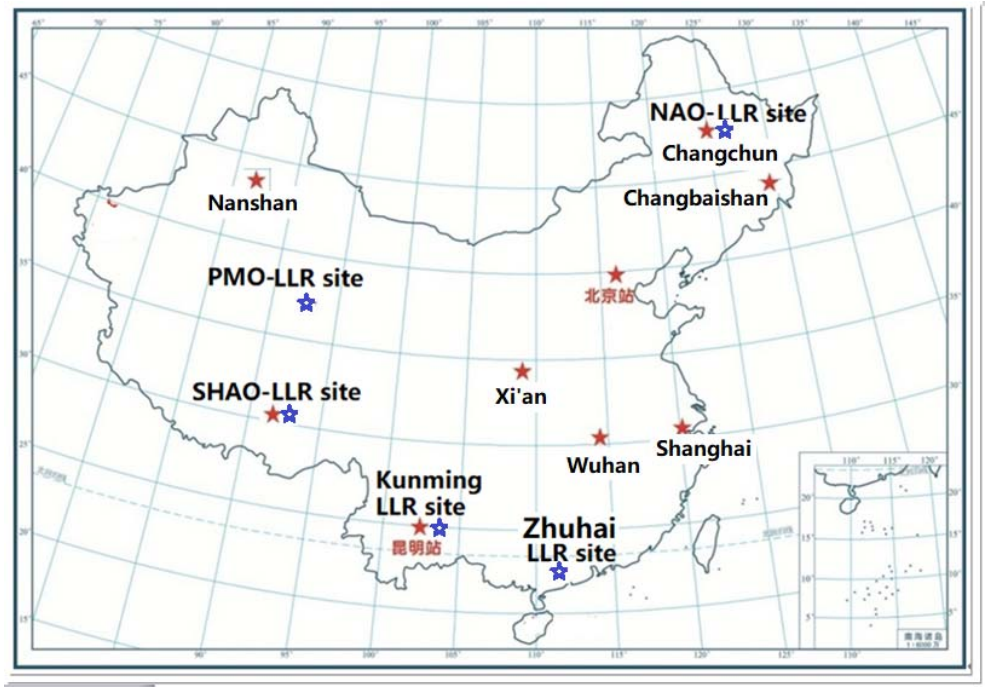




4. Future developments

2) Enlarging Chinese SLR network

- SanJuan site will perform the routine SLR measurements next year to provide the laser data at the southern hemisphere.
- The dedicated SLR sites join the network.
- New LLR sites will be built for SLR, LLR, LTT in the next 3-5 years.



- The enlarging Chinese SLR network will support the missions, such as earth's satellites, lunar satellites with LRAs and LTT, new LRAs deployed on the lunar surface.

Thanks for your attentions.

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