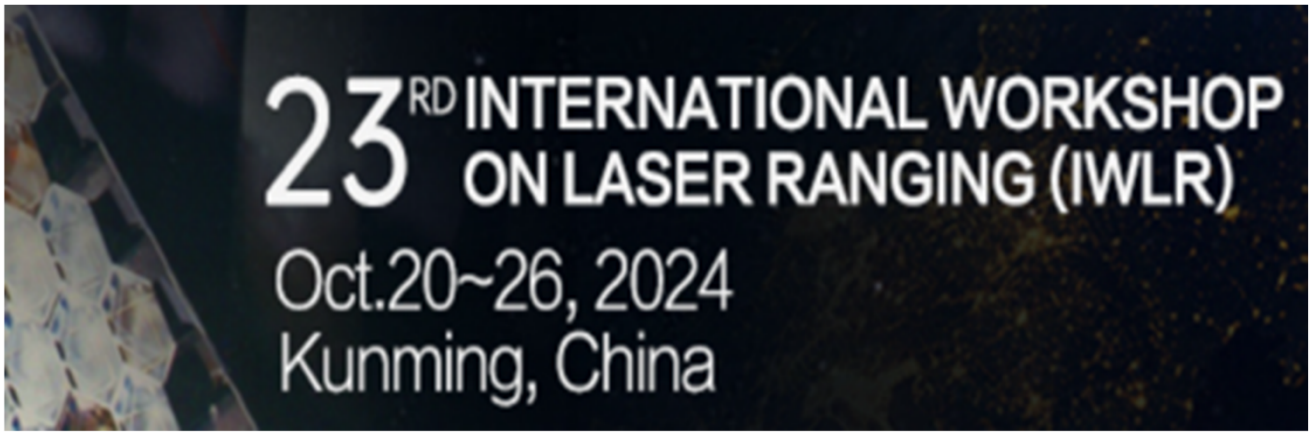
Lunar Laser Ranging Progress at Kunming Station

Yuqiang Li，Zhulian Li，Honglin Fu，Dongsheng Zhai，Rongwang Li, Haitao Zhang, Xiaoyu Pi, Rufeng Tang，Yongzhang Yang，Xiong Yaoheng

Outline

1. introduction
2. progress
3. plans for the future
4. Summary



1.introduction

The 1.2m telescope was first built in 1984 and was the largest horizon type astronomical optical telescope in China at that time.

its goals:

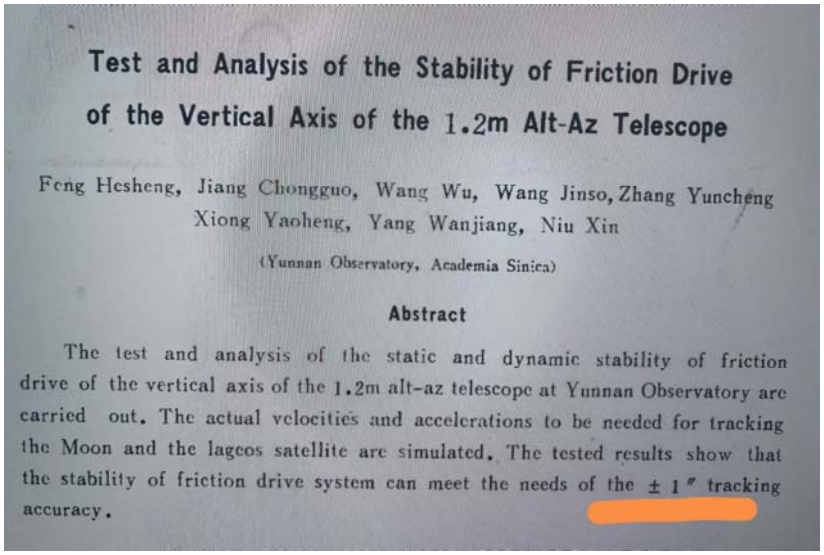
- **satellites laser ranging**
- **lunar laser ranging**

1.2m telescope

1. introduction

Its advantages are high stabilities of axis, good tracking accuracy and high pointing accuracy.

- ✓ **After subtracting the system error, the random accuracy are 0.08" of vertical axis and 0.16" of horizontal axis.**
- ✓ **Tracking accuracy of the moon and lageos: ± 0.5"**
- ✓ **pointing accuracy: ~1"**



Test and Analysis of the Stability of Friction Drive of the Vertical Axis of the 1.2m Alt-Az Telescope

Feng Hesheng, Jiang Chongguo, Wang Wu, Wang Jinso, Zhang Yuncheng
Xiong Yaoheng, Yang Wanjiang, Niu Xin

(Yunnan Observatory, Academia Sinica)

Abstract

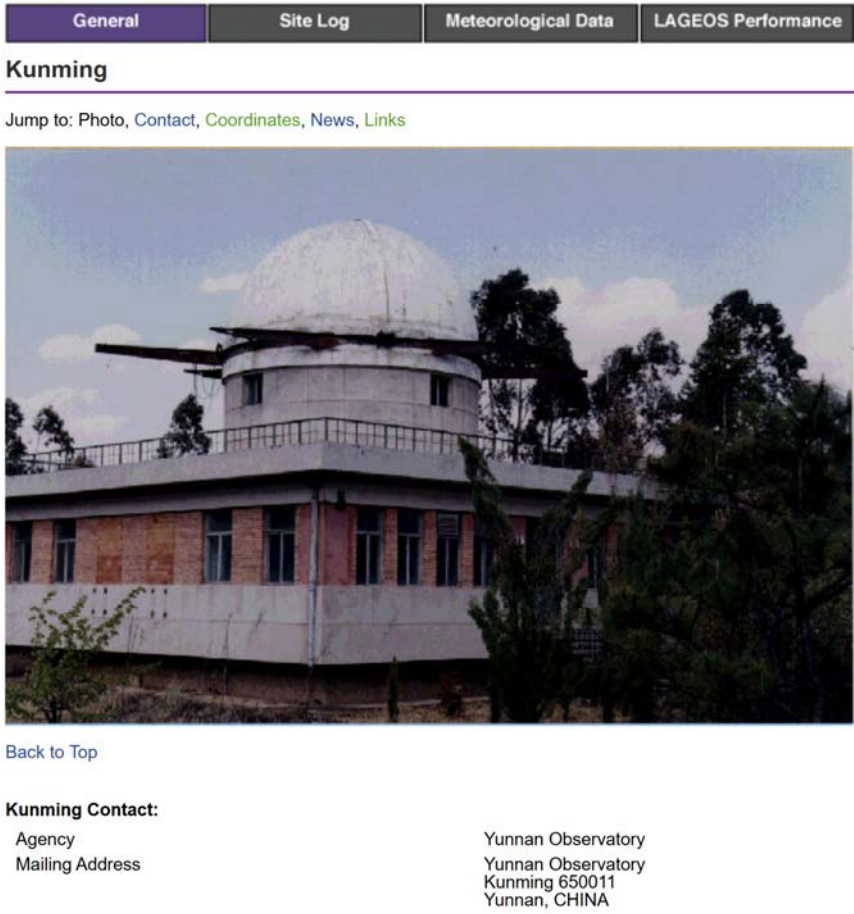
The test and analysis of the static and dynamic stability of friction drive of the vertical axis of the 1.2m alt-az telescope at Yunnan Observatory are carried out. The actual velocities and accelerations to be needed for tracking the Moon and the lageos satellite are simulated. The tested results show that the stability of friction drive system can meet the needs of the ± 1″ tracking accuracy.

1. introduction

important events:

- ✓ **in 1996, the first laser ranging system was established on the 1.2m telescope(532nm,4Hz, 100ps, 100mJ/pulse, 3-4 cm)**
- ✓ **from 1998, regularly operated SLR**
- ✓ **in 2003, with AO system for LLR research**
- ✓ **in 2018, it first got the echo from the lunar surface retroreflector(532nm,10Hz, 10ns, ~3000mJ/pulse, ~100cm)**

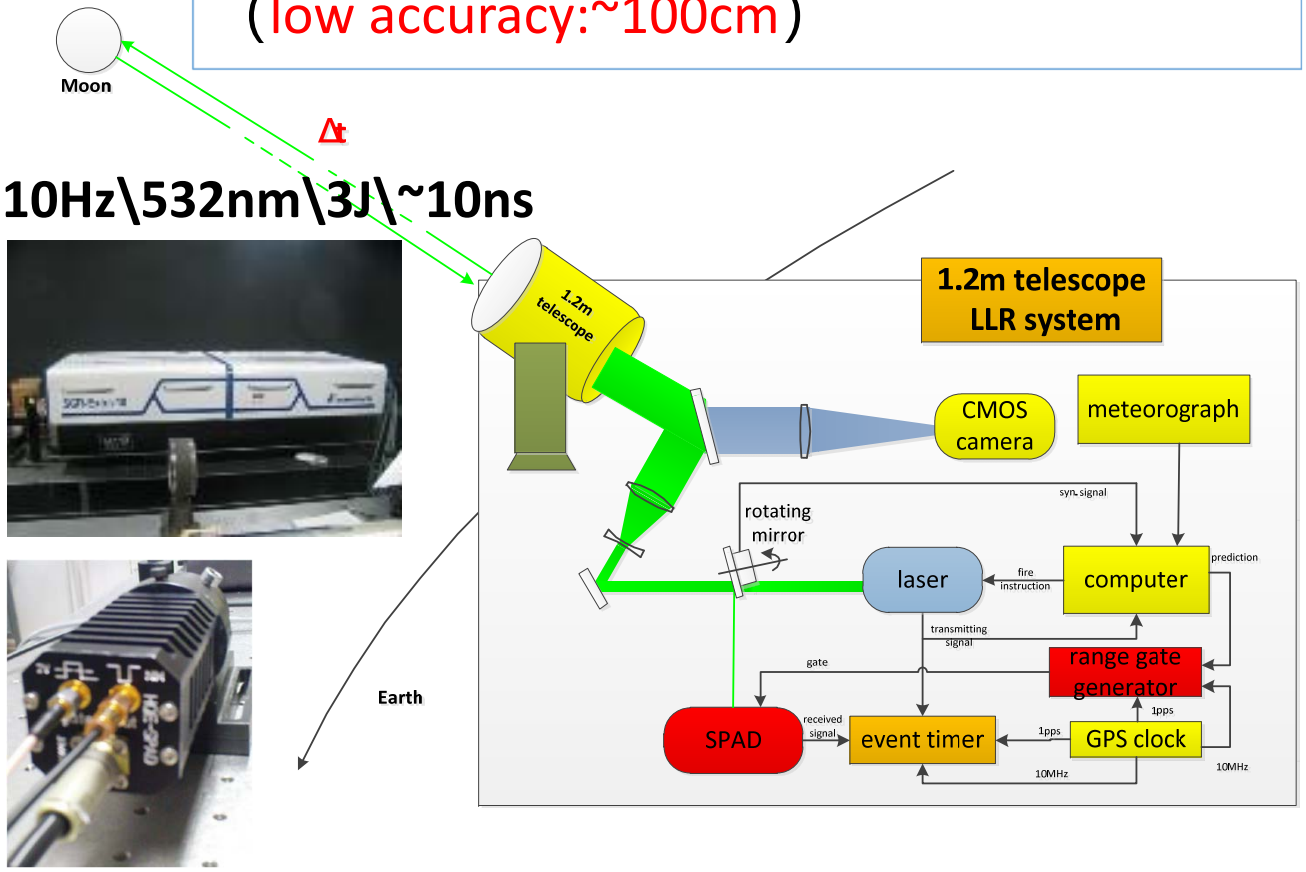
Kunming Station(7820)

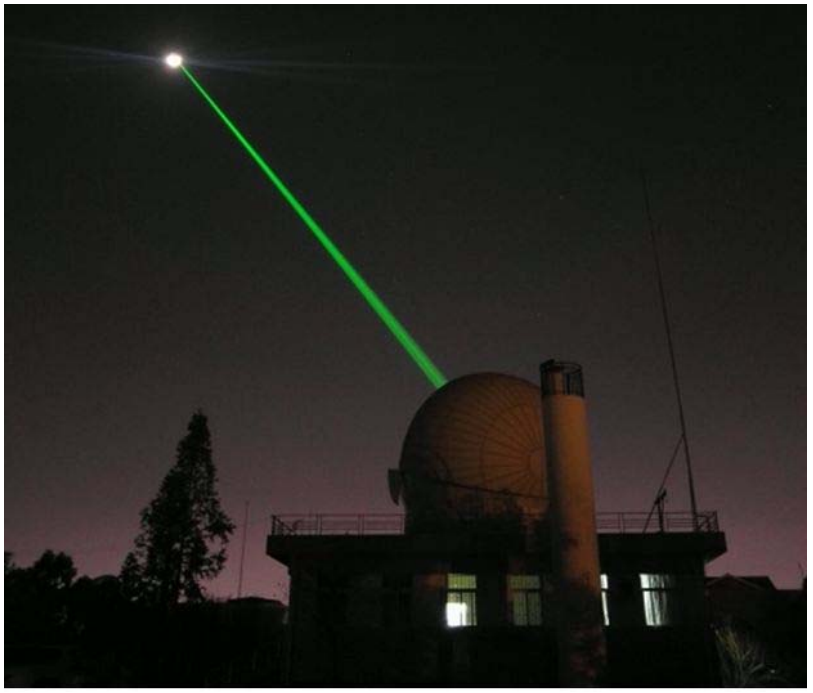


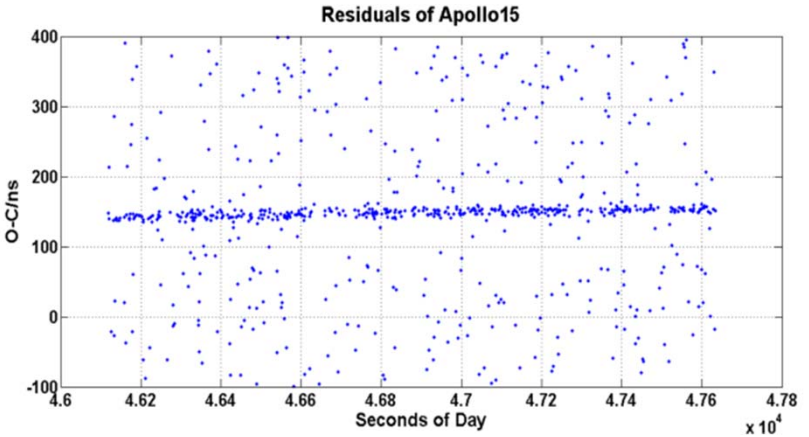
1. introduction

10Hz Lunar Laser Ranging System

(low accuracy:~100cm)

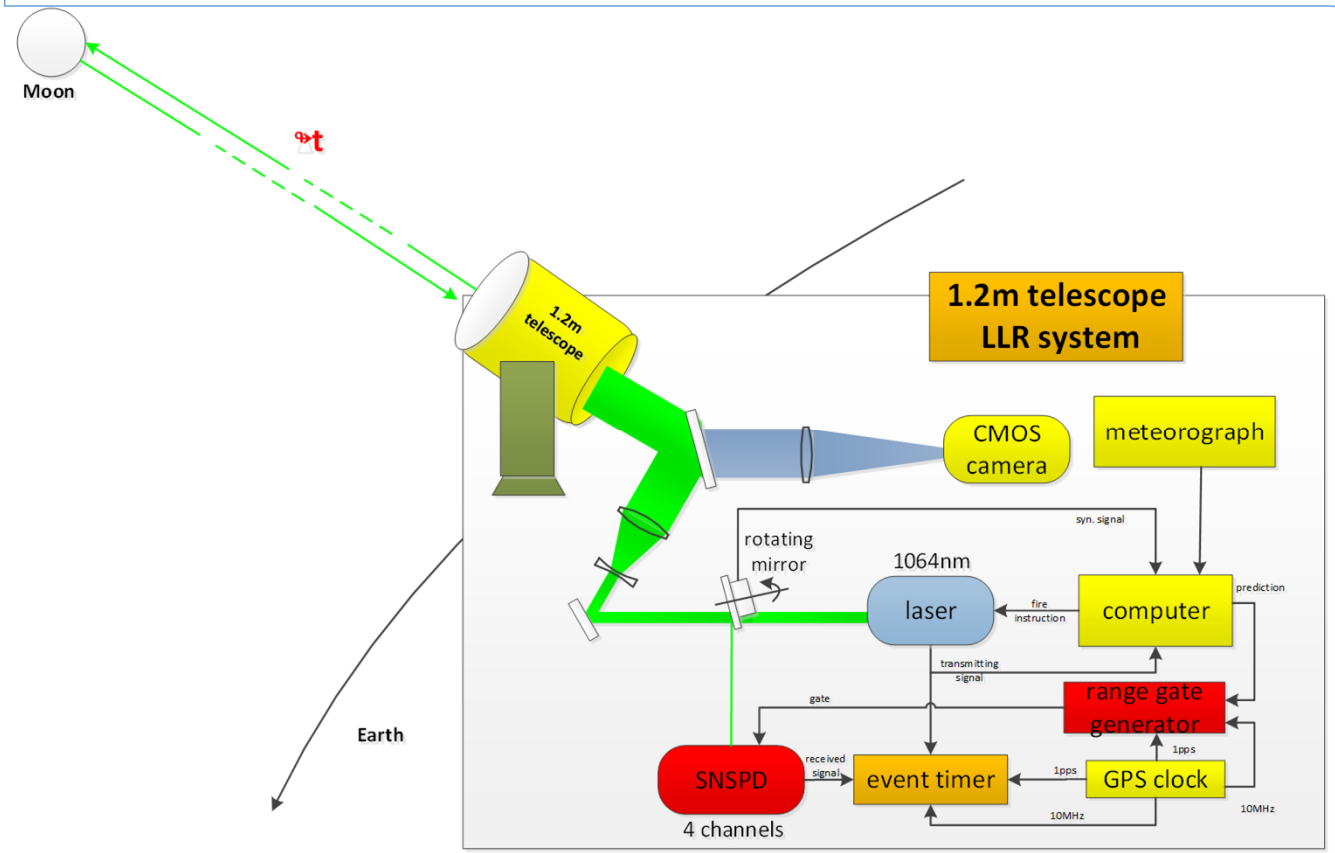






2. progress

100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System has been established this year (higher accuracy: ~3cm).



Laser: high frequency and 1064nm;

Detector:SNSPD/multi-Channel

Camera :CMOS

ET: GT9000/4 channels

2. progress

100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System.

Frequency: 100Hz

Wavelength:1064nm

Energy per pulse :300mj

Width of pulse: ~32ps

2. progress

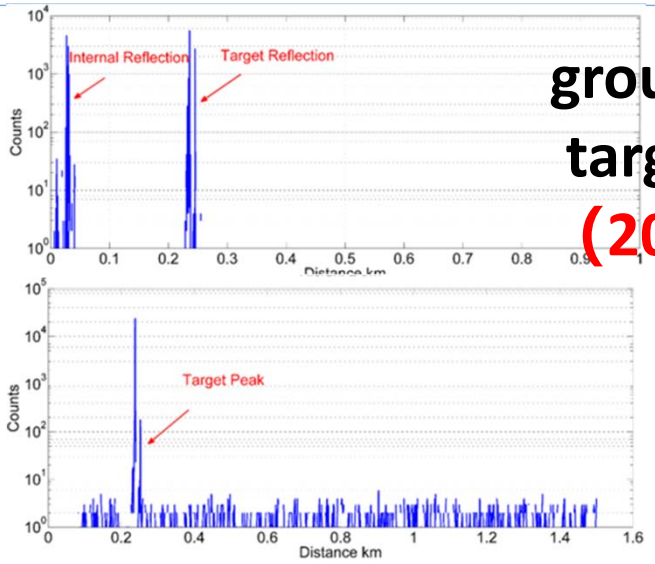
100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System.

receiving area： 200μm

detecting effciency： ≥60%

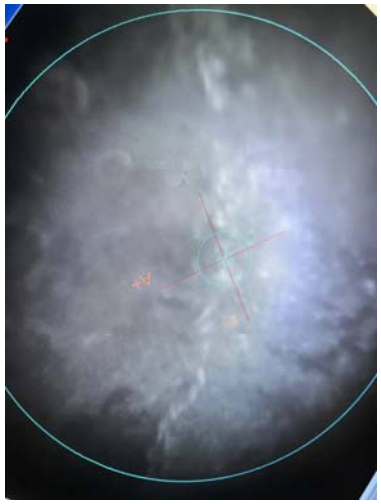
dark noise： ≤100cps

pixels： 2×2

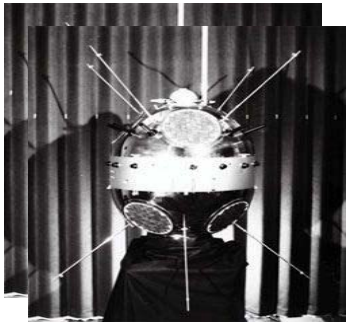


ground target (2015)

lunar retro-reflector (2019)



small debris (2017)



2. progress

100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System.

Event Timer

GT9000;

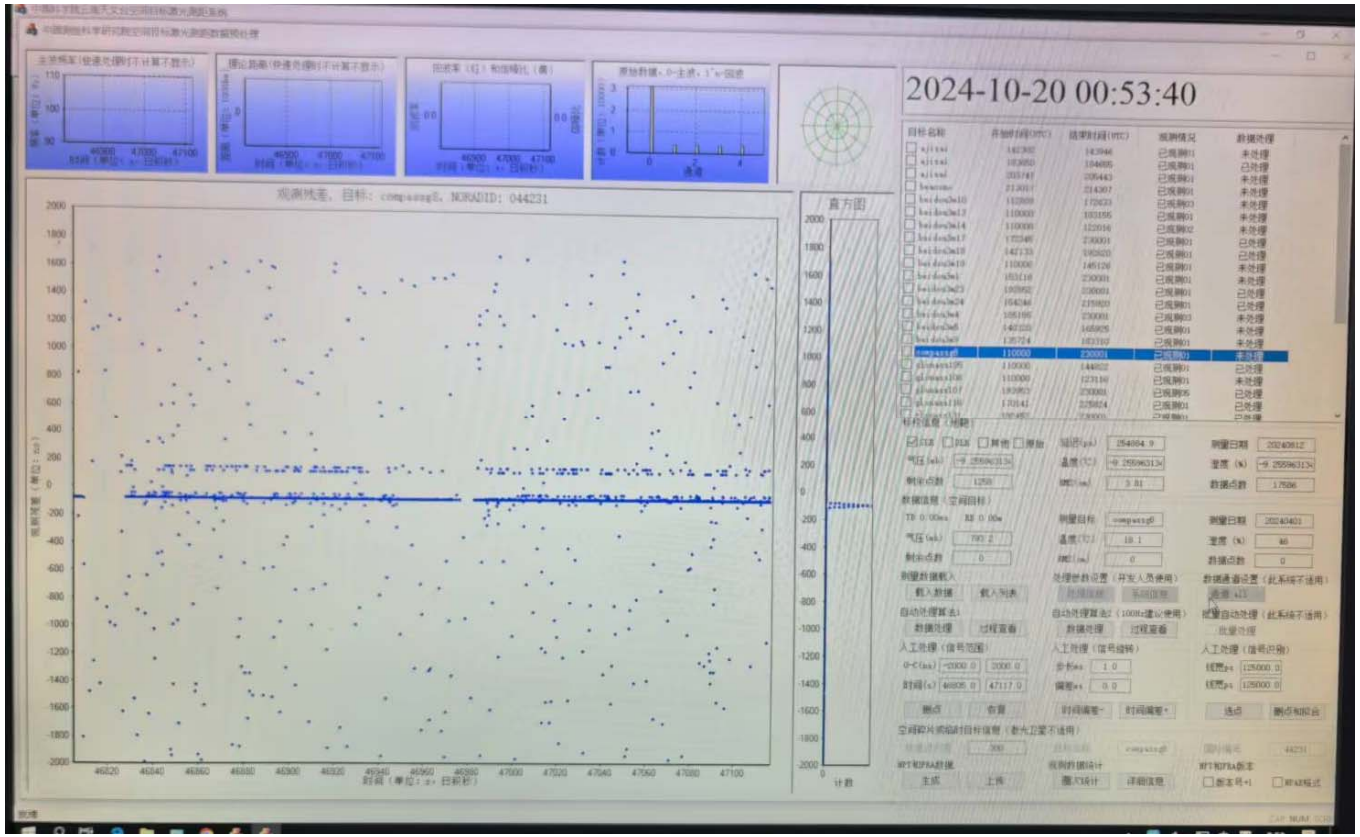
Multi-channel≥4channels

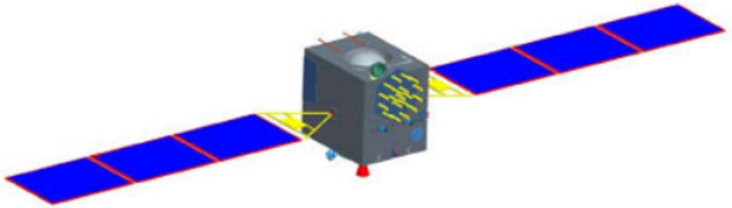
dead time:<1ns

resolution: ~1ps

2. progress

100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System.



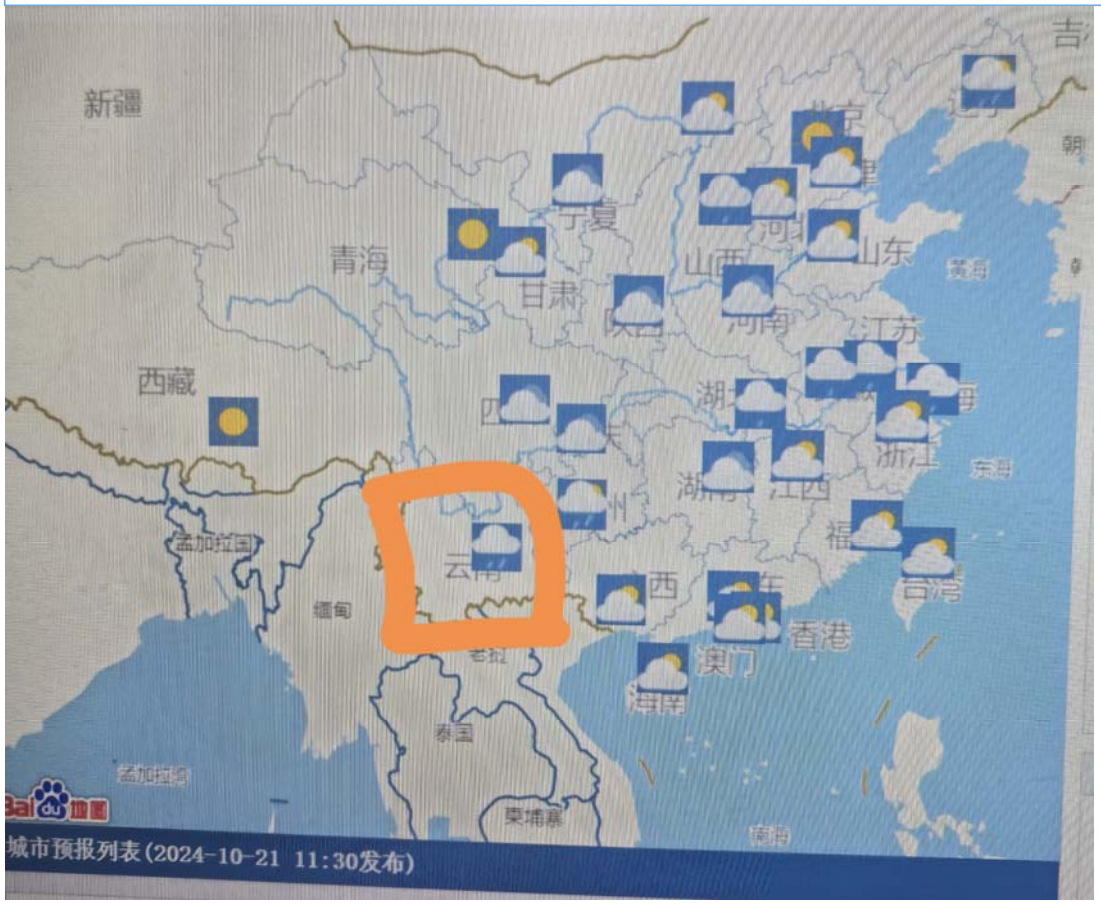


Compassg8(~36000km)

The 100Hz ranging system began to do laser ranging early April this year, and we have gotten returns from all ranging satellites and some debrises.

2. progress

100Hz , 1064nm and 4 channels detecting Lunar Laser Ranging System.



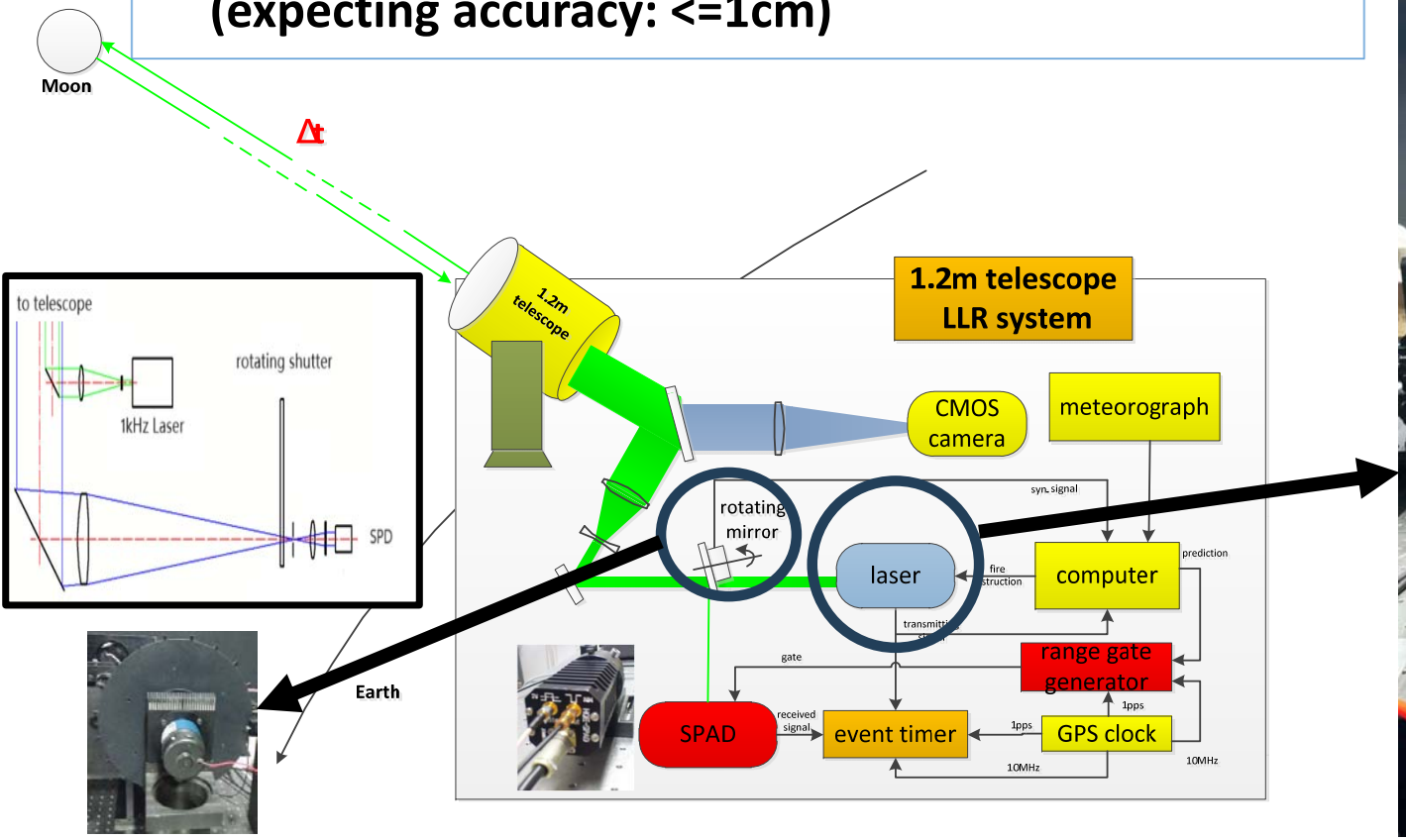
From April to October, Kunming is in the rainy season, so we have a few days to do LLR observation.

Next month or maybe end of this month,we will have some clear days for LLR observation.

3. plans for the future

(1)to realize 1000Hz Lunar Laser Ranging Technique

(expecting accuracy: <=1cm)



532nm/1000Hz/30mJ/30ps

3. plans for the future

（2） to operate regularly and provide higher accuracy LLR NPT data to the ILRS data center(station code:7820).

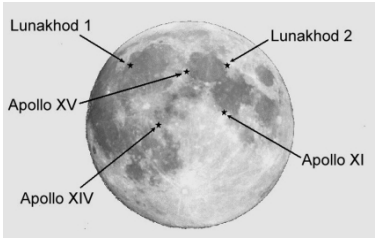
after **completed system upgrade:**

✓ three type operating frequency:10Hz, 100Hz and 1000Hz



✓ two type laser wavelength: 532nm and 1064nm

✓ lunar targets: Apollo15,Apollo 14, Apollo 11, Lunakhod17, Lunakhod21 and new retroreflector



3. plans for the future

(3) AO technique used to the LLR system

Increase the number of photons reflected by the lunar retroreflector

idea:

use a small area near the retroreflector array on the moon surface as an extended source to detect and calculate the wavefront tilt, then carry on the real - time tilt compensation for the laser beam on the LLR.

Some results:

- ✓ The Effect of Image Rotating on the Computation of the Wave-front Tip-tilt Error in the Adaptive Optics for the Lunar Laser Ranging
- ✓ The detection and computation of atmospheric tip-tilt in LLR when adaptive optics technology is used.
- ✓ The Real-Time Compensation of Wavefront Tilt for Extended Source Objects Based on a High-Speed PCI-Express Image Acquisition System.

3. plans for the future

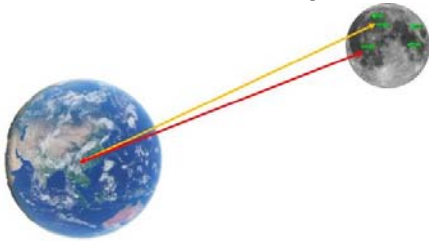
(4) daylight LLR technique realization

1064nm

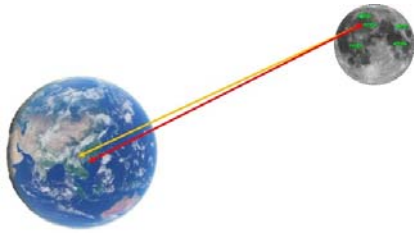
SNSPD's performances: single photon detecting capability, low dark count and not easy broken by the slight strong light.(proper to the daytime laser ranging)

(5) differential LLR technique research

to reduce atmospheric effects and improve the measurement accuracy of lunar laser ranging



Quasi-simultaneous observations



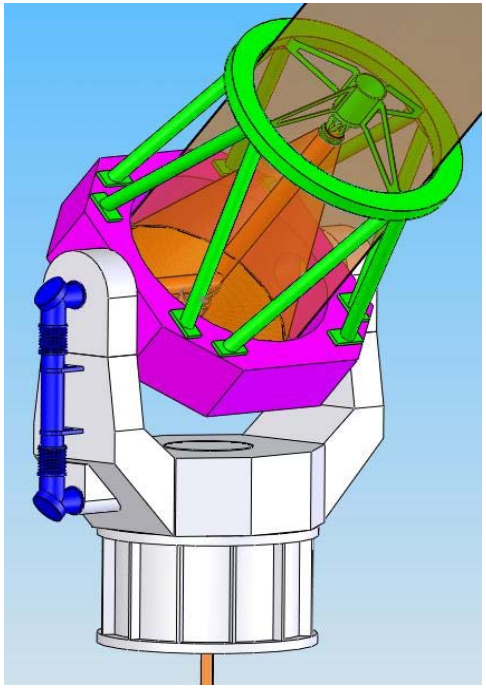
Multi-station joint observation

Double differential observation

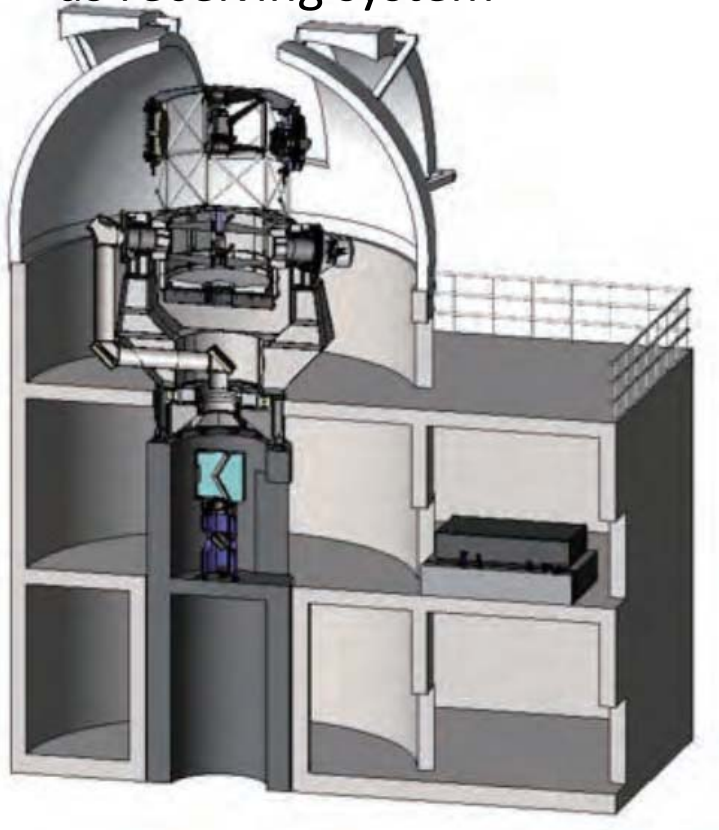
3. plans for the future

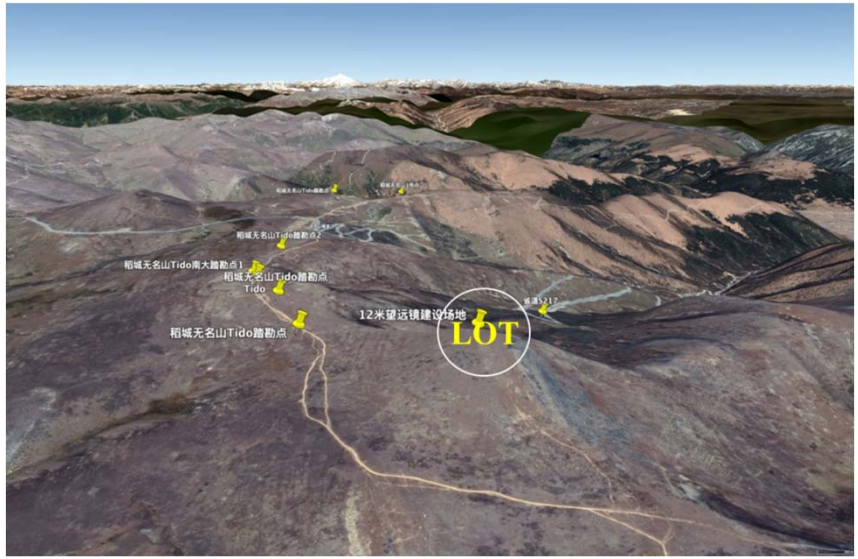
(6) to establish higher performance LLR system(designing and concepting)

2.5m astronomical and solar telescope
as receiving system



1.2m transmitting telescope





Daocheng Wumingshan mountain
Altitude about 4600-4800 m
Good seeing!

4. summary

(1) to introduce our kunming station's lunar laser ranging here, especially the 1.2m telescope.

(2) progress: we are building higher frequency and higher accuracy LLR system

- ✓ 100Hz frequency system(successfully tested in another system)
- ✓ 1000Hz frequency system
- ✓ we are doing lunar ranging experiments this year

(3) future plans:

- ✓ new techniques are researched and tried in our LLR system
- ✓ combine bigger astronomical and solar telescope to do LLR observation
- ✓ ……

Thanks for your attention!