Research and Experiment of Lunar Laser ranging

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LLR researchs & experiments in Kunming

Overview

- Key problems of LLR
  - Very long distance ranging, sub-single photon detection,……
  - How to increase the echo photons from moon retro-reflectors ?
- New technical method research for LLR :
  - Adaptive Optics (AO) technique applied to LLR
- Technical problems, some solutions :
  - Adding OTL110P and A033-ET Event Timer
  - Establishing the local pointing model for 1.2m telescope
  - Realizing correlation tracking system to compensate the distortion of wave-front tilt of the extended source on real-time
  - Developing aberrational compensation system
  - Developing the control system for LLR
- Perspectives

Key problems of LLR

Lunar Laser Ranging is:

- A expected goal in the LR field
- A significant job for scientific research of the Moon and the Earth
- An challenging experiment which relates to many fields such as optics, mechanism and electronics, etc.
- Simultaneously, a tough job because of few returned photon

How to overcome this key problem?

New technical method research for LLR

A new technical method of increasing returned photon numbers: the real-time compensation low order atmospheric turbulence effects in LLR combining with the Adaptive Optics technique.

The realization method is to use a small area near the retro-reflector array on the moon surface as an extended source to detect and calculate the atmospheric tip-tilt, and then carry on the real-time tip-tilt compensation for the laser beam on the LLR.

Adding OTL110P and A033-ET Event Timer

OTL110P(developed by group)

A033-ET (Riga)

Parameters:

dead time：1μs

resolution：4ps

precision： typical 40ps

dead time：50ns

resolution：1ps

precision： <5ps

……

Establishing the local pointing model

- ## Global Pointing Model

errors can be moved using a mathematics model & through star observation & CCD image processing, But the processing need long time, and the pointing accuracy is not higher for LLR.

- ## local Pointing Model

$$dA\sin Z = a_0 + a_1 \times Z + a_2 \times A\sin Z + a_3 \times Z^2 + a_4 \times Z \times A\sin Z$$

$$+ a_5 \times (A\sin Z)^2 + a_6 \times Z^3 + a_7 \times (A\sin Z)^3$$

$$dZ = b_0 + b_1 \times Z + \ldots\ldots + b_7 \times (A\sin Z)^3$$

A and Z is the azimuth and zenith of star; a1, a2……a7 and b1, b2……b7 are the model's fitting coefficients.

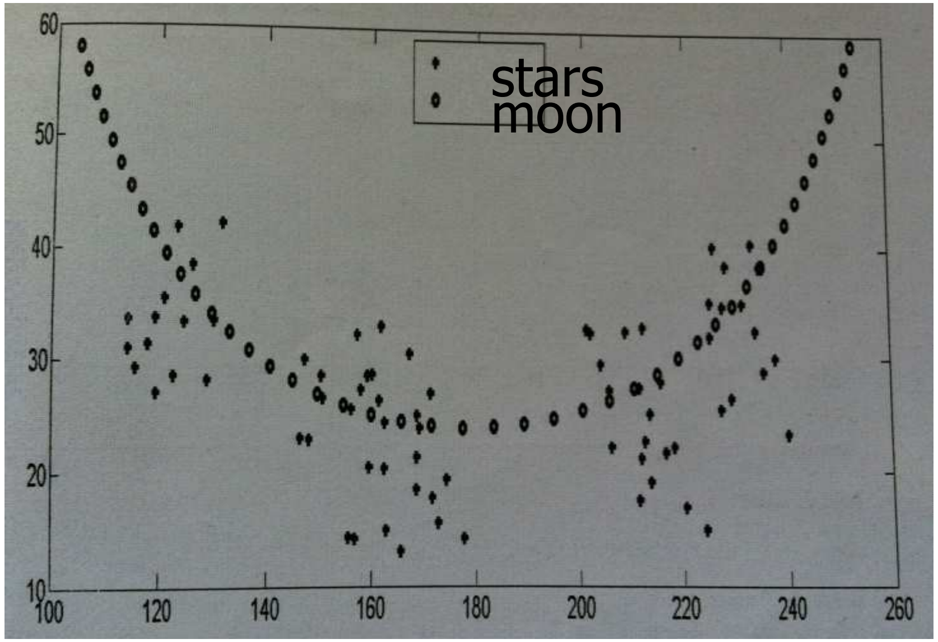
Stars selected for model:

To choose a number of stars around a observed target as local calibrator of Directions in the pointing mode. i.e. to select several points as the center at lunar orbit, and choose the star whose distance is less than 10deg from the center, like the following picture.

Establishing the local pointing model

Stars selected for model near the lunar orbit

Zenith (deg)

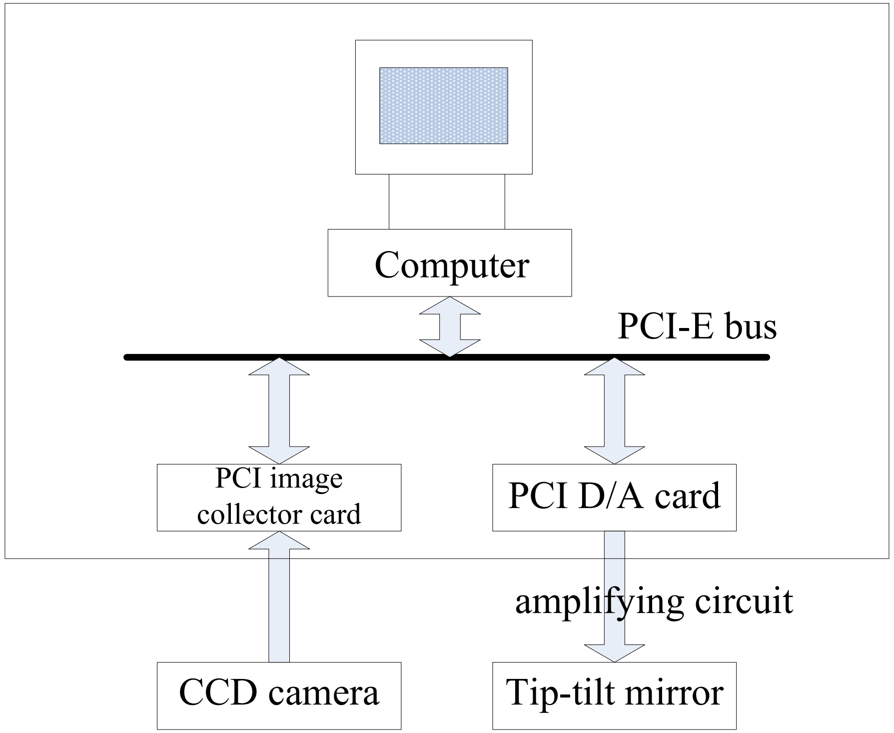


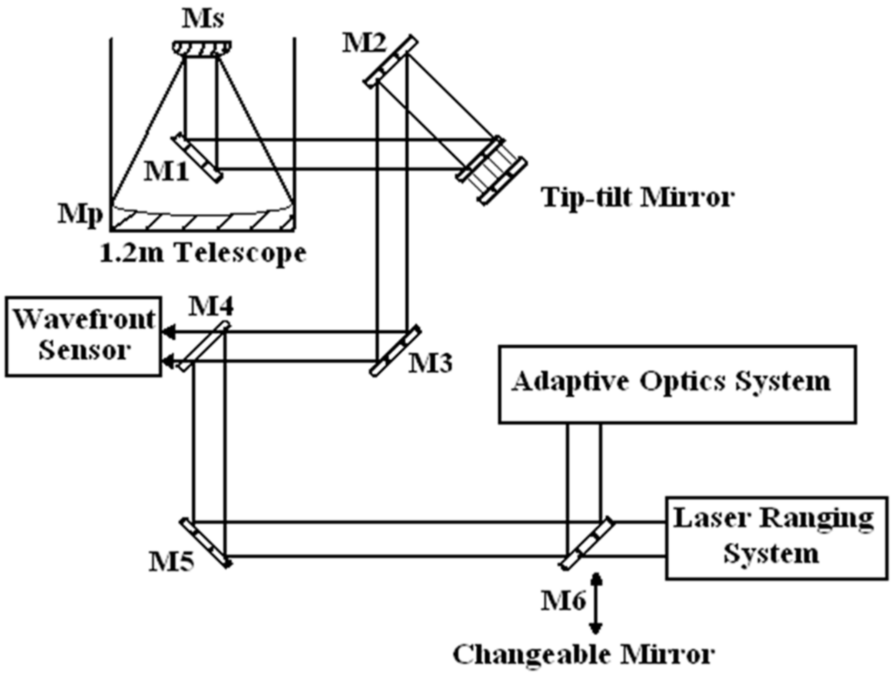
Azimuth (deg)

M_{Asinz}=6.16 (pixel) =(6.16*0.22) ″=1.35″

M_z=3.51 (pixel) =(3.51*0.22) ″=0.77″

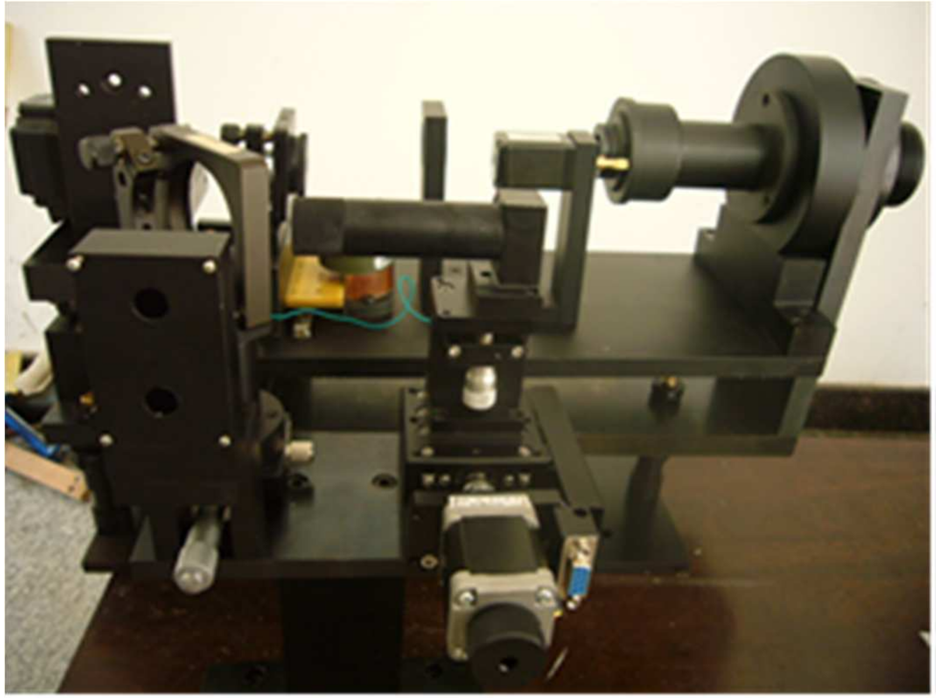
Realizing correlation tracking system





This system introduced tilt-correction adaptive optical system to the LLR, it realized high-speed image acquisition based on PCI-Express bus, and adopted the absolute difference algorithm, etc.

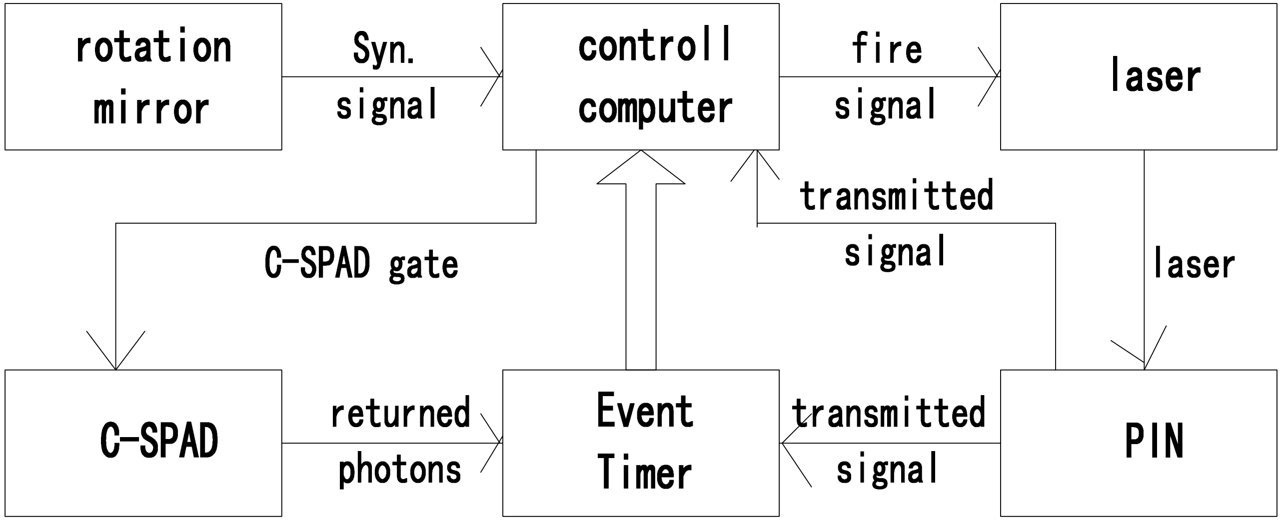
Aberration compensating system



aberration compensating device

Due to the earth rotation, movement of the moon is about 14.5”/s relative to the earth, the aberration on laser emission path can be calculated by the prediction of lunar orbit, the laser echo is detected by single photon avalanche diode (SPAD) , as a detector, the SPAD surface diameter was only 0.1 ~ 0.2 mm, and the FOV is small, so, in order to increase the number of echo, the aberration compensating system is developed.

Developing the control system



Rotation Shutter

- designing rotation mirror to generate synchronous pulse
- generating C-SPAD gate for LLR
- developing control program, including lunar orbit generation, ranging control, returned photons recognition and data post-process functions.

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The Perspectives of Kunming LLR

In order to successfully get returned photons and high precision distance data, the laser need have high or enough pulse energy and relative narrow width for LLR system,.

Now Kunming station's SLR had upgraded to kHz laser ranging, so we hope to utilize the current laser to do the experiment of LLR.

Energy: 3mJ@1KHz

Width: 10~20ps

Wavelength: 532nm

Frequency: 1~10KHz

Now energy of the laser is only 0.7mj/p!

so we need a new laser to continue to our experiment of LLR.

LLR Experiments in Kunming Station