Fulfilment of SLR Daylight Tracking In Changchun Station

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Abstract

The paper introduces the performance and progress for Satellite Laser Ranging (SLR) system daylight tracking in Changchun station. This paper first introduces the problems and difficulties facing this system for daylight tracking—mount model, the separation of emitting and receiving parts of the telescope, control range gate, installing narrower filter. Third it presents some work which was done in the system for daylight tracking: system stability improvement, laser stability improvement, mount model adoption, control system, etc. From these analysis and work which have been done, the system performance has been greatly improved. A routine operation system in daylight tracking has been set up.

***Keywords*:** SLR, daylight tracking

Introduction

Some main technical problems for daylight tracking

The daylight tracking is necessary and the tendency of SLR in the future. Many stations in the world can take the daylight observations. According to the experience at the most successful station, recent years, Changchun station has been working on the daylight tracking technique. Some things to consider:

- Precise orbit prediction

Predictions of position and range of satellites and pointing of tracking mount with high accuracy. No problem for current CPF predictions.

- Reduce the effect of daylight sky background noise on photoelectric detector

Day background noise level is higher in SLR daylight tracking. Pointing of the telescope; Mount model problem for the telescope; Generating control range gate narrower; the application narrow Spectrum filter; the receiver filed of view want to be small, above all will efficiency reduces amount of background light.

- Parallelism of transmitting and receiving paths

For our station using telescopes with separated transmit and receive, it is sometimes difficult to maintain correct laser beam pointing due to Coude path mirror drifts. It required good collimation.

- Intensive light protective methods

To avoid the damage of the detector by focused Intensive light.

Progress for Daylight Tracking in Changchun SLR System

Even there are so many difficulties, we still have done some work to try to fulfill daylight tracking, such as system stability improvement, laser stability improvement, mount model adoption, control system, etc. In order to improve the system stability, a new control system has been adopted, including an industrial control computer, data collecting board and counter card for timing and range gate. Control and data preprocessing software are also updated so that all work can be done automatically. For

laser stability, the room is air-conditioned. The cooling system is also improved for its liable working, including some system protections. In order to improve the pointing accuracy, mount model correction is also adopted in the satellite prediction. A spherical harmonics pointing model was built by using astronomical observation at our telescope system. It is proved that the pointing model is an effective correction to the system error. This makes the pointing bias become very small in most directions. The design of tracking optical scheme on Changchun SLR system is shown in Figure 1.

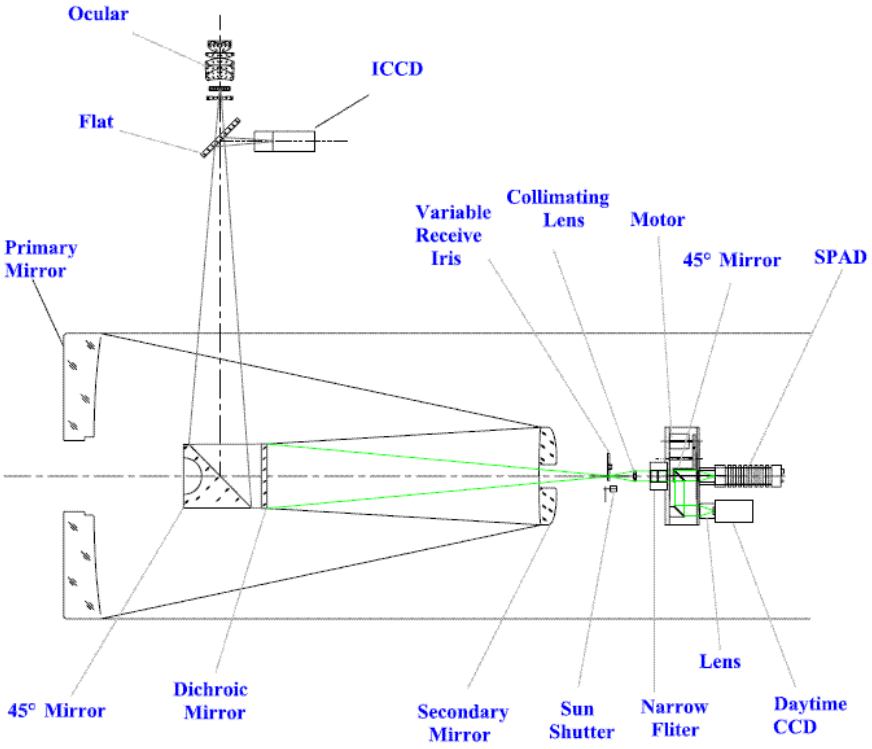

Figure 1. *Optical scheme of Changchun SLR system*

Ways to reduce effect of daylight background noise

Space filter

The electric-powered adjustable iris is used for field of view.
Receiving Field of view: 45"-12'. Figure 2 shows receiving iris diaphragm.

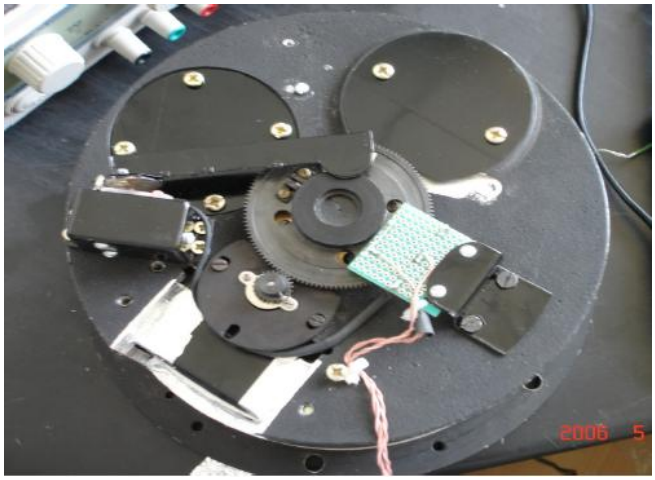

Figure 2. *Variable Receiving Iris diaphragm*

Timing filter

We designed and developed the precise range gate generator.
It can produce 1ns range gate to make the time closer to the arrival echo. We provide two devices to generate range gate:

AD9501: Programmable digital delay generator.10ps precision time delay, delay: 2.5ns—10us (capacitance and resistor);

DS1020: 8 bit programmable delay device, serial parallel mode. Max. Delay time: 48.25ns (fast mode), 520ns (slow mode). Figure 3 is the control precise range gate Generate Circuit Chart.

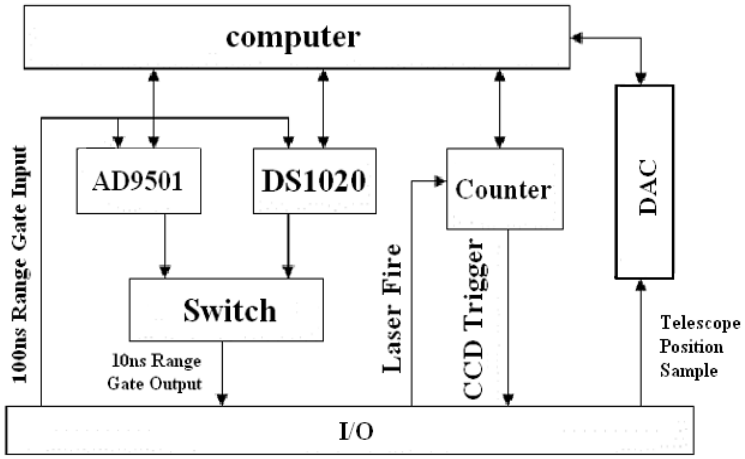

Figure 3. *Control precise range gate Generate Circuit Chart*

Spectrum filter

The application of 0.3nm narrow band pass interference filter form Andover Corp**.** and the constant temperature box to cut more background noise and to make the filter working in a constant temperature environment. The temperature controller provides protection against the influences of ambient temperature fluctuation. The specs of Andover Narrow Band Interference Filter are: Center Wavelength: 531.9 nm; Bandwidth: 0.3±0.1 nm; Peak transmission: 41.30 %; Ambient temperature: 23ºC; Size:Φ25.00 ± 0.25 mm. Figure 4 is the photograph.

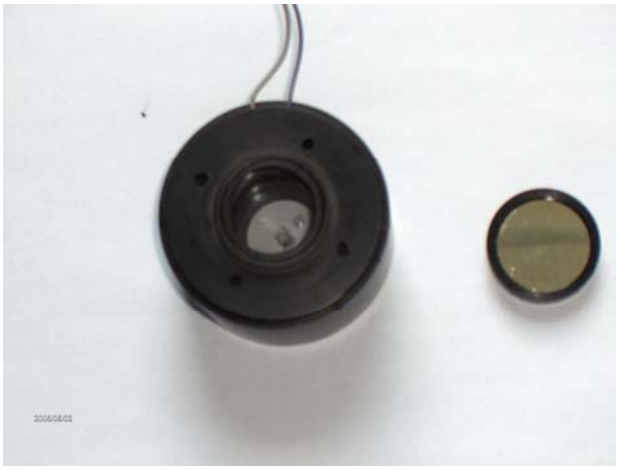

Figure 4. *Spectrum filter and constant temperature box*

Pointing of the telescope

- Mount leveling Collimation measurement

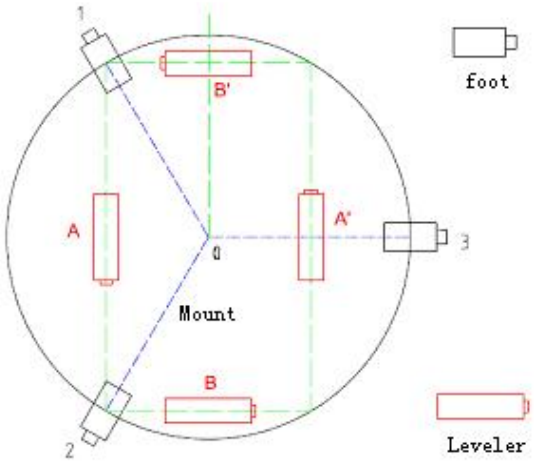

Figure 5. *Mount leveling Collimation measurement*

The first step is mount leveling. The data of mount leveler is recorded each 30 degree.

After leveling

$$i = \sqrt{a_1^{\,2} + b_1^{\,2}}$$

$$A = \arctan\left(\frac{a_1}{b_1}\right)$$

where

$$a_1 = \frac{1}{6}\sum_{j=0}^{11} f(\alpha_j)\cos(30^\circ \cdot j); b_1 = \frac{1}{6}\sum_{j=0}^{11} f(\alpha_j)\sin(30^\circ \cdot j)$$

After calculation: the azimuth angle perpendicular to the slant direction is A=1.2"

- Collimation measurement

$$C = (A_R - A_L \pm 180^o)/2$$

RMS = 3'02"

- Zero error measurement of encoder

Polestar observation the error of encoder zero position:

$$\Delta A_0 = 180.682431^o$$

$$\Delta E_0 = 0.01684^o$$

- Star Calibration

Observe positions of known stars (calculation from FK5) using night camera. Mark reference position on screen of night camera. Our system can to gather data from 48--60 stars in 1 hour. Compare observed (encoder readings) with calibration position (O-C). The Least Squares to fit the mount model parameters (13 parameters each axis). Application of current mount model provides a good fit for elevations from 15 degrees to 80 degrees. System pointing is at the few arc second level.

RMS of fit: Azimuth: 5.5"

Altitude: 4.8"

Parallelism of transmitting and receiving paths

1) Adjustment of sensitive area of detector.
2) Coude path fine adjustment.
3) Monitor laser beam during daylight.

We have installed a CCD camera in the receiver path; a switched mirror can direct this green light into the CCD or into the SPAD. This CCD is triggered by the laser start pulse that is delay 153us; an exposure time of down to 1/20000 s. Using software image / contrast enhancement techniques to display the backscatter of laser beam in real time.
4) Directional adjustment of output laser beam.

To adjust the laser beam direction with remote control of the last Coude mirror to fit the parallelism of transmitting and receiving path. Figure 6 is the image of daylight laser beam.

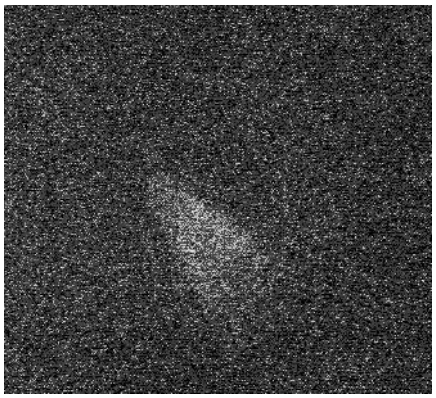

Figure 6. *Image of Daylight Laser Beam*

Intensive light protective methods

In order to avoid the damage of the C-SPAD detector by focusing sunlight, we must prevent the mount from pointing to the Sun. The double methods were used:

Hardware protection

Four strong light detectors were adopted on the top of mount, when the telescope moves to the place with strong light (such as to the sun or moon), the detectors will trigger a circuit to shut off the emergency shutter of the field of view. Figure 7 shows the electronic circuit diagram.

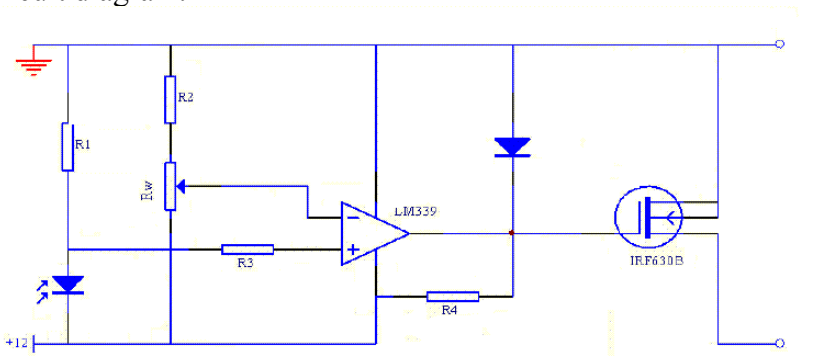

Figure 7. *Electronic diagram of light protective circuit*

Software protection

The software will control the telescope to avoid the sun when the satellite path travels across the sun area (less than 15º distance to sun) and stop the laser. It can choose a tracking path automatically when multi-satellite alternative tracking.

Conclusion

Almost everything, including hardware and software, is ready since the end of last year. Because of the cold weather we decided to do the test at the beginning of this year. In March of 2006, Galileo project was launched. Changchun station was selected to track Galileo satellite by Chinese government and ESA. So we have to change our plan and daylight tracking test has to be delayed. The Galileo project of first phase was finished, but the acceptance is not done. We have to wait for until it is over. But we are sure the condition is suitable for daylight tracking. And we will try the daylight tracking in the near future.

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