
System Improvement and GIOVE-A Observation of Changchun SLR

ZHAO You¹, FAN Cunbo¹, HAN Xinwei¹, YANG Dingjiang², CHEN Nianjiang²,
XUE Feng², GENG Lin², LIU Chengzhi¹, SHI Jianyong¹, ZHANG Ziang¹,
SHAO Baodong¹, ZHANG Haitong¹, DONG Xue^{1,3}

1. National Astronomical Observatories/Changchun Observatory, CAS
2. North China Research Institute of Electro-Optics, CGI, Beijing
3. Graduate University of Chinese Academy of Sciences, Beijing

Abstract

This paper introduces the system improvement for tracking GIOVE-A in Changchun station. During the more than two months improvement, the new servo and encoder systems were installed. And primary mirror, second mirror and some other mirrors have been cleaned and recoated. The laser system was adjusted in order to improve the laser efficiency and output. The paper gives out the improvement results, and the GIOVE-A satellite observation results.

Key Words: *system improvement, GIOVE-A observation, SLR*

Introduction of project background

Galileo system consists of 27 satellites distributed in three uniformly separated planes. In 2006, two GSTB-V2 satellites were planned in orbit. The nominal lifetime is 2 years. Four IOV Galileo satellites were planned to be launched towards the end of 2007. Full Deployment Phase and Long Term Operation will be followed the IOV. Galileo In-Orbit Validation Element (GIOVE) satellites: GIOVE-A and GIOVE-B. The objectives of the deployment of these two satellites are to:

- secure use of the frequencies allocated by the International Telecommunication Union (ITU) for the Galileo system
- verify the most critical technologies of the operational Galileo system, such as the on-board atomic clocks and the navigation signal generators
- characterize the novel features of the Galileo signal design, including the verification of user receivers and their resistance to interference and multipath, and
- characterize the radiation environment of the medium-Earth orbit (MEO) planned for the Galileo constellation.

GIOVE-A and -B were built in parallel to provide in-orbit redundancy and to secure the mission objectives. They provide complementary capabilities. GIOVE-A was launched on December 28, 2005, into an MEO with an altitude of 23,260 kilometers. Carrying a payload of rubidium clocks, signal-generation units, and a phase-array antenna of individual L-band elements, GIOVE-A started broadcasting on January 28, 2006, securing the frequencies allocated by the ITU for Galileo. Performance of the on-board atomic clocks, antenna infrastructure, and signal properties is evaluated through precise orbit determination, supported by Satellite Laser Ranging (SLR), an independent high-precision range measurement technique for orbit determination based on a global network of stations that measure the round-trip flight-time of ultra short laser pulses to satellites equipped with laser retro reflector arrays (LRAs). SLR provides instantaneous range measurements of millimeter-level precision which can be compiled to provide accurate orbits and to measure the on-board clock error.



Fig.1. Changchun SLR telescope

Due to the urgent need, it is necessary to select an existing SLR station to provide laser ranging service for GSTB-V2 satellites. Given the importance of SLR data for the characterization of the GIOVE clocks, the People's Republic of China contributed to the Galileo program the refurbishing of a Chinese SLR station to provide GIOVE laser-ranging observations. The Changchun station in northeast China was selected among the Chinese stations contributing to the ILRS because it had demonstrated strong MEO satellite tracking; collocation with an existing International GPS Service station; and good weather conditions. There are 5 fixed SLR stations in China nowadays. Among the stations, Changchun station possesses the best performance. Its data quantity is the most in China. It has the ability to range to the distance more than 20,000km with the accuracy less than 2cm. So Changchun SLR Station is selected to service for Galileo in the early stage. Followings are photos of Changchun station and SLR telescope:



Fig.2. Bird view of Changchun station

Changchun Observatory (ChO) of National Astronomical Observatory, Chinese Academy of Sciences, is a member of global SLR and GPS networks. It started Satellite Laser Ranging (SLR) since the early of 80th last century. The third generation of SLR in ChO was established during 1985. The system has the ability of tracking satellites with the distance of more than 20000km. Single-shot RMS is less than 2cm. From years ago, ChO SLR has been the best one in Chinese network, and got the No.10 rank in the

global SLR network. It is also an important and high performance station in the International Laser Ranging Service (ILRS). According to the report of ILRS, ChO SLR has the ability of tracking the high orbit satellites, such as Glonass, Etalon and GPS which have orbit height more than 20000km. Based on the Galileo satellite orbit height and the effective area of Laser Retro-Reflectors Array (LRA), the strength of return signal from Galileo satellites will be similar to that from GPS or Glonass satellites. So ChO SLR has the ability of tracking Galileo satellites.

Contents of SLR improvements

Though ChO SLR has the ability of tracking the high orbit satellites such as Glonass, Etalon, GPS and Galileo satellites, it can only get less return signal from above satellites. This is caused by the following causes:

- The coated film of the primary mirror and second mirror are damaged seriously, and now they have low reflectivity.
- The tracking system has lower precision. The mount of the telescope shakes so hard that less data can be obtained from high orbit satellite.
- The energy of output laser pulse is a little low.

Following is the Changchun SLR system structure. The dark color parts are the parts which are to be refurbished for GIOVE-A observation.

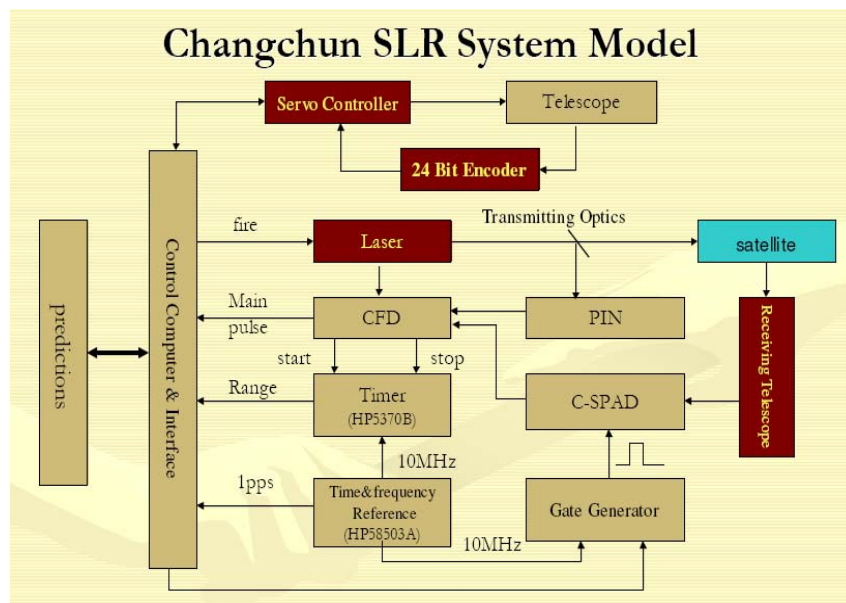


Fig.3. Changchun SLR System

If these parts were not improved, it would be very difficult for us to get more data from Galileo satellites and to support a long-term tracking of the satellites routinely. In order to track the Galileo satellites and get more SLR data with high precision, the following things will be done in short-term:

- Telescope. Primary mirror and second mirror of the receiving telescope must be recoated, tested, adjusted and calibrated. This will result in higher transparency of the receiving optics.
- Encoder. A new type photoelectric encoder will be installed in the tracking mount to replace the old one. This will improve the resolution of the angular sensor of the

tracking mount. This can be done in the same period with the telescope modification.

- Servo System. A new type of servo driver will be used to improve the telescope tracking performance. This will heighten the tracking precision.
- Laser System. The old laser components will be replaced in order to heighten the laser output energy up to 70-100mj and improve output stability. This will greatly increase the number of photons reflected back from the satellites.

After the system improvement, the tracking system can have less than 2'' tracking precision for high orbit satellites, the output laser energy will be stronger. And these will benefit to improve the return rate and the tracking capability for high orbit satellite of ChO SLR. Finally, the system can execute the Galileo mission and get more data routinely.

Table 1. System Specifications

<i>Label</i>	<i>Unit name</i>	<i>Spec. name</i>	<i>Spec</i>	<i>Listed in Addendum</i>	<i>To be Tested</i>	<i>Reason</i>
M1	Mirrors	Reflectivity of Primary Mirror	$\geq 98\%$ (532nm)	Yes (p17)	Yes	
M2	Mirrors	Reflectivity of Secondary Mirror	$\geq 99\%$ (532nm)	Yes (p17)	Yes	
M3	Mirrors	Reflectivity of 45° Mirror	$\geq 99\%$ (532nm)	Yes (p17)	Yes	
E1	Encoder	Temperature Characteristics	Independent	Yes (p18)	No	Determined by principle (digital electro-optic encoder)
E2	Encoder	Current	Tens of mA	Yes (p18)	No	It's a middle spec and can be reflected by accuracy
E3	Encoder	Resolution	0.078''	No	Yes	It's critical spec of a encoder
E4	Encoder	Accuracy	$\sigma \leq 1''$	No	Yes	It's critical spec of a encoder
E5	Encoder	Sampling rate	500Hz	No	Yes	It's critical spec of a encoder
S1	Servo	Elevation Max Speed	8°/s	Yes (p18)	Yes	
S2	Servo	Elevation Max Acceleration	12°/s ²	Yes (p18)	Yes	
S3	Servo	Elevation Min Speed	<5''/s	Yes (p18)	Yes	
S4	Servo	Azimuth Max Speed	10°/s	Yes (p18)	Yes	
S5	Servo	Azimuth Max Acceleration	15°/s ²	Yes (p18)	Yes	
S6	Servo	Azimuth Min Speed	<5''/s	Yes (p18)	Yes	
L1	Laser	Pulse Energy	80mJ	Yes (p18)	Yes	

Performance after improvement

Table 1 lists the specifications to be tested after system refurbishment and the results. All are met the specified value. After recoated, the reflectivity and transparency of the mirrors for 532nm are as follows: primary mirror: 97.29%; second mirror: 99.049%; dichroic mirror: 99.55%; 45°reflector: 99.83%. After system modification, tracking speed and stability of the system greatly improved and output laser energy increased from 30mj to 100mj. Ranging ability increased obviously and points and passes from high satellites increased.

Following are the photos to show the recoated primary mirror, new operation console, laser output on screen, and the encoder system.



The recoated primary mirror



New operation console



Laser output on monitor



New encoder system

Up to Dec.12 of 2006, there are 28 passes of GIOVE-A and 12 passes of GPS-35, -36 to be tracked. Refurbishing work had been finished and acceptance tests were underway. The observations performed by Changchun at the time of the campaign were included in the data set as the data revealed itself to be of high value for the analysis carried out. The geographical location of Changchun (see Figures 4) was of primary importance in providing better laser-ranging coverage of GIOVE-A.



Fig.4. World map showing geographical distribution of the first GIOVE-A ranging campaign

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