13-Po50

The Ground Calibration System of Korean SLR system

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Abstract.

Since 2008 Korea Astronomy and Space Science Institute (KASI) is developing two SLR (Satellite Laser Ranging) systems under the ARGO project (Accurate Ranging system for Geodetic Observation) in Korea. The finished mobile SLR station (40 cm), ARGO-M, is now under the starting phase, while the fixed system (1m class), ARGO-F, is in the design phase. The ARGO-M operates with the kHz repetition rate laser and is equipped with the near ground calibration target mounted under the dome. The ground calibration allows evaluation of the SLR system delay, which depends on the configuration of the hardware, but also on the temporary atmospheric conditions. We conducted the finite element analysis (FEA) to examine the structure error of the ground calibration target, and performed 3D distance measurement between the virtual reference point of the mount and the ground target. We also measured the environment vibrations which are able to affect the calibrations process. This presentation describes design of the ARGO-M ground calibration target, as well as the conditions of its environment and the results of the system calibration.

Introduction

Korea Astronomy and Space Science Institute (KASI) has developed a mobile SLR system (ARGO-M) which is in the starting phase now. The aperture of the receiving telescope is 40 cm and the system is able to observe satellites at the altitudes from 300 km up to 24000 km.

The single-shot accuracy of the system is lower than 10 mm, RMS of the Normal Points is below 5 mm and RMS of the range measurements to the ground target is below 5 mm.

ARGO-M is composed of 6 subsystems: optical, opto-electrical, laser, mount, operation subsystem and the radar (Figure 1)

Figure 1. ARGO-M configuration

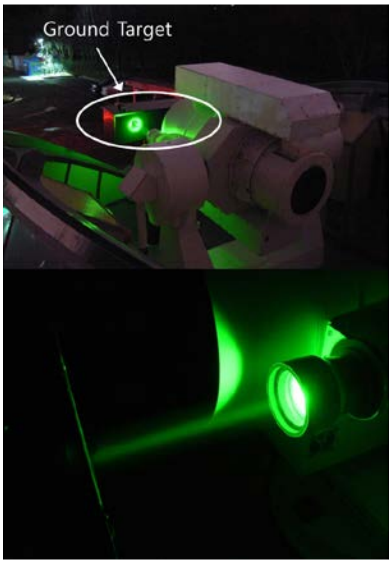

Figure 2. Ground Calibration

The range measurements performed by the SLR system are affected by the signal delay caused by the hardware configuration, and the temporary atmospheric conditions. In order to determine the SLR system delay the calibration range measurements to the ground target are performed. In the case of ARGO-M, the calibration target is mounted under the dome; the location near to the telescope allows minimizing the environmental effects (Figure 2).

Ground Calibration Target

The ground calibration target is composed of a prism, an iris, a filter bank and a black diffuser (Figure 3).

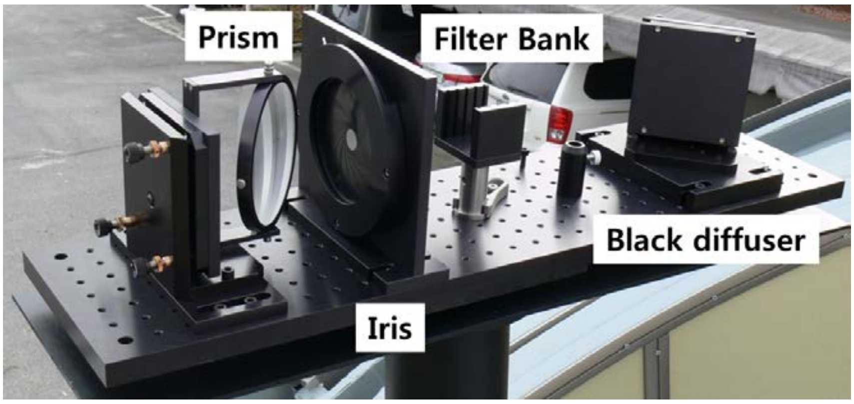

Figure 3. Ground Target

The prism is the wedge prism (D = 120 mm, ~0.5% reflectance), it reduces intensity of the laser light, and has tip/tilt function for alignment. The iris (D = 100 mm) and the filter bank are used to adjust the light intensity, and control the return rate of the calibrations. The black diffuser (115 mm × 115 mm, < ~ 3% reflectance) is used to reduce the reflected light intensity and has tip/tilt function for alignment.

We conducted the finite element analysis (FEA) to examine the structure error of the ground calibration target. The FEA was performed for the two cases:

1) stress analysis, the displacement by self load (gravity)

2) modal analysis, the frequency by self load.

The ground calibration target is deformed up to 47 μm on 20 N (prism) and 20 N (black diffuser) (Figure 4) and is mainly vibrated at 5.22 Hz on the same loads (Table 1).

Table 1. Modal analysis result

order	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Frequency	5.22 Hz	6.6Hz	38.32 Hz	43.87 Hz	56.98 Hz	72.99 Hz	87.30 Hz

We also measured the environmental vibrations which can affect the calibrations process. We measured three axes (X, Y: horizontality, Z: verticality) between the telescope base and the rising block (Figure 5) in the 5 minutes sessions. The results of the vibration measurement are better than Class C. Class C allows for installation of the electron microscope with 30,000 magnification. Environment vibration does not affect the ground calibration process because the resonance frequency of the target is not equal to the environmental main vibration frequency, and because of small displacement (< 0.35 μm) (Figure 5).

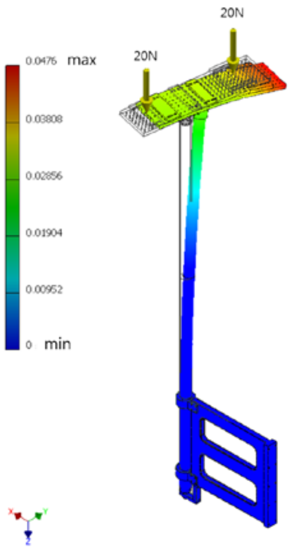

Figure 4. Displacement

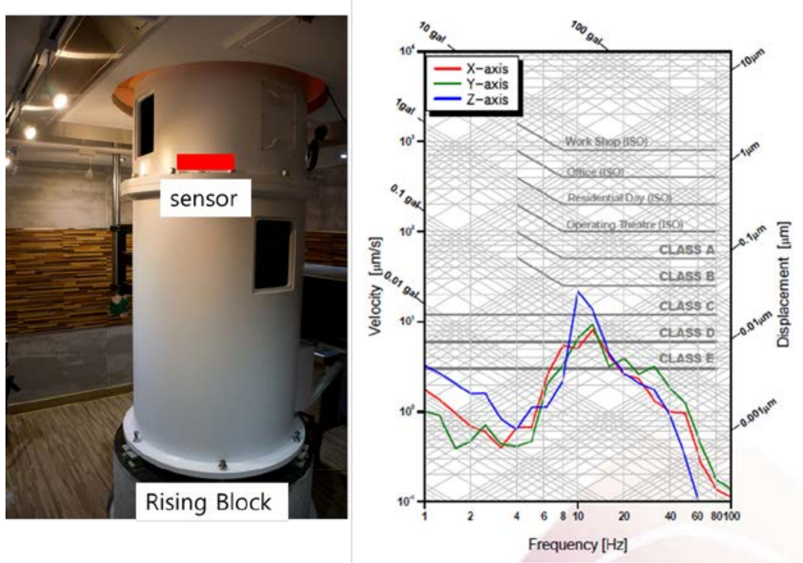

Figure 5. Environmental vibration measurement

Distance & Calibration Measurement

We performed 3D distance measurement between the virtual reference point of the mount and the ground target in order to obtain the precise distance (Figure 6). The optical path distance with micrometer precision and reflect angle were measured by 3D distance measurement.

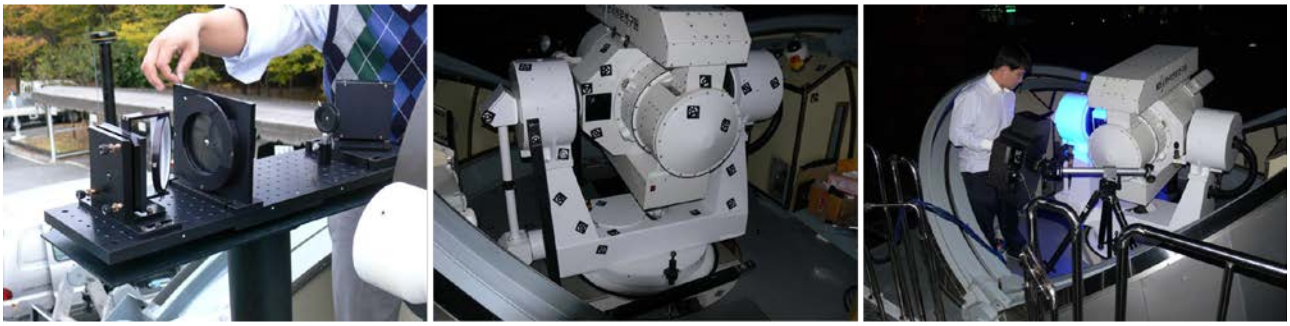

Figure 6. 3D measurement

The result of the optical path distance measurement is 2630.532 mm (8.768 ns). The angle reflected by the ground calibration target is 90.1° (Figure 7, Table 2).

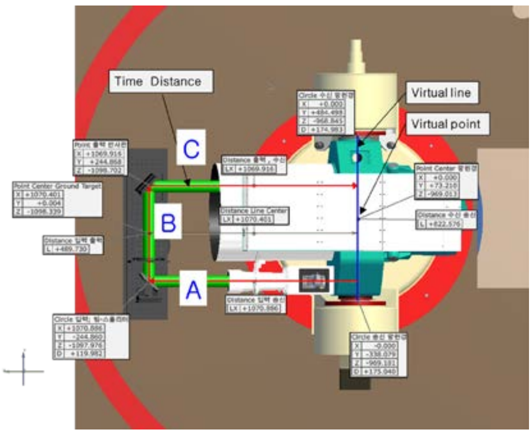

Figure 7. Ground calibration target measurement

Table 2. Distance and angle

	Distance
A	1070.886 mm
B	489.730 mm
C	169.916 mm
A+B+C	2630.532 mm
	Angle
∠AB	90.113°
∠BC	90.085°

Result

We measured the SLR system delay and the system accuracy using the ground calibration target. The post-processing of the range measurements to the target relies on the 2.2 sigma filtering. After the cleaning process the system stores the statistical information about the calibrations, such as the number of measurements per calibration session, the calculated system delay, the variation of the system delay, RMS of the calculated range residuals, skewness and kurtosis (Figure 8).

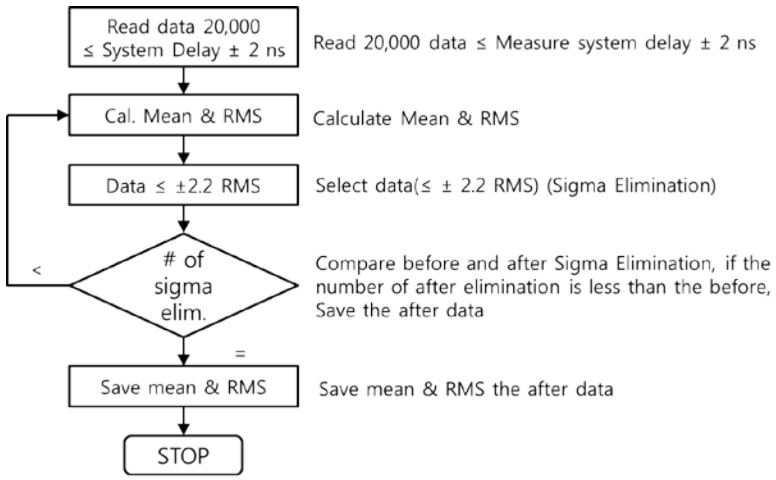

Figure 8. Ground calibration algorithm

The determined average system delay of ARGO-M is 278.169 ns, and the average RMS of the range residuals is 6.109 mm (20 October, 2013 - 24 December 2013).
Recently we have installed a device to stabilize temperature of the detection package which contains the C-SPAD photodetector. The temperature inside of the detection box is kept at 30° Celsius. This improvement can help to minimize the temperature dependent daily-variations of the system delay.