Development of the Automatic Transmitter/Receiver Alignment System for ARGO-M

Poster #3063

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Abstract

Korea Astronomy and Space Science Institute (KASI) has fulfilled the design, development, installation, and operation of Accurate Ranging system for Geodetic Observation–Mobile (ARGO-M) which is a bi-static telescope for Satellite Laser Ranging (SLR) measurement in Korea. While the laser is propagating through the atmosphere, very small amount of laser is scattered by air molecule. And some of the scattered photons travel back to the receiving telescope. The scattering particles, when it encounter the laser beam, scatters the laser beam, it becomes a point source. Through the camera on board the receiving telescope, the individual point sources contribute in forming a back scatter image. However, the laser propagation direction is also subject to the misalignments and drifts thermal gradients, due to the sun light during the day time observation. These misalignment and drift in the laser propagation direction causes difficulty in acquiring target. KASI is developing the Automatic Transmitter/Receiver Alignment System (ATRAS) that is to stabilize the laser direction while SLR observation is being conducted. Finally, ATRAS system developed by KASI is expected to be utilized for enhanced operating during the daytime and nighttime in SLR observations.

Overview of ARGO Project

❑ Name of Korean SLR program : ARGO

- ARGO : **A**ccurate **R**anging system for **G**eodetic **O**bservation

❑ Final Goal

- One mobile system(40cm / 10cm) : ARGO-M
- One fixed system(1m) : ARGO-F

❑ Development Period : 2008 – 2016 (9 years)

❑ Applications

- Precise orbit determination of satellite
- Space geodesy
- Space Situation Awareness

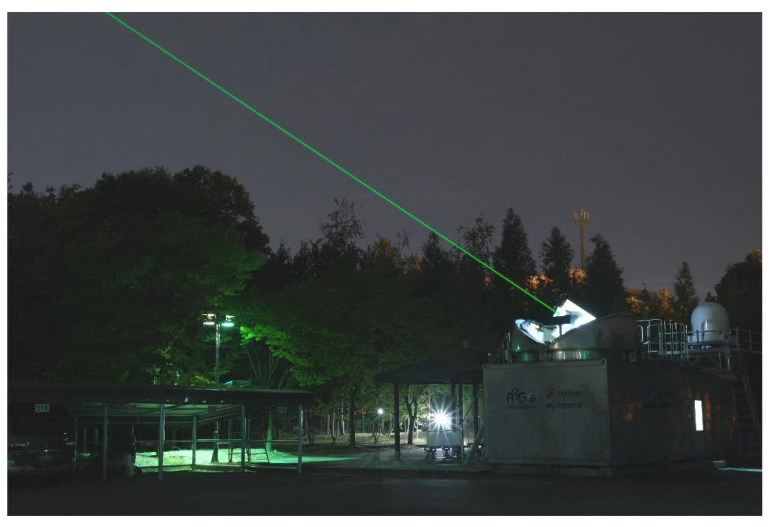

Fig. 1. ARGO-M in KASI

❑ Objectives

- Space geodesy research / Precise obit determination(POD)
- GEOSS/GGOS contribution by laser ranging for satellites with LRA
- Contribution to international SLR societies and ILRS network participation

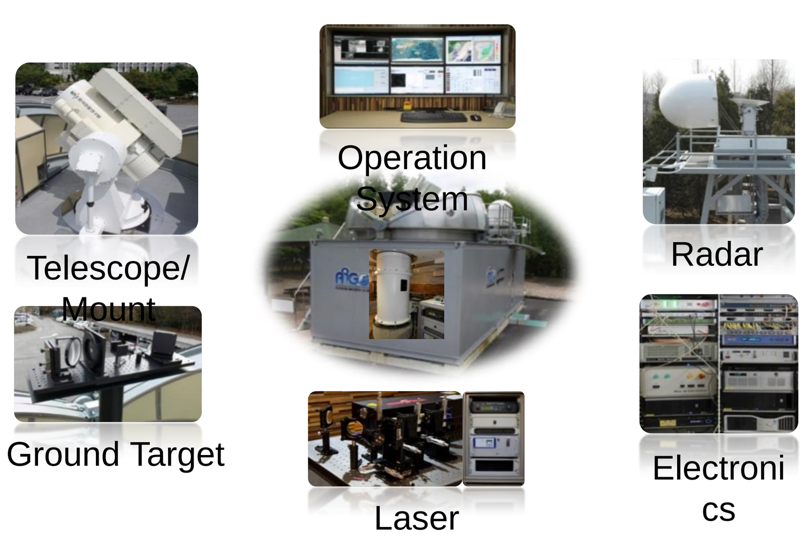

Fig. 2. Configuration of ARGO-M

Fig. 3. External Image of ARGO-M

Basic Design and theoretical model for ATRAS

❑ Background

- ARGO-M is a bi-static telescope for satellite laser ranging measurement
- The alignment between the laser beam transmitting axis and receiving axis has to be maintained very small
- The laser propagation direction is also subject to the misalignments and drifts thermal gradients, due to the sun light during the daytime observation
- And at the same time, as the ARGO-M is tracking the target, by changing elevation and azimuth angle of the telescope, the misalignment and the drift cause the target move away from the detector

❑ ATRAS(**A**utomatic **T**ransmitter/**R**eceiver **A**lignment **S**ystem)

- System Configuration

Tab. 1. System Configuration for ATRAS

Item	Parameter	ARGO-M
Telescope	Path type	Bi-static
	Rx and Tx telescope	40/10 cm
	Primary mirror F-ratio	1.5
	Beam divergence	5 ~ 200 arcsec
Laser	Wavelength	532 nm
	Pulse energy	2.5mJ @2KHz
	Pulse width	50 ps
	Repetition rate of Operation	2 KHz
Camera	Resolution(pixel)	1600 x 1200
	Pixel size (μ²)	7.4 x 7.4
	Field of View	5 arcmin x 5 arcmin
Pico-motor	Motorized Axes	3
	Type	Gimbal mount

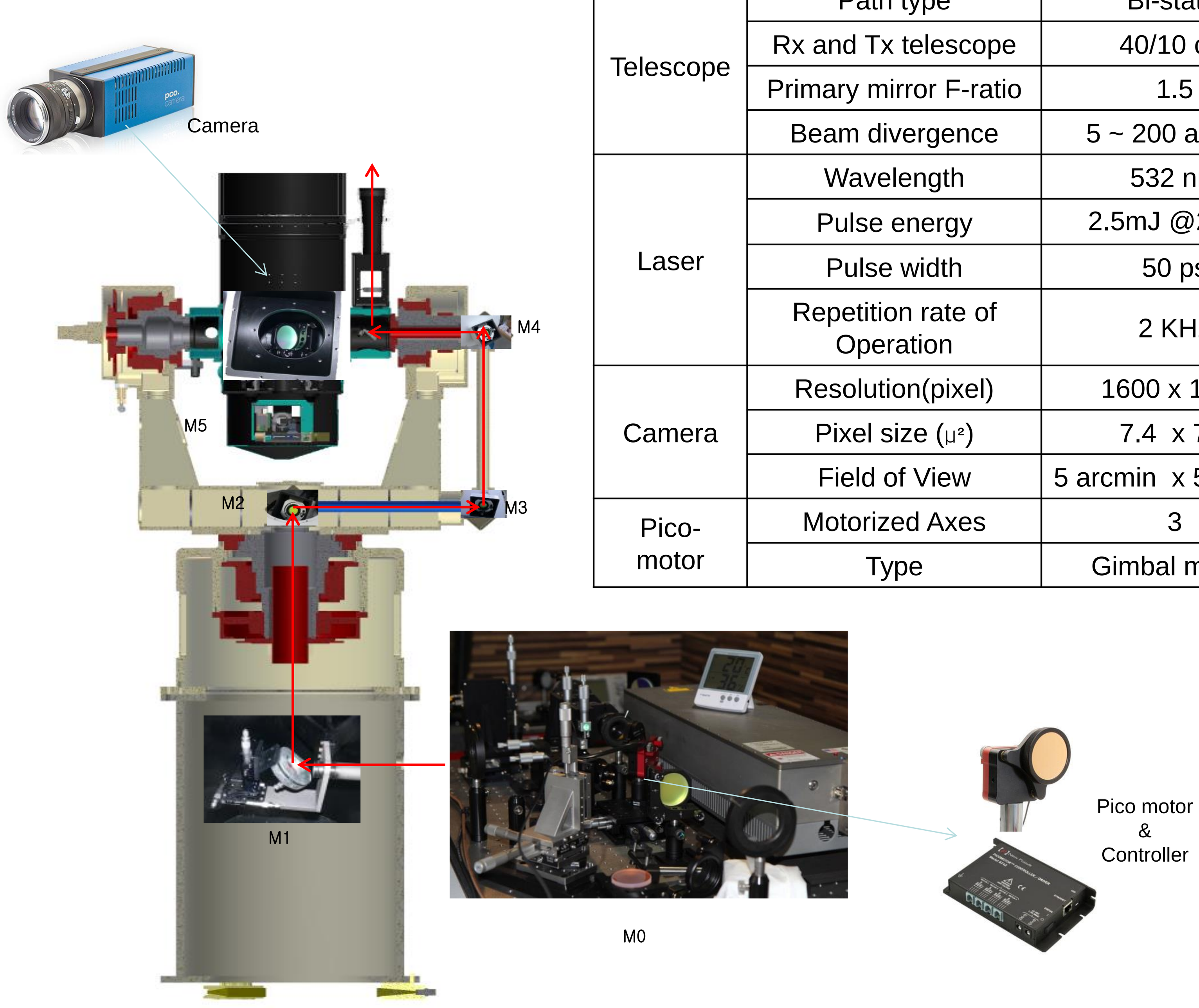

Fig. 4. ATRAS H/W Configuration

❑ **B**ack **S**catter **I**mage(BSI) Acquisition

- BSI Model : Back Scatter Image Model + Back Scatter Image Noise Model
  - · Single scattering dominates in SLR back scatter image
  - · Readout noise included(10 electrons RMS noise)
- ➔ **Obtain Laser propagation direction from the Back Scatter Image of the Camera**

❑ Image Signal Processing

- **M**aximum **L**ikelihood **E**stimation(MLE) theory has been employed
- MLE Algorithm is to compute the estimate of laser propagation direction relative to ARGO-M receiving telescope
- ➔ **Estimation of differential direction between Laser propagation direction and receiving axis of the telescope**

❑ Fig.4. Camera : PCO1600

- PCO1600 has the modulation capability, which allow multiple exposure images can be accumulated into a single frame
- PCO1600 yields the best back scatter images on camera when the beginning and the end of each exposure is synchronized with laser fire pulses(2 kHz)

Preliminary Implementation and Results

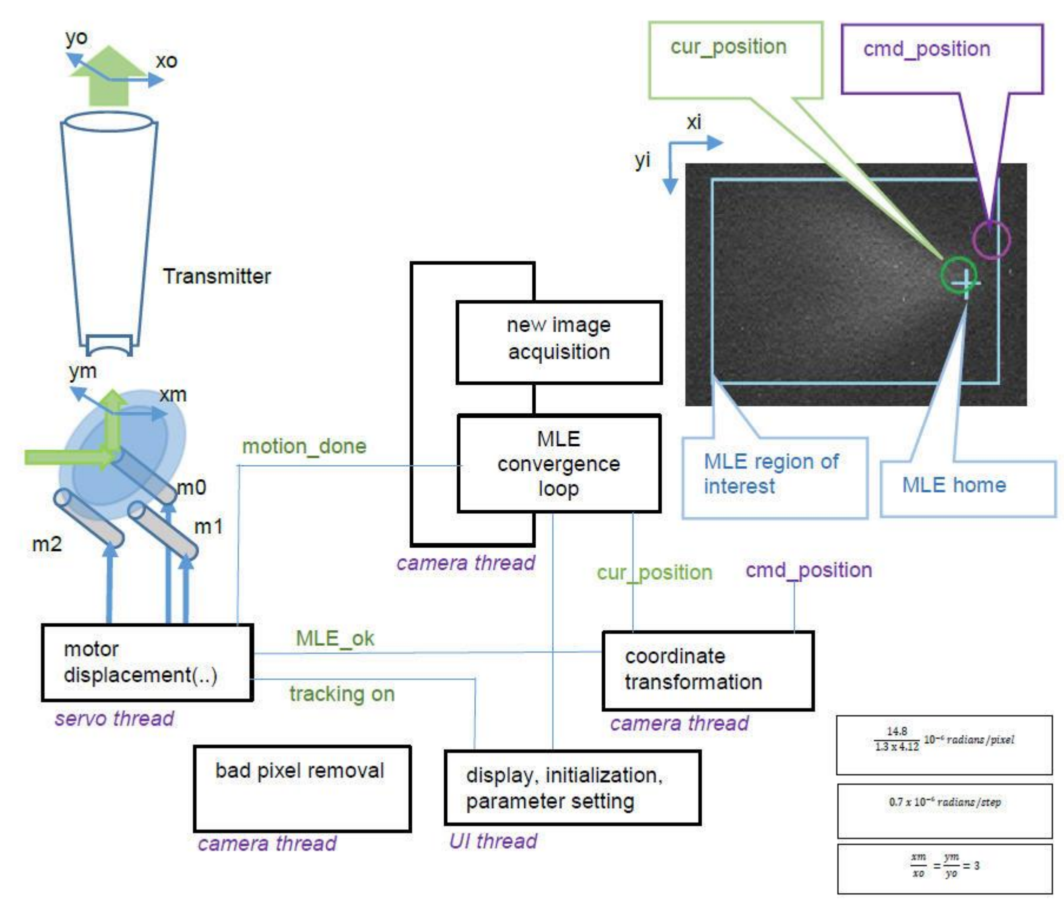

Fig. 5. ATRAS S/W Configuration

- cur_position : the laser firing position which is estimated from the image processing
- cmd_position : the position of target direction
- MLE region of interest : the area for the Image processing

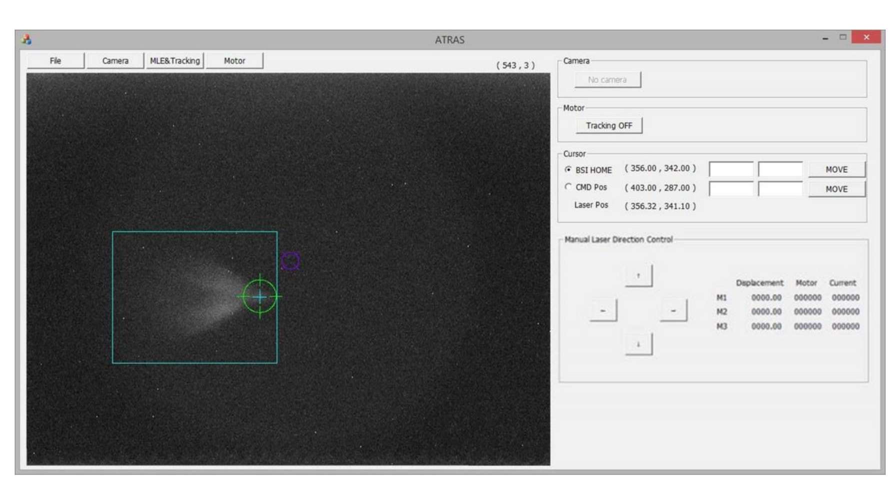

Fig. 6. ATRAS Main program

Tab. 2. Test Result

Item	Description	Result
cur_position	Time for finding the laser directions	≤ 3 sec
cmd_position	Time for moving to the position of target	≤ 5 sec
Auto-control	Auto-enable or disable the ATRAS operation by the fire signal of laser (aircraft detection etc.)	OK

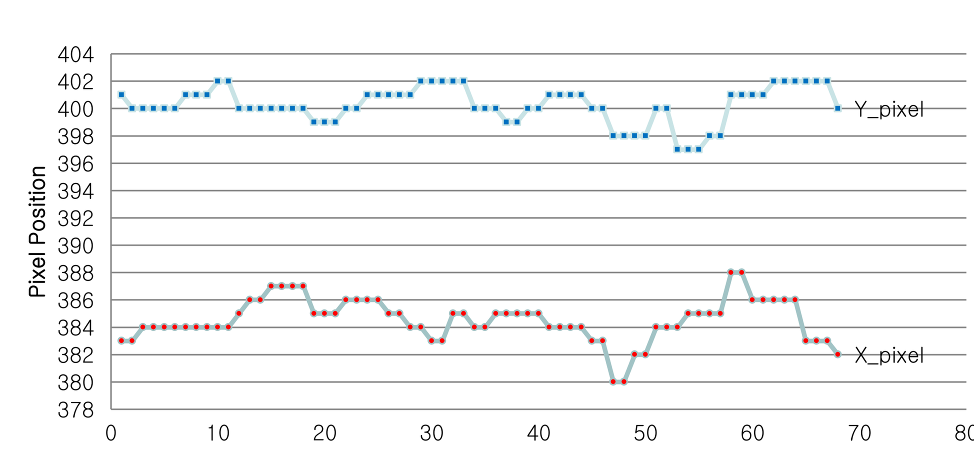

Fig. 7. Variation of pixels position during the on-track

- Sensor deviation while Tracking ON
  - - X pixel Range : 380~388 pixels
  - - Y pixel Range : 397~402 pixels
  - ※1 pixel = 2.763 μRAD = 0.57 arcsec

➔ Peak-Peak deviation : 3.8 arcsec
➔ RMS deviation : 1.6 arcsec

Conclusions

- Based on very rigorous theoretic and engineering approach, KASI has developed a high performance automatic back scatter image laser direction tracking and control system for SLR
- In order to obtain the most accurate and reliable laser direction estimate possible, KASI used proprietary technology and theoretical analysis, in designing and implementing Automatic Transmitter/Receiver Alignment System
- The laser direction estimate using MLE technique provide very accurate and reliable. It performs well with atmospheric turbulence and even under very adverse atmospheric conditions
- KASI will conduct more test for performance and function of ATRAS
  ➔ ATRAS access to elevation, azimuth angle, and beam divergence angle from the ARGO-M