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

Man-Soo Choi1,2, Seong-Geol Yu1, Hyung-Chul Lim1, Sang-Jung Lee2, Nam-Soo Myung3
1Korea Astronomy and Space Science Institute, 2Chungnam National University, 3Ray Applications, Co. Ltd

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 SLR while SLR observation is being conducted. Finally, ATRAS system developed by KASI is expected to be utilized for enhancing operated during the daytime and nighttime in SLR observations.

Overview of ARGO Project

- Name of Korean SLR program : ARGO
  - ARGO : Accurate Ranging system for Geodetic Observation

- Final Goal
  - One mobile system(40cm / 10cm) : ARGO
  - One fixed system(1m) : ARGO

- Development Period : 2008 – 2016 (9 years)

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

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

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 day time 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(Automatic Transmitter/Receiver Alignment System)
  - System Configuration

Preliminary Implementation and Results

- Back Scatter Image(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
  - Maximum Likelihood Estimation(MLE) theory has been employed
  - MLE Algorithm is to compute the estimate of laser propagation direction relative to ARGO-M receiving telescope
  - Estimation of difference 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)

- 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

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

Fig. 5. ATRAS S/W Configuration
- Tab. 2. Test Result

Tab. 1. System Configuration for ATRAS

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
<th>ARGO-M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telescope</td>
<td>Path type</td>
<td>Bi-static</td>
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<tr>
<td></td>
<td>Fis and Fis telescope</td>
<td>40/10 cm</td>
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<tr>
<td>Laser</td>
<td>Primary mirror F ratio</td>
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<td></td>
<td>Beam divergence</td>
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<tr>
<td></td>
<td>Wavelength</td>
<td>532 nm</td>
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<tr>
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<td>Pulse energy</td>
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<td></td>
<td>Pulse width</td>
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<tr>
<td>Camera</td>
<td>Repetition rate of Operation</td>
<td>2 KHz</td>
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<tr>
<td></td>
<td>Resolution(pixel)</td>
<td>1600 x 1200</td>
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<tr>
<td></td>
<td>Pixel size [μ]</td>
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<td></td>
<td>Field of View</td>
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<tr>
<td>Pico-motor</td>
<td>Motorized Axes</td>
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<tr>
<td></td>
<td>Type</td>
<td>Gimbal mount</td>
</tr>
</tbody>
</table>

Fig. 6. ATRAS Main program
- Sensor deviation while Tracking ON
- X pixel Range : 380–388 pixels
- Y pixel Range : 397–402 pixels
- Peak-Peak deviation : 3.8 arcsec
- RMS deviation : 1.6 arcsec

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