# A-RGG development for 10 kHz Laser Ranging of Sejong station

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## Abstract

Korea Astronomy and Space Science institute (KASI) has developed the range gate generator, named A-RGG, for 10 kHz laser ranging of Sejong station. The A-RGG can generate the range gate with maximum speed of 13.89kHz, and the laser fire firing with maximum speed of 20kHz using Lagrange interpolator implemented in the FPGA H/W. The FIFO size is 56x2048 bit for the storage of event epochs from start and signal detectors. It can be synchronized with a GPS timing device(XLI) through the IRIG-B, 1PPS and 10MHz input ports. It has two Lookup tables with 64x265 bit size to switch laser ranging operation quickly between two adjacent satellites. The A-RGG consists of RG signal generator for C-SPAD, FIRE signal generator for laser, 3 output ports to control external device and 7-segment display. RGG port has H/W delay chip(DS1023S-50) with 0.5ns resolution. On the other hand, Both FIRE port and 3 outputs have the 100ns resolution. Two functions, time bias and range shift, are implemented for satellites with inaccurate orbit ephemeris. Even though the ground target has a short distance, it can also support the calibration ranging. The operator can control all A-RGG functions and diagnose the internal operation status from the computer through RS-232 serial communication. In addition, it has a display panel in front of the A-RGG to monitor its status.

## Features

- Lagrange interpolation method : FPGA (Stratix 2P2S30S)
- Lagrange calculation time : 65 65μs(@50MHz)
- Lookup table Memory : 256 x 64bit x 2
- FIFO memory : 2048x56bit
- Delay generation : Digital delay(DS1023S-50)
- Operation mode : Range, Ground calibration, Overlap avoidance, Dual selection satellite(A,B)
- Operation control : Serial or TCP/IP
- Resolution : RGG generator - 0.5ns, Internal Event timer - 0.5ns, FIRE signal - 100ns
- Timing input signal : 1PPS, 10MHz, IRG-B
- Input signal : START, IN1
- Output signal : RGG, FIRE, Out1~3(Sync with RGG or FIRE, variable width)
- LED indicator for I/O port : 1PPS, 10MHz, IRIG-B, START, IN1, RGG, FIRE, Out1~3
- Status FND Display :
  - UTC(Day, Hour, Min, Second)
  - Range(ns)
  - Laser Fire(Set, measure)
  - FIFO(Number of Fires in the sky)

## Time Bias & Range Shift

It is hard to track the satellites because the predicted orbit is not accurate and the beam divergence angle of the SLR system is narrow. It is required to control the time bias and range shift to get the returned signals. The A-RGG has several registers associated to solve these problems. If a satellite is moving faster or slower than predicted satellite orbit, the Time Bias Register enables to compensate for the time difference. The Time Bias Register can be also controlled up to ±10 seconds to compensate the time difference. The A-RGG calculates Time Bias before Lagrange Interpolation procedure. In addition, it has Range Bias Register. The Range Bias Register can compensate error of the satellite distance. The Range Bias Register can be controlled up to ±10ms for the compensation of range difference. It has also additional Register to compensate delay for the length of the cable or the part propagation. Each Register can be enabled / disabled depending on the operator's selection.

| Register | Adjust Range | Time / Range | Application |
|---|---|---|---|
| Time Bias | -10sec ~ +10 sec | Time adjust | Time Bias adjustment |
| Range Bias | -10ms ~ +10ms | Range adjust | Range Bias adjustment |
| Range Shift | -10ms ~ +10ms | Range adjust | Temperature compensate |
| Input Delay | 0 ~ +10ms | Time / Range adjust | Cable/chip delay compensate |
| Output Delay | 0~ +10ms | Range adjust | Cable/chip delay compensate |

## Timing Block

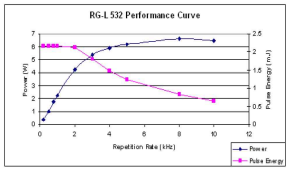
The A-RGG sampling clock of laser START signal is 200MHz which is generated by PLL. The reference clock of the PLL is 10MHz from GPS Timing reference. The resolution of START signal is 0.5ns based on 5ns(200MHz) resolution using FPGA logic delay chain. The RGG epoch time is made by combination of measured START epoch time and IRIG-B time information.

The AM-modulated IRIG-B signal detection uses a simple H/W comparator. UTC time is generated by sync decoder, bit decoder and byte decoder after sampling part of "1" in entered IRIG-B signal.

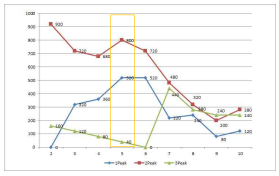
## Power Variation & Several Laser Pulses

Sejong station uses the RGL-532 high pulse energy picosecond laser system(2.5mJ@2kHz) made by Photonics Industries. A vital problem encountered when operating RGL-532 on 10kHz was the change of laser output depending on the applied frequency as shown below. It is verified that pulse energy decreases when the repetition rate varies from 2 kHz to 10kHz. Therefore, Sejong station used 5 kHz which shows the least reduction of pulse energy.

[unit : mV]



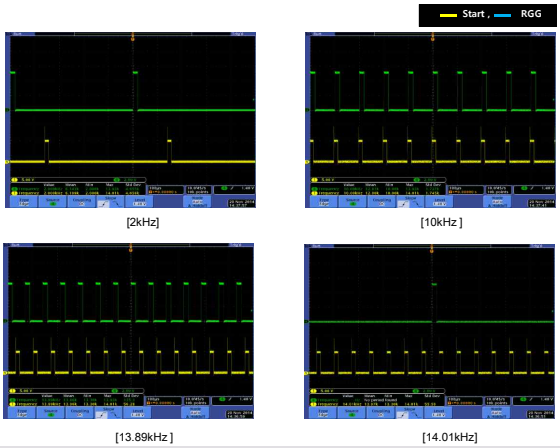

Photonics Industries Specification



KASI test start sensor Detection result(Oct 12, 2014)

## Range Gate Generator

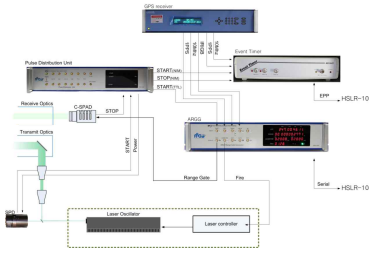
The calculations of Lagrange Interpolation is 43.36us. On the conditions of that, the RG maximum speed is measured up to 23kHz. However, the maximum RGG speed of the A-RGG, measured by entering satellite orbit predictions is 13.86khz. The reason for difference between the result of Lagrange Interpolation and the A-RGG is because of the internal system delay of A-RGG. It is contented with the requirement of the A-RGG, the operating speed of 10khz as a result.



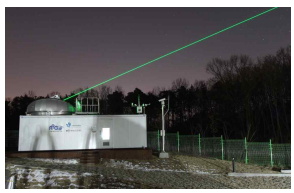

[2kHz] [10kHz ] [13.89kHz ] [14.01kHz]

## Ground Calibration and Satellite Ranging in A-RGG

The A-RGG and the HSLR-10 operation system were connected by serial communications. The Sejong station has been successfully operating Ground Calibration and Satellite tracking with 5kHz laser pulse.



(Configuration of Electronics system)



(External Image of Sejong station)

| Quarter | Laser repetition rate | Term | count | RMS Average |
|---|---|---|---|---|
| GC | 5khz | 2016.04.01~30 | 706 | 3.46mm |
| Lageos | 5khz | 2016.04.01~30 | 28 | 11.32 |
| Starlette | 5khz | 2016.04.01~30 | 25 | 8.75 |