A-RGG development for 10 kHz Laser Ranging of Daedeok station

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Abstract

Korea Astronomy and Space Science institute (KASI) has developed the range gate generator, called A-RGG, for 10 kHz laser ranging of Daedeok station. The A-RGG can generate the range gate with maximum speed of 16 kHz using Lagrange interpolator implemented in the FPGA H/W. The FIFO size is 56x2048 bit for the storage of event epochs from start and stop signal detectors. It can be synchronized with a GPS timing device through the IRIG-B input port. It has H/W delay chip(DS1023S-50) to fulfill the 0.5 ns resolution, and two lookup tables with 64x256 bit size to switch laser ranging operation quickly between two adjacent satellites. Two functions, time bias and range shift, are implemented for satellites with inaccurate orbit ephemeris. It has also collision avoidance function based on epochs of laser fire commands instead of laser fire shifting method. There are three output ports to select RGG (Range Gate Generation) or Fire functions whose delay values can be programmable. In addition, it has input and output delay registers to compensate the cable delay for more accurate RGG. The A-RGG provides the simulation mode to check the operation of internal Lagrange interpolator. 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 the 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 have 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

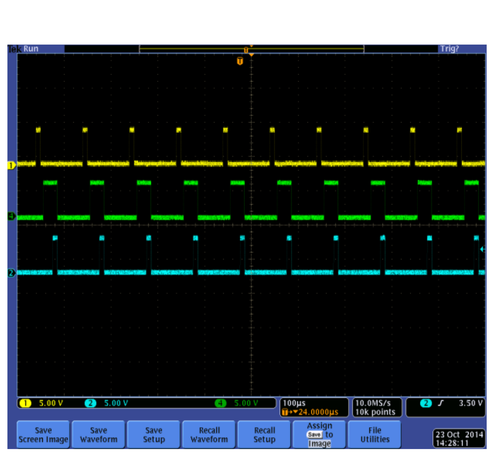
The ARGG sampling clock of laser START signal is 200MHz which is generated by PLL. The reference clock of the PLL is 10MHz from GPS Timing reference. The resolution of START signal is 0.5ns based on 5ns(200MHz) resolution using FPGA logic delay chain. The RGG epoch time is made by combination of measured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

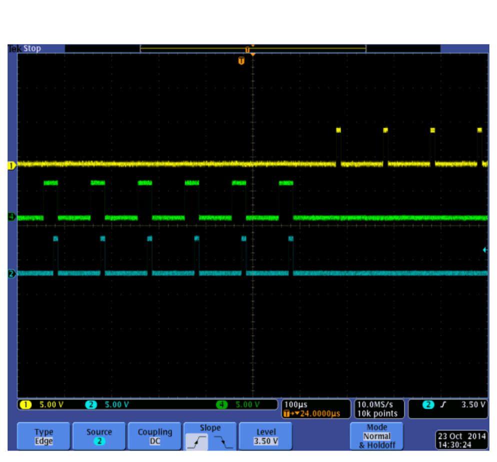
Collision Avoidance

If the arrival time of the returned laser is near the laser firing, the C-SPAD can detect fired laser instead returned laser. These phenomenon degrades the observation efficiency as well as may also cause a damage of C-SPAD. When the phenomenon occurs, the time of laser firing is shifted to solve this problem in general. This method is can repeated when the time-of-flight is a multiple of the period of laser firing. In particular, the problem is occurred more frequently on high repetition rate system.

The A-RGG stops firing laser instead of shifting laser firing to avoid this problem. After the calculation of arrival time of the returned laser from satellite is completed, the epoch for non-firing time and its duration is recalculated. The A-RGG has two registers for this process. The picture below shows wave form of Fire, RG and Fire avoid duration on 10 kHz operating frequency.



[Normal Operation]



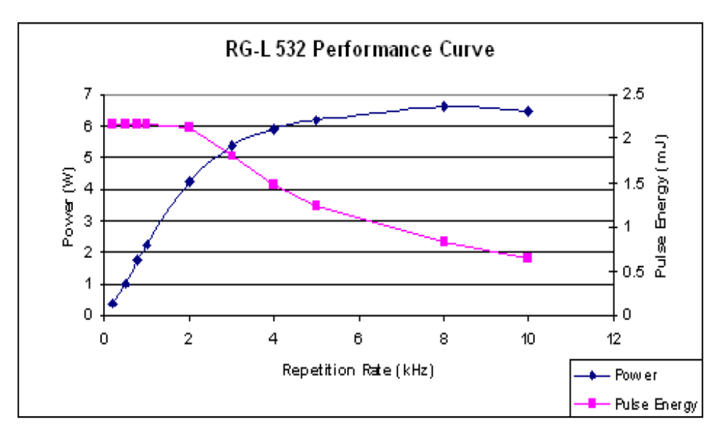
[Fire→On, RGG→no Return]

[wide View of Overlap Avoidance]

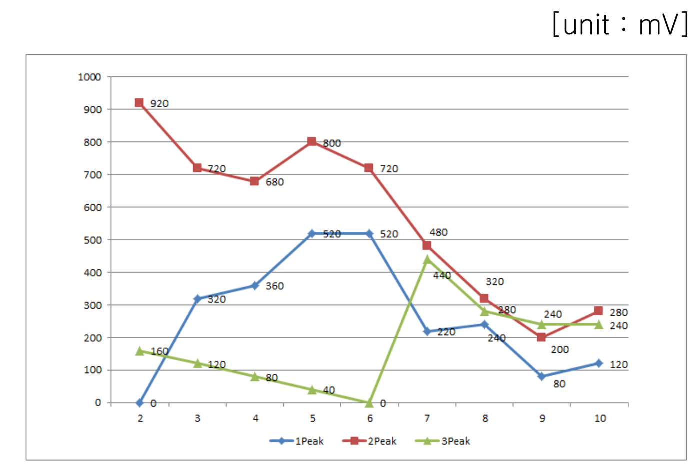
Power variation & several Laser pulses

Deadeok station uses the RGL-532 high pulse energy picosecond laser system(2.5mJ@2kHz) made by Photonics Industries. When we run RGL-532 on 10kHz, we encountered vital problem. The following result shows the change of laser output depending on the applied frequency. We expected pulse energy decrease by the change of repetition rate of 2 kHz to 10kHz. But the unexpected problem is multiple laser pulses. We expect this problem to be solved by the cooperation of laser manufacturer, Photonics Industries.

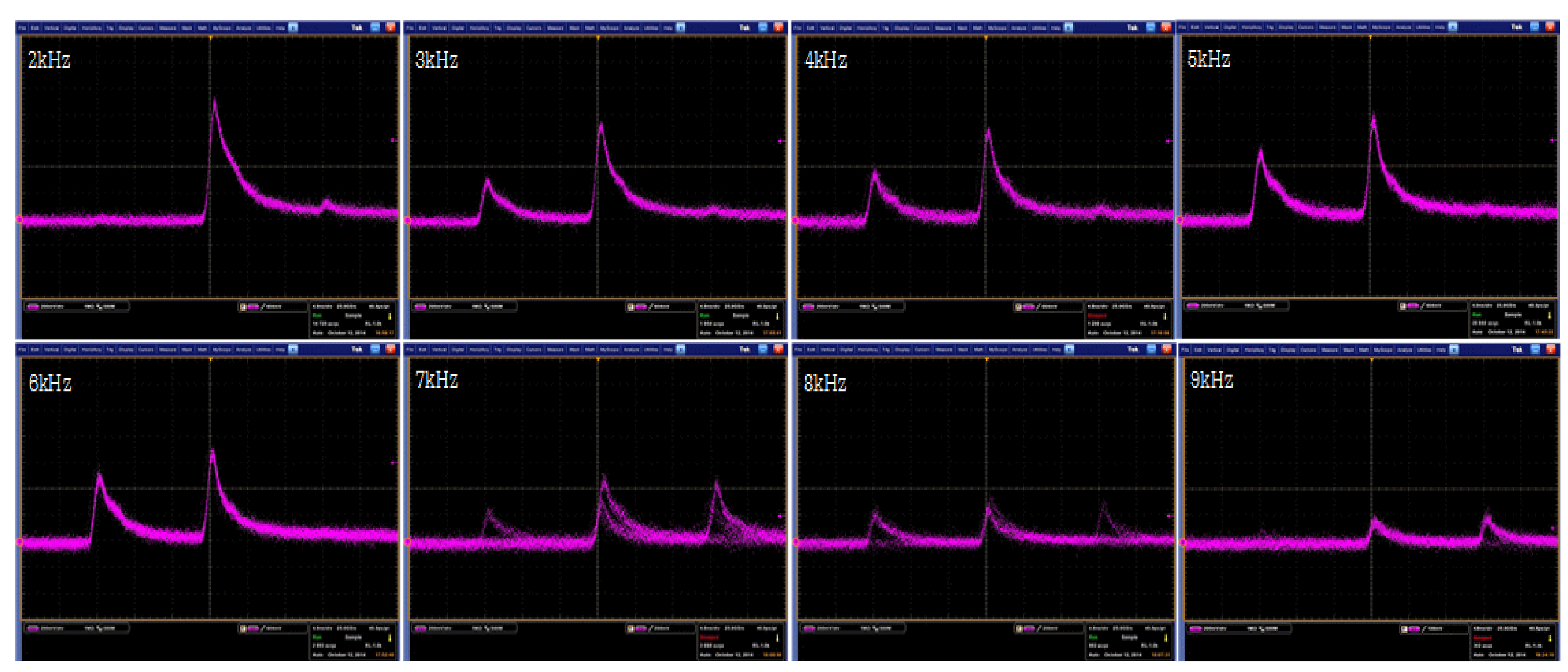
[unit : mV]



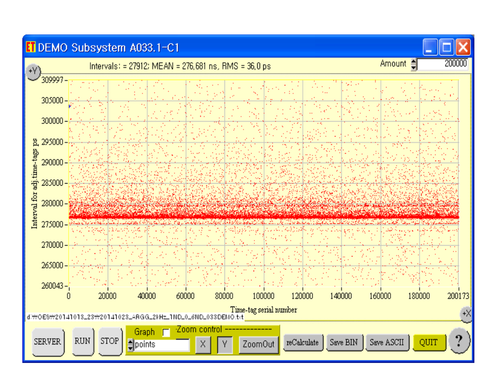
Photonics Industries Specification



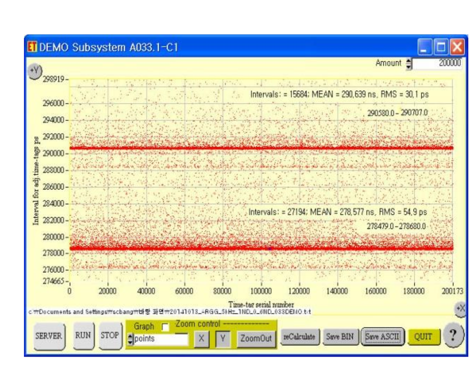
KASI test result(Oct 12, 2014)



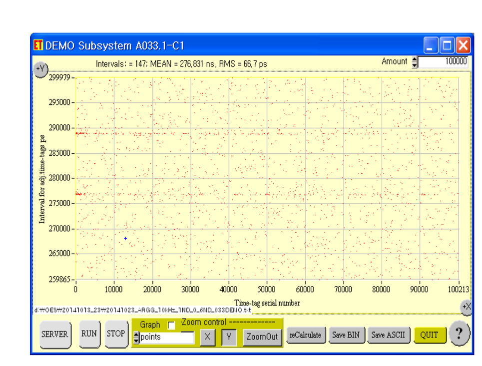
4.0ns/div 25.0G/s, Tektronix, MSO70404C(50GHz)



[2kHz A032-ET result]



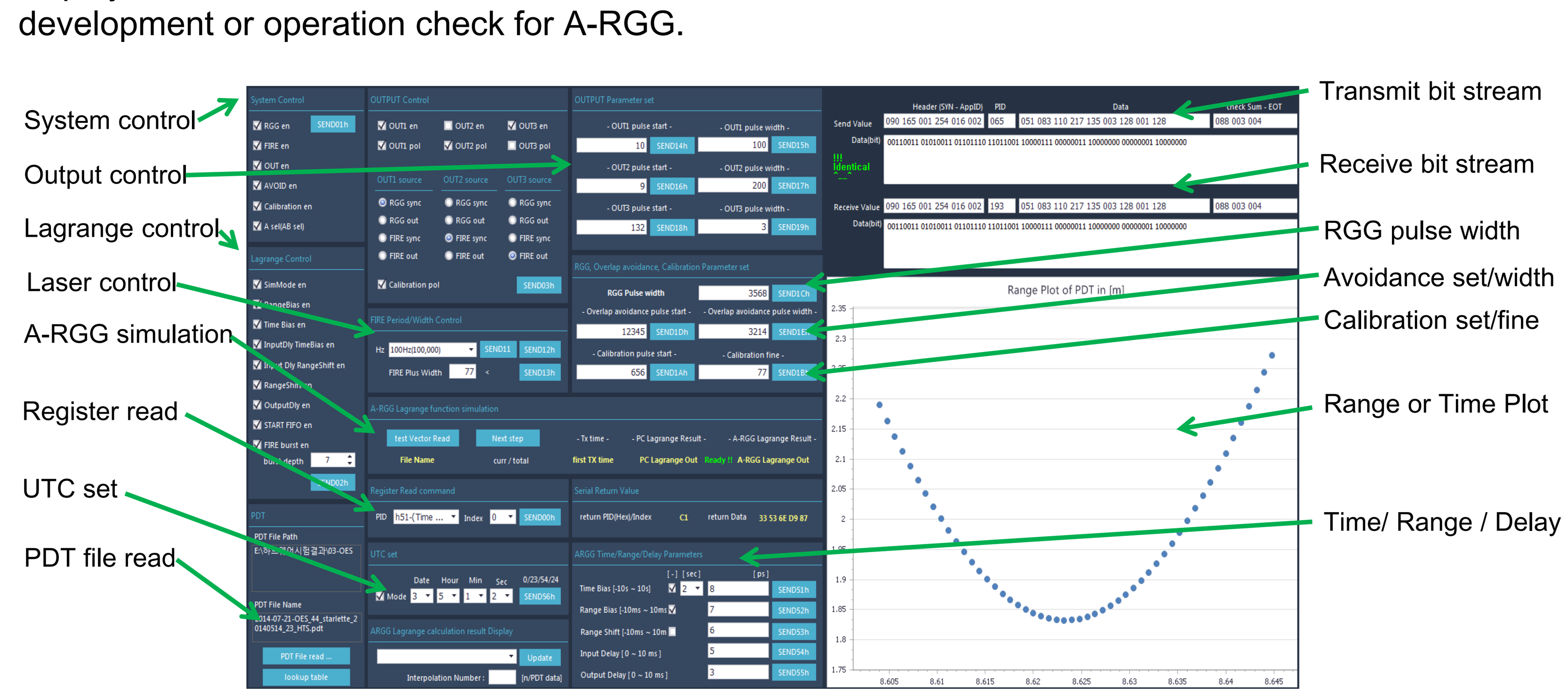
[5kHz A032-ET result]



[10kHz A032-ET result]

Diagnostic program in HSLR-10

The HSLR-10 is the operation S/W in Deadeok station, which has diagnostic program to do the functional test of A-RGG. This diagnostic program can read .pdt file format and display TOF plot in time or distance. Also this program can read or write the internal register of the A-RGG. It has a display function the transmitted or received data to the A-RGG. This function makes easier the development or operation check for A-RGG.



Conclusion & Future Plan

The 10kHz operation experiment of A-RGG for satellite laser ranging has not been done. The laser of Photonics Industry is used in Daedeok station, which has a problem of multiple pulses on the 10kHz operation. But this laser has been configured to operate at 2kHz for optimum frequency. When we increase the frequency from 2kHz to 10kHz, output power decreases and multiple pulses are generated for more than 2kHz. For 10kHz satellite laser ranging with single pulse, adjustment of the laser seems to be required.

The A-RGG has been doing performance matching to the operating system, HSLR-10. The A-RGG and HSLR-10 will be completed within this year.