Tracking orbital debris in a busy airspace environment. (3115)

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Abstract: With the amount of orbital debris increasing dramatically, the development of methods to remove the debris or predict its future impact to other orbital assets is becoming critical. The first step in either effort is to develop the ability to accurately locate and track the debris. Ground based laser ranging can provide higher resolution position information than the current radar systems, and by using multiple stations to track the same object even more accurate orbits can be obtained. In this scenario the more stations participating in the effort, the more accurately and reliably the orbit can be defined. However, stations in areas where the airspace is crowded are limited in the amount of laser power they can use to track such objects without endangering passing aircraft. To reduce these effects we examine the design implications of shifting the laser wavelength from 0.532 µm or 1.064 µm, the standards for laser ranging, to the 1.5 µm range where more powerful lasers can be used without generating safety concerns. We will examine the trade space of the amount of eye safe power at different wavelengths, combined with link analysis of a sample target and the efficiency of the receive detectors to the returning signal.

Maximum Eye Safe Power

	532 nm	1064 nm	1550 nm
10 sec exp.	0.0001 J	0.001 J	0.982 J
0.25 sec exp.	0.0001 J	0.001 J	37.767 J

-Based on results using USAF LHAZ6.0 which is calculated using 2014 ANSI standards
-Calculated using 1 ns pulse, 50 Hz rep rate, 25 cm beam diameter
-1550 nm remains eye safe at orders of magnitude higher powers than 1064 or 532 nm

QE for Detectors

	532 nm	1064 nm	1550 nm
Si APD	~70%	~5%	Neg.
InGaAs APD	Neg.	<10%	~10%

-QE values taken from data sheets for commercially available single photon counting detectors
-Can achieve within an order of magnitude QE for all wavelengths considered

Discussion

- Both systems require single photon detection
- Both systems compared for a 50 cm target at 1,000 km range
- Presumed x2 improvement over Graz in laser power while remaining eye safe; can improve by additional x3
- Orders of magnitude more power while maintaining eye safe levels going from 532 or 1064 nm to 1550 nm
- Still need to investigate potential lasers to determine output power upper limit
- Eye-safe NASA/GSFC laser terminal ~ 10X more performance per laser pulse than successful, non-eye safe GRAZ system
- Extra performance at GSFC could be used for sensing smaller debris field

References:

-Kirchner, G., et al. Laser measurements to space debris from Graz SLR station. J. Adv. Space Res. (2012),http://dx.doi.org/10.1016/j.asr.2012.08.009
- "Instability of the Current Orbital Debris Population", N. Johnson and J.-C. Liou, Orbital Debris Quarterly News, April 2006, Vol. 10, Issue 2

Reflection from surfaces

	532 nm	1064 nm	1550 nm
Gold	~70%	~98%	~98%
Aluminum	>90%	>95%	~98%
Silicon			>30%

1550 nm reflects from common satellite surfaces as well or better than both 532 and 1064

Comparison of Proposed System with Orbital Debris Tracking Work Done at Graz

Lidar sensing assumptions & parameters	Proposed NASA/GSFC	Austria/GRAZ 2013
Lidar Transmitter Parameters:		
Transmitter Wavelength (nm)	1557	532
Photon Energy (J)	1.28E-19	3.74E-19
Laser ouput pulse energy (J)	0.400	0.200
Transmitter optics transmission	0.90	0.90
Launched Pulse Energy (J)	0.36	0.18
Laser pulse-rate (Hz)	50	100
Launched Pulse Power (W)	18.00	18.00
Launched beam divergence effective diam. (microradian)	50	50
Target Link Assumptions		
Range to target (km)	1,000	
1-way Atmospheric transmission	0.6	
Target cross-section diameter (m)	0.5	
Area of target surface (sq. m)	1.96E-01	
Area of transmitted beam at the target range (m)	1.96E+03	
Fraction of beam reflected	1.00E-04	
Diffuse Surface Target reflectivity	0.1	
Target backscatter coeff. ((fraction*reflectivity)/ster)	3.18E-06	
Receiver Parameters:		
Telescope Diameter (m)	1.2	0.5
Telescope Central Obscur. (m)	0.3	0.1
Telescope Area (sq. m)	1.060	0.188
Receiver System optics transmission	0.5	0.5
Receiver time gate duration (microsec)	10	10
Detector Parameters:		
Detector material and type	InGaAs APD geiger mode	SiAPD geiger mode
Detector Photon Detection Efficiency	0.18	0.5
Detector Dark count rate (/sec)	30,000	10,000
# of Detector Dark Counts in Integ. Time	0.30	0.10
Received mean signal (photo-electrons) per transmittted pulse	**0.308**	**0.026**

Conclusions

-Little difference in wavelengths for reflectance from debris
-Less then order of magnitude difference in detector quantum efficiency
-At least 2 orders of magnitude difference in level of eye safe output power between 1064 and 1550 nm
-Comparison of NASA/GSFC facility with debris work done by Graz indicates an increase in received signal by ~factor of 10 and be eye safe, due in part to larger telescope
-Can increase output power in comparison by ~x3 and remain eye safe, allowing the tracking of smaller objects or use of smaller telescopes