Infrared Laser Ranging to Space Debris – a Chance for ILRS

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Abstract

Using the fundamental wavelength of lasers used within the ILRS network, the efficiency to range to uncooperative targets like space debris should increase by a factor of at least 10, and up to about 50 times. The adaption for selectable IR ranging mode is cheap, and involves mainly an occasional removing of the frequency doubler crystal, a separate IR detection package, and dual-frequency coating of the involved optical elements. The benefit and chance for ILRS is a potential participation and contribution in the rapidly increasing field of space debris laser ranging, offering a worldwide laser tracking network for this special purpose.

Introduction

Almost all SLR stations are using the 532 nm wavelength for the standard ranging to cooperative (i.e. equipped with laser retro-reflectors) targets. These lasers are operating at wide spread repetition rates, and energy per shot; the scale goes from 5 Hz / 100 mJ per shot (Haleakala) up to 2 kHz / 0.5 mJ per shot (NERC). Despite these variations, the output power of all these systems is quite similar, and ranges from 0.5 to 1.2 W (fig. 1).

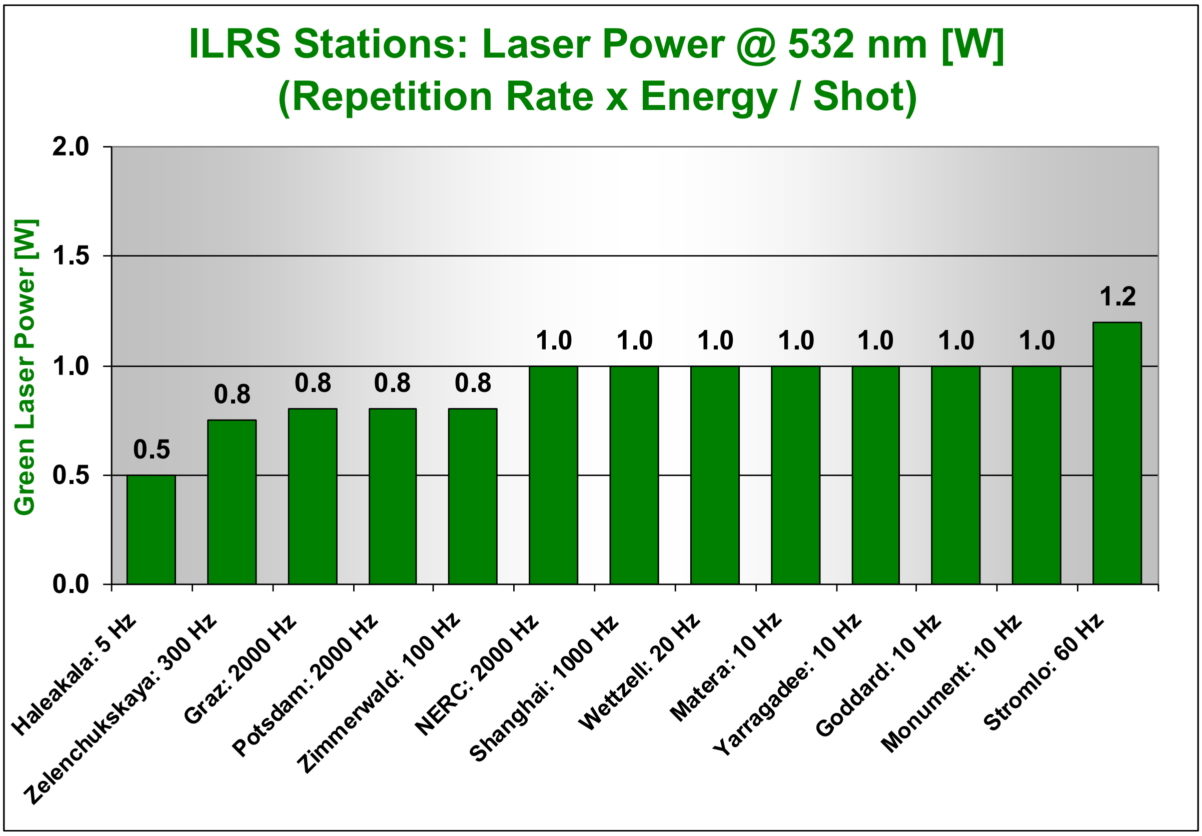

Fig. 1: All SLR stations operate with comparable laser power, despite large variations of laser repetition rate: From 5 Hz (Haleakala) up to 2 kHz (NERC, Graz)

Such a laser power is perfectly suited for standard ILRS targets (with retros); however, it is too low for ranging to uncooperative targets. For comparison: All successful debris laser ranging 2013 in Graz has been done with laser powers between 16 and 20 W (80 - 100 Hz, 200 mJ@532 nm per pulse) (fig. 2)

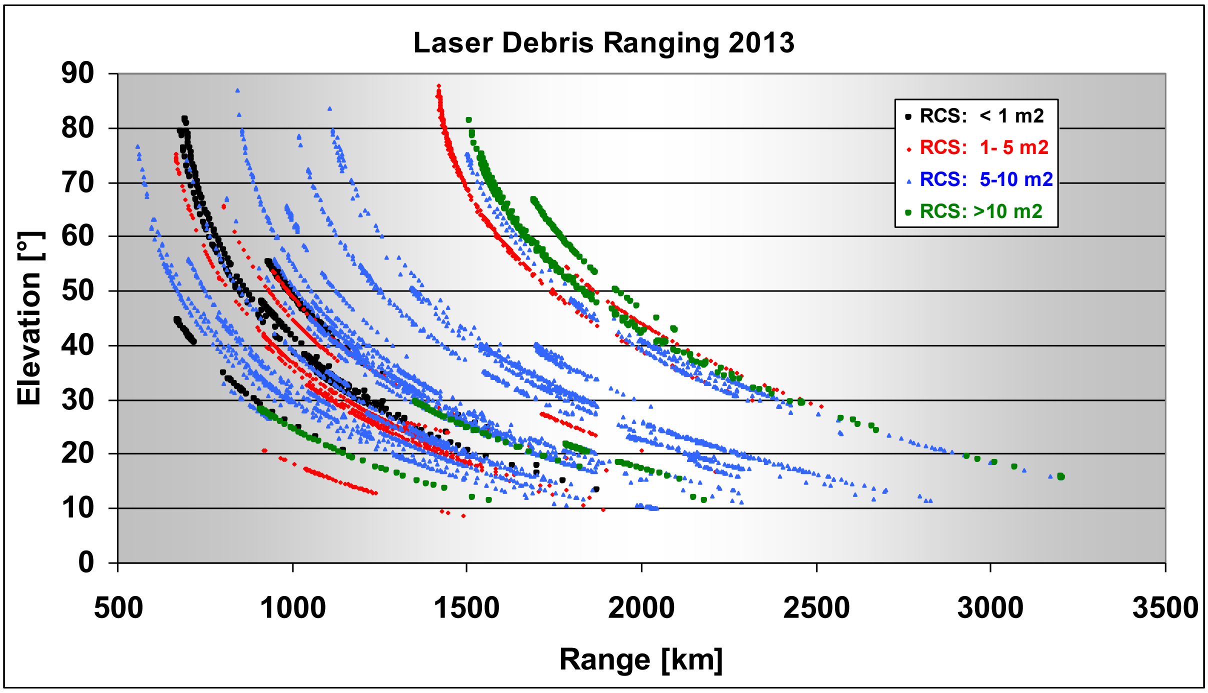

Fig. 2: Graz debris laser ranging 2013, using an additional STRONG laser with 16 to 20 W; all measurements using 532 nm / 200 mJ / 3 ns / 80 – 100 Hz; the majority of data was taken at relatively low elevations (due to LEO orbits); Radar Cross Sections (RCS) between 0.3 m^2 up to about 19 m^2

Debris laser ranging at Infrared wavelength

Switching to the fundamental infrared wavelength offers a substantial increase in ranging efficiency: From about 10 times (at zenith angle) to about 50 times (at an elevation of 20°) (Voelker et at. 2013). This increase is due to several factors:

- Doubling the laser energy by removing the frequency doubler
- Doubling the number of available photons by switching to IR wavelength
- Increased atmospheric transmission, especially towards lower elevation

Comparing these considerations with the Graz debris ranging experience, it seems possible to achieve a similar debris ranging efficiency with standard SLR station using their laser at fundamental wavelength, than we achieved in Graz using a 20 W green laser. Therefore, Graz is now preparing the SLR system to test debris ranging at 1064 nm with the original High-Q-Laser system.

Necessary changes for debris laser ranging at fundamental wavelength

a) Removal of frequency doubler crystal / Second Harmonic Generator (SHG)

Our SHG in Graz is a rather bulky device, and needs – like most SHGs – careful alignment to achieve its conversion efficiency of about 50%. Therefore we will not remove it, but rather switch out the IR beam BEFORE entering the SHG; thus, the original alignment is never touched. The IR beam then is redirected into the standard laser Coudé path using a sliding mirror (manually for first tests, maybe later with remote control if IR debris ranging should become operational).

b) Double Wavelength coating for involved optics

This is necessary mainly for the Coudé mirrors; cost depends on the number and size of mirrors; coatings for 1064 / 532 nm are standard options, and offer reflectivity of > 99% for both wavelengths and random polarization. This option possibly should be considered at least once the mirrors have to be renewed / recoated anyway.

c) Detector for 1064 nm

Single Photon Avalanche Diodes (SPAD) are widely used as detectors in SLR systems; however, all of them are Silicon devices – which suffer from a cut-off short above the 1064 nm. The remaining quantum efficiency is about 1% at this wavelength, which would simply cancel all possible efficiency advantages.
Fortunately, there are Geiger mode diodes available - based on InGaAs/InP – allowing single photon detection between 0.95 and 1.1 µm. The quantum efficiency at 1064 nm is 20% to 30%, and dark noise is in the order of 100 kHz (e.g. Lightwave PGA-200-1064, 3-stage Peltier cooling). For comparison: The C-SPAD used at SLR Graz – operated at maximum possible accuracy, using relatively high voltage above break – shows a dark count rate of 400 kHz, when gated with 2 kHz.
The major drawback of these InGaAs/InP Geiger mode diodes is their relatively small 80 µm diameter, which requires a careful design of the SPAD input optics, and reduces also the operational Field-of-View. For the planned operational modes however (night only, with the targets illuminated by sun / visible on the screen), this seems to be manageable.

A chance for ILRS

Space debris laser ranging is by itself not a suitable method e.g. to establish or update the debris catalogue; its main advantage is the possibility to determine accurate orbits of selected targets within a short time (few days or so). However, due to weather problems this is a bit contradictory if only one or very few debris laser ranging stations are available...
However, if IR ranging using standard ILRS stations is possible at least to larger targets, this would offer a large, experienced, 24/7/365 available laser ranging network for space debris, where local bad weather can be compensated easily by the global distribution of the ILRS stations.

References:

Uwe Voelker, Fabian Friederich, Ivo Buske, Daniel Hampf, Wolfgang Riede, Adolf Giesen: Laser Based Observations of Space Debris: Taking Benefits from the Fundamental Wave.
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