Upgrading kHz SLR at the SGF, Herstmonceux

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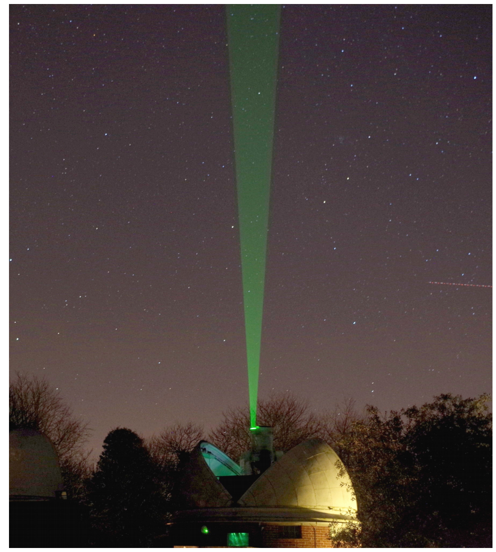
Introduction



The SGF operates a productive and precise high repetition rate SLR system that has unfortunately not so far performed to reasonable expectations. In late 2014 the SGF again began kHz SLR with significantly modified laser hardware, electronics and operation procedures. This report gives a brief historical overview of kHz SLR at Herstmonceux, a description of the upgrades completed in 2014, details on adaptations to the SLR system and reports on the improved SLR capability.

SLR at kHz rates is significantly more responsive than low firing rate systems and a newly implemented automated satellite search and lock system is reported. Further improvement to daytime SLR at Herstmonceux is anticipated with the installation of an identified narrowband filter with improved transmission characteristics.

kHz at Herstmonceux

The Space Geodesy Facility, Herstmonceux upgraded to 2kHz SLR operation in 2007 using a 10ps, 0.4mJ High-Q laser. Over time, all ILRS targets were successfully tracked with this system, but the overall experience with kHz SLR did not meet expectations for acquisition, productivity or reliability. This led to discussions with the manufacturer and, simultaneously, close investigation in to all optical components of the SLR system, leading to replacement of the telescope dichroic mirror and laser coudé path mirrors.

Fortunately, the SGF operates a dual laser system because it retained its original 12Hz Nd:YAG laser. Consequently no loss of full SLR capability was experienced during maintenance or offline periods of the kHz laser.

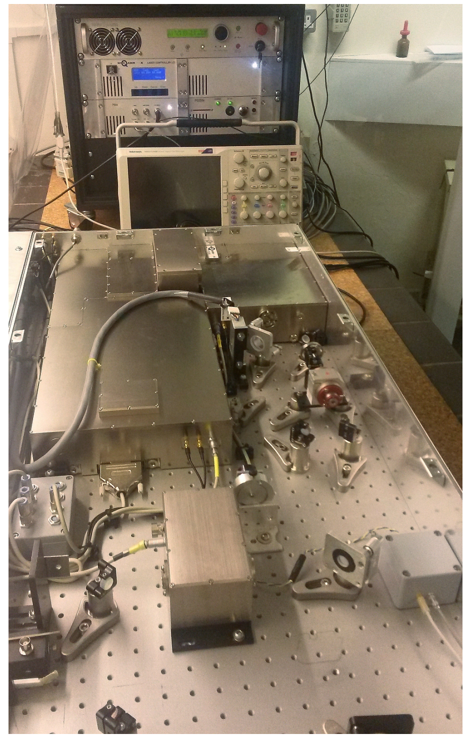
For example, at times the 2kHz laser was not available due to:

- Burnt out frequency doubler crystals and/or surrounding optics.
- Shot to shot pulse energy instability
- Energy loss in the post amplifier.
- Other problems with the frequency doubler peltier and the TEC controller.

In 2013 the kHz SLR performance improved significantly after a redesign, which moved the focal beam waist. It continued to perform well for 6 months without major failure. The laser was then sent for a planned upgrade and was returned to Herstmonceux in March 2014.

Hardware Upgrade

Major changes were made in the hardware make-up and optical generation method in the High-Q laser. The post amp has been removed entirely, all amplification now takes place inside the regenerative amplifier, which has new beam paths and design. The seed laser is original and was cleaned and aligned. The Pockels cell is new and has been relocated. The Pockels cell driver, the laser diode driver and TEC controller were also upgraded.



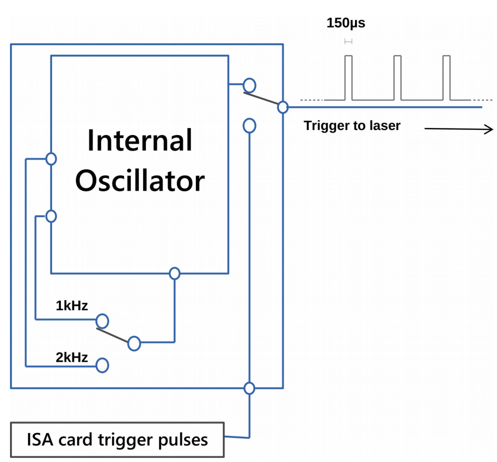
Due to the higher energy density at the crystal, Nd:VAN had to be replaced with Nd:YAG. This changed the output wavelength and matches that of our 12Hz laser. This could potentially help with the selection of a single narrow spectral daytime filter. The reworked laser has a reported functionality of being able to switch from 1kHz to 2kHz without optical realignment. The pulse energy has increased to 0.7mJ per pulse at 2kHz, or 1.1mJ per pulse at 1kHz.

Previously, to reduce output energy for calibrations, the post-amp was desynchronised, but this is no longer possible. So for this reason, and due to the increased pulse energy the calibration eye-safe filter arrangement was modified. This now includes an initial stage of a 90% mirror directing the reflected beam to a beam dump, before the transmitted signal is further reduced with ND filters The glass element is corrected for at the calibration application stage of SLR data processing.

Maintaining laser stability - best practice kHz firing control

Following the upgrade and to avoid the possibility of thermal lensing occurring in the laser medium it was necessary to modify the firing procedure to ensure stability and to prolong the laser lifetime. This firstly requires an initial 10-15 minute period to warm up, during which trigger pulses are supplied without the laser firing at full power. Once the laser has warmed up it can then be fired at full power with the application of a 5V signal to the diode laser. Control of the 5V signal required a modification to our ISA card and we are very grateful to our Graz colleagues for carrying this out.

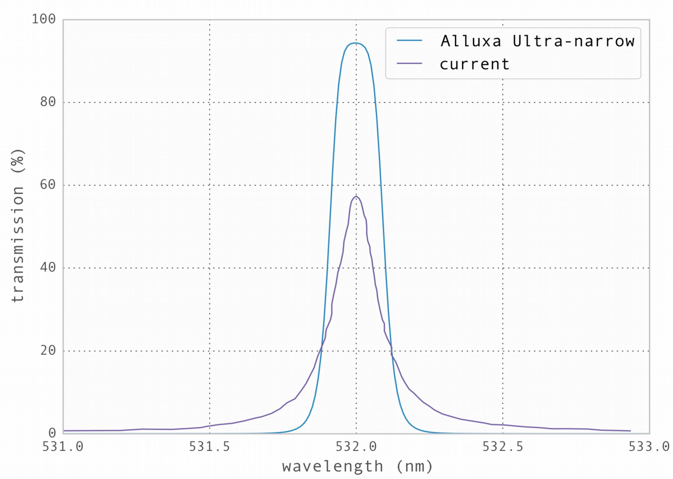
Secondly, in order to maintain stability, laser trigger pulses must be continually be provided at the selected rate (1kHz or 2kHz). This was previously not possible as triggers were only provided by the ISA card when the system is in a satellite or calibration loop. To provide continuous triggering a card was designed and built at the SGF to switch between sending the ISA card trigger pulses or providing pulses from an internal oscillator. A schematic diagram is present to the right.



Results
After Herstmonceux returned to kHz SLR data was briefly put in to quarantine by the AWG but was quickly given the all clear. Observers are routinely tracking all objects at night and are also having good daytime SLR success. Glonass, Galileo and Compass targets are now all potential daytime targets. The kHz laser has remained stable and performed very well without issue for 3 months.

Daytime narrow filter
The difference in return signal strength between night and day SLR at the SGF is significant from observer experience and it is suspected that the old narrow spectral filter is degraded. A significant improvement is possible by replacing the current narrowband filter for an identified Alluxa Ultra narrow filter. This filter offers greater transmission and is a single filter, not requiring an additional blocking filter. The plot below shows the transmission of the Alluxa filter in comparison to the specification of the current filter when originally installed.

Automated searching and locking
One advantage of kHz SLR is its rapid response which is of great help when satellite searching. Once the SLR telescope is correctly aligned on the target a return signal is instantly acquired.



This is certainly the case with return rates > 1%. This lends itself to fast automated satellite searching and a method has been developed and in use at the SGF, Herstmonceux.

Spiral step adjustments are made to the telescope pointing by the display software through a TCP/IP feedback loop with the primary Ranging PC. To find a target the right search step size and interval between steps must be decided. The ability of automatic searching is limited if the beam is moving in the iris or if the skies are intermittent with clouds.

Once the satellite is found the automatic searching software enters a different mode in which small azimuth and elevation corrections are made. The return rate is fed back continually. If a step results in a reduced signal strength then it is removed and if it results in a large increase then the same correction is applied again. This is intended to help with the imperfections of the pointing model applied and to keep hold of the satellite as it moves across the zenith.