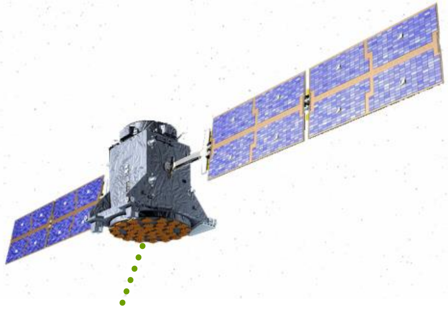
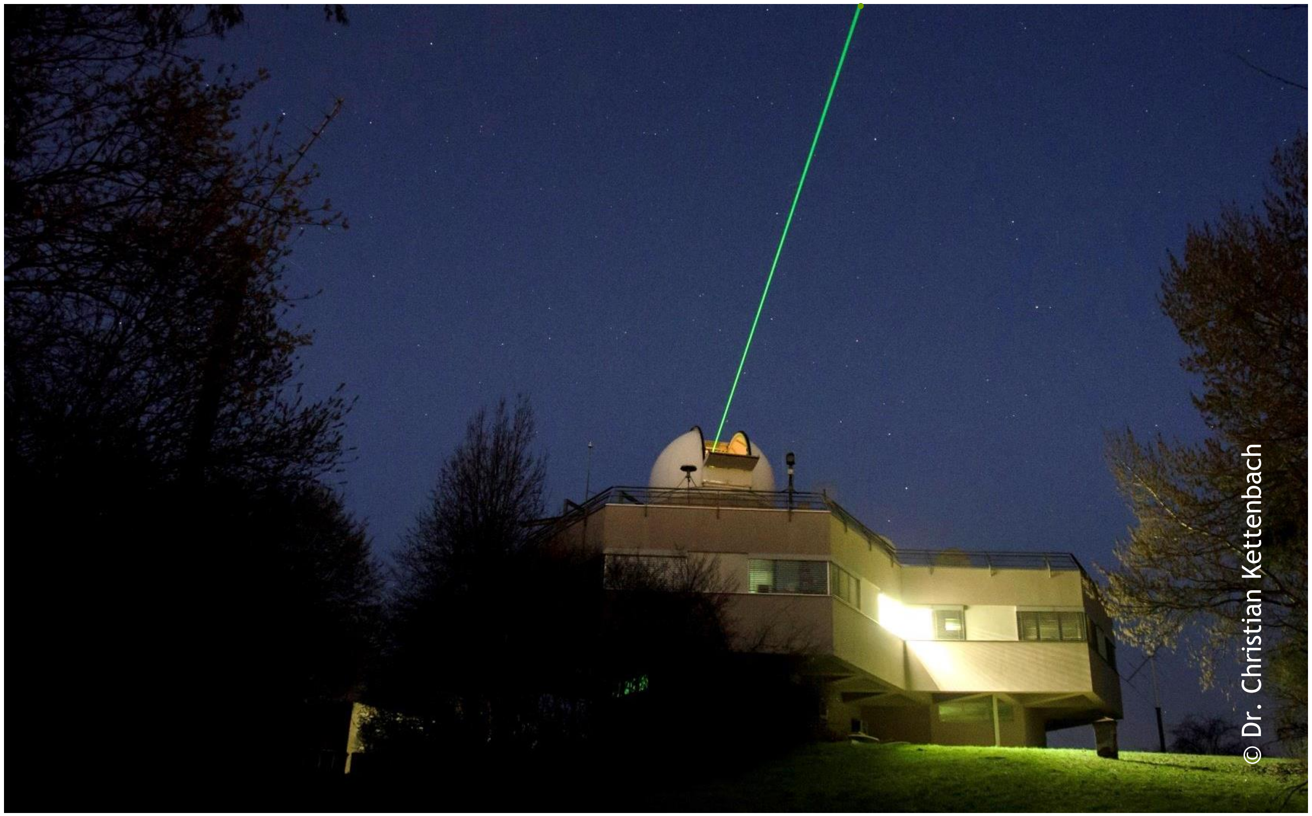
SLR in 7.5 Years - trying a ‚forecast' ☺



Galileo retro panel



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Why **7.5** years ???

Well, we could not decide if this ‚forecast‘ should be

=> for the next 5 years; or even
=> for the next 10 years

In such a case: Always use the average => 7.5 years ☺

And in any case: „Same as for weather forecasts:
NO GUARANTEE !“

(just my personal opinion ….)

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Let us start with the CONCLUSIONS ☺

In several years, we can expect SLR stations like this:

- Modular design; extended use of COTS => significant cost reduction;
  - can be a standard SLR station, or e.g. a miniSLR station (Stuttgart)
  - This would allow a significant denser SLR network / more stations
- Routine [sub-] mm SLR with < 100 kHz to > 1 MHz, up to GEOs
- Same 10 ps laser used for Space Debris Laser Ranging (20 - 40 W !!!)
- Laser(s) mounted on telescope; silicon and InGaAsP SPADS as standard
- SLR at 532 and / or 1064 nm; includes LC recording for Attitude / motion
- Automatic / autonomous operation (with some minimum human backup ?)
- Add-ons, like LIDAR for cloud detection; atmosphere recording etc.

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100 kHz, 1 MHz, xx MHz SLR ?
Example: IPG Laser Unit

Example: YLPP-25-1-50 R; IPG Photonics; Fiber laser
Head: 1.5 kg; 216 x 70 x 65 mm;
Control Unit: 580 x 448 x 132 mm

50 kHz – 2 MHz rep rate

< 3 ps pulse width

25 µJ / shot

25 W @ 1 MHz

Needs water cooling

M^2: 1.2 typ (< 1.4)

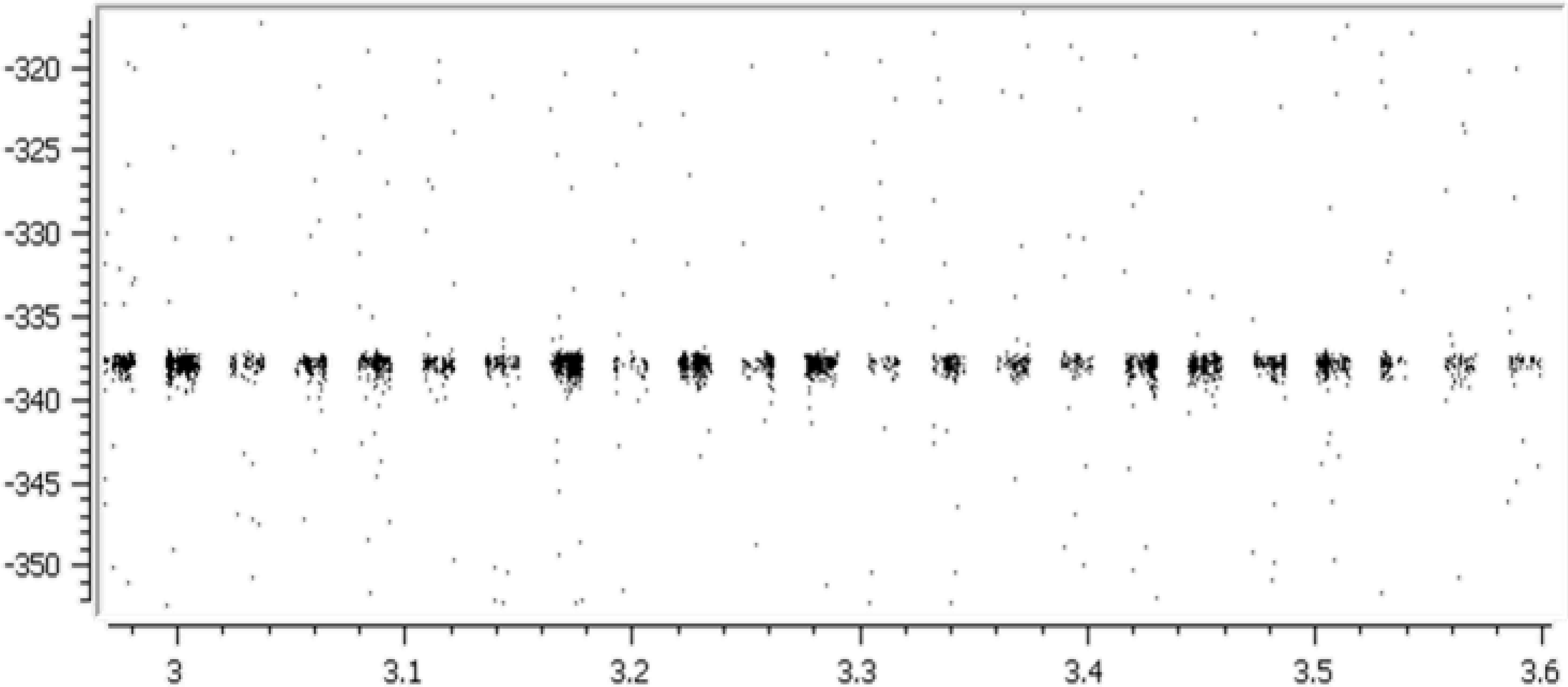
1030 nm / 515 nm

The price: ≈60 k €

Demo unit tested: With 8 µJ per shot => 1% ret from GNSS (giving 10 k returns / sec !!!)

BUT: Too large BW for SLR

MHz tests in Graz: Preliminary results



- First test results with 1 MHz (500 kHz due to burst mode)
- At 1 MHz: <8 µJ/shot: still >1% return quote from GNSS satellite
- But again: Too large bandwidth for SLR

100 kHz, 1 MHz, xx MHz SLR ? Another example: Sirius (SPARK)

Single pulse to – 1 MHz

< 10 ps pulse width

≈ 100 µJ / shot (50 kHz)

> 5 W @ 1064 nm

M^2: 1.2

Needs water cooling

The price: ≈70 k €

With a 70 mm Transmit: Eye safe only after > 60 km ☹

Example: SPARK: Sirius Fiber laser
Head: 16 kg; 464 x 290 x 118 mm;
Control Unit: 12 kg; 19“ / 3U

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1 MHz SLR: The Detector Unit

- Use of a standard / gated detector (e.g. C-SPAD) is difficult:
  - Gating with rates higher than e.g. 50 kHz causes high noise, and additional emission of photons; a C-SPAD then looks more like an LED ☺
- Instead: Use a SPAD in free running mode (as used in photon counting modules);
  - Active quenching: > 1 MHz (linear counting) (up to 30 MHz: Non-Linearity)
  - Add separate gate AFTER SPAD output => gate the pulses for Event Timer
  - Add additional gate to block too short intervals between noise and signal
- Use a low noise SPAD (e.g. SAP500, or MPD); add Time Walk compensation:
  - Not easy to avoid multi-photons from LEOs, even with 25 µJ / pulse
- At laser rep rates of > 10 kHz: Continuous overlap (laser pulses <> echoes):
  - Use ‚burst mode' to avoid this continuous overlap: e.g. for LEOs / 800 km:
  - @ 1 MHz => fire 5000 shots, than detect echoes for 5 ms; and so on …

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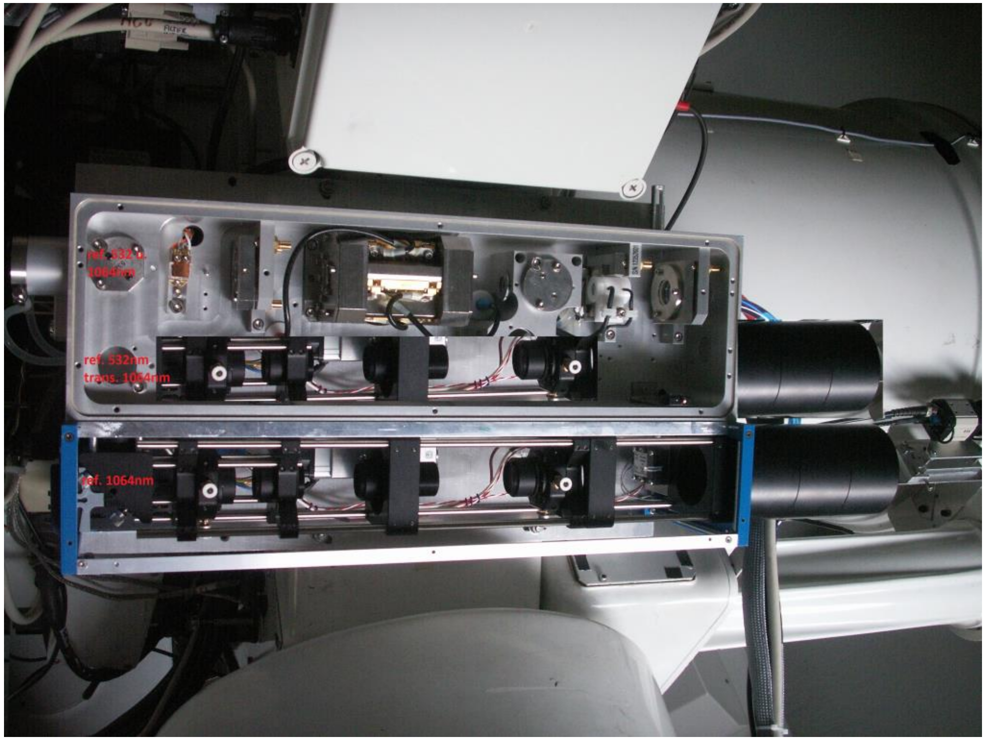
Choice of Wavelength(s)

Wavelength selection:

- 532 nm will remain for longer time still, but:
- 1064 nm (and others) are knocking on the door
- Most probably: Stations might implement BOTH wavelengths (for ease of switch)



1550 nm: Most likely NOT:

⇒ It is NOT REALLY eyesafe;

⇒ Just one order higher MPE

Example of a 2-wavelengths setup: 532 & 1064 nm space debris laser in Graz

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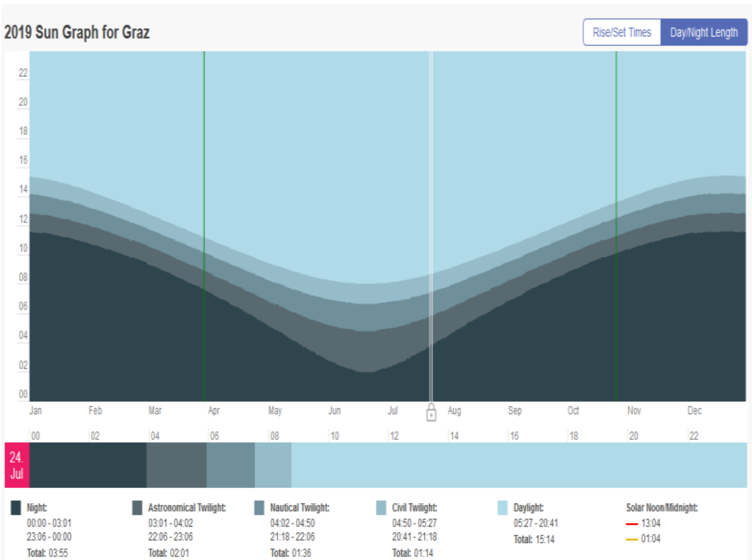
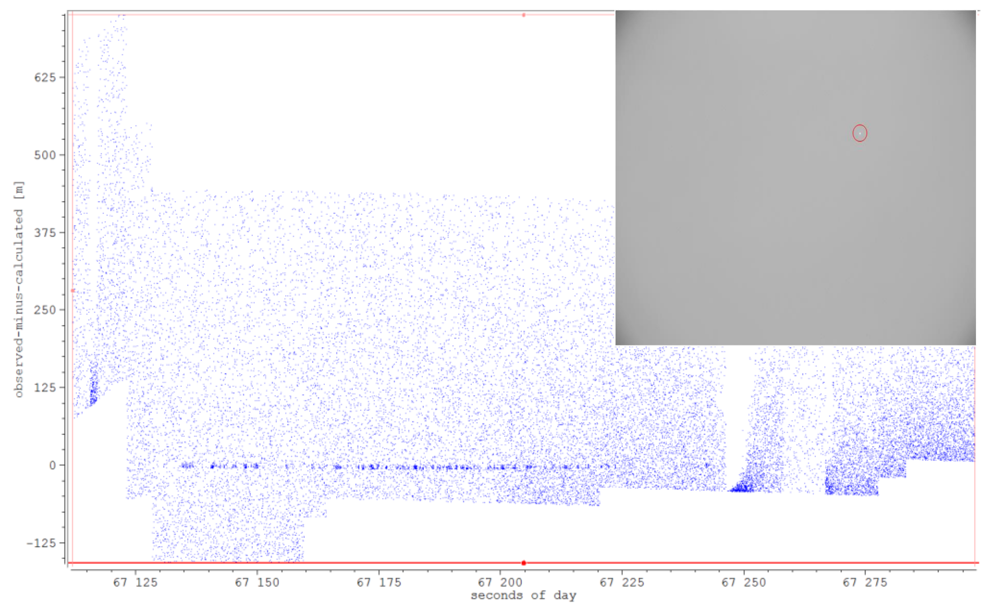
Space Debris Laser Ranging - SDLR



- At least small SDLR networks needed in future (weather, fast data delivery and POD for selected targets / conjunction warnings)
- Should allow fast network reaction in case of conjunction forecasts

- Now limited to terminator period
- First daylight SDLR successful
- Should be routine in 7.5 years ☺
- Also night time / blind tracking
- Much better CPFs / TLE …



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Modularity

Nowadays – and even more in future – most items can be COTS units:

- Laser, with complete transmit telescopes, all mounted on telescope, including cloud LIDAR, energy control etc.
- Mount & Receive Telescope, including control software
- Detector units, with compensated digital outputs, for mm SLR and SDLR; complete detection packages
- Event Timers with ps accuracy, Time & Frequency receivers
- Add-on units: Meteorology, ADS-B units etc.

- **Anything else where you would need a soldering iron ?**

Calibration

- Many SLR stations are using **WRONG** CAL targets for **(sub) mm** SLR:
  - Too far away => difficult to prove „400 m ± 0.1 mm“
  - Nobody takes care about the atmosphere at the 400 m target
  - Targets and station are placed on different soil => moving with seasons, day/night, humidity etc…..HAS BEEN PROVED ALREADY

- Instead, mount / invariant point should be fixed together:
  - CAL target on same pillar, or directly mounted on telescope (for rare reference (geometric) CALs only) => routine CALs then via fiber)

THANK YOU !

In 7.5 years, I hope to see all these forecasts from my favorite observer position ☺

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Thank you !

http://www.youtube.com/watch?v=5o6OtPJKRJ8

Video of Graz SLR station ranging to ILRS satellites