Satellite Laser Ranging with a fibre-based transmitter

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DLR

Stuttgart observatory

Goal

Development of new technology for SLR

Milestones

2010: Financing, planning

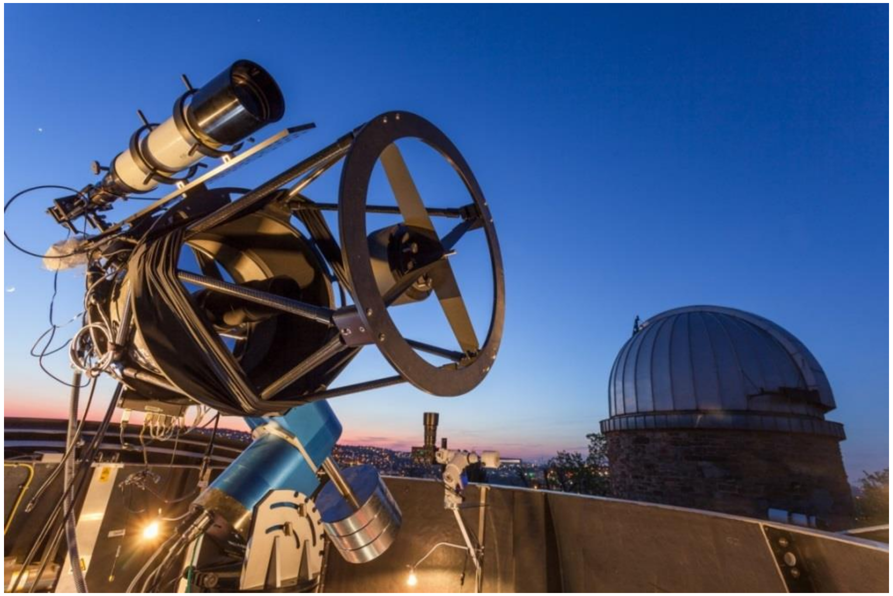
2013: First light passive-optical

2016: First SLR

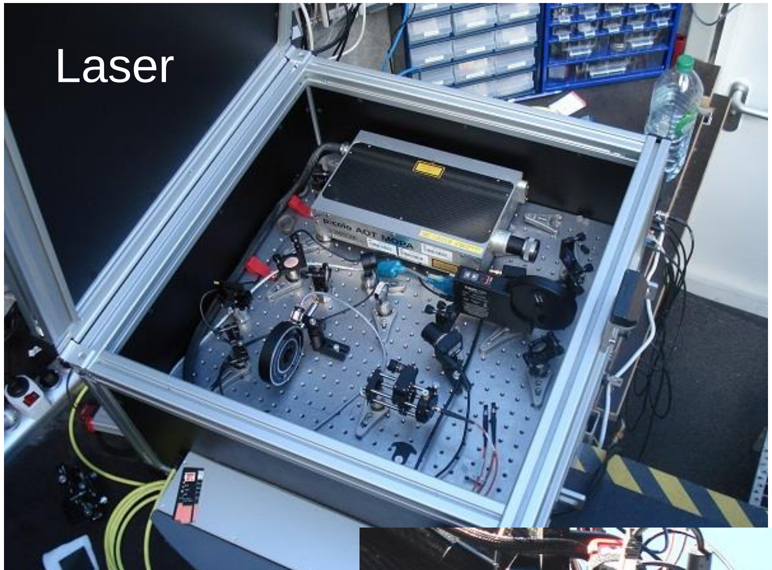
Design and set-up

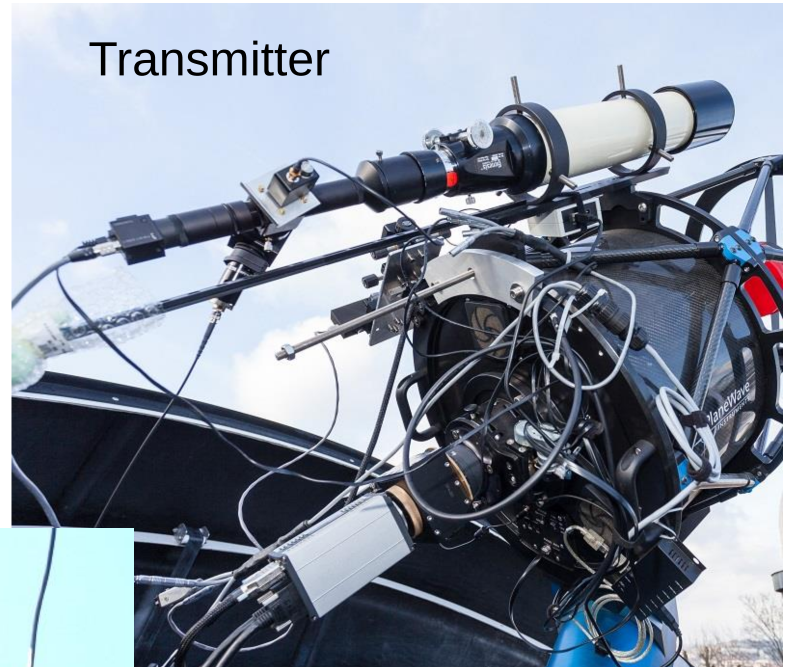
- Design drivers
  - Inexpensive standard components
  - Modular set-up
  - Small footprint
  - Development of all critical know-how

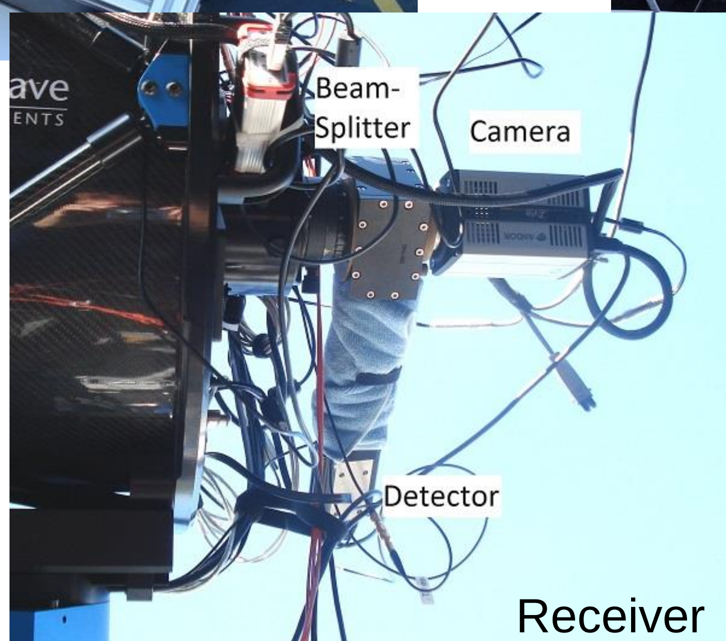
- Features:
  - Fibre-transmission from laser to transmitter
  - Operation at 1064 nm
  - High repetition rates (> 5 kHz)



Components

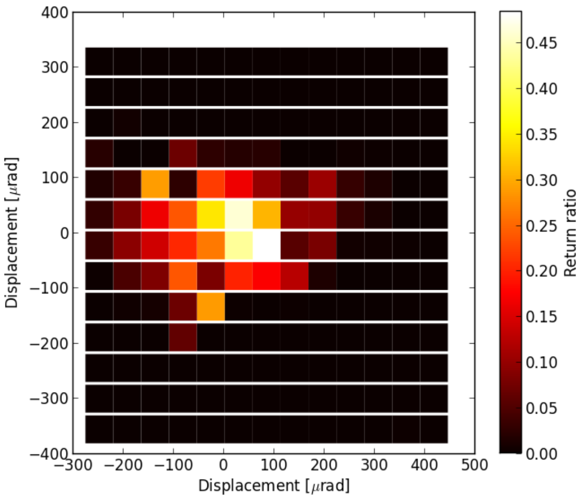

Laser

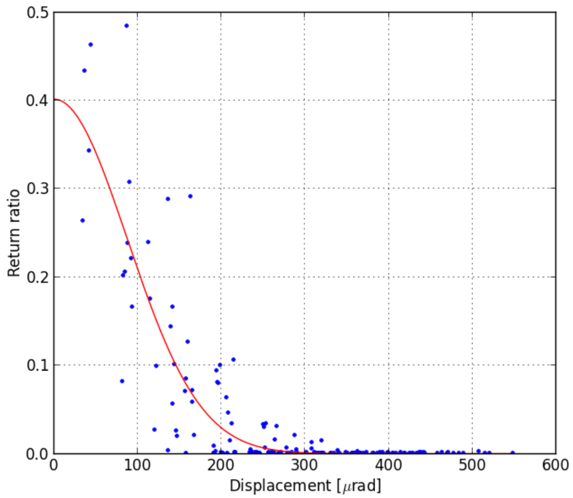

Transmitter


Beam-
Splitter
Camera
Detector
Receiver

Specs

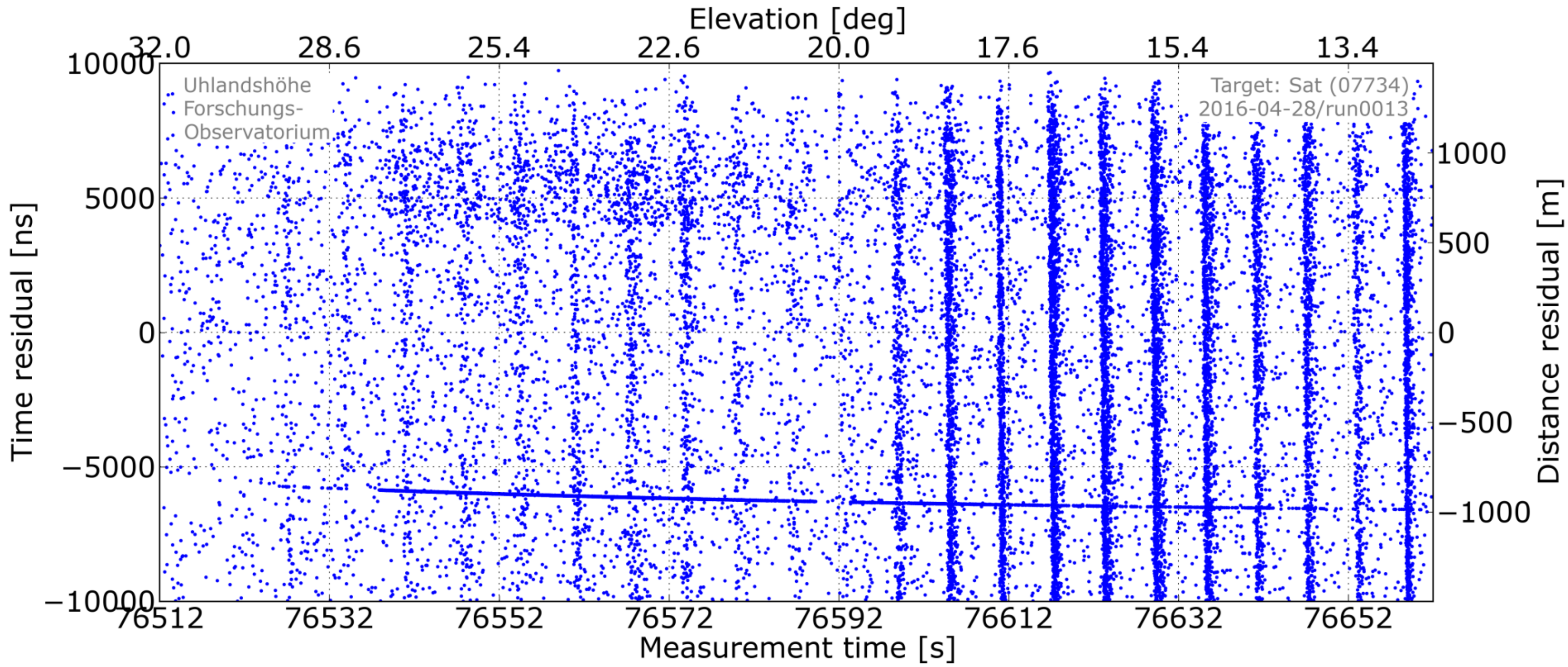
Laser power	~ 500 mW
Rep rate	5 kHz
Pulse duration	3 ns
FoV detector	10 arcsec / 50 µrad
Beam divergence	80 arcsec / 400 µrad
Detector noise	2 kHz





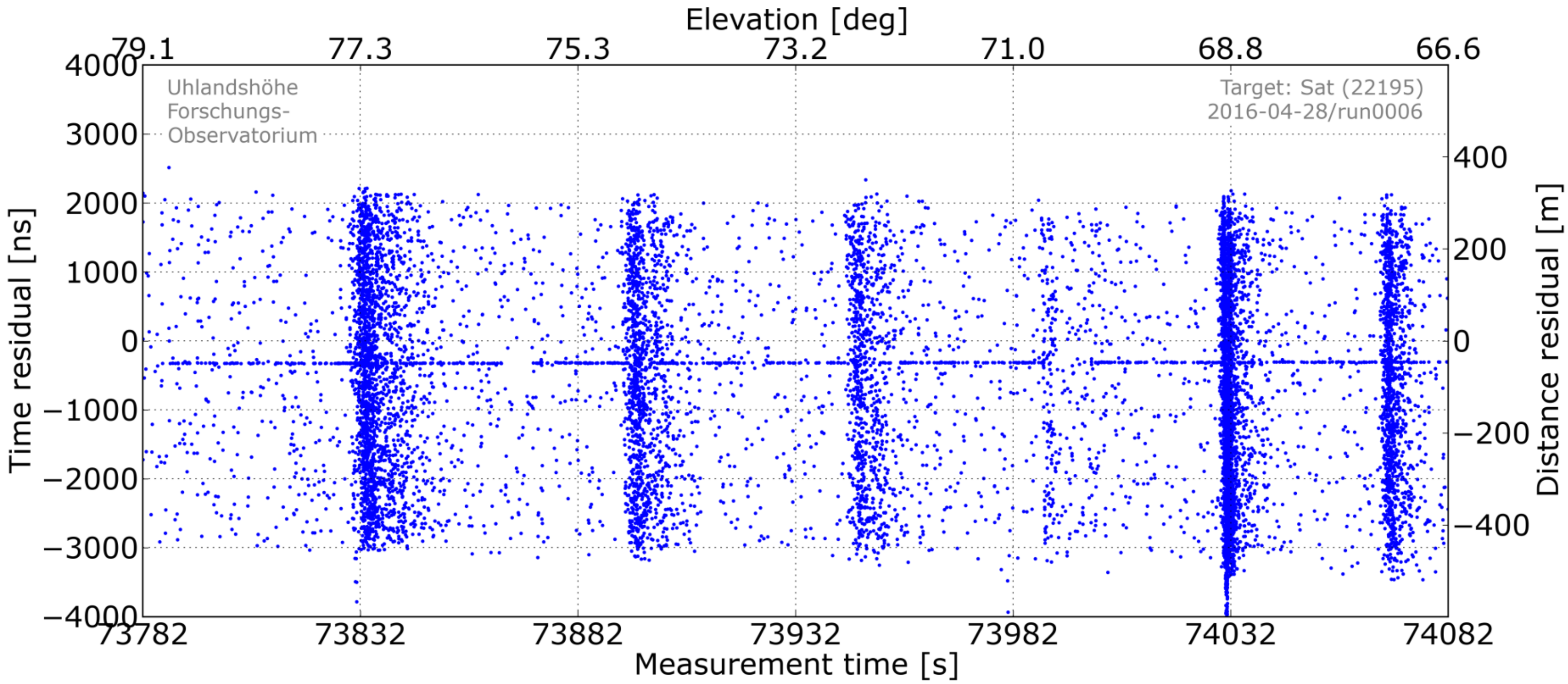
First results

- GEOS 3, tracking with TLE data, gating 20 µs



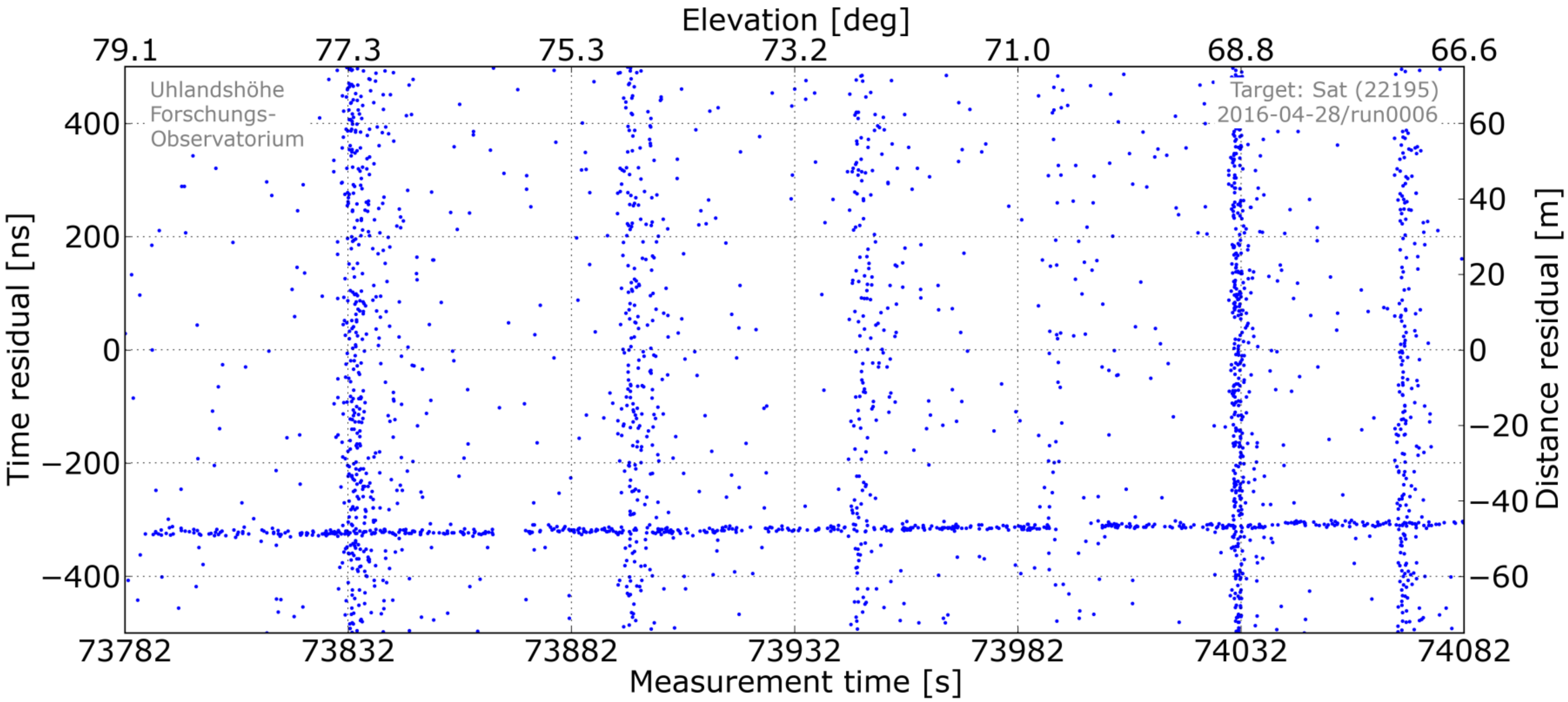
First results

- LAGEOS 2, using CPF prediction, gating 2 µs



Systematic offsets

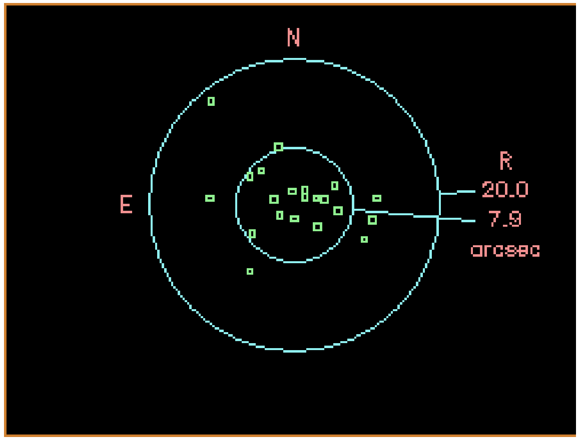
- All results show systematic offset of 40 to 50 m against CPFs



Challenges and planned improvements

- Better calibration
  - High rep rate should result in high precision of NPT
  - Systematic offsets have to be understood and eliminated

- Improvement of pointing model
  - ➔ Blind tracking
  - ➔ Daylight ranging



- Extend range up to GNSS satellites
  - Decrease beam divergence
  - Increase pulse energy
  - Increase repetition rate

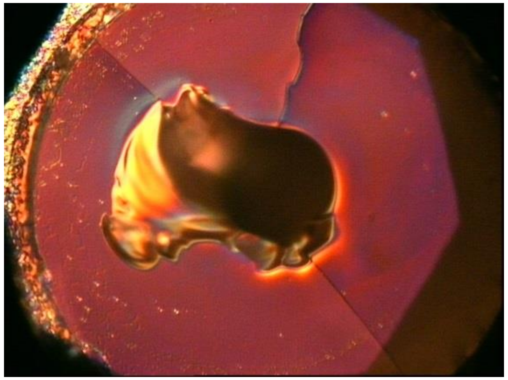
Fibre technologies

- Currently using standard optical fibres (multimode, 50 µm core diameter)
  ➔ max: 100 µJ / 3 ns pulses

- Hollow core fibres (e.g. Kagome fibres) allow for much higher pulse energies

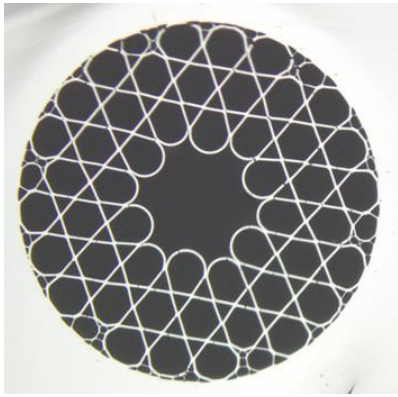
"…using a Nd:YAG laser at 1064 nm. Pulse energies as high as 30 mJ were transmitted for 30 ns pulse durations."

(Ciprian Dumitrache, Jordan Rath and Azer P. Yalin, Materials 2014, 7, 5700-5710)



Standard MM fibre damaged in tests

Kagome hollow core fibre



http://www.laserfocusworld.com/articles/print/volume-52/issue-05/features/photonic-frontiers-fiber-for-laser-beam-delivery-new-fibers-deliver-the-laser-beams.html

High rep rates: How much is useful?

- Ambiguity:
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- Sensitivity:
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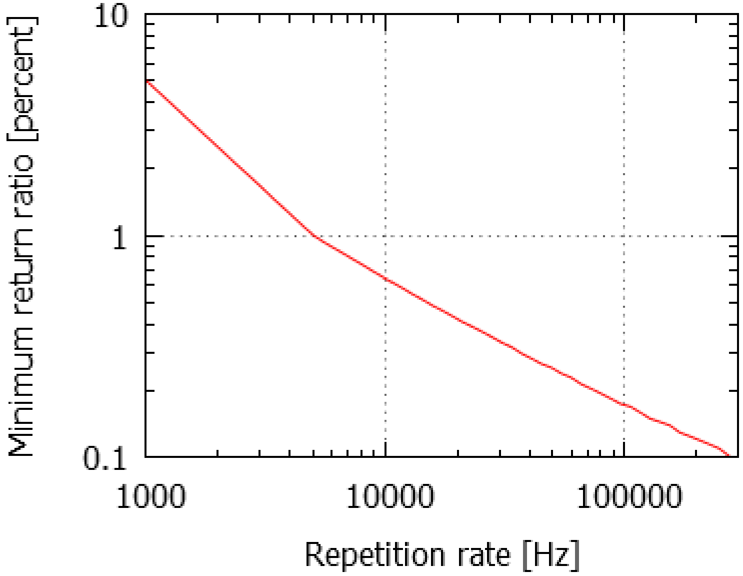
  - Assuming:
    - Min 50 events / second
    - Significance 5 sigma
    - Detector noise: 10 kHz
    - Gate size: 1 µs

At 100 kHz, a return ratio of 0.1% is sufficient for clear signal



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- High data rate needs to be handled
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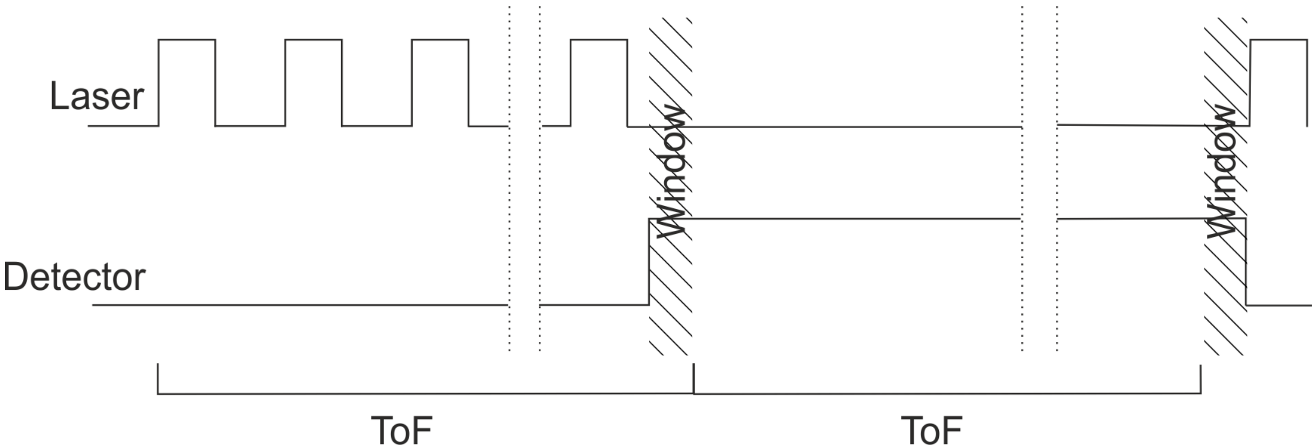
- What about backscatter?
  - ➔ Use of burst mode

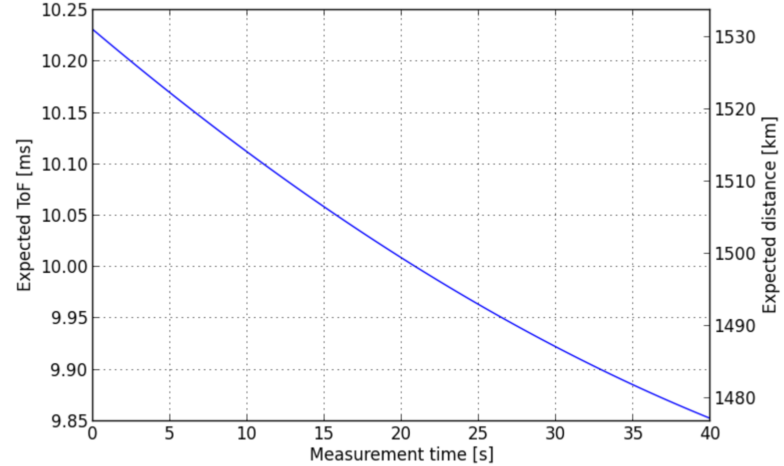


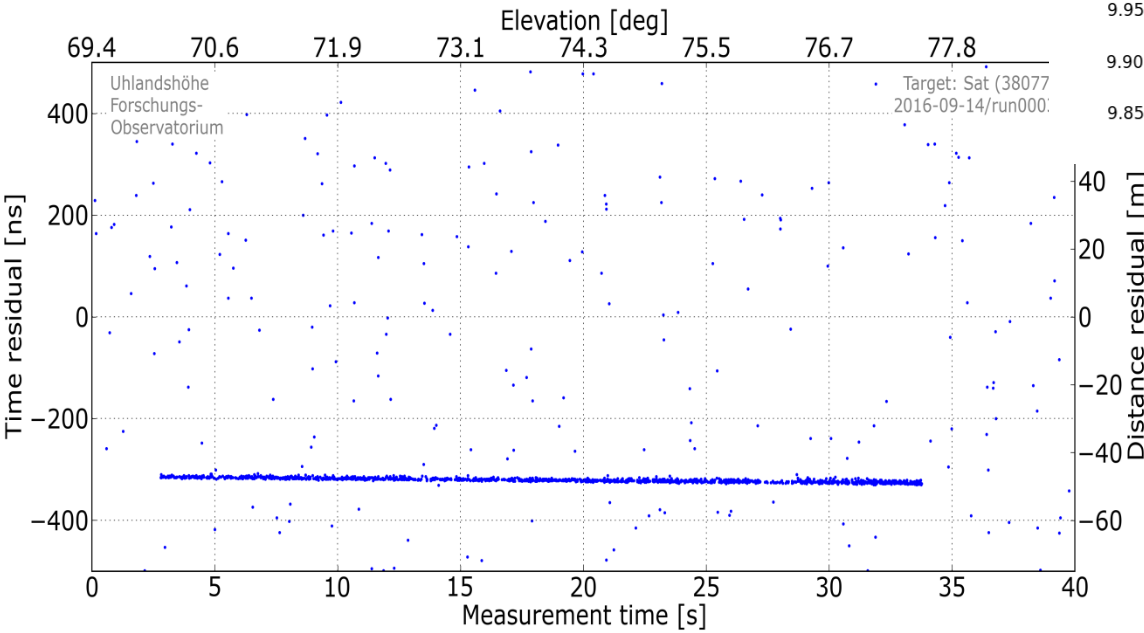
Example:

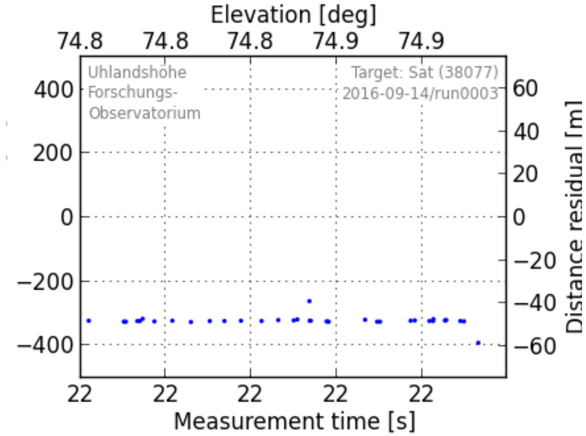
- 10 ms ToF
- 100 kHz rep rate

➔ 1000 pulses per burst

Burst mode ranging







Trigger rate: 5 kHz

Effective laser rate: 2.45 kHz

Pulses / burst: ~50

Detector rate: 2.1 kHz

0.5 seconds

DLR

Conclusions

- Fibre-coupled transmitters can be used for SLR
- Stuttgart station is up and running
- Improvements in accuracy, maximum range and towards daytime ranging are underway