Building a SLR Station in 2019

ILRS Technical Workshop 2019 – Stuttgart

Session: SLR School

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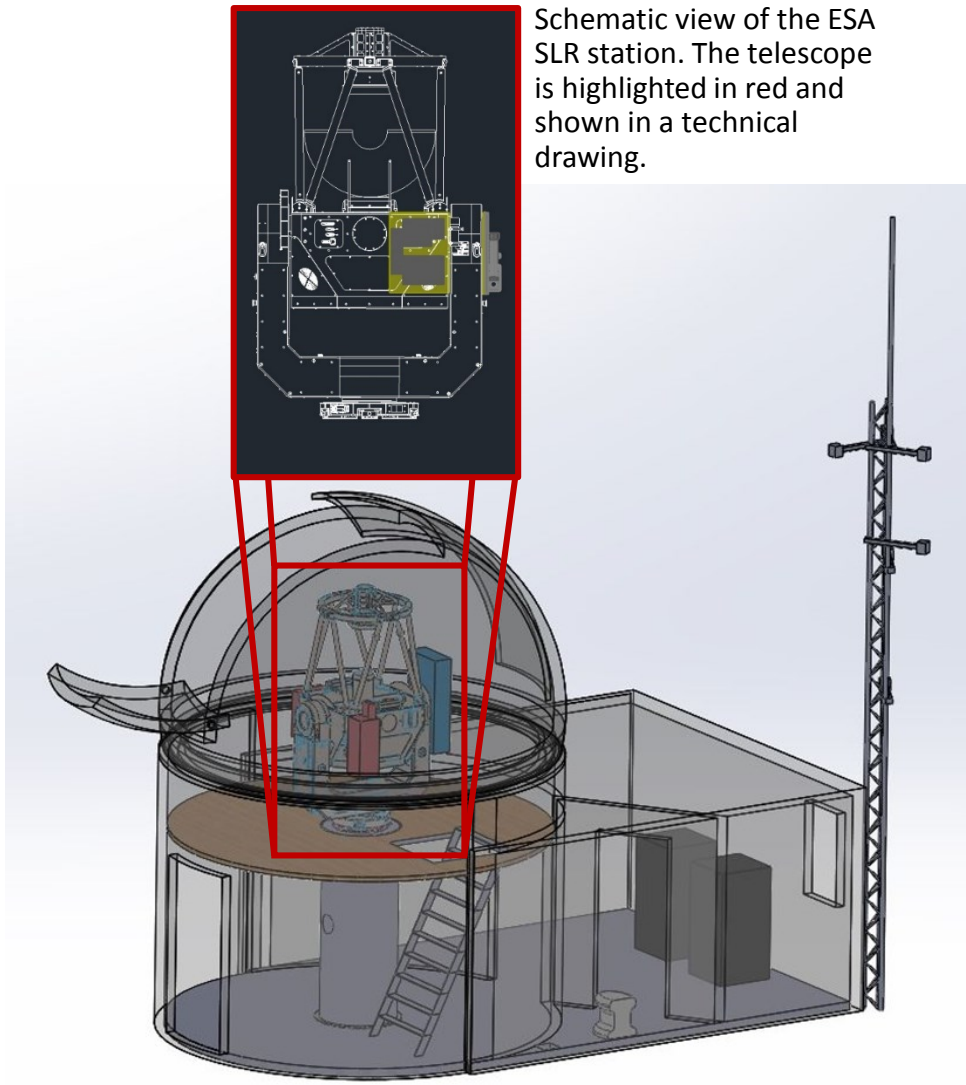
DiGOS

Content

- Approach
  - Tell others how to build a station does not make sense
  - Decision for survey on “what are the special features of current or new systems”
  - Get a picture on what a “2019 SLR station” can look like
- Request to stations
  - Questionnaire send to stations on various aspects and pictures of selected systems
- Structure
  - Following slides: replies from the stations
  - Highlighted special features which are also used for the discussion
- Order
  - “Large” stations
  - “Miniaturized” systems
- Sorry
  - If we forgot to include your system, highlight an important aspect or detail of it or if there is an error!

New stations for ESA/JAXA

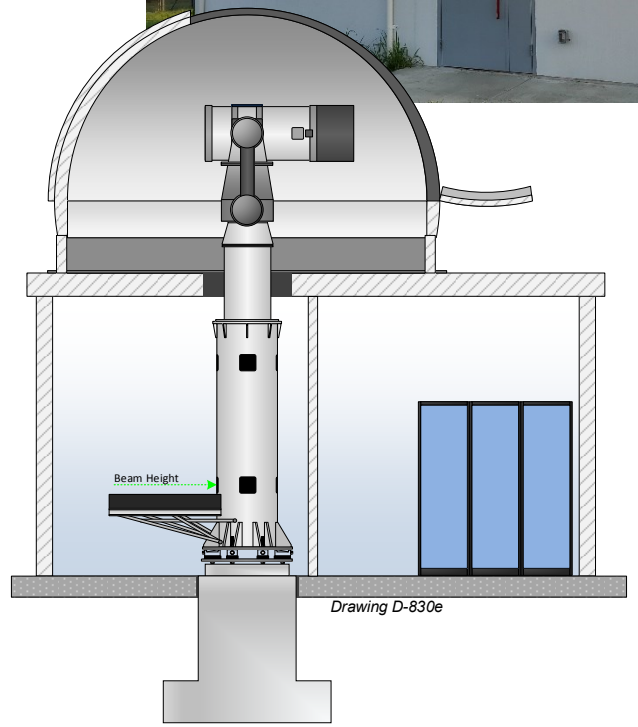
- **System key parameters**
  - **Laser package:** 532/1064nm, ~0.3/0.6mJ, ≤8ps, 400Hz ESA, 1kHz JAXA, piggyback
  - **Telescope:** Ritchey-Chrétien, 80cm, AltAz mount, 4 foci, no Coudé path
  - **Detector package:** 532 & 1064nm detectors (C-SPAD & SPAD), SP-DART design
  - **Accuracy / Precision:** sub-centimetre (Full Rate)
  - **Dome:** Slit-type
  - **Special features:**
    - Turnkey, commercial product by DiGOS
    - Insky safety (ADS-B, Allsky camera optical monitoring)
- **Innovations, design objectives, applications**
  - Piggyback mount of laser & detector packages
  - Flexible & extensible design by 4 foci (space debris, laser comms, light curves)
  - Remote & fully automated operation
  - Autonomy: AI optimized operation



Schematic view of the ESA SLR station. The telescope is highlighted in red and shown in a technical drawing.

New NASA SGSLR stations (replacing MOBLAS/TLRS)

- **System key parameters**
  - **Laser:** 532 nm, 2.5 mJ/pulse, 50 ps, 2 kHz
  - **Telescope:** Cassegrain, 50 cm, sealed, Az/El mount, Coudé path
  - **Detector package:** 7 x 7 pixelated 532 nm SensL detector
  - **Accuracy / Precision:** < 1 mm Normal Point precision in < 10 sec for LAGEOS at 30° elev., even in light haze
  - **Dome:** High speed, slit-type, capable of operating in snow and ice
  - **Special features:**
    - Well known / measured center of rotation (invariant point)
    - Single design for diverse climates (Yarragadee to Ny-Ålesund)
    - Capable of satellite interleaving following ILRS guidelines
- **Innovations, design objectives, applications**
  - Mostly Commercial-Off-The-Shelf (COTS) parts
  - Designed for remote & fully automated operation (24 x 7)
  - Pixelated detector provides closed loop tracking
  - Common optics (monostatic system for transmit / receive)
  - Ranging from LEO to GEO (and potentially the moon) and Time Transfer
  - All SGSLR stations will be monitored and will communicate interactively with Space Geodesy Network Operations Center (SGNOC) but will be capable of operating independently

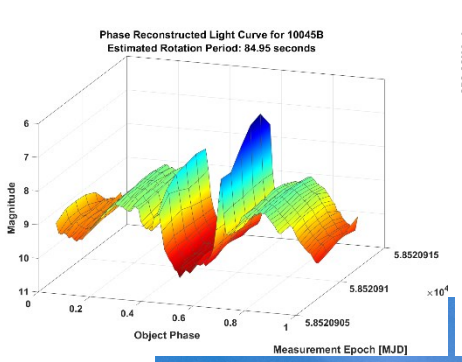


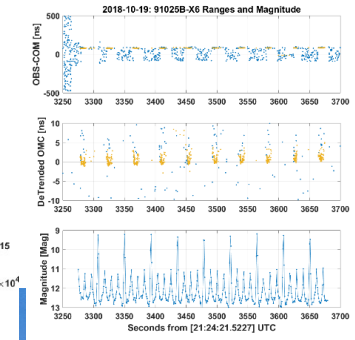
The new gen Russian SLR system «Tochka»

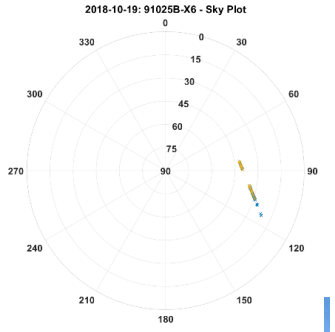
- **System key parameters**
  - **Laser package:** 532 nm, 2.5 mJ, ≤50 ps, 1 kHz
  - **Telescope:** 360 mm aspherical, Alt-Az mount, Nasmith foci for receiving path, Coudé foci for transmitting path
  - **Detector package:** 532 nm hybrid photodetector with high quantum efficiency and symmetrical response
  - **Accuracy / Precision:** 9 mm (single measurement precision)
  - **Dome:** Eye-type
  - **Special features:**
    - Time transfer ready
    - Colocated with the nav receiver (by default)
    - Single-electron reception mode
    - Tracking at any time (day and night)
- **Innovations, design objectives, applications**
  - Automatic ranging mode
  - Station calibrates itself using the built-in etalon length which occurs as the station performs ranging
  - Automatic alignment of the transmitting and receiving paths

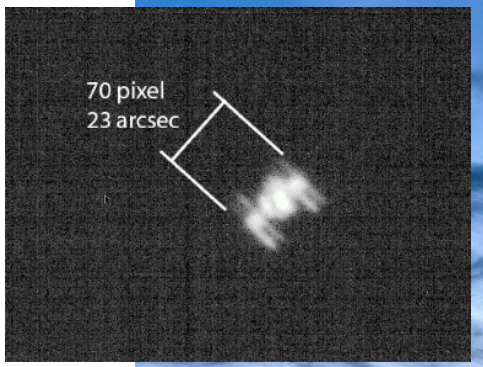
Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald

- **System key parameters**
  - **Laser package:** 532/1064nm, ~6/7mJ, 58ps, 110Hz, Coudé, Monostatic
  - **Telescope:** Ritchey-Chrétien, 1 m, AltAz mount, 5 foci: 1 Coudé (SLR), 4 Nasmyth (Photon Counter, CCD, and CMOS cameras)
  - **Detector package:** 532 nm detector C-SPAD, PESO Consulting
  - **Accuracy / Precision**: < 1 cm
  - **Dome**: Clamshell
- **Special features and applications**
  - **Precision:** Firing time accuracy > 30 ns for Time Transfer
  - **Flexibility**
    - SLR Observation
    - Astrometric and photometric Observation (space debris, NEO, double stars, supernovae, light curve and color photometry)
    - Fundamental physics (Entangle photons experiments)
  - **Automation**
    - Remote & Fully Automated operation mode without user interaction
    - Dynamical scheduling
    - Automatic optimization of echo returns (power attenuation and target search)
    - Switch between astronomical and SLR obs.
    - Air traffic safety
- **Innovations, future developments**
  - Tracking camera for telescope pointing correction, space debris orbit determination and characterization
  - Extension of CMOS camera observation during daytime
  - New high precision laser with kHz rep. rate
  - Space debris laser







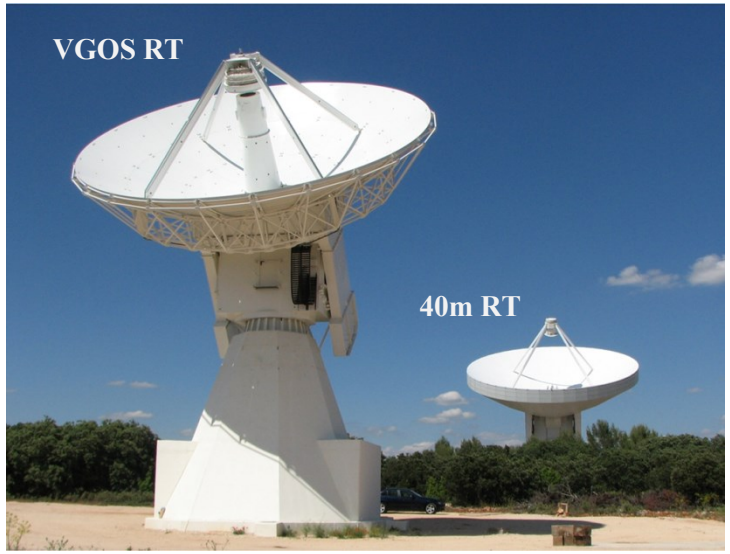


New station at Yebes Observatory

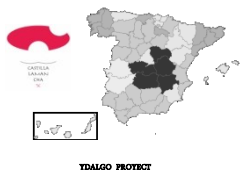
- **System key parameters**
  - **Laser package:** 532/1064nm, 0.5 … 5mJ, ≤25ps, ≥1kHz, piggyback mount
  - **Telescope:** biaxial telescope, 50-80cm, AltAz mount, several foci, Coudé path available
  - **Detector package:** 532 nm C-SPAD detector
  - **Accuracy / Precision:** sub-centimeter (Full Rate)
  - **Dome:** Slit-type
  - **Special features:**
    - Commercial products
    - Insky safety (ADS-B, FLARM, Allsky camera optical monitoring)
- **Innovations, design objectives, applications**
  - Two possible configurations: Coudé Path or Piggyback mount of laser & detector packages
  - Flexible & extensible design with several foci (space debris, laser comms, light curves)
  - Remote & fully automated operation

Geodetic Fundamental Station: VGOS RT, GNSS receivers, SLR station, gravimetry (relative superconducting gravimeter and absolute), local tie, T&F…

Yebes Observatory Radio Telescopes and future YLARA station location (Yebes Laser RAnging).

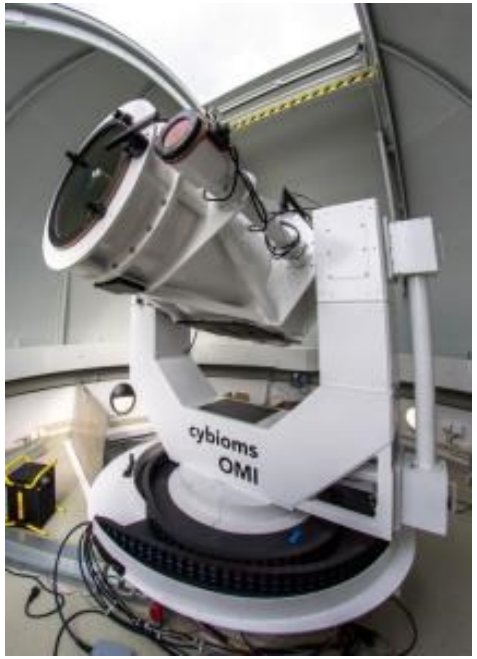


European Regional Development Fund
Investing in your future



New station at Metsähovi Finland

- **System key parameters**
  - **Laser package:** 532, ~0.4mJ, ~12ps, 2kHz (Looking for a new 532+1064nm ps-laser)
  - **Telescope:** Bistatic 50cm RX / 10cm TX + 15cm refractor for visual imaging, Coudé-path & sealed optics (possibility for several piggyback options)
  - **Detector package:** C-SPAD
  - **Accuracy / Precision:** sub-centimetre (Full Rate)
  - **Dome:** Slit-type
  - **Special features:**
    - Insky safety (ADS-B, tracking camera, microphone, allsky camera optical monitoring, automatic cloud detection)
    - Indoor calibration, possibility for outdoor targets in addition
    - SCOPE master control software



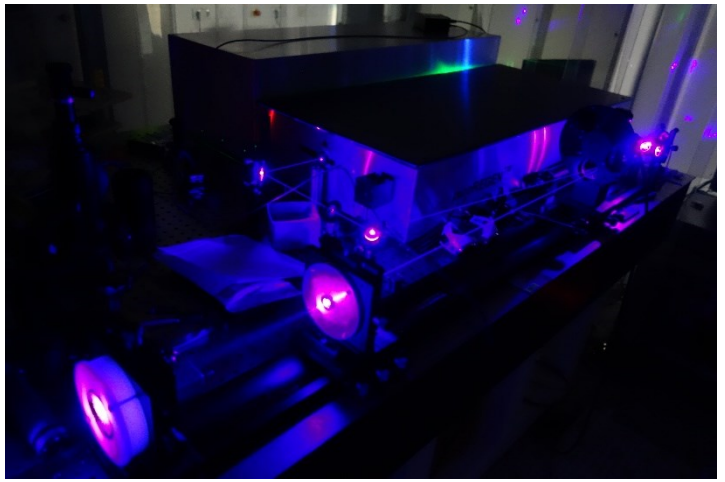
- **Innovations, design objectives, applications**
  - **A GGOS Fundamental site** with all techniques, including DORIS,

  VGOS VLBI, superconducting+absolute gravity, environmental monitoring etc.
  - Space debris laser ranging and light curve option in the future
  - Operational status by the end of 2020

Satellite Observing System Wettzell – SOS-W

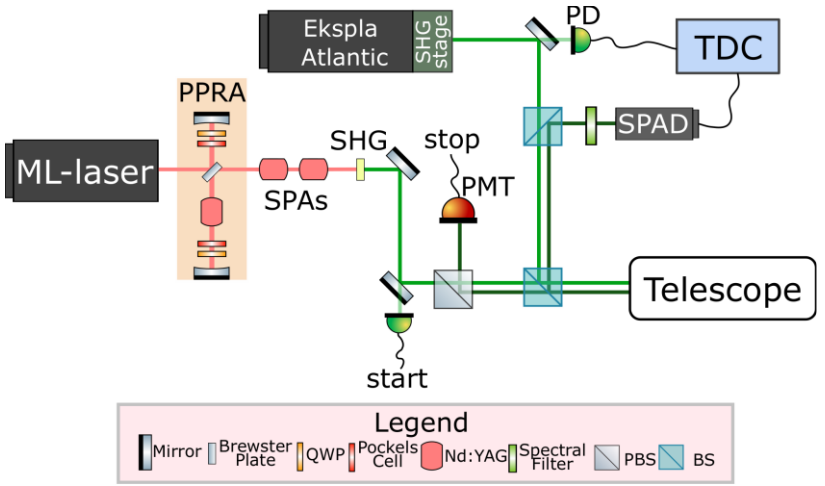
Bundesamt für Kartographie und Geodäsie

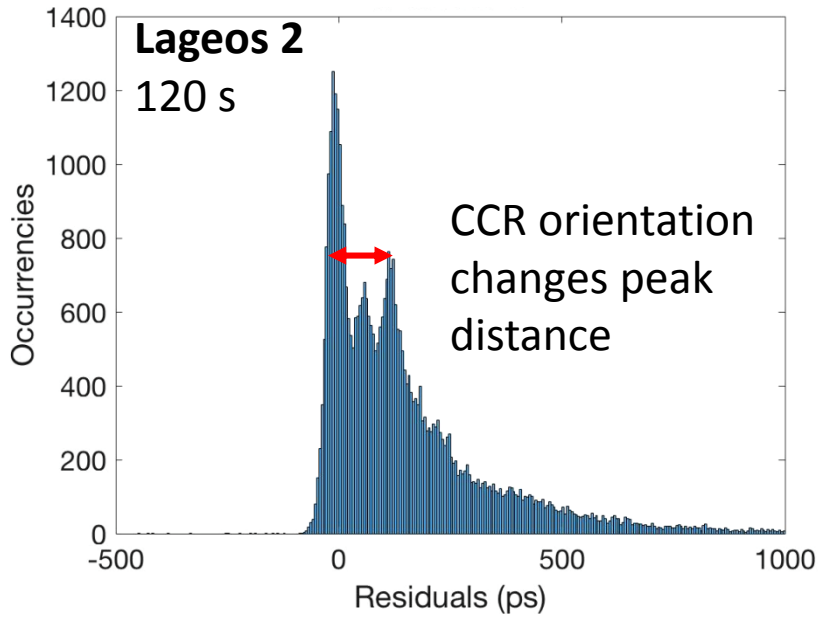
- **System key parameters**
  - **Laser package:** 425 & 850 nm, 1.5mJ, 40 ps, kHz
  - **Telescope:** ???
  - **Detector package:** ???
  - **Accuracy / Precision:** ???
  - **Dome:** Slit-type
  - **Special features:**
    - First two colour kHz SLR system
    - Single photon mode from LEO to HEO
- **Innovations, design objectives, applications**
  - Highly autonomous operation
    - Automatic scheduling of observations
    - Predefined scheduling input for special observation campaign support
  - Active optics and sophisticated optical setup enabling for
    - Automized Coude adjustment
    - Compensation of velocity aberration (point ahead)
    - Local tie monitoring



Test of very high repetition rate SLR in Matera

- **System key parameters**
  - **Laser package:** 532 nm, ~0.4 mJ, ≤10 ps (FWHM), 100 kHz Ekspla Atlantic 60
  - **Telescope:** Cassegrain, 1.5 m, AltAz mount, with Coudé path
  - **Detector package:** MPD SPAD, 532 nm, eff ≈ 50%, jitter 40 ps (FWHM)
  - **Time tagger**: quTAG (quTools), inter-channel jitter 23 ps (FWHM)
  - **Accuracy / Precision:** sub-centimeter (Full Rate)
  - **Dome:** Slit-type
  - **Special features:**
    - Two SLR systems in parallel (10 Hz and 100 kHz)
    - Multi-color SLR possible (1064/532/355 nm)
- **Innovations, design objectives, applications**
  - Very high repetition rate SLR (f_{TX} =100 kHz)
  - Much improved return statistics (F_{RX} up to 25 kHz on LEOs)
  - Insights on satellite orientation and spin
  - Targeting sub-millimeter ranging



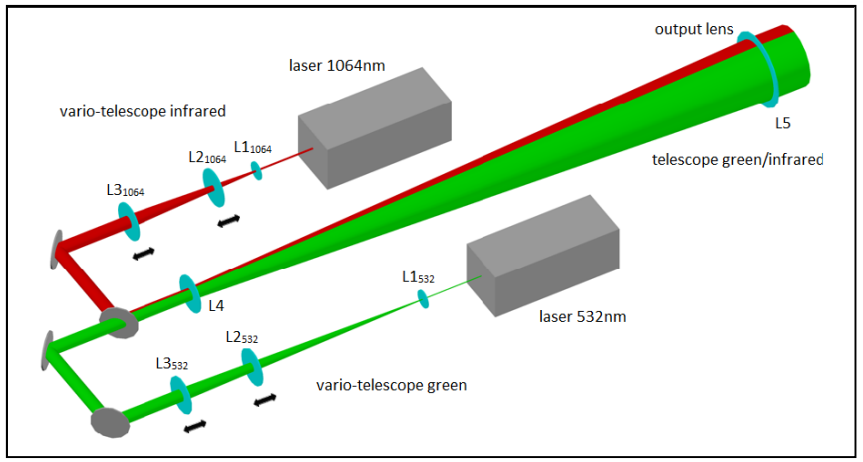


DLR miniSLR System

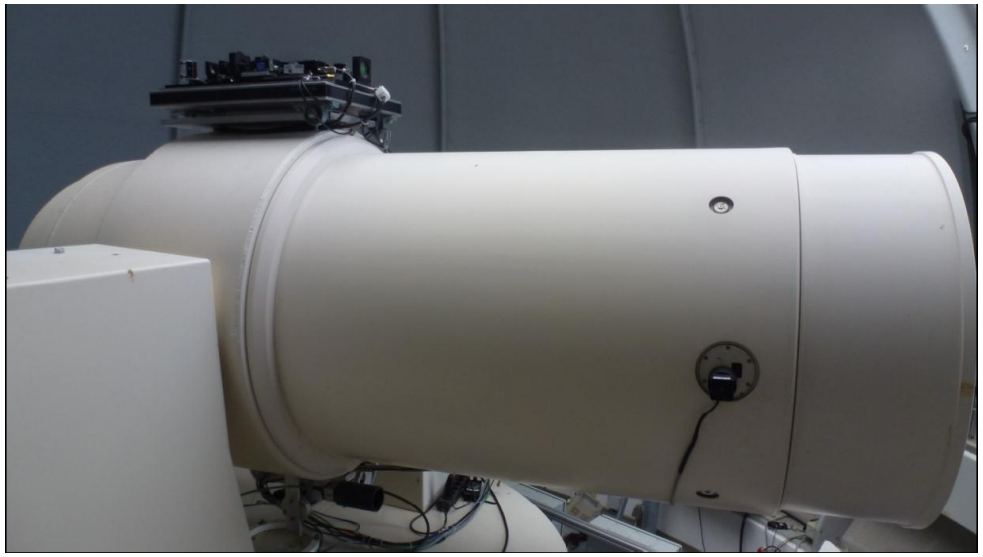
- **System key parameters**
  - **Laser package:**
    - 1064 nm, 30 kHz, 200 µJ, 5 ns
    - 1555 nm, 50 kHz, 150 µJ, 5 ns (eye-safe option)
  - **Telescope:** Newton 20 cm aperture, no Coudé path
  - **Detector package:** InGaAs SPAD for 900 – 1700 nm
  - **Accuracy / Precision:**
    - Single-shot: 70 cm
    - Normal point: < 1 cm
  - **Dome:** Slit-type, glass-covered
  - **Special features:**
    - Completely automated operation
    - Fully sealed and air-conditioned
    - Permanent calibration
- **Innovations, design objectives, applications**
  - Transportable
  - Low-cost production and operation
  - Small footprint
  - Application: Workhorse for routine measurements (LEO to nav-sats)

Graz SP-DART: Adds SLR to Astro-Telescope

- SP-DART: **S**ingle **P**hoton – **D**etection, **A**lignment & **R**eference **T**ool:
  Contains ALL parts for SLR station, but WITHOUT receive telescope
  - Laser: 532/1064nm, ~15/30 µJ, ≤ 1 ns, 2 kHz, piggyback mounted
  - low cost, medium accuracy
  - Detector(s), GPS-Clock, Meteo devices, FPGA card
  - Mounted on any Astro-Telescope: Converts it into a complete SLR System
- No Coudé path optics, standard Astro-Telescope: LOW COST SLR
- SLR up to geostationary orbit demonstrated



SP-DART schematics ↑ and hardware ↓



SP-DART Laser mounted on Wettzell telescope

Summary

- What are trends?
  - Up to 100 kHz
  - Sub mm ranging
  - Multiple foci and detector packages
  - Prepared for multiple applications (Space Debris, Laser Comms, TT, Quantum Key Distr.)
  - Automated / autonomous operation
  - Piggy back lasers
  - Two color, IR (switchable / simultaneously)
  - Miniaturized systems
  - Usage of COTS equipment
  - Low cost for experimental systems
  - Fundamental stations
- What is the current status or what do SLR stations do in 2019?
  - SLR community currently does many new things and research
  - New technologies (scientific and commercially relevant) are included in the planning
- Potential suggestion?
  - Provide the research platform so these technologies can become mature **AND advance SLR itself**

Thanks

For listening
and
to all the stations for the input!!!

GFZ
Helmholtz-Zentrum
POTSDAM

DiGOS