Advances, updates and new techniques at Graz station

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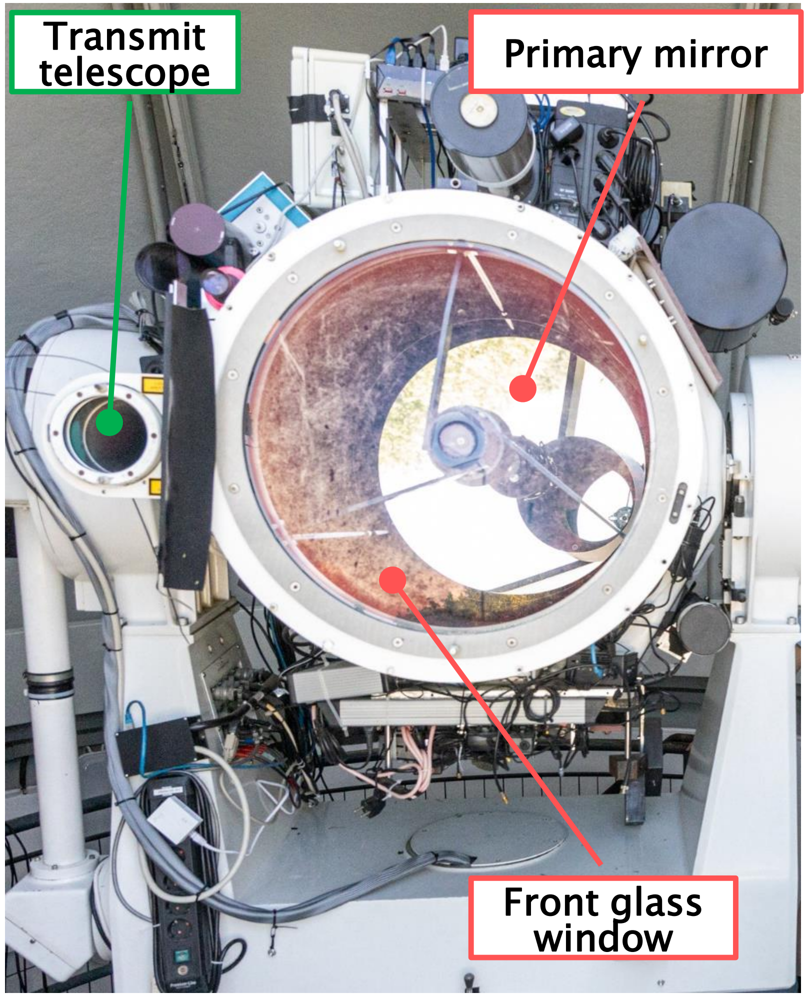
Outline

1. A glass window installed in front of the receiving optics, the old replaced.
2. A kit based a pellicle beam splitter to align detection optics.
3. Simultaneous daylight beam visualization, replacing PCO camera.
4. Detection package environment monitor and stabilization.
5. Bistatic ranging experiment, burst mode free for ultra-high repetition rate.

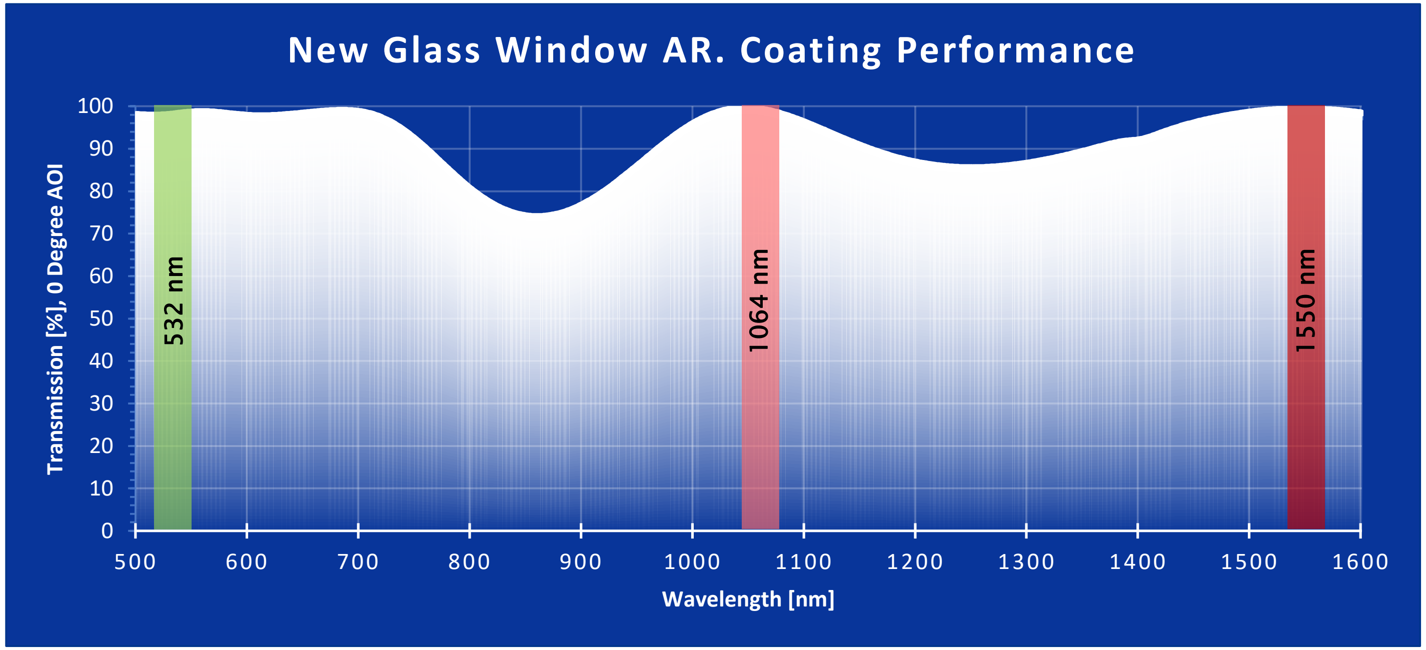
1. Front glass window replacement

- ❑ Graz's Contraves telescope no further refurbishment since early 1980s.
- ❑ Coating of both primary and secondary mirrors still in good condition (looks like..).
- ❑ Coating of the front protection window heavily oxidized or hurt by sunlight.

- ➢ A new front window installed in January 2024, the station history log update to ILRS.
- ➢ Antireflection coating: R. < 1% @ **532** nm & **1064** nm & **1550** nm &VIS., AOI zero degree.



Ø50 cm Contraves Cassegrain optics sit in a sealed environment with a protecting glass window (Summer 2023)



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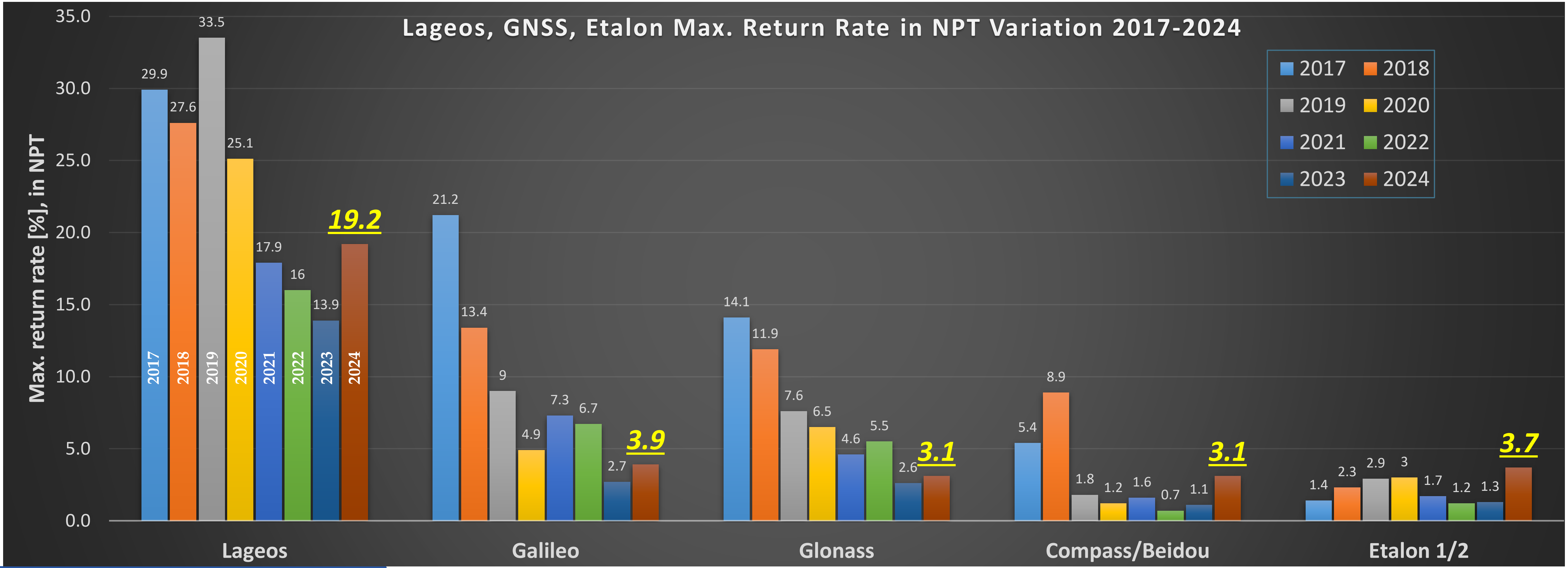
Graz SLR performance variation over years

- Find max. return rate in NPT for individual year / satellite families; for better revealing system performance; any other statistic approach??
- Graz's SLR performance continuously dropping over last years: components (laser, detector, optics) degrading, climate change (other stations ??), super observers left…
- Improvement in 2024: front glass window replacement, laser maintenance, Coudé path cleaning (before 0.190 Watt, after 0.275 Watt).



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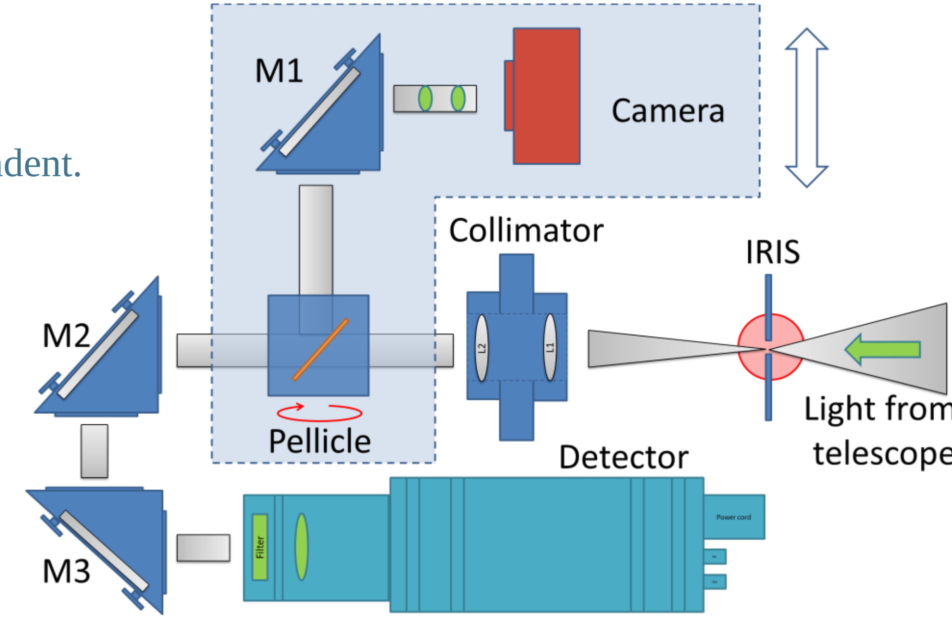
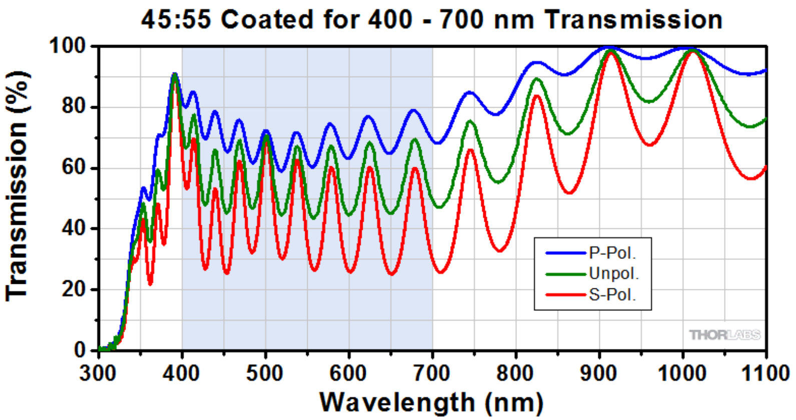
2. Alignment and inspection kit for detection optics

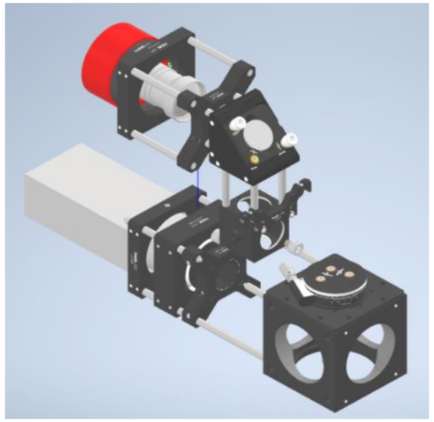
- Mounting status of Collimator, mirrors define the efficiency of SLR system.
- Old method: counting noise from star to align detection optics, > 90% weather/darkness dependent.
- New method: an alignment kit includes a pellicle beam splitter, a set of lens and a camera.
  - Pellicle splitter (45:55) reflects a portion of beam light to the camera, lets the rest pass through.
  - Only 2 µm thick (DO NOT TOUCH), in/out no influence to any exiting optical setup.
- Reference and alignment procedure:
  - Face to incoming light to align IRIS and collimator, star as a reference, the pellicle as a mirror.
  - Face to detector to align detector (M2, M3), monitor star/iris image on the detection active area.



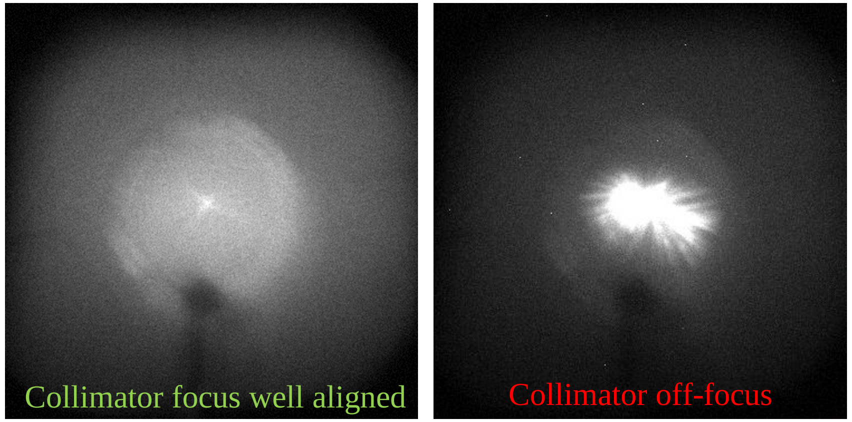
Alignment kit for detection optics



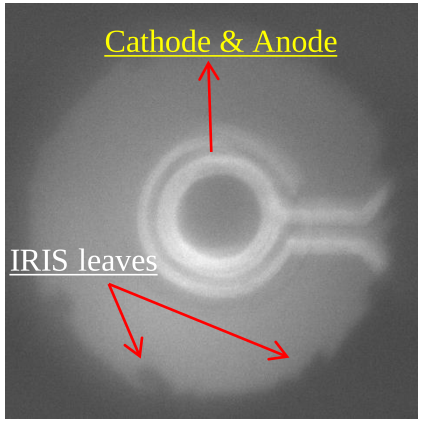
Pellicle beam splitter (45:55), 2 µm membrane thickness



Kit construction
Easy mount or dismount
Cage system



Polar star image on C-SPAD active area surface



IRIS image on MPD 100µm surface

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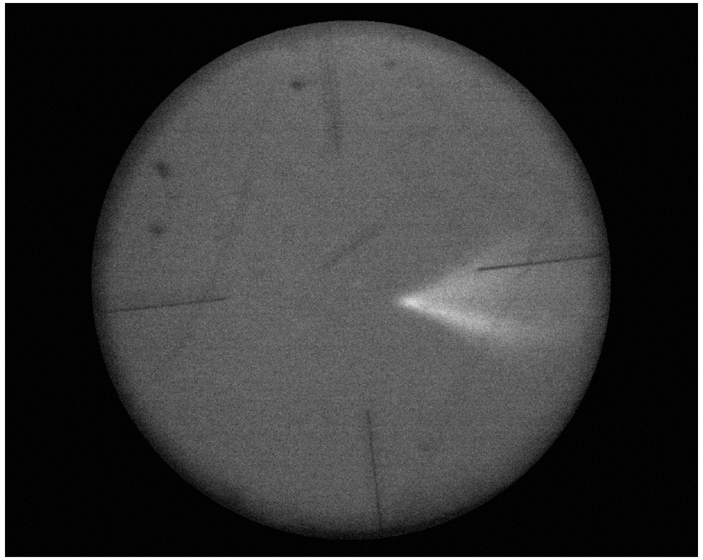
3. Continuous daylight laser direction watching -- an alternative to PCO

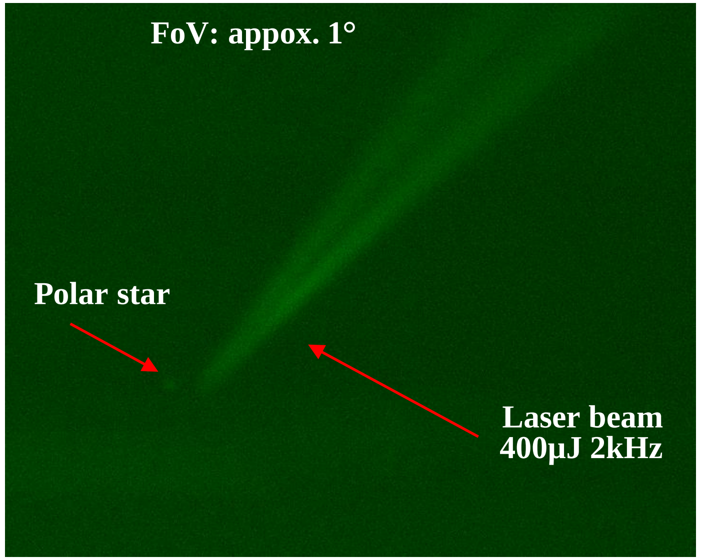
- PCO SensiCam have been widely used for visualizing laser beam direction during daylight:
  - Thermal issue / high temperature protection
  - Bulky connection
  - Need full laser energy: switching between SPAD and camera
  - Commercially discontinued
- An alternative method: Ø250 mm AG10 telescope + ASI camera (ASI715MC):
  - Continuously laser beam direction monitor
  - Stability while elevation moving
  - Approx. 1° FoV, according to chip size of Camera
  - Multi-channels / spectrum spilt

AG10 Specification	
Diameter	250 mm
Focal length	950 mm
Focal ratio	f/3.8
Spot size on Axis	3.0 µm
Weight	Approx. 12 kg
Tube length	81 cm

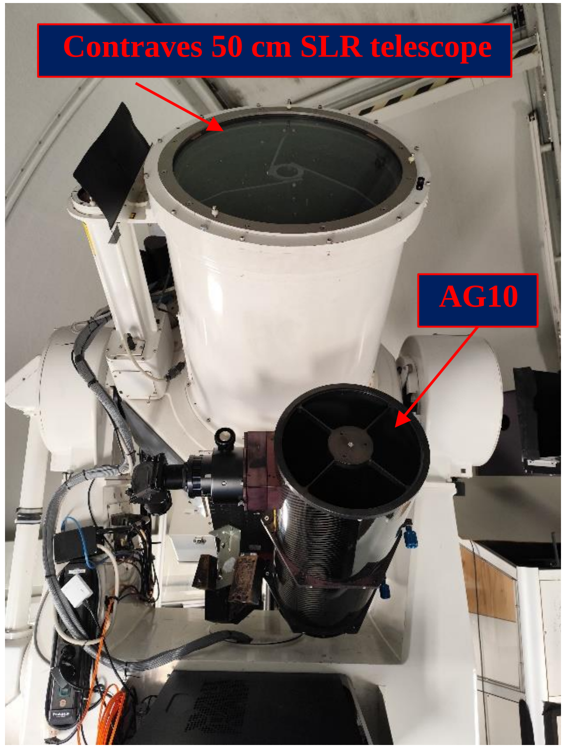


Laser beam on PCO SensiCam

AG10 Newtonian telescope



Laser beam and Polar star on AG10 + ASI camera (250 ms exposure) + 1 nm filter during daylight



AG10 piggy-back mounted on Contraves

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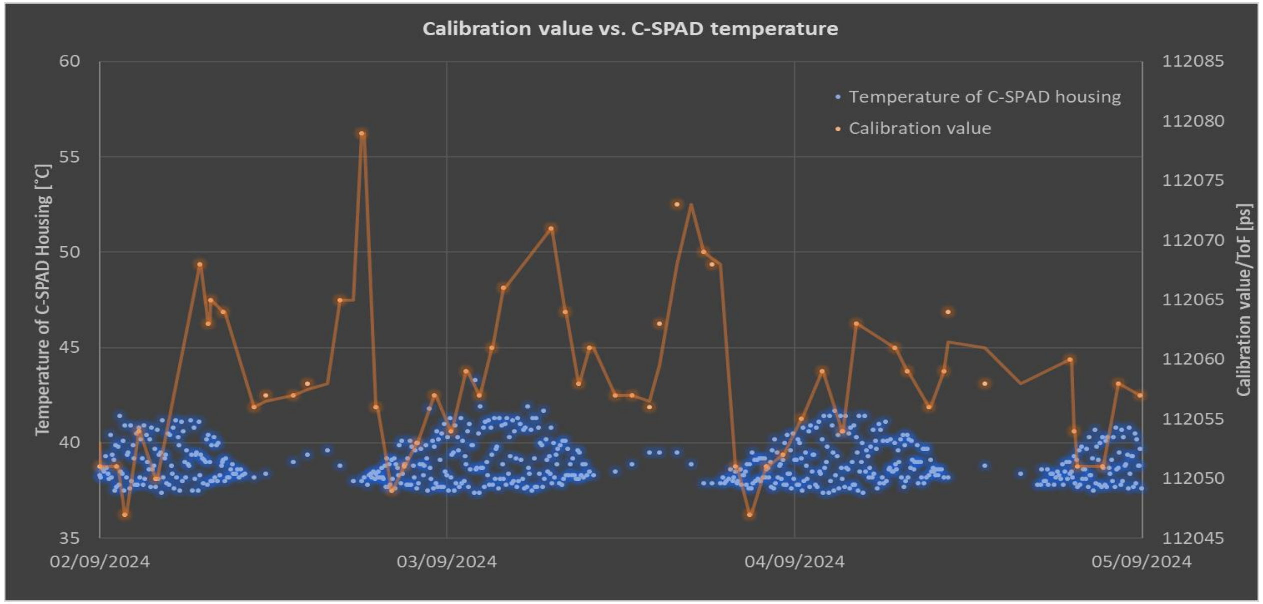
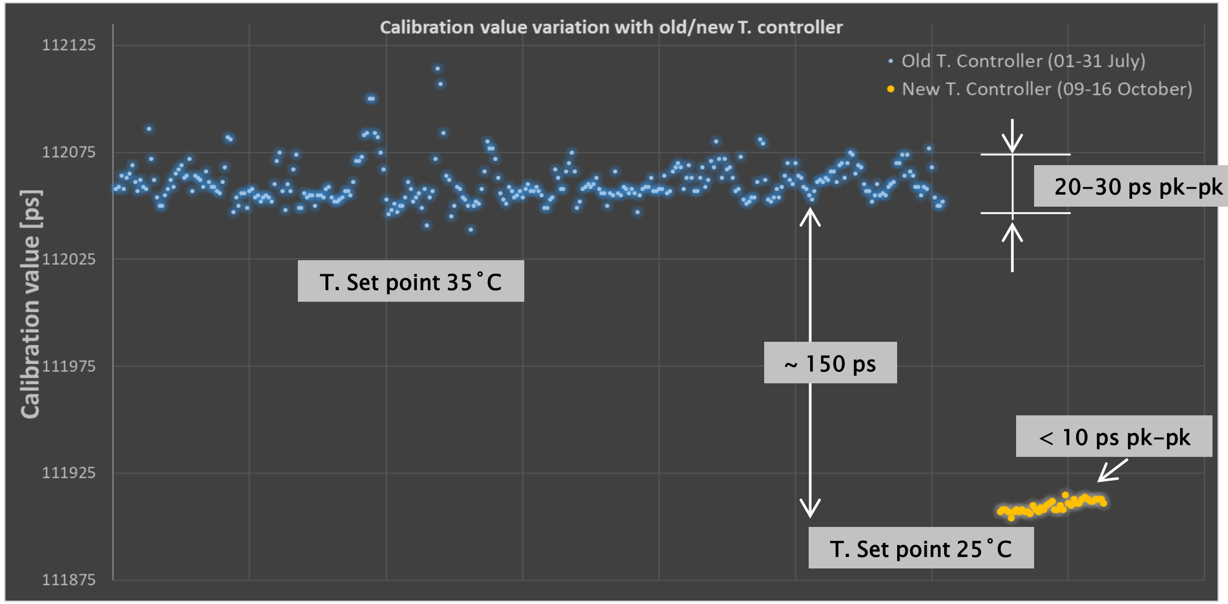
4. Detector (C-SPAD) Temperature monitor and stabilization

- ❑ Regular calibration with 1 hour interval to compensate temperature drift; on the other hand, also necessary to reduce temperature drift, e.g. thermal control.
- ❑ Since many years Graz SLR detection package has a T. controller, mainly for C-SPAD area;

  Found out: 5 - 8˚C variation of temperature -- controller defect/not suitable (??), T. variation causes (??) a 20-30 ps pk-pk of calibration measurement.
- ❑ A newly designed T. controller keeps +/- 0.5˚C variation of temperature; over last weeks, calibration measurement varies within +/- 5ps.
- ❑ The different set point from 35˚C in July to 25˚C in October caused approx.150 ps drop in the calibration measurements.
- ❑ Home Assistant is used to log all temperature and monitor the whole system.



Malfunction of T. controller causes 5-8˚C variation (blue); This might cause (??) a variation of 20-30 of the calibration values over time (orange).



The old T. controller caused a big variation of the calibration measurement over July 2024, with a set point of 35˚C; The new T. controller keeps the variation of the temperature within 0.5 ˚C at 25 ˚C set point.

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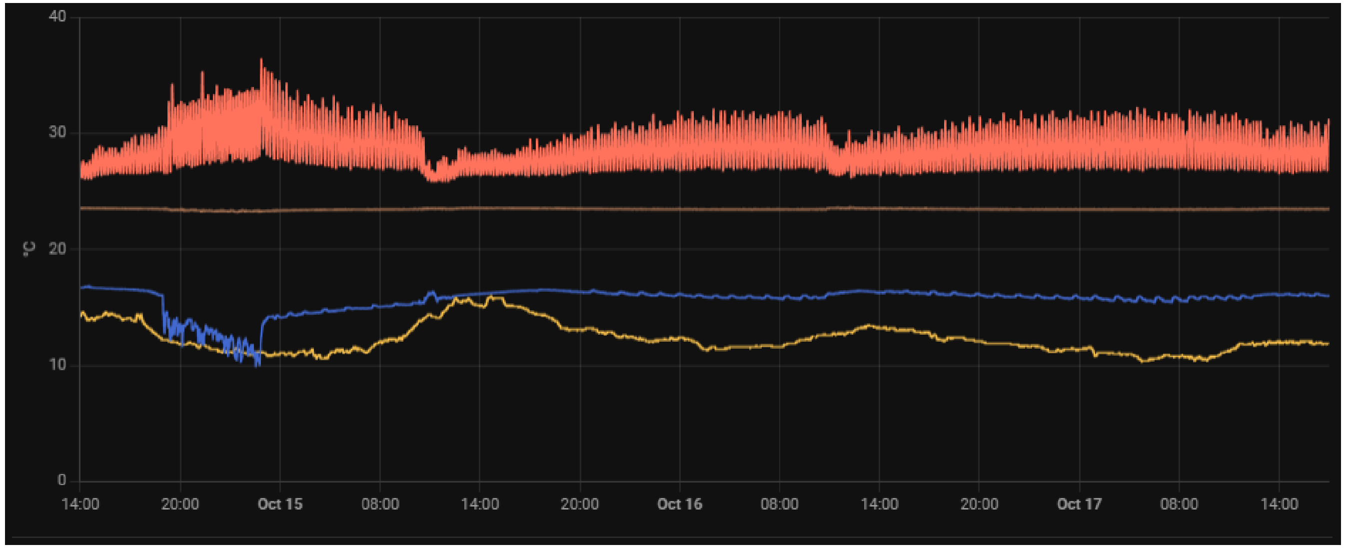
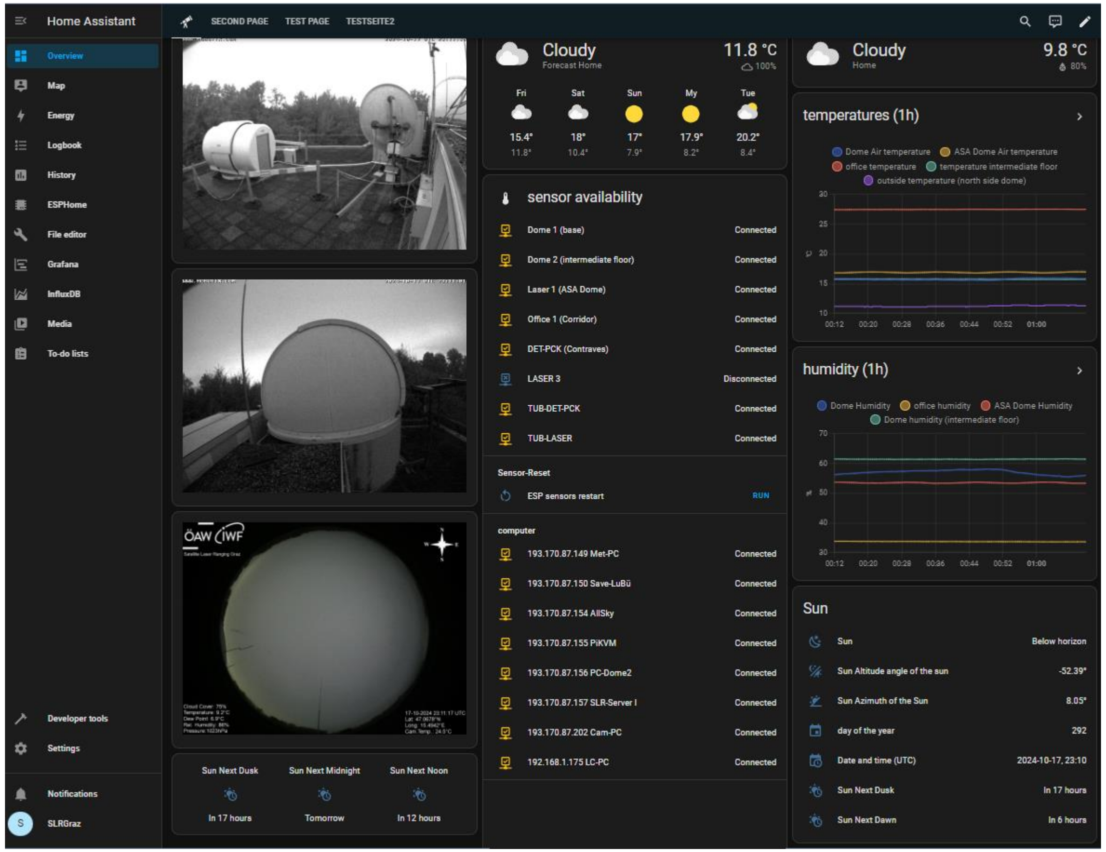
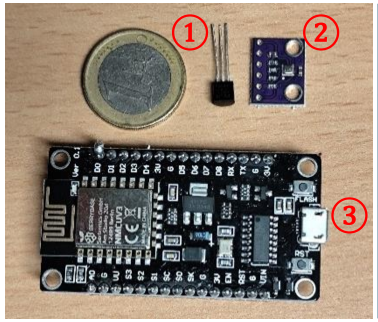
Home Assistant -- Internet of things (IoT) supports your system

- ❑ Home Assistant is an open-source platform for automation to centrally control and monitor various devices and systems in a home or a station.
- ❑ Very simple coding, configuration and integrate a variety of measurements, events…
- ❑ All components commercially available and affordable (each 1-5 USD), compact.
- ❑ Easy data management, high-availability retrieval, and visualization;
- ❑ Support many commercially protocol, MQTT, InfluxDB or Grafana ….
- ❑ Application for SLR stations: temperature/humidity/pressure measurement, laser cooling water flow monitoring, rain detection, special events log….



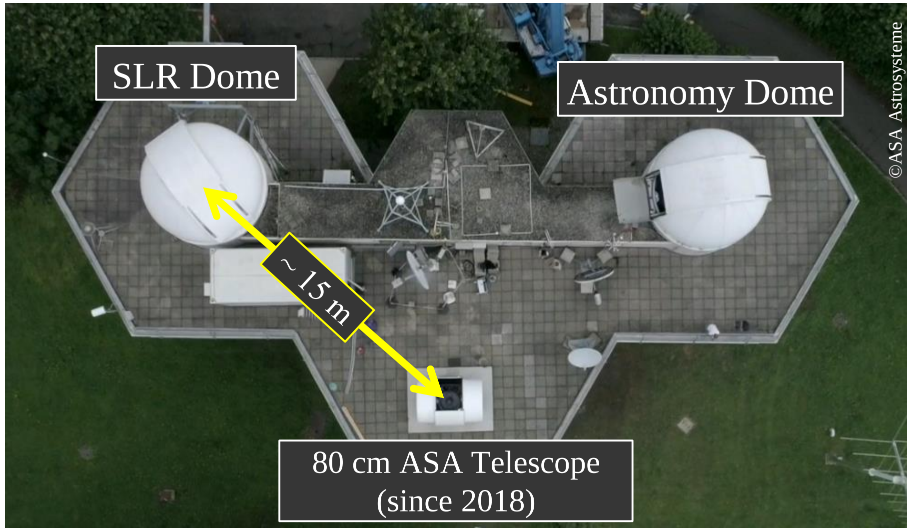




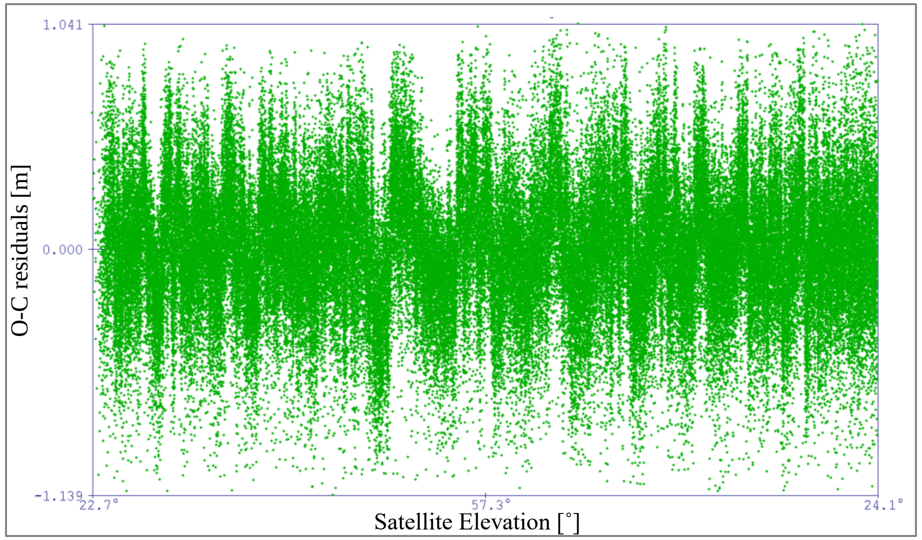
①	DS18B20	Temperature sensor
②	BME280	Temperature, humidity and air pressure sensor
③	ESP8266	Microcontroller with Wifi & USB

5. Laser backscatter free -- one site bistatic ranging

- Atmosphere backscatter might overflow the detector in high repetition rate (multi laser pulses on the way) SLR, when collision happens between 'go' and 'back' pulses. Backscatter avoidance (kHz, fire shift) or burst mode (>100 kHz) used.
- Backscatter collision defined by:
  - Atmosphere density, increasing towards to low elevation;
  - Field of view of both T. and R. optics;
  - Laser energy;
  - Equivalent distance between T. and R. optics, defined by baseline distance and direction, azimuth and elevation pointing. Max. backscatter appears as T. and R. point to the baseline.
- Setup:
  - Two telescopes on the top of Graz observatory with a distance of approx. 15 m.
  - One telescope acted as a transmitter with laser, another as a receiver with a SPAD.
  - The SPAD detector enabled by a RG generator, and epoch calculation based on the laser start.
- Result & future
  - Co-location bistatic successful to LEO (e.g. Jason) and HEO (e.g. Galileo, Glonass) satellites.
  - In most tracked passes, backscatter collision <u>not clearly visible</u>.
  - Need to check further experiment with 2 kHz and "real" MHz laser.



Observatory at Lustbühel, Graz



Jason, bistatic O-C residuals with Innolas laser (200 Hz), Clear backscatter not visible

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Thank you!