SLR-System Upgrade and Experiments at Zimmerwald

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22th International Workshop on Laser Ranging,

9th November, Guadalajara

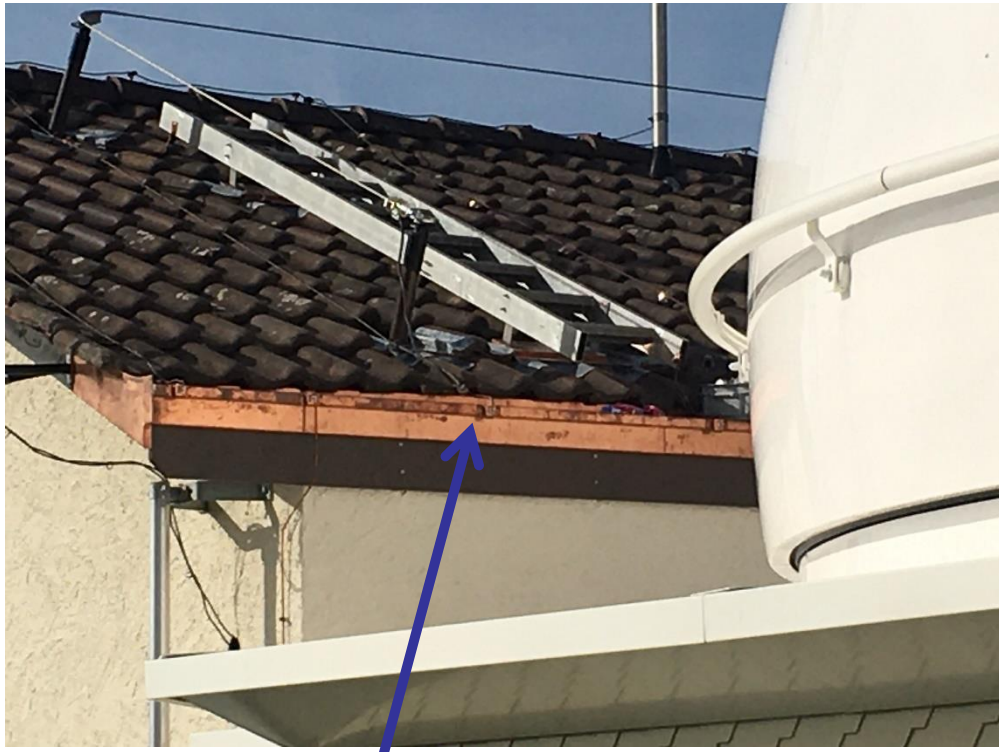
Outline

- **Part A: SLR-System Upgrade**
  - New Dome
  - New Others
  - New Nd:YAG Lasers (in progress)
- **Part B: Experiments**

  of Quantum Communication
  - Campaign Vertigo
  - Drone Flights

Part A: SLR-System Upgrade

New Dome



- Baader dome, 6 m, max. speed 35°/s
- 2 Hz software sync, ~1 s look ahead
- Software interfaces supports TCP/IP now
- Observations already possible

- Special rain water gutter
- New roof

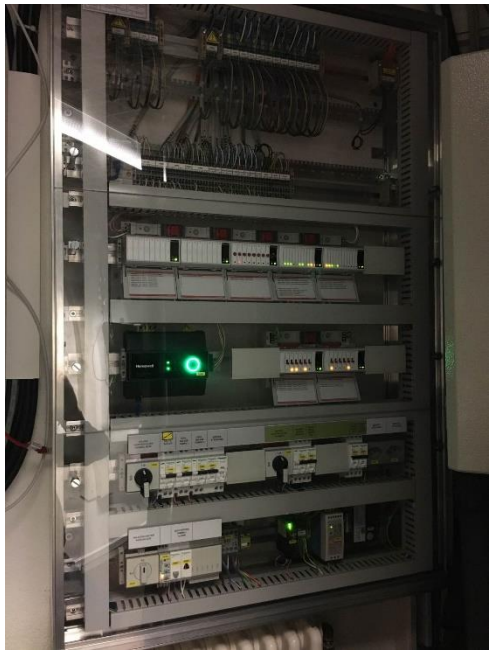
New Others: Cooling System

Outer devices

What's different?

- Cooling fluid: R-718 = water
- Be careful with electricity
- Bigger devices and hoses etc.
- Thermal isolation of hoses and Coudé room

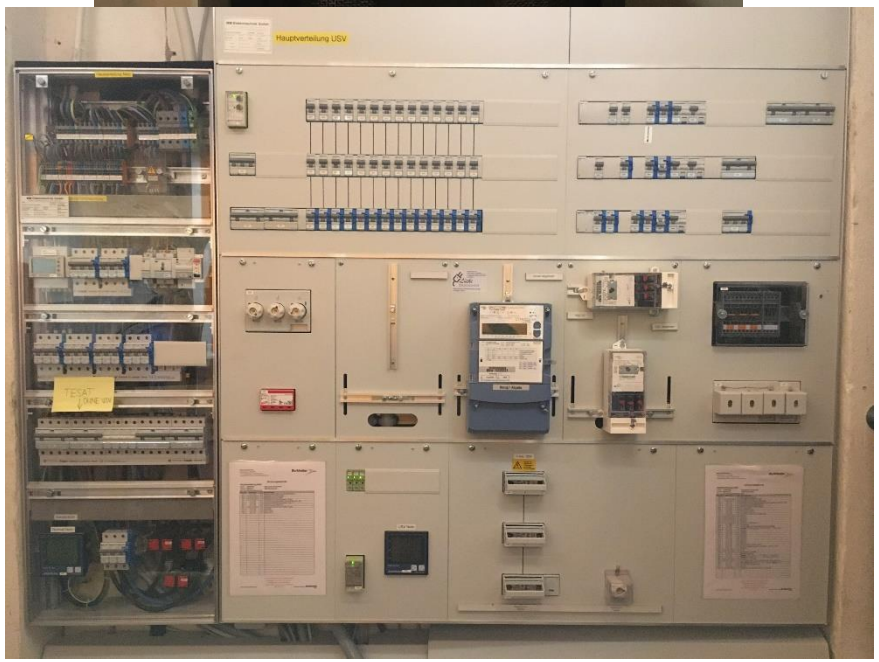
Inner devices



Control unit

New Others: Environment

UPS 230VAC for entire station



UPS 24VDC for SLR

self designed

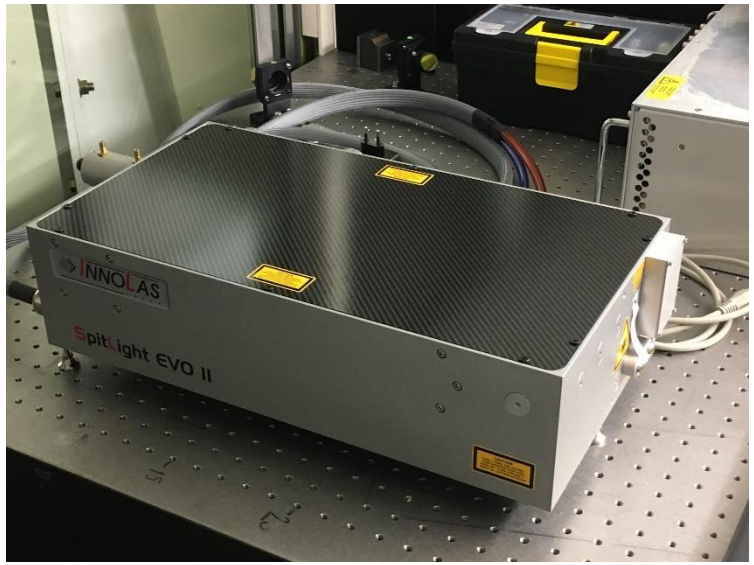
Batteries at load

Compressor

New Others: Remaining

- **Just new**
  - **Two USB Riga event timers for higher rep.-rates:** Software interface almost attached to the system, old parallel port devices have no failure and are still in use for SLR
- **Damages**
  - **De-rotating shutter**: electronics failed, renewed, cause: runtime?
  - **Maser**: Ion pumps are gone, switched back to quartz, should be repairable, has some difficulties, cause: runtime, pumps are after 6 years end of life
  - **Laser chiller cooling flow controller**: corrosion, repaired
  - (Software **OS upgrade**: let object code linking fail, recovered by using the old linker)
- **Downtime damages**
  - **Some movable devices** had to be shifted several times, cause: adhesion
  - **Laser oscillator (laser or controller)**: SLR show stopper, Sesam, currently 180 mW instead of 230 mW@1064 nm, 100 MHz, pulse width 8 ps, worked fine for ~15 a (50% standby)
  - **Reasons?**: during cooling system change, temperatures between 17°C and 30°C instead of 22°C and missing convection, vibrations due to outdoor ground compressor, runtime/ aging, power switch off/on

New Nd:YAG lasers (in progress)



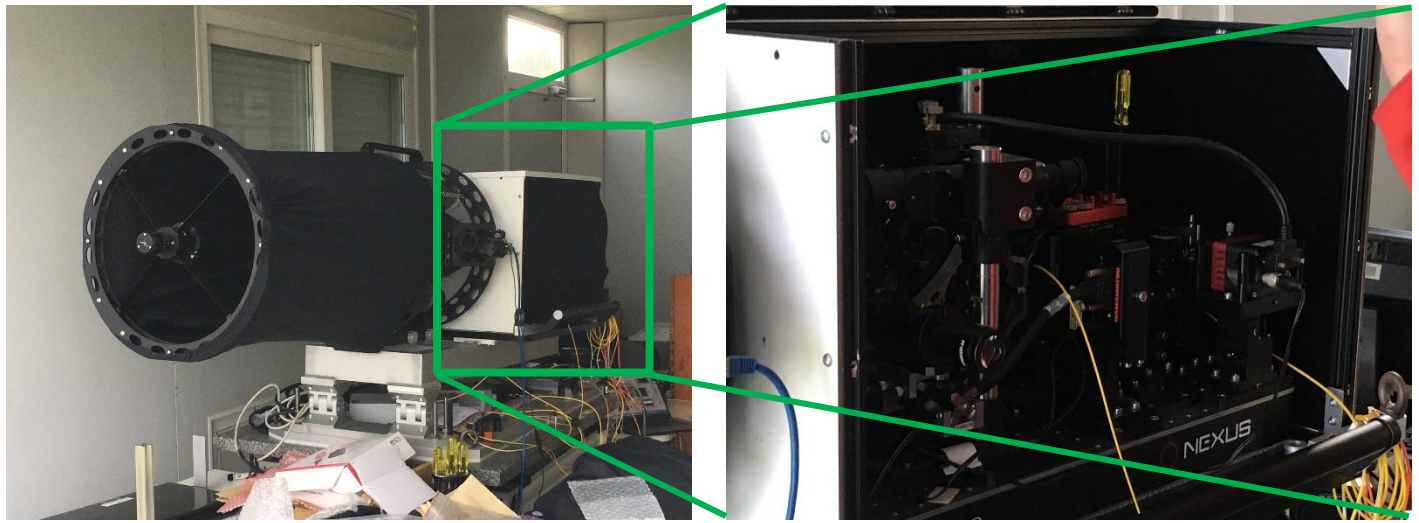
- **For Geodetic use**
  - Passat Compiler 1000, 532/1064 nm, **1 kHz**
  - Pulse energy/width: 1.6 mJ@1064 nm, 8 ps
  - Will be mounted on top of the telescope tube within a thermal isolation box
  - Try to combine IR/green paths into one: under construction at the Institute of Applied Physics
- **For Space debris use**
  - Innolas EVO II, 1064 nm, **200 Hz**
  - Pulse energy/-width: 200 mJ, 5-9 ns
  - Located on ground close to the old and current Thales laser
  - Installation ongoing
- **Added modifications (to stock version, both lasers)**
  - access to a reflex of the internal beam for start

Part B: Experiments of Quantum Communication

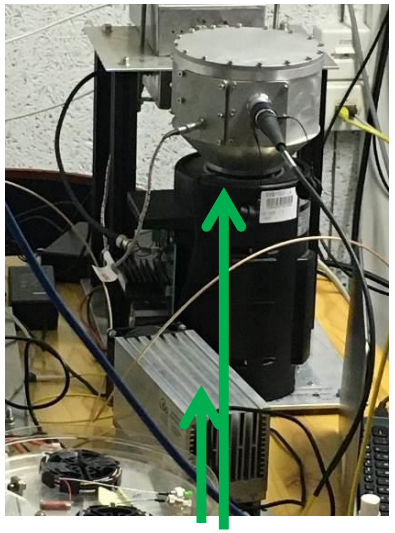
Campaign Vertigo

- **Zimmerwald observatory provides infrastructure only**
  - Some limited room, some limited help from stuff (e.g. me ☺)
  - 230 VAC, ~1 Gbps internet
  - **Access to Zimmerwald Air Traffic Control system**
    - uses from SkyGuide the Swiss radar data and Swiss aircrafts Flarm data
    - Client sends direction to check for aircrafts to server and receives GO/NOGO
  - Some help from university/mechanical workshop – only 15 km away
  - Was for free up to now, but this will change in the future
- **Campaign Vertigo**
  - Partners: Thales Alenia Space Zürich and Toulouse, ETH-Zürich, Onera – The French Aerospace Lab (close to Paris), Fraunhofer Heinrich-Hertz Institut Berlin
  - Additional user: University of Geneva
  - **Quantum communication from Zimmerwald to Jungfraujoch**
    - Remote Control of devices in Zimmerwald from Onera (~Paris)
    - Remote Control of devices at Jungfraujoch through fast university local Ethernet

Campaign Vertigo – Zimmerwald site



Onera telescope and adaptive optics



Detectors

QKD, QKP

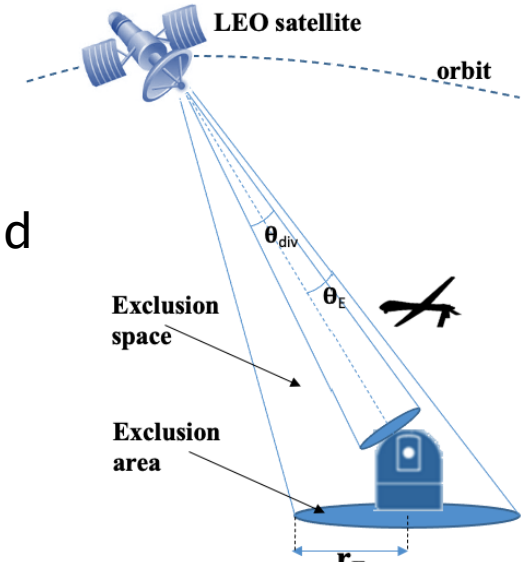
- **Some measurements to Jungfraujoch were possible**
- Horizontal link attenuated by ~50 km humidity

Drone Flights

- **Idea: Show communication between Zimmerwald and an High Altitude Platform HAP with finally a balloon flight and firstly a drone**
  - **Zimmerwald ZIMLAT telescope: ground host for experiment**
  - Univ. Bern cooperation with following institutes: Implementation of
    - techniques at Univ. Geneva and FH Nordwestschweiz[ToProjectWebsite]
    - secure channel at Univ. of Barcelona and Hochschule Luzern

Weather balloon sample

- **Secure = tap-proof communication channel:**
  - **there are different techniques of quantum physics**
  - **try to improve difficult ones by additionally simplifying them:**
    - restrict field of views by using low laser beam divergence lobes, and
    - use a simplified quantum key technique: Quantum Keyless Privacy QKP, call it rather a modulation than a coding technique



Courtesy of Univ. Barcelona

Drone Flights: RF and Laser Links

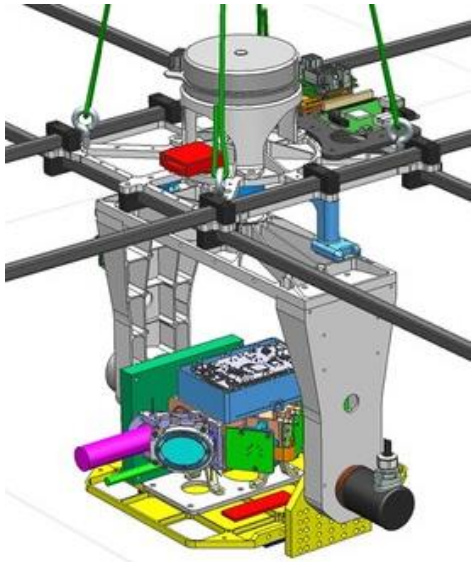
In time parallel/simultaneously

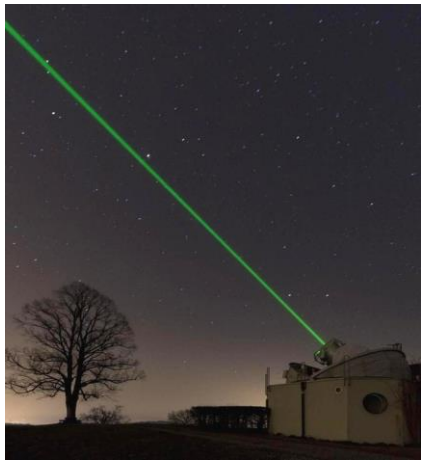
Two optical laser links

1. Link: Setup an SLR link to the target, in principal realized by the Zimmerwald standard SLR system

2. Link: Setup communication laser link from target to the SLR station, implemented by Univ. Geneva, FHNW

3. Link: GPS data from the current position of the drone is transmitted to the SLR station on a separate RF channel





GPS receiver

Drone Flights: Drone itself

- **Drone must be able to carry**
  - Optics, retro-reflector
  - Bread-board for optics
  - Laser, QKP encoder
  - Electronics, Batteries
  - GPS receiver and data transmitter
  - Raspberry PI
  - Gimbal
- **Milestone: Show communication between drone and detector at station**
  - Firstly, close around the station
  - 600m at the SLR calibration target
  - 3 km from the station
  - Maybe others …

Movie of new drone

Gimbal

Drone Flights: Slew Telescope to Drone

- **Payload attached via rope to drone**
  - GPS receiver and data transmitter
  - Gimbal
  - Retroreflector
- **Telescope followed drone**
  - If change of |Az| or |El| <1.5° uses incremental "manual corrections" as in SLR spiral search mode
  - Else uses rough absolute positioning command
    - extrapolates to position in 15 s from past values
    - needs ~30 s setup time
  - Both modes worked successfully
  - During wind, the two mass system of drone and payload became more unstable, then changes often >1.5°.
- **SLR simultaneously did not work, reason not yet clear**
- **Gimbal pointed to ZIMLAT successfully**

Drone payload

1.5° determined empirically for stability of Delta-Tau PMAC Motion Controller

Outlook

Hope to be back soon for

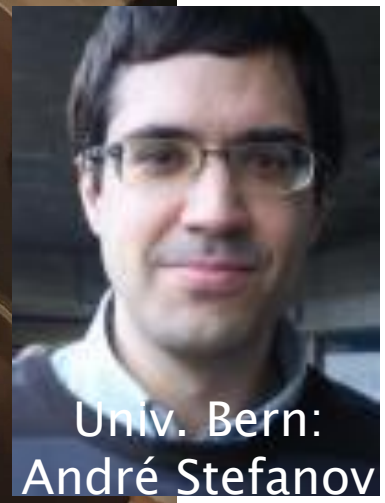
- **Standard-SLR**
  - Dome: some firmware changes and fixes pending
  - **Laser: Recovery from issue:**
    - Repair/replace oscillator laser/controller
    - Setup one of the other lasers?
  - hopefully last downtime damage
  - Lesson learned: Never change too much of a running system

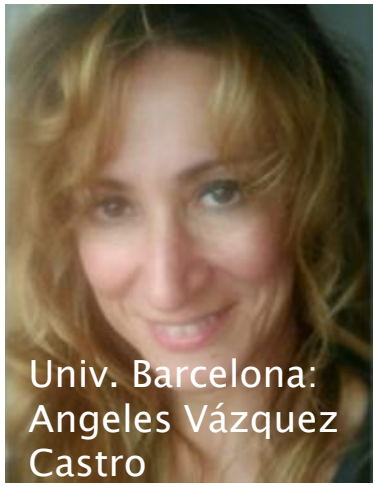
- **Our own quantum communication experiments:**
  - Setup of all hardware and software make it working together properly
  - Next minor Step: Last experiment at Zimmerwald plus SLR simultaneously
  - Next Milestone: Full experiment with Drone
  - And all other experiments … especially with the balloon hopefully

Acknowledgements


FHNW: Christoph Wildfeuer


University of Geneva
Davide Rusca
Alberto Boaron
Hugo Zbinden


Univ. Bern: André Stefanov


Univ. Barcelona: Angeles Vázquez Castro

Without pictures
Univ. Geneva: Raphael Houlmann
FHNW: Simon Burkhardt


HSLU: Esther Hänggi

Backup Slides

- **For more detail on the optical quantum communication project, see AIUB seminar presentation Zimmerwald ZIMLAT Preliminary experiments for balloon communication project.pdf**