Federal Agency for
Cartography and Geodesy

Optical Laser time transfer and high repetition rate monostatic SLR

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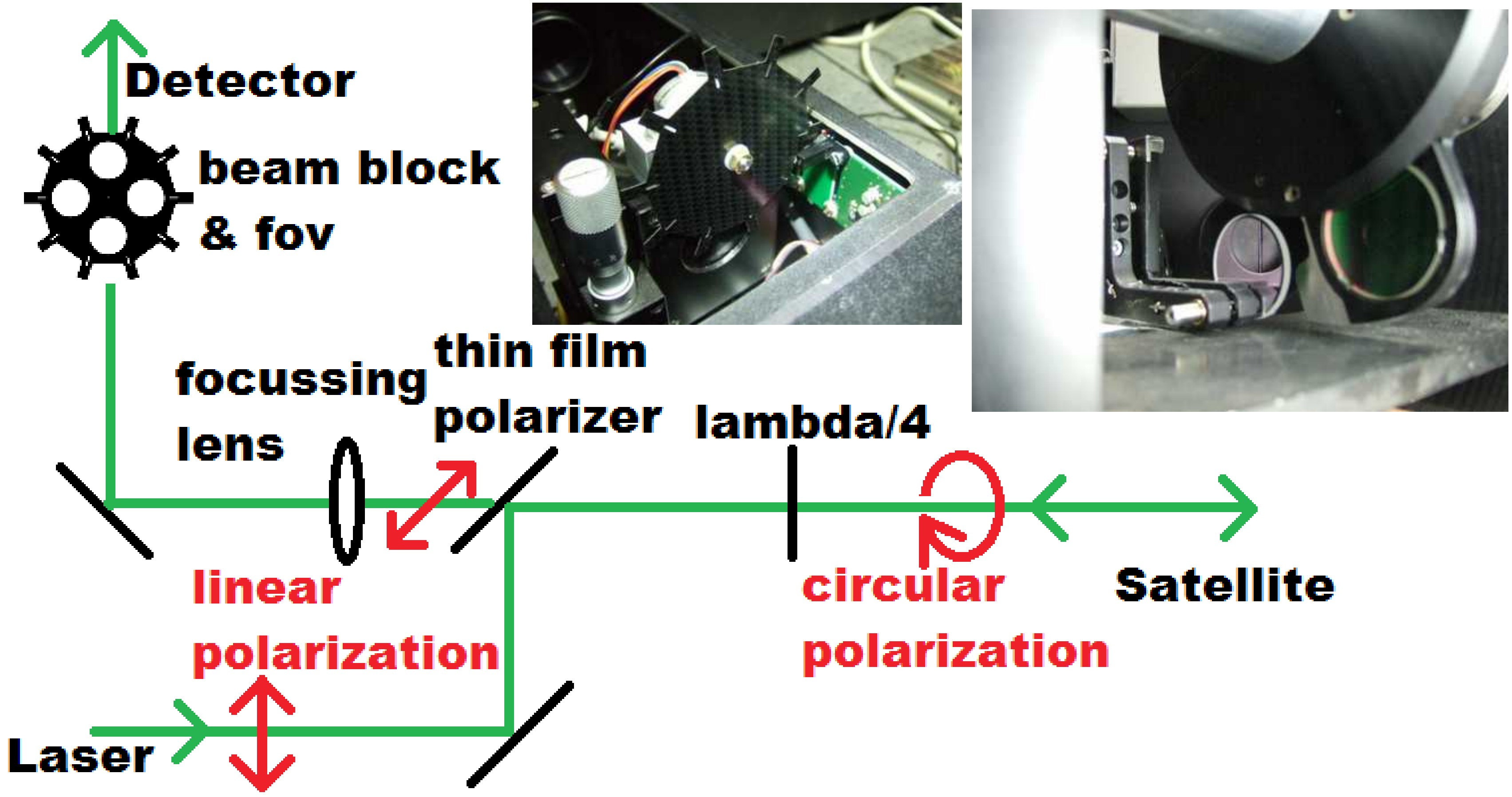
Review
- design goals -

Increase Repetition Rate
- Return Rate > 0.01 to allow daytime automatic SLR
- Precision < 1 mm for all ILRS targets, but reduce systematics → going optical?

NIR ranging (already shown @ 2013 ILRS WS)
- Eye-Safe in combination with telescope aperture
- Improved link efficiency

Time Transfer capability
- Laser Fire synchronization to local Timescale
- Improved system stability by new Start & Event-Timer electronics (CTU Prague)

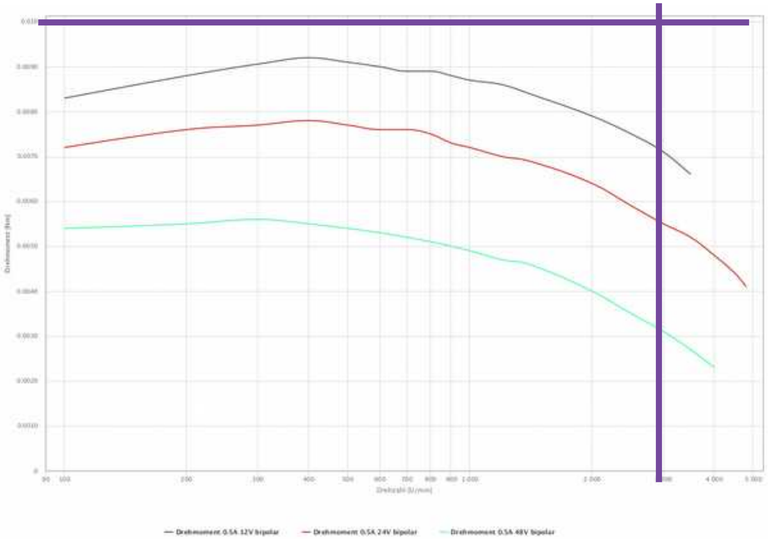
Review
- T/R switch optics -

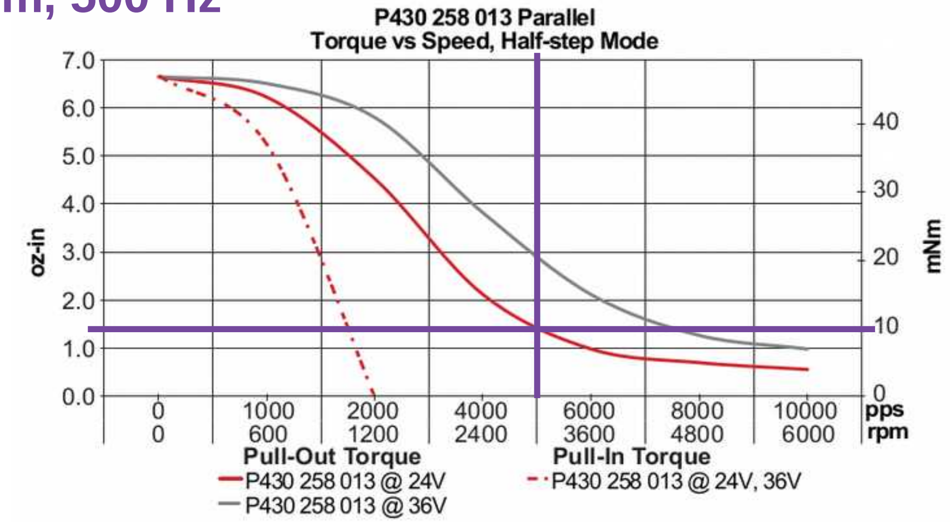


Signal is forced to be circular polarized!

T/R switch
- stepper motor -

10 mNm, 500 Hz

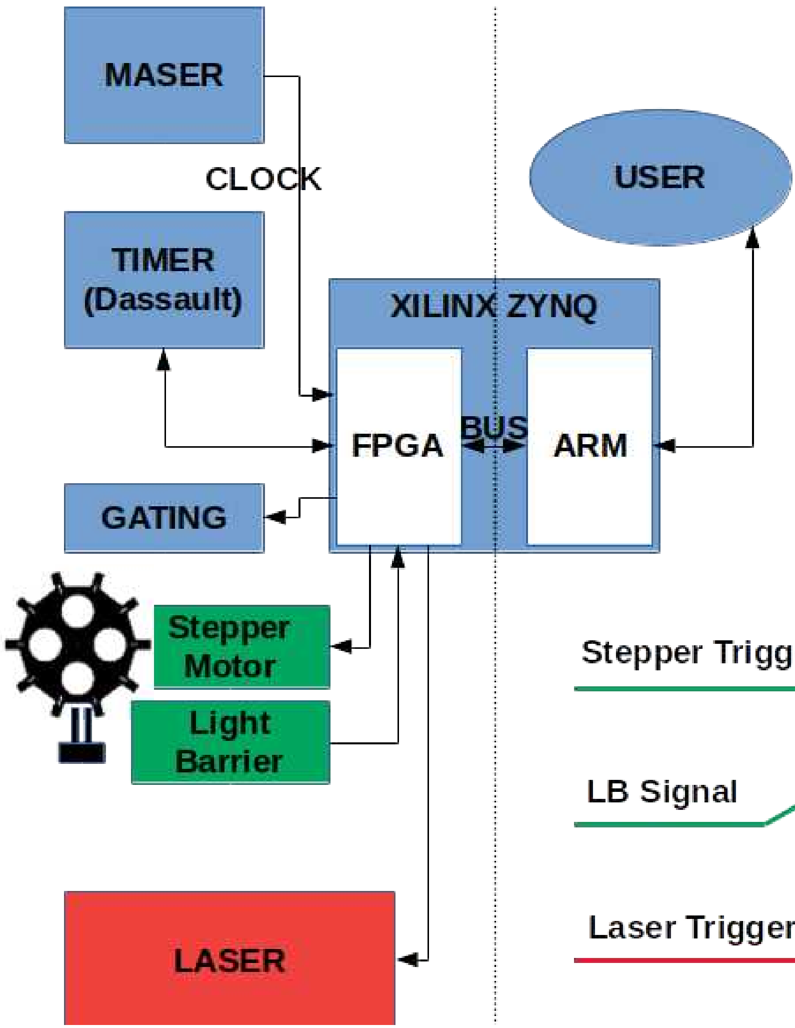


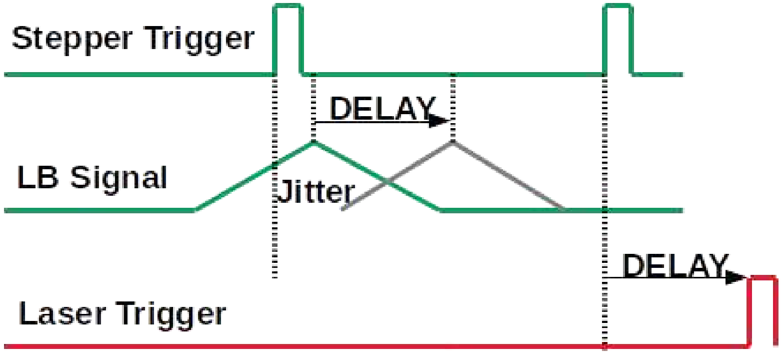


now

future

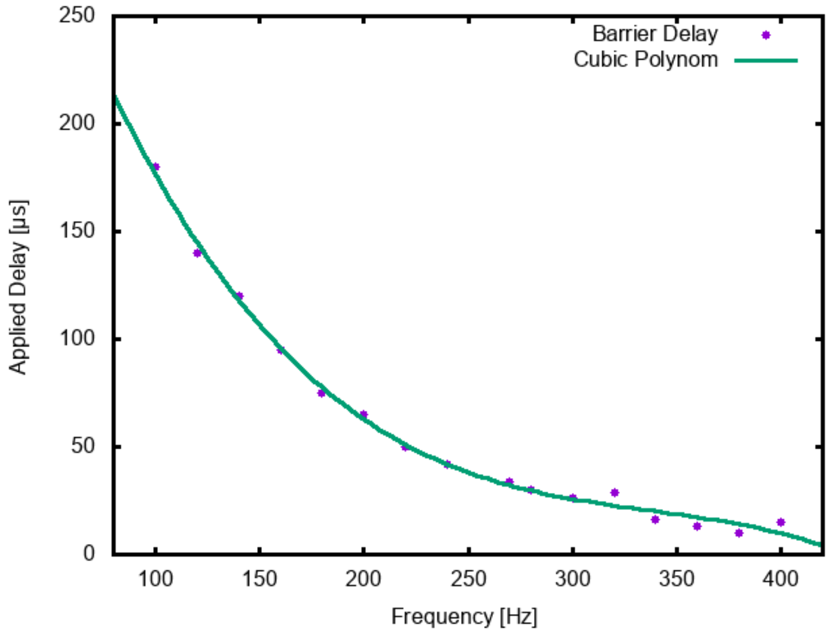
T/R switch
- electronics & timing -

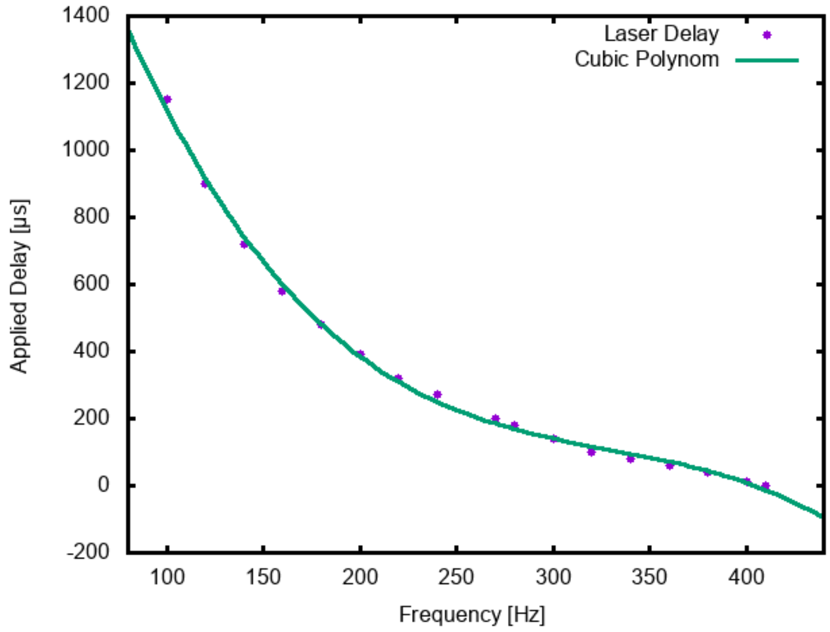




T/R switch
- beam block -

- Light Barrier & Laser Delay frequency dependent
- Collision avoidance requires frequency shift
  → adjusted using cubic fit

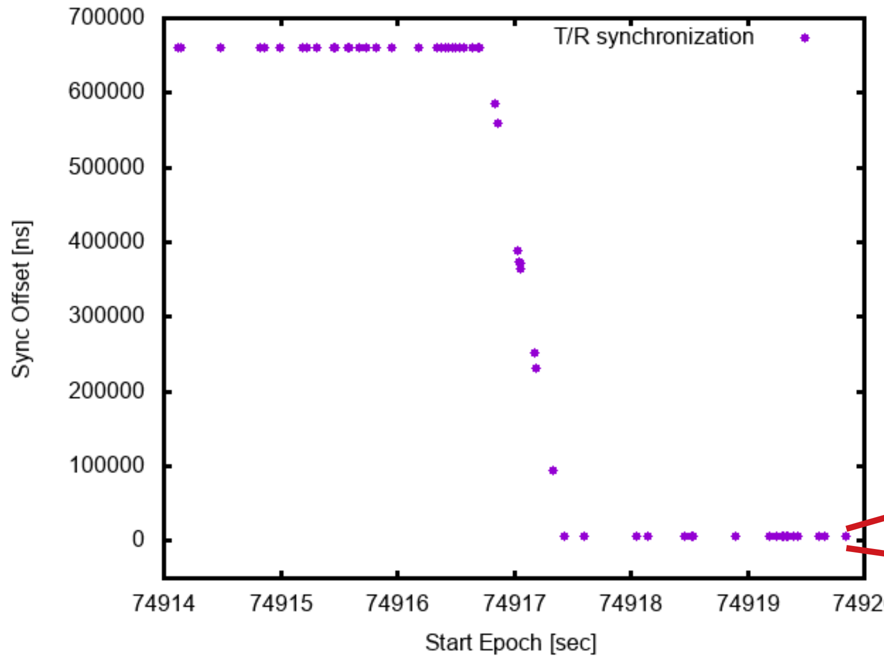


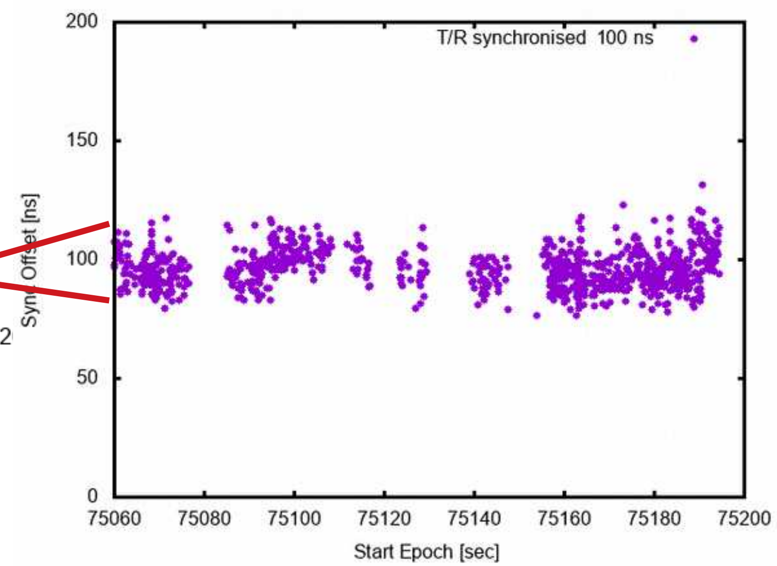


- Further Requirement: Passive Mode-Locked Oscillator lasing continuously → AOM implemented

T/R switch
- sync performance -

Synchronization of Laser Fire Times to external Time-Base via phase shift of stepper trigger frequency





- Slew rate ~ 1 ms/sec
- P-P Jitter ~ 25 ns

High Rep-Rate Mode
- overview -

Max. Laser pulse energy: 1.2 mJ (used: ~0,7 mJ)
Repetition Rate: 400 Hz
Ranging Wavelength: 1064 nm
Telescope aperture: 0.75 m (transmit & receive)

Data clipping:
2.0 for internal calibration (spurious tail)
2.2 for external reference calibration (Gaussian)
2.2 for satellites

Data rejection:
> 2.5 mm precision
< 10 FR points per NP
> 10% Return Rate

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High Rep-Rate Ranging
- pulse energy -

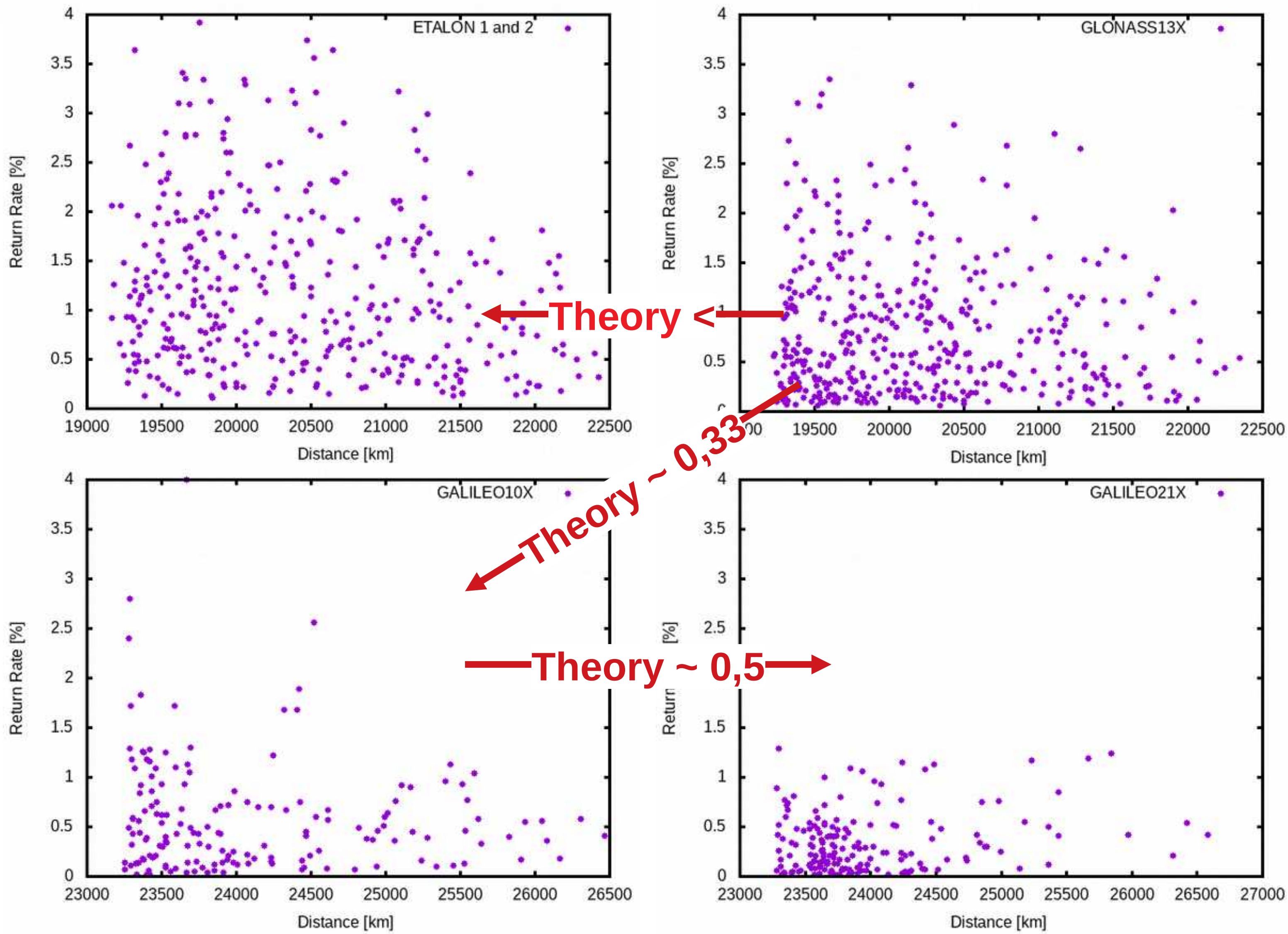
- Measure laser pulse energy of brightest spot of beam profile @ telescope output:
  532 nm → 1.5e-8 J/cm2
  1064 nm → 0.5e-7 J/cm2

- *Max. ANSI Z136.1 (2014):*
  532 nm → 1e-7 J/cm2
  1064 nm → 2e-6 J/cm2

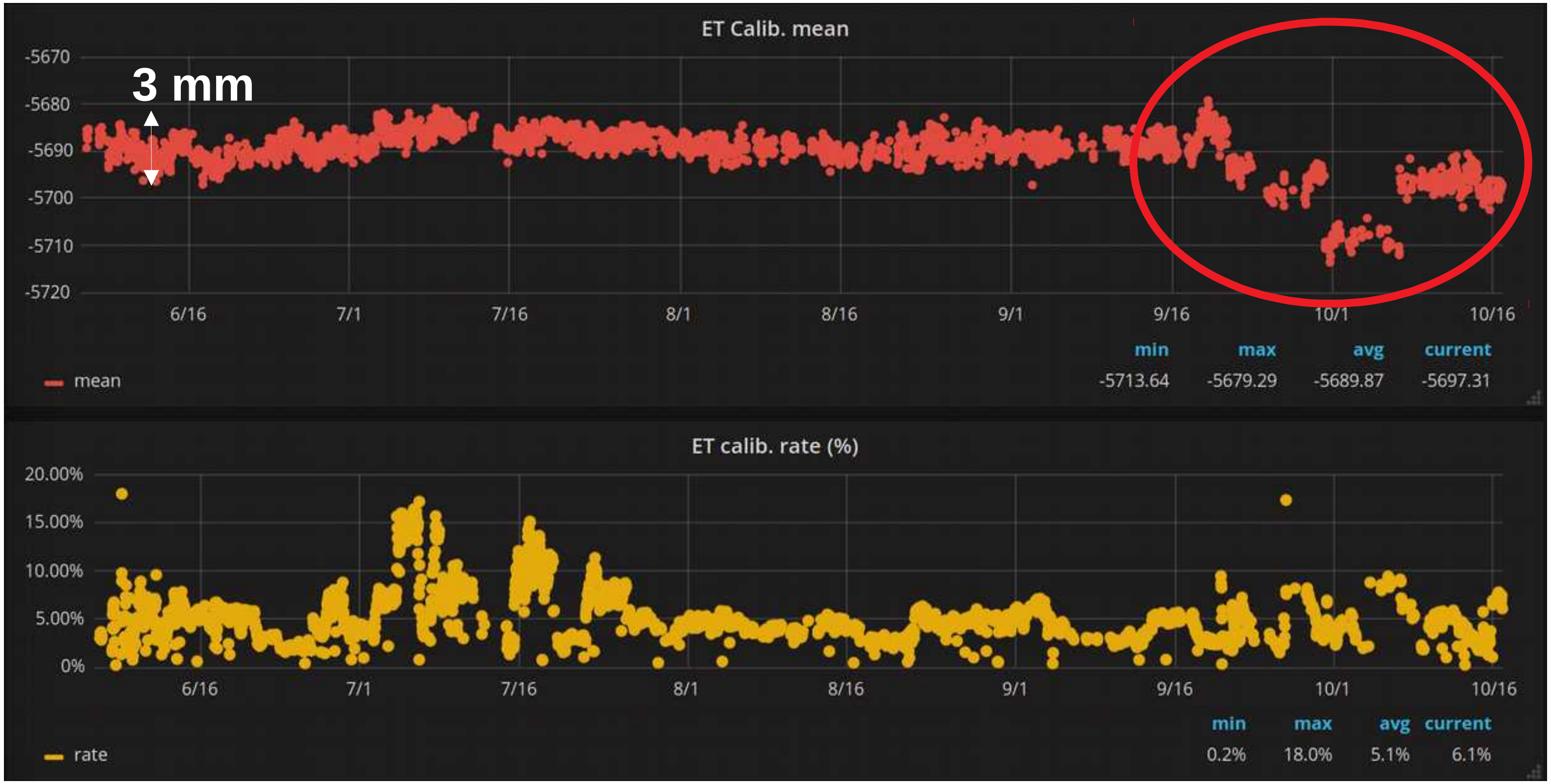
- *Max. IEC 60825-1 (2014):*
  532 nm → 1.9e-9 J/cm2
  1064 nm → 2.5e-8 J/cm2
- Factor 2 only!

NO MPE! - CLASS 1: Starring 10 sec with  into the laser beam

High Rep-Rate Ranging
- heo performance -



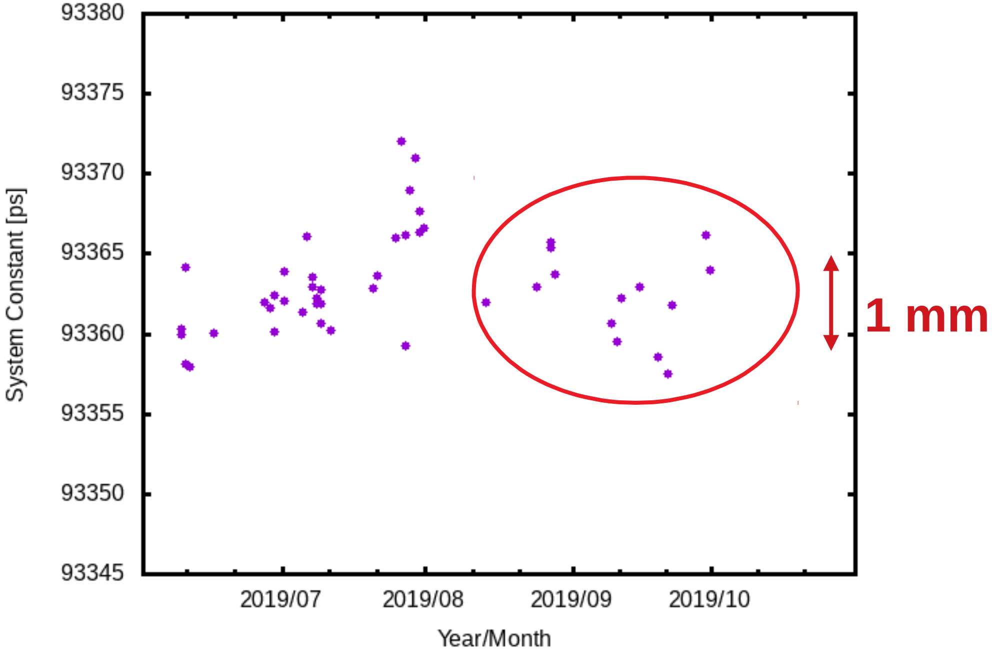
Calibration
- absolute delay stabilization -



P-P Variation of <u>internal</u> calibration 15 ps (<3mm) over month!

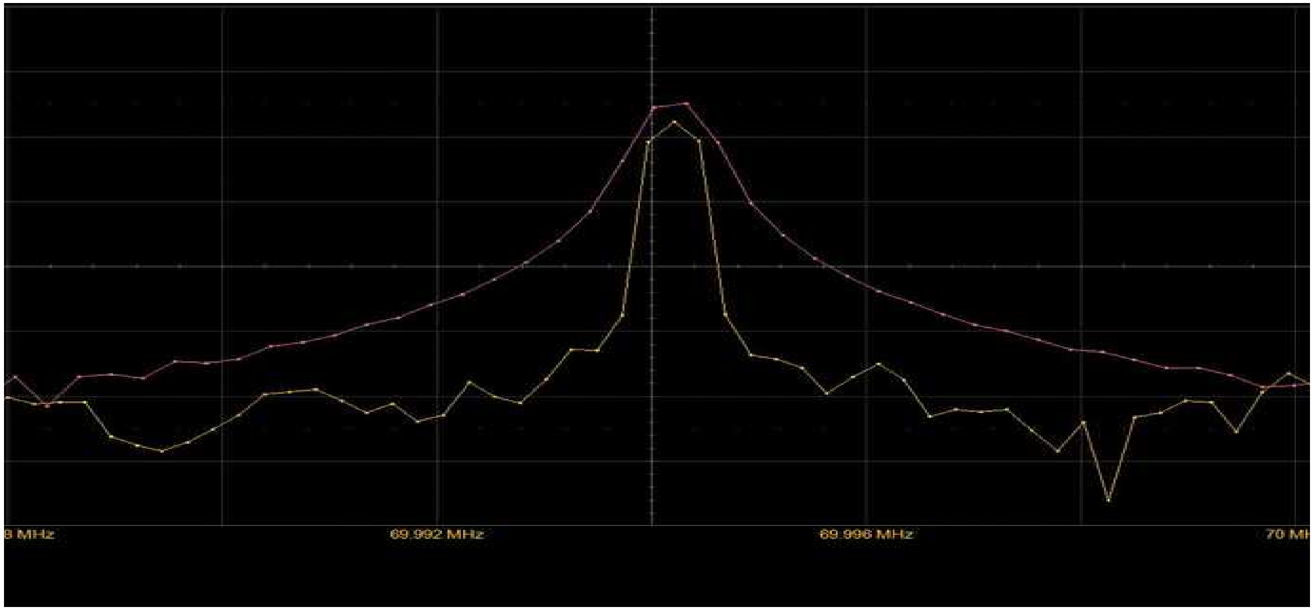
Calibration
- system constant -

- Use telescope internal calibration to interpolate external target reference measurements
- Advantage:
  - No telescope positioning required
  - Determination of system constant possible

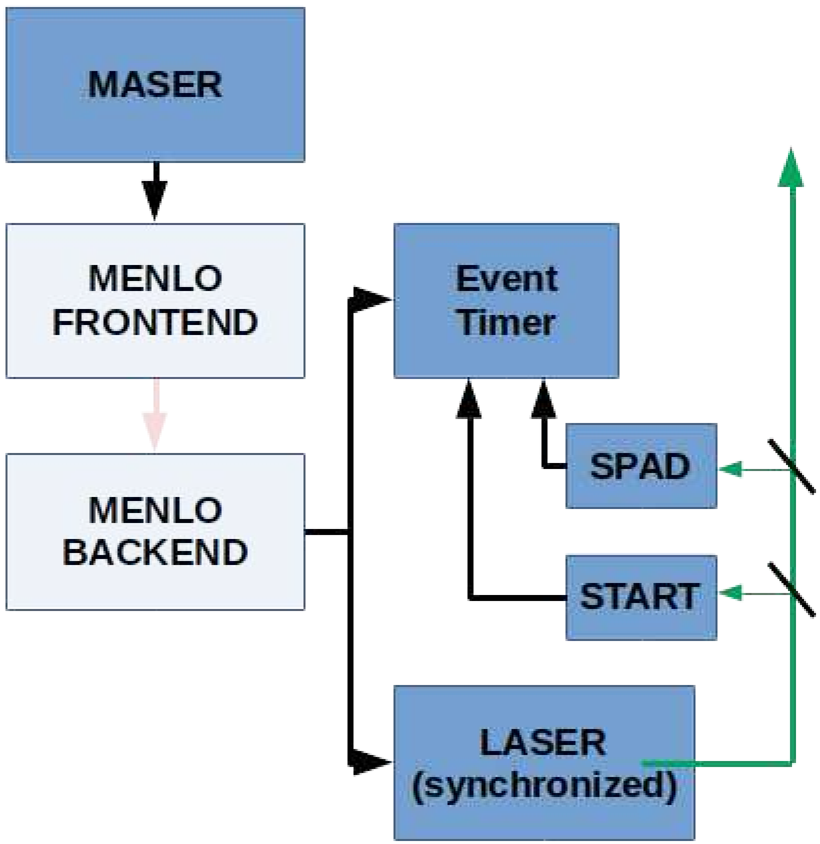


Time Transfer
- 1st step towards going optical -

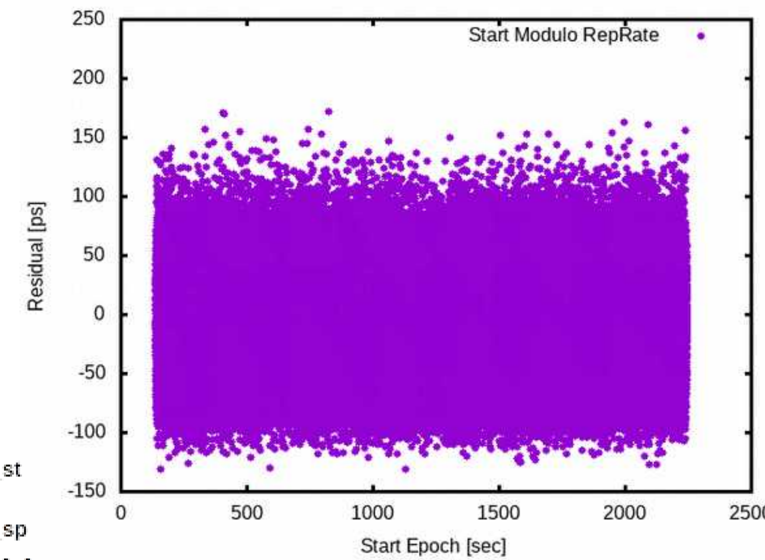
- Passive mode-locked laser oscillators provide high spectral purity
- Lock repetition rate to reference frequency to stabilize start epoch or verify timing electronics



Time Transfer - laser synchronization -



START EPOCH	STOP EPOCH	RANGE (Calibration)
.	.	.
.	.	.
.	.	.
.	.	.



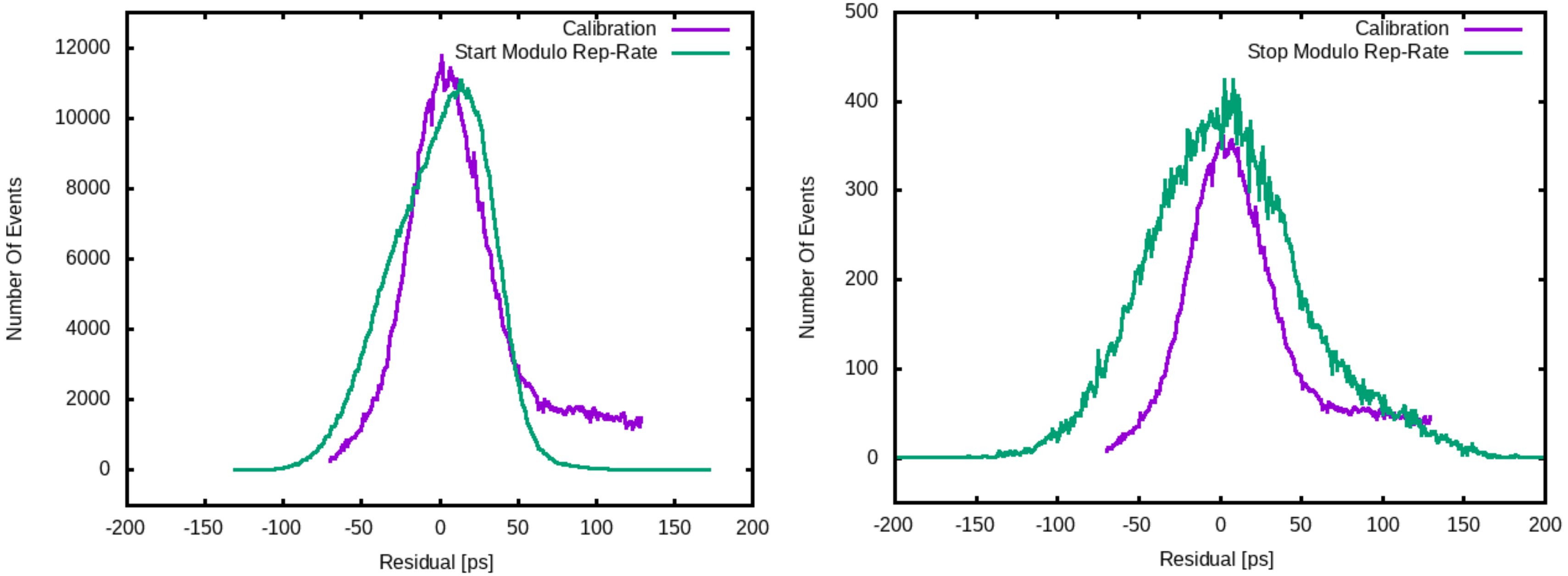
$$\text{START} = n * (\text{RepRate})^{-1} + \Phi_{Start} + d\Phi_{common} + d\Phi_{err\_st}$$

$$\text{STOP} = n * (\text{RepRate})^{-1} + \Phi_{stop} + d\Phi_{Common} + d\Phi_{err\_sp}$$

$$\text{RANGE} = \text{STOP} - \text{START} = \Phi_{stop} - \Phi_{Start} + d\Phi_{err\_sp} - d\Phi_{err\_st}$$

Time Transfer
- laser synchronization -

- Identify errors common to both channels
- Independent validation of Start & Stop channel
- Preliminary result!



- Future: start epoch generation @ “sub”-ps accuracy with two-way link to maser

Conclusion??? - questions -

- Galileo2XX tracking: Is 532 nm front coating problematic for 1064 or 850, is there a coating?
- Do other stations have similar experience with HEO ranging?
- What is general opinion about 1064 nm ranging?
- Do other stations apply data rejection criterion, which one?
- Sentinel ranging at 1064 nm?
- Should we sent passage or passage segment data?