Coherent Time and Frequency Distribution System for a Fundamental Station

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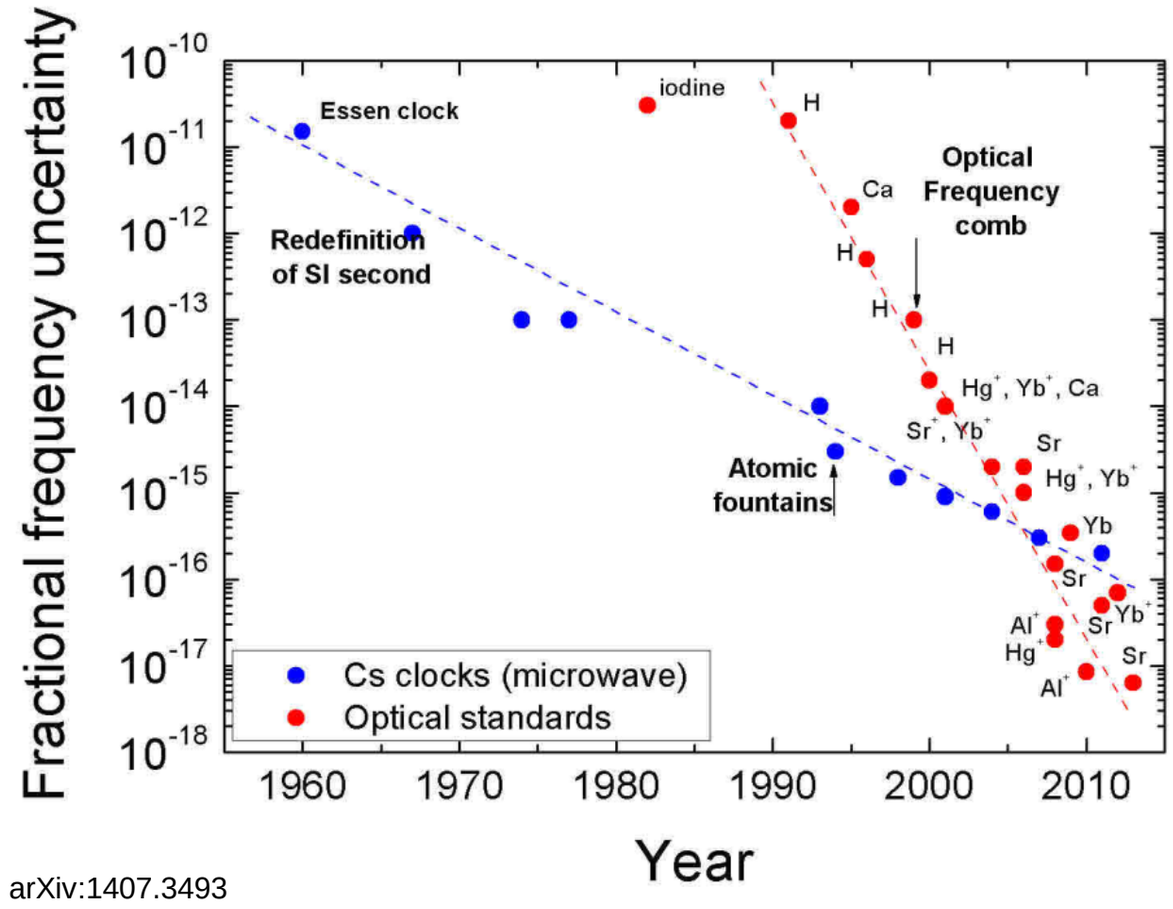
Optical Clocks in Space Geodesy



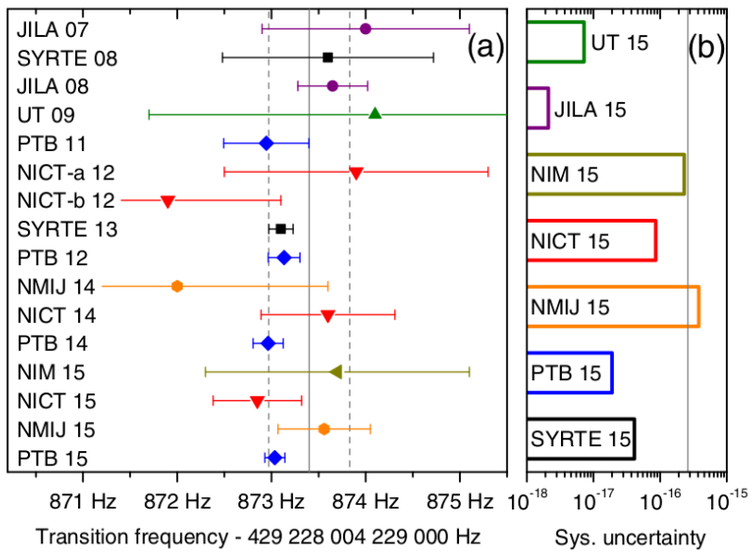
arXiv:1407.3493

Optical clocks has extremely good accuracy and stability. Both properties we would like to transfer into space geodesy.

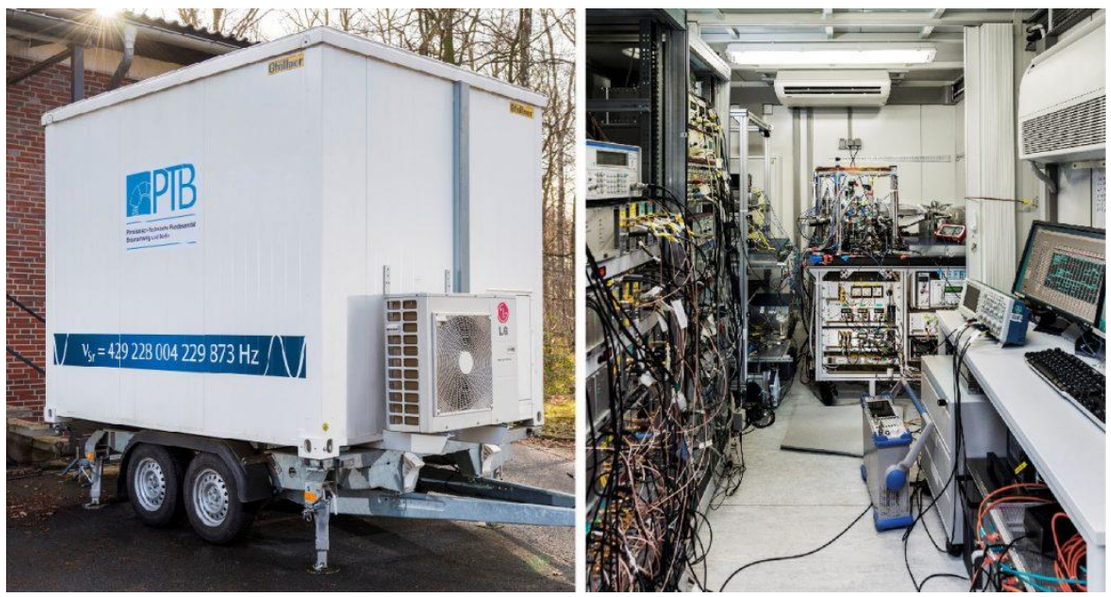
Space Geodesy measures signal delays, therefore we require high accuracy and stability to track phase.

Highly accurate clocks allow to exploit GR for a height system.

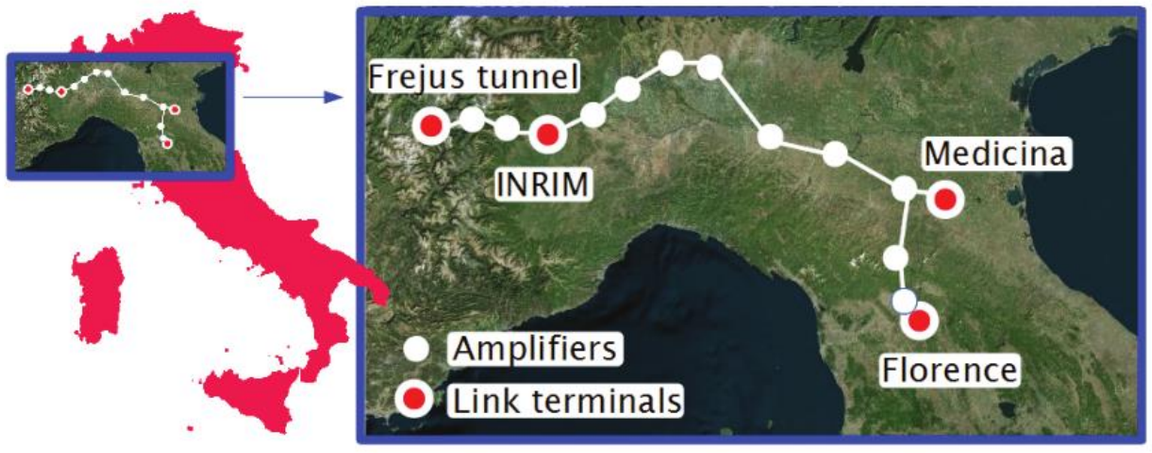
Optical Clocks in Space Geodesy



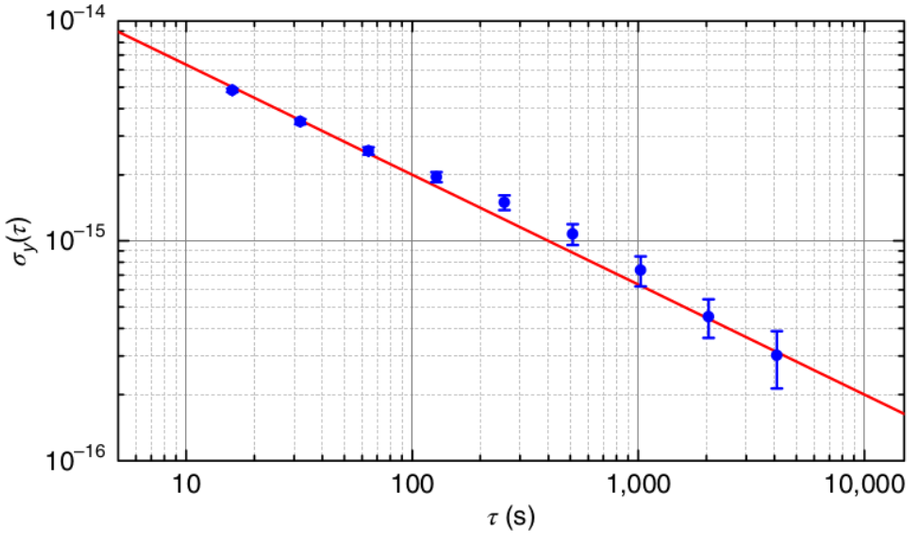
C. Grebing et al., „Realization of a timescale with an accurate optical lattice clock", Optica, č. 6, s. 563–569, erven 2016.



Pictures taken from the publication arXiv:1609.06183

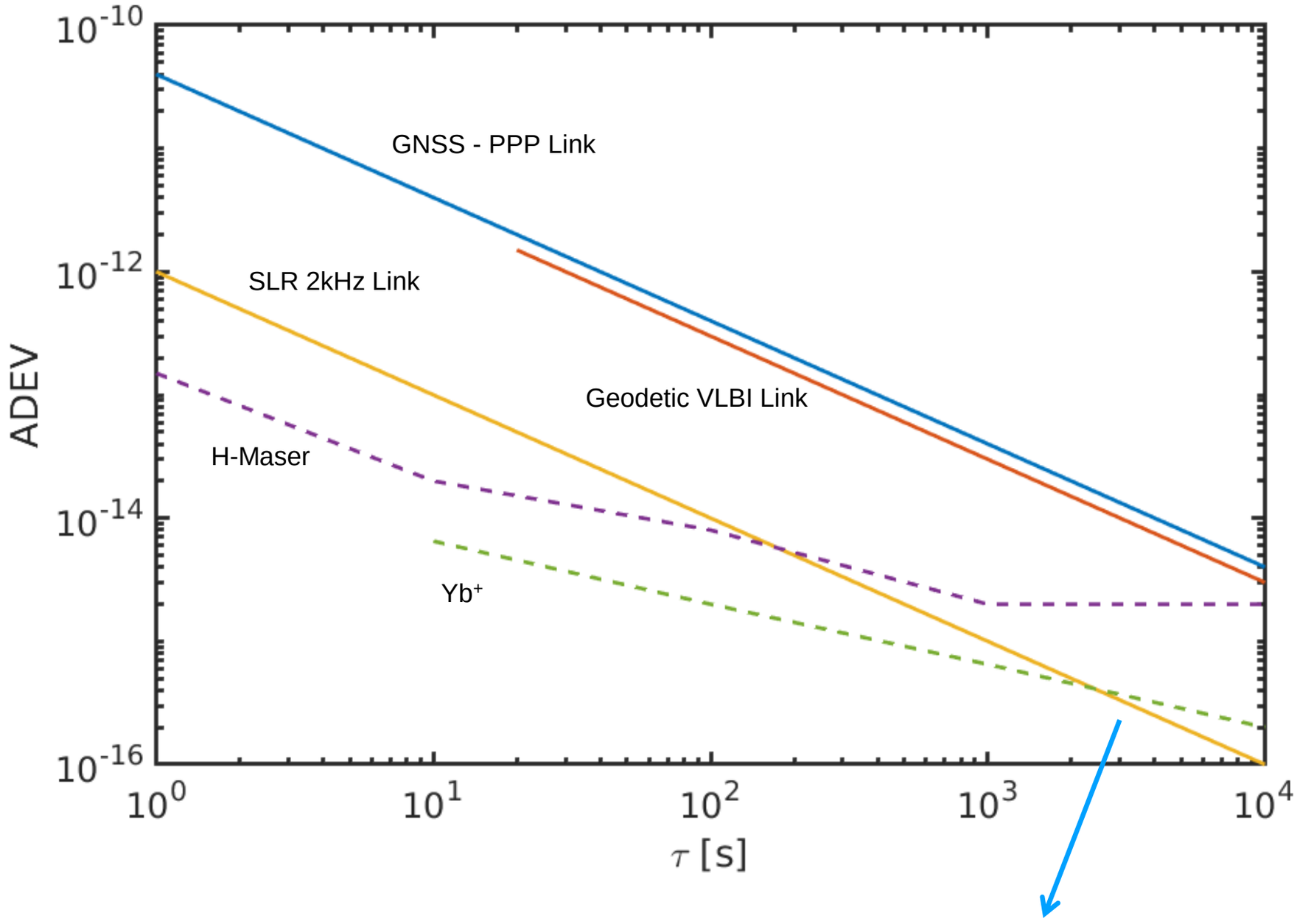


C. Clivati et al., “A coherent fiber link for very long baseline interferometry,” IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 62, no. 11, pp. 1907–1912, Nov. 2015.



J. Grotti et al., “Geodesy and metrology with a transportable optical clock,” Nature Phys, vol. 14, no. 5, pp. 437–441, May 2018.

Space Geodesy Instrumentation, where and how we can gain from ultrastable cloks



To reach 10^{-16} we must make our measurement stable and accurate.

T. Hobiger, C. Rieck, R. Haas, and Y. Koyama, “Combining GPS and VLBI for inter-continental frequency transfer,” Metrologia, vol. 52, no. 2, p. 251, 2015.
J. Leute et al., “Frequency Comparison of ^171text Yb^+ Ion Optical Clocks at PTB and NPL via GPS PPP, Ferroelectrics, and Frequency Control, vol. 63, no. 7, pp. 981–985, Jul. 2016.

Gola is

$\tau_1=\tau_2=\tau_3=\tau_4=$const.

τ_{l1}, τ_{l2}, τ_{l3} - proper calibration

τ_{l1}

τ_{l2}

τ_{l3}

CLOCK

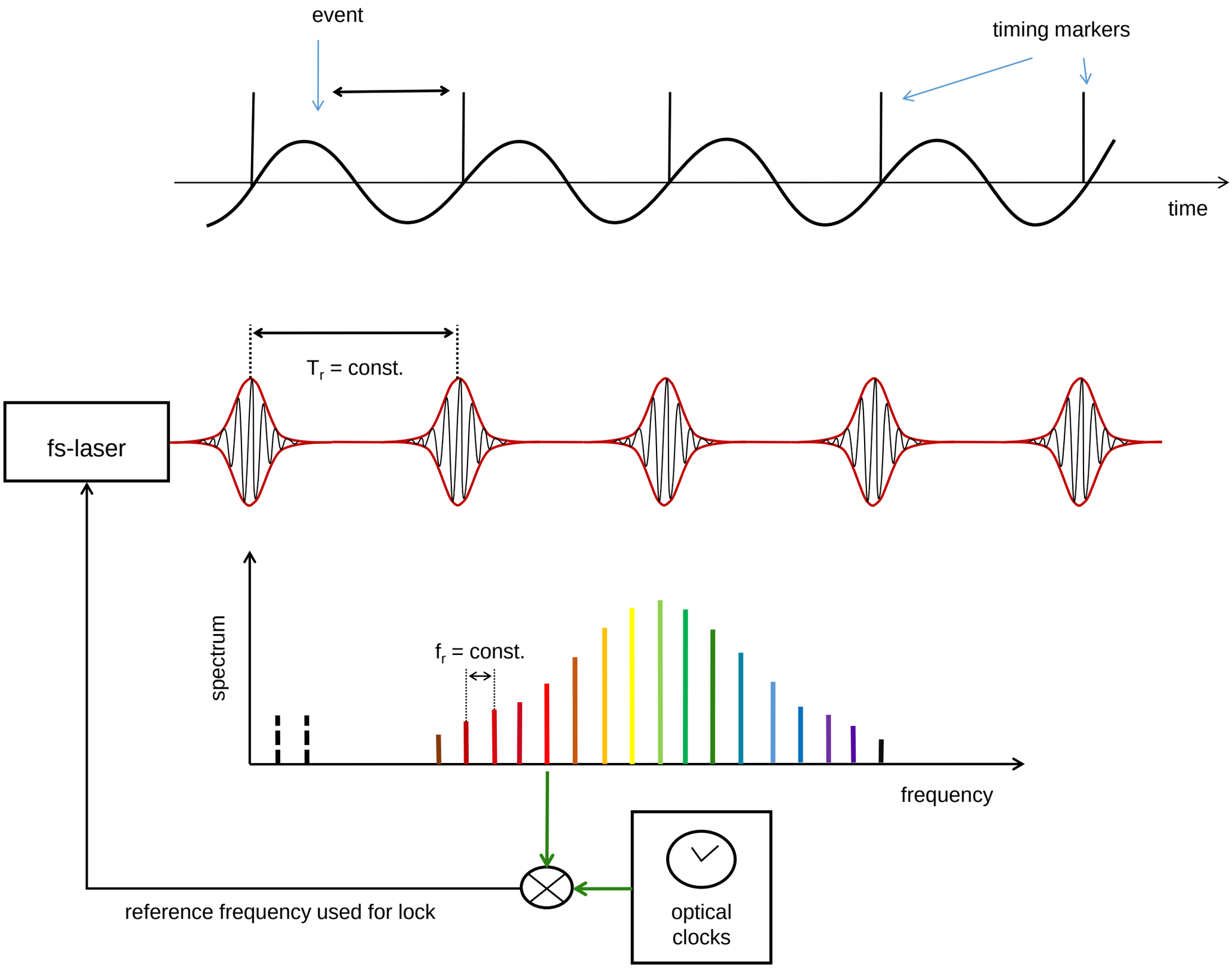
time

τ_1

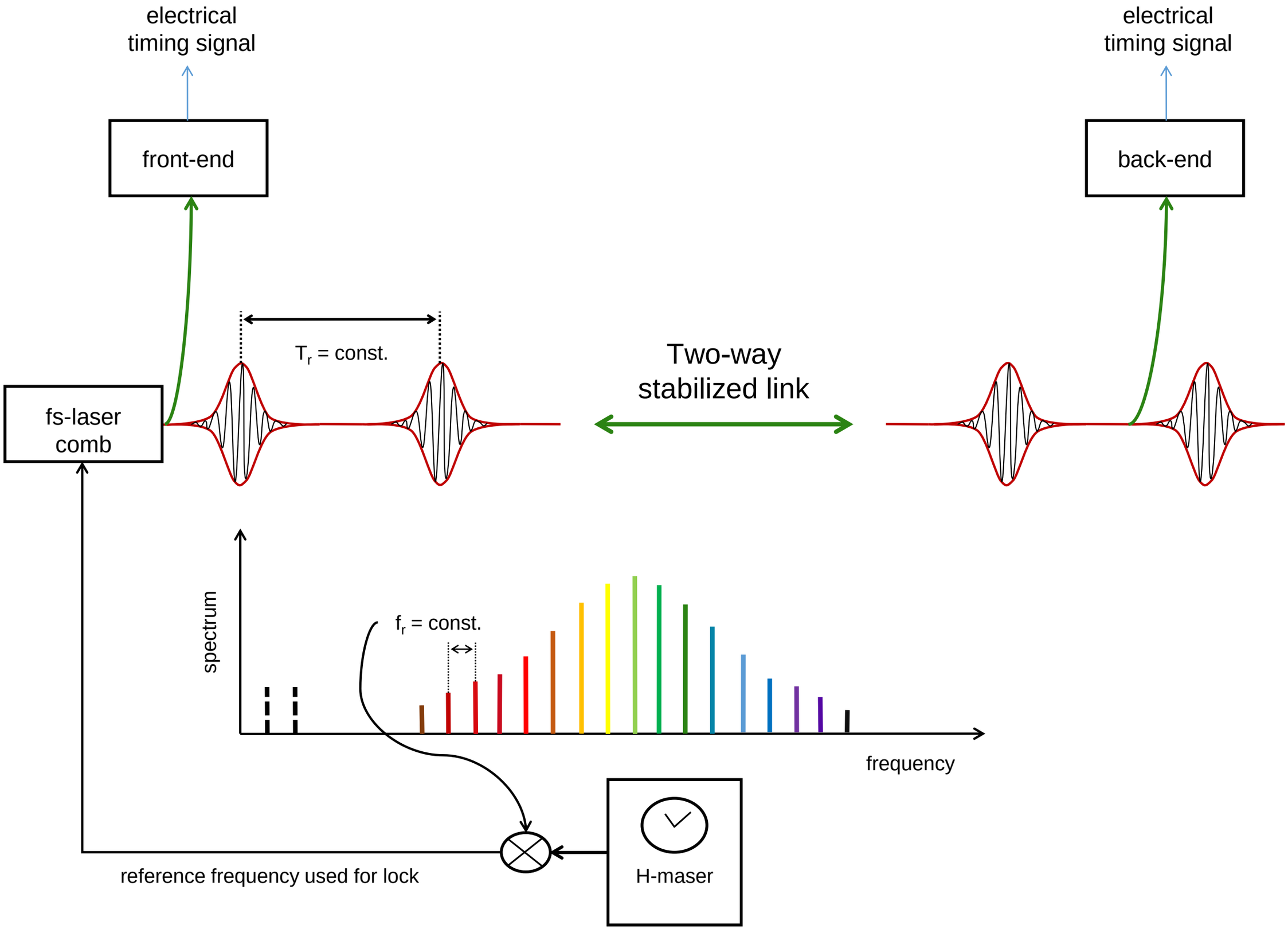
τ_2

τ_3

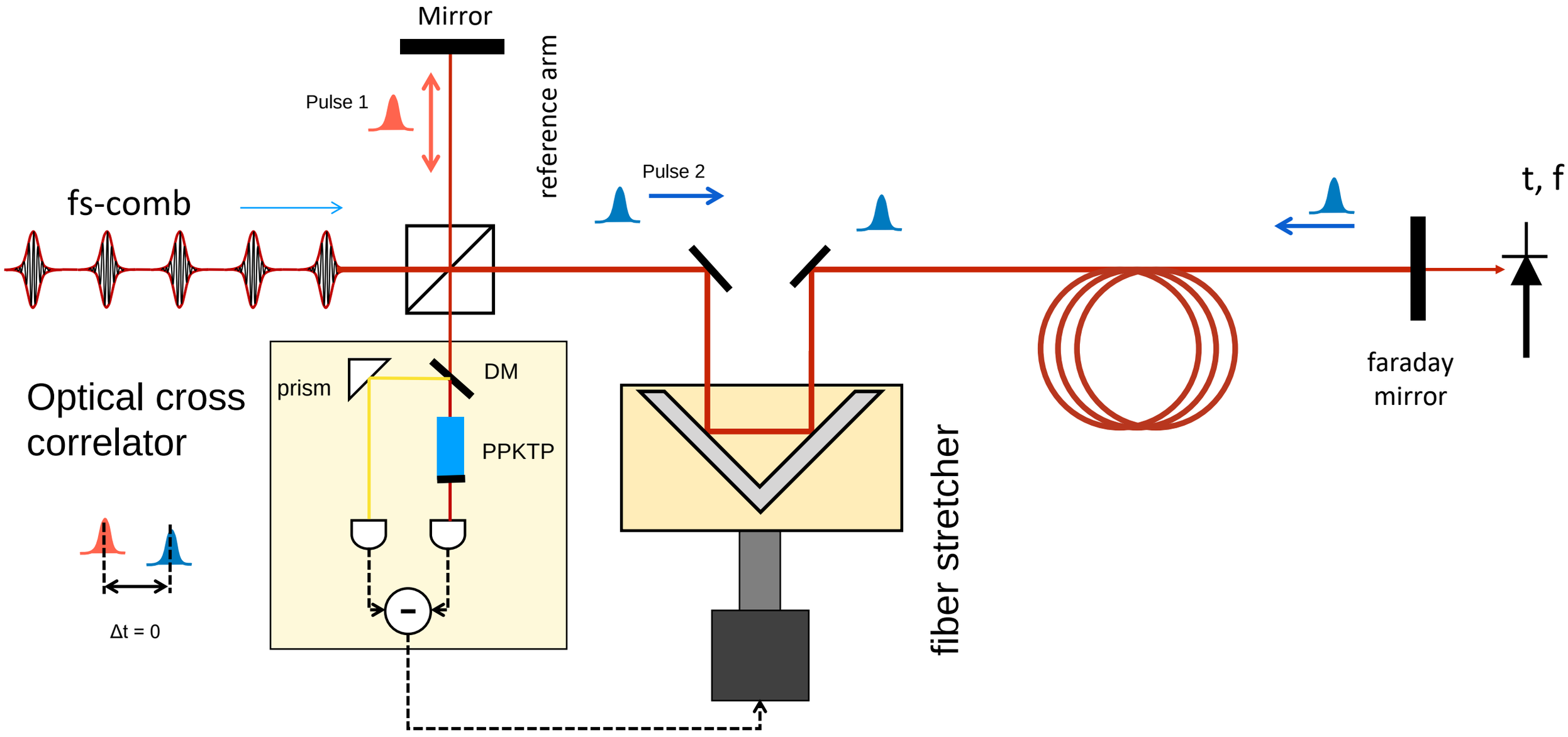
Optical Frequency Comb as an Ruler



Optical Frequency Comb as an Ruler



Drift-free timing synchronization of remote space geodetic instruments

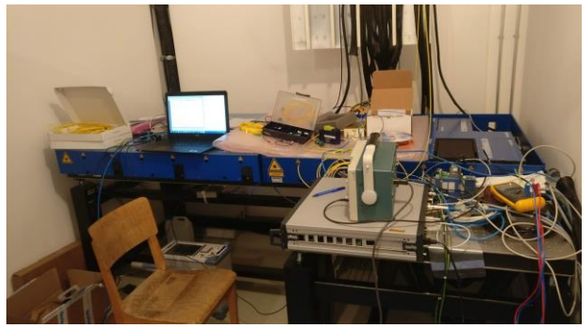


Example: FEL in Trieste

Schreiber et al.: Space Science Reviews, **214 (**1), p. 1371, (2017)

MenloSystems

Optical Time Distribution system at Geodetic Observatory Wettzell



H-Maser (frequency standard)

fs-laser

Cs clock UTC(k)

UTC

Future

Opt. Ref. Cavities

Comp. Clock

fiber links

τ_1

τ_2

τ_3

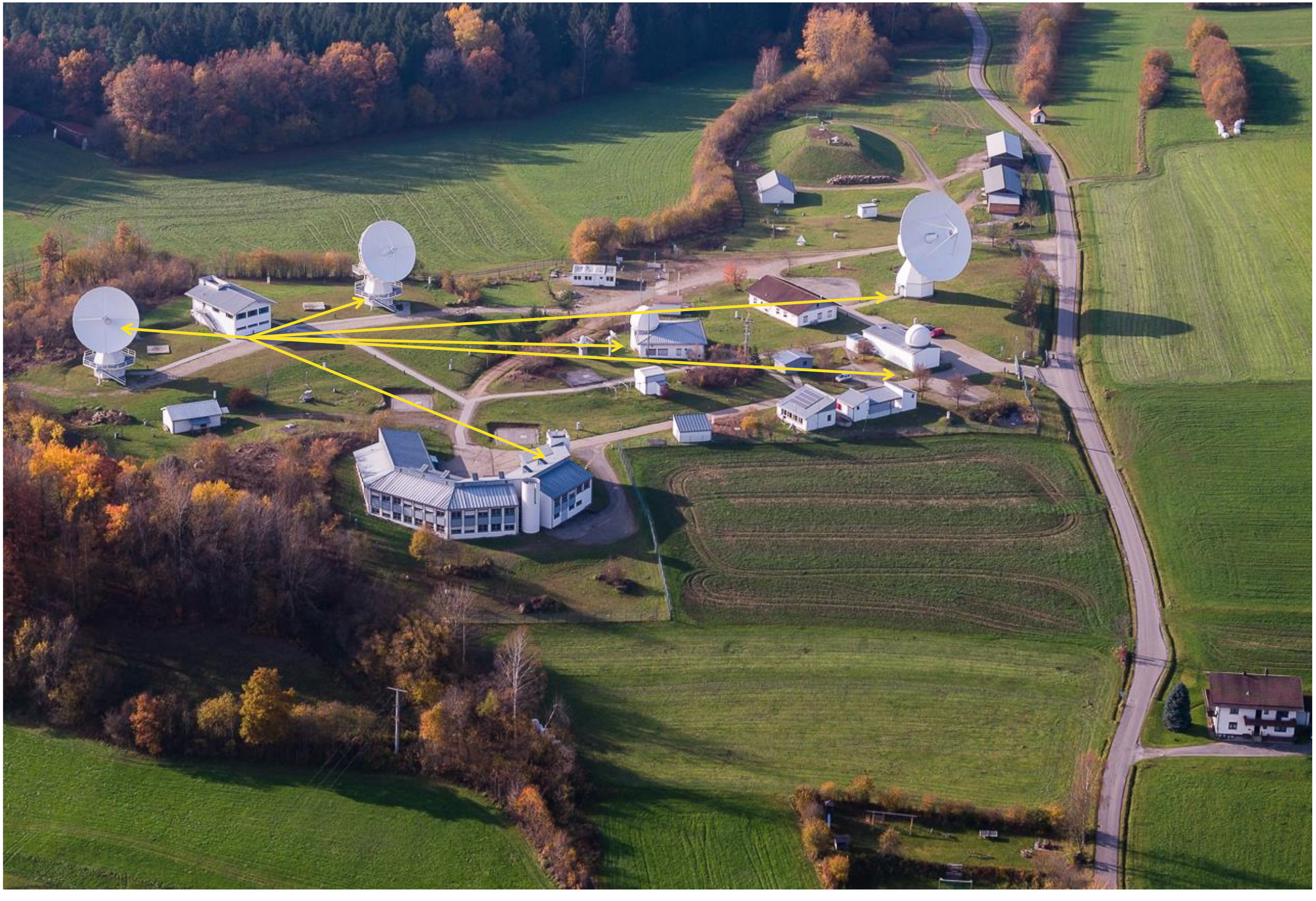
ΔT

ΔT

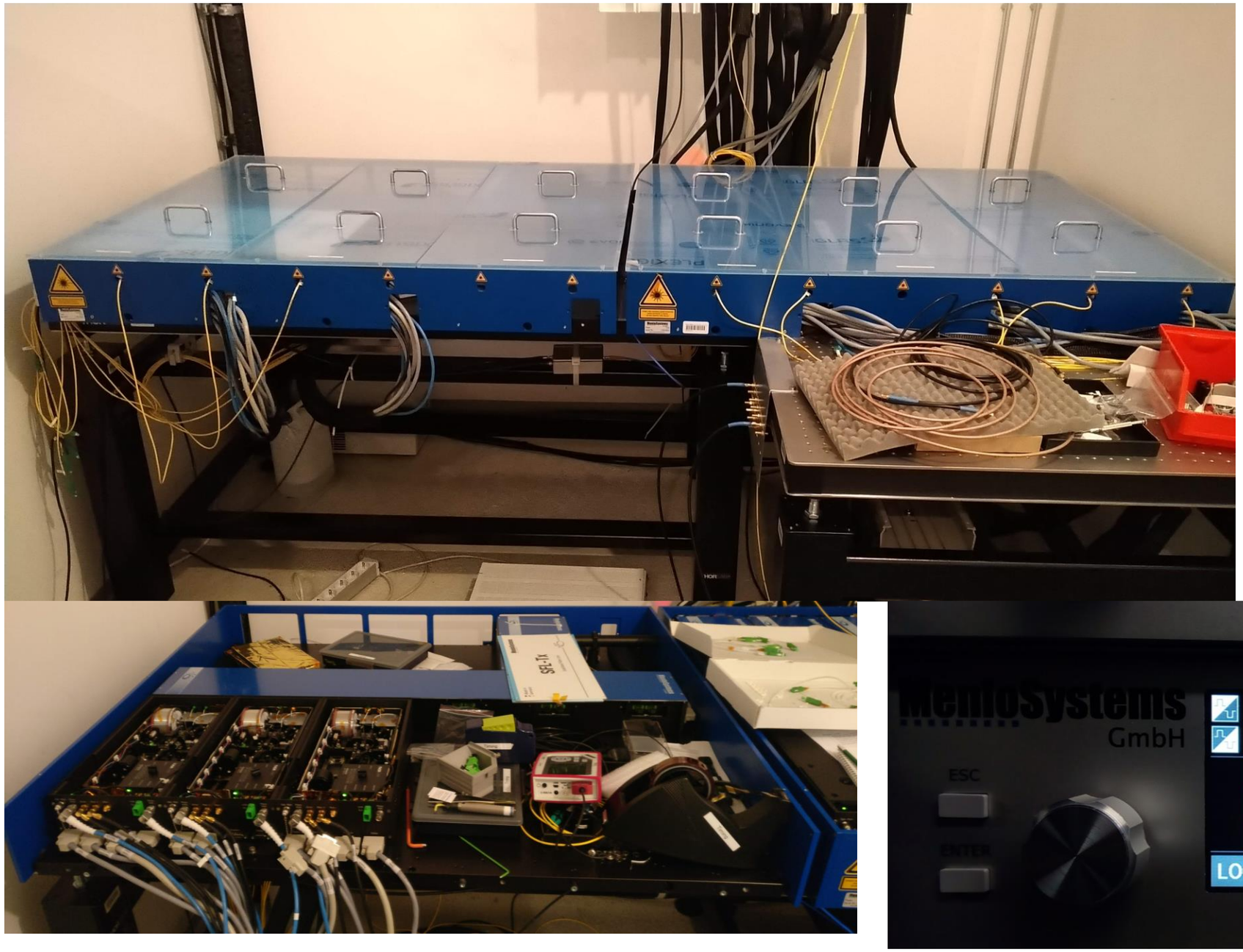
ΔT

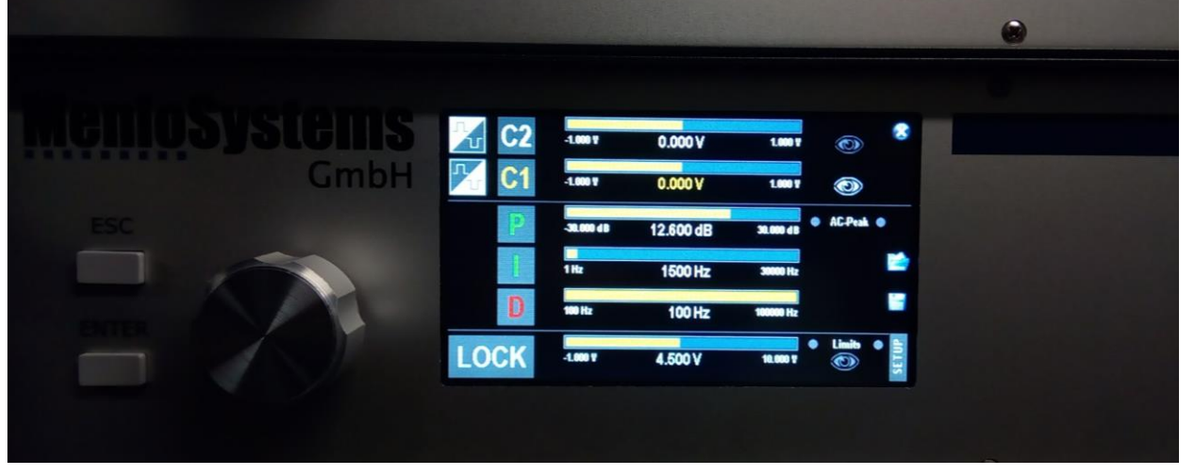
C/A code

Geodetic Observatory Wettzell



Campus Distribution for accurate Time





- laser - 1560nm
- laser lock unit
- 2x optical amplifier
- 10 links in operation

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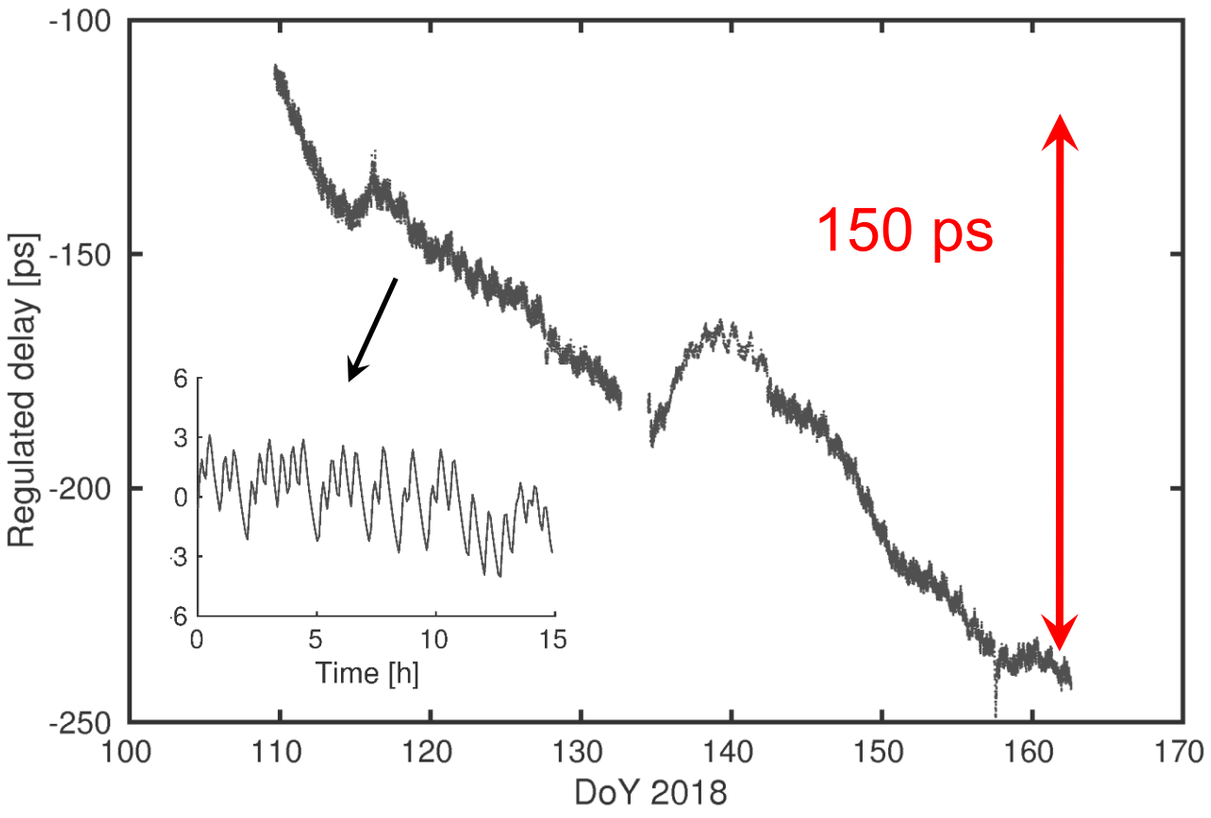
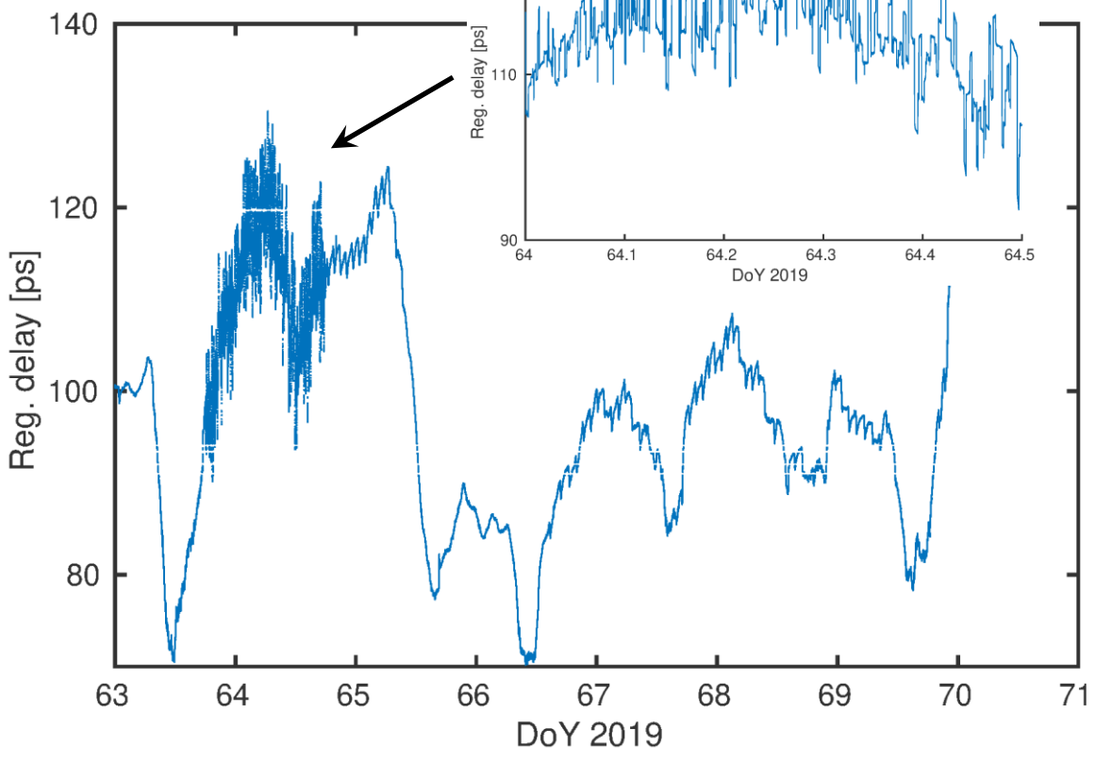
Error signal for the closed loop fiber stretcher

Stationary link length ~300 m

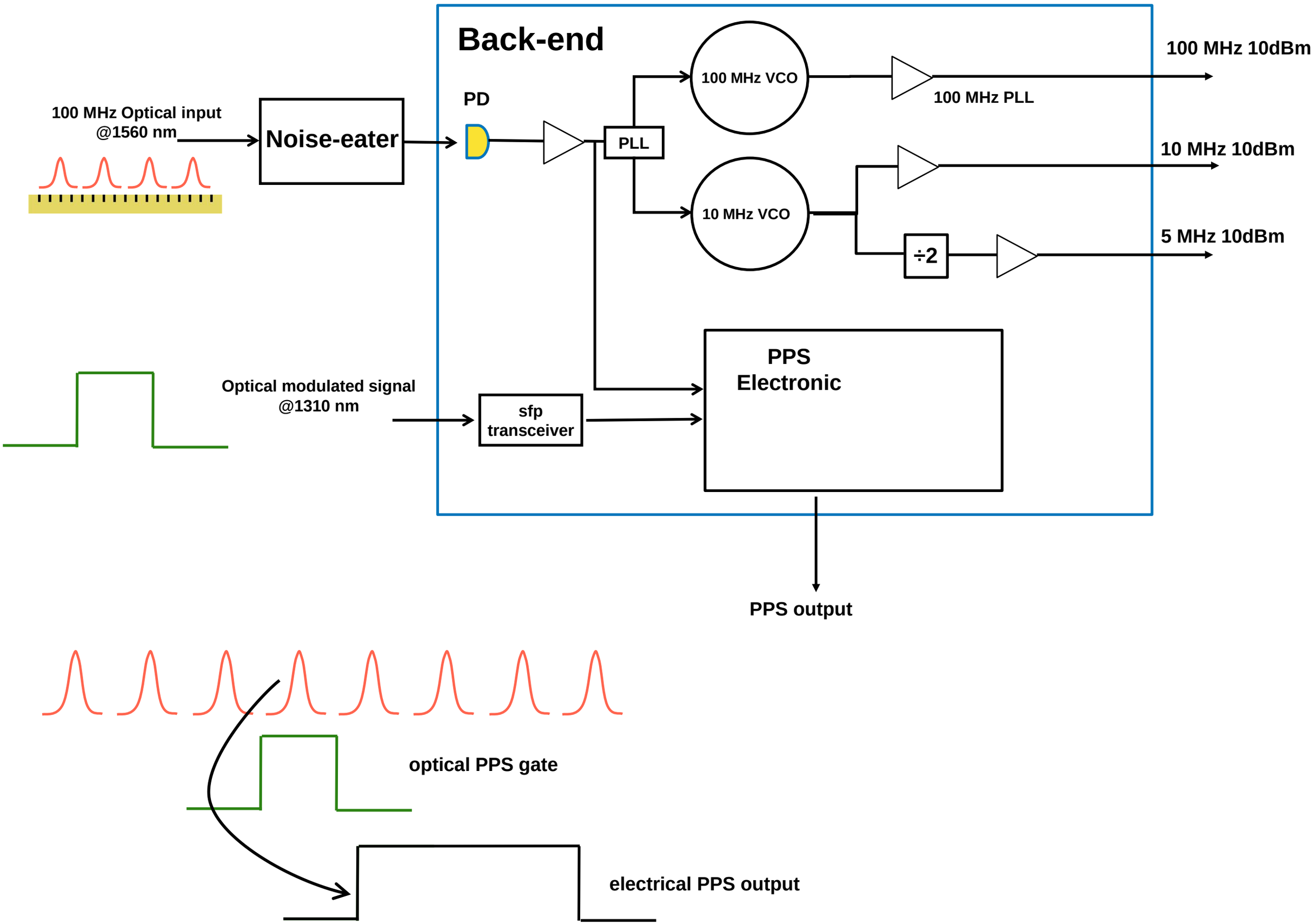


Moving link TTW2

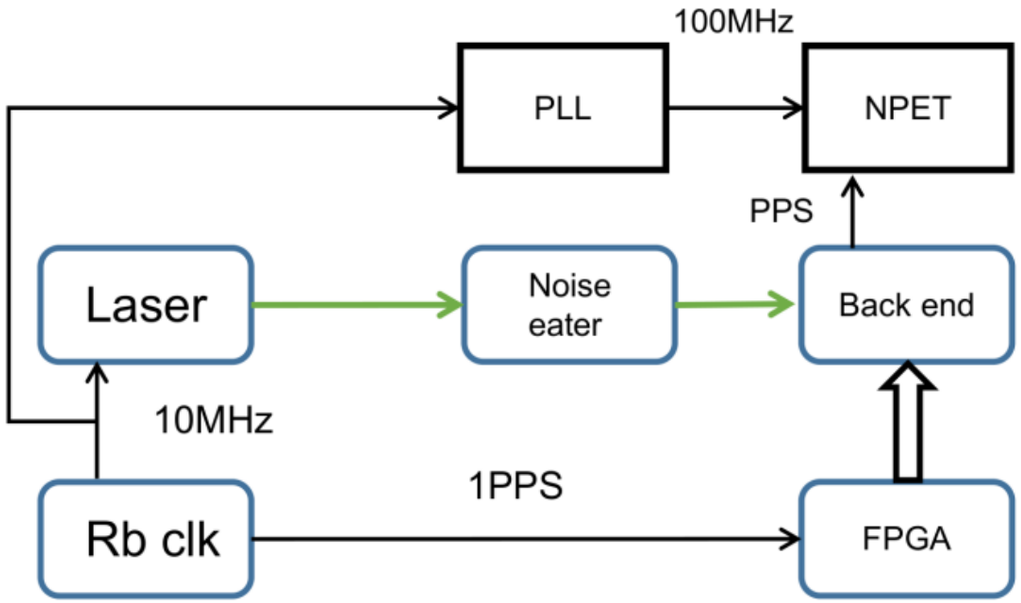


Most of the excursions appear to be caused by the air conditioning and movement of the radioteleskop.

Back-end diagram



Timing properties of the timing signals



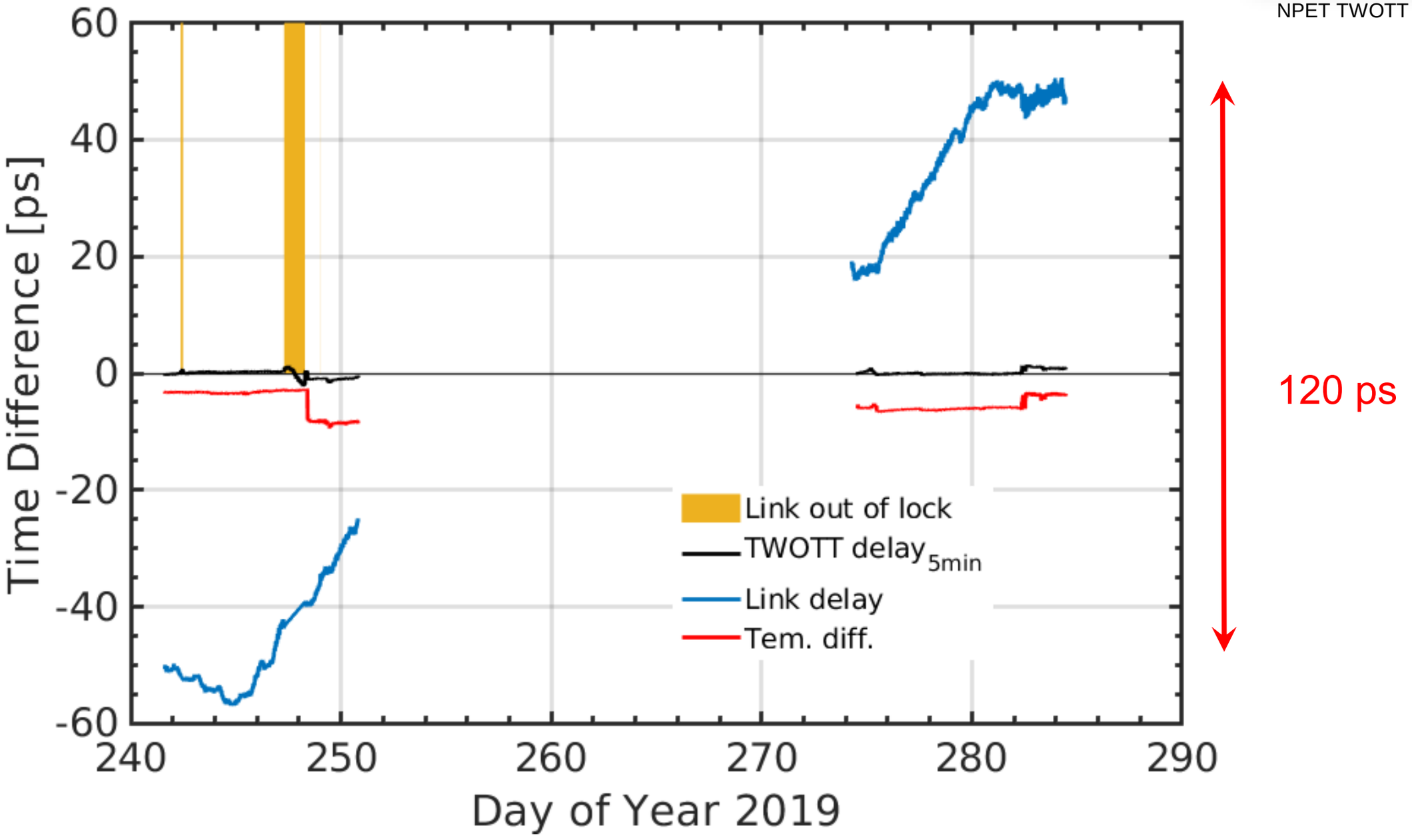
Additive jitter by Back-end electronic

Signal Name	RMS Jitter	Temp. Coef.
Electrical PPS 1	0.43 ps	0.84 ps/°C
Electrical PPS 2	0.43 ps	0.83 ps/°C
CMOS PPS	1.26 ps	2.2 ps/°C

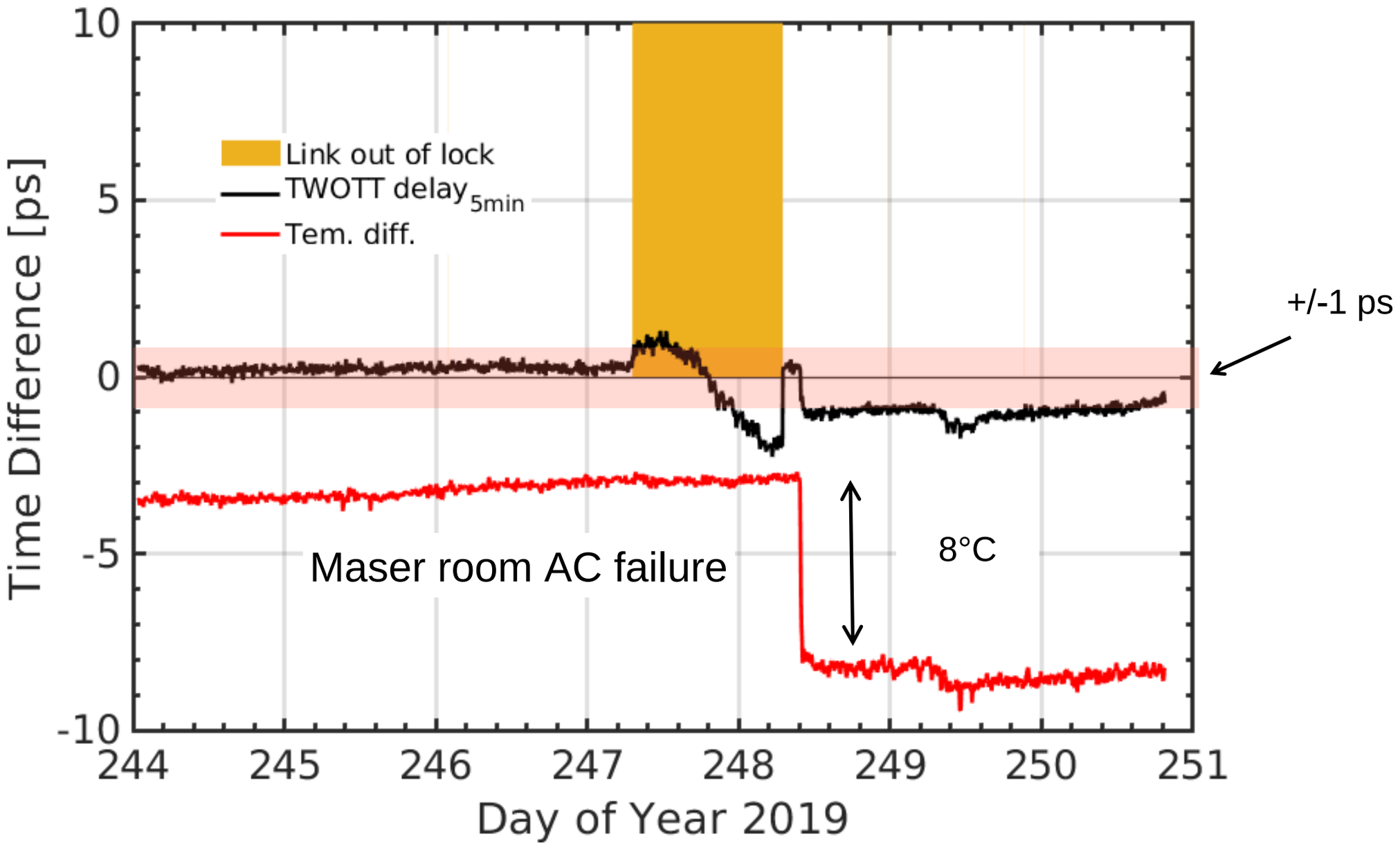
Error signal and time distribution of stationary link

To validate new timing system in terms of stability and absolute delay we developed TWOTT system Event Timer **NPET.** J. Kodet et al., Metrologia, 2016.

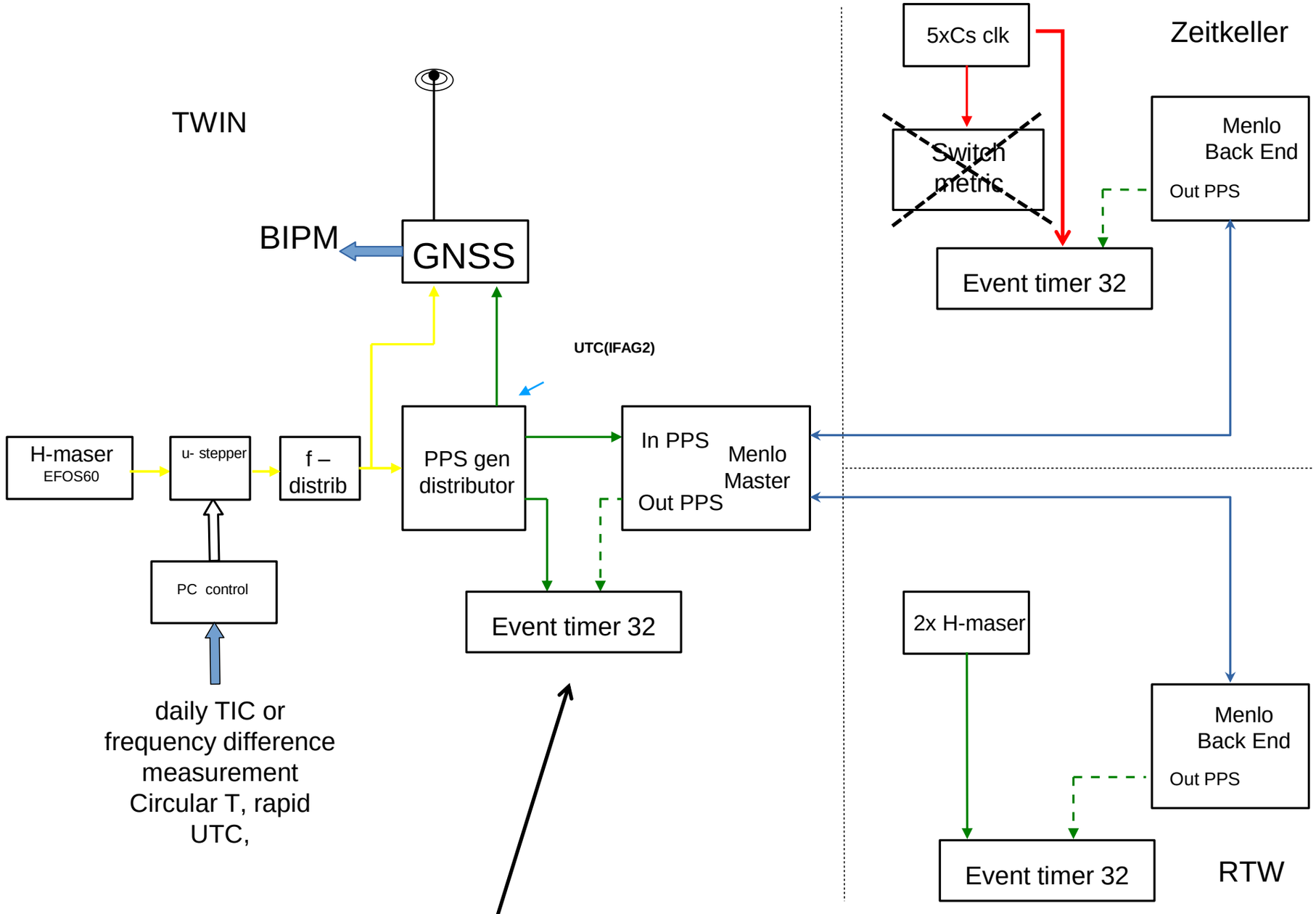
NPET TWOTT terminal

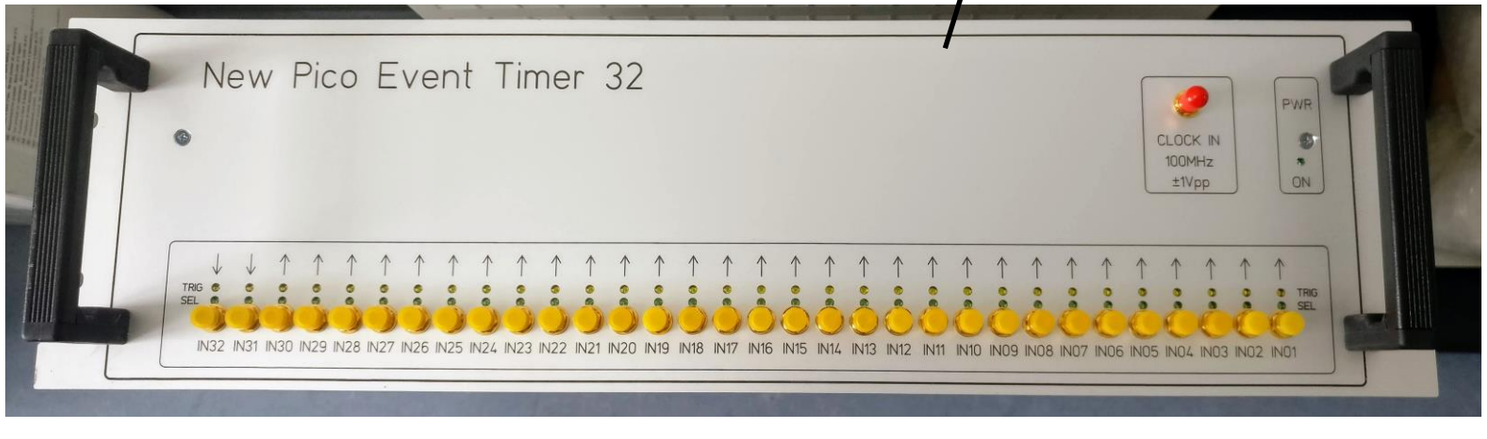


Time distribution of stationary link

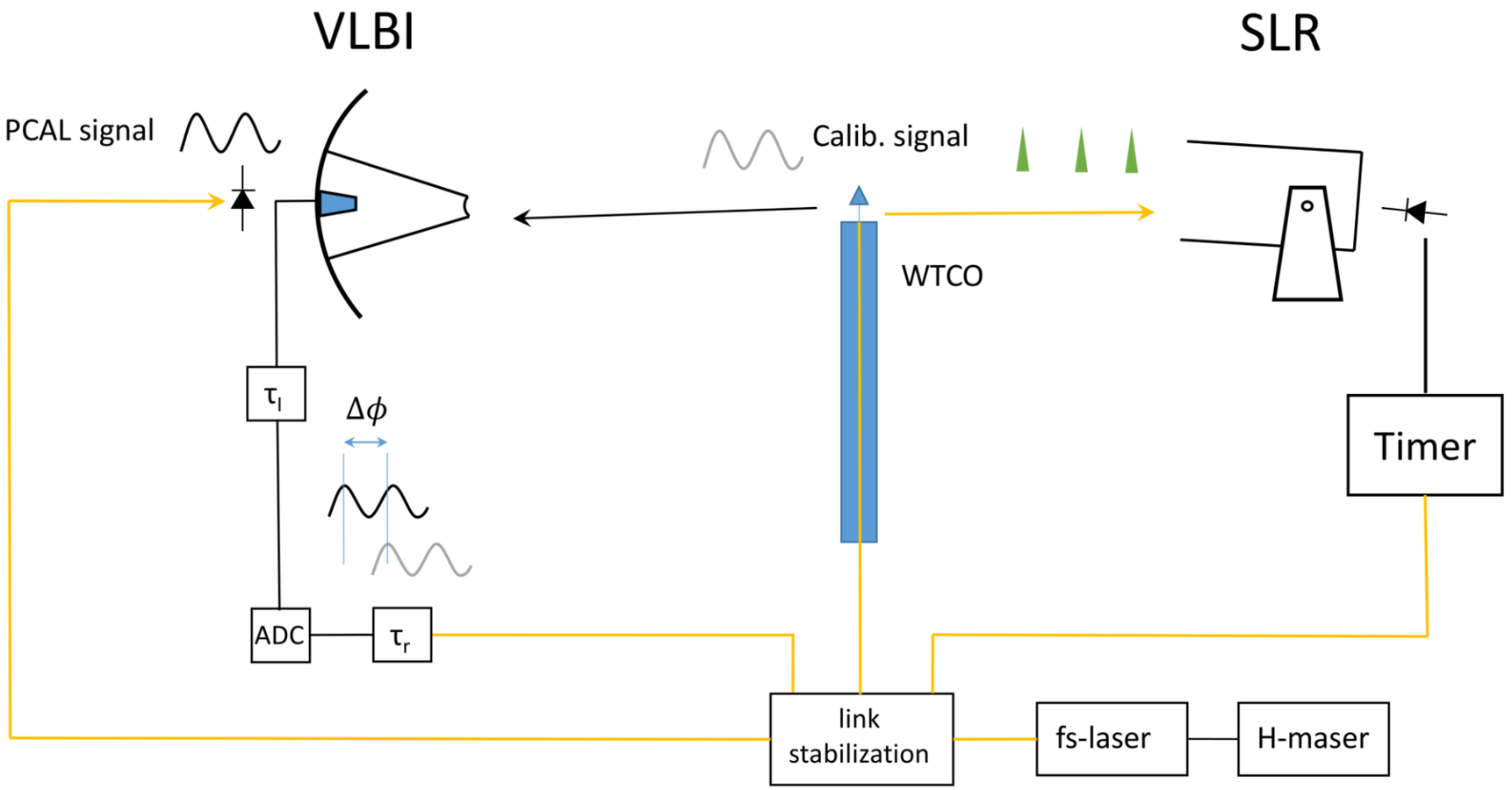


Future reorganization of UTC(k)





Accurate Geodetic Ties by Closure Observations in Time



The biases in the geodetic measurement techniques can be quantitatively obtained for the first time in a closure measurement configuration with a resolution of a few ps.

Thank you for your attention