Delay compensated Optical Time and Frequency Distribution for Space Geodesy

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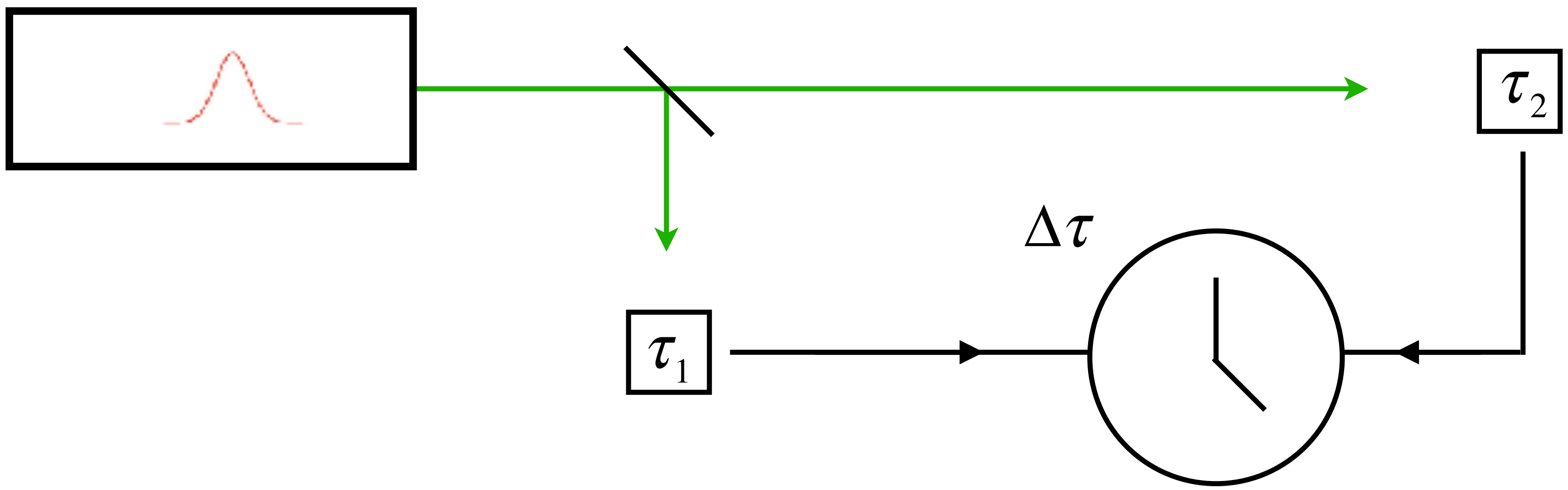
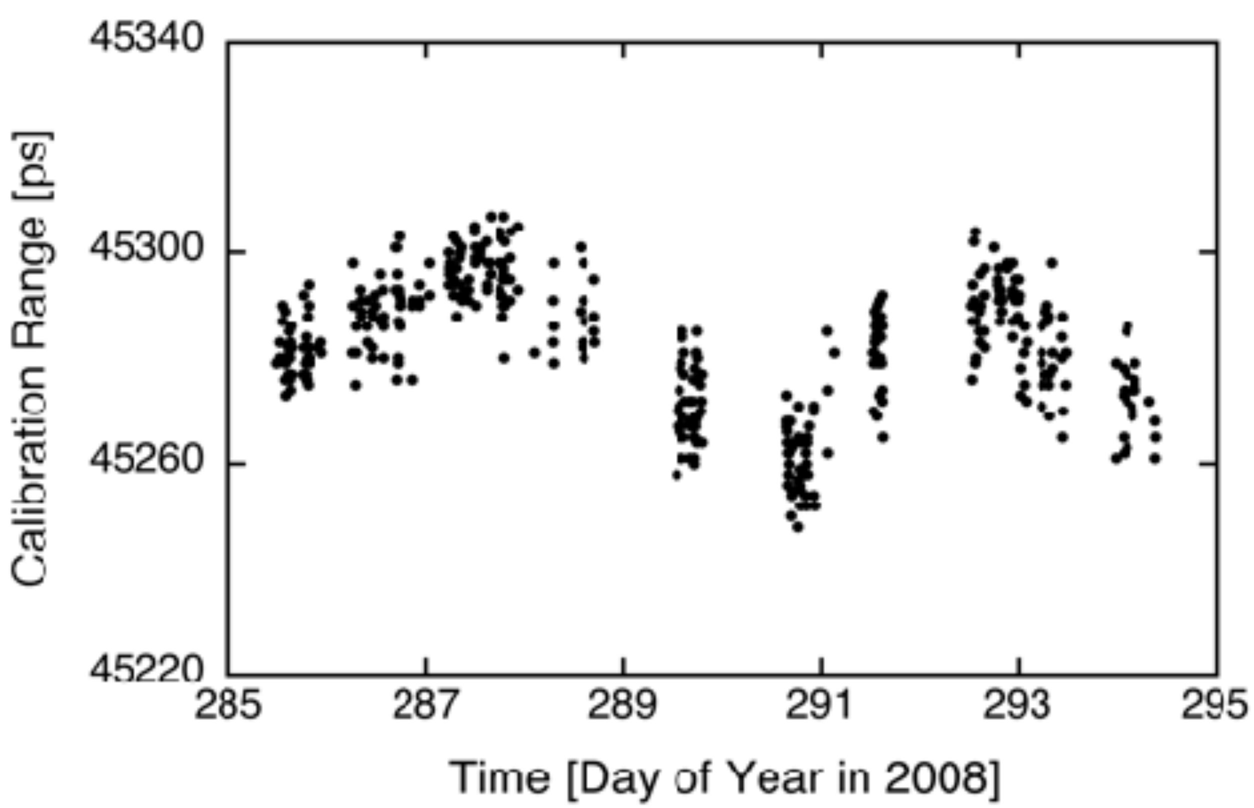
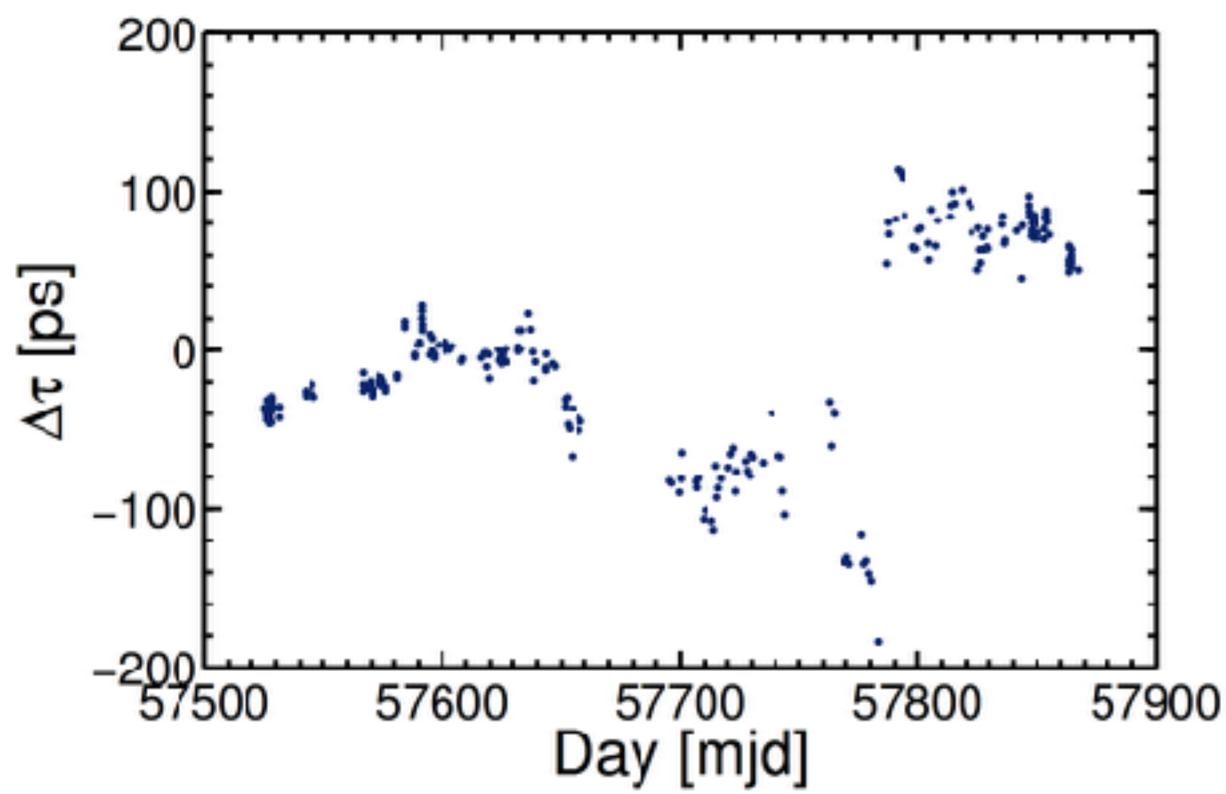
In order to achieve a delay compensated time and frequency distribution, we have designed an all optical two-way system, which allows the campus synchronization of a distributed set of geodetic measurement systems in time and frequency with an accuracy of 1 ps. The goal is to make it possible to eventually use time as an observable and not as an adjustment parameter in a non-linear fitting process. With a centralized fs- pulse laser and a star like fiber network it is possible to reference all measurements to the same time scale and to control system biases. This opens the door to accurate closure measurements of system delays within each geodetic measurement technique and from one technique to the next (e.g. from SLR to VLBI).

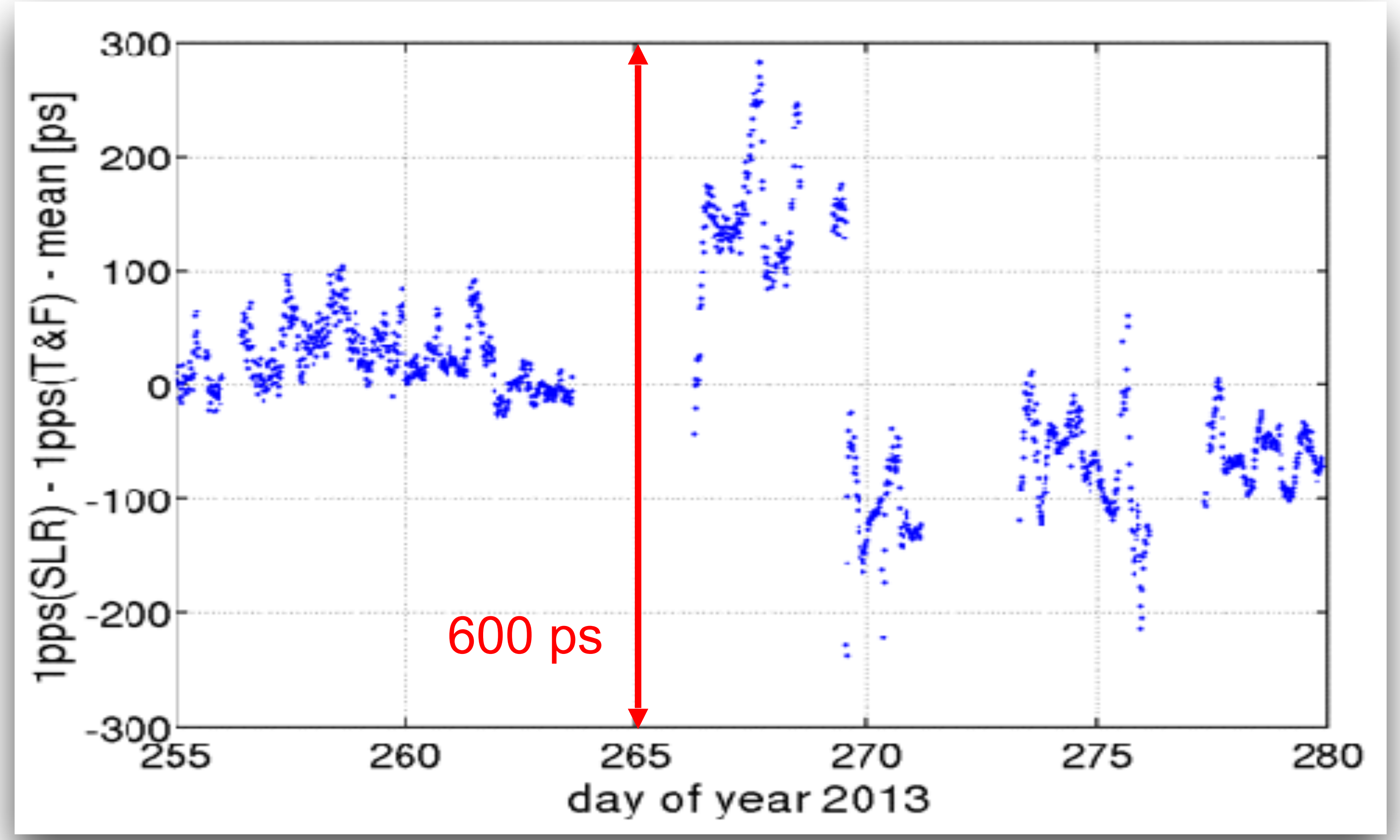
Observation: Variable Delays due to electronics



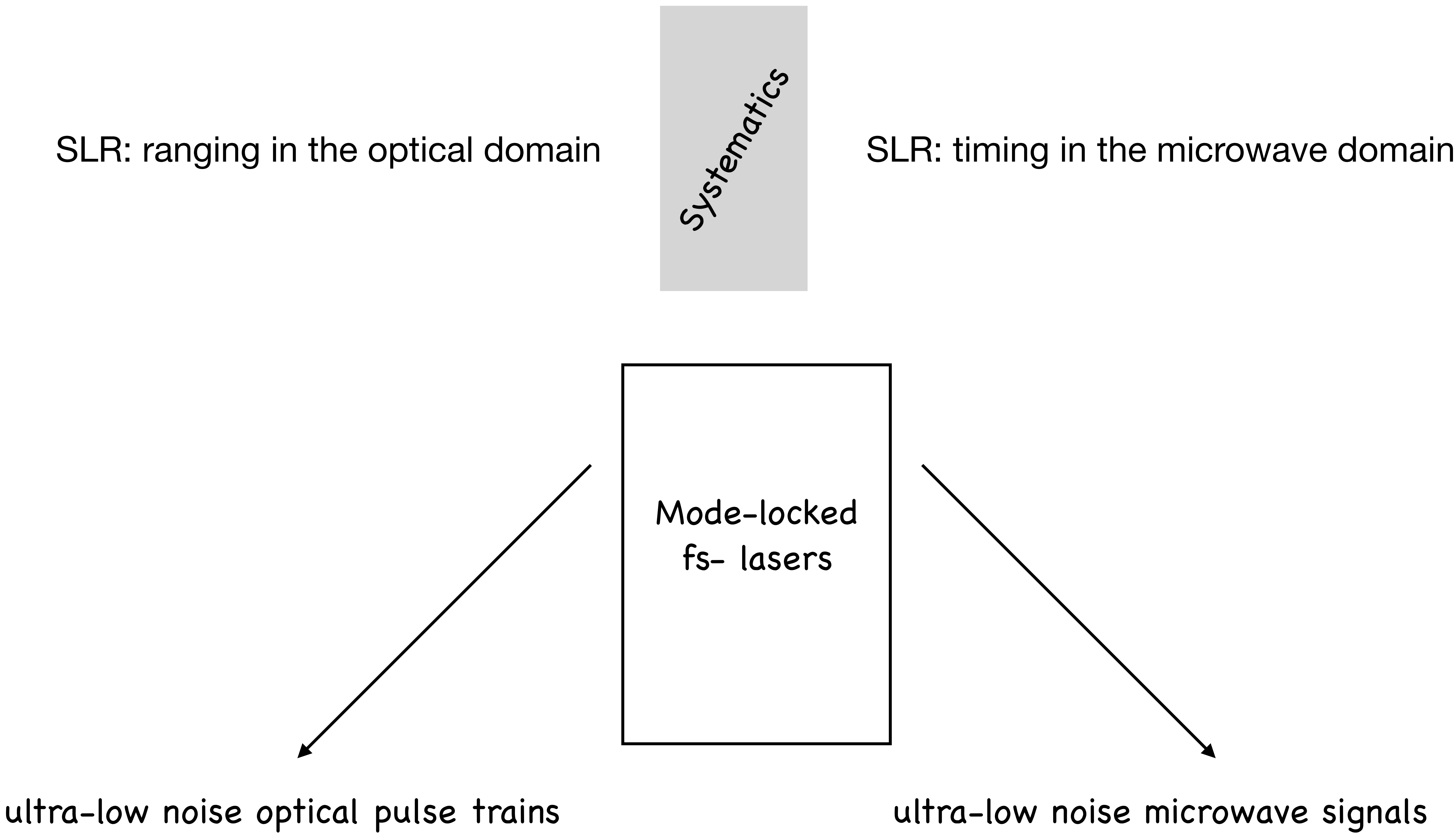




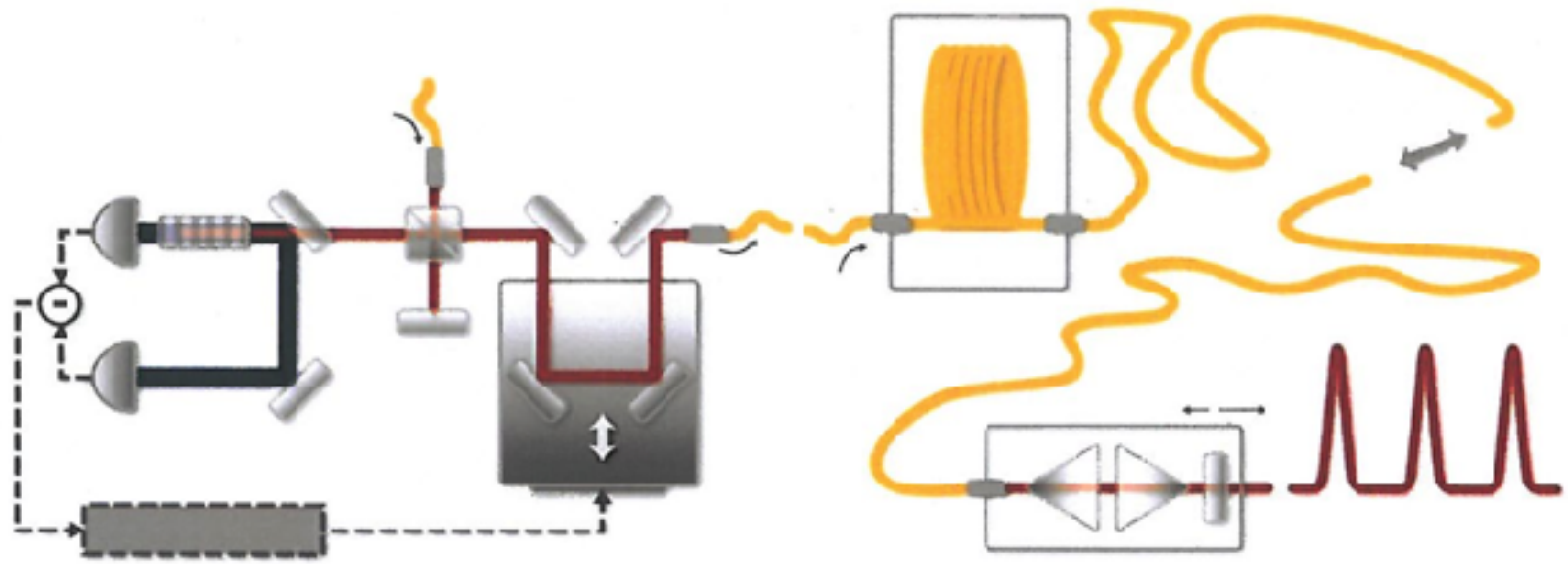
The distribution of the broadband PPS time signal also shows variability at the level of several hundred ps.



... over a longer period: $\Delta t \leq 5$ ns

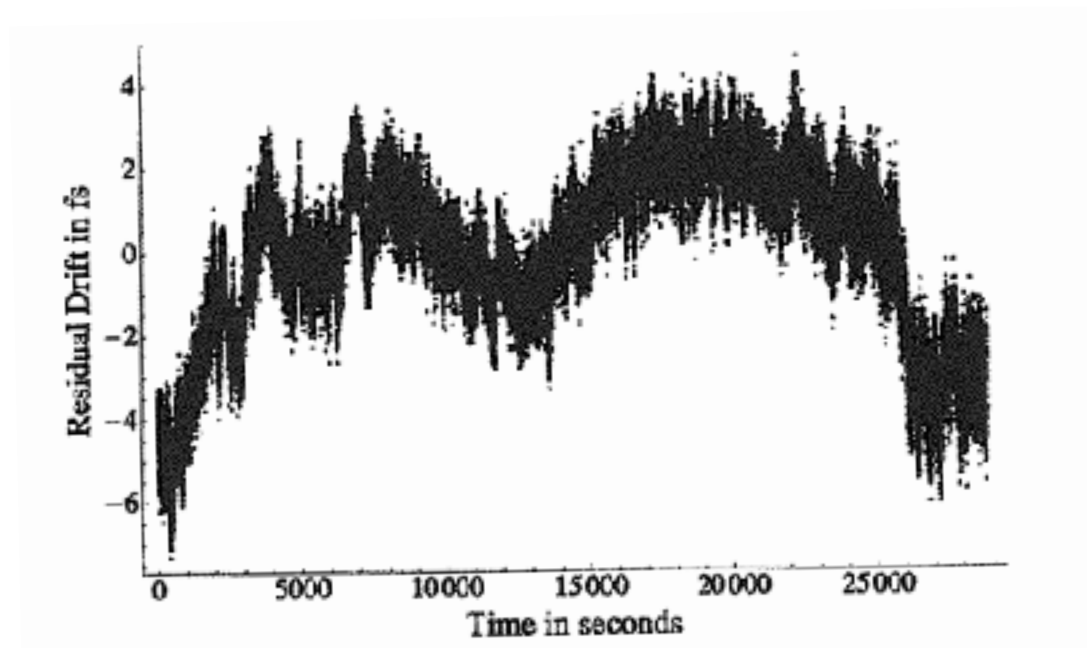

SLR: ranging in the optical domain
Systematics
SLR: timing in the microwave domain
Mode-locked fs- lasers
ultra-low noise optical pulse trains
ultra-low noise microwave signals

Two- Way Timing Techniques (local)



Example: FEL in Trieste

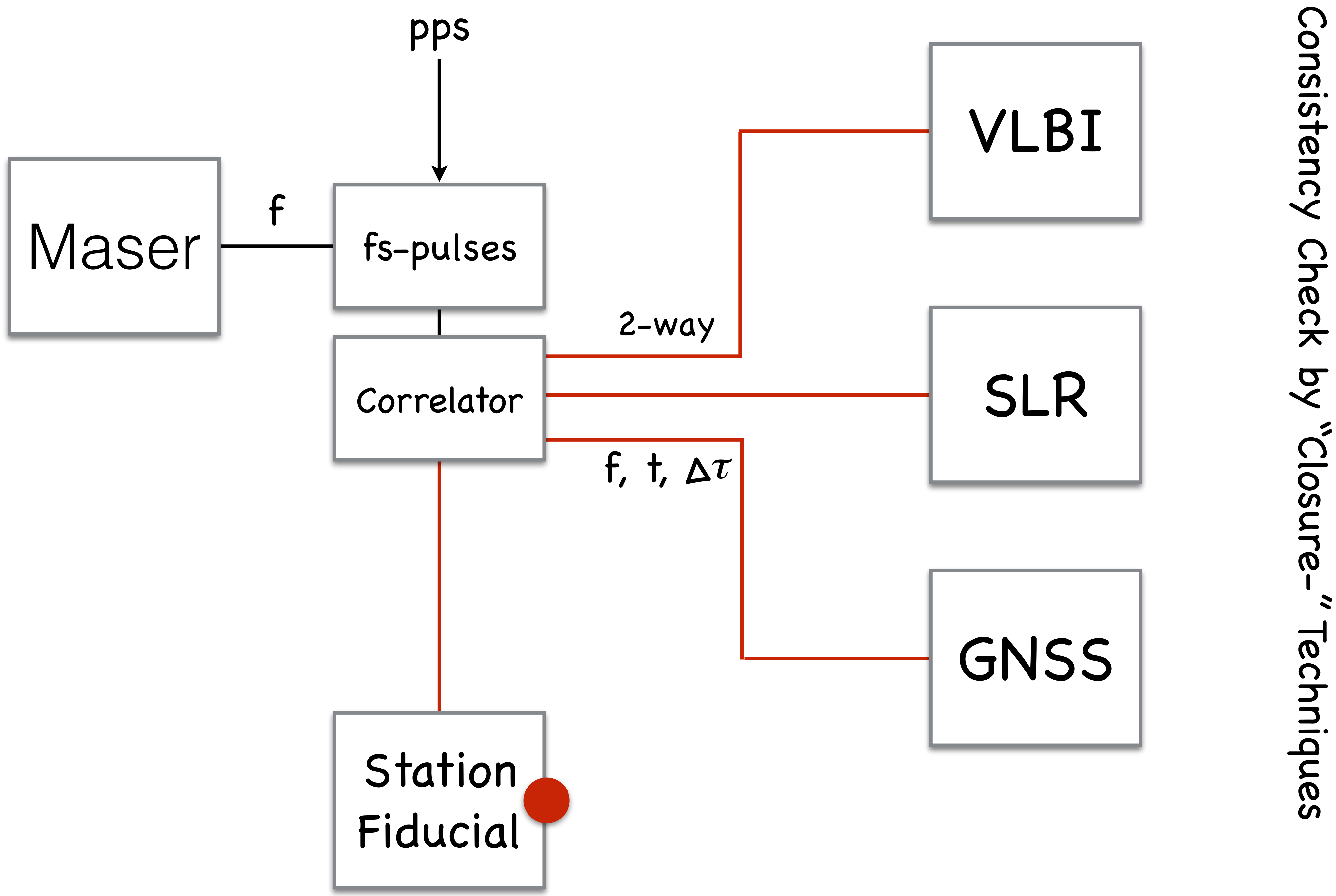
- 2-Way compensation technique only possible in the optical domain
- required broadband signal available from fs-pulse lasers only
- Expected uncertainty < 100 fs: ≈ 5 orders of magnitude gain over current situation
- Consequences for Local Survey: 1 mm = 3 ps



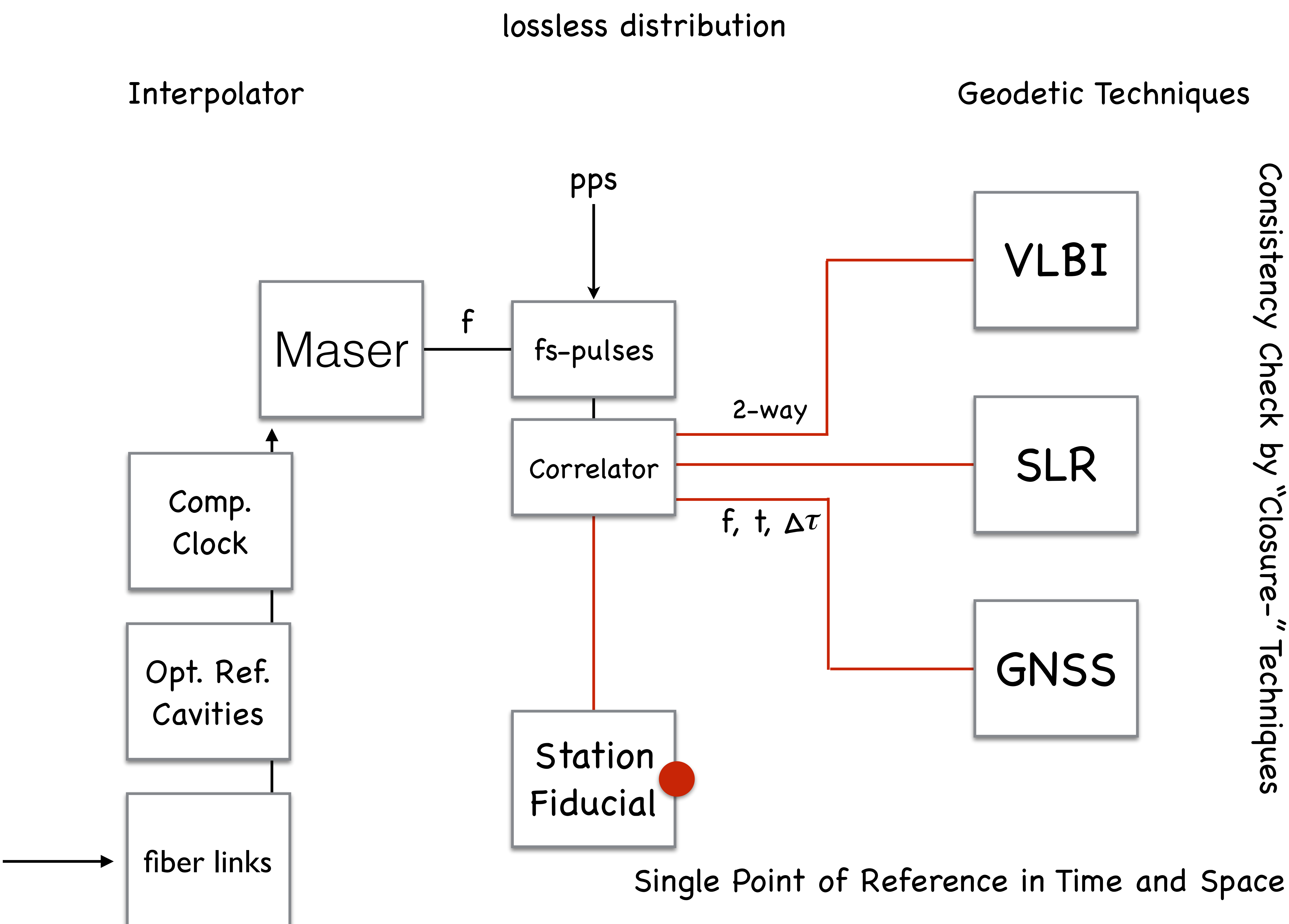
lossless distribution

Interpolator

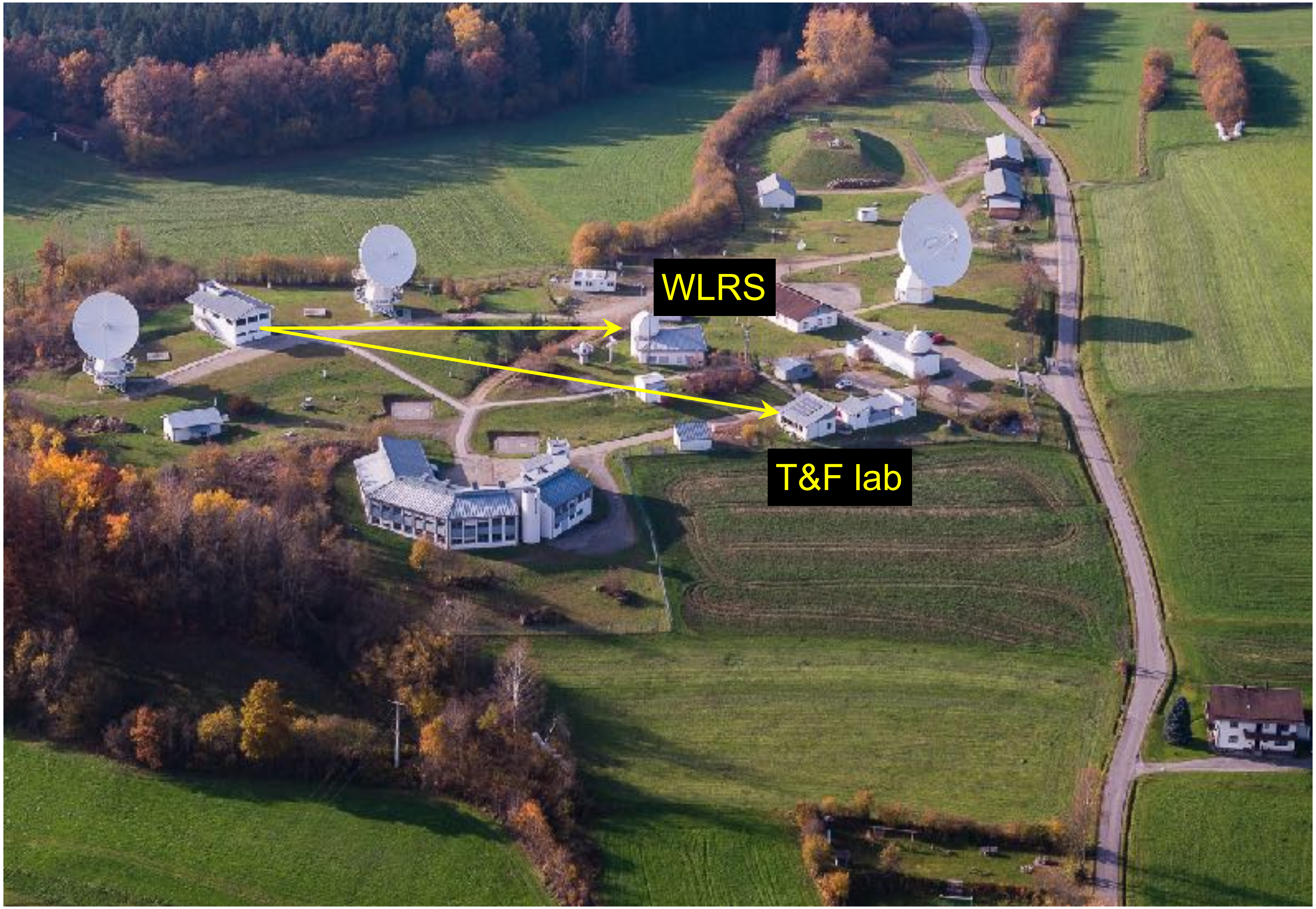
Geodetic Techniques



Single Point of Reference in Time and Space

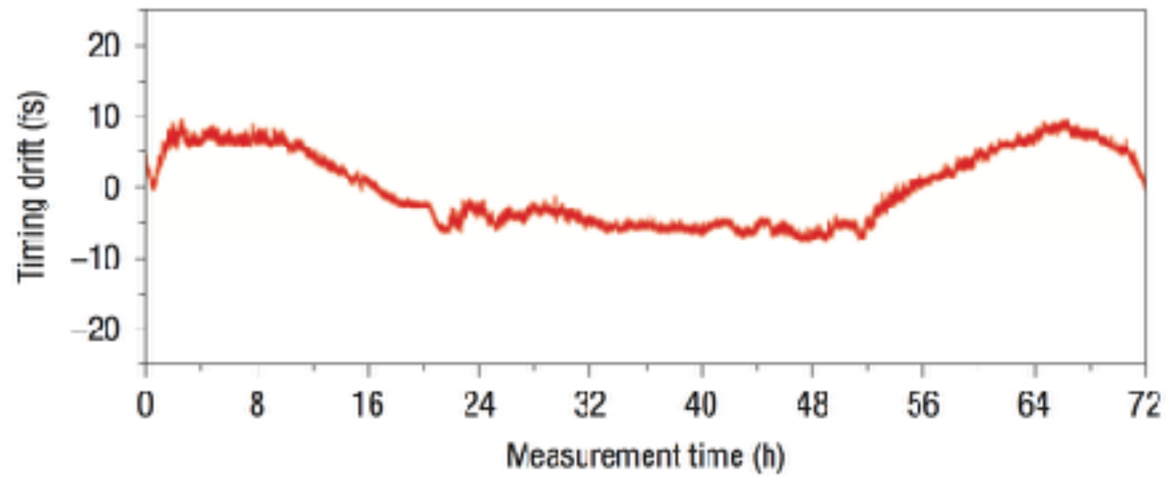

lossless distribution
Interpolator
Geodetic Techniques
pps
Consistency Check by "Closure-" Techniques
VLBI
Maser
f
fs-pulses
2-way
Correlator
SLR
Comp.
Clock
f, t, Δτ
GNSS
Opt. Ref.
Cavities
Station
Fiducial
fiber links
Single Point of Reference in Time and Space

ELT (Time Transfer via ACES)



Common Clock for Space Geodetic Techniques

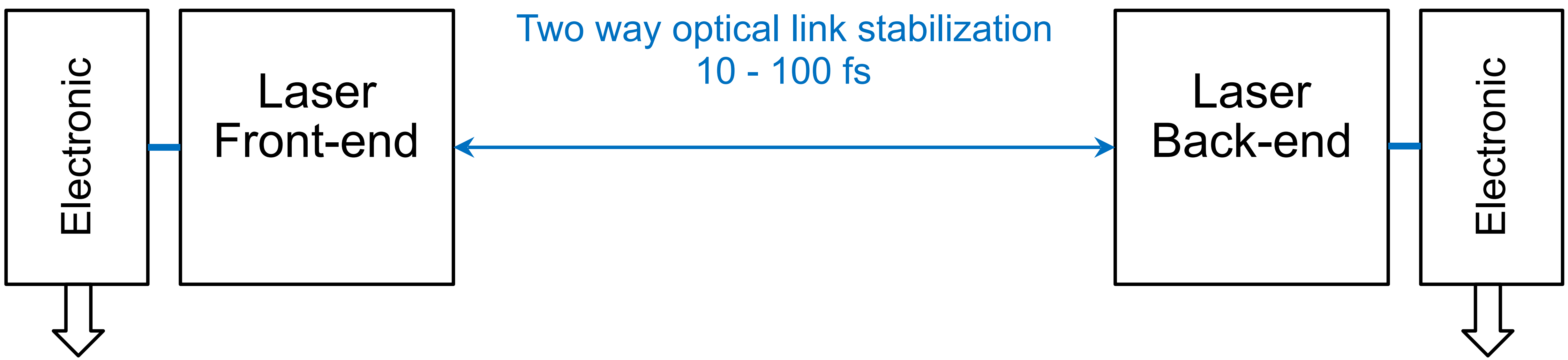
optical cross- correlation of
2 fiber lines (300 m)



6.4 fs r.m.s.

Kim et al. Nature Photon, **2(**12), 733–736, (2008)

MenloSystems

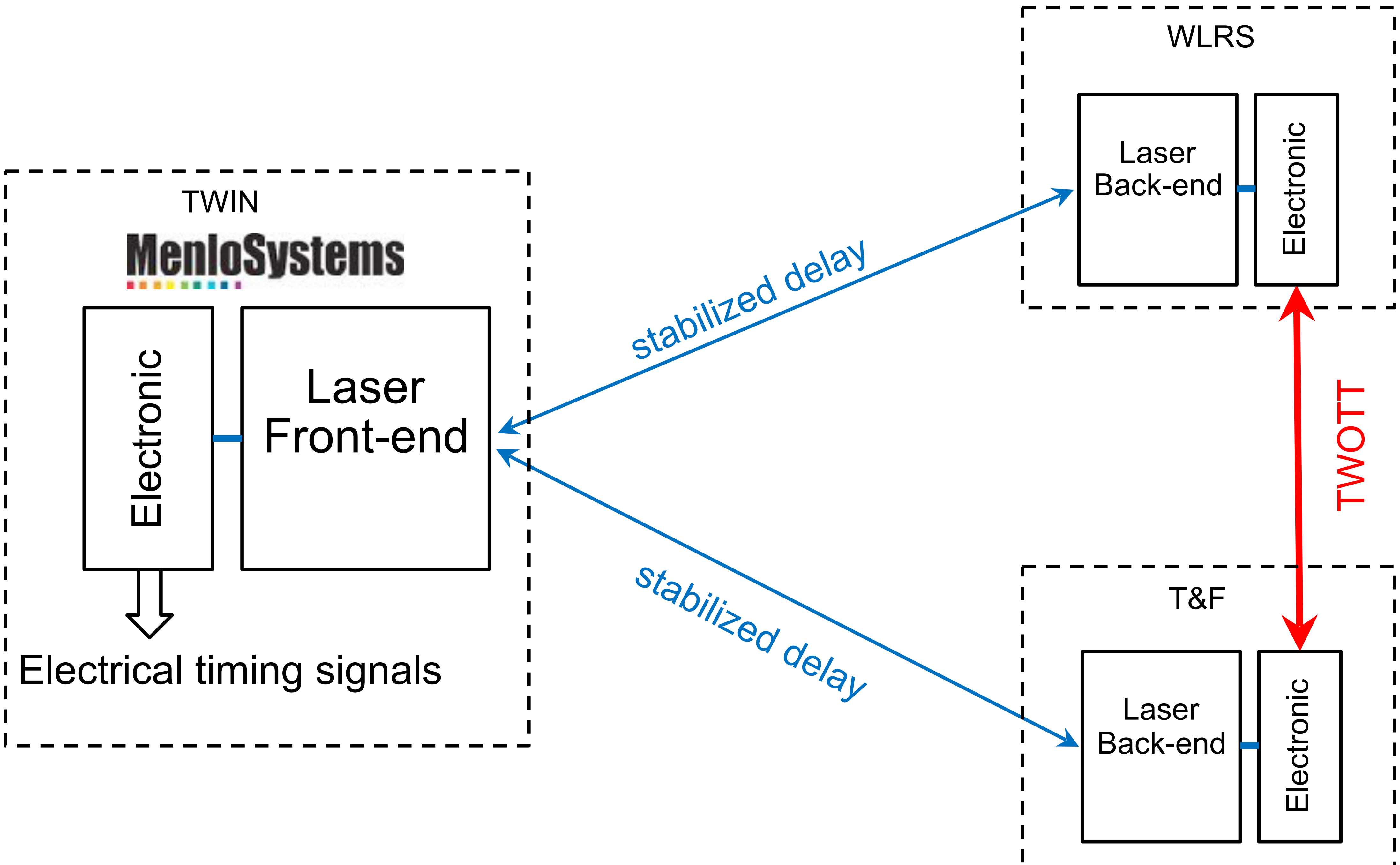


Electrical timing signals

Electrical timing signals

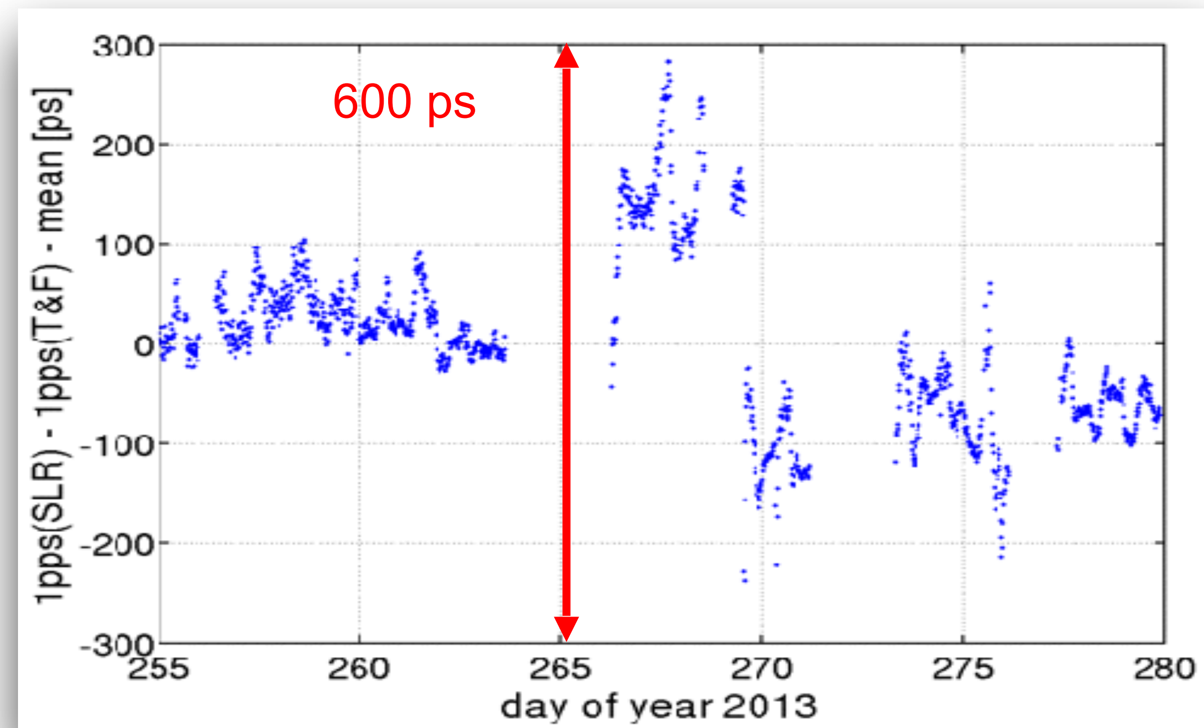
“electrical” Timing stability ~1ps

Common Clock for Space Geodetic Techniques

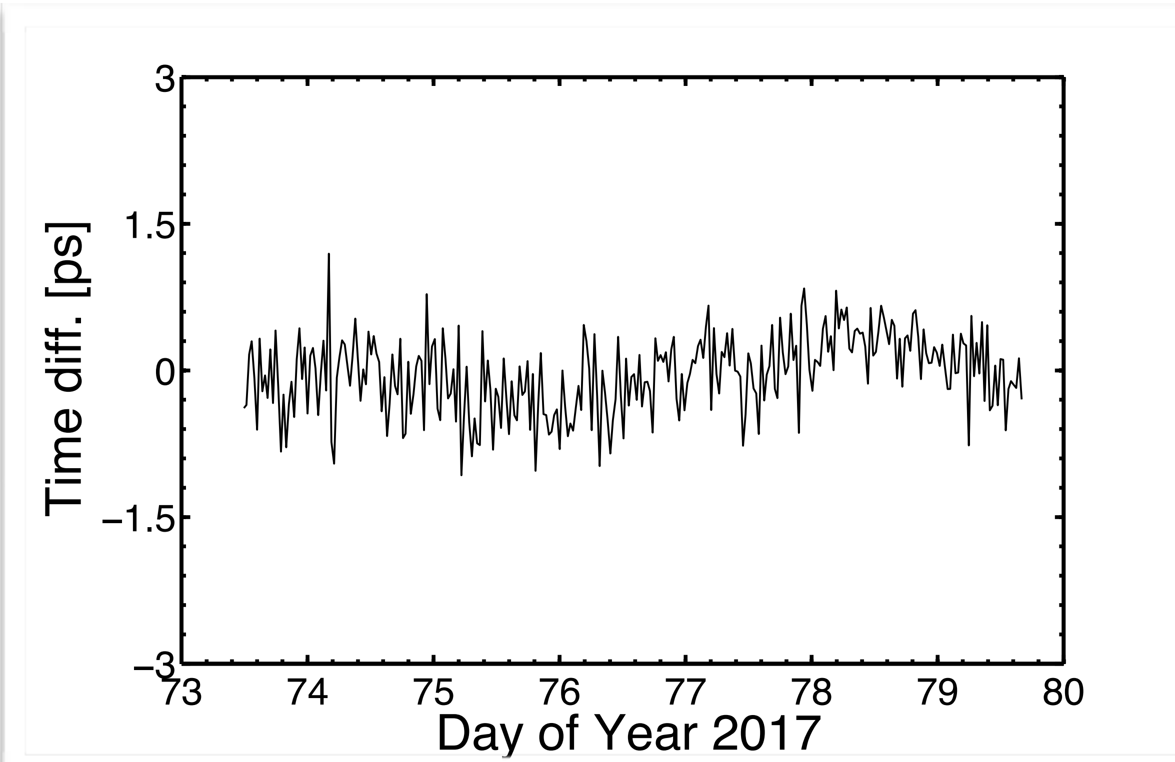


The distribution of the broadband PPS time signal over cable and electronic devices shows variability at the level of several hundred ps - and next to none over a compensated fiber link

cable based

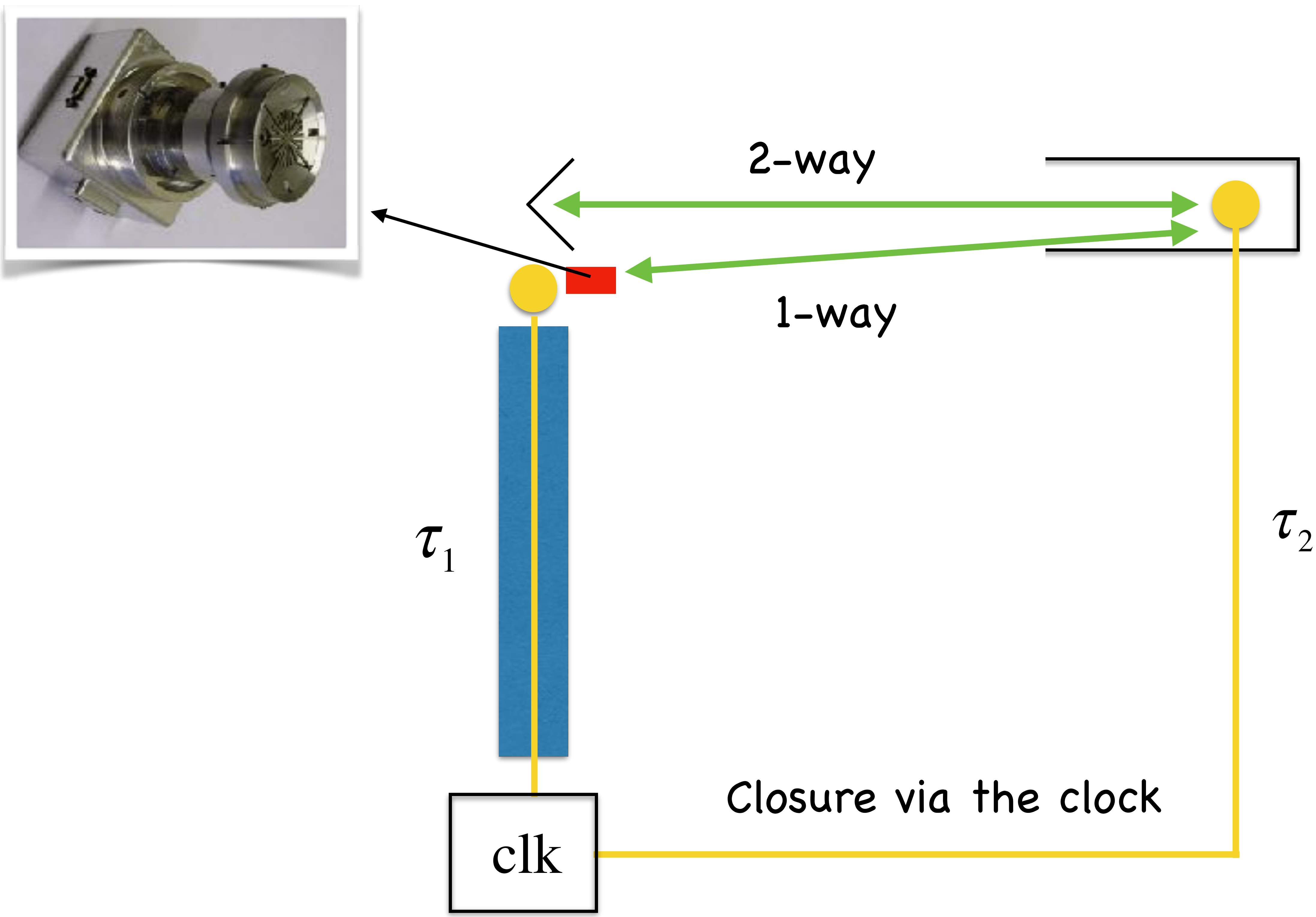


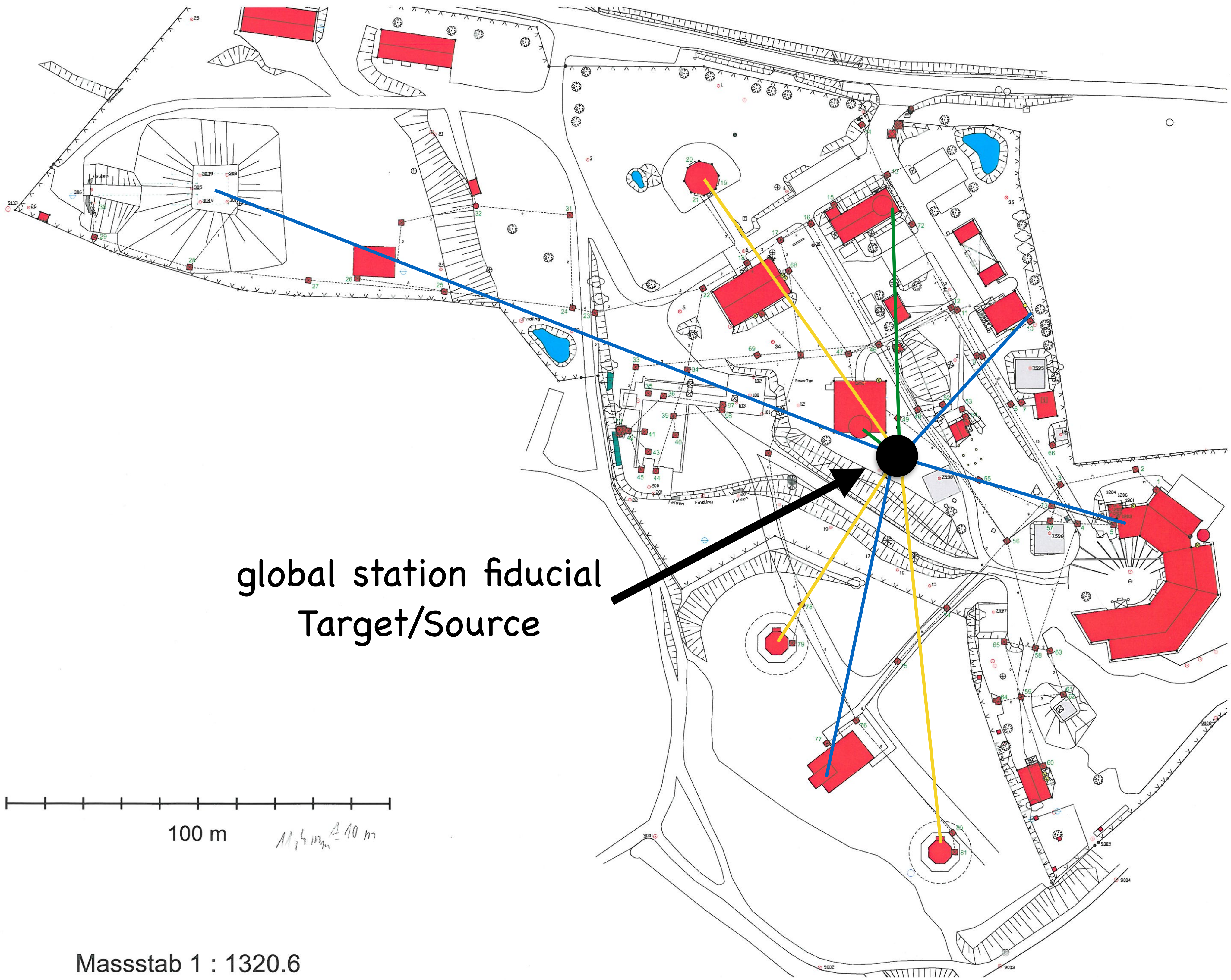
fiber based



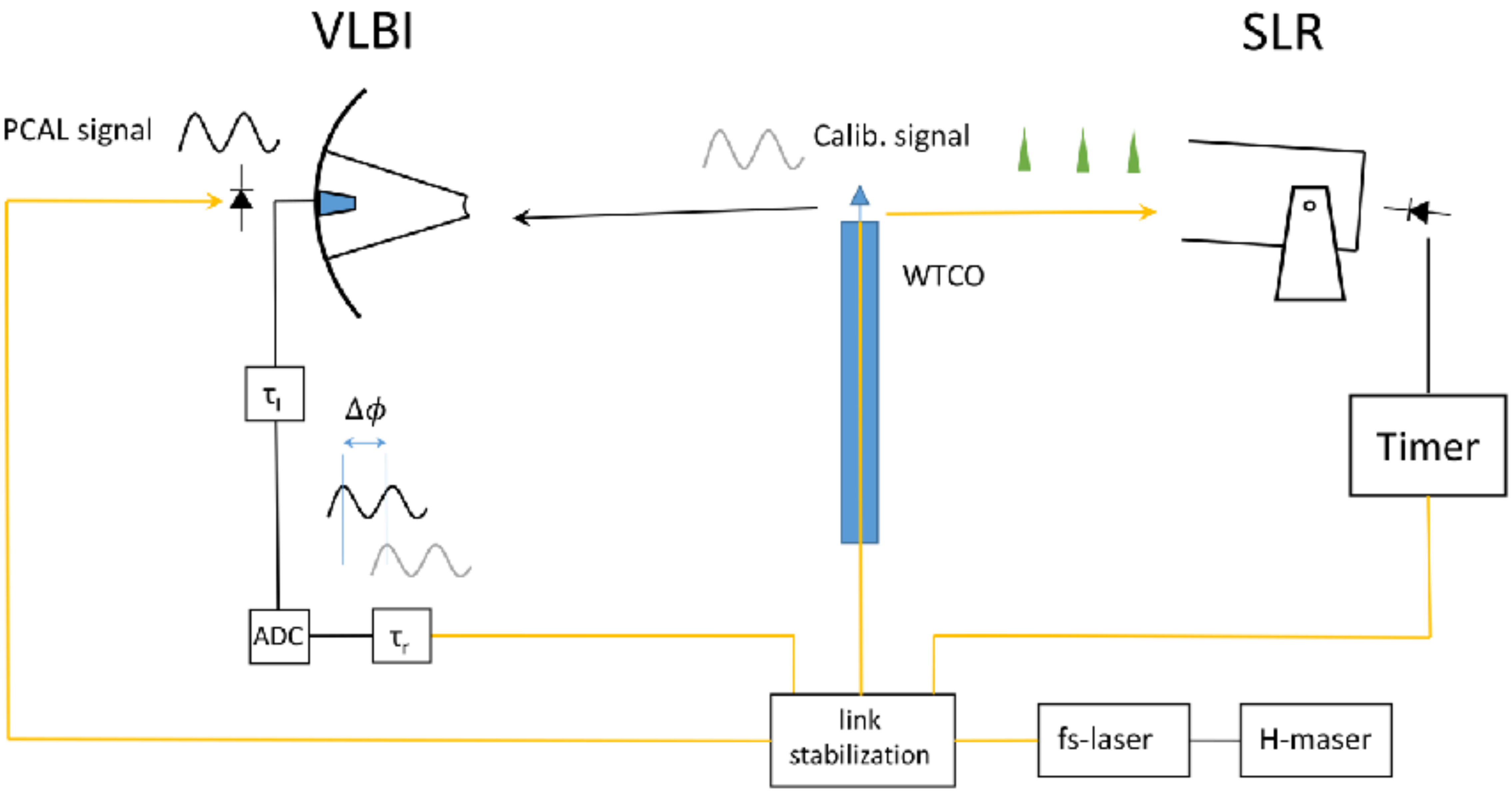
… over a longer period: $\Delta t \leq 5$ ns

?


2-way
1-way
τ_1
τ_2
Closure via the clock
clk


global station fiducial
Target/Source
100 m
Massstab 1 : 1320.6

Technique independent Closure for Space Geodesy



IAG: Sub-Commision 1.1.

Coordination of Space Geodetic Techniques

WG 1.1.1 Co-location using Clocks and New Sensors

The establishment of accurate local ties of different space geodetic techniques at fundamental geodetic observatories poses a long-standing problem. While geometric ties can be determined at sub-millimeter-level, the relation to physical phase centers of the instruments and temporal stability of such offsets are usually known with significantly lower precision. Novel ways for inter-technique calibration at a geodetic site need to be developed using existing and new sensors and technologies, such as highly accurate time and frequency transfer, ultra-stable clocks, and co-location targets. Complementary to such development the tying of techniques shall be exploited to their limits at the analysis level e.g. to using common clock and troposphere parameters.