All Optical Time and Frequency Distribution for Space Geodesy

Ulrich Schreiber[1], Jan Kodet[1], Johann Eckl[2], Günther Herold[2], Gerhard Kronschnabl[2], Christian Plötz[2] and Alexander Neidhardt[1]

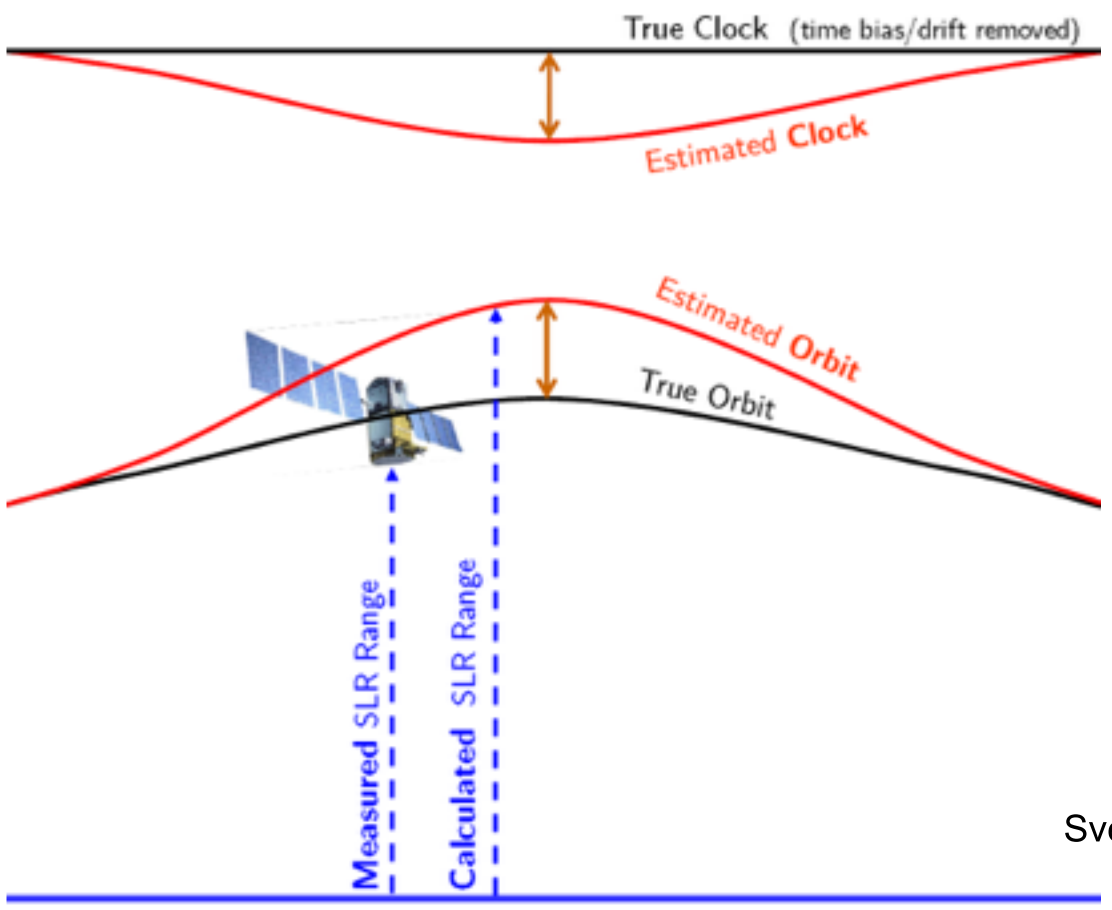
[1)]Technische Universitaet Muenchen, Geodetic Observatory Wettzell,
[2)]Federal Agency for Cartography and Geodesy, Geodetic Observatory Wettzell,
93444 Bad Kötzting, Germany

The demands of GGOS are a high for a modern system for the distribution of time and frequency on a geodetic fundamental station…

We have designed an all optical time and frequency system based on the "Einstein Synchronization Procedure" that allows a synchronization accuracy of 1 ps for all the distributed systems across the campus. Therefore it will be possible to reference all measurements to the same time scale at every measurement system and more importantly to control the system delays to the same level of accuracy. This opens the door to accurate closure measurements of system delays within each measurement technique and from one technique to the next (e.g. from SLR to VLBI). Furthermore this also means that optical time transfer to satellites is no longer limited by the system delays on the ground. This talk outlines the physical properties of the new time and frequency distribution system and emphasizes its importance for inter- and intra- technique co-location measurements.

Clock and measured delay τ (orbit) are highly correlated for the 1-way techniques

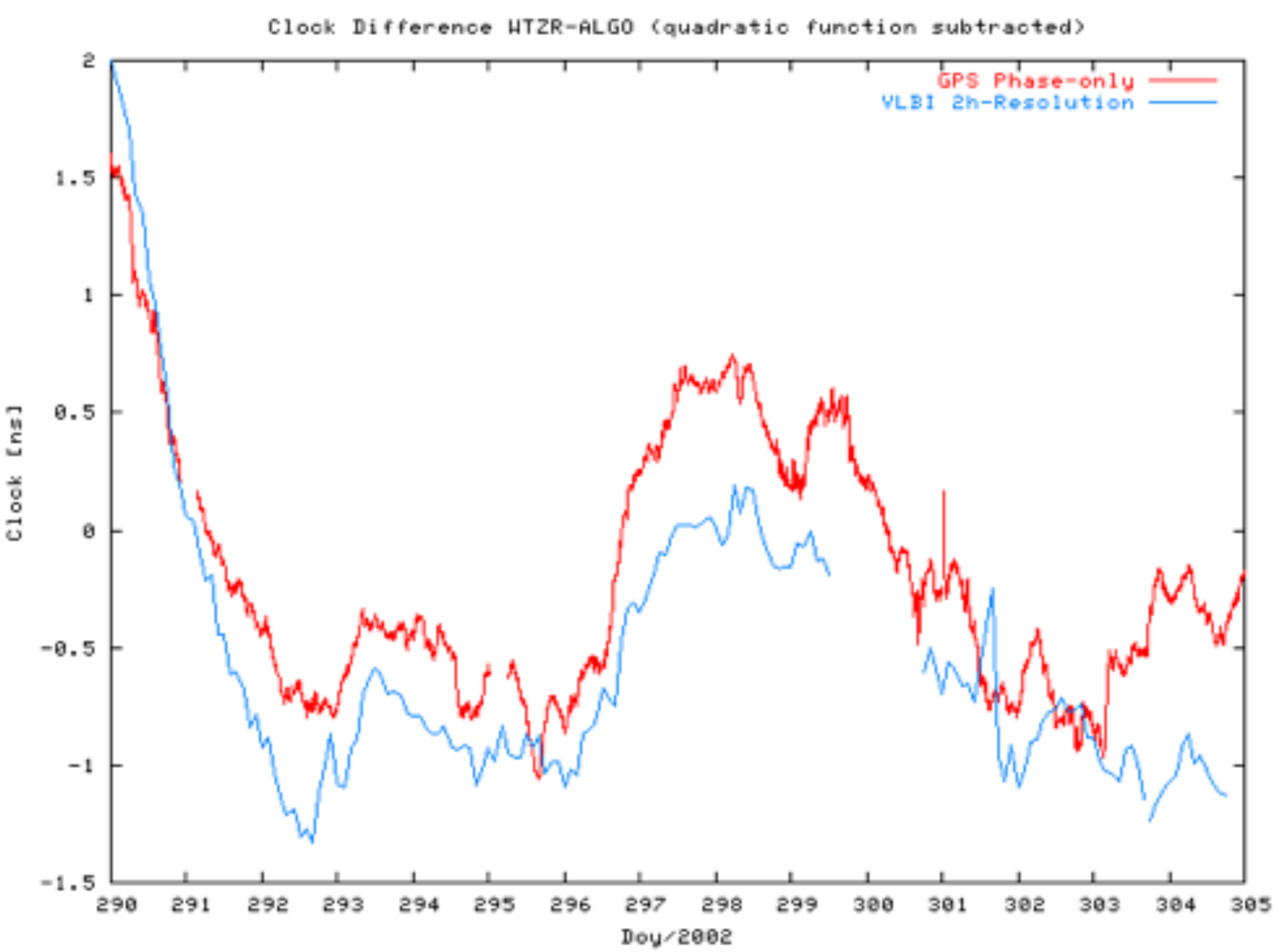
+ variable and unrecognized system delays are causing biases



Svehla et al. 2013

Consequence: Time is not an observable in space geodesy

Closure measurements are powerful tools



Observation: Clocks accumulate all sorts of systematics (Delays) of the various techniques.

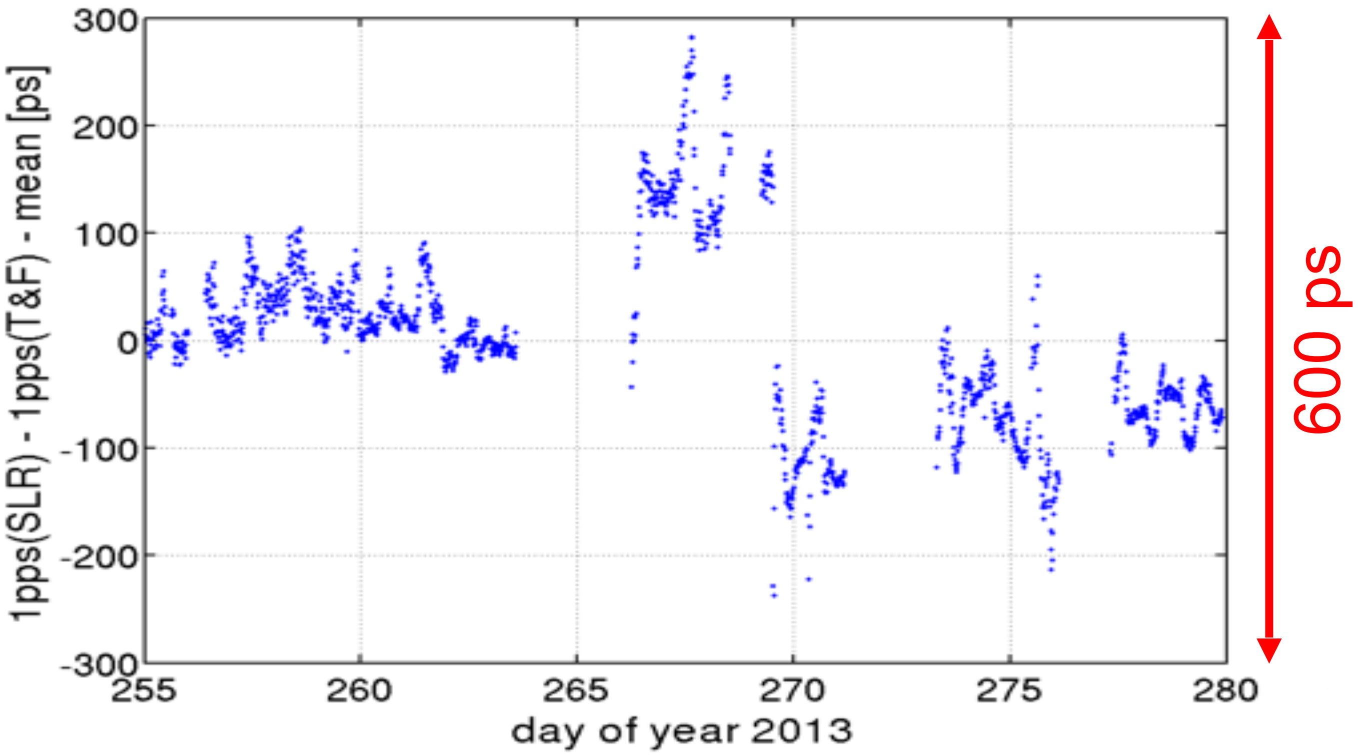
Therefore clock parameters are showing technique specific delays. This applies for inter- and intra- technique comparisons.

Goal: It would be desirable to operate a "**Common** (super) **Clock**" for all techniques within an observatory and link the instrumentation with a

"super-conductor for time" and

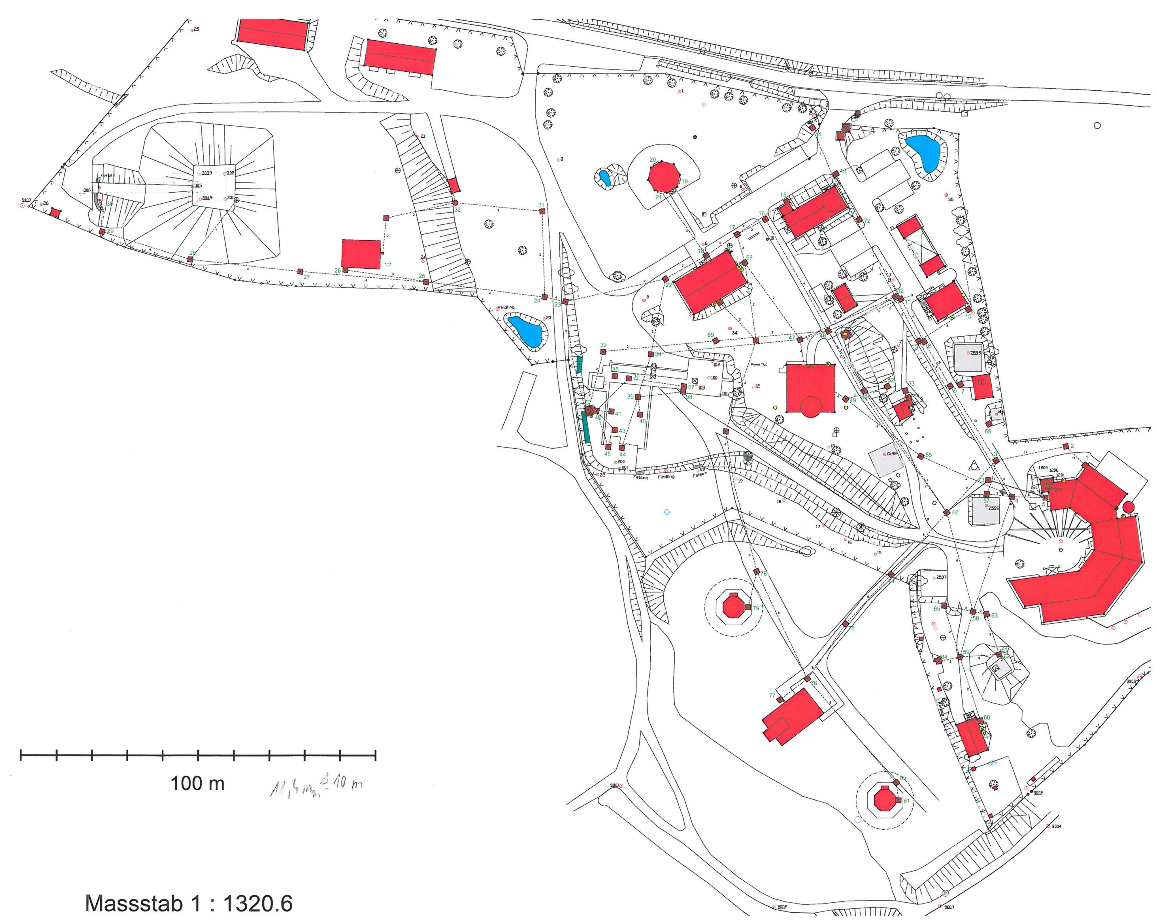
tie all techniques to a single point regardless of their nature

- Time (broadband) and Frequency (narrowband) are two distinct flavors of clocks
- In order to monitor (variable) delays we need to watch the phase of a clock

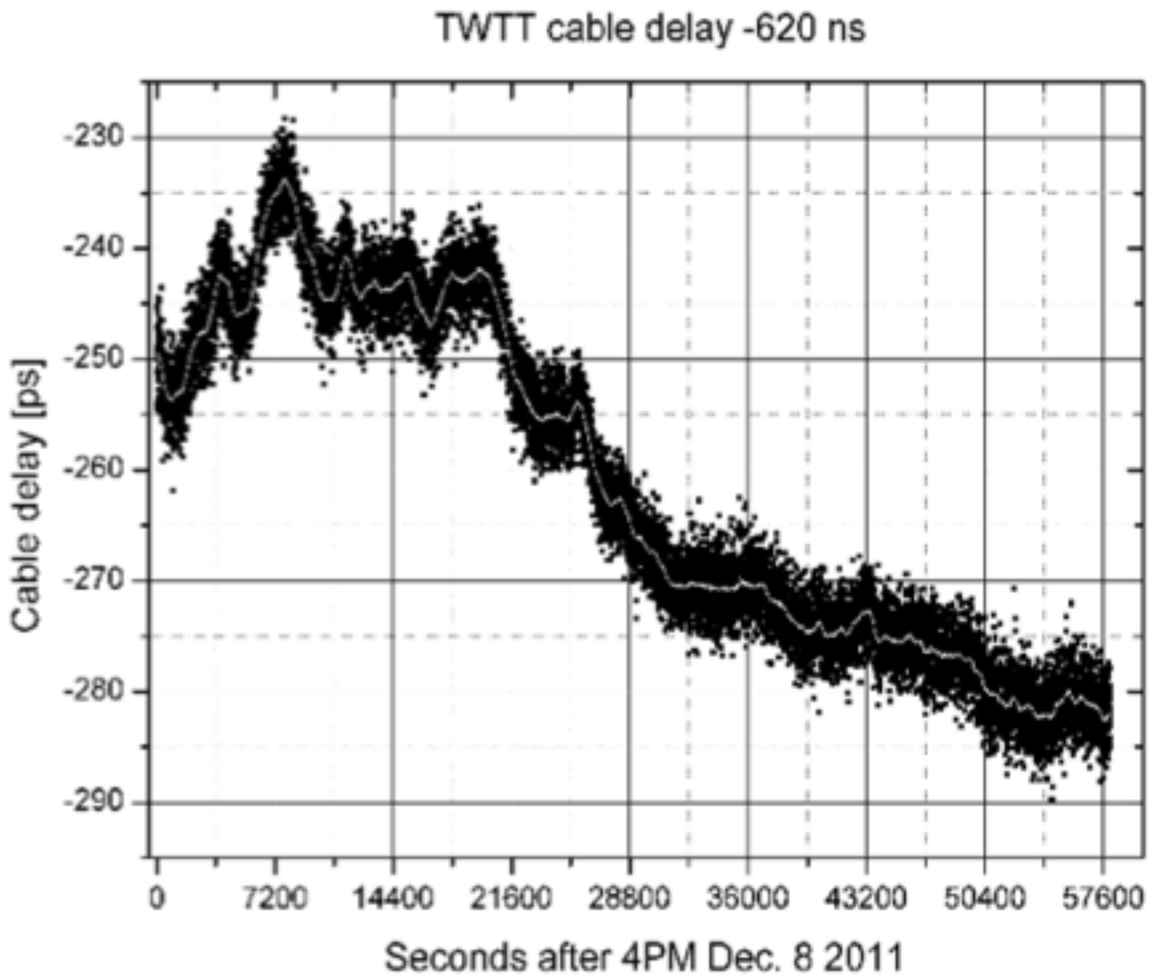


Wish list

- Control of local System- Delays on Campus
- Common Clock for all Techniques
- Spacetime definition for entire Observatory

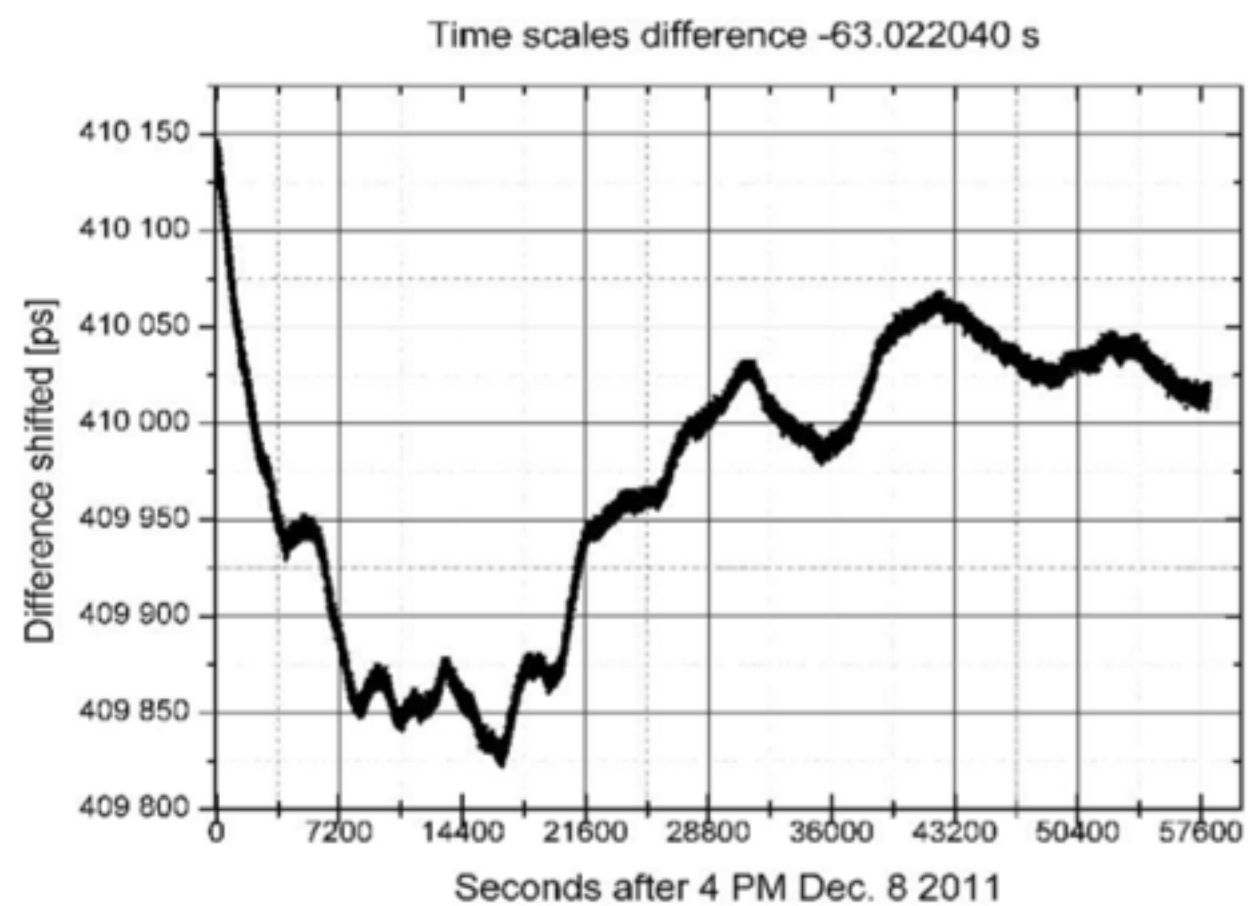


Clock Comparison between buildings 100 m apart

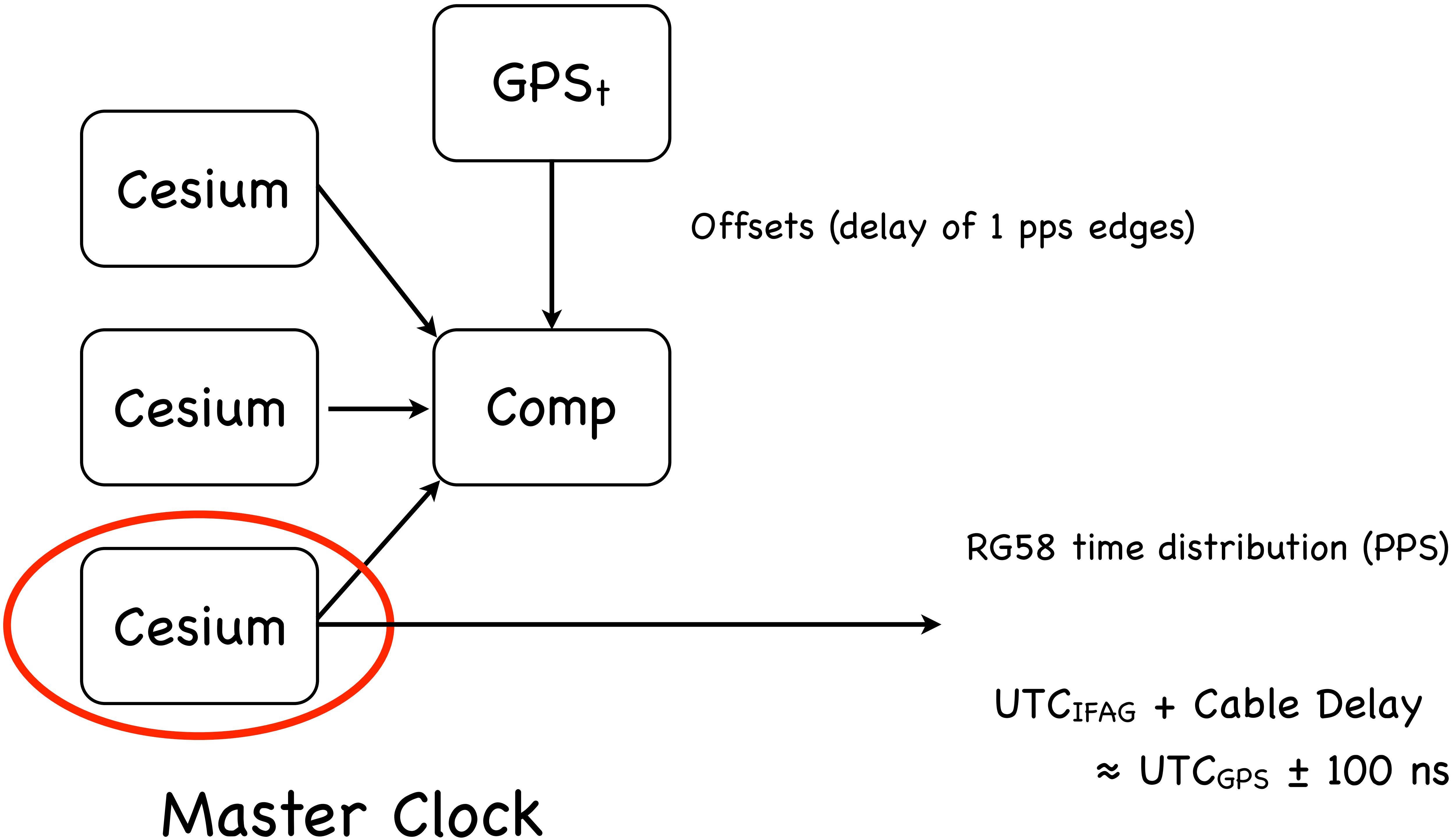


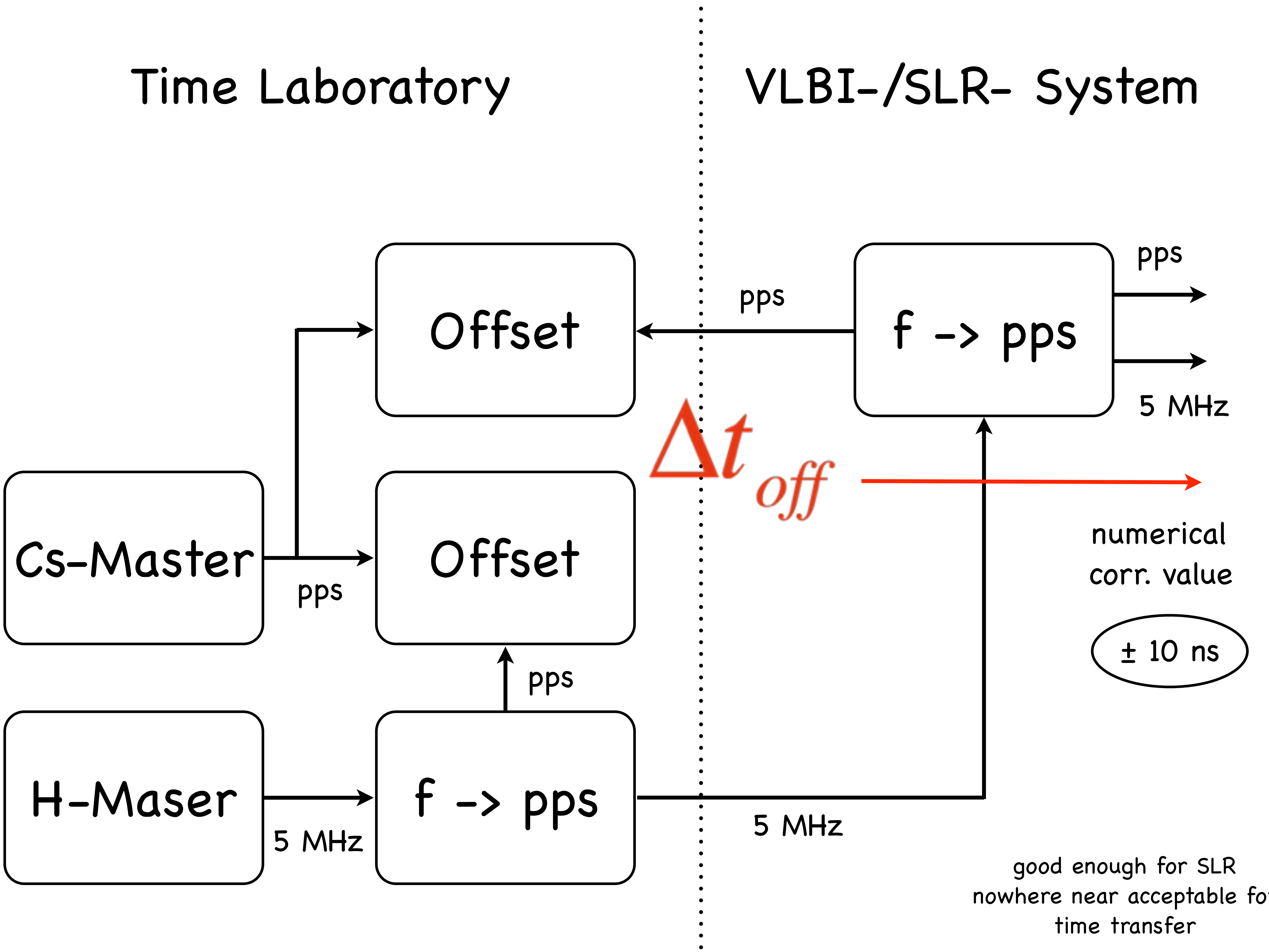
Variation of cable delay (Δt ≈ 60 ps) over 16 hours

Variation between timescales (Δt ≈ 320 ps) over 16 hours



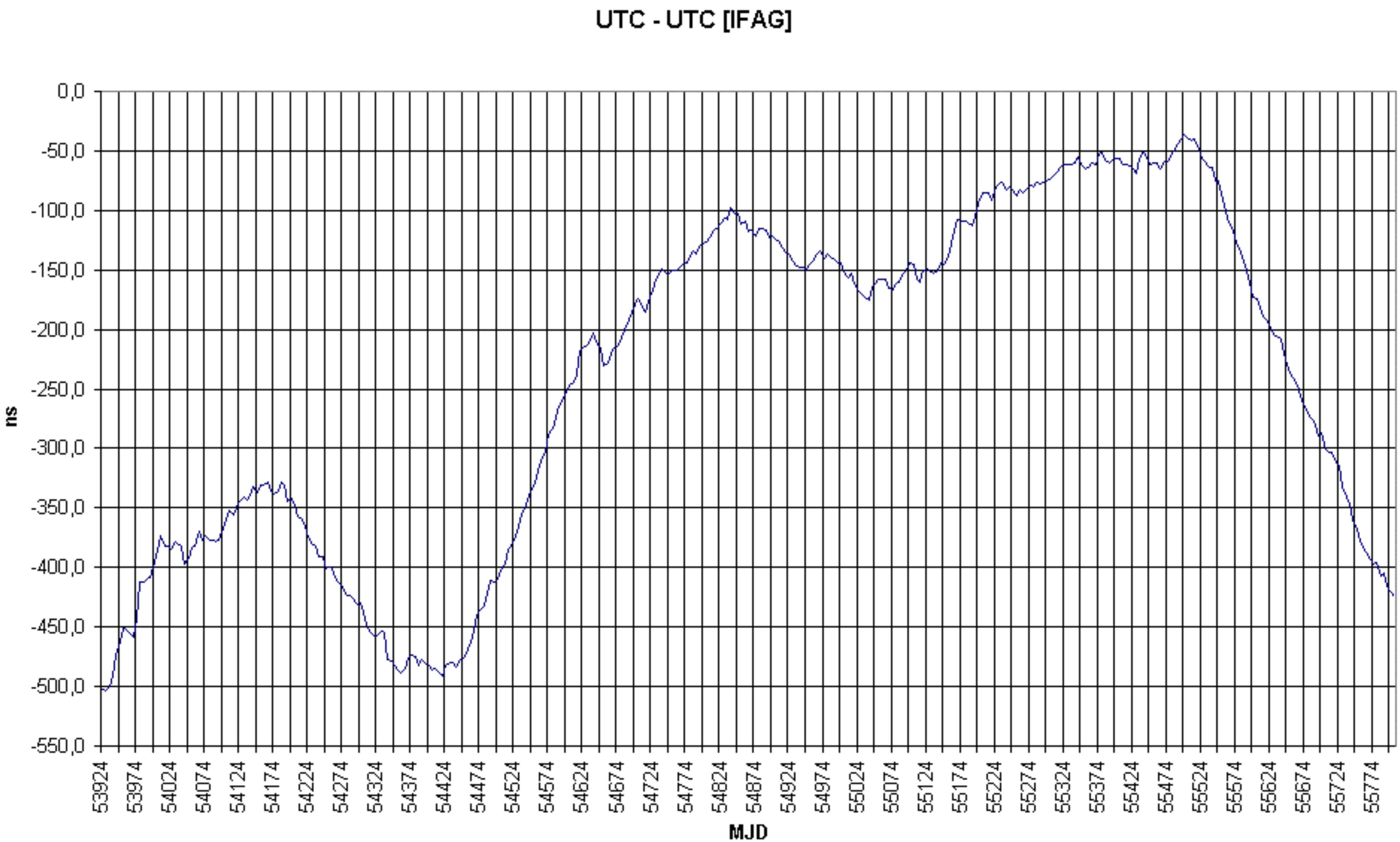
Generation of Time in Wettzell





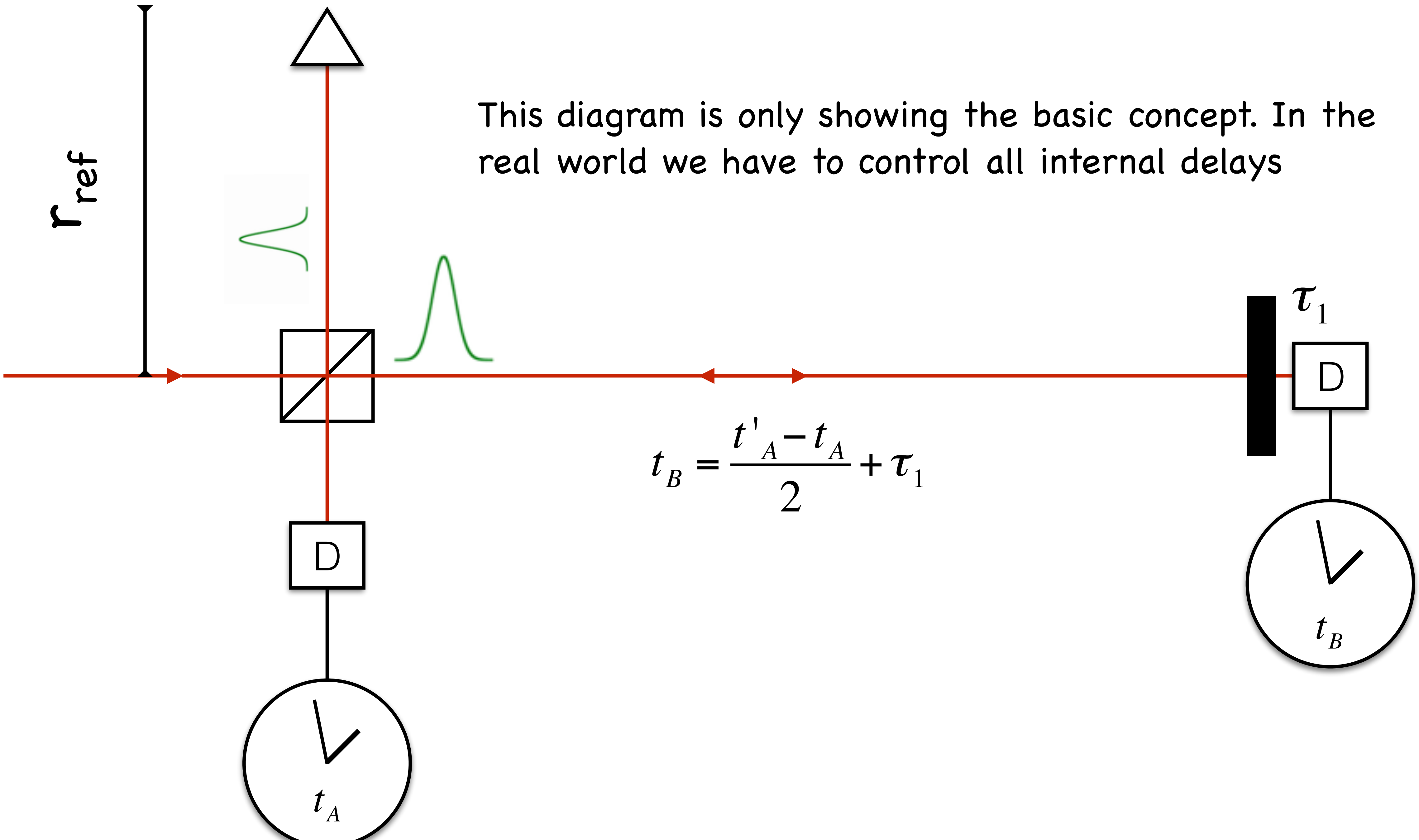
Time Laboratory
VLBI-/SLR- System
Offset
pps
f -> pps
pps
5 MHz
Δt off
Cs-Master
Offset
numerical
corr. value
pps
± 10 ns
pps
H-Maser
f -> pps
5 MHz
5 MHz
good enough for SLR
nowhere near acceptable for
time transfer

Trend over 5 years



practical Realisation of the Einstein Synchronisation...

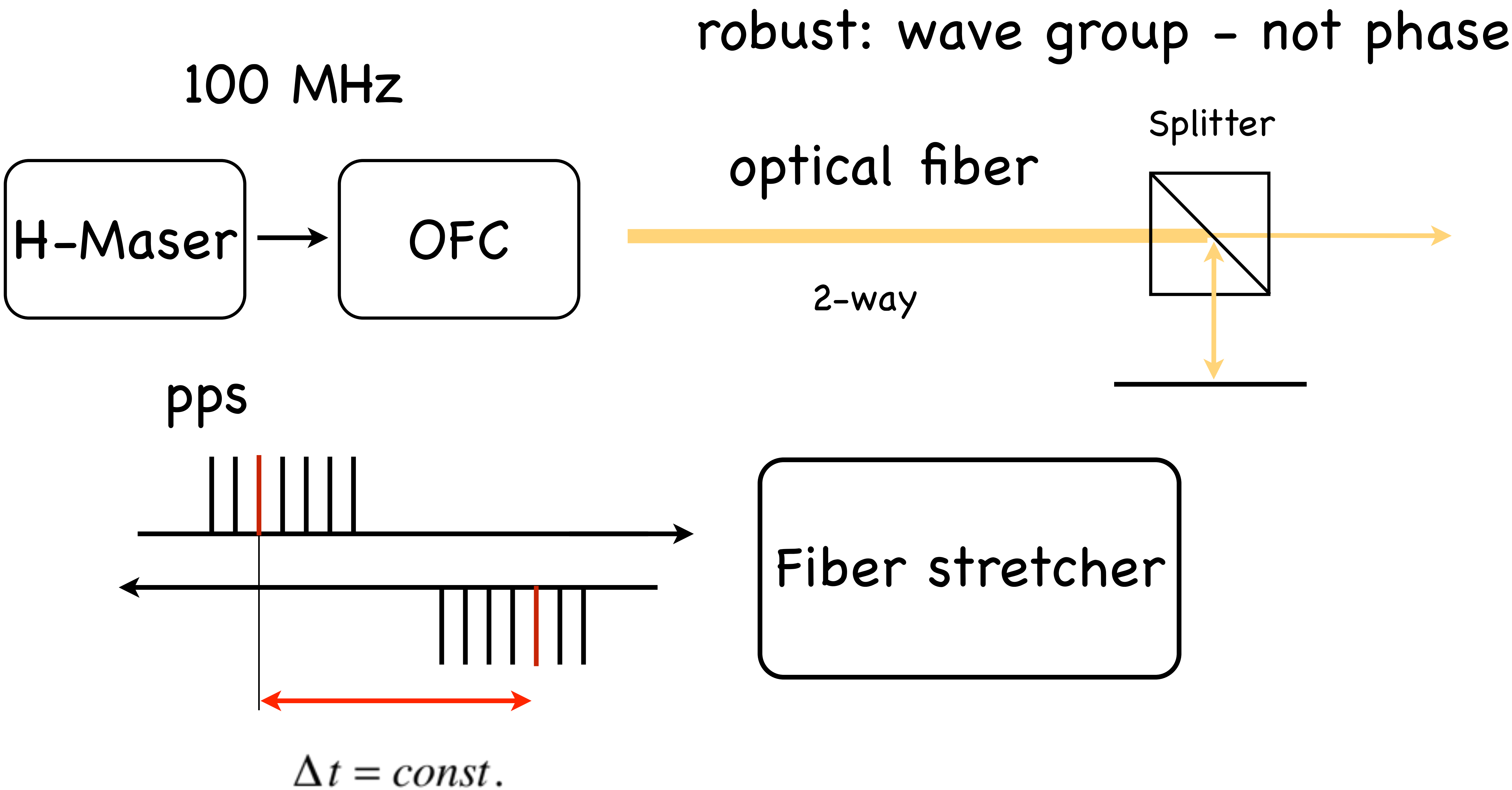
This diagram is only showing the basic concept. In the real world we have to control all internal delays

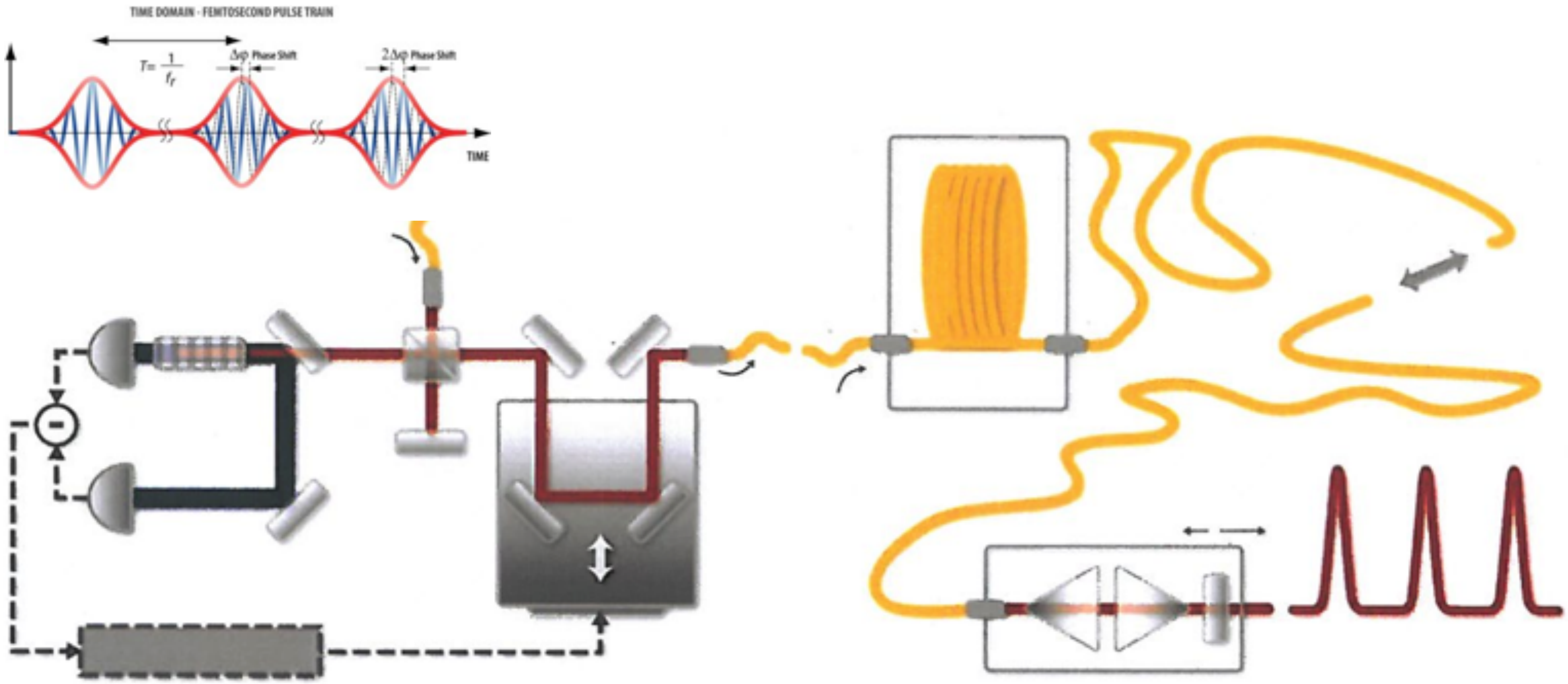


$$t_B = \frac{t'_A - t_A}{2} + \tau_1$$

... unter Berücksichtigung der System- Delays

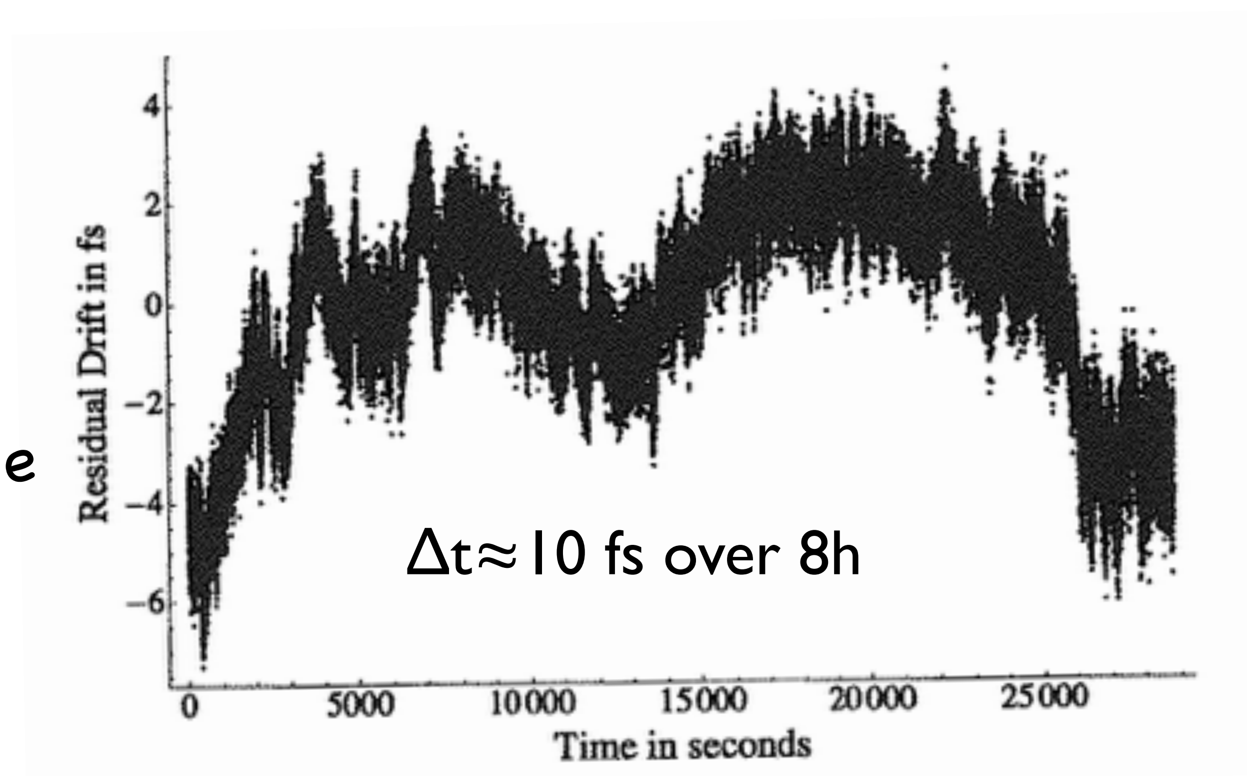
General Idea



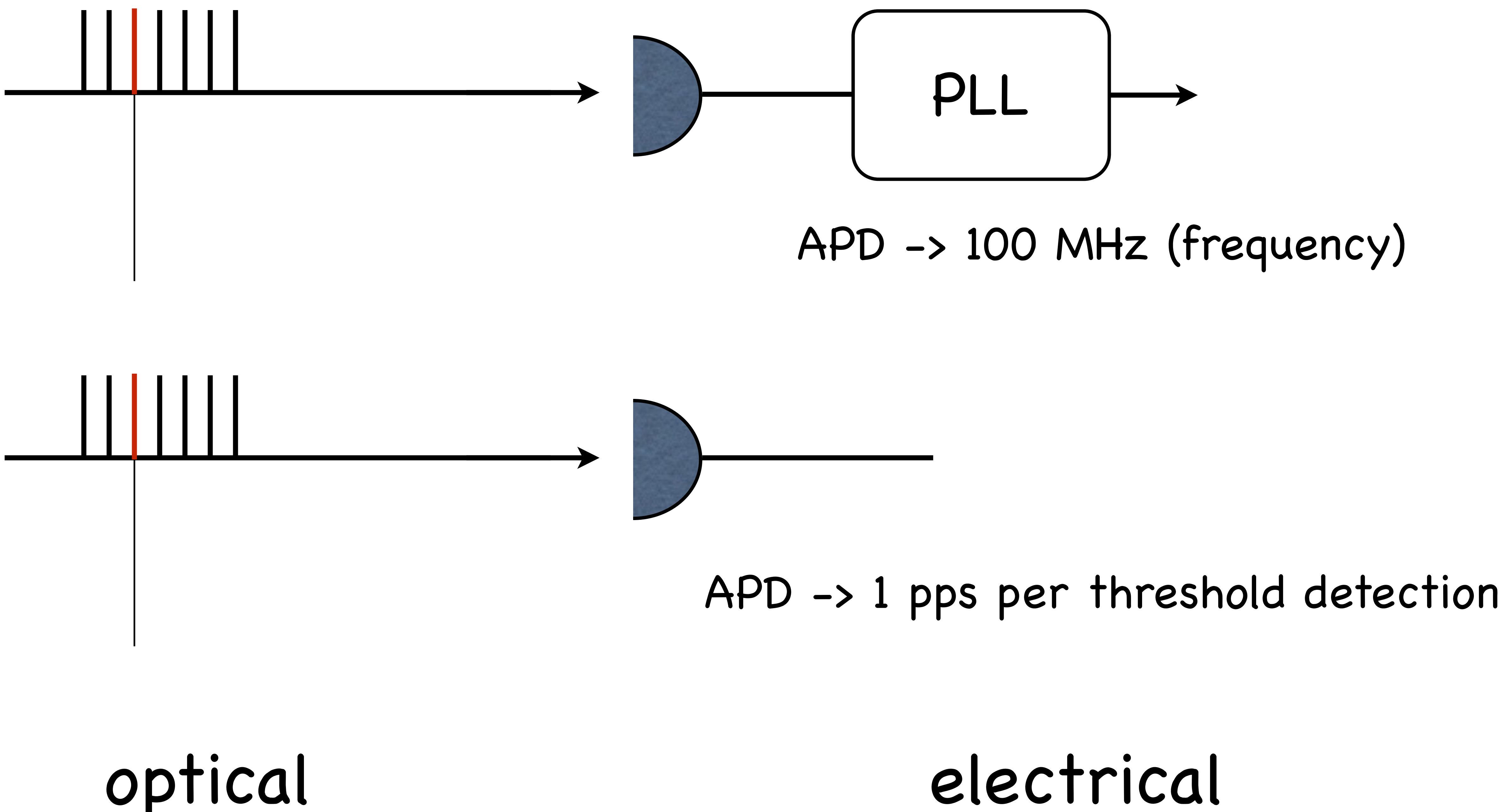


- 2-Way compensation technique only possible in the optical domain
- required broadband signal available from fs-pulse lasers only
- Uncertainty < 100 fs: ≈ 5 orders of magnitude gain over current systems
- Consequences for Surveying: 1 mm = 3 ps

Example: FEL in Trieste



OFC pulse train and 100 fs pulse width and marker laser

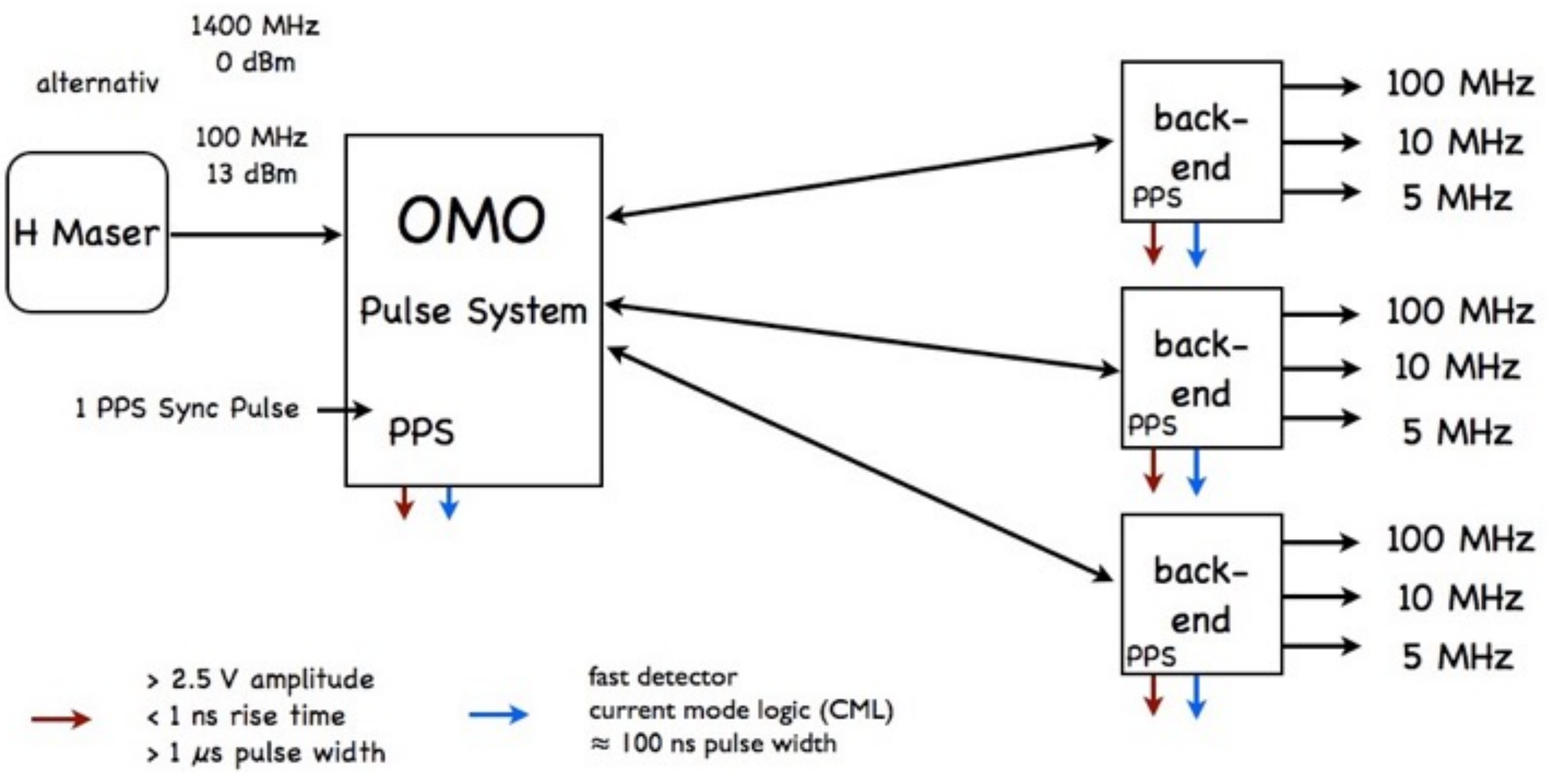


-> per 2-way comparison space time definition

Frequency Interpolator

Optical T&F Distributor
(2- Way System)

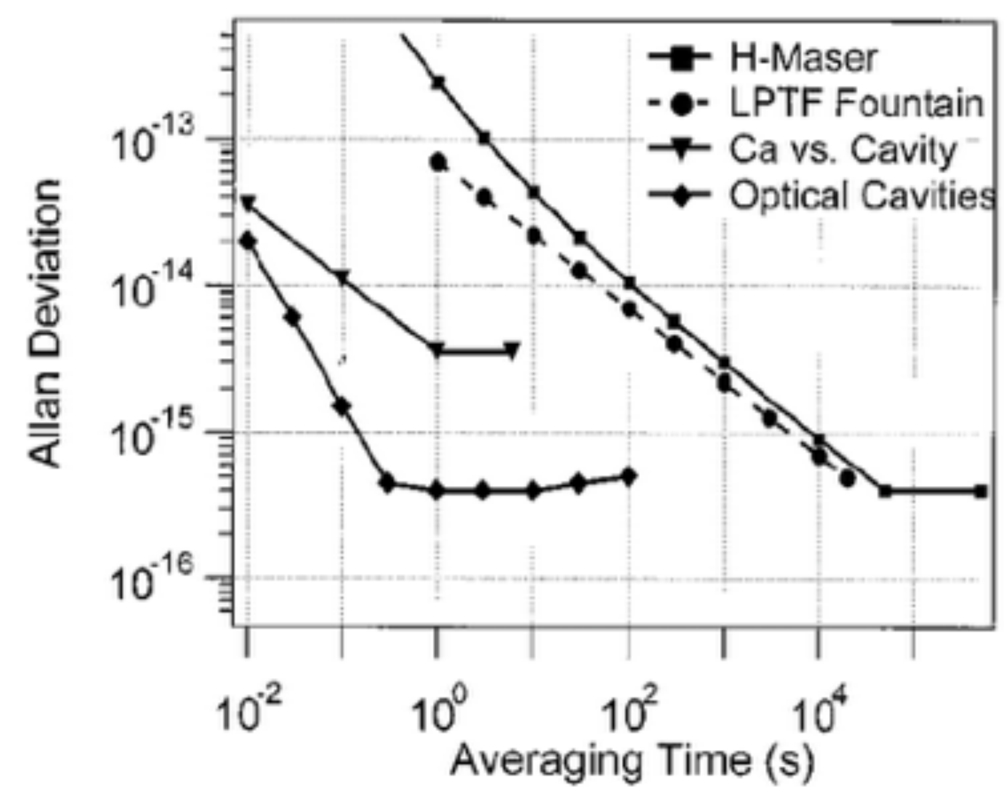
local Time and Frequency Sources
(for every Technique)



- all Delays actively held constant
- Interpolater can be substituted by next generation oscillator at any time
- First Links to be installed in 4/2016

Scenarios for the Future of Time and Frequency in Geodesy

- Campus Distribution: active Delay- compensated T & F
- Stabilisation of Interpolator (Maser) by Composite Clock Approach
- Extreme Low Noise Frequency Source: optical Resonator
- Frequency Stabilisation by fiber Link and optical clock (PTB - Syrte)



Vision: Make Time an Observable