The next generation timing system at the Geodetic Observatory Wettzell

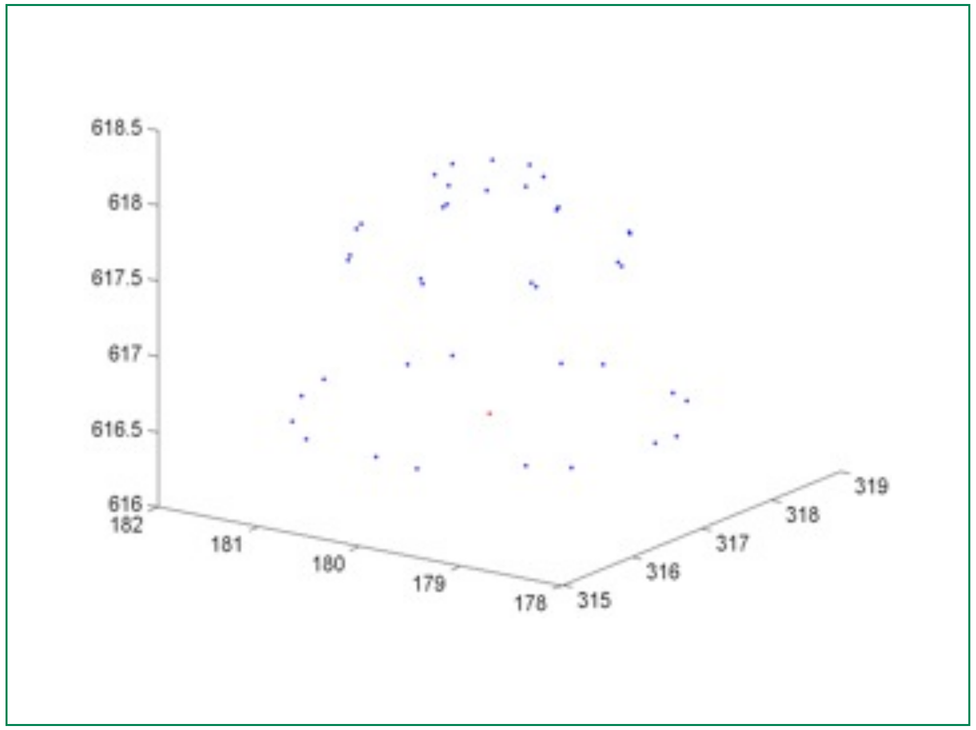
Goals and Prospects...

...and what it has to do with GGOS

WLRS Wettzell (Mähler, 2009)

campaign 09-23-2009:

Method	East	North	Up
geodetic 3D adjustment (PANDA)	316.92439	180.04240	616.51425
sphere adjustment (MatLab LSGE-bib.)	316.92438	180.04237	616.51454
circle adjustment	316.92438	180.04250	616.51454
max. difference	**0.01 mm**	**0.13 mm**	**0.29 mm**



campaign 09-01-2009:

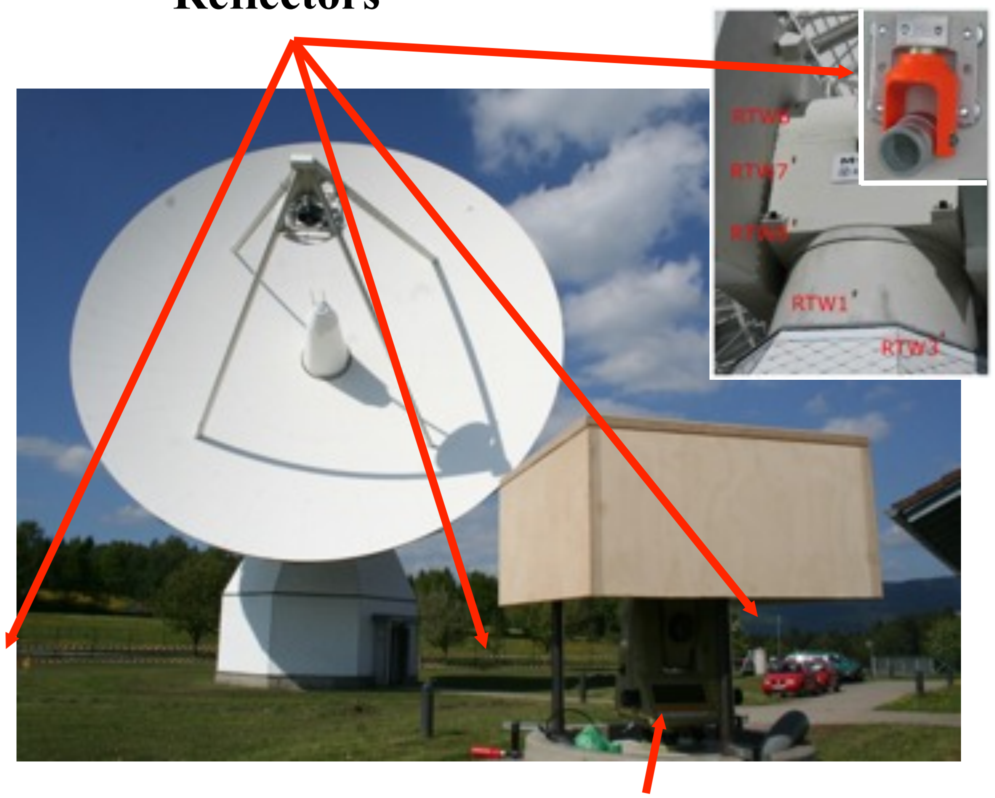
Method	East	North	Up
geodetic 3D adjustment	316.9253	180.0426	616.5134
Difference to above	**0.9 mm**	**0.1 mm**	**0.85 mm**

Source: T. Klügel (EGU 2010)

Permanent survey of the reference point of the 20m radio telescope (Mai - July 2009)

In cooperation with the University of Karlsruhe (Lösler, Eschelbach)

Reflectors



Programmable Total Station (Tachymeter)

<u>Each 15 minutes one complete survey</u>
distance, direction, zenith angle

+ <u>additional sensors</u>
Invar cable, 4x tower-temp., meteorology, nivel, telescope pointing

Refraction correction

Laser **Receiver**

Source: Neidhardt, Ettl 2009

Permanent survey of the reference point of the 20m radio telescope (Mai - July 2009)

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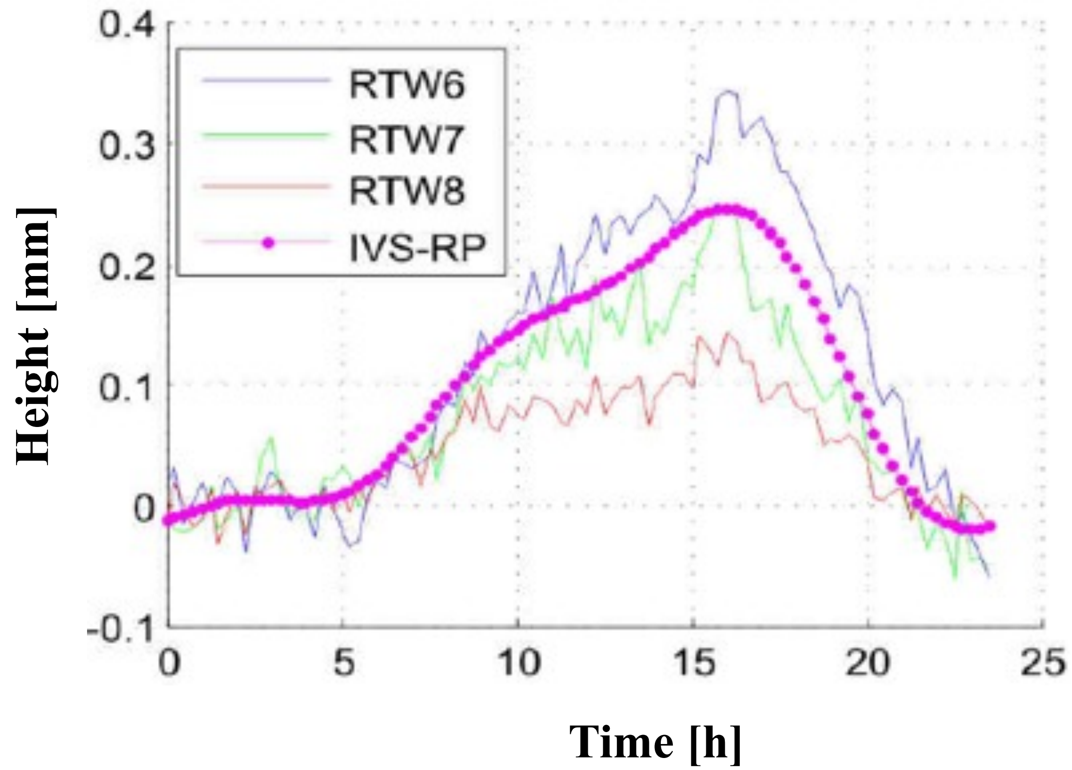
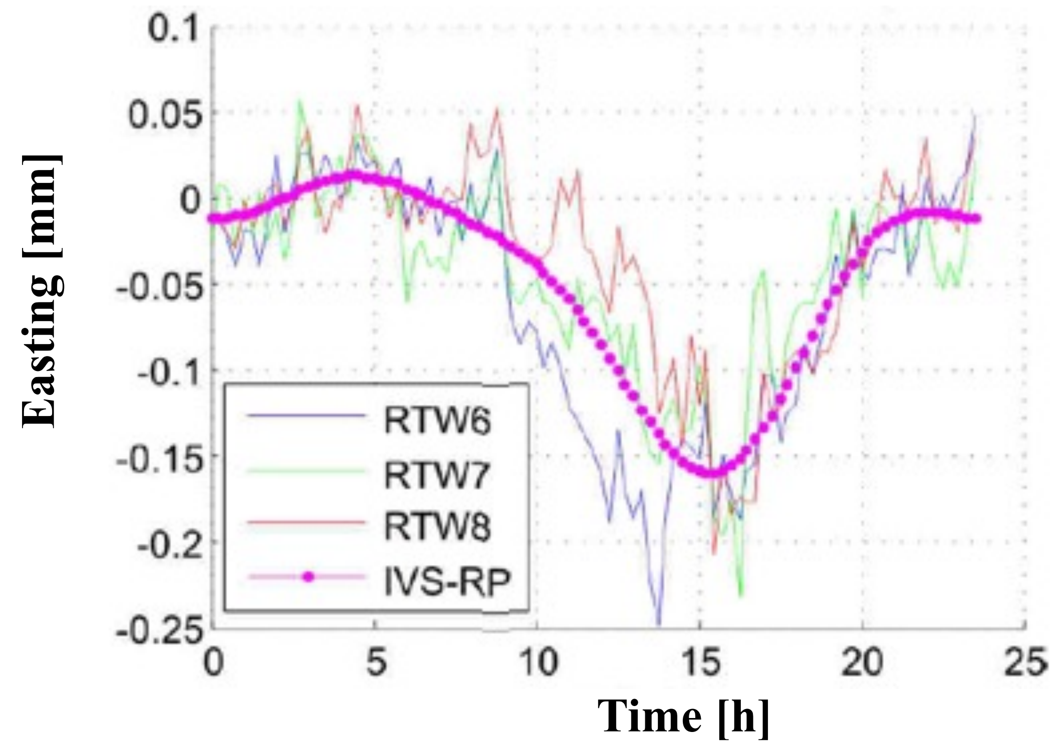
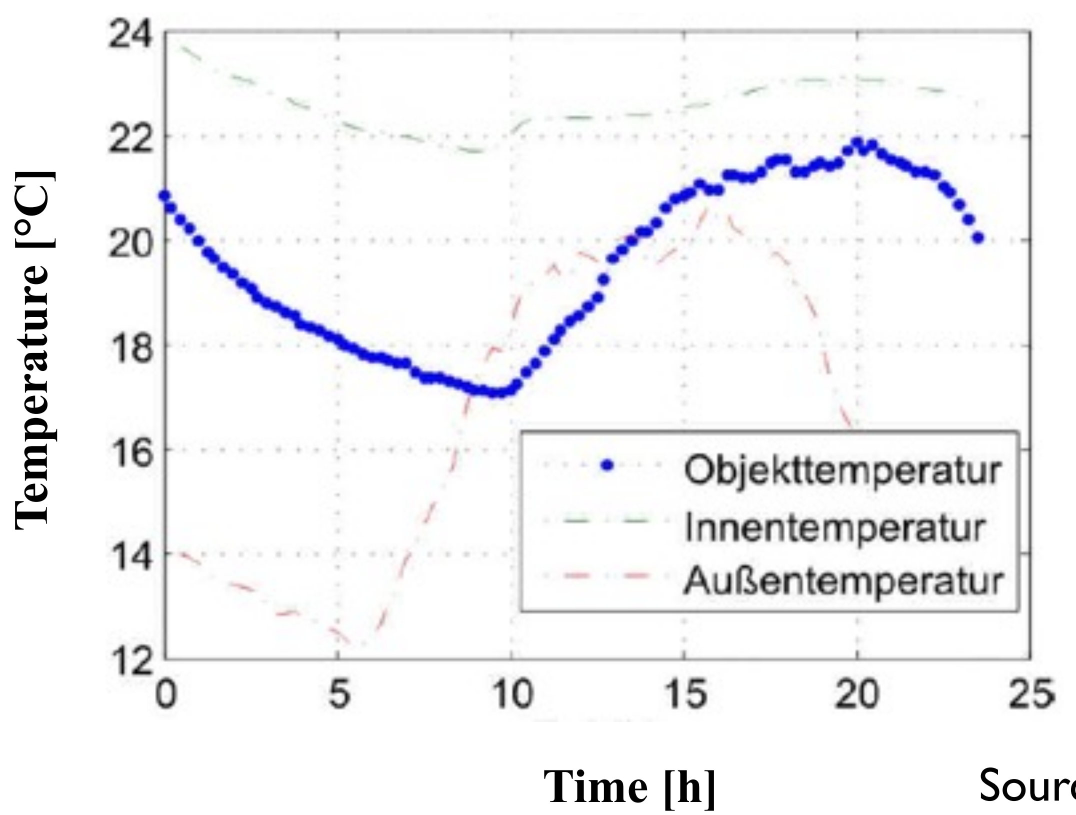
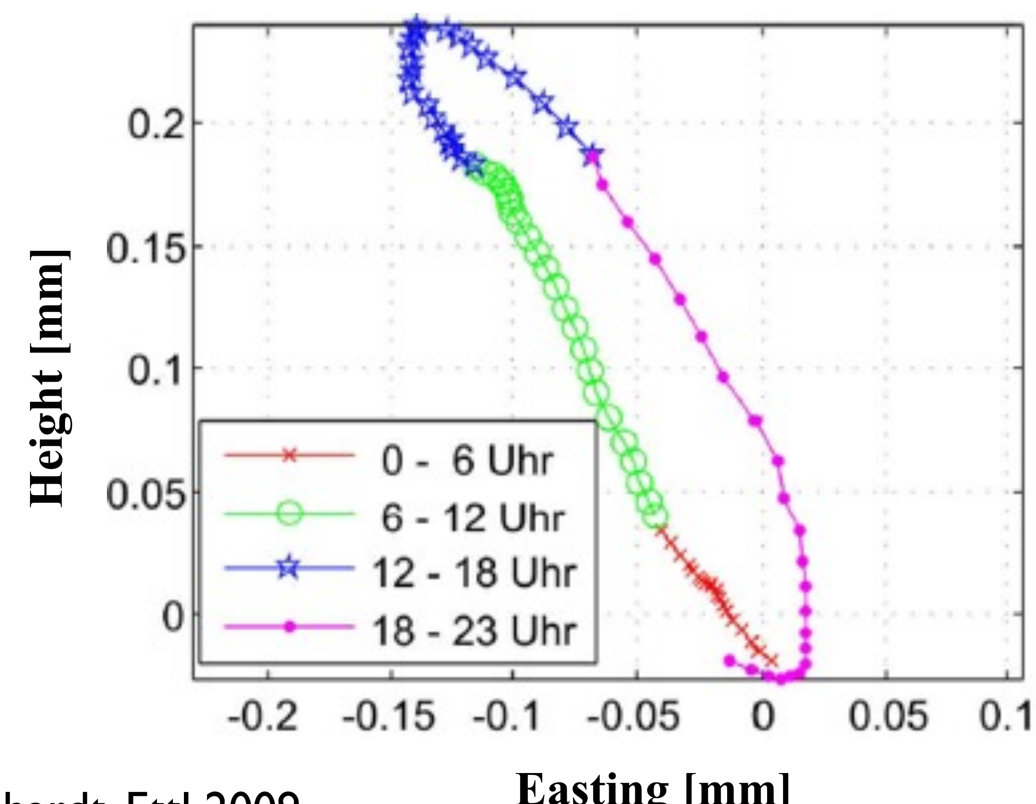
Results





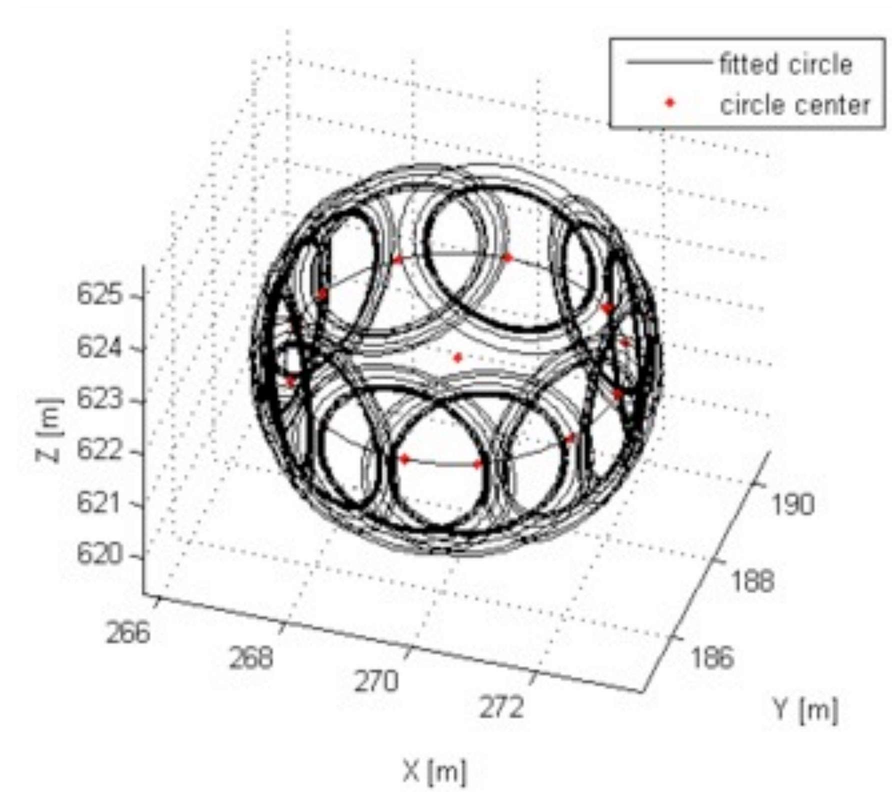




Source: Neidhardt, Ettl 2009

Radio Telescope Wettzell (Lösler, 2008)

Method	East	North	Up
2D adjustment + height (NetzCG)	269.71713	187.69011	622.46484
3D adjustment (JAG3D)	269.71715	187.69011	622.46482
circle adjustment	269.71720	187.69008	622.46502
max. difference	**0.07 mm**	**0.03 mm**	**0.2 mm**



Laser tracker data:

Method	East	North	Up
3D adjustment (JAG3D)	269.71739	187.69056	622.46506
Difference to tachymeter data	**0.24 mm**	**0.45 mm**	**0.24 mm**

Source: T. Klügel (EGU 2010)

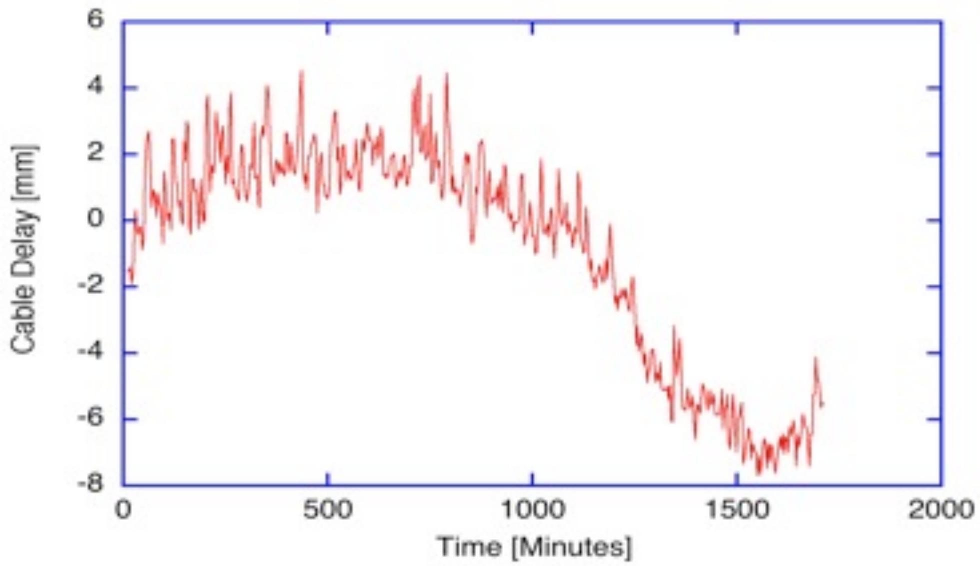
Survey Errors are obtained consistently small

Conclusion from a series of surveys

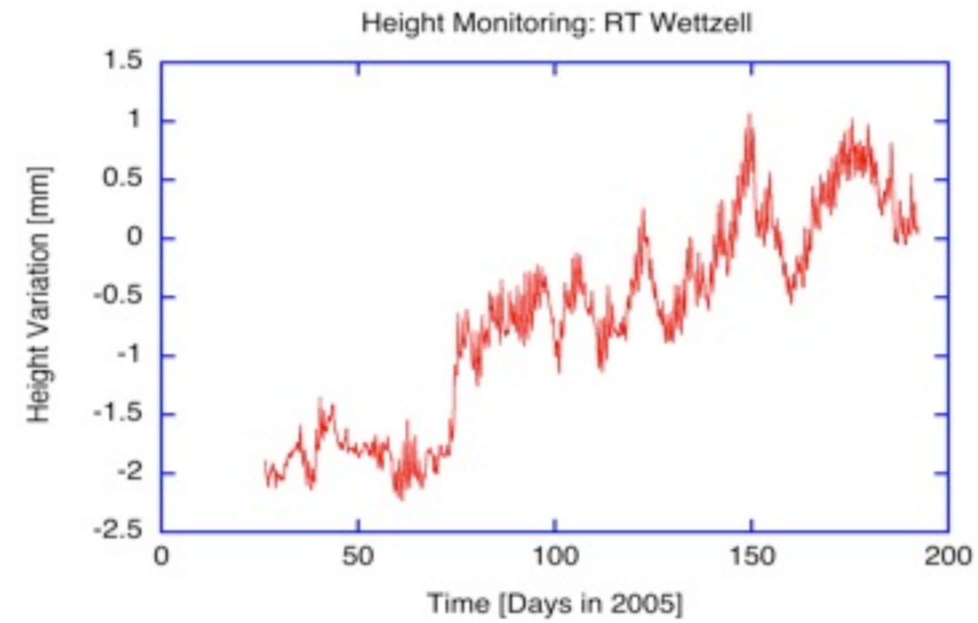
- The space technique reference points show no significant displacements w.r.t. the local network
- Good repeatability, also when using different instruments small systematic errors
- The accuracy of the local ties in Wettzell are in the **order of 1-2 mm**
- **We certainly need a yet closer look at intra technique biases**

Laser: (satellite signature, signal strength, asymmetry between satellite ranges and calibration)

VLBI: (system delay, phase-cal)



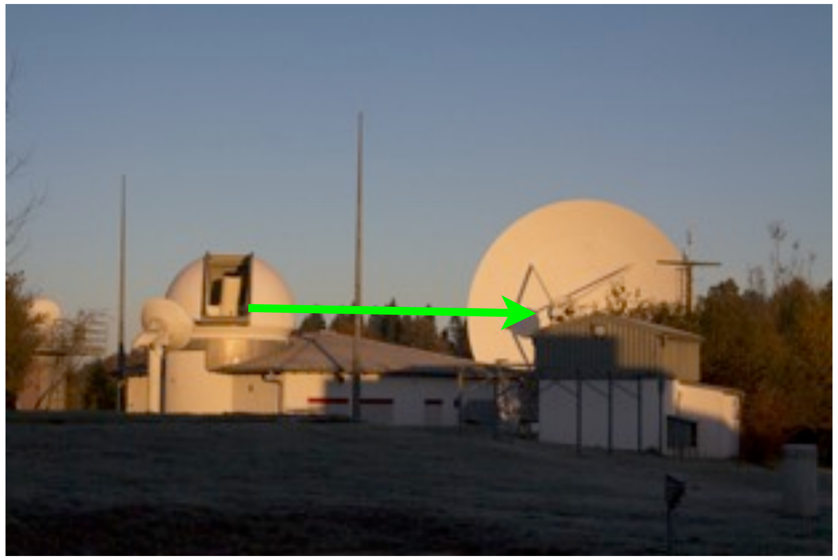
Instrumental biases: cable delays in VLBI



Instrumental biases: height changes of VLBI telescope

Present Status:

- Inaccurate, incomplete or missing local ties at many fundamental sites
- No use of co-location of instruments onboard satellites for ITRF
- Considerable technique-specific biases of the individual techniques



Innovations:

- Wettzell: 3 VLBI, 2 SLR telescopes and 5 GNSS antennas; common timing for all instruments
- Dedicated satellite missions for co-location of GNSS, SLR, VLBI (and DORIS) presently considered

Measurement device - Oscilloscope Tektronix - DPO 7254 - 2.5GHz / 40Gs/s

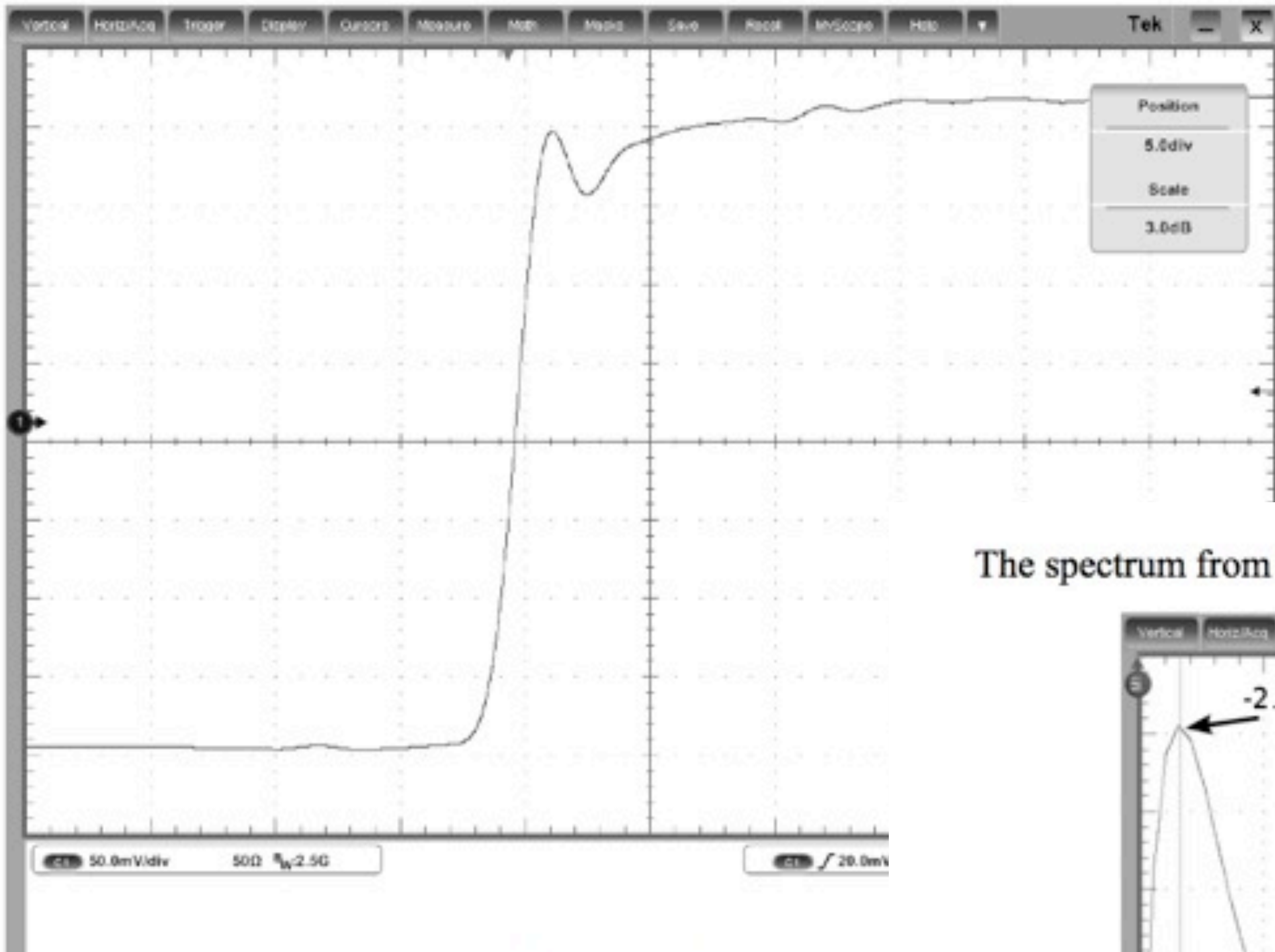


Figure 1: Edge with rice-time below oscilloscope BW, time = 35 ps.

Concept: Fire Laser at VLBI feedhorn, convert optical pulse to RF and calibrate the entire geometry by timing the process

The spectrum from Figure 1:

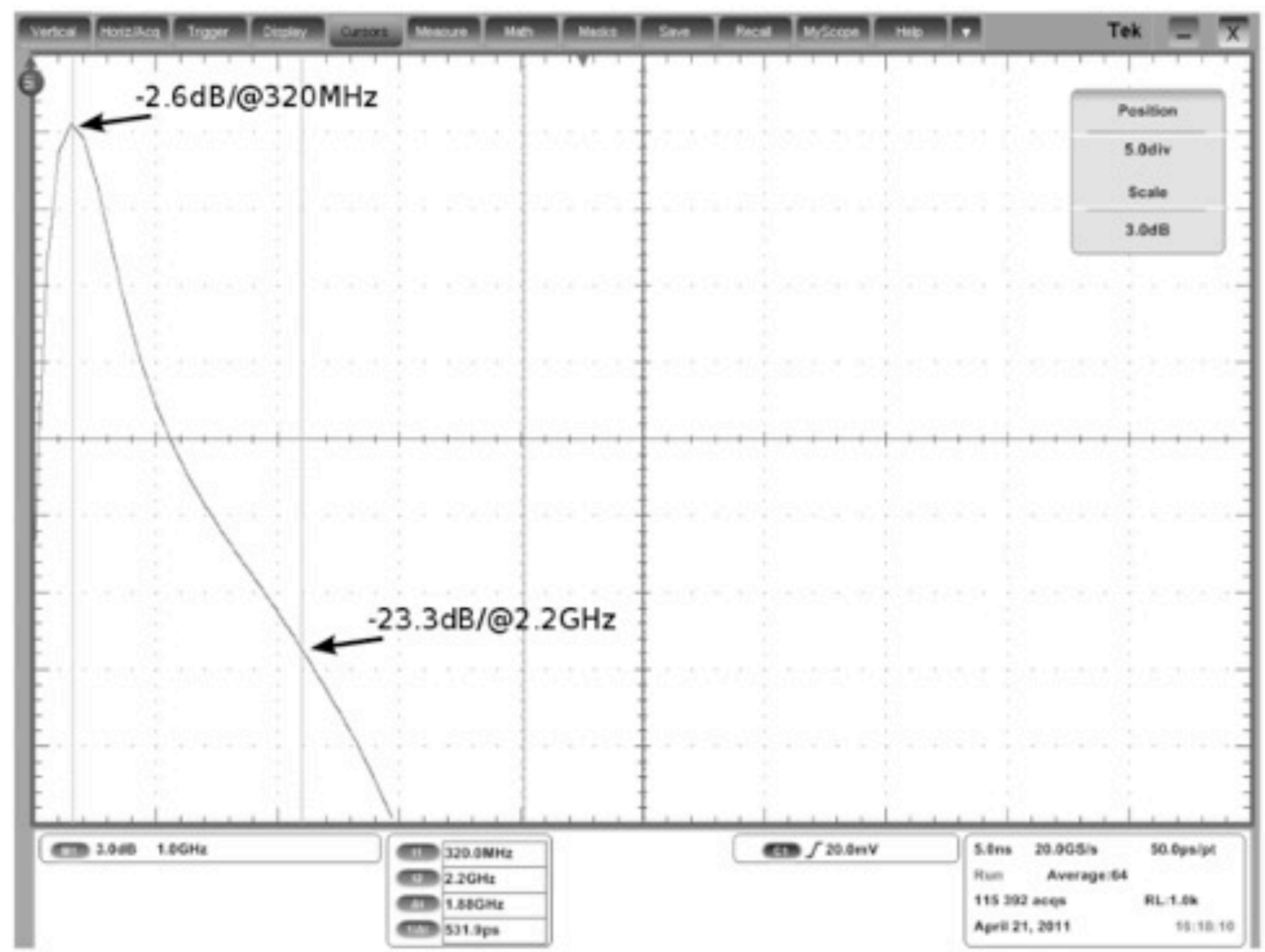
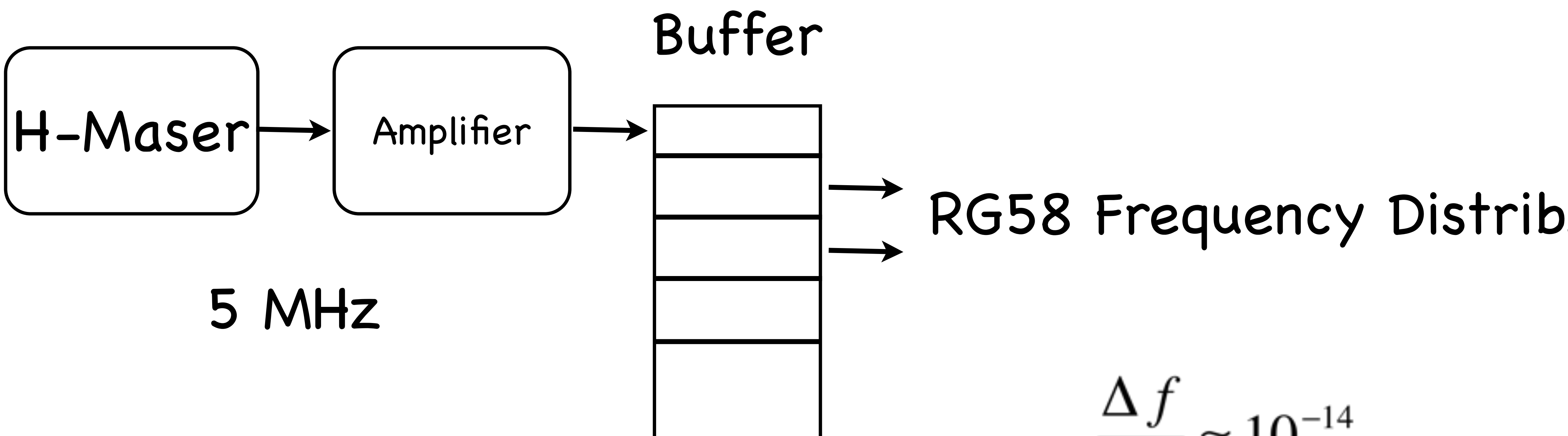


Figure 2: Edge spectrum.

Preliminary experiment at CTU: J. Kodet

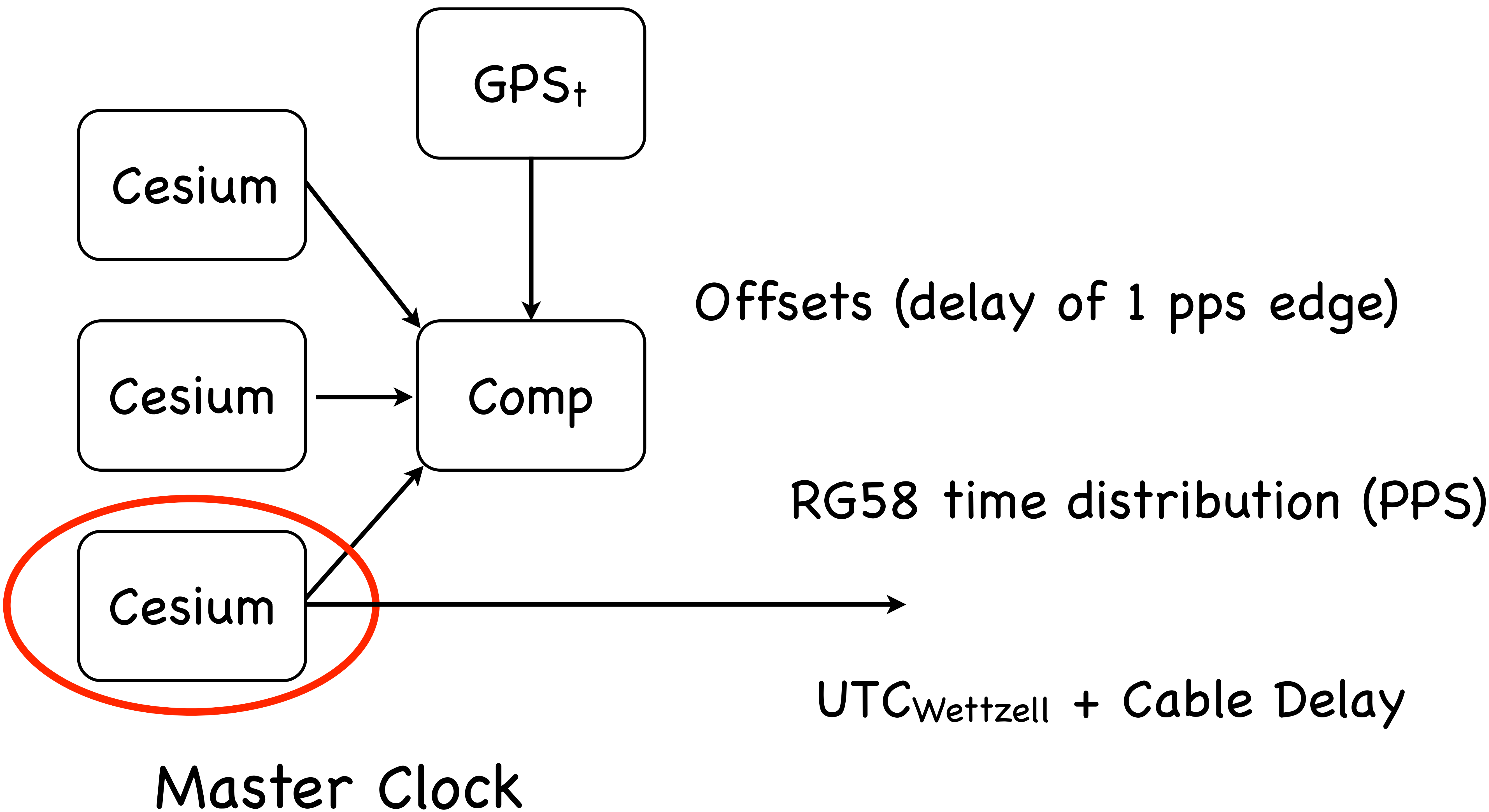
- light and RF not identical domain (cal.)
- SPAD not bad, more Bandwith needed
- Timing System needs consolidation

Timing System: Current State



$$\frac{\Delta f}{f} \approx 10^{-14}$$

@ (1000 s)


GPS$_t$
Cesium
Cesium
Comp
Cesium
Offsets (delay of 1 pps edge)
RG58 time distribution (PPS)
UTC$_{Wettzell}$ + Cable Delay
≈ UTC$_{GPS}$ ± 100 ns
Master Clock

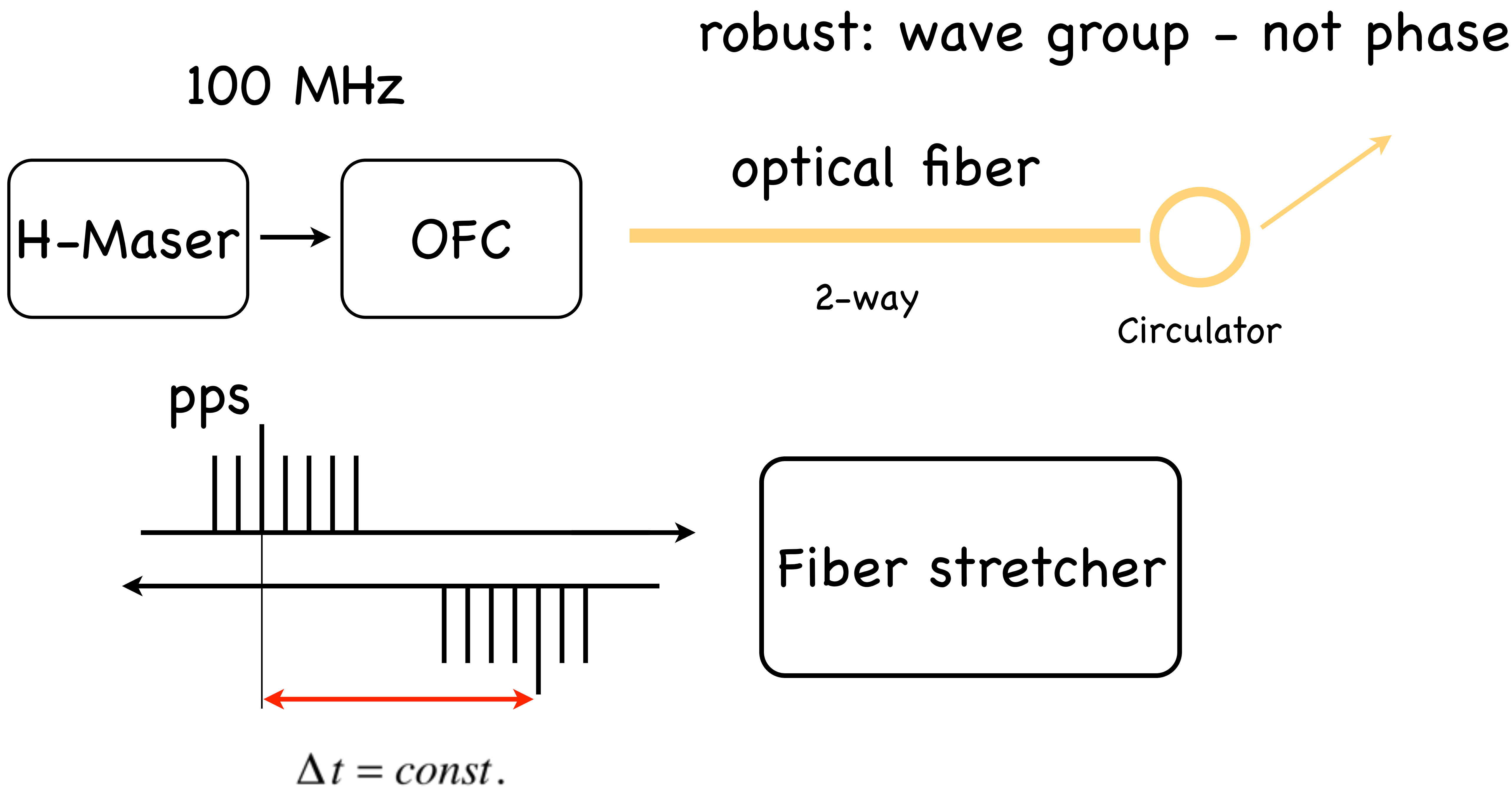
Known Issues

- PPS Pulse not sharp (bandwidth limited RG58)
- Cable delays sort of known (insufficient)
- Reference Frequency is low (5 MHz)
- 1pps jitters as potentials float between systems
- Cable distribution (no 2-way-comparison)
- insufficient for the definition of space time (ART) on observatory

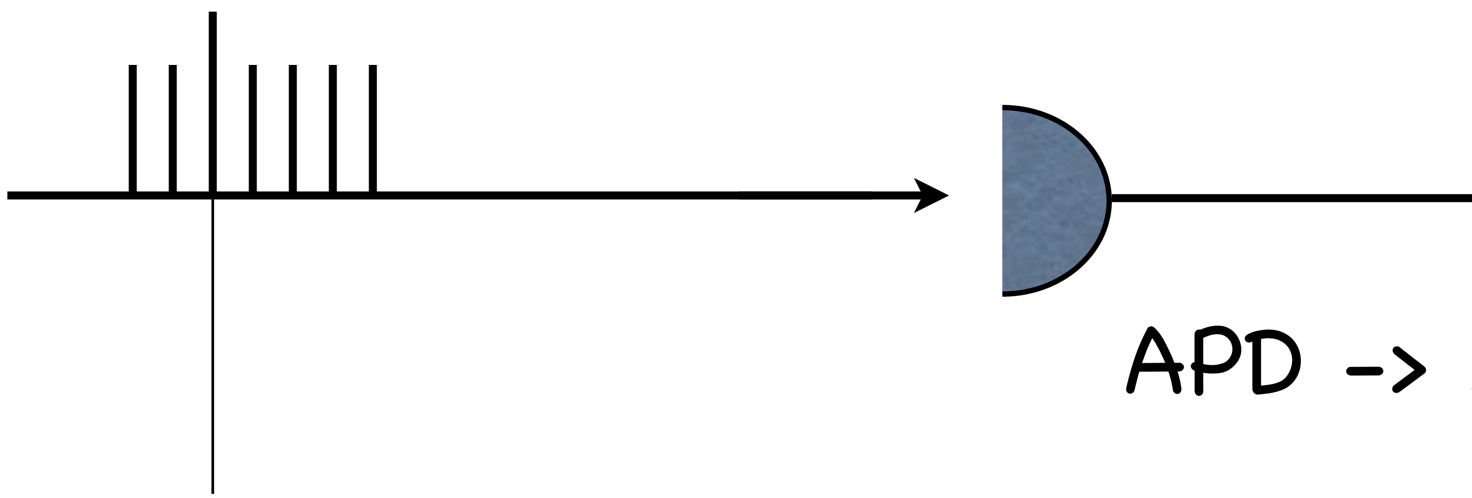
Goals for Wettzell

- Optical Frequency Distribution (Fiber)
- continuous precise 2-way-delay compensation
- Reference Frequency high (100 MHz)
- exact reference (±1 ns) relative to external source (PTB)
- T & F generated from same signal (OFC technology)
- Definition of Space Time (in anticipation of optical clocks)

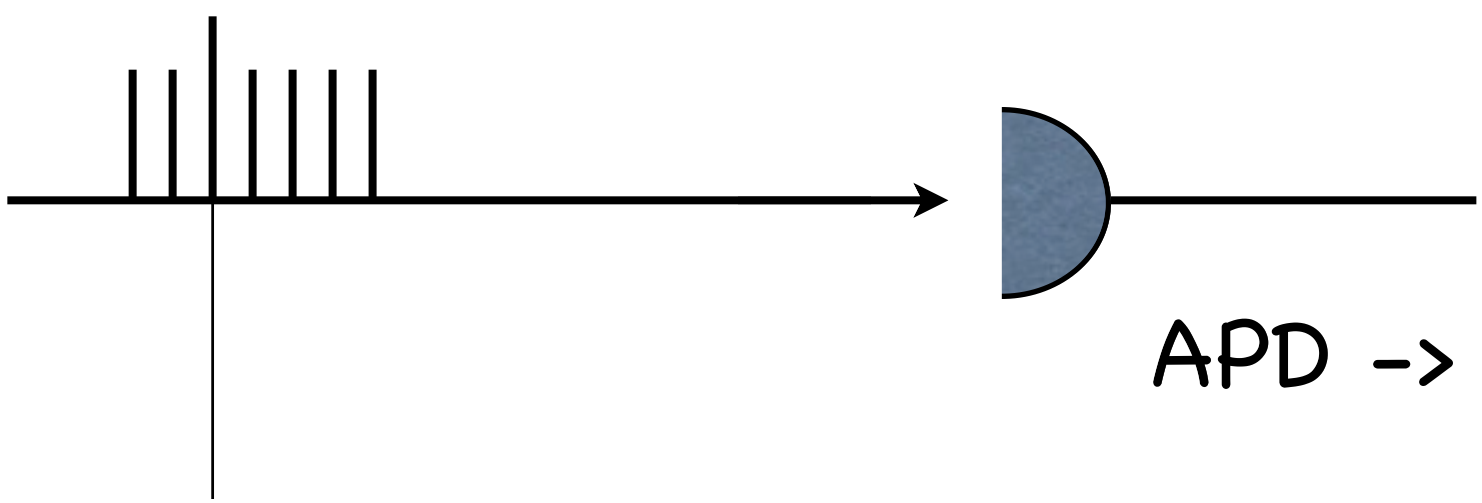
Basic Concept



OFC pulse train and 100 fs pulse width



APD -> 100 MHz (frequency)



APD -> 1 pps per threshold detection

optical

electrical

-> per 2-way comparison space time definition

Application: Time Transfer

- optical sub-picosecond link between event timer - UTC_{Wtz}
- optical time transfer per laser link
- optical (frequency) time transfer by fiber link - PTB

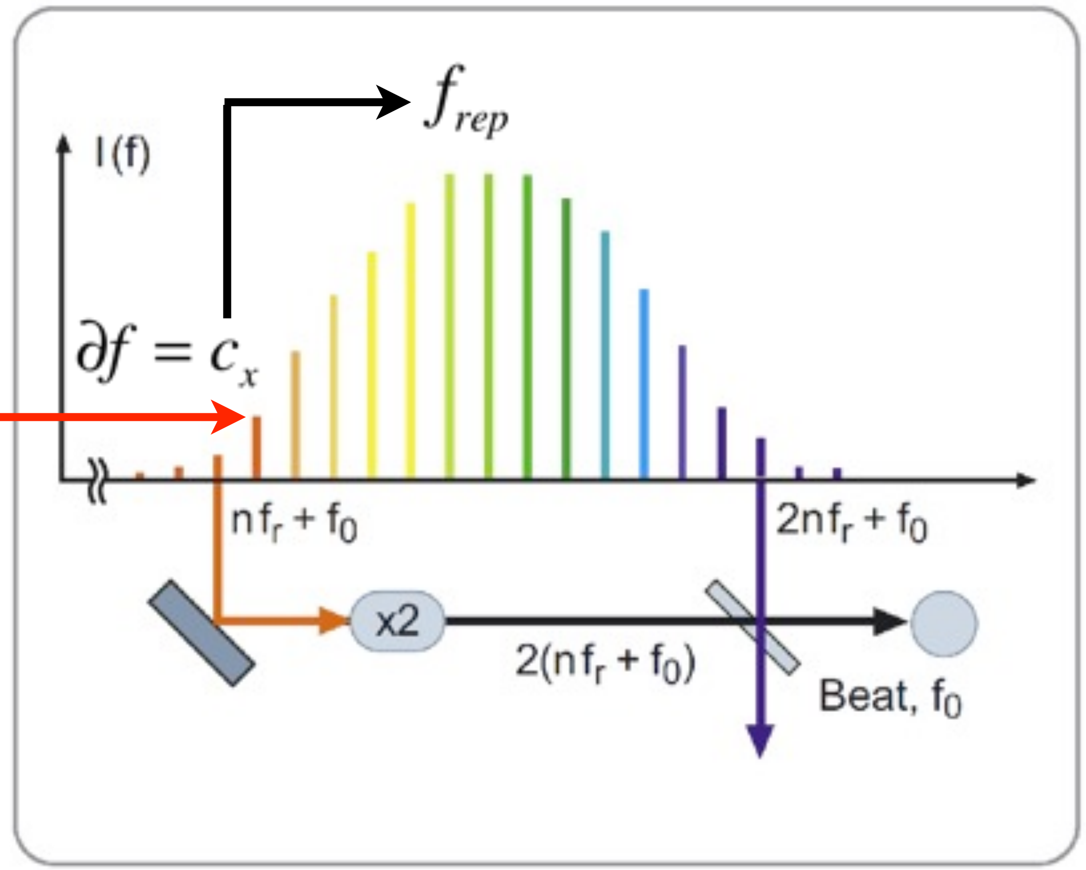
Application: Frequency Stab.

- Application of optical pulses for Phase-Cal. in VLBI
- 100 MHZ frequency ref. not 5 MHz for mixer
- direct conversion of 2 + 8 GHz from OFC?
- Inter-technique calibration SLR - VLBI

More OFC-Technique options for VLBI?

RLG as a flywheel for freq. stability

$$\boxed{Q > 10^{12}}$$



∂f = 10 Hz -> 2e-14 (1s)

∂f = 3 Hz -> 6e-15 (1s)

+ surprises

Potential:

- New arena for intra- and inter-technique biases?
- Common clock for VLBI via PTB?
- New challenges for Time Transfer?
- What is in with better space clocks with GNSS?
- Time and frequency; a geodetic observable rather than a adjustment parameter?

Dawn of a new era in space geodesy...?

Photo: U. Schreiber

Wettzell: 15.9.2011