A Campus-Wide Time Synchronization System- „BuTiS"

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BuTiS – Bunchphase-Timing-System

GSI

System Overview

Demands

- Synchronisation of PHELIX Laser with UNILAC or SIS/ESR
- Bunch-to-Bucket Transfer Synchronization between Particle Accelerators
- Distributed RF-Cavity-Synchronisation in FAIR SIS100/300 etc.

Parameters

- Distribution of rf-clock frequency: 200 MHz
- Synchronisation of rf-cavity phases: < 1 degree at 10MHz (=277ps)
- Synchronisation PHELIX and SIS: < 1 ns, distance: 500m

„Bunch-Synchronous" Timing !

Design Goals

- A campus wide time and frequency distribution system:
- Bandwidth: > 1 GHz
- Timing tolerance: < 100 ps/km

BuTiS – Bunchphase-Timing-System

Distribution Aspects of BuTiS:

A double reference frequency generates phase coherent sinewaves

- Frequencies will be 10 MHz and 200 MHz
- Frequency stability better than 10^{-9}
- Time information can be added as coded stream
- These signals will be distributed via a campus-wide network

➢ *The precision signals will be available throughout the GSI campus !*

➢ *Any locations in the campus can be time synchronized and frequency locked*

Lowcost solution:

The propagation delay and the temperature drift is neither measured nor corrected.

Absolute time precision: 5 us/km (fixed propagation delay)
+ 150 ps/km * K (temperature drift)

Precision solution A:

Each total path delay will be measured, and the known delay will be numerically corrected.

Absolute time precision: < 100 ps/km + local correction resolution

Precision solution B:

Each path delay will be measured, and the temperature drift is compensated by an optical delay to hold the total delay stable.

Absolute time precision: < 100 ps/km

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To be realized: 100 ps/km propagation delay stability, at 40 K temperature variation

Use of coaxial cable for long runs is ruled out due to temperature coefficients of copper and high signal attenuation!
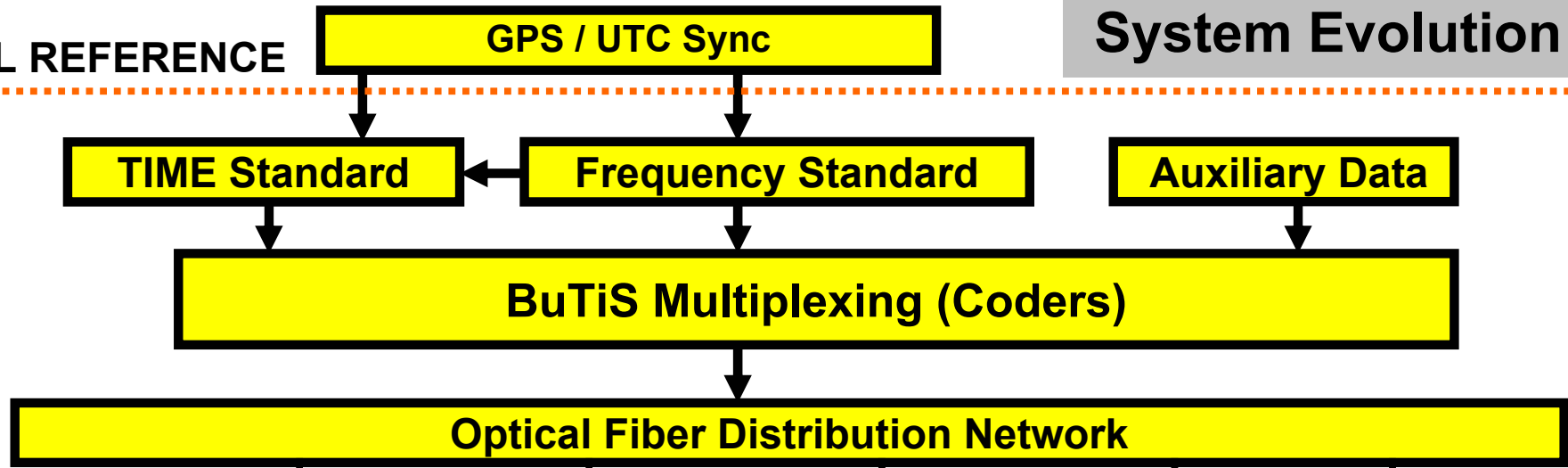
Single Mode Optical Fibers

- **Total delay variation for 40 K temperature change: 6 ns/km (150 ps/km * K), 600 ps/km claimed for PSOF fiber**
- **Propagation delay stabilization necessary to achieve 100ps@1km**
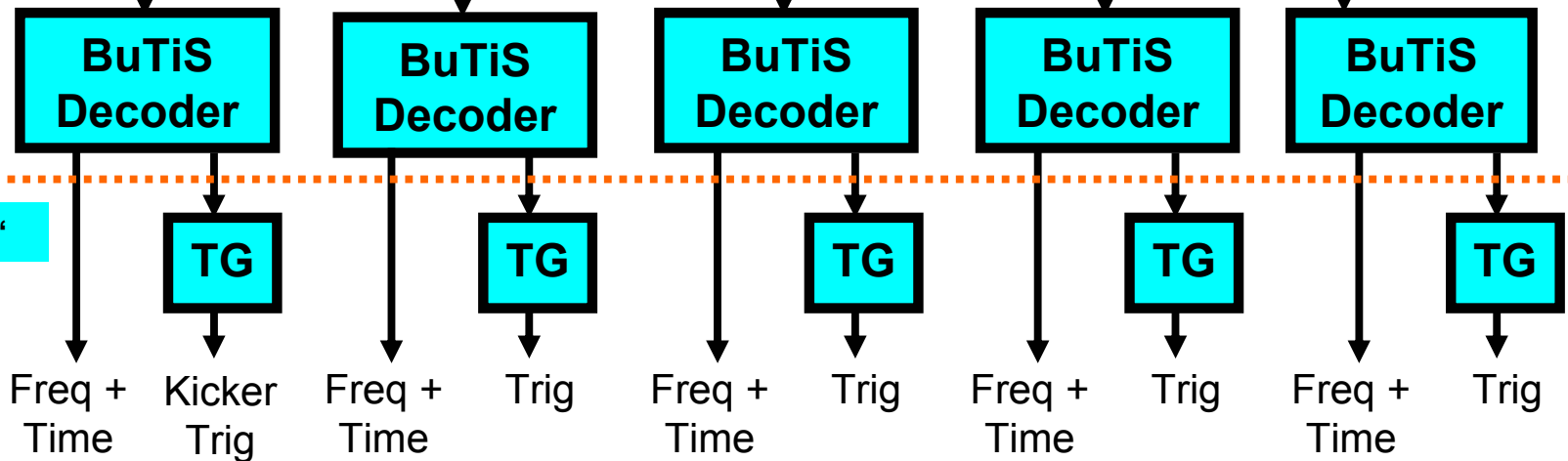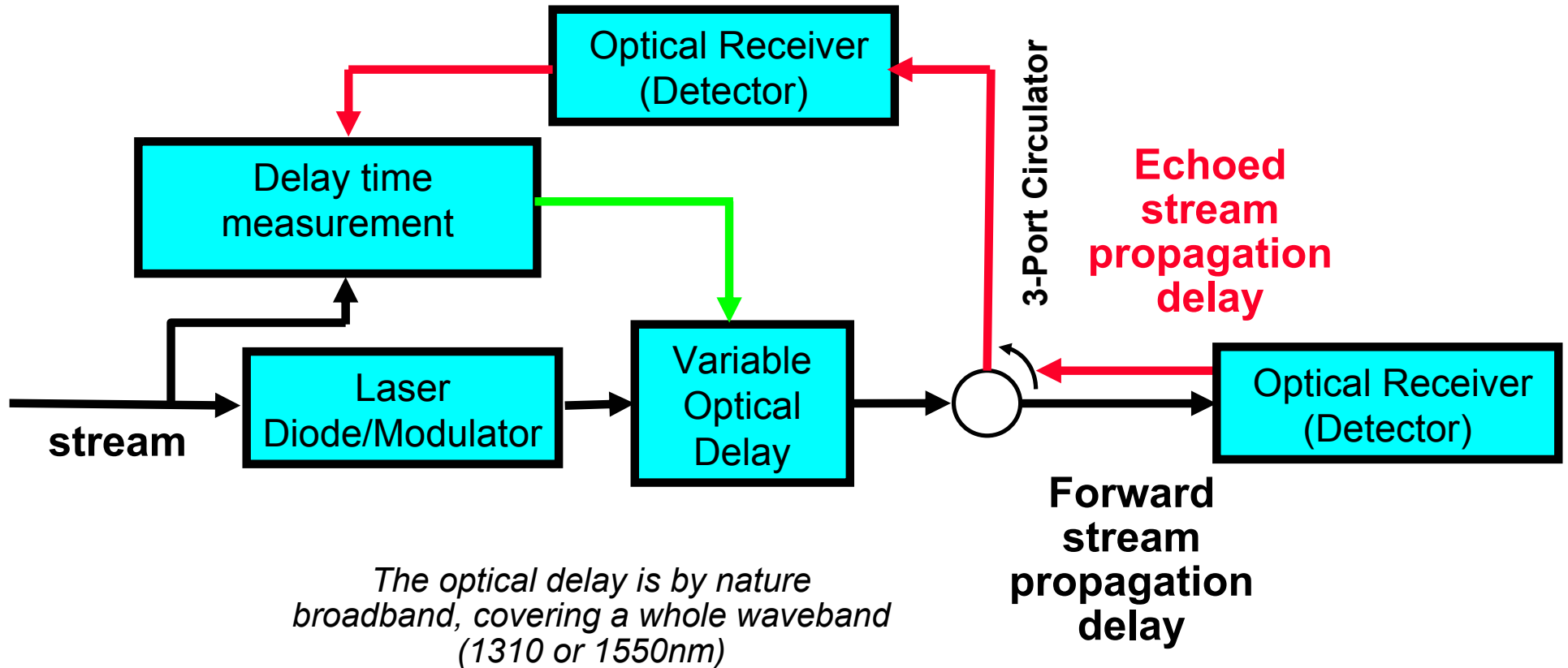- **No EMC interference, low attenuation (0.3 dB/km)**

BuTiS – Bunchphase-Timing-System

GLOBAL REFERENCE

GPS / UTC Sync

System Evolution

TIME Standard ← Frequency Standard | Auxiliary Data

BuTiS Multiplexing (Coders)

Optical Fiber Distribution Network

CAMPUS REFERENCE

| BuTiS Decoder | BuTiS Decoder | BuTiS Decoder | BuTiS Decoder | BuTiS Decoder |

TG=„Timing Generator"

TG | TG | TG | TG | TG

LOCAL REFERENCE

| Freq + Time | Kicker Trig | Freq + Time | Trig | Freq + Time | Trig | Freq + Time | Trig | Freq + Time | Trig |

Propagation delay measurement and stabilization system

The optical delay is by nature broadband, covering a whole waveband (1310 or 1550nm)

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Options of BuTiS System

Additional Channels
- WDM (Wavelength Division Multiplex) – channels can be added within the optical fiber distribution system at any time
- Each additional wavelength can carry 10 GBits/s digital signals, or 10 GHz bandwith analog signals per optical carrier

Bidirectional Operation
The WDM capability offers the ability to send signals in reverse direction – An upstream signal can be sent to the distribution center and redistributed downstream to other targets

GPS Synchronization
The longterm stability of the frequency-/time-reference can be improved by GPS global reference synchronization

Conclusion

- A „BuTiS"- like system will surely be needed for FAIR accelerators
- BuTiS has „campus-wide" capabilities for realtime synchronization and timing to 100 ps/km
- The distributed 10 MHz clock is a common standard frequency
- The 200 MHz clock is coherent to the 10 MHz clock.
- The construction of the 10/200 MHz coherent clock generator can be used to lock other required clock frequencies to the reference, as well.
- At present conceptual design stage, system modifications can be realized without too costly modifications
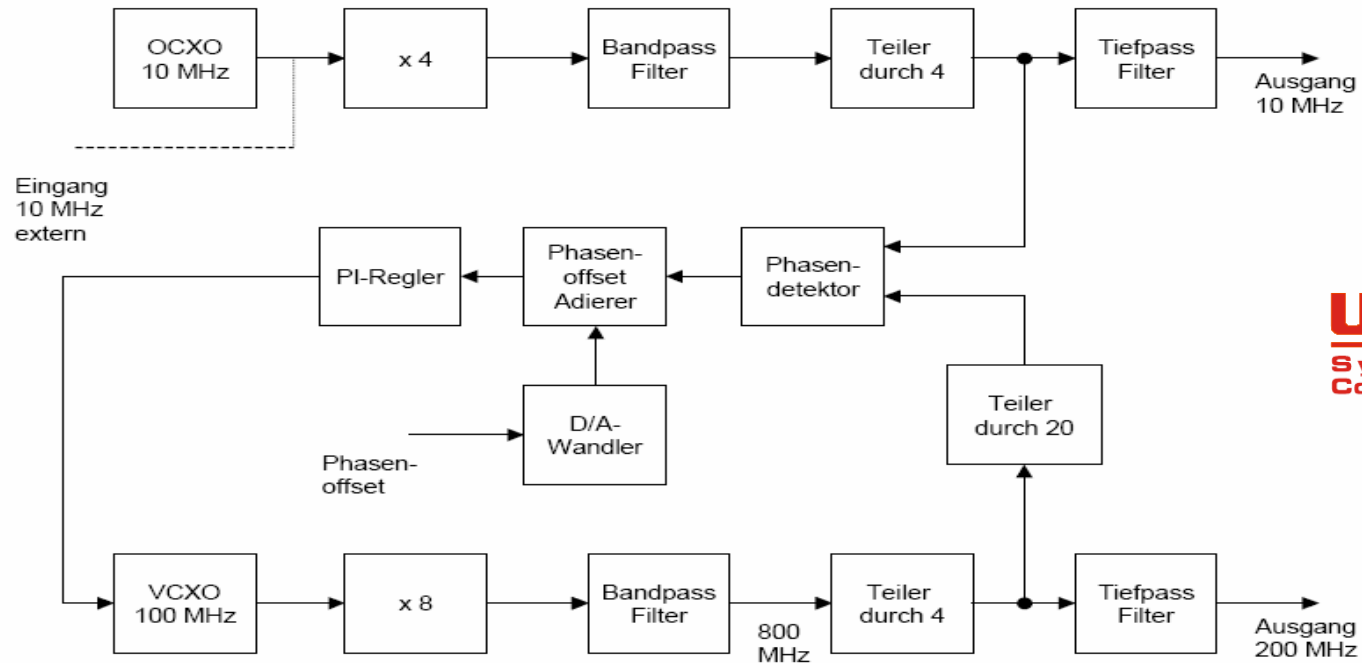
Yes, we´re open:

Participation is welcome !

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APPENDIX

Coherent reference generator 10/200 MHz

Optical Fiber RF-Links

- **Broadband analog „optical rf-links" link GSM basestations**
- **Available from stock**
- **Bandwidth 100kHz…2GHz or more, linear**
- **Available at any level:**
  devices, modules, boards, link stations, distribution systems
- **Also bidirectional analog links on market:**
  2 x 2GHz over the same fiber using 1310nm / 1550nm WDM
- *Capability to transmit digital signals, as well*
- *No need to develop new electronic link components*
- *Available for 1310nm or 1550nm wavelength*

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The First Step - SIS18 and Phelix Synchronisation

76MHz Clock → Optical-RF-Link Transmitter → **Downstream 1310 nm** → Optical-RF-Link Receiver → 76MHz Clock → *to Laser-Frontend*

Lasertrigger → Optical-RF-Link Transmitter → Optical-RF-Link Receiver → Lasertrigger

From SIS-TG

upstream sync is optional

76MHz Clock ← Optical-RF-Link Receiver ← **Upstream 1310 nm** ← Optical-RF-Link Transmitter ← 76MHz Clock

to SIS-DDS

From Laser-Frontend

SIS 18

PHELIX