

Laser Synchronization with MicroTCA

MicroTCA.4 for Femtosecond-stable Optical Synchronization Systems at FLASH, XFEL and more.



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DESY MSK group

6th MicroTCA Workshop
for Industry and Research

DESY, Hamburg, Germany
December 6, 2017

Overview

> Introduction / Motivation

- Lasers at FELs
- Optical Synchronization Systems

> Laser Synchronization

- How to Synchronize a Laser
- MicroTCA Components for Laser Synchronization

Motivation - Lasers at FELs (here: FLASH)

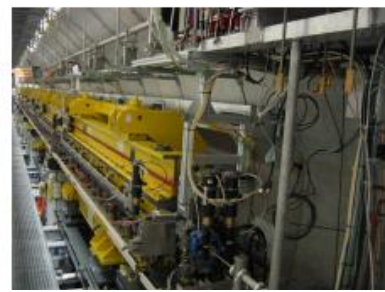
> 3rd harmonic sc module 3.9 GHz



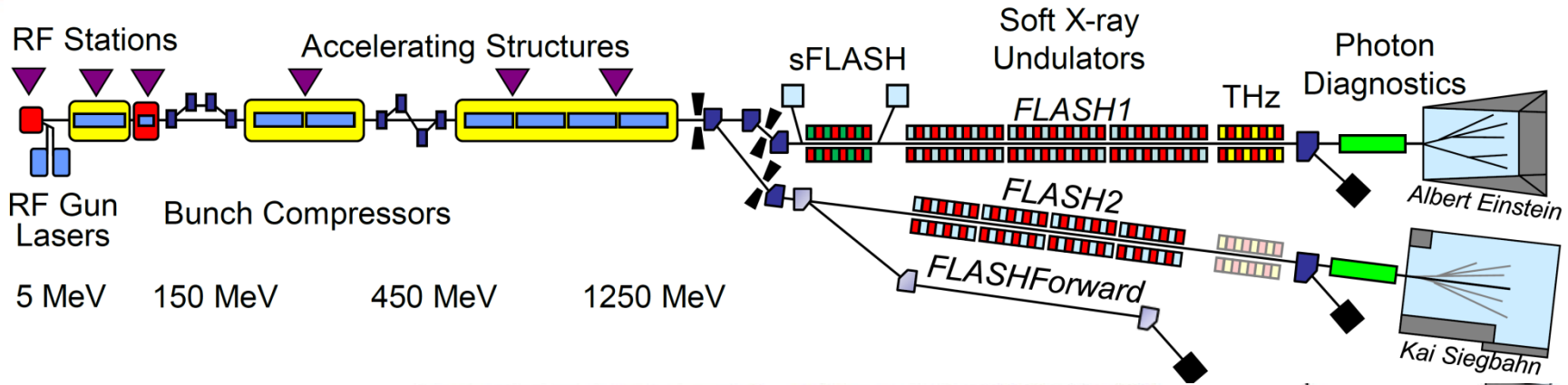
> TESLA type superconducting accelerating modules 1.3 GHz



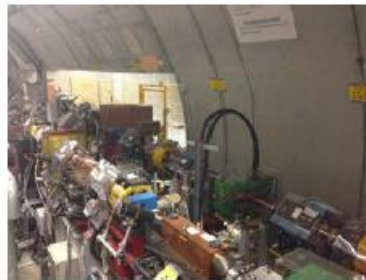
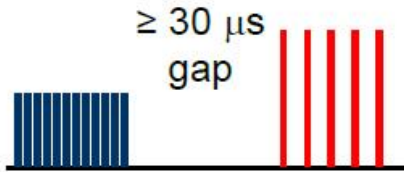
> FLASH1 fixed gap undulators



> FLASH1 Experimental Hall



2 lasers



> Extraction to FLASH2



> FLASH2 variable gap undulators



> FLASH2 Experimental Hall

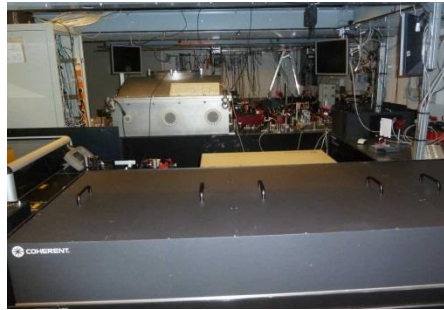
FEL Experiments

Motivation - Lasers at FELs (here: FLASH)

Master Laser Oscillator



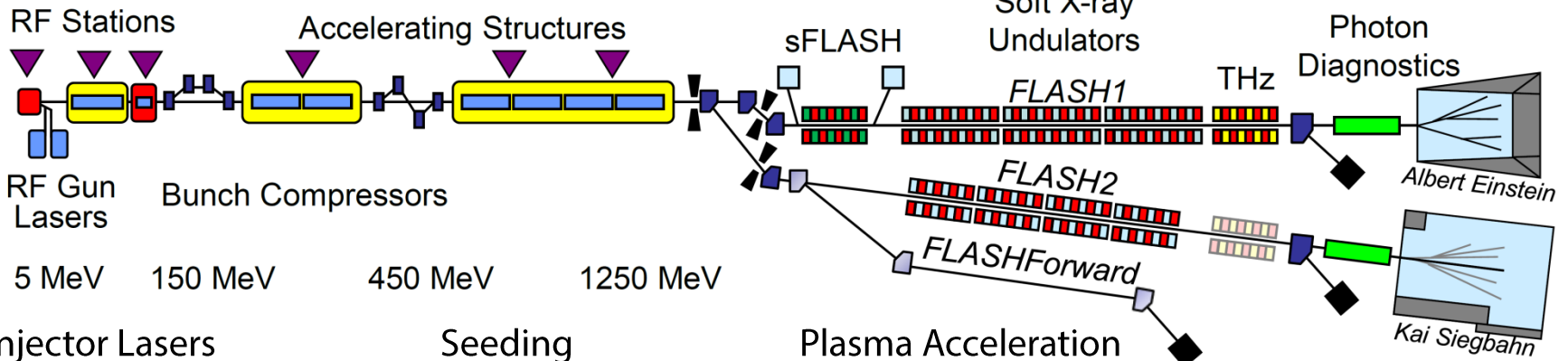
sFLASH



EO Diagnostics



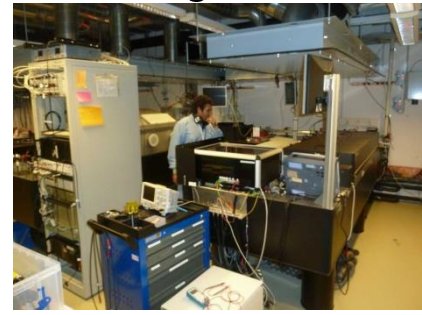
Pump-Probe FL1



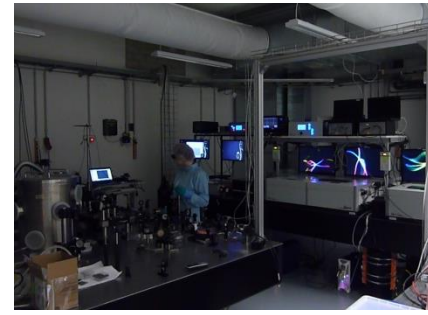
Injector Lasers



Seeding



Plasma Acceleration

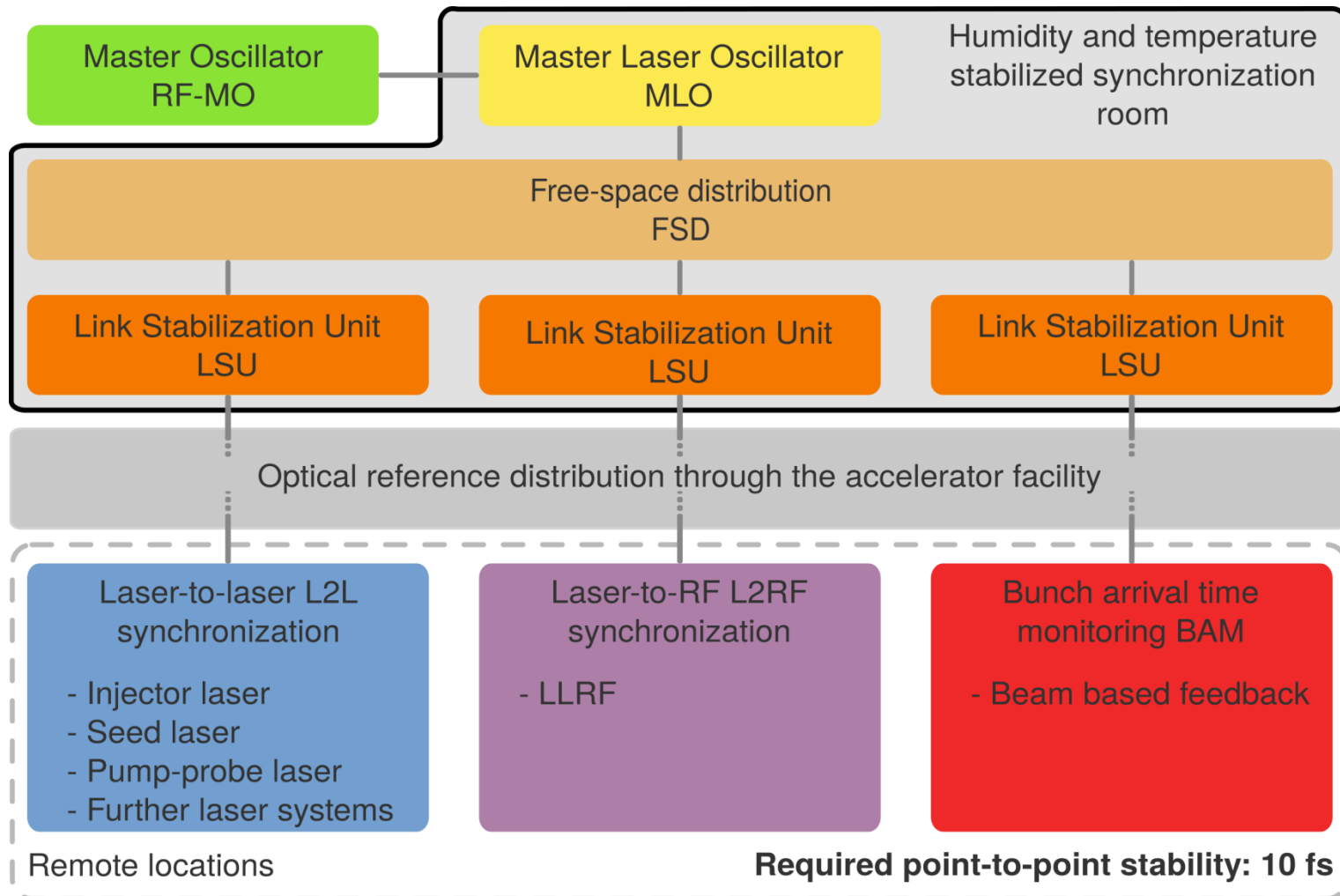


Pump-Probe FL2



Optical Synchronization System with Endstations

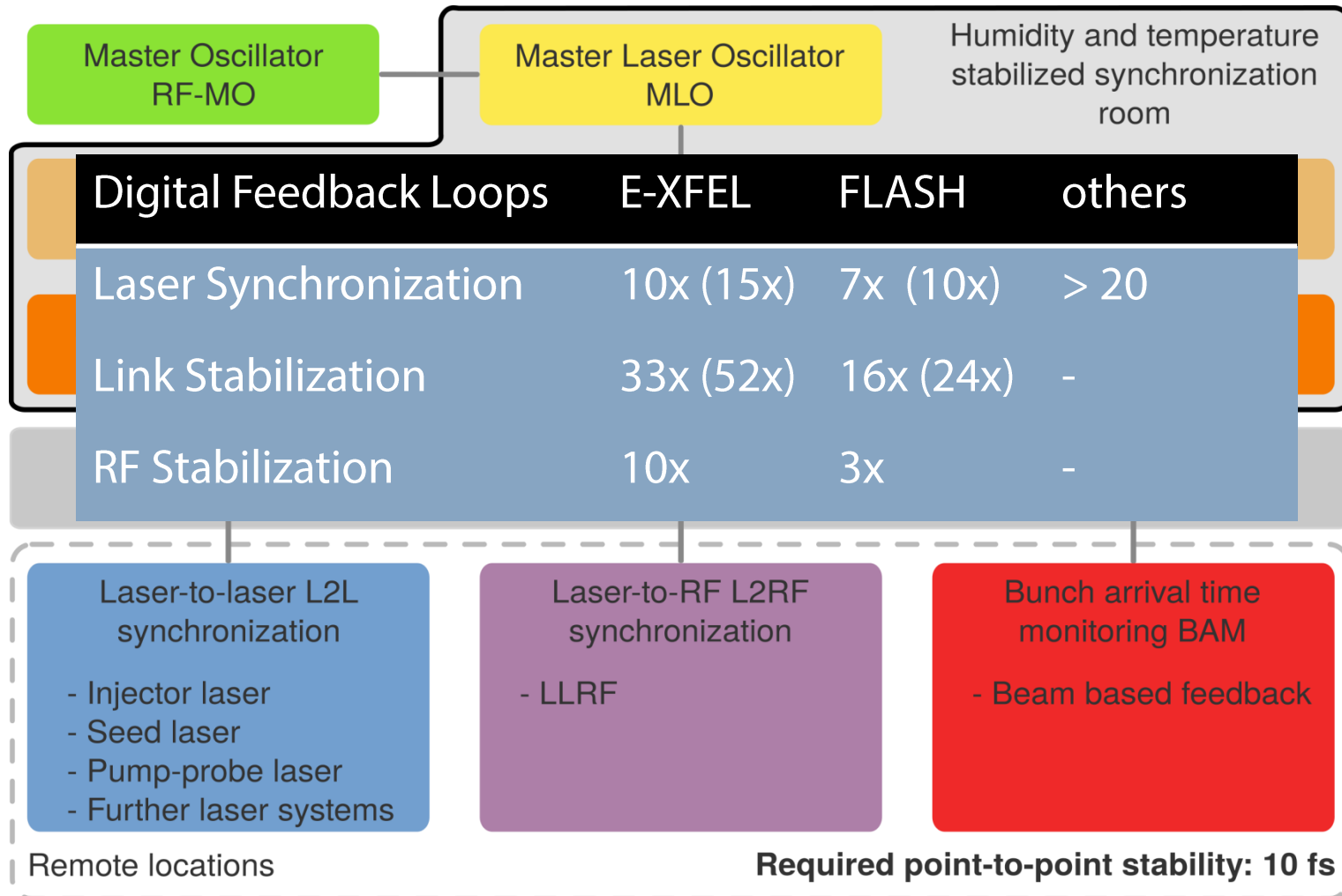
Goal: Provide a global, femtosecond stable reference for the synchronization of timing-critical systems of the accelerator



Courtesy
C. Sydlo

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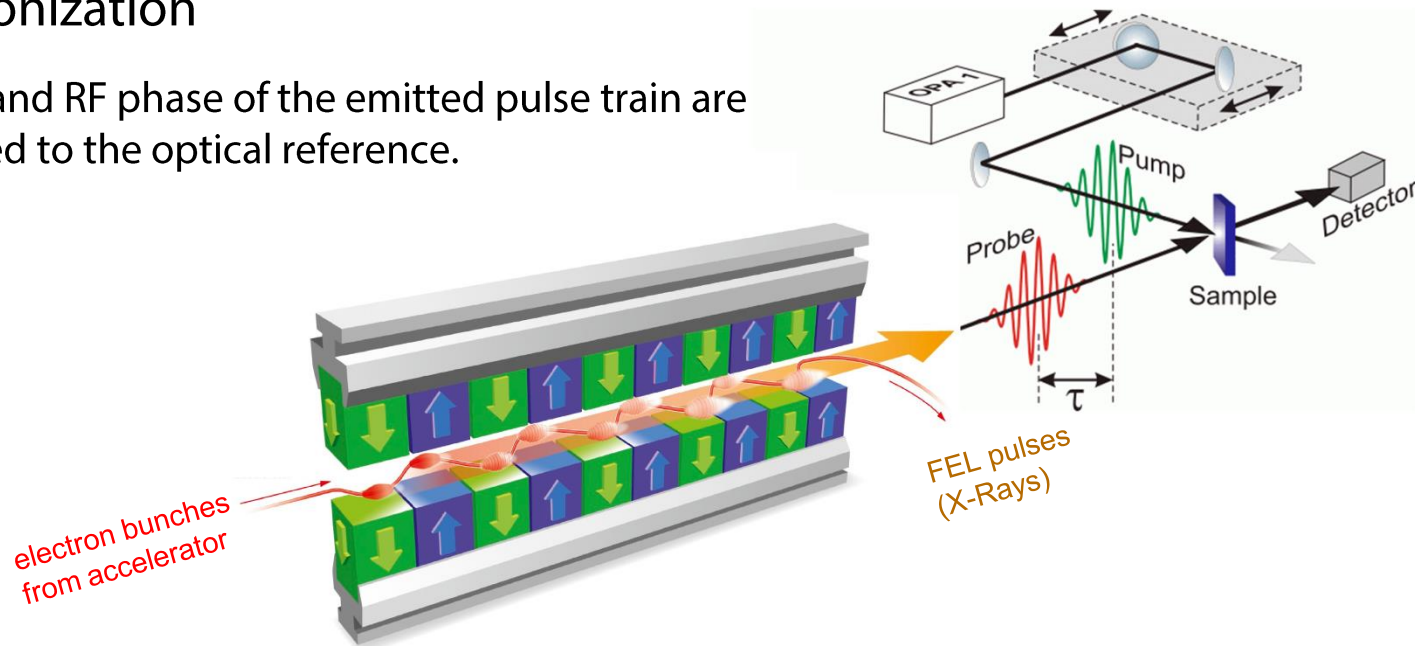
Courtesy
C. Sydlo

Motivation: Time-resolved Pump-Probe experiments

Desired time resolution of user experiments is often in the fs range

> Laser synchronization

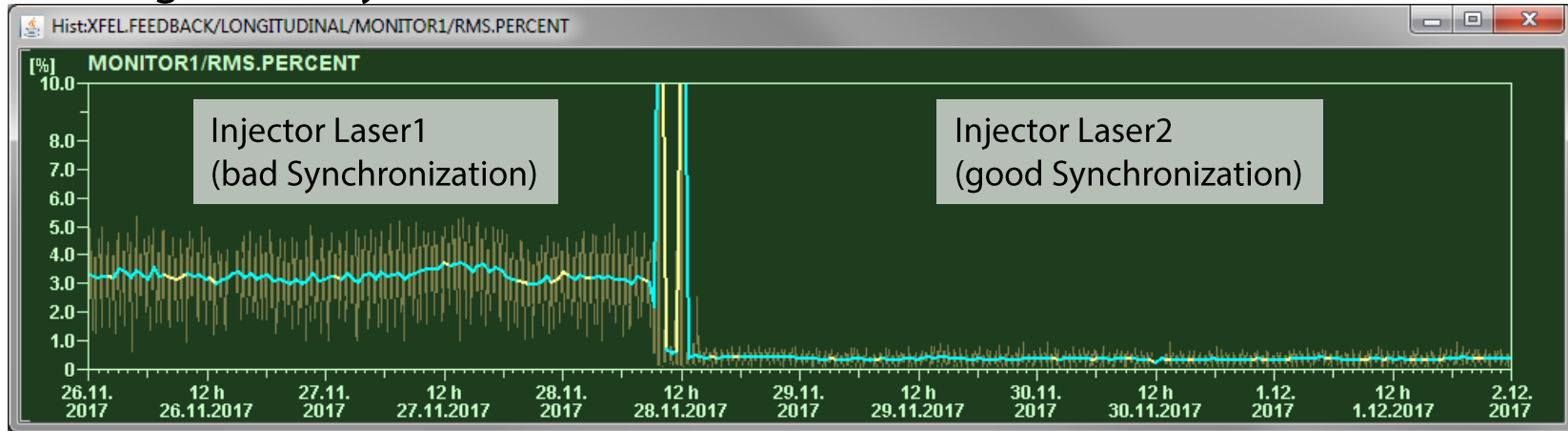
- Frequency and RF phase of the emitted pulse train are synchronized to the optical reference.



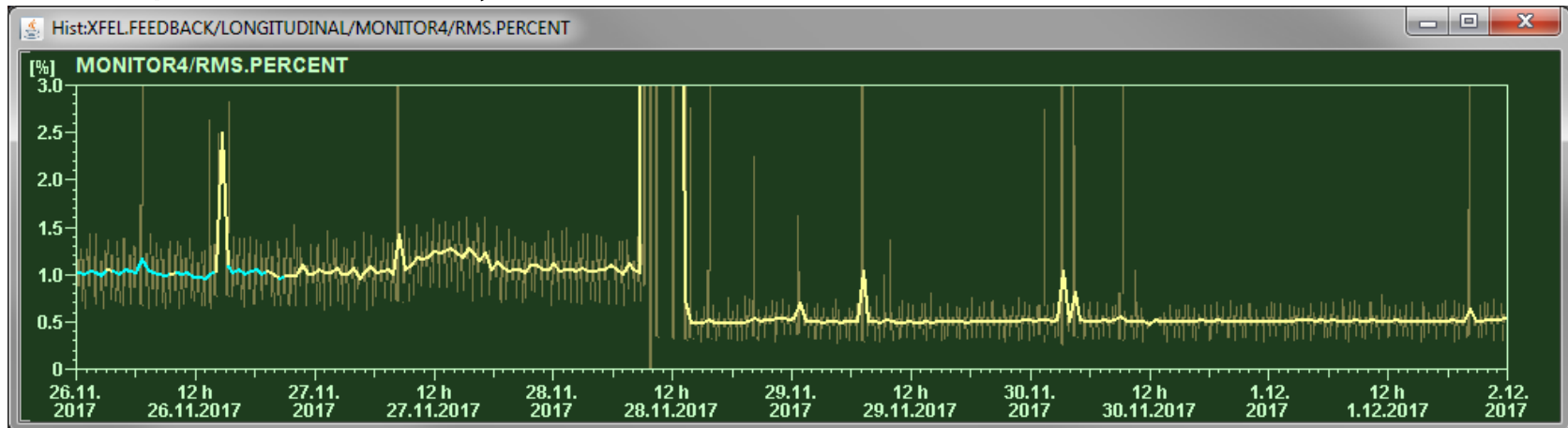
- Injector
- Pump-Probe
- FEL Seeding
- Plasma acceleration

Injector Laser Sync at E-XFEL

> Charge stability

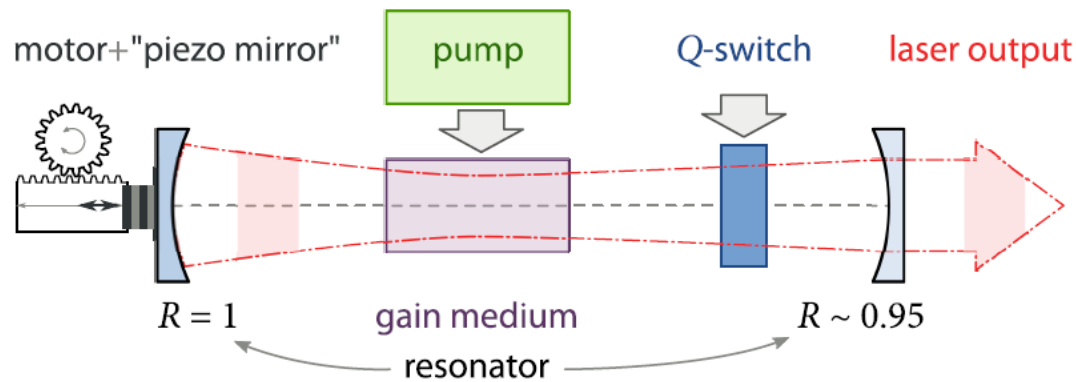


> Compression stability



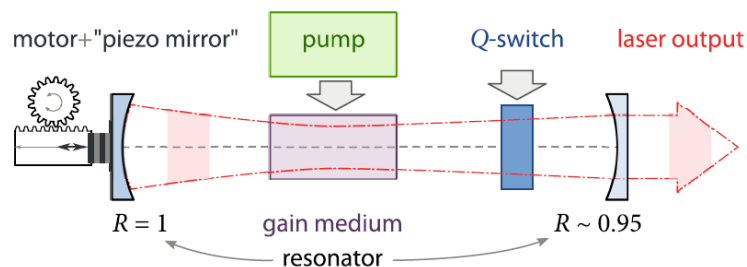
How to Synchronize a Laser

- Laser resonator needs **actuator** to change optical length → move a mirror
 - Piezo stacks for fast control: usually a few kHz bandwidth, μm range
 - Stepper motor or piezo driven delay stage for slow, coarse tuning
 - Temperature variation for coarse tuning (mostly driven by GPIO signals to laser controller)

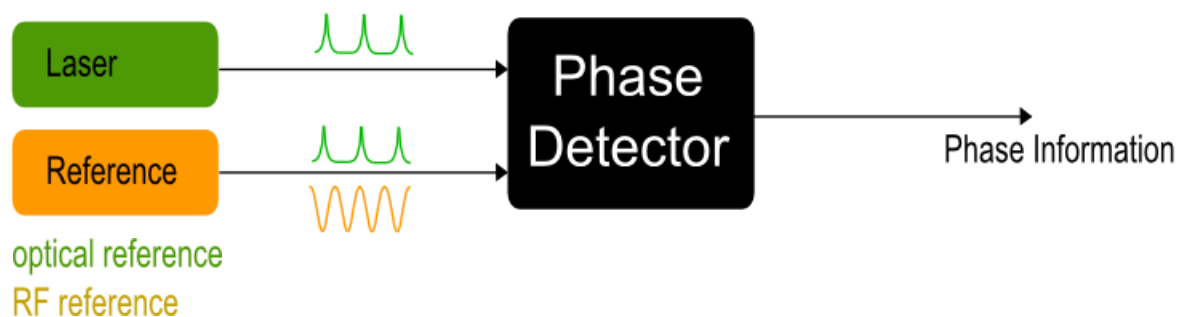


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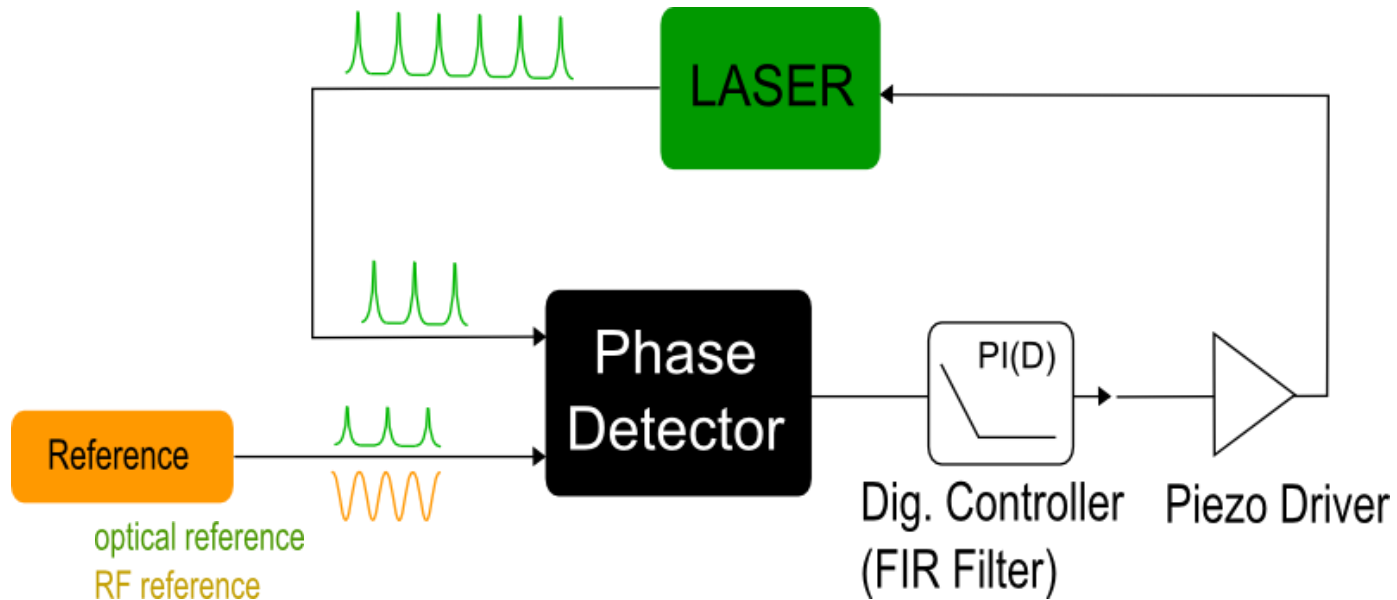


- Need **reference signal** and **phase detector** to measure the deviation



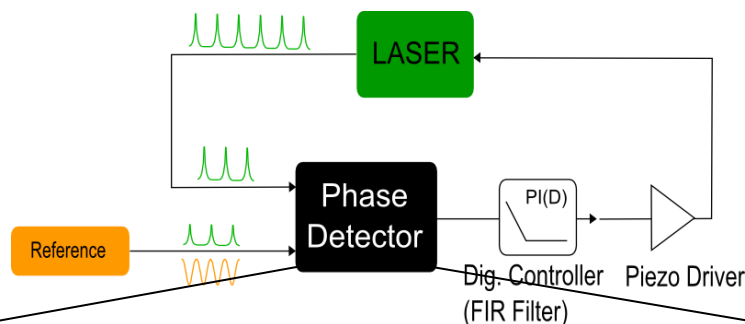
How to Synchronize a Laser

- Build a Feedback Loop to lock the laser (RF-)phase to the reference → PLL



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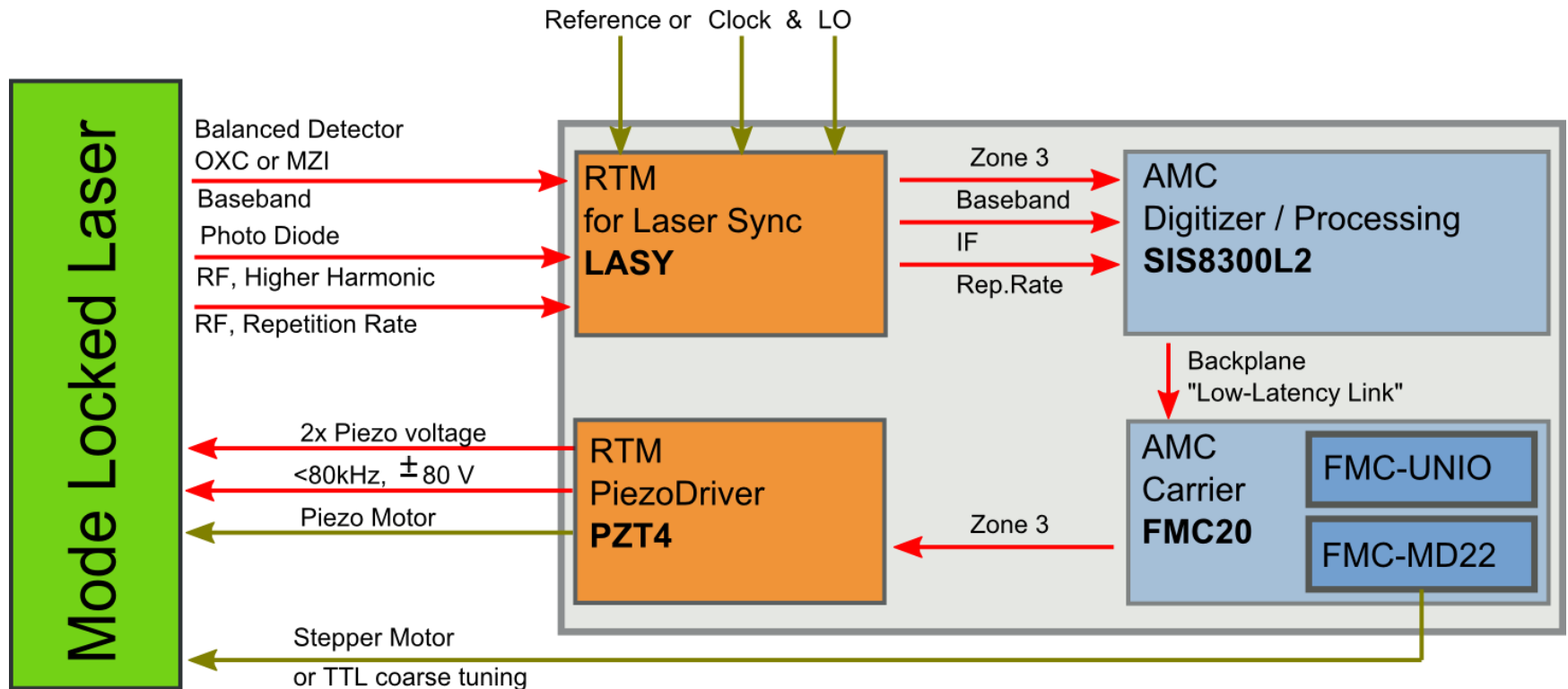
Scheme	Method	Processing	Algorithm (FPGA)
Fundamental Frequency (1. harmonic)	Direct Conversion <i>PFA*</i>	Direct Sampling (non-IQ)	IQ -> Phase
Laser RF Lock (1.3 GHz harmonic)	Direct Conversion Downconversion <i>PFA* + Mixer</i>	Non-IQ sampling of Intermediate Freq.	IQ -> Phase
Laser Optical Lock (for opt. Reference)	Balanced Optical Cross- Correlator <i>Balanced Detector</i>	Baseband Sampling	-
Laser RF Lock (Electro-optical amplitude modulation)	Laser2RF Phase Detector <i>Photodiode</i>	Direct Sampling (non-IQ)	IQ -> Amplitude

*) PFA = Photodiode Filter Amplifier

MicroTCA Components for Laser Synchronization

MTCA Setups for Laser Synchronization

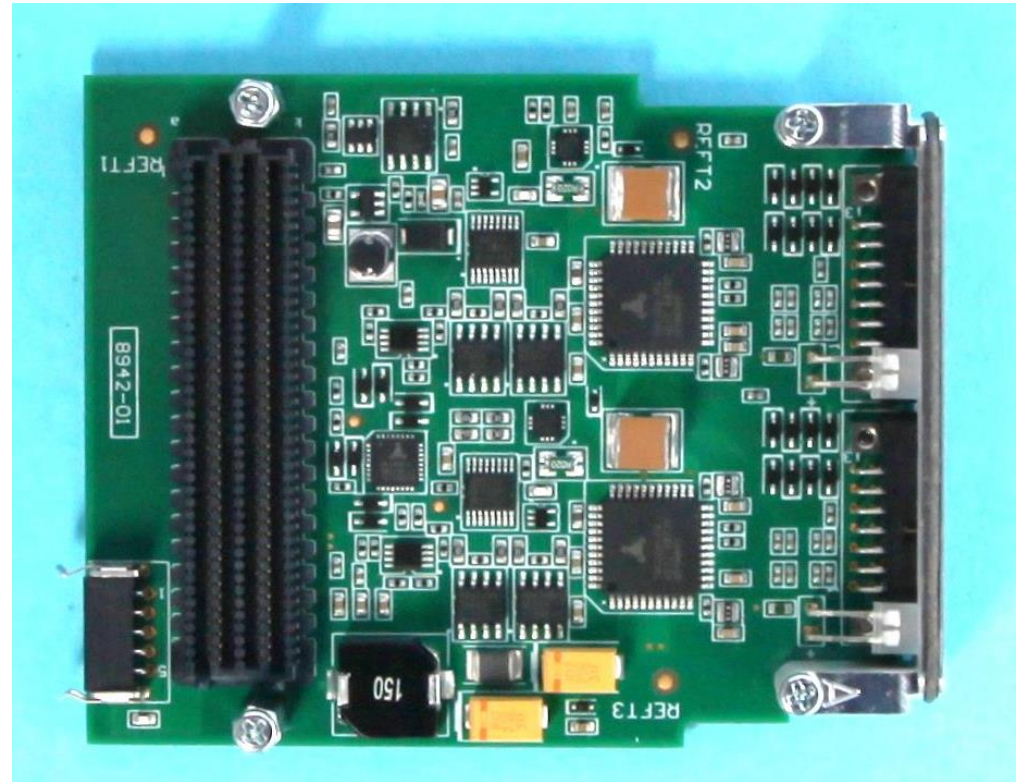
Simplified block diagram



Motor Driver-FMC

DFMC-MD22

- Stepper Motor Driver
- 2 x Channel
- End switch readout
- Encoder readout

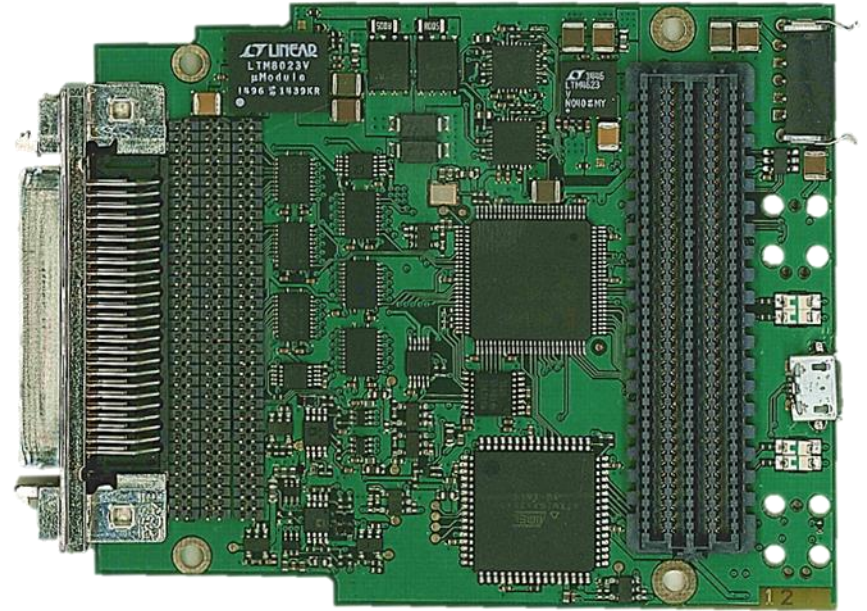


Available at CAEN ELS S.R.L.

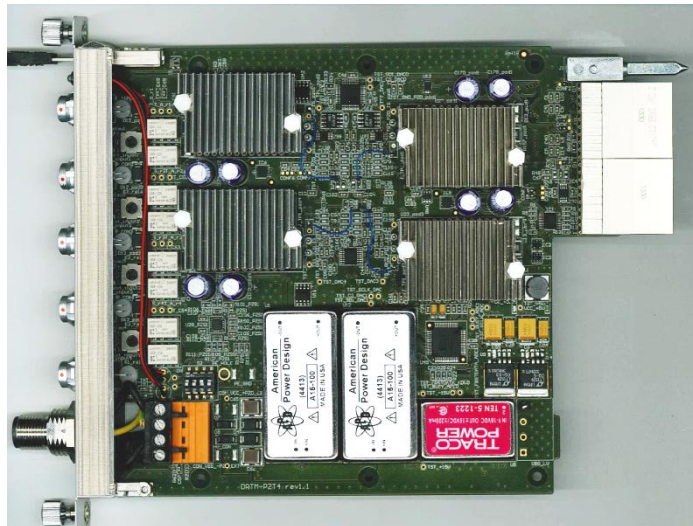
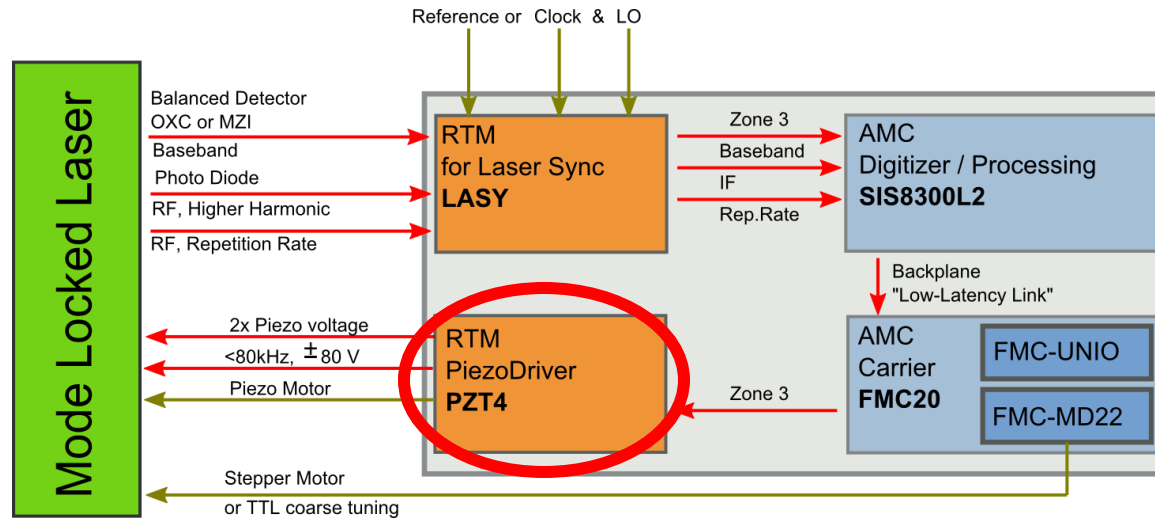
GPIO-FMC

DFMC-UNIO (or UNI-IO)

- On-board microcontroller and CPLD
- Up to 48 general-purpose digital IO pins.
- In or Out configurable
- 5 V or 3.3 V configurable
- Optional Special Functions:
 - 2x Laser Shutter Control
 - 2x DAC (12 bit, 0-5 V, 50 mA)
 - 2x ADC (12 bit)
 - 2 x 2 pins useable as two independent power channels
 - 4 pins useable as standard UART (12V levels)



MTCA Setups for Laser Synchronization

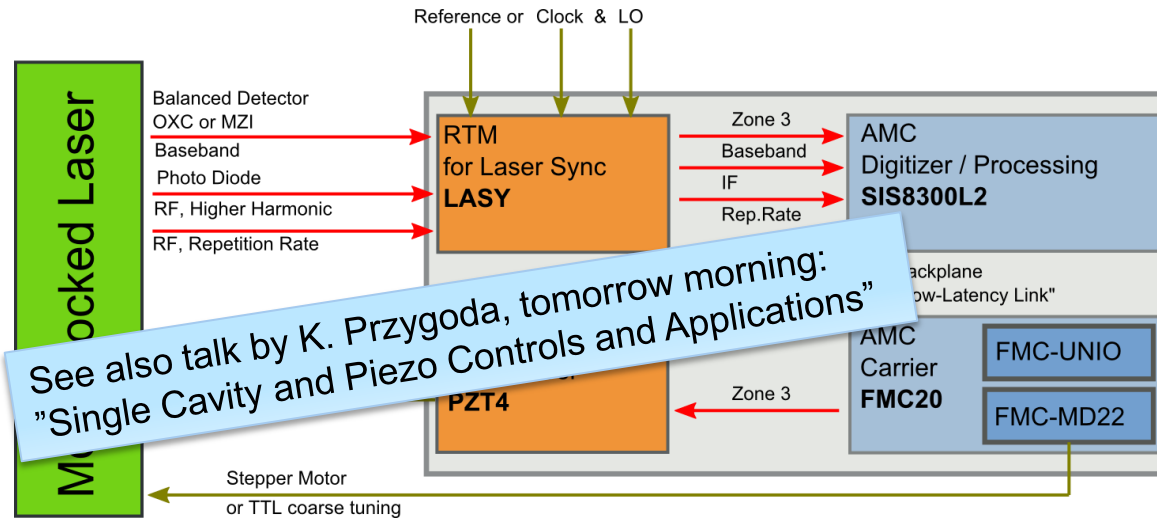


DRTM-PZT4 (PRTM-PZDR4)

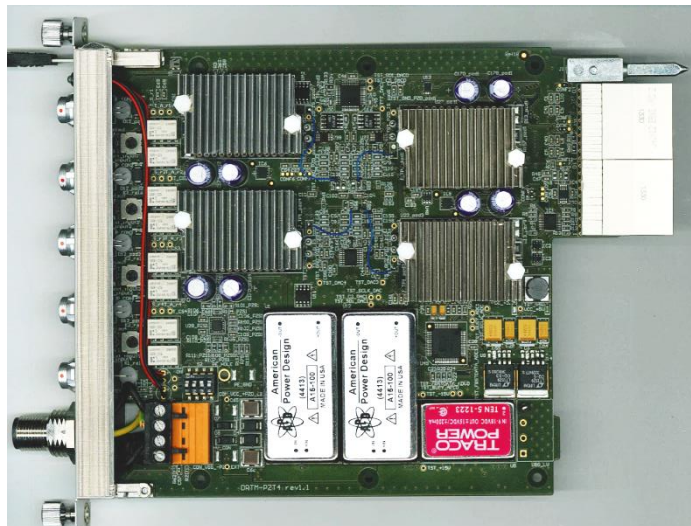
- 4 x Channel
- HV-Supply
 - On-board $\pm 100\text{V}$
 - Ext. input
- On-board DACs
- Monitoring ADCs
- Interlock support
- Metal-cover
- Zone 3: D1.0 / D1.1 / D1.2

Soon available at Piezotechnik Dr. Jänker GmbH

MTCA Setups for Laser Synchronization



See also talk by K. Przygoda, tomorrow morning:
"Single Cavity and Piezo Controls and Applications"

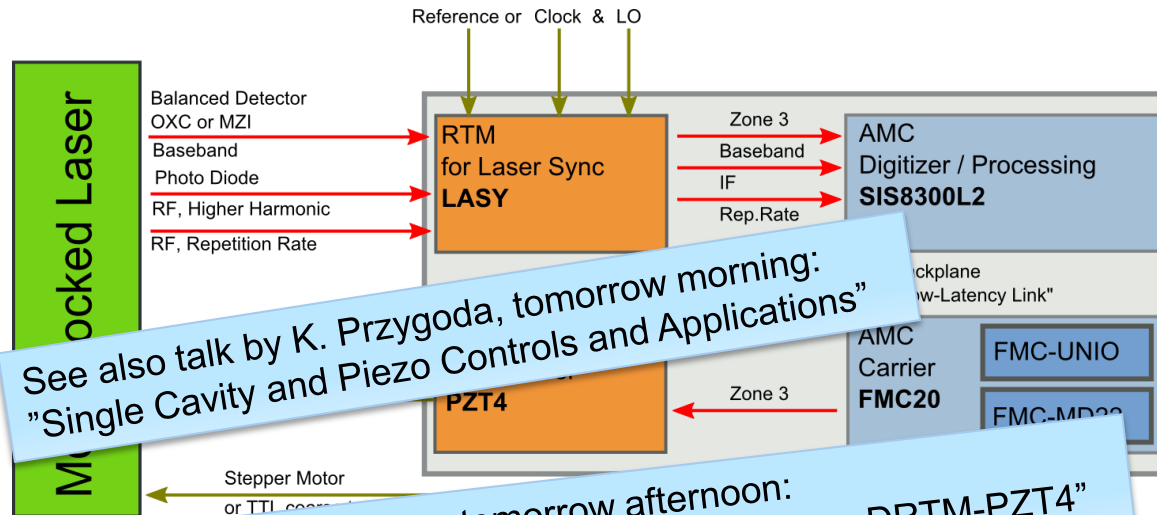


DRTM-PZT4 (PRTM-PZDR4)

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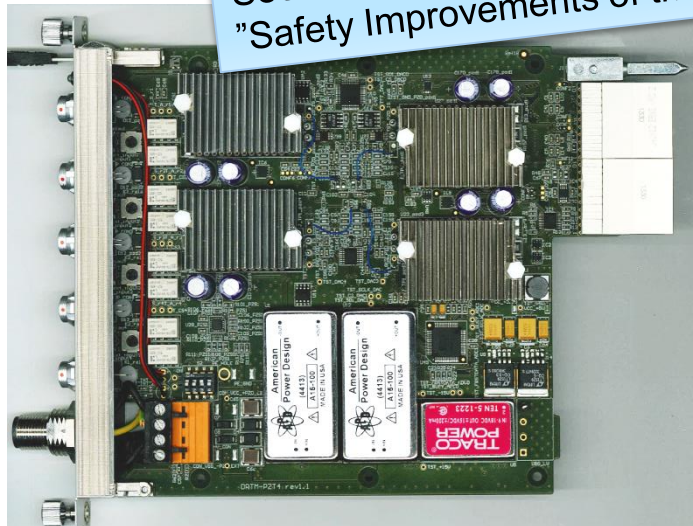
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MTCA Setups for Laser Synchronization



See also talk by K. Przygoda, tomorrow morning:
"Single Cavity and Piezo Controls and Applications"

See also talk by M. Fenner, tomorrow afternoon:
"Safety Improvements of the MicroTCA Piezo Driver DRTM-PZT4"

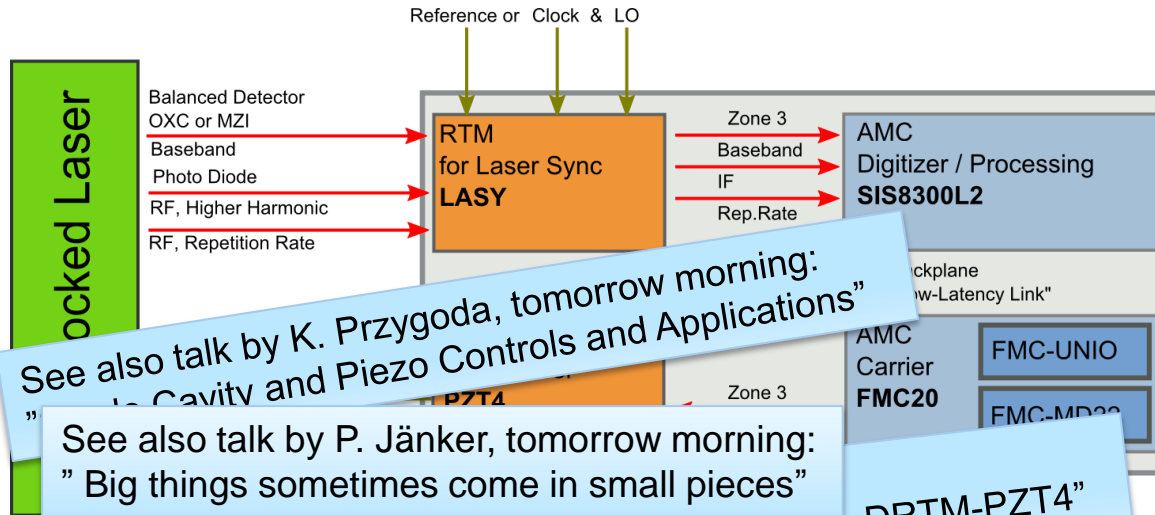


DRTM-PZT4 (PRTM-PZDR4)

- 4 x Channel
- HV-Supply
 - On-board ± 100 V
 - Ext. input
- On-board DACs
- Monitoring ADCs
- Interlock support
- Metal-cover
- Zone 3: D1.0 / D1.1 / D1.2

Soon available at Piezotechnik Dr. Jänker GmbH

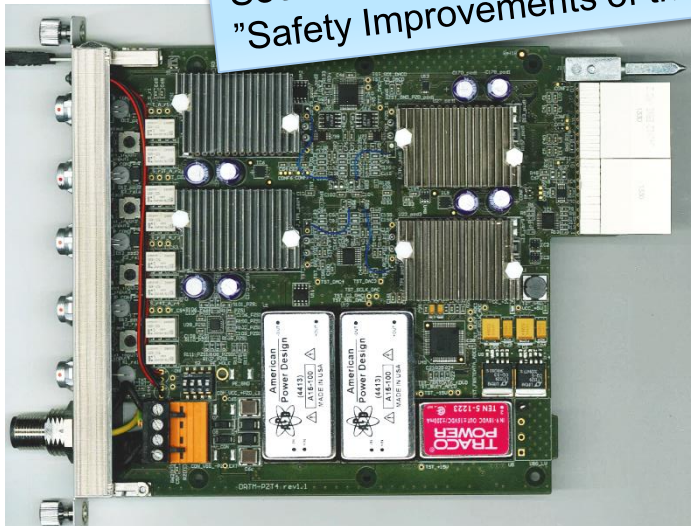
MTCA Setups for Laser Synchronization



See also talk by K. Przygoda, tomorrow morning:
"Cavity and Piezo Controls and Applications"

See also talk by P. Jänker, tomorrow morning:
"Big things sometimes come in small pieces"

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"Safety Improvements of the MicroTCA Piezo Driver DRTM-PZT4"

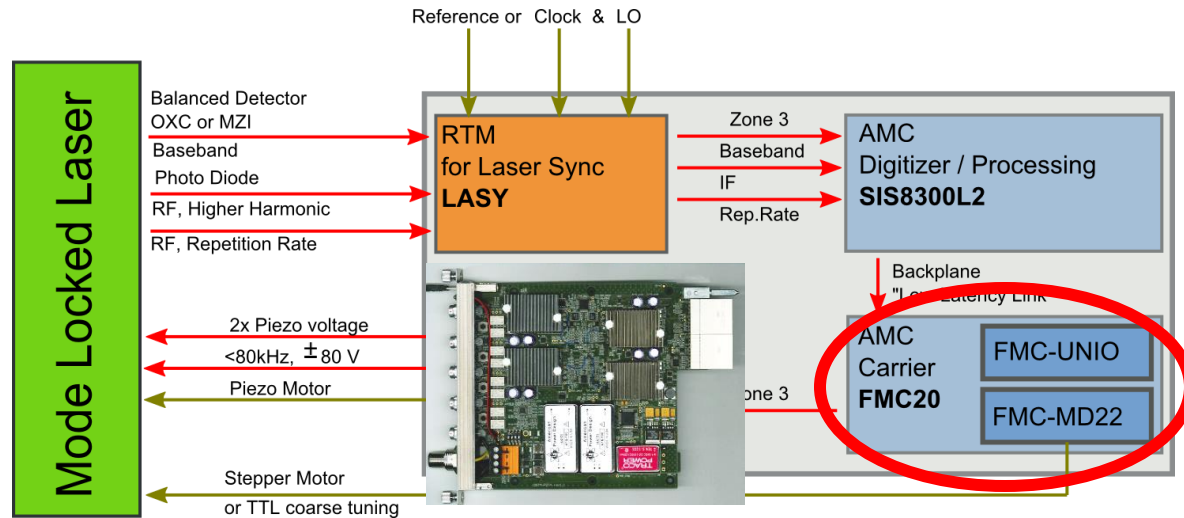


DRTM-PZT4 (PRTM-PZDR4)

- 4 x Channel
- HV-Supply
 - On-board $\pm 100V$
 - Ext. input
- On-board DACs
- Monitoring ADCs
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MTCA Setups for Laser Synchronization

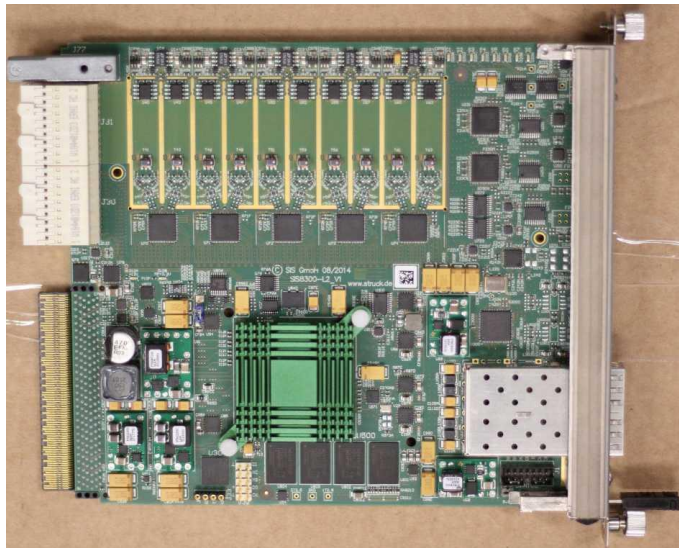
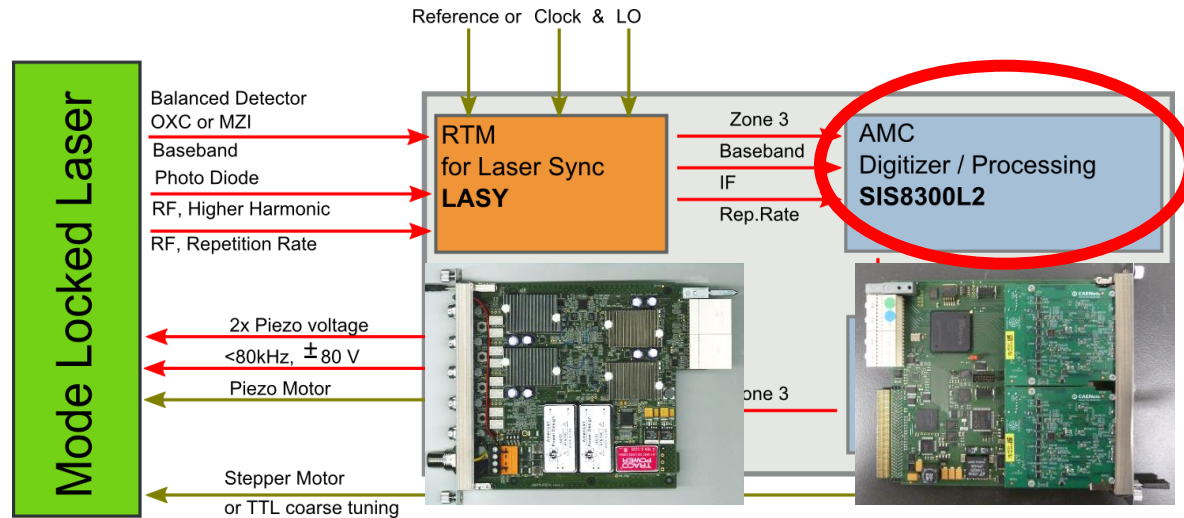


DAMC-FMC20

- Dual FMC Carrier
- Processing: Spartan 6 (LX150)
- Communication: Spartan 6 (LX45)
- 2 x FMC (HPC/LPC)
- Zone 3: D1.0

Available at CAEN ELS S.R.L.

MTCA Setups for Laser Synchronization

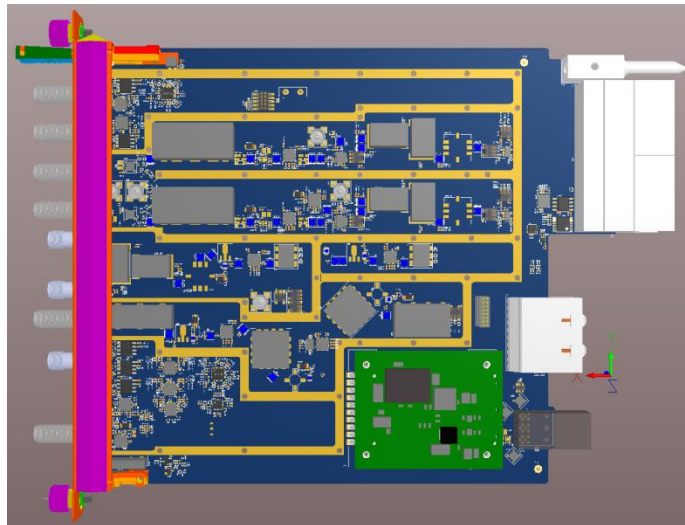
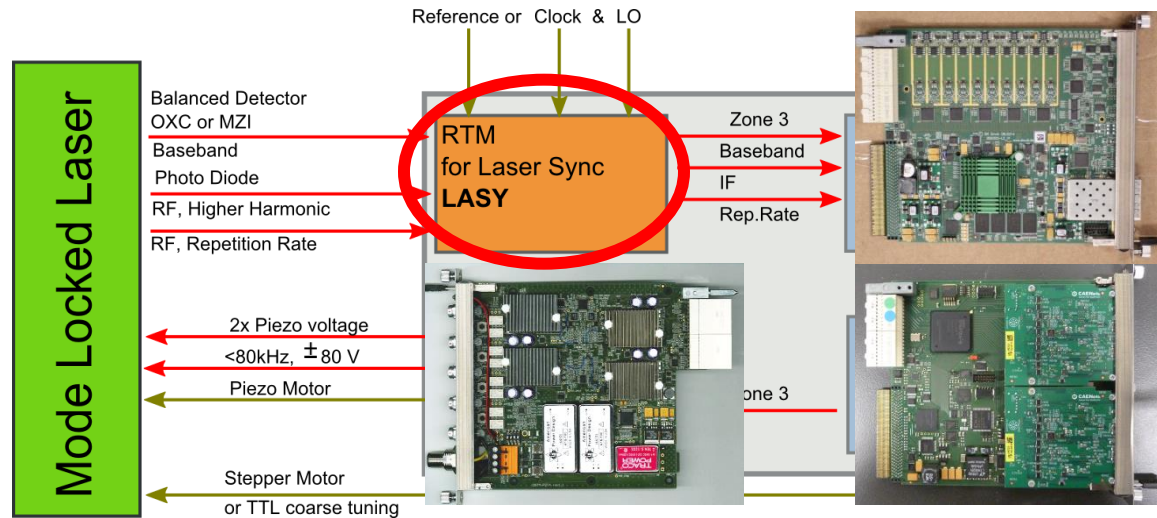


AMC SIS8300L2

- 10 x ADC
 - 16 bit
 - 125 MSPS
 - DC or AC coupled
 - Assembly variants for BW (up to 340 MHz)
- 2 x DAC
 - 16 bit
- FPGA: Virtex 6
- Zone 3: A1.0, A1.0C or A1.1CO

Available at Struck Innovative Systeme GmbH

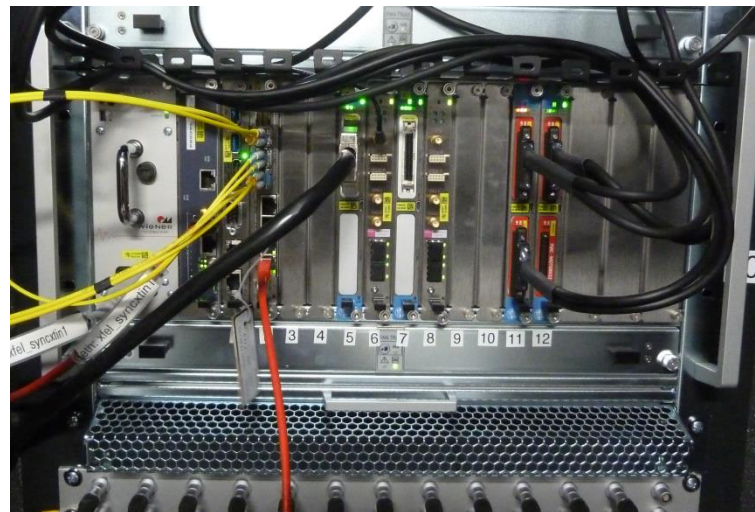
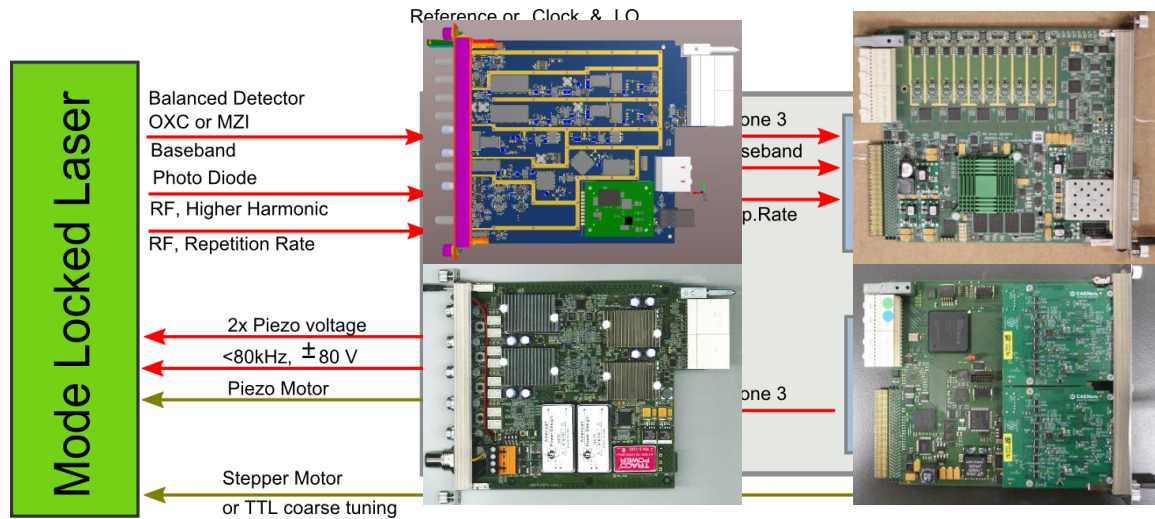
MTCA Setups for Laser Synchronization



DRTM-LASY (new development)

- Downconverter
- Reference tracking for eliminating LO and Clk drifts
- 2-tone calibration for removing channel-to-channel variations
- Low noise baseband channels for cross-correlator
- Low noise direct sampling channels
- Low noise L2RF channel
- Photodiode power supply
- Carrier for signal generation mezzanine (LO, Clk, 2nd tone calibration signal)

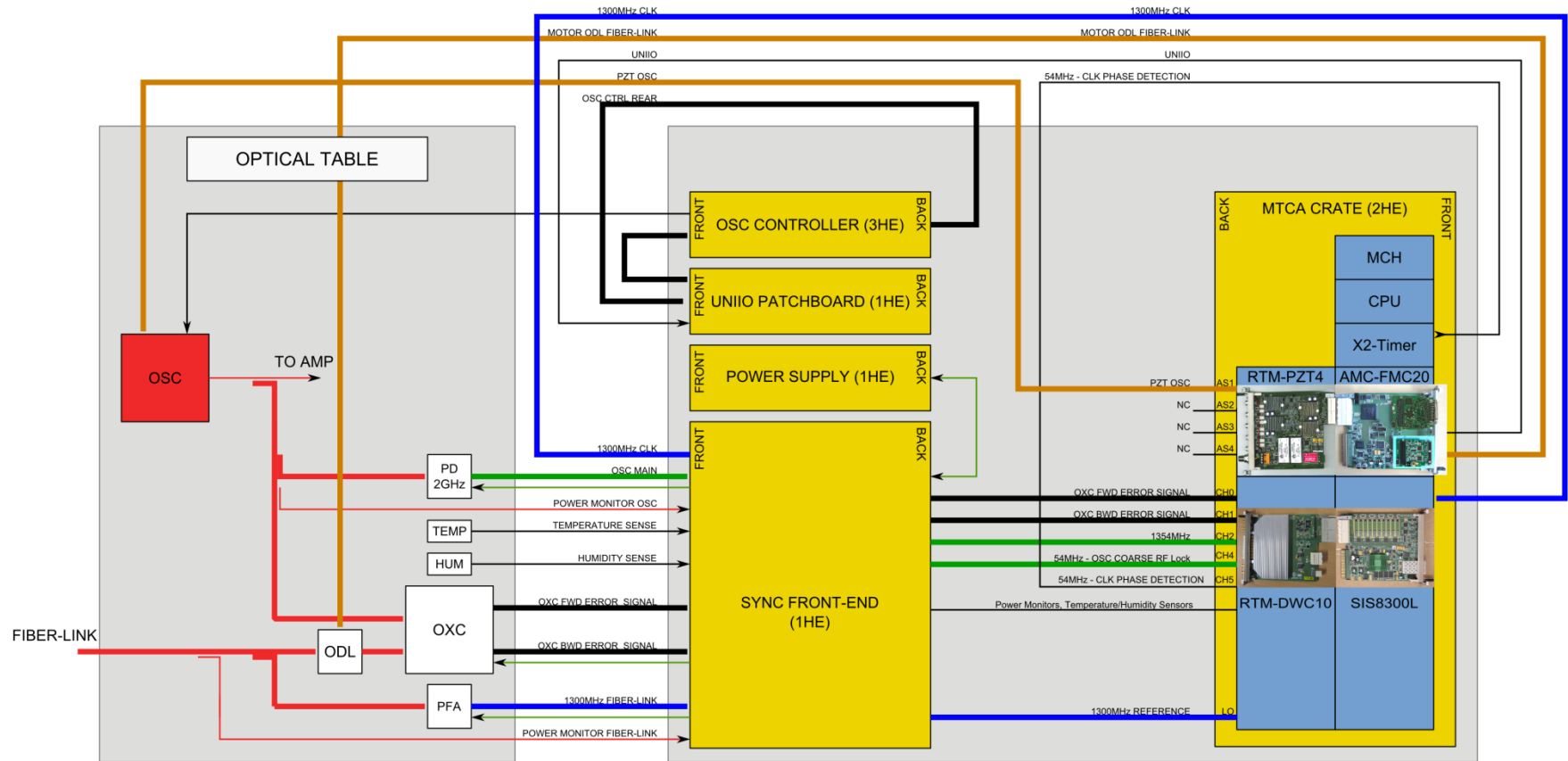
MTCA Setups for Laser Synchronization



MTCA Setups for Laser Synchronization

Full laser sync setup – example: XFEL SASE1 Pump-Probe

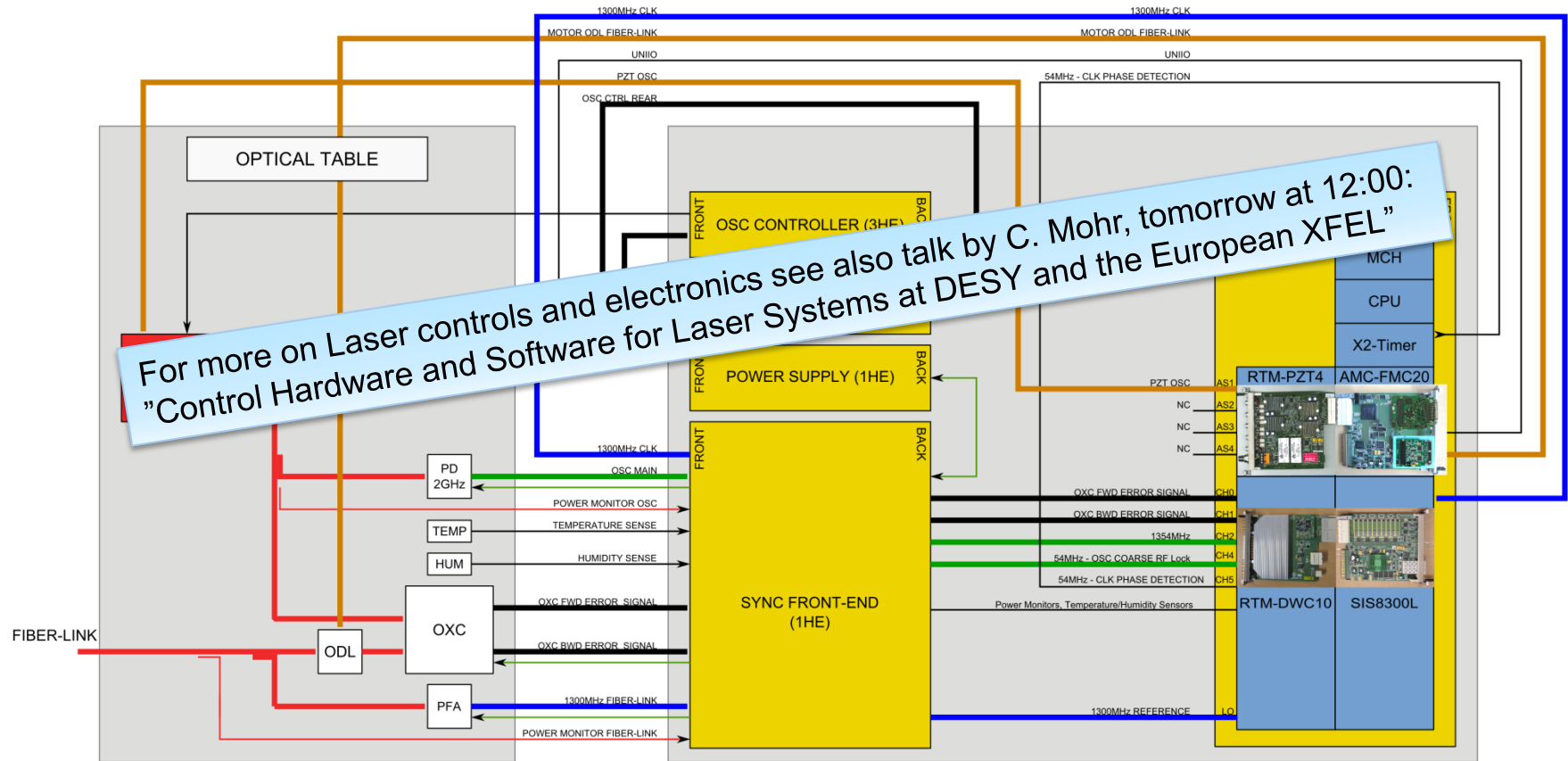
→ LASY will simplify the setup and most likely improve the performance



MTCA Setups for Laser Synchronization

Full laser sync setup – example: XFEL SASE1 Pump-Probe

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Thank you for your attention!

> Synchronization Team

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- T. Kozak M. Hoffmann P. Prędkie
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> With support from MSK

- Digital Electronics Team
- Analog Electronics Team
- Technicians
- Mechanics Workshop
- Firmware & Software Team
- Special Diagnostics

