

WUT



Institute of Electronic Systems

Selected Projects for Large Scale Research Facilities

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WUT

Institute of Electronic Systems

Largest Polish technical university

- 19 departments
- ~2 100 scientific staff
- ~36 000 students

- 4 Divisions
- 70 staff persons including:
 - 13 professors (2 tenured and 11 associate professors)
 - 19 assistant professors
- 44 PhD students



ISE – MCID - WUT Team Competences

- RF and analog circuit design
- Oscillator and synthesizer design
- Low-noise and phase noise design
- Mixed signal including fast ADC and direct sampling techniques
- Signal and power integrity, multilayer PCBs
- Synchronization systems including low phase drift design
- RF measurement techniques (VNA up to 0,5 THz)
- Software and firmware for electronics and signal processing

Long-Term (2001 -) Bilateral Cooperation with DESY

Contributions to:

- FLASH Master Oscillator and synchronization system
- Analog front end for the VME based LLRF (DWC, LO)
- ATCA Based LLRF system (VM, CLK & Timing, RF Backplane)
- MTCA Based LLRF system components (DWC, VM, RTM Backplane)
- XFEL Master Oscillator and RF synchronization
- XFEL optical synchronization components (laser locking hardware, laser-to-RF conversion, phase transient monitoring)
- XFEL racks and electronics infrastructure installations
- SINBAD synchronization system (3.0 GHz)
- Universal LO generation modules used in FLASH, XFEL and several other facilities

Developments for FLASH

Base for XFEL projects

Master Oscillator System for
FLASH



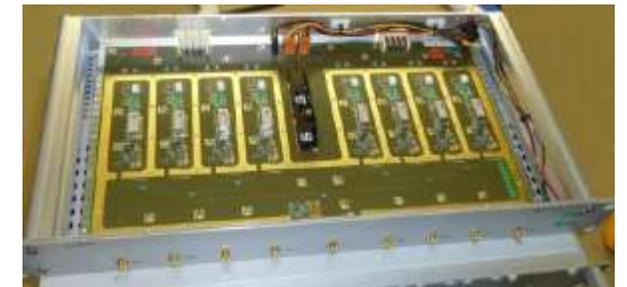
8-channel Downconverter
1.3GHz \rightarrow 9 MHz



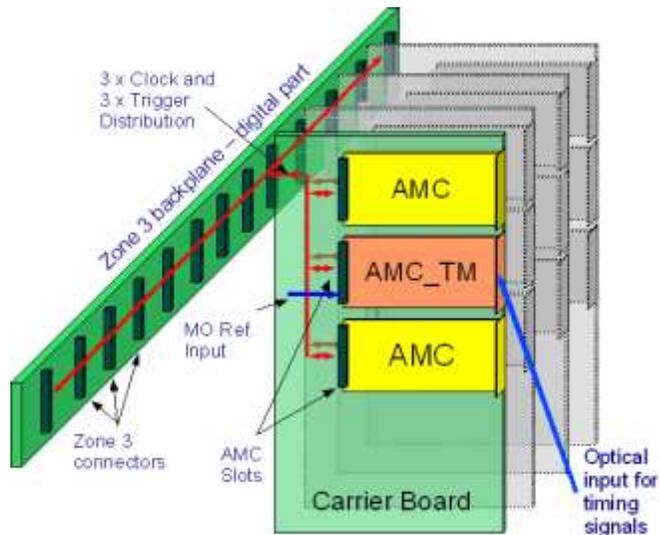
3.9 GHz reference



8-channel Downconverter
3.9 GHz \rightarrow 54 MHz



Initial Developments for XFEL LLRF

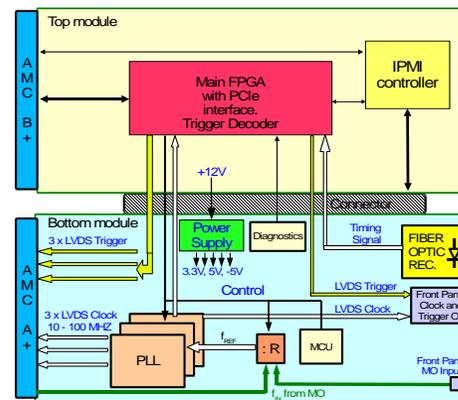


Components for ATCA based LLRF Control System

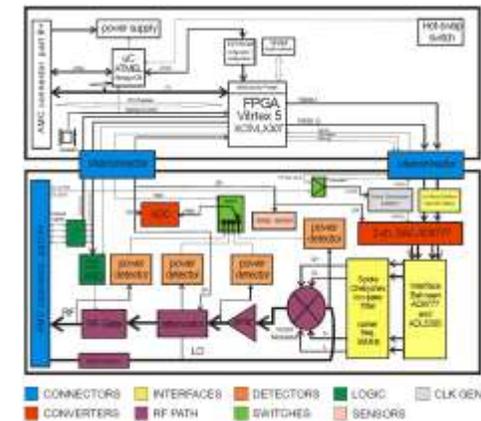
- Together with LUT-DMCS
- Developed Timing Receiver, Vector Modulator and Timing Backplane for ATCA
- Project terminated / converted to MTCA.4 by DESY



Timing Receiver Card



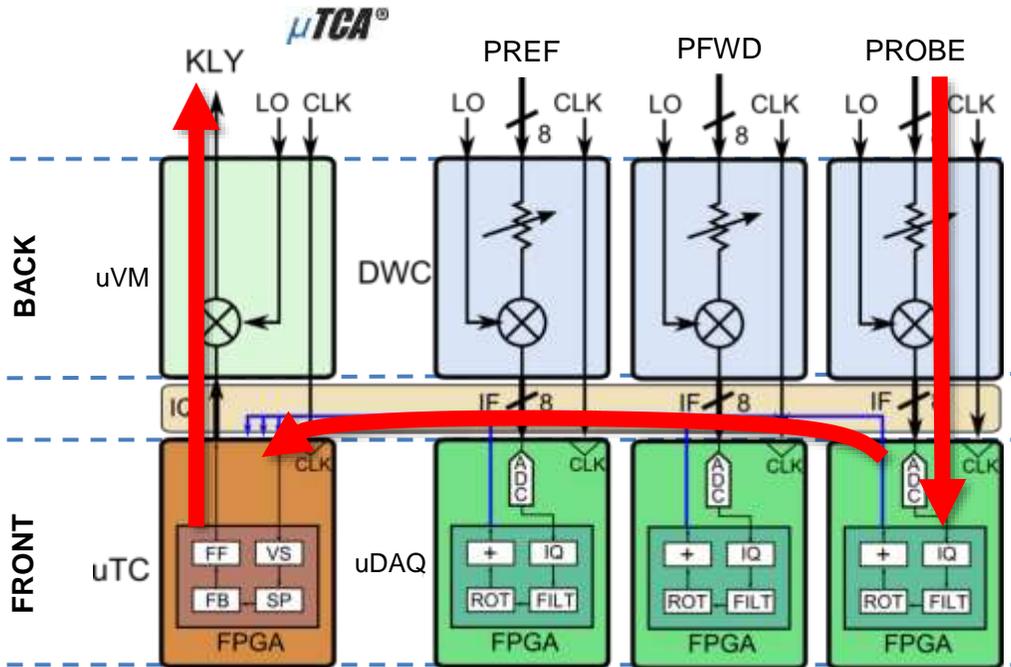
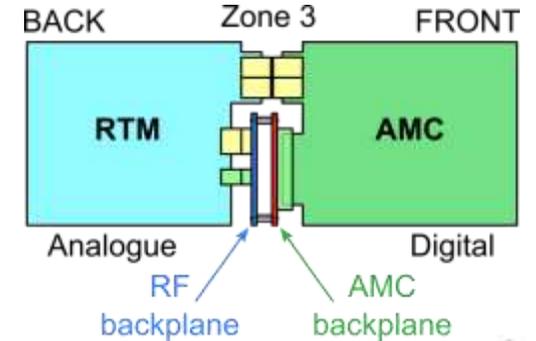
Vector Modulator Card



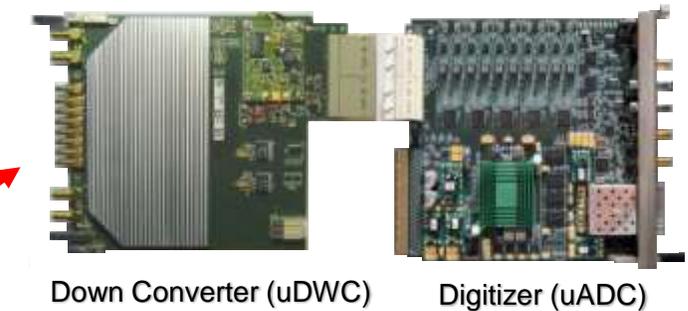
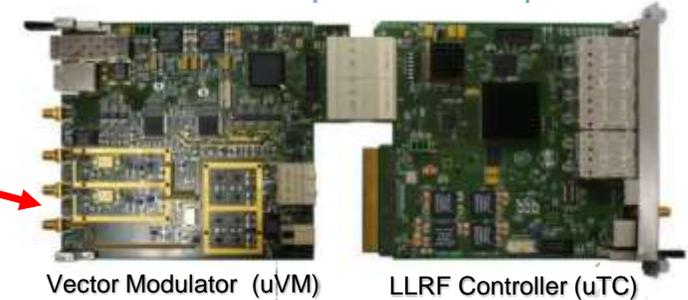
Contribution to MTCA.4 LLRF System for XFEL



- AMC: Advanced Mezzanine Card
- RTM: Rear Transition Module
- 12 slots, hot swap
- Redundant power supply



Design by WUT and DMCS*

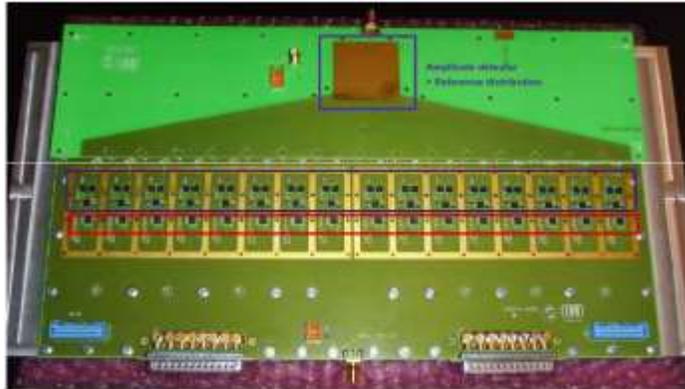


Design by WUT*

* DESY supervision

Other Activities

Drift Calibration Module for LLRF: WUT developed the prototype, DESY produced and installed ~50 modules in XFEL



Laser – to – RF signal conversion / synchronization

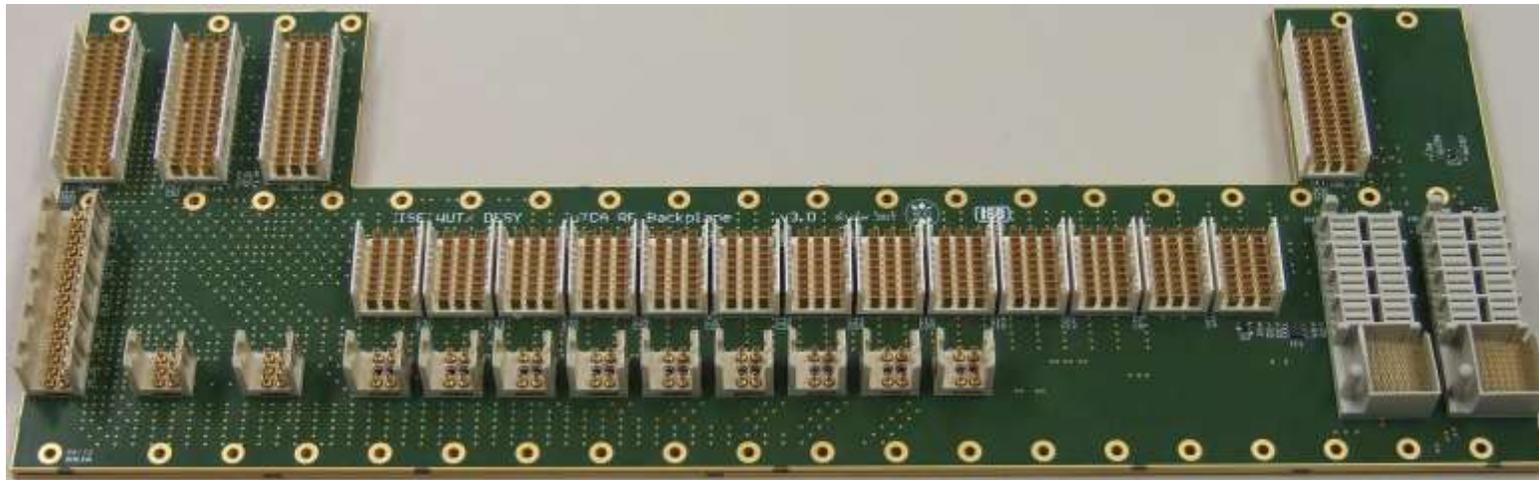


Frequency Divider module
40 boxes produced



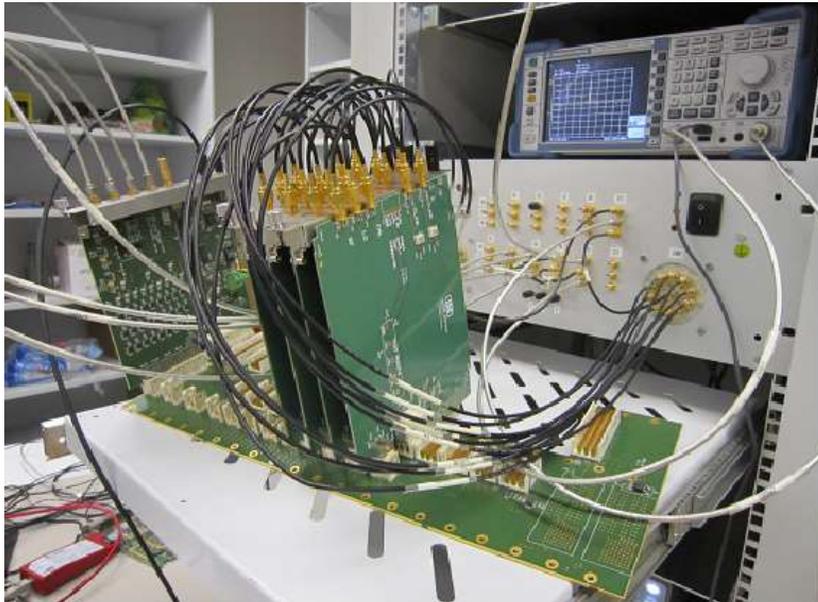
RTM Backplane for MTCA.4 Crates

- Designed to distribute precise RF and CLK signals for LLRF system
- Significantly extends MTCA.4 capabilities
- All XFEL LLRF crates were equipped with this backplane
- Interesting solution for LLRF community – introduced to PICMG standard in 2016
- US Patent No. 9374915 and European Patent No. 2672793 granted to DESY and WUT



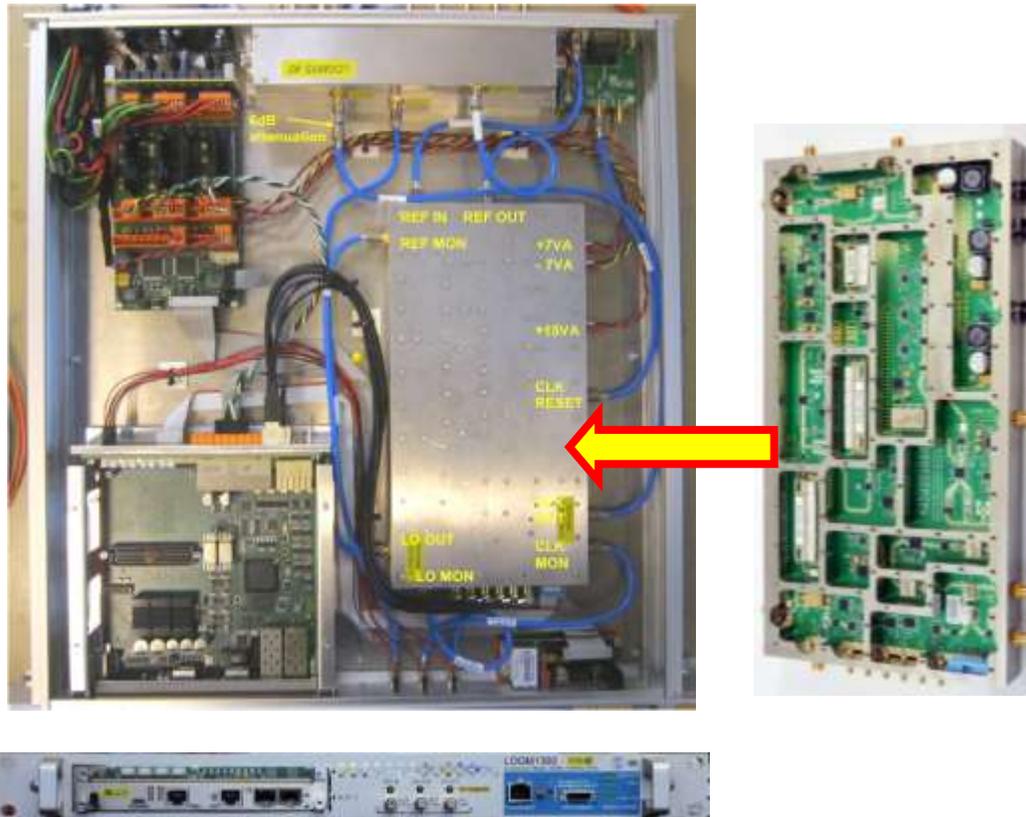
MTCA Test Stand

- System bandwidth: 9 kHz – 6 GHz
- Automated test of multi-channel boards
- Automated report generation (pdf files)
- Downconverter test time reduced from ~1 day to ~10 minutes



Ultra-low Phase Noise LO and CLK Generation Module

- High-performance LOGM, 9x LO, 9x CLK and REF outputs
- Designed to cover 1 – 6 GHz frequency band
- Advanced internal diagnostics with access via Ethernet
- **<3 fs additive jitter @ 1,354 GHz. Worlds best known signal source of this kind!**
- 20 LOGM 1.354 GHz LOGM build for XFEL in Warsaw

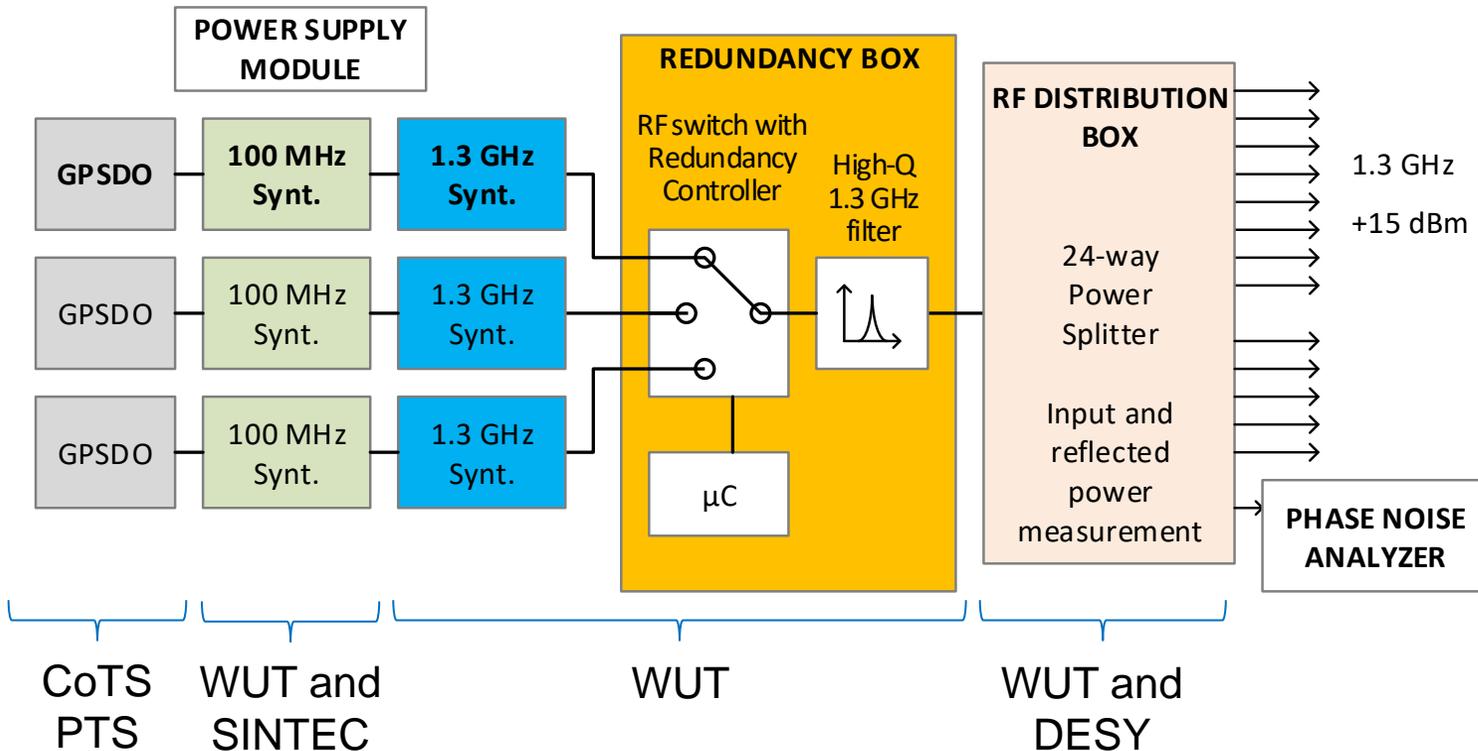


LOGM sub-modules for other frequencies. E.g. 3.954 GHz for XFEL

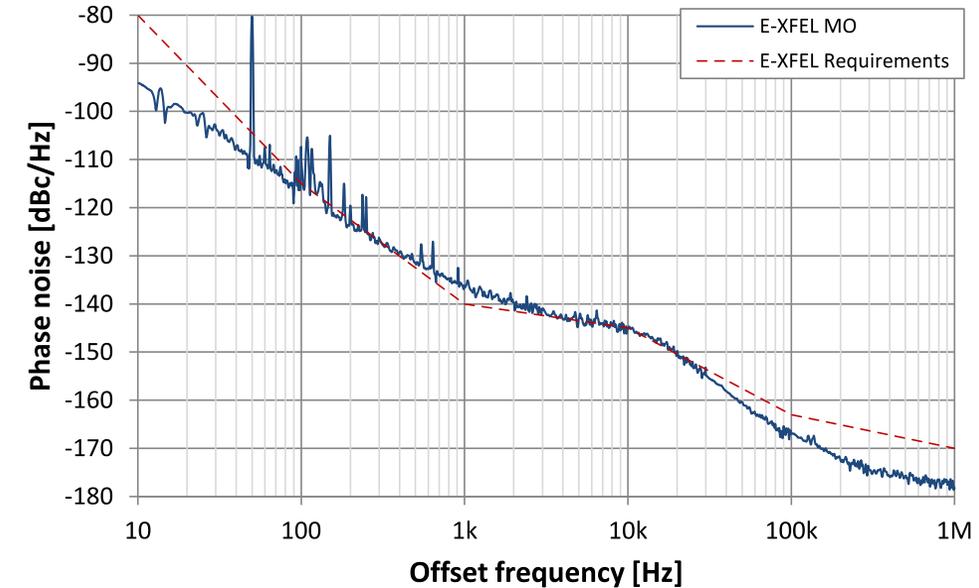


XFEL Master Oscillator

- Required to be extremely reliable (> 99 %) 1.3 GHz signal source
- Required absolute jitter < 40 fs
- 3 channel system with fast redundancy controller and signal switch
 - Take decision and switch within 300 ns. Concept proven by hardware.
- 7 of 10 modules (3 types) developed and built in Warsaw



PHASE NOISE



Integrated phase noise (rms jitter), 10 Hz–1 MHz:

- random: 10.3 fs
- spurious: 16.5 fs (mostly @ 50 Hz)
- total: 19.4 fs

Master Oscillator for European XFEL

European XFEL Master Oscillator System



- Master Oscillator System was installed in XFEL and runs since 2017
- Achieved absolute jitter of ~ 11 fs!
- Precise on-line diagnostic system
- Redundancy controller under development

Main 1,3 GHz generation and amplifier unit



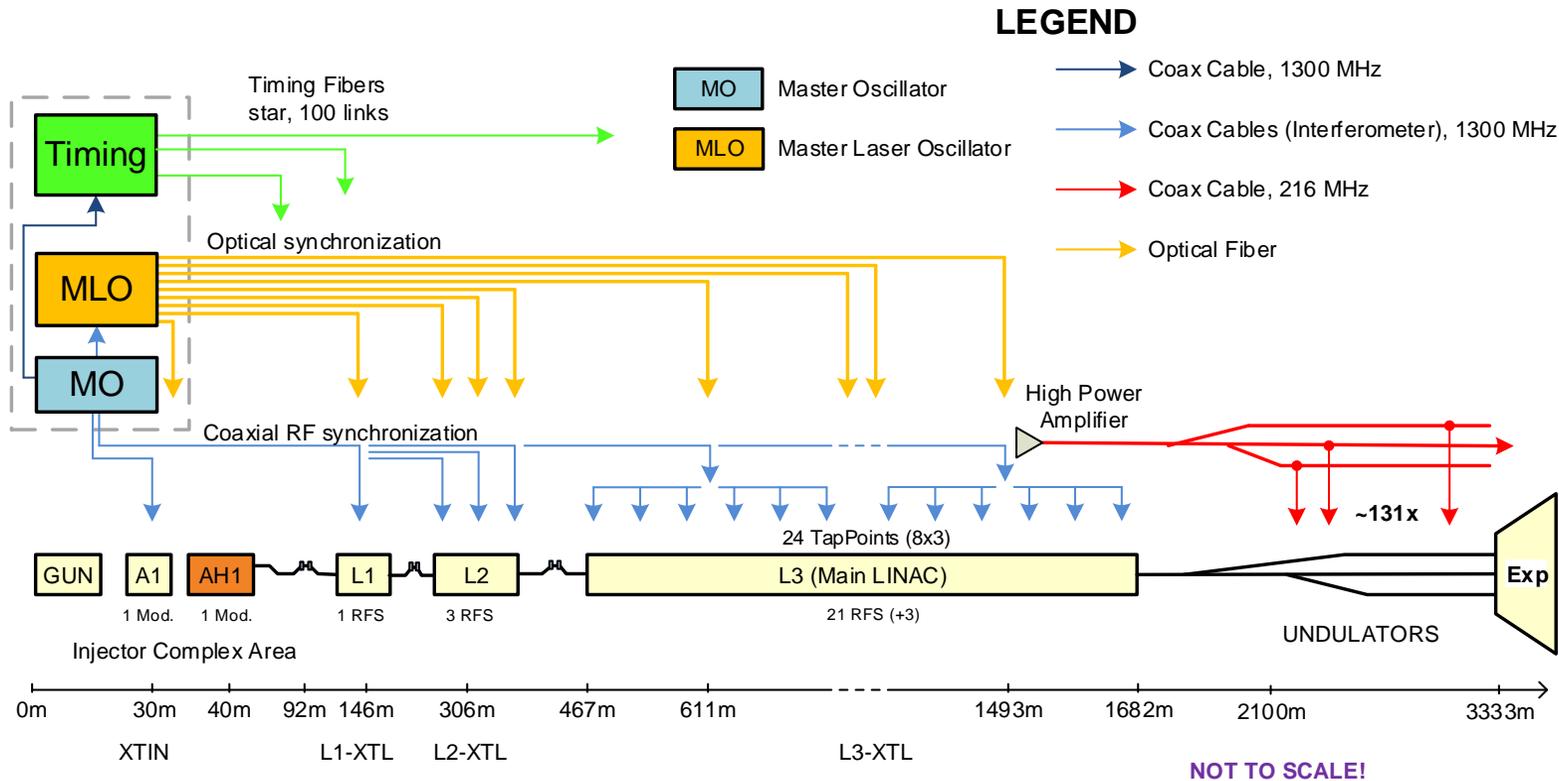
Redundancy switch



High-Q filter (courtesy of A. Abramowicz)



E-XFEL RF Synchronization System



- Three complementary systems (compromise between performance and cost)
 - Optical synchronization: sub-10fs (jitter, drift) performance, 12 links
 - RF Coaxial distribution: sub-100fs (jitter) and sub-1ps (drift) performance, interferometers, local distribution (44 links, ~260 reference outputs)
 - Timing system
- All systems phase synchronized to the RF Master Oscillator

European XFEL Master RF Synchronization System

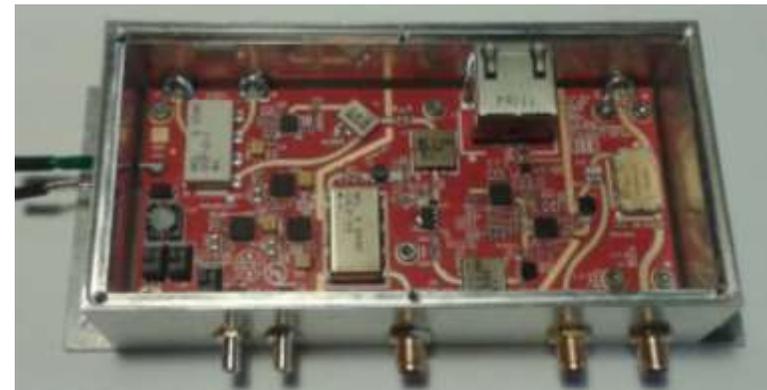
Low-noise 1,3 GHz -> 3,9 GHz synthesizer + power splitter with diagnostics



Phase and power transient detector



Frequency divider 1.3 GHz -> 216 MHz



Phase Reference Line for ESS



Distribution of 2 frequencies (352.21 MHz and 704.42 MHz) from MO to the tunnel

Total length: ~600m.

Number of taps: 58

No of outputs: 294

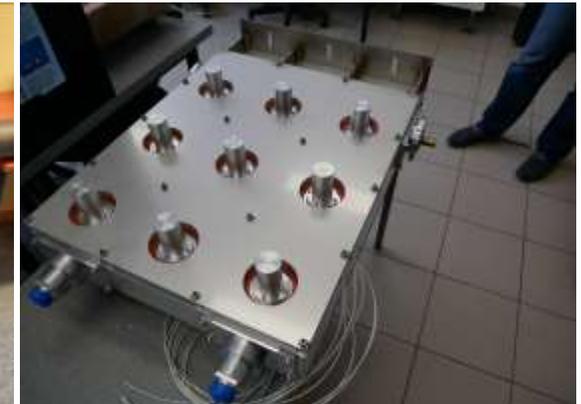
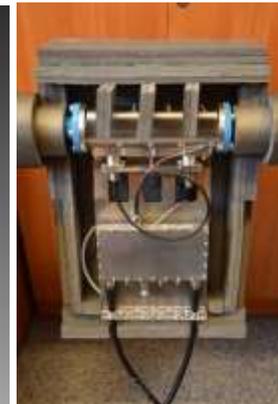
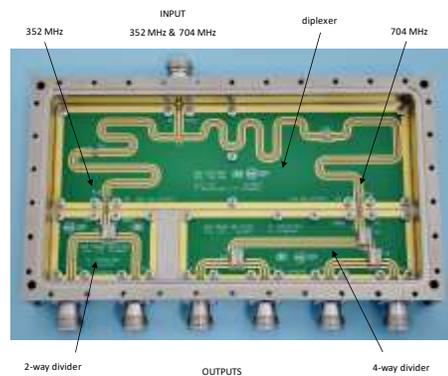
Power level at each tap: +17 dBm

Stability requirement:

0.1° for short term(during pulse 3.5 ms)

2° for long term(hours to days) between any two points in the linac

Stabilization of temperature, air pressure and humidity for the line

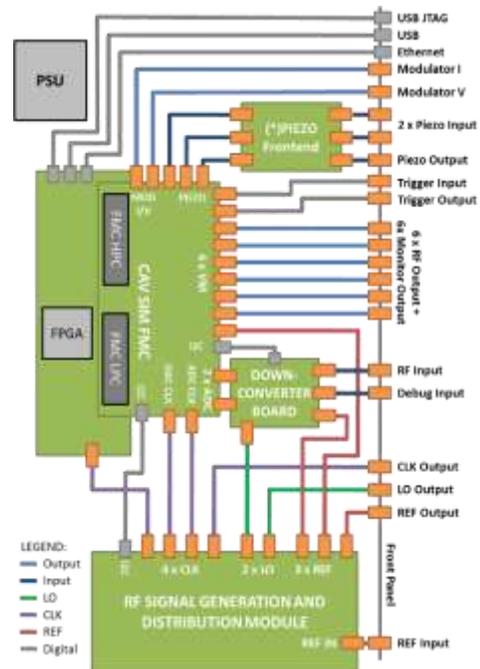


LLRF Control System for ESS

Concept and top-level design by Lund University

Hardware design and production by PEG (ISE, TUL, NCBJ)

120 MTCA.4 based systems to be delivered to ESS



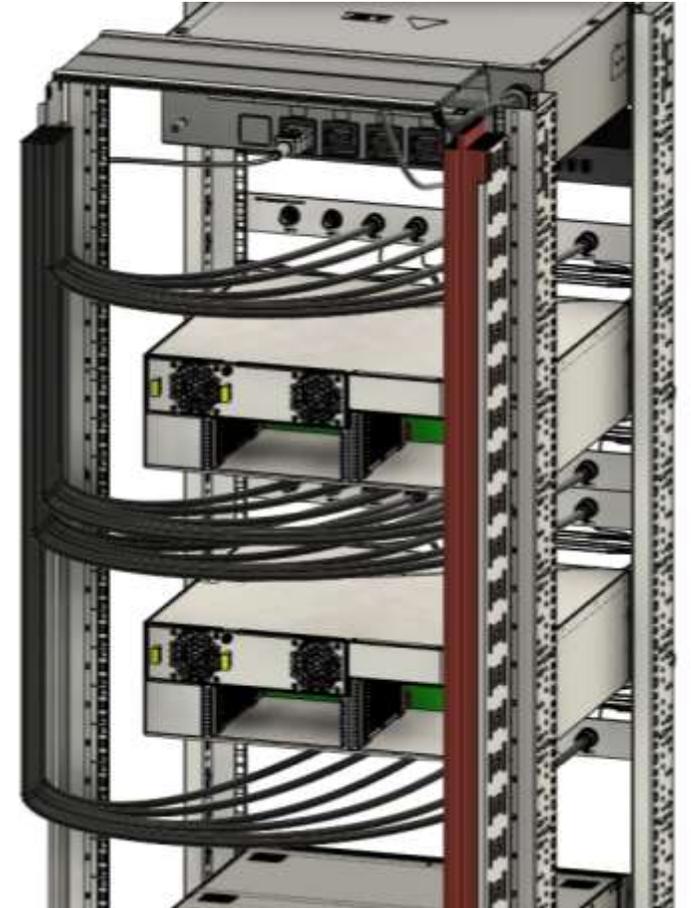
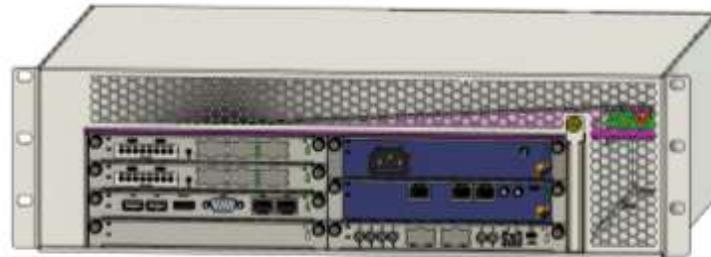
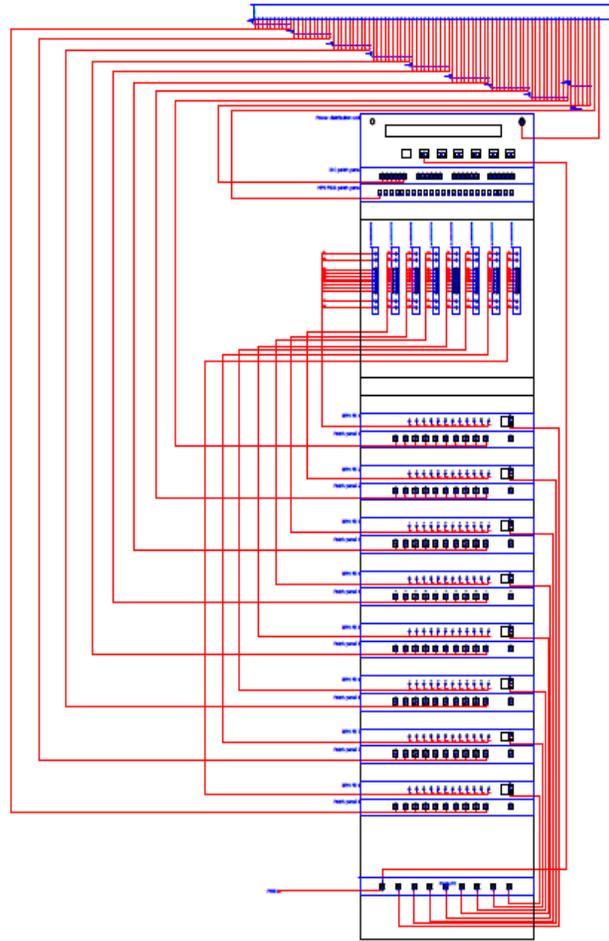
ESS Cavity Simulator



LO Generation, MTCA.4 RTM



ESS BI Infrastructure Design and Installations



Thank You for Attention!