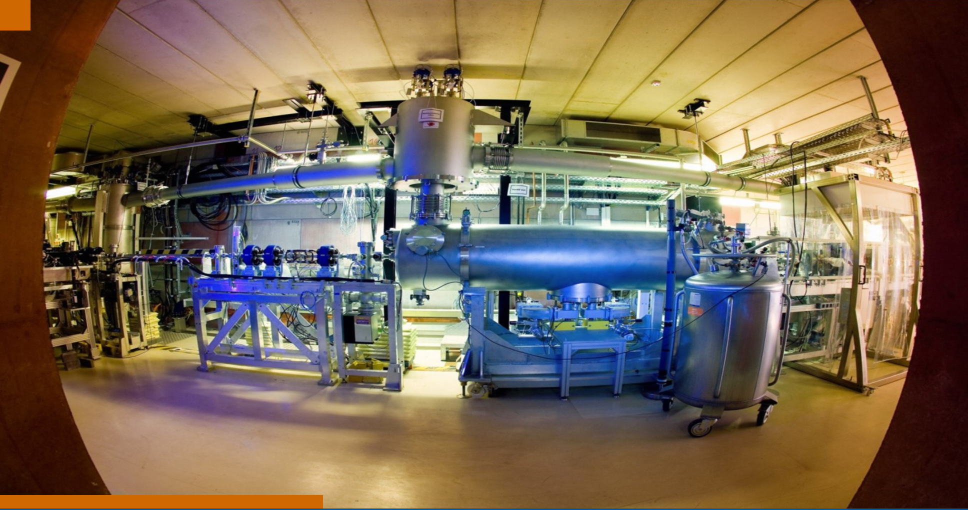


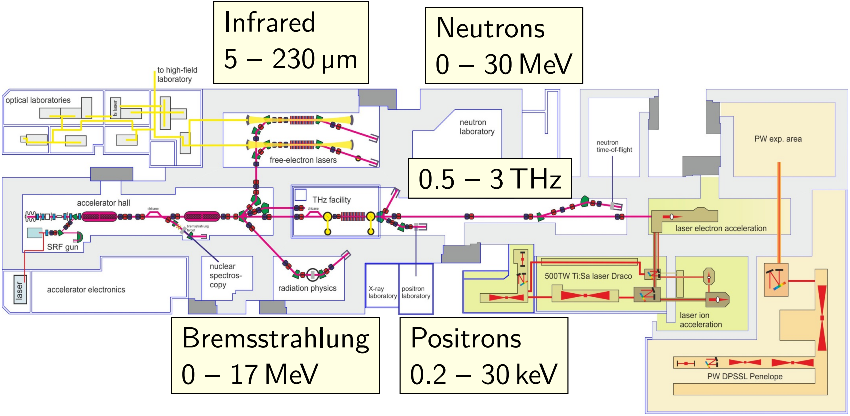
Upgrade of the LLRF system at ELBE

HZDR: Michael Kuntzsch, Reinhard Steinbrück, Klaus Zenker

DESY: Çağıl Gümüş, Martin Hierholzer, Sven Pfeiffer, Christian Schmidt

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

ELBE – Center for high power radiation sources



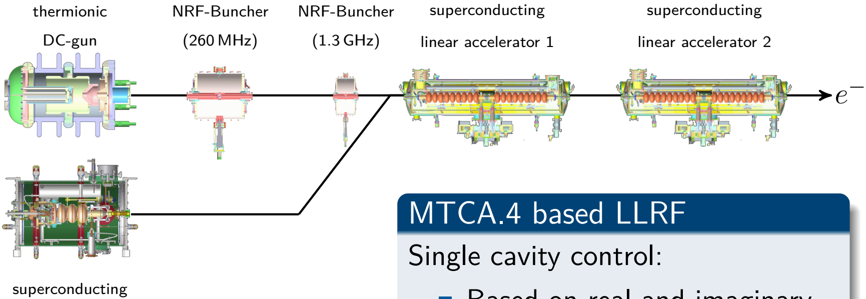
electron beam energy	8 MeV – 40 MeV
average beam current	1600 µA
bunch charge	100 pC
minimal bunch length	0.2 ps

cw operation

Micro pulse rate:
100 kHz – 26 MHz

HZDR

Accelerator



Analogue LLRF

Single cavity control:

- Separate amplitude and phase controller

$\Rightarrow$

MTCA.4 based LLRF

Single cavity control:

- Based on real and imaginary component of the field vector
- MIMO controller for:
  - I-Q decoupling
  - Pass band mode suppression

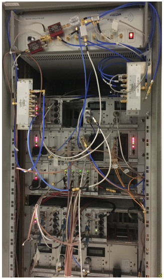
Why replacing the analogue with a digital LLRF?

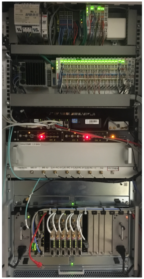
Analogue LLRF:

- Components are partly not available anymore / will not be available in future
- The system can not cover 360° for phase shift

Digital LLRF:

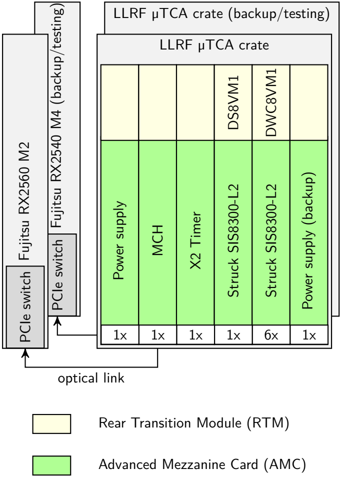
- Improves diagnostics
- Improves phase and amplitude stability (at least long term)
- Allows implementation of a longitudinal beam based feedback system
- Based on MTCA and ChimeraTK





HZDR

Components of the digital LLRF at ELBE



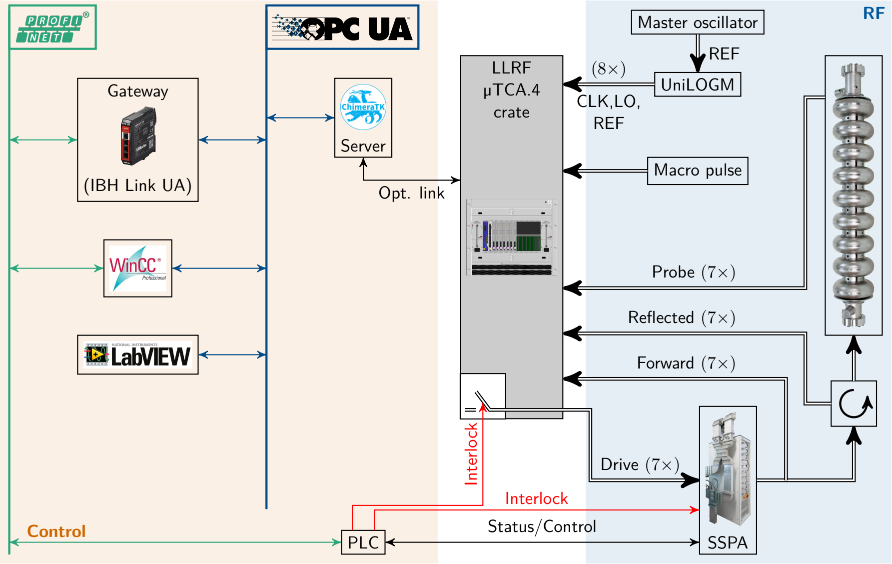
Hardware:

- Master oscillator: 1.3 GHz (REF), 260 MHz (REF), 78 MHz (CLK)
- UniLOGM: $8\times$LO (1.3 GHz$+54{}^1/_6$ MHz), $8\times$CLK (65 MHz), $8\times$REF (1.3 GHz))

Software:

- Firmware for struck boards $\Rightarrow$ LLRF controller (adopted for cw operation in collaboration with DESY)
- Control software for the LLRF $\Rightarrow$ ChimeraTK (together with DESY)
- Adapter for ChimeraTK that is compatible with WinCC $\Rightarrow$ OPC-UA Adapter (TU Dresden, now IOSB Karlsruhe)

Integration into ELBE infrastructure



Contributions to ChimeraTK

1. DeviceAccess-Modbus
   - SSPA control
2. DeviceAccess-1wire
   - Temperature and humidity control (LLRF long term drift correlation)
3. Watchdog
   - System monitoring including LLRF Server Application control
4. Server based history
5. ROOT based long term DAQ buffer

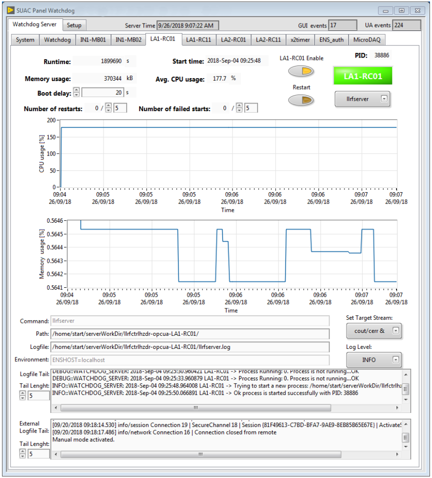
$\Rightarrow$ see also talk by Martin Killenberg

ChimeraTK benefits

All these developments are applicable at other facilities (TARLA, MESA, ...) out of the box independent of their control system!

Watchdog


SUAC Panel Watchdog
Watchdog Server
Setup
Server Time 04.12.2018 21:50:50
System
Watchdog
IN1-MB01
IN1-MB02
LA1-RC01
LA1-RC11
LA2-RC01
LA2-RC11
x2timer
ENS_auth
MicroDAQ
System uptime:
Server start time: 2018-Nov-30 14:12:44
Total CPU usage:
Log Level: WARNING
Memory usage [%]:
Disk usage [%]:
Network load [MiB/s]:
System load:
CPU usage per core [%]:
Color code: red (off) green (server) blue (dummy) gray (custom)
Start all
Stop all
CPU usage [%]
System load
Time
Last minute
Last 5 minutes
Last 15 minutes


SUAC Panel Watchdog
Server Time 9/26/2018 9:07:22 AM
Runtime:
Start time: 2018-Sep-04 09:25:48
LA1-RC01 Enable
PID: 38886
Memory usage:
Avg. CPU usage:
Boot delay:
Restart
Number of restarts:
Number of failed starts:
CPU usage [%]
Memory usage [%]
Time
Command: llrfserver
Path: /home/start/serverWorkDir/llrfctrlhzdr-opcua-LA1-RC01/
Logfile: /home/start/serverWorkDir/llrfctrlhzdr-opcua-LA1-RC01/llrfserver.log
Environment: ENSHOST=localhost
Set Target Stream:
Log Level:
INFO
Logfile Tail:
Tail Lenght:
External Logfile Tail:
Manual mode activated.

Performance of the LLRF server host

System parameter:

- 2×14 cores (56 threads)
- 64 GB RAM (ECC)
- Fujitsu Server tools (mail alert, iRMC)

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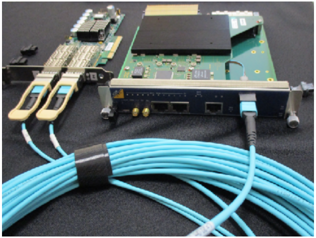
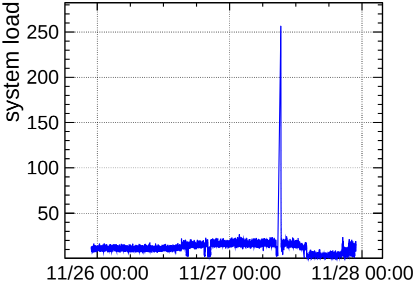
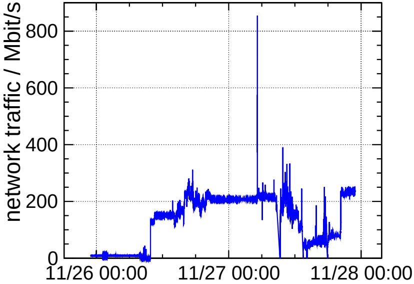
System parameter:

- 2×14 cores (56 threads)
- 64 GB RAM (ECC)
- Fujitsu Server tools (mail alert, iRMC)
- NPCIEx8-Opt-QSFP-UPLINK (8 lanes, PCIe Gen 3)



[NPCIEx8-OptQSFP-UPLINK manual]





LLRF controller design

Characteristics of the MIMO controller:

- Infinite impulse response filter of 2nd order

$\Rightarrow$ 10 parameters per cavity/buncher to be fixed

- Used to:
  - Decouple I and Q
  - Avoid passband mode excitations ($7/9\pi$ mode and $8/9\pi$ mode)

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Procedure:

- System identification using system excitations optimized to study the system characteristics (e.g. identify pass band modes)
- Model building based on the system characteristics
- Deriving of the MIMO controller parameters from the model

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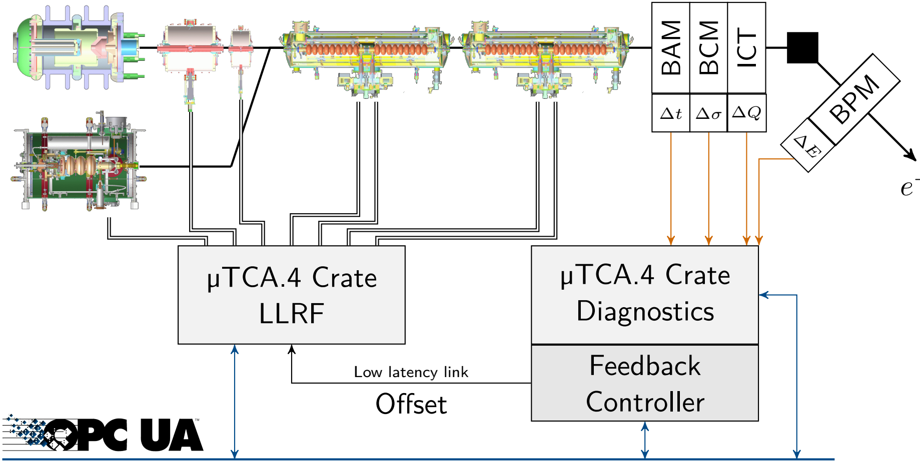
Performance:

- Out-of-loop noise measurement (Signal Source Analyser)
- Jitter (10 Hz–10 MHz): 26 fs (digital LLRF), 36 fs (analogue LLRF)

Summary

- ✓ Parallel operation of analogue and digital LLRF
- ✓ Integration into machine protection system
- ✓ Integration into HMI (WinCC)
- ✓ Controller design for all supercunducting RF cavities and the normal conducting buncher cavities
- Short development cycles thanks to our collaborators at DESY (LLRF Server+Firmware) and TUD/IOSB (OPC-UA)
- **Goal: User operation end of 2018**

Outlook



Beam based feedback:

- Diagnostic crate design and firmware (DMCS Łódź)
- ChimeraTK diagnostics application (HZDR)
- Feedback controller (HZDR)