Status and Experience with MicroTCA.4 LLRF systems at DESY.

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On behalf of the LLRF team
4th MicroTCA.4 Workshop
2015/12/09
DESY LLRF installations overview

Venue

FLASH

REGAE

E-XFEL

CMTB

AMTF
Time resolved electron diffraction experiments (MPI) and test facility for laser driven plasma-wakefield acceleration (LAOLA)

Generation of sub-10 fs electron bunches
- **Timing stability:** <10 fs at the target
- **Very low charge:** 150..300 fC

RF parameter of the REGAE accelerator:
- NRF gun (1.5-cell) and buncher cavity (4-cell)
- 2.998 GHz S-band structures
- 6 μs pulse length and up to 50 Hz repetition rate (up to now only 12.5 Hz)
- Driven by one klystron, with motorized waveguide phase shifter

Laser driven plasma wakefield
LLRF system at REGAE

- MicroTCA.4 based LLRF system
  - Running since Nov. 2011
  - Single cavity controller since 2014

- Stability requirements:
  - $\frac{dA}{A} < 0.01\%$
  - $d\phi < 0.01^\circ$ (9.3 fs @ 3.0 GHz)

- One klystron for two cavities
  - Coupling of cavities
  - 2 input/4 output system
  - Buncher phase = RF gun phase + 90°

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Free Electron LASer Hamburg

Flash | and FLASH II location site view

User experimental hall
Regular FLASH operation

> System for all SC modules in operation since >2 years
  - Startup issues mainly due to software migration
  - Hardware mostly prototype versions (no major issues found)
  - Partly installed inside the accelerator tunnel

> RF-Gun in regular operation since Jan 2015

> Currently concentrating on stepwise upgrades
  - Software/Firmware + specific HW components

System fulfills expectations regarding quality and reliability.
Gained a huge amount of experience for the XFEL commissioning and operation!
MicroTCA.4 LLRF System – signal flow

- Klystron
- Pzt. Drive
- PSM
- REFM
- LOGM
- DCM

- VM
- DAC
- Ctrl
- Lin
- BLC
- MIMO FB
- Feedforward
- FF Correction
- Setpoint
- ORC
- Detuning
- LFF
- LLRF Front end server
- Master

- Vector Modulator
- LLRF Controller
- Down Converter
- Digitizer

- waveguide
LLRF@FLASH counted downtime in categories (2015)

- **Infrastructure** (Timing, power, cooling water, crate)
- **Server** (crashes, malfunction, restarts)
- **Automation** (diverging routines, not working functions, ...)
- **Firmware** (malfunctions, required reboots, crashing)
- **Operation** (misusage, exceeding thresholds, ...)
- **Performance** (no machine operation, because of not working regulation)

> Tunnel installation requires access (machine recovery counted)
  - Exchanging parts, hardware failures

> RF-Gun system was installed in this year

> ACC45 tuning time for variable gradients

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Communication lost

VM exchange

- RF GUN
- ACC1
- ACC39
- ACC23
- ACC45
- ACC67

**Hours**

0 5 10 15 20 25 30 35 40
Examples of most recent hardware failures

> Broken Zone3 connection
  - VM ACC39 exchange for upgrade
  - FLASH installation space very limited

> Failures of SSD’s / Raid array
  - Mainly visible on the RF GUN
  - Often not the SSD’s are broken but the RAID (sw) was loosing a disk
  - Installed new special single cell type SSDs
  - Installation of radiation monitors to study what is the correlation

> In the past we have seen:
  - Broken cables (optical and copper)
  - Power cuts of the whole rack system

> We have not seen:
  - Individual modules dying or degrading in performance or availability
# Currently installed LLRF MicroTCA.4 hardware at FLASH

<table>
<thead>
<tr>
<th>Hardware</th>
<th>RF GUN</th>
<th>ACC1</th>
<th>ACC39</th>
<th>ACC23</th>
<th>ACC45</th>
<th>ACC67</th>
<th>Test-stand</th>
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<tbody>
<tr>
<td>MTCA Crate</td>
<td>Schroff 2U</td>
<td>Schroff 12S LLRF AMC BP</td>
<td>Schroff 12S LLRF AMC BP</td>
<td>Schroff12S LLRF AMC BP</td>
<td>ELMA 12S AMC BP, LLRF RTM BP Prep</td>
<td>ELMA 12S AMC BP LLRF RTM BP Prep</td>
<td>ELMA 12S AMC BP,RTM backplane compatible</td>
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<td>NAT MCH-PHYS</td>
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<tr>
<td>Power supply</td>
<td>1x Vadatech PEM</td>
<td>1x Wiener PS 1kW</td>
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<td>Vadatech PEM</td>
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<tr>
<td>Controller</td>
<td>Struck SIS8300LS</td>
<td>Vadatech TCK7</td>
<td>uTC</td>
<td>Vadatech TCK7</td>
<td>uTC</td>
<td>uTC</td>
<td>Vadatech TCK7 + uTC</td>
</tr>
<tr>
<td>VM</td>
<td>Struck DWCVM rev 1.1</td>
<td>1xVM 2.3LF</td>
<td>VM 1.2HF</td>
<td>VM 2.2LF</td>
<td>VM 1.2</td>
<td>VM 2.2 + 1.2</td>
<td></td>
</tr>
<tr>
<td>Digitizer (STRAK)</td>
<td>SIS8300LS+KLM</td>
<td>2xSIS8300LS 1xSIS8300LS2</td>
<td>SIS8300LS</td>
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</tr>
<tr>
<td>DWC</td>
<td>1x DWCVM rev 1.1</td>
<td>3x Vers 2.2</td>
<td>3x Partly broken (re-soldered)</td>
<td>6x Vers 2.2</td>
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FLASH ➔ 56 SRF 1.3GHz / 4 SRF 3.9GHz/ 1 NRF gun
Upgrade goal: consistent setup for FLASH and XFEL => maintenance
Accelerator Module Test Facility

(3 x RF stations 1.3GHz + 1 x 3.9GHz)

- AMTF (Accelerator Module Test Facility)
  - Development of automatic test and qualification of modules
  - System parameter characterization and database storage
  - Automated test routines essential => 7 days/module

- All modules have to be tested prior tunnel installation!

- Retrieved characterization data is being used in XFEL system setup
  - Tuner, fundamental modes, piezo, maximum gradients
CryoModule Test Bench

Test facility with cryomodule installation (left), amplifier IOT (mid) and MicroTCA test setup (right)

- Same LLRF system as used for AMTF/FLASH
- R&D basic principles for continuous wave and long pulse operation
  - Challenging: microphonic suppression
  - No pulse to pulse adaptations
  - Higher $Q_I >$ lower bandwidth
- Coupling of frequency and RF control much stronger
  - New control schemes / strategies required

Talk tomorrow
R. Rybaniec

Courtesy: R. Rybaniec
European Xray-Free Electron Laser
European XFEL (808 SRF 1.3GHz / 8 SRF 3.9GHz / 1 NRF gun)

Currently injector commissioning, in parallel installation and pre-commissioning of the main linac components

Complete in-tunnel installation for all LLRF components (except injector and MO)
LLRF system for XFEL

> LLRF: DESY in-kind

- 26 RF stations (808 cavities, 101 cryomodules)
- MicroTCA.4 LLRF system, master / slave
- Vector sum (32 cavities) RF control
- 2 piezo per cavities (1kHz tuning)
- Motorized cavity tuners
- Motorized $Q_L$, one-time fixed power ratios

**RF parameters:**
- Pulse length 1.4msec (750 + 650 usec)
- $Q_L = 4.6e6$ ($\frac{1}{2}$ bw = 140 Hz)
- 10 Hz rep. rate
- $\Delta A/A = 0.01\%$  $\Delta \Phi = 0.01$ deg.
Injector setup and commissioning

GUN: commissioning since Dec 2013
AH1: installation Sep 2015
Injector: cool down Nov 2015

- 10 Hz repetition rate
- 20 bunches
- 2nC bunch charge

First accelerated photo electrons at XFEL!

10 Feb. 2015
~ 7 MeV

May 2015

GUN, A1, 3rd harmonic

LLRF
Summary

- Several facilities in DESY which require LLRF support
  - Moved from prototype stage to mass production
  - Commissioning and maintenance work will increase dramatically in 2016

- FLASH and REGAE are running user facilities
  - Have a permanent monitor of system behavior and fault
  - Amount of lessons learned and bug fixes here are extremely important

- CMTB as test facility brings us to the next R&D project directions
  - New setups, cards can be tested here in a real system environment

- AMTF and XFEL
  - Permanent module test and system characterization
  - XFEL injector commissioning starts now => beam until the end of this year
  - Next year commissioning of the main linac (~ 50 MicroTCA crates fully equipped !)

Thanks for your attention