PAUL SCHERRER INSTITUT



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Lab Talk: LLRF Status and Activities at PSI

LLRF Workshop 2017, Barcelona

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4 Accelerator Facilities

- SwissFEL (Swiss Free Electron Laser)
- SLS (Swiss Light Source)
- HIPA (High Intensity Proton Accelerator)

WISSFF

Proscan (Proton Cancer Therapy)



- Operation & Maintenance
 All
- Realization & Commissioning
 SwissFEL
- Planning
 HIPA injector 2 RF upgrade
 Upgrade
 SLS 2.0 storage ring upgrade

HIPA

Proscan



RF systems in operation

Facility:	HIPA	SLS	Proscan	SwissFEL
LLRF oper- ated since	1980's	2000	2005 (1980's)	2015
System Type	Analog	Analog	Analog	Digital
RF Op. Type	CW	Pulsed 3 Hz + CW	CW	Pulsed 100 Hz
Hardware	Own design	External institute	Internal HIPA + Ext.company	COTS (Controls HW) + own RF
Controls integration	Analog interface	Analog interface	Analog interface	Full remote access

Table: LLRF systems in operation:

SwissFEL: (today with tes	⇒ 36	RF Stations	
HIPA: (today situatio	8 x 50 MHz (3 types); 4 x 150 MHz (3 types); 1 x 500 MHz n with test facility)	⇒ 13	RF Stations
SLS: (today with tes	7 x 500 MHz (<i>3 types</i>); 2x 3 GHz; 1x1.5 GHz SC passive st facility)	⇒ 10	RF Stations
Proscan:	1 x 72.8 MHz	⇒1	RF Station

total 60 RF Stations



Realization & CommissioningOperation & Maintenance



SwissFEL Project Summary & Outlook



Schedule

	2017	2018	2019	2020
Aramis	Pilot experiments	Start user operation		
Athos				
- dual bunch operation		Dual bunch operation	Individual control	Individual control
- RF systems installation & commissioning		Installation	Commissioning	RF Operational
- user operation				Pilot experiments



SwissFEL LLRF – Hardware & Installation







SwissFEL LLRF – RF Stability / Conditioning

SwissFEL LLRF System Key Points

S-, X-, C-band use similar IF 40 MHz and share dig. processing platform fw/sw
 Control system and processing platform based on Linux mainline kernel
 Full remote access: 100 Hz live synchronous data stream of all 24 ADC waveforms

RF Stability

RF Station	Phase Tolerance (rms)	Voltage Tolerance (rms)		
	Required / Reached	Required / Reached		
S-band ACC (2.9988 GHz)	0.018 / 0.016 degS	0.018 / 0.006 %		
C-band (5.7120 GHz)	0.036 / 0.018 degC	0.018 / 0.003 %		
X-band (11.9952 GHz)	0.072 / <mark>0.38</mark> degX	0.018 / <mark>0.082</mark> %		

 RF receiver frontends S- and C-band in "pizza box"
 Jitter Measurement to 10ppm Level for Pulsed RF Power Amplifiers 3 - 12GHz



RF Station Automation for Operation

Master sequence state controller: Simplify operation for ctrl. room





SwissFEL LLRF – Automation

→ To facilitate operators / experts life

Low-Level RF High Level Application

- Collection of user triggered or permanently running jobs that use / optimize RF signal figures.
 - RF pulse shaping & optimization, group delay calibration, DAC offset correction, loop gain/ phase calibration, structure detuning measurement





Beam Based Optimization Algorithms and Procedures

- Collection of user triggered jobs that use / optimize beam signal figures by tuning of the LLRF knobs.
 - Optimize the DAC / RF pulse vs. beam timing
 - Find the exact beam interaction time
 - Optimize RF performance & jitter study





Operation & MaintenancePlanning for Injector 2 RF upgrade

HIPA



HIPA LLRF upgrade project



Old analog LLRF

New resonator 50 MHz



Injector 2 cyclotron

New resonators

Project outline: Replacement of the following Inj. 2 RF related components...

- 1. $2x 150 \text{ MHz} \rightarrow 2x 50 \text{ MHz}$ resonators
- 2. RF amplifier chain (tube lifetime)
- 3. Digital LLRF, RF ILK + tuning systems

Schedule Inj. 2 (simplified and only resonators 2+4)

	2018	2019	2020
Res. 2	- Res. Installation as vacuum chamber - LLRF installation	- Commissioning & operation	
Res. 4		- Res. Installation as vacuum chamber - LLRF installation	- Commissioning & operation

LLRF Roadmap

- 1. IF 40 MHz \rightarrow RF 50 MHz
- Base on SwissFEL LLRF proc. platform (FPGA, CPU, FMC) for CW operation



Operation & MaintenancePlanning for SLS 2.0 Upgrade



SLS \rightarrow SLS 2.0 upgrade preparatory phase

Goal: Upgrade storage ring to provide factor >30 improved emittance + harder X-rays

For all subsystems such as RF/LLRF: Upgrade to ensure other 20+ years operation, to optimize operation + maintenance cost, optimize perf. ...

Schedule

	2018	2019	2020	2021	2022	2023	2024
SLS-2 preparatory phase							
financing period							
procurement/ testing/pre-assembly							
maximum "dark" period							

LLRF Roadmap in preparatory phase

1. Internally define with other groups next **processing platform** requirements and start development

 \rightarrow 500 MHz systems: ready for test stand operation 2021/22.

 Upgrade Linac stations (currently with feed-forward only) with the SwissFEL type digital LLRF (exact fit: pulsed 3 Hz @ S-band)





SwissFEL

- LLRF System is ready and has no show-stoppers
- Due to in-house development have the flexibility for upgrades or new feature requests with reasonable cost and manpower effort
- □ RF vs. beam jitter and drift stability to be studied and optimized
- Consolidation phase with user operation and dual bunch commissioning Athos is the main task for the next two years

HIPA Injector 2 Upgrade

Concept to re-use digital back-end (ADC, DAC, processing board) from SwissFEL
 LLRF implementation in 2018, first RF operation new resonator 2019

SLS 2.0 Upgrade

- Next processing platform requirements driven by internal demands for various applications: Need to start now to be ready 2020 for test stand systems
 - E.g. stay with VME because of internal synergies and cost-optimal electronic housing until requirements demand for new bus standard.



Wir schaffen Wissen – heute für morgen

My thanks go to

- All team members
- All colleagues for their contributions to the workshop







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