Low Level RF Control Implementation and Simultaneous Operation of Two Undulator Beamlines at FLASH

V.Ayvazyan, S.Ackermann, J.Branlard, B.Faatz, M.Grecki, O.Hensler, S.Pfeiffer, H.Schlarb, C.Schmidt, M.Scholz, S.Schreiber, DESY, Hamburg, Germany; A.Piotrowski, Fast Logic, Lodz, Poland

LLRF'15 Workshop, Shanghai, Nov. 4, 2015







Outline

FLASH and the FLASH II project

- Layout of the facility
- Pulsed operation mode and timing aspects
- LLRF control for multi-beamlines
 - Requirements and functionality extension
 - Regulation performance
- Simultaneous operation and results
- Summary

Free-electron Laser in Hamburg - User Facility since 2005



The FLASH II Project

- Separation of FLASH and FLASH2 beamlines behind the last accelerating module
- Tunability of FLASH2 by undulator gap change
- Extend user capacity with SASE (Self-Amplified Spontaneous Emission)

RF Control Requirements for Multi-Beamlines

- > Amplitude and phase can in certain limits be independently chosen for both FELs
 - Ability of phase tuning at injector for variation in compression FLASH1 and FLASH2
 - Ability of gradient tuning of last two RF stations for wavelength scans
- > Handling different beam loading scenarios
 - Bunch repetition rate, number of bunches and charge



Temporal Structure (An Example)



- > Same optics setup for both beamlines, limitations of the bunch parameter range
 - Energy acceptance in dispersive sections, slow magnet changes
 - Two lasers operating on one cathode (alignment, orbit)

The Low Level RF System Overview

> In 2013 was the last major LLRF control hardware/software upgrade to a MicroTCA.4 based system



- Digital feedback based on vector sum control group of cavities gradients
- > MIMO controller
- > Learning feed forward
- > Beam based feedback
- > Application software



See talk by U. Mavric: Operational experience with the MicroTCA based LLRF system at FLASH

RF Control Functionality Extension for FLASH2



- Besides LLRF, all machine timing triggered systems receive a priori beam information => no manual synchronization
- LLRF control tables are generated from the operational setting according to the provided timing information
- Independent RF operational parameters adjustment (defined limits)



RF Settings

Phase

3.5

1.5

0.5

-0.5

-1.5-

RF Control Performance

> Vector-sum amplitude and phase stability fulfills given requirements



- Kicker given minimum transition time can be achieved
- Smooth transition steps to avoid broadband excitation



Lasing with Two Independent Bunch Trains

- FLASH features two injector lasers to produce electron bunch trains with different numbers of bunches, charges and repetition rates
- It has been shown that for the same charge the same amount of SASE is present (top), while for different charges the difference in SASE is as theoretically expected (bottom)



First Lasing FLASH2

- Most of the commissioning for FLASH2 was done in parallel with FLASH1
- > First lasing FLASH2: August 20, 2014
- FLASH1 lasing in parallel 250 bunches with about 50 µJ
- First lasing FLASH2 was also first parallel operation
- After the demonstration of the first lasing at FLASH2 SASE operation was established at various wavelengths







> FLASH: The first soft X-ray FEL operating two undulator beamlines simultaneously

Parallel SASE Operation

Separate panels for FLASH1 and FLASH2



> Parameters affecting both BL are blocked from individual panels

Achieved Photon Wavelengths during Parallel SASE Operation



- Achieved photon wavelength during parallel SASE operation in the period from August 2014 to August 2015
- > Variable gap undulators in FLASH2 allow different photon wavelengths at fixed beam energies

Summary and Outlook

- Low Level RF control functionality has been extended which makes simultaneous RF operation of multi-beamlines possible
 - Can operate with different compressions, charges and bunch patterns
 - Maintaining RF field amplitude and the phase stability requirements
- > Achieved simultaneous operation and lasing of two undulator beamlines
 - SASE operation at various wavelengths was established
- > LLRF commissioning for multi-beamlines at European XFEL in progress
 - Operations of alternating RF pulses (from pulse to pulse)

Thanks for your attention!