

RF Operation Experience at the European XFEL

Poster presentation

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Julien Branlard
DESY, Hamburg, Germany
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HELMHOLTZ RESEARCH FOR
GRAND CHALLENGES



The European X-ray free electron laser (XFEL)

Short Overview

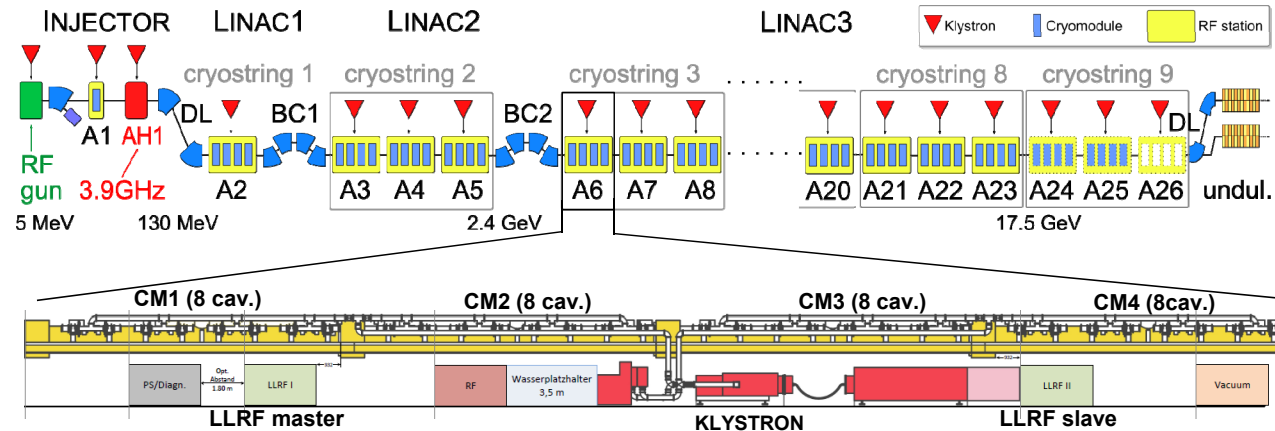
Hard and soft X-ray user facility

- 17.5 GeV light source user facility
- TESLA 1.3 GHz SRF cavities
- 1.4 msec RF pulses at 10 Hz
- e- beam 1.35 mA nom.



1 RF station

- 1x 10 MW klystron
- 32x cavities per 4 cryomodules
- 32x motorized power couplers
- 32x motorized tuners
- 64x piezo (actuator / sensor)
- 36x motorized phase shifters (1/ cav + 1/ cryomodule)



XFEL Operation Timeline

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Selected milestones

- 12/16 Linac cooled down to 4K
 - 01/17 RF commissioning
 - 05/17 First lasing
 - 09/17 First User program (2x 3weeks)
 - 04/18 Last 2 RF stations ready for operation
 - 05/18 First simultaneous lasing (SASE 1, 2, 3)
 - 07/18 17.5 GeV design energy reached!
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- User program in 2018: 1600 hours
 - User program in 2019 4800 hours

You  watch online:

<https://www.youtube.com/watch?v=p3G90p4glQA>



POSTER OUTLINE

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PART 1: "Advanced" LLRF commissioning

- Example 1: klystron lifetime management
- Example 2: optical synchronization of the RF reference

PART 2: RF related study

- Example 1: Maximum gradient investigations
- Example 2: Cavity detuning versus cryogenic pressure

RF OPERATION EXPERIENCE AT THE EUROPEAN XFEL

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J. Branlard*, V. Ayzayan, L. Butkowski, M. Grecki, M. Hierholzer, Mar. Hoffmann, Mat. Hoffmann, M. Killenberg, D. Kostin, T. Lamb, L. LiJe, U. Mavrič, M. Omet, S. Pfeiffer, R. Rybaniec, H. Schlarb, C. Schmidt, N. Shehzad, V. Vogel, N. Walker, DESY, Hamburg, Germany

Abstract

The European X-ray free electron laser (XFEL) is a user facility delivering unparalleled hard and soft X-ray flashes with the highest brilliance worldwide. Through 3 undulator lines and serving up to 4 experiments, it is based on a 10 Hz pulsed 17.5 GeV superconducting linac, commissioned since 2017. The first self-amplified spontaneous emission (SASE) light was demonstrated in May 2017, the first user run took place in September 2017 (delivering photons at a wavelength of 1.3 Å). After a month shutdown in April 2018, the last 3 RF stations were commissioned. In May 2018, using was demonstrated simultaneously in all 3 beam lines (SASE 1, 2 and 3). A total of 1600 hours are devoted to user programs in 2018, this number should increase to 4800 hours in 2019. In this poster, the focus is set on the experience gathered during the first operation years of the XFEL, in particular the commissioning of the LLRF system beyond its basic functionality and an insight on a couple of dedicated machine studies.

The European XFEL

One RF station comprises:

- 1x 10 MW klystron
- 32x TECA-Type cavities housed in 4 cryomodules
- 32x motorized power couplers
- 32x motorized tuners
- 64x piezo-actuator/ sensor
- 36x motorized phase shifters (1 cav + 1 cryomodule)
- 100+ RF channels (probe, forward, reflected)
- 600+ RF connectors

LLRF "Advanced" Commissioning

The "basic" LLRF commissioning steps guarantee the proper operation of all RF stations, controlling the RF fields, the superconducting cavities and accelerating the particles to the desired energy.

The "advanced" LLRF commissioning steps taking into operation LLRF subsystems related to more advanced exception handling mechanisms such as the:

- Klystron lifetime management (Example 1)

or modules related to performance optimization such as:

- Drift compensation module,
- Tandem based beam loading compensation
- RF reference optical synchronization (Example 2)

Ex.1: Klystron Lifetime Management (KLM)

The KLM monitors the signals from the high power RF klystron input, output, high voltage and stops the LLRF drive if an exception is observed.

Ex.2: Optical Reference Synchronization (REFM-OPT)

The REFM-OPT synchronizes the 1.3 GHz RF reference between the linac and the user experiments. This is achieved by synchronizing the phase of the optical link and RF signals and corrects for any drifts taking place in the RF distribution chain.

DC Specific Operation Studies

Detuning versus Cryogenic Pressure

- Goal: Measure the cavity detuning to the pressure fluctuation and establish feedback mechanisms.
- Change the He pressure set point while recording the induced cavity detuning for all XFEL cavities.
- RF kept constant, operating in open loop as a reference for the detuning.

DC Specific Operation Studies

- Goal: assess the XFEL maximum energy and find the limitations.
- Possible limitations:
 - RF cavity quench
 - RF field emission
 - High power chain limitation (incompatible, interdependent aspects)
- Procedure:
 - Minimize gradient until limit is found
 - If the limit is:
 - incompatible: by conditioning, otherwise stop
 - incompatible: by conditioning, otherwise stop
 - Quench: detune and repeat

CONCLUSION

This contribution gives an overview on the continued RF commissioning and RF related studies performed at the European XFEL to illustrate the ongoing effort to better understand and characterize the new accelerator.

With the focus will shift in the coming years towards more user operation and less machine study time, the XFEL operation team is building up the effort to increase machine availability and reliability. This includes developing tools to check, analyze and document any RF trips, their root cause and recovery.

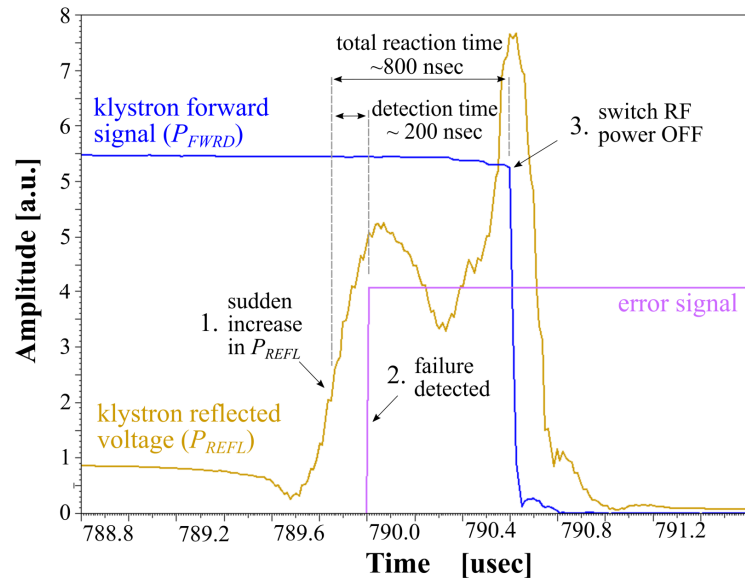


POSTER OUTLINE

PART 1: “Advanced” LLRF commissioning

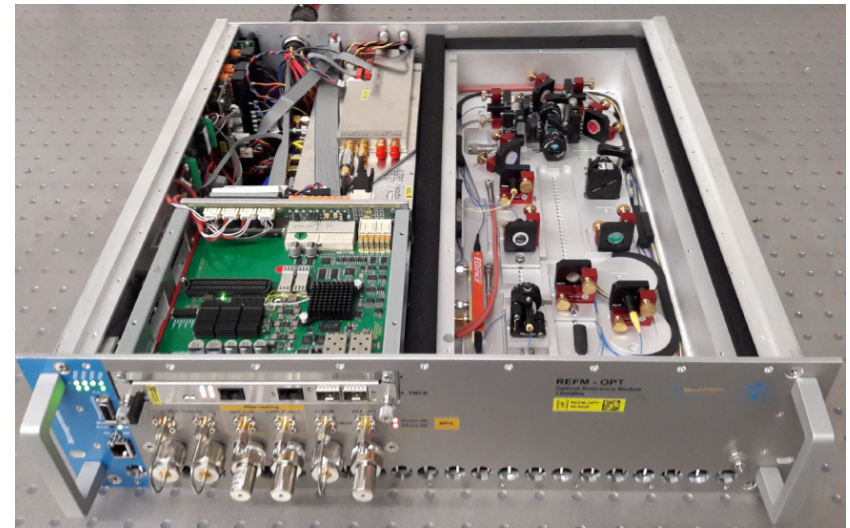
Ex.1: Klystron Lifetime Management

- Monitors klystron signals
- Stops the RF if some exception occurs



Ex. 2 Optical RF reference synchronization

- Re-synchs the RF with optical links
- sub-fs resolution

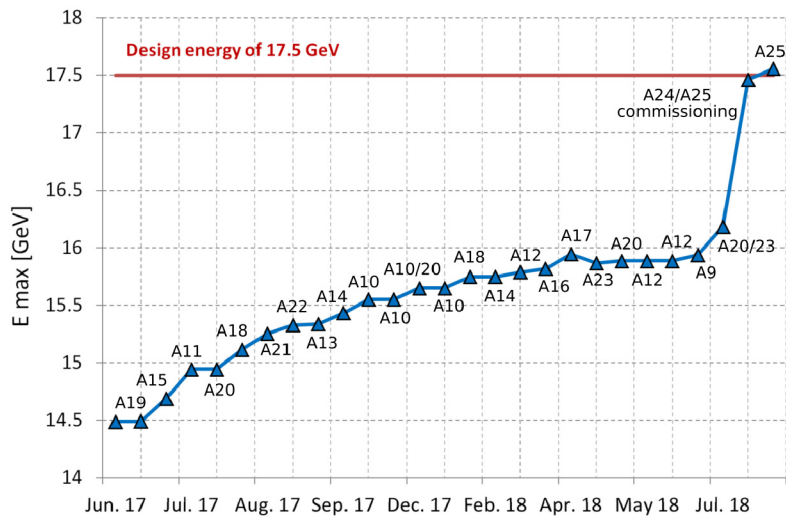


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PART 2: RF related studies

Ex.1: Energy reach

- What is the max energy for each RF station?
- What are the limitations?
- What can we do about it?



Ex.2 Detuning versus He pressure

- Cryo fluctuations: what's safe for RF operation?

Thank you

谢谢

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Julien Branlard
DESY - MSK

julien.branlard@desy.de

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