Winni Decking
Riko Wichmann
DESY - MXL
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European XFEL Accelerator R&D Policy

1 Introduction

The R&D budget is a common budget to enhance the capabilities of the European XFEL both in the areas of accelerator, FEL, photon transport and experiments.

DESY proposes to pursue a vigorous accelerator R&D program to keep the European XFEL at the forefront of FEL facilities worldwide and ensure the accelerators competitiveness for decades to come. The program will at the same time address operational needs and provide an interesting scientific and technological program for engineers and scientists. The program will be grouped in 5 research package groups (RPGs) composed out of individual Research Packages (RPs) by guiding topics:

- Improvement of operational stability and efficiency (RPG 300)
- Continuous Wave (CW) operation of XFEL (RPG 200)
- Extension of the facilities parameters and performance range (RPG 400)
- Intelligent Process Control (IPC) (RPG 500)
- Open short term R&D (RPG 100)

The R&D program will be coordinated with the European XFEL GmbH, and many topics are pursued together. There is also significant overlap with DESY's R&D plans within the framework of the Helmholtz Accelerator Research and Development (ARD) program. Strong synergies therefore exists and it can be expected that the XFEL and DESY R&D activities mutually benefit from each other, make common use of infrastructure and will actually join forces for developments in certain areas.

In the following the five groups will be detailed further.

1.1 R&D activities towards improvement of operational stability and efficiency

Continuous R&D is necessary to improve operational stability and efficiency of the existing facility. The direction of these activities might alter during operation, but emphasis will be given to the following fields:

Improved diagnostic capabilities: Improvement of diagnostic capabilities, for instance through the implementation of an X-band deflector after the undulators, will greatly reduce tuning and set-up times, and can provide the users with valuable information about bunch properties.

Improved feedback systems: Development of faster and more accurate pick-ups and actuators for feedback systems can improve both stability and flexibility of the accelerator operation.

Subsystems stability and reliability: R&D will be necessary to work out new concepts or alternatives for vulnerable components in addition to the technical improvements that are part of the maintenance and repair.

1.2 R&D activities towards (quasi-) CW operation of the European XFEL

The CW or quasi-CW operation of the European XFEL would increase the flexibility in the photon beam time structure. A more even distribution of photon pulses can enable certain new classes of experiments. For many applications the average pulse rate could be substantially increased, depending on bunch charges up to the beam power limit at the beam dump. Furthermore, CW operation would ideally support an extension of the facility with additional beam lines.

Several R&D topics will have to be pursued to come up with a credible proposal for such an upgrade to the European XFEL.

Superconducting accelerator: Optimized cavity and module design, verified by the respective cold tests, for both accelerator module types (1.3 GHz and 3.9 GHz system); development and test of CW high power RF sources and distribution; investigations of alterations to the LLRF system and its operation.

Electron Source: A reliable and performant CW electron source requires fundamental research. R&D on superconducting electron guns is needed to verify the principle design and feasibility. As a possible alternative or backup, the developments of conventional CW RF guns have to be closely followed. General R&D on cathode & laser is also to be carried out.

Accelerator Subsystems: Several of the accelerator sub-systems have to be improved to enable a CW facility operation, most importantly beam diagnostics, control system and its data acquisition, machine protection system, and the fast beam distribution elements.

In addition, the CW operation needs new undulators to obtain the low K values required at lower energies. Possible concepts involve low gap in-vacuum or cryogenic undulators. Integration into the accelerator requires R&D.

Overall Facility Layout: The CW operation leads to lower beam energies and eventually to different electron source properties. This requires exploring and adopting the facilities parameter space to obtain again and overall integrated design.

1.3 R&D activities towards extension of the facilities parameters and performance range

Extension of the European XFEL performance range will require R&D in various areas. This accelerator R&D program has strong interconnections to the photon systems R&D and will evolve during operation. It certainly depends on the developments in the field of FEL physics and experimental techniques. The following topics can already be envisioned today:

Electron source: Development to reach smaller emittances, shorter pulses and a fast variation of parameters within a bunch train. Developments to construct a high duty cycle cold gun with improved reliability.

Electron bunch manipulations: Manipulations of the electron bunches to influence the spectral bandwidth (de-chirper) or temporal bandwidth (slotted foil, temporal laser shaping, laser-plasma beam interactions).

Novel diagnostics: New electron bunch parameters (charge, length, temporal stability …) require the investigation of novel diagnostic schemes.

Novel radiation source schemes: Theoretical and experimental investigations of novel source schemes (FEL, tapering, seeding, oscillator) as well as development of concepts for the usage of the empty tunnels XTD3 and XTD5.

1.4 Intelligent Process Control

Automation: IPC is the newest pillar in the XFEL accelerator R&D portfolio and is still in the early stage of definition. This activity aims towards more automation of facility operation by applying novel methods from computer and controls science, like artificial intelligence or big data. Standard learning algorithms will be applied and further developed to create automated operation tools based on model descriptions of the accelerator and photon systems making use of the large data samples stored in the DAQ system. For this the DAQ system will have to undergo a major rework which will be prepared by dedicated study and development activities within this R&D pillar.

Robotics: With the MARWIN system, XFEL already makes use of robot technology to support the operation of the XFEL. R&D activities can extend the capabilities of the system to more autonomous performance of measurement and repair campaigns in the accelerator room.

1.5 Open R&D on short-term disposal for machine coordination

Whilst the R&D activities of the RPGs 200 to 500 will pursue mid- to long-term goals, a small amount of investment capital is foreseen for free and yearly distribution by the accelerator coordination to enable ad-hoc activities and 'off the beaten path' developments.

2 Procedures

A long term budget line of about 5 M€ is available to support the R&D activities focused on the accelerator. This allows funding of proposals which have a long time scale of several years mandatory to move many of the above outlined activity strands forward.

A proposal mechanism is in place to describe a new R&D activity and apply for funding. In order to ensure the strategic consistency of the overall R&D program, R&D proposals shall not only be put

forward by the technical groups/operation packages but shall be actively asked for by the accelerator coordinators as well. A proposal is reviewed from the point of view of the overall R&D strategy for the XFEL accelerator, the available funding, and scientific excellence. If so reviewed positively it will be accepted by the XFEL accelerator coordination MXL. New proposals are then sent to the XFEL Operation Board for information and discussion e.g. to establish links with R&D activities in the XFEL company portfolio. After discussion in the operation board new proposals are made available for the XFEL Management Board.

The accelerator R&D is prepared and followed up by the accelerator coordination (MXL). Proposals and project progress will be reported to MAC and SAC for advice and guidance.

The detailed budget for the accelerator R&D program is defined as part of the annual budget procedure of the XFEL facility. R&D budget details are based on the proposal and status report procedure outlined below. The budget is reviewd by the XFEL AFC and finally approved for the upcoming year in the November meeting of the XFEL Council. Longer term aspects are included in the so called Medium Term Financial Estimate presented to Council together with the overall budget proposal.

2.1 Proposal

Each R&D project will be formally proposed to MXL. The proposal shall include

1. Project description and benefits to the European XFEL
2. Milestones/Deliverables
3. Time Plan
4. Budget estimate

based on a template available from the https://xfel.desy.de/rd web pages.
The project proposals should not exceed 3 pages. After approval a new RP will be set-up for this activity with its own set off cost centers to account for FTE and expenditures.

2.2 Reporting

Each R&D project should report formally at least once per year to the accelerator coordinator. Each report should include:

1. R&D highlights
2. Milestone analysis
3. Budget and time plan update

The report has to be based on the corresponding template available from the R&D web page. The project report should not exceed 3 pages.

A final report closes the R&D project.

2.3 Web Page

Information about the XFEL accelerator R&D program, it‘s structure and links to templates is also available on:

https://xfel.desy.de/rd/