SwissFEL Porthos Workshop, Baden, 28-30 Nov 2023
Discussion Points

History and background:

SwissFEL is currently operating a 6 GeV linac, feeding electron bunches into two undulator lines at a repetition rate of 100 Hz for each branch. The undulator lines are the tender to hard X-ray ARAMIS line with photon energies from 2 keV to 12 keV and fixed polarization and the soft X-ray ATHOS line with variable polarization Apple-X type undulators serving photon energies from approx. 0.25 keV to 1.9 keV. A special feature of the ATHOS line are small chicanes (CHIC chicanes) in between each undulator segment, allowing advanced beam manipulation control modes. Recent developments include first steps towards an externally seeded Athos line.

The overall design of SwissFEL allows for the installation of a third undulator line, the PORTHOS line. The initial plans for PORTHOS called for a two-color hard (>20 keV) X-ray line with flexible polarization and good transversal coherence. This initial science case may be difficult to defend in view of the capabilities of our neighboring European XFEL, their science program and future plans. The European XFEL has electron beam energies up to 17 GeV and can thus reach higher photon energies with higher pulse energies. Moreover, it is the materials under extreme conditions community, which has a strong interest in this photon energy range, which is not represented in the SwissFEL user community. The structural biology community, which is very active at SwissFEL, is mostly using X-ray energies already delivered by ARAMIS (12 keV). Trends from SLS show that there is a tendency to go softer for anomalous scattering. To reach higher resolution, an energy upgrade of the existing ARAMIS line to 7 GeV / 15 keV could be considered. It is noted that such an upgrade would also include the Fe^{57} 14.4 keV Mössbauer lines.

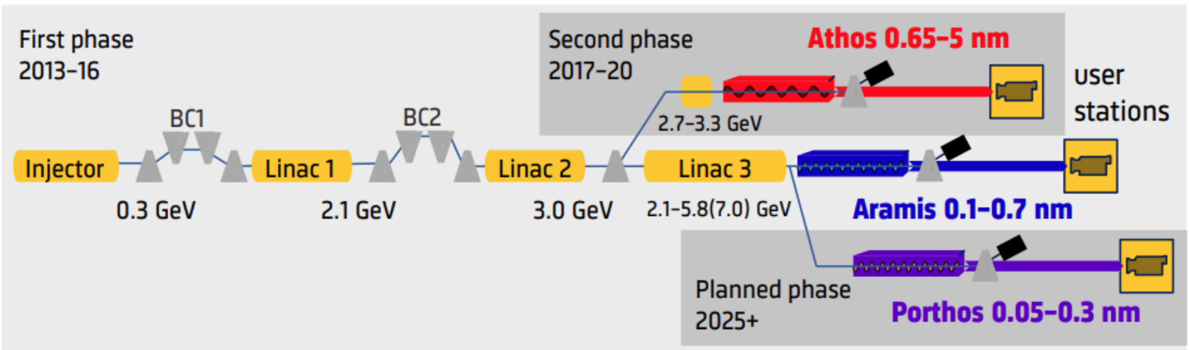

Figure 1: Currently operating and planned layout of SwissFEL. The properties of Porthos shall be re-evaluated in favor of a fully coherent, tender to hard X-ray line with variable polarization. A potential linac upgrade to 7 GeV and accordingly a photon energy upgrade to 15 keV in Aramis should be also considered during the discussions.

A new focus for PORTHOS could be a good coverage of the tender to moderately hard X-ray range from approx 1-9 keV. This range covers the K edges from Phosphor Z=15 to Copper Z=29. Already today there is a good demand at SwissFEL for tender X-ray energies. The demand at the SLS-Phoenix beamline for tender x-ray is growing for chemical and environmental sciences. The tender RIXS beamline at PETRA III has demonstrated the scientific potential of this photon energy range for materials sciences. LCLS-II is also actively exploring the tender x-ray regime. Sciences cases range from biology (S, P) to chemistry, environmental, and materials sciences (batteries, catalysis, earth sciences, photochemistry – P, S, Na, Mg, Ru, Br, Mo, S, Rh etc), condensed matter physics and quantum materials (Ge, Si, Ru, Ir, Mo). A specific opportunity in this energy range could be the overlap of the L and K edges of relevant elements, e.g., for the investigation of the spin properties (L edges) and structure (K-edge EXAFS, imaging, or diffraction) on the same sample.

For a newly envisioned tender to hard X-ray PORTHOS line, the advanced beam manipulation features from the ATHOS line (CHIC chicanes, variable polarization undulators) could be incorporated to produce high-intensity pulses with variable pulse duration (attosecond to 100 femtoseconds) and any polarization. External or self-seeding concepts could be incorporated to produce fully coherent X-ray pulses. A special opportunity lays in electron beam manipulation with external lasers during the lasing process: Here the synchronization between the X-ray lasing process and optical pump lasers reduces to measuring the relative timing jitter between two optical pulses and therefore femtosecond time resolution should be attainable.

A fully coherent PORTHOS undulator source could also dramatically shift the way how X-ray experiments are performed, e.g., from spectroscopic to interferometric approaches. Therefore, PORTHOS should exhibit an extended photon beamline footprint to allow advanced photon beam manipulation like beam splitters, delays and recombiners. Novel opportunities in the X-ray regime include quantum science experiments with photon pairs or non-linear spectroscopy with non-collinear beams. It may even be possible to conceive and implement currently unspecified seeding/undulator schemes to generate entangled photons.

Discussion point suggestions for your consideration:

Photon energies:

PORTHOS is foreseen to extend the capabilities and flexibility of the (seeded, 0.25-1 keV) Athos line to the tender and hard x-ray regime. At the same time the ARAMIS line may undergo an energy upgrade to reach approx. 15 keV.

- What is the ideal energy range for the (seeded) PORTHOS line
- What is the ideal cut-off energy for an upgraded (SASE) ARAMIS line.
- What are the science cases for each branch line?

Polarization control:

The Athos undulator line allows full polarization control, including linear horizontal, linear vertical, circular plus, and circular minus.

- Should the new PORTHOS line include full polarization control?
- Should the existing ARAMIS line be upgraded for polarization control?
- What are the scientific applications for variable polarization at each branch line?
- What are technical advantages for variable polarization experiments at each branch line?

Timing accuracy for x-ray / optical experiments:

The current state of the art for timing accuracy (instrument response function) at existing “warm” XFELs reaches about >30 fsec fwhm with x-ray / optical cross correlators. External beam manipulation can reduce the timing accuracy problem to measuring the jitter between two optical lasers and improve the timing accuracy to femtoseconds

- What are critical timing needs or thresholds for x-ray/optical laser experiments
- Which science cases open up depending on timing accuracy (e.g. for 1, 5, 10, 30 fsec)
- Is measuring and correcting the jitter sufficient? Or do we need to stabilize the machine)

Coherence

External or self-seeding can provide fully (transversal and longitudinal) coherent X-ray pulses compared the currently mostly available transversally coherent SASE pulses.

- What new experiments can we envision in the x-ray domain e.g. in interferometry (and accordingly plan for a lot of space for optical systems)
- What is the sweet spot or at least what is a good parameter space within the time-bandwidth product? Attosecond pulses and broad multi-eV bandwidth or longer pulses and narrow meV bandwidth

Special aspects about external seeding

External seeding concepts are able to generate pulse trains rather than single pulses.

- What opportunities come out of X-ray pulse trains and how can they be applied?
- What level of chirp is allowable for pulse train applications?

Workshop and talks:

The primary goal of the workshop will be to brainstorm new ideas and applications for PORTHOS and promote active discussions.

- The sessions will be typically 2 hours long and include three talks
- **Each talk should be 25 minutes long plus 10 minutes for discussions**
- There is another 15 minutes discussion time window at the end of each session