Operation modes

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Scope of this talk

- Overview
- From commissioning to full operation
- User program
Scientific excellence
- Outstanding scientific research
- Framework for excellent science
- Peer-review access scheme

State-of-the-art instrumentation
- Cryogenic high repetition rate accelerator
- FEL modes and x-ray operation
- Scientific instrumentation
- Sample preparation facilities

Widen access possibilities
- Large number of experiment slots
- Efficient conduct of experiments
- Support of user groups
An experiment at European XFEL

- **Electron accelerator**: Deliver highly defined pulses at user-defined pattern
- **X-ray optics**: Shape x-ray pulse in space & spectrum
- **Photon diagnostics**: Measure x-ray pulse properties
- **Optical laser**: Excite sample systems
- **Sample delivery**: Refresh & reposition samples
- **Detectors / DAQ**: Take and store large number of large data data sets
Overview of e⁻-beam & FEL operation modes

**Electron energy**
- 8.5, 12, 14, 17.5 GeV
- ±1.5 % fast scanning

**Bunch charge/compression ↩ pulse duration**
- 20 – 1000 pC ↩ 2 - 100 fs

**X-ray delivery pattern**
- From pulse-on-demand to 4.5 MHz

**Special**
- Seeding
- Variable polarization
- and more …

In addition: each instrument can determine x-ray settings
- Focus size
- Bandwidth
- Exact photon energy

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Dedicate & distribute electron bunches to instruments

- Operate accelerator as continuous as possible
  → *stability / performance*
- Distribute electron bunch train on two lines
  → *10 Hz switch (few µs duration)*
- Switch on/off lasing for SASE 1/ SASE 3 line (optional)
  → *4.5 MHz switches*
- Determine exact bunch pattern
  → *4.5 MHz switch*

Electron bunch distribution: 27,000 bunches/sec to 3 (5) beamlines; in average 10-20 Hz and ~800 (500) pulses/train; using kicking methods to make bunches lase only in dedicated undulator
e-beam distribution to 2 beamlines
- Slots for feedback & switching
- Equal splitting on both e\textsuperscript{-}-BL

- Equal splitting on 3 undulators

- Equal splitting on 5 und. (future)

- Asymmetric splitting

- Specific electron bunch properties
Concept

- Typical experiment slot 5 days; start/end on machine day
- Share day with two 12 hrs shifts
- Setup /changes on machine days
- Major modifications during shutdown weeks

→ Optimized instrumentation

- dedicated setups & permanent installation where possible
- possibility to swap entire setups (chambers or interior) (only where applies)
Annual operation

- **4800 hrs** accelerator operation for generation of x-rays
  - Peer-reviewed proposals [4000 hrs]
    - Review committees
    - UC prioritized time allocation
  - Internal activities [800 hrs]
    - Maintenance
    - R&D program & management contingency
- **~5600 hrs** total accelerator operation
  - Dedicated machine time
    - Maintenance (w. beam, short access) & tuning
    - R&D

User experiments

- **12000 hrs** user time by operation of three instruments in parallel
- **~200 user experiments / year**
Operation modes

Some challenges

Accelerator operation
- First FEL facility to operate several FELs/instruments quasi-simultaneously. Initially 3, later 5 or even 10-15 instruments.
- At the same time FEL electron beam delivery to undulator is much more individual than e.g. for a storage ring.

Maintain x-ray performance
- Size of facility leads to unprecedented long x-ray beam paths.
- Coherence & wavefront preservation.
- Effects of bunch train operation.

User program
- Conduct complex experiments in relatively short user slots.
- Fast switching between experiments (preparation, setup time).
- User support before, during & after experiments.
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Commissioning aims

- Commissioning of electron beam to generate **hard x-ray SASE FEL radiation as soon as possible**
- Commissioning of x-ray instrumentation to launch **early user program**
- Continue development of e\(^{-}\)-beam and instruments for ~1 ½ yrs to reach **extended electron and x-ray beam delivery**

Early user operation

- Starts 14 weeks after first SASE and includes all instruments after 7.5 months

Full user program

- Provide full number of user hours when reaching the milestone of extended electron and x-ray beam delivery

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Ramp-up of experiments

SPB & FXE (SASE1)
- First beam end 2016
- Early user operation from May 2017

SQS & SCS (SASE3)
- First beam Feb 2017
- Early user operation from June 2017

MID & HED (SASE2)
- First beam Apr 2017
- Early user operation from August 2017
Ramp-up operation

If main accelerator commissioning starts summer 2016:

<table>
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<th></th>
<th>hrs</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<td>5600</td>
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<td>Users $\Sigma U_{NNN}$</td>
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<td>2 x 1000</td>
<td>3 x 2100</td>
<td>3 x 4000</td>
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</tbody>
</table>
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User program

- Access to beamtime based on scientific peer-review
- Invitation for experiments following successful review
- User groups are on-site for few (1-8) days only. Successful conduct of the proposed experiments requires:
  - Preparation
  - Performance (of accelerator and x-ray systems)
  - Support
- For each group peak performance is what counts
  - High availability of all sub-systems

How to enable this

- Provide the infrastructures
- Provide the staff
- Provide the data management & scientific computing tools
### Infrastructures for users

#### Sample injection/insertion
- Liquid jets and sample changer

#### Optical lasers
- MHz/mJ/fs laser pulses

#### Detectors
- MHz frame rate area detectors

#### Sample preparation
- 2x23m² chemistry wet labs
- 30m² x-ray lab for crystallography, SAXS, and reflectometry
- 30m² vacuum labs
- 44m² dry sample preparation
- 2x22m² Electron microscopy and nano-fabrication lab
Enable successful experiments

- Before: Preparation; setup
- During: Monitor instr. performance & change setup; optimize strategies
- After: Checkout (initial & final data analysis, publication)

Scientific instrument groups [MID, HED, FXE, SPB, SQS, SCS]

- Responsible for user program/instrument operation
- 3 teams of 4 scientists (always one team associated with an user group)
- Correspondent for Before/During/After periods
- Contact to experts (instrument support & development (ISD) groups)

Continuous presence of team member(s) during user experiments

- Enable highly efficient usage of beam time
- Involve ISD group members where required
- Plus: on-call service for ISD groups & hall operation group
Karabo: tight integration of applications

Control
- drive hardware and complex experiments
- monitor variables & trigger alarms
  - allow some control & show hardware status
  - show online data whilst running
  - setup computation & show scientific results

DAQ
- data readout
- online processing
- quality monitoring (vetoing)

DM
- storage of experiment & control data
- data access, authentication, authorization etc.

SC
- processing pipelines
- distributed and GPU computing
- specific algorithms (e.g., reconstruction)

Accelerator
Undulator
Beam Transport
Sample Injector

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Operation model of European XFEL is being established

- Ramp-up period of accelerator and x-ray delivery
- Increase operation for users over 3 yrs to final 4,000 hrs per annum
- Aim at operation of 3 science instruments in parallel → 12,000 user hrs

Facility operation

- Define accelerator operation modes
- Operation of accelerator & x-ray systems from different locations while maintaining a high level of collaboration and coordination
- Operation of scientific instruments for users over several weeks and at high level of support
- Learn from initial operation, evaluate and adjust where necessary

Thank you for your attention