Electron Accelerator – Commissioning Experience and Plans for 2018

Winni Decking & Hans Weise, DESY 01.2018
User Program Started
Who is getting the First Photons?
More about experiments: http://www.xfel.eu
electron accelerator – commissioning experience and plans for 2018

sase 2

u 2

u 1

sase 1

sase 3

mid  hed

spb  fxe

sq  scs

study of molecule structure and functions

spb single particle & biomolecules

fxe femtosecond x-ray experiments

more about experiments: http://www.xfel.eu
European XFEL History

2000:
First laser light (109 nm) at the Tesla Test Facility (TTF); today known as FLASH

2001 / 2002 / 2006:
TESLA Linear Collider TDR with XFEL Appendix (2001)
TESLA TDR Supplement with stand-alone XFEL (2002)
European XFEL TDR (2006)

2009:
Foundation of the European XFEL GmbH
Start civil construction

2010:
Foundation of the Accelerator Consortium
16 institutes coordinated by DESY

2012:
Tunnel finished
Start infrastructure installation

2016:
Accelerator finished
Start commissioning with cool down
Special Thanks to all Colleagues and Friends
The European XFEL uses the by far Longest Superconducting Linac Worldwide
Superconducting Technology

- The successful construction and commissioning of the European XFEL was the result of excellent cooperation within the DESY coordinated Accelerator Consortium consisting of 16 institutes.

- The used TESLA technology was developed since the early 90ies. FLASH is the first result of this R&D and can be seen as the prototype.

- With the European XFEL the fully successful technology transfer to industry reached an important point:
  - Other worldwide projects (LCLS-II, ESS, new SRF based FELs at e.g. SINAP, China) are profiting greatly from our efforts.
The first months after the last Users’ Meeting

13/01* 15/01 @ 130 MeV 19/01 @ 600 MeV

27/04 Beam spot before dump

02/02 @ 600 MeV 22/02 @ 2.5 GeV

25/02 @ 2.5 GeV 19/03 @ 6 GeV 08/04 @ 12 GeV

27/04*

* Beam permission on 13/01
* Beam permission on 26/04

“keen on lasing…”
Accelerator Status as of today

- Accelerator has been commissioned according to schedule and towards expected parameters, about 6400 h of scheduled beam time, always being very close to the commissioning schedule.

- **23 out of 25 RF** stations commissioned (last two in CS9, will be ready in Q2/2018).

- Maximum potential final energy obtained during dedicated LLRF studies: **16.1 GeV**

- Maximum beam energy **14.9 GeV**, user operation with **14.0 GeV**

- Routine operation with **300 bunches/second** in user mode

- Test operation in linac mode with **3000 bunches/second** (≈ 18 kW beam power)
RF Commissioning: process and results

- About 3.5 month total commissioning time with up to 3 teams in parallel
- Without and with electron beam in parallel to other beam commissioning
- 23 out of 25 RF stations initially commissioned
- Operation automated; energy goal for 2017/2018 reached with 1-2 stations in reserve
- Reserve stations can be and are used for further studies / gradient increase
First Lasing Results

- 1st lasing at about 1.6 keV (02/05)
- Undulator trajectory alignment (23/05)
- 1st lasing at about 6.2 keV (24/05)
- Photon beam transport (26/05)
- First photons in hutches (26/06)
First Lasing Results

- 1st lasing at about 1.6 keV (02/05)
- Undulator trajectory alignment (23/05)
- 1st lasing at about 6.2 keV (24/05)
- Photon beam transport (26/05)
- First photons in hutches (26/06)
- Photon systems / experiment commissioning
- First user run (14/09)
- 1200 X-Ray pulses / s (27/11)

1200 bunches/s lasing – during radiation protection tests
Facility performance during user run

- 7 user blocks, 5 days each, with 2 days in between for set-up & tuning
- 14 GeV, 1-30 bunches, 9.2 - 9.3 keV
- Availability (= SASE delivery above threshold) between 10% (Block 4) and 97% (Block 6&7)
- Little tuning needed (because of limited flexibility offered), but frequent small wavelength changes and variation of bunch number (1-30)
- Prominent error sources: X-ray mirror, operation & controls, RF trips (speedy recovery), magnets

*European XFEL*
Good User Day (30.09.)

- 14 GeV, 500 pC, 1 to 30 bunches
- Photon energies: 9.2 – 9.3 keV
- Fine tuning: Gap & number of bunches on user demand

- Challenging:
  - Easy control of photon wavelength
  - Missing possibility to look for correlation between electron and photon signals
  - Global undulator controls
Stability & Feedbacks

- Stability will be greatly improved by feedback systems (needs bunch trains)
- Continue to find – and hunt for – jitter and drift sources
- Need more on-line correlation with photon based signals from photon diagnostics and experiments
- Electron beam measured jitter
  - Transverse jitter about 0.1 $\sigma$ for bunches 5 – 30
  - Energy jitter about 1e-4
  - Arrival time jitter about 30-40 fs, potential for 10 fs
**Individual Bunch Pattern**

- Kick bunches into dump after linac

- Operate SASE3: Suppress lasing in SASE1

---

**European XFEL**
Schedule 2018

<table>
<thead>
<tr>
<th>Legend:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weiland</td>
<td>Bank holiday</td>
<td>Scheduled down</td>
<td>ST</td>
<td>AD</td>
<td>XD</td>
<td>NP/MD</td>
<td>XC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2018</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Mo</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
<td>Tu</td>
<td>We</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mrz</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
<td>Tu</td>
<td>We</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mai</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okt</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dez</td>
<td>Tu</td>
<td>We</td>
<td>Th</td>
<td>Fr</td>
<td>Sa</td>
<td>Su</td>
<td>Mo</td>
</tr>
<tr>
<td>Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **About 6800 hours of operation**
- **Shutdowns:**
  - January & April for CS9
  - June/July for IL and MKK work
  - December for SASE2 self-seeding
Accelerator R&D – Different Categories

IMP:

Improvement of operational stability and efficiency

Continuous R&D to improve operational stability and efficiency of the existing facility. The direction of these activities might alter during operation.

CW:

Continuous Wave (CW) operation of XFEL (common interest with ARD-ST1 program)

R&D with the goal for a credible proposal for an upgrade of the European XFEL towards CW operation.

EXT:

Extension of the facilities’ parameters and performance range (common interest with ARD-ST3 program)

Electron source, electron bunch manipulation, novel diagnostics, novel radiation schemes.

OPEN:

Open short term R&D
Goals for 2018

- **SASE1**: About 1,600 h user operation
- **SASE2**: First e-beam in March, first lasing in May
  - Commission laser and photon systems parallel to user runs
  - Installation of Self-Seeding Chicanes (December)
- **SASE3**: First lasing in February
  - Photon systems commissioning influences SASE1 operation
- **Accelerator**:
  - 17.5 GeV by July (continue high gradient task force & CS9 installation and commissioning)
  - 3,000 bunches/second lasing in SASE1 by mid of the year (Possible limitation: dose rate in undulators)
  - 27,000 bunches in XTL by December
### 2018 E-beam Parameters

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Project Goal</th>
<th>Achieved</th>
<th>Routine</th>
<th>2018 Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron energy</td>
<td>GeV</td>
<td>8/12.5/14/17.5</td>
<td>6-14.9</td>
<td>14</td>
</tr>
<tr>
<td>bunch repetition frequency within pulse</td>
<td>MHz</td>
<td>Up to 4.5</td>
<td>1.1, 4.5</td>
<td>1.1</td>
</tr>
<tr>
<td>bunch charge</td>
<td>pC</td>
<td>20 – 1000</td>
<td>100, 500</td>
<td>500</td>
</tr>
<tr>
<td>electron bunch length after compression</td>
<td>fs (FWHM)</td>
<td>2 – 180</td>
<td>20, 90</td>
<td>90</td>
</tr>
<tr>
<td>beam power</td>
<td>kW</td>
<td>500 kW</td>
<td>18 kW</td>
<td>1.8 kW</td>
</tr>
<tr>
<td>undulators in operation (lasing)</td>
<td>SASE1-3</td>
<td>SASE1</td>
<td>SASE1</td>
<td>SASE1-3</td>
</tr>
<tr>
<td>photon energy (SASE1)</td>
<td>keV</td>
<td>0.25 - 25</td>
<td>1,6,9</td>
<td>9-9.5</td>
</tr>
<tr>
<td>photon pulses / s / undulator</td>
<td></td>
<td>27000</td>
<td>1200</td>
<td>300</td>
</tr>
<tr>
<td>saturation power (@ 14 GeV, 500 pC, 9 keV)</td>
<td>mJ</td>
<td>1</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>