STATUS OF THE EUROPEAN XFEL
CONSTRUCTING THE 17.5 GEV SUPERCONDUCTING LINEAR ACCELERATOR

Winfried Decking, DESY
for the European XFEL Accelerator Consortium
- Up to 17.5 GeV SC Linac, 27000 pulses per second
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Three moveable gap undulators for hard and soft X-rays
- Up to 17.5 GeV SC Linac, 27000 pulses per second
- Three moveable gap undulators for hard and soft X-rays
- Initially 6 equipped experiments
Built by 12 European Nations at DESY, Hamburg

Budget 1.150 MEuro incl. preparation and commissioning
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>electron energy</td>
<td>10.5/14/17.5 GeV</td>
</tr>
<tr>
<td>macro pulse repetition rate</td>
<td>10 Hz</td>
</tr>
<tr>
<td>RF pulse length (flat top)</td>
<td>600 μs</td>
</tr>
<tr>
<td>bunch repetition frequency within pulse</td>
<td>4.5 MHz</td>
</tr>
<tr>
<td>bunch charge</td>
<td>0.02 – 1 nC</td>
</tr>
<tr>
<td>electron bunch length after compression (FWHM)</td>
<td>2 – 180 fs</td>
</tr>
<tr>
<td>Slice emittance</td>
<td>0.4 - 1.0 mm mrad</td>
</tr>
<tr>
<td>beam power</td>
<td>500 kW</td>
</tr>
<tr>
<td># of modules</td>
<td>101</td>
</tr>
<tr>
<td>(containing eight 9-cell superconducting 1.3 GHz cavities)</td>
<td></td>
</tr>
<tr>
<td>accelerating gradient for 17.5 GeV</td>
<td>23.6 MV/m</td>
</tr>
<tr>
<td># of 10 MW multi-beam klystrons</td>
<td>27</td>
</tr>
<tr>
<td>average klystron power</td>
<td>5.2 MW</td>
</tr>
<tr>
<td>(for 0.03 mA beam current at 17.5 GeV)</td>
<td></td>
</tr>
<tr>
<td>photon wavelength</td>
<td>0.05 – 4 nm</td>
</tr>
</tbody>
</table>
Accelerator Consortium: 16 Institutes that construct the Accelerator ‘In-Kind’
Three construction sites

5.8 km tunnels

12000 m² surface area are buildings

150000 m³ of underground building volume
4 June 2012
Tunnel breakthrough
All tunneling finished
Accelerator Installation – Warm Beamlines
Detailed planning of needed infrastructure previous to tendering and installation

Installation has started in main linac tunnel Q1/2012

Planning diagram shows

- when, where and how long a task takes place
- which tasks can go on in parallel (or not)
European XFEL at a Glance

Experimental Hall
Photon Beam Lines
Beam Dumps
Undulators
Collimation
Linear Accelerator
Bunch Compressors
Injector

Schenefeld
Osdorfer Born
DESY-Bahrenfeld
- Gun development at PITZ, DESY Zeuthen
- New best values for emittance achieved
- XFEL gun cavity starts to be conditioned in autumn 2012
- 3.9 GHz accelerator module (for bunch length control), design finished, prototype cavities in test

TUPB020 Elmar Vogel (DESY)
*Status of the European XFEL 3.9 GHz system*

MOPB015 Igor Isaev (DESY)
*Multipactor Discharge Simulation for the RF Photo Gun at PITZ*
Collimation & Beam Distribution

- Collimation system for beam halo cleaning and emergency beam stop
- Transvers Intra-Bunch Feedback
- Flexible beam distribution system for quasi-simultaneous operation of two primary electron beam lines

XFEL Collimator
European XFEL – Undulators

- Series production of 90 undulators started
- Focusing quadrupoles manufactured and precision fiducialization
- Series production of intersection components started

THPB089 Iván Moya (CIEMAT)
Magnetic Characterization of the First Phase Shifter Prototypes Built by CIEMAT for E-XFEL
**Beam Dumps**

- **bunch compressor diagnostic dumps**
  - 0.5 and 2.5 GeV
  - small fraction of max. beam power
  - $P_{ave} = 12$ kW
  - max. beam power

- **injector dumps**
  - 130 MeV
  - $P_{ave} = 12$ kW
  - max. beam power

- **main beam dumps**
  - $P_{ave} = 300$ kW
  - 1/2 max beam power
Cavity Material Supply

- Nb sheets and supplementing material purchased by DESY through 4 pre-qualified vendors
- Pressure Equipment Directive: Qualification of material, certification of QM, supervision of production through notified body (TUEV Nord)
- Quality inspection of all semi-finished parts at DESY prior to shipment to companies
  - eddy current scanning
  - tactile 3d measurements
- 70% - 100% material already delivered to companies
Mechanical fabrication

- Mechanical fabrication at RI & Zanon
  - deep drawing of half cells
  - welding of dumb bells
  - rf measurements
  - e-beam welding of 9-cell cavities
- Process qualification through production of reference cavities (RC) and dummy cavities (DC)

E-beam welding at Zanon (courtesy Zanon)
E-beam welding at RI (courtesy RI)
RF measurement and tuning equipment at RI
Mechanical fabrication

- All RCs and DCs produced and treated and RF tested at DESY

![Graph showing XFEL reference cavities Q0(E_acc)]

MOPB012 Alexey Sulimov (DESY)
*First RF Measurement Results for the European XFEL SC Cavity Production*
Surface Treatment

- Installation of equipment for surface treatment at companies almost finished
- Qualification of surface treatment in multi-step process with intermediate RF tests at DESY this fall

Furnaces for $120^\circ$ C baking (courtesy Zanon)

Ultrasonic Cleaning and BCP in ISO 10 clean room (courtesy Zanon)

$800^\circ$ C annealing furnace (courtesy RI)
Cavity Measurements

- All 800 cavities CW power measured in vertical cryostat at AMTF
- Four cavities/cryostat
- Non-conforming cavities repaired at DESY infrastructure
- Conforming cavities shipped to Saclay

34 steps to perform:
- Assembly
- Cool down
- RF test
- Warm up
- Disassembly
Status of the European XFEL

10.09.2012, LINAC12, Tel Aviv
Winfried Decking, DESY

String Assembly
String Assembly

- Infrastructure installed at CEA Saclay (XFEL-Village) for string assembly
- Training of CEA staff with XFEL proto-type cavities
- Assembly will be performed by industrial operator
- Contract signed, training will start autumn this year
String Assembly

- 8 cavities
- 8 Power couples (LAL Orsay)
- 8 Cavity tuners (DESY)
- Quadrupole package (CIEMAT Madrid & DESY)
Module Assembly

- Cold masses from IHEP and Zanon
- Assembly at CEA Saclay
- Tools and infrastructure ready
- Training of industrial operator starts autumn 2012
Module Assembly

- Assembly:
  - string connected to the He return pipe (cold mass)
  - components aligned
  - insulation and shields
  - insertion into cryostat
  - Assembly of warm coupler parts
  - transportation preparation: assembly of end-caps, nitrogen filling of the cavities and assembly of surveillance instrumentation

- Road transport from CEA Saclay to DESY for final testing
Module Testing
where the cavities and the modules will be tested
Flow Diagram of Module Test

229 steps to perform:

- Assembly
- Cool down
- RF test
- Warm up
- Disassembly

- 2 weeks/module
- 3 test stands => 1 module/week tested
- Small fraction of non-conforming modules can be repaired at DESY
High Power RF System

- 10 MW multi-beam klystron
- Contract Awarded, first series klystrons delivered 8/2012

Pulse Transformer and klystron installed in tunnel

Modulator installed on surface
Connection with up to 2 km long pulse cables
All components ordered, cable installation starts next month
Waveguide Distribution

- Pre-installed in AMTF
- AMTF wave-guide test are
- the call for tender started with specified delivery date of first waveguide distribution system in autumn 2012
Low Level RF System

MicroTCA based LLRF system

- RMS amplitude regulation of $5 \times 10^{-5}$
- Phase regulation of $0.009^\circ$
- Expected beam energy stability $< 0.005\%$

THPB085 Julien Branlard (DESY)
LLRF Automation for the 9mA ILC Tests at FLASH
THPB086 Christian Schmidt (DESY)
Precision Regulation of RF Fields with MIMO Controllers and Cavity-based Notch Filters
Cold Linac Infrastructure

- Refurbishment of HERA cryo plant started
- Challenging schedule because of early operation start in 2014 to operate the XFEL injector
- Planning, production and installation of cryogenic equipment for accelerator and AMTF continued
### Overall schedule – and its challenges

<table>
<thead>
<tr>
<th>Civil Construction</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td>XTL</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Halls XHEE, XHE1</td>
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</table>

<table>
<thead>
<tr>
<th>LINAC Fabrication</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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</thead>
<tbody>
<tr>
<td>Cavity Production</td>
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<tr>
<td>String Assembly</td>
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</tr>
<tr>
<td>Module Assembly</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>XTL Installation &amp; Commissioning</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td>Infrastructure</td>
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</tr>
<tr>
<td>Machine</td>
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<tr>
<td>final installation &amp; cool down</td>
<td></td>
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</tbody>
</table>

- **Start-up of series production and assembly**
- **final installation and commissioning**

**Title of your talk**

**Start-up of series production and assembly**

**final installation and commissioning**
Progress on construction, infrastructure planning and ramp up of accelerator component fabrication

Challenge to get the series production of accelerator modules started

Working hard to finish installation in time for

- start of injector commissioning mid 2014
- start of linac commissioning mid 2015
- observe first SASE by end of 2015

Thanks to all people contributing to this exiting project
Back Up
Conclusion:

Projecting to 8 cavities operating at 1.8 K, one should be able to reach 21.5 MV/m at DF=17% (flat-top 140 ms) at 20 W/cryomodule.
Prior surface treatment.
EP 110-140 μm (main EP), ethanol rinse, outside BCP, 800°C annealing, tuning

Final surface treatment - two alternative options
1. Final EP of 40 μm, ethanol rinse, high pressure water rinsing (HPR) and 120°C bake (RI)
2. Final BCP of 10 μm (BCP Flash), HPR and 120°C bake (EZ).

Integration of the helium tank, assembly of HOM, pick up and high Q antennas before vertical RF test