Commissioning and First Cooldown of XFEL Linac

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Deutsches Elektronen-Synchrotron (DESY) - for the XFEL work package 13

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C2OrD
Overview

- XFEL cryogenic system overview
- Main cryogenic components
- Cool Down: limitations & procedures
- Cool Down of the XFEL linac and injector
- Static heat loads to the XFEL linac
- Conclusion & Acknowledgements
Key figures:
- Length of accelerator: 1500m
- Length of facility: 3400m
- Accelerator modules: 96
- Max. electron energy: 17.5 GeV
- Laser wavelength: 0.2 – 0.05 nm
- Start of regular operation: July 1st, 2017
Use of 'TESLA-Technology' for XFEL

800 superconducting 9-cell 1.3 GHz cavities
Helium II bath cooling at 2.0 K - 5/8K and 40/80K thermal shields

8 cavities + sc Quadrupole = 12m Cryomodule
**XFEL Cryogenic System- main components (1)**

- Two former HERA refrigerators
- Overhauled
- Modified for XFEL process
- 20K return flow integrated

**Contractor: Linde Kryotechnik AG (LKT)**

**XFEL Refrigerator Capacities**

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Parallel CB operation measured, kW</th>
<th>17.5 GeV operation calculated, kW</th>
<th>17.5 GeV design specification, kW</th>
<th>Single CB operation measured, kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2K</td>
<td>&gt;2.56</td>
<td>1.46</td>
<td>1.90</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td>5/8K</td>
<td>&gt;4</td>
<td>2.4</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>40/80K</td>
<td>&gt;26.7</td>
<td>16</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>
Added refrigerator components

Contractor: LKT

- Distribution box DB54
- LT Purifier
- Refrigerator Transfer Lines
  Cryoworld, NL
XFEL Cryogenic System - main components (3)

Distance: 170m
Refrigerator bldg.
Contractor: DeMaCo

XIVB
XIVB (BINP)
Cold Compressors
Linac
Transferline to linac XLTL1
XFEL XSE shaft bldg.

CB44 (LKT)
XLVB (BINP)

XIVB
Injector

XRTL Transfer Line
XFEL Injector cryogenic components

3.9 GHz  1.3 GHz

FB

XIVB

FB-feedbox

Budker Institute Novosibirsk (BINP)
Contractor: DeMaCo, NL

3 Feed-Caps & 3 End-Caps

Transfert Lines XLTL 1, 2, 3

96 XFEL 1.3 GHZ cryomodules

6 String Connection Boxes
Limitations of thermal gradients must be respected for all circuits!

\[ \Delta T < 20 \text{ K} \]

\[ \Delta T < 50 \text{ K} \]

\[ 5/8 \text{ K} \]

\[ 40/80 \text{ K} \]

**XFEL Cryomodule Cross-Section**
**Cool Down 300K -> 40K**

**Cold Box '80K' mode**

7th turbine switched off

1.9 MPa pressure for supply of all circuits

**Cool Down 40K -> 4.5K**

**Cold Box regular mode**

**Cold Mass & Helium Inventory**

<table>
<thead>
<tr>
<th>Process circuit</th>
<th>Cold mass [kg]</th>
<th>He mass transient [kg]</th>
<th>He mass stationary [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2K</td>
<td>161000</td>
<td>5600</td>
<td>3600</td>
</tr>
<tr>
<td>5/8K</td>
<td>44000</td>
<td>1100</td>
<td>1100</td>
</tr>
<tr>
<td>40/80K</td>
<td>61000</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

**Mixing of warm and cold gas in XLVB and XIVB to keep the limitations of thermal gradients in all circuits.**
First Cool Down of XFEL Linac

,80K mode' one CB

second CB switched on takes over 40/80k circuit

cold gas returns to CBs

regular CB mode second CB switched off

return temperatures

- 40/80K circuit
- 2K circuit
- 5/8K circuit

CEC/ICMC 2017 C2ORD Bernd Petersen DESY
Static heat load to the XFEL linac 40/80K shield

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate, g/s</td>
<td>111,1</td>
<td>65,8</td>
<td>93,2</td>
<td>81,2</td>
<td>80,7</td>
<td>85,0</td>
<td>80,8</td>
<td>81,3</td>
<td>84,9</td>
<td></td>
</tr>
<tr>
<td>Heat load seen by XLVB, W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9813</td>
<td>9616</td>
<td>9826</td>
<td>9751,5</td>
</tr>
<tr>
<td>Heat load seen by XTL1, W</td>
<td>9224</td>
<td>8689</td>
<td>9605</td>
<td>9128</td>
<td>9364</td>
<td>9249</td>
<td>9424</td>
<td>9192</td>
<td>9374</td>
<td>9250,1</td>
</tr>
<tr>
<td>Heat load XLVB calc., W</td>
<td>9916</td>
<td>8879</td>
<td>9892</td>
<td>9396</td>
<td>9609</td>
<td>9523</td>
<td>9691</td>
<td>9482</td>
<td>9576</td>
<td>9562,6</td>
</tr>
</tbody>
</table>

-> 86 W / Cryomodule – almost 'as calculated' in TDR
Static heat load to the XFEL linac 5/8K shield

- 8 W / Cryomodule – almost 'as calculated' in TDR
Results of static heat load measurements of the XFEL linac 2K circuit

<table>
<thead>
<tr>
<th>Total flow rate, g/s</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>48</td>
<td>50</td>
<td>49</td>
<td>74</td>
<td>54</td>
<td>54</td>
<td>50</td>
<td>59</td>
</tr>
<tr>
<td>Total heaters power, W</td>
<td>477</td>
<td>457</td>
<td>484</td>
<td>467</td>
<td>1025</td>
<td>536</td>
<td>551</td>
<td>516</td>
<td>684</td>
</tr>
<tr>
<td>Heat losses, W</td>
<td>634</td>
<td>590</td>
<td>616</td>
<td>603</td>
<td>593</td>
<td>635</td>
<td>629</td>
<td>580</td>
<td>598</td>
</tr>
</tbody>
</table>

- **XFEL linac 2K static heat losses:** 609 W +/- 20W (incl. Transfer Lines)
- {Very preliminary! Dynamic losses (about 13 Gev, 18 MV/m, 10Hz) 290 W corresponding to about $Q_0 => 1.1 \times 10^{10}$}

**Static load:** < 6.3 W / Cryomodule – almost 'as calculated' in TDR
Conclusions

- Straightforward cool down of XFEL linac
- So far: about 6 month continuous & stable cold operation
- So far: no indication of any cold leaks
- 40/80K, 5/8K, 2K static heat loads: as ‘calculated’
- Low heat loads allow ‘one cold-box-operation’
- XFEL reached commissioning milestones: 14 Gev, 0.15 nm
- Since July 1st, 2017: XFEL in regular operation state
- 2K operation: See next paper this conference
Design and construction of the superconducting XFEL linac is based on achievements of the international TESLA (Technology) Collaboration.

H.Edwards (†2016, Fermi National Accelerator Laboratory, FNAL, USA) was a main supporter of the collaboration from the start.

In particular, we thank our colleagues from FNAL for their contributions to TESLA cryogenics.

The basic concepts for TESLA cryogenics were developed about 25 years ago by G.Horlitz (†1997, DESY).

B.Wiik (†1999, DESY) started it all.

Thank you for your attention!