OVERVIEW ON E-XFEL STANDARD ELECTRON BEAM DIAGNOSTICS

Dirk Nölle for the XFEL Diagnostics Team

BIW 2010, Santa Fe, 5.5.2010
DESY has its 50th anniversary
Reception in the City hall of Hamburg
The European XFEL: Birds View

Hamburg
City Centre (7 km)

HERA

FLASH

PETRA III

DESY
E-XFEL Diagnostics

Accelerator Layout

- One injector initially installed
- Connection to 2nd stage upgrade included in beam distribution layout

- 17.5 GeV superconducting LINAC
- RF photoinjector, two bunch compression stages
- 3 SASE undulators plus 1 spontaneous source, extension possible
- 5 experimental stations to be extended to 10
- Potential extension with a second experimental hall
E-XFEL Time Structure: High Duty Cycle

- Repetition rate
- Macro-pulse
- Bunch
- Slice
- Up to 27000 Bunches/s

FLASH and E-XFEL will have the same time structure
Civil Construction started 2009
- Orders of about 250 M€ placed

Christmas 2009: XFEL Company founded
- We have a legal entity now!
- In-kind Contributions: Negotiations and Contracts

Production Infrastructure under Construction
- Saclay: Module Assembly Facility
- Orsay: Coupler Preparation
- DESY: Advance Module Test Facility

First big Orders for the Machine
- Cavity Orders will be placed in May
You can already see something!
Pictures taken in April 2010

WEBCAMS: http://www.xfel.eu/project/webcams

Acceptance of the tunnel boring machine
3.2.2010
tunneling starts in June!
<table>
<thead>
<tr>
<th>BPM Type</th>
<th>Number</th>
<th>Beam Pipe Diameter</th>
<th>Max. Length</th>
<th>BPM Pick-Up Type</th>
<th>RMS SB Resolution</th>
<th>Bunchtrain Drift</th>
<th>Drift (1 hour)</th>
<th>Drift (1 week)</th>
<th>Range of max resolution (^1)</th>
<th>Reasonable signal range (^2)</th>
<th>Linearity</th>
<th>(x/y) Crosstalk</th>
<th>Charge Dependence (Dx for D/I = 0.1)</th>
<th>Bunch to Bunch Crosstalk</th>
<th>Transv. Alignment Tolerance (rms)</th>
<th>Pipeline Latency</th>
</tr>
</thead>
</table>
High Precision Beam Position Measurements
Resolution of 1 µm @ 1nC
Cavity BPM with Reference and Dipole Resonators
2 Types with "same" RF Properties
3.3 GHz, Low Q (~70)
No tuning -> Precision Manufacturing
Ready for Series Production
We need 120 of these sections!

Contributions from Spain, Sweden, Russia, Germany
17 Undulator Cavity BPMs with 3.3 GHZ resonance frequency produced so far (this includes discs and brazing), 9 with feedthroughs

- Problem: Brazed HF contact between discs caused lower internal quality factor
- Solution:
  - Braze with pure Cu wire higher temperature (T>1050° C)
  - Move brazing joint as close as possible to the resonator

<table>
<thead>
<tr>
<th></th>
<th>$f_L$(Dipole) / MHz</th>
<th>$Q_L$(Dipole)</th>
<th>$f_L$(Ref) / MHz</th>
<th>$Q_L$(Ref)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>3300 ± 50</td>
<td>70 ± 10</td>
<td>3300 ± 50</td>
<td>70 ± 10</td>
</tr>
<tr>
<td>All (17)</td>
<td>3296.4 ± 8.3</td>
<td>72.8 ± 4.2</td>
<td>3290.2 ± 9.4</td>
<td>66 ± 18</td>
</tr>
<tr>
<td>Good HF-contact(13)</td>
<td>3297.3 ± 9.3</td>
<td>73.2 ± 4.1</td>
<td>3291 ± 10</td>
<td>74.4 ± 6.3</td>
</tr>
</tbody>
</table>

Errors of measurement are standard deviation
Cavity BPM: 40.5 mm Beampipe Type

- 3.3 GHz, 40.5 mm Beampipe BPM for high precision measurements and Fast Intra-Bunchtrain Feedback System
- Design and first Prototypes ready
- RF Measurements correspond to Expectations
- Prototypes installed in FLASH (and PSI test facility)
- First Beam Measurements, next weeks
2 Types of Cold BPM (Button, Re-entrant Cavity)
- Modest Resolution: 50 µm
- Operation at 2 k Level (-272 °C)
- Close to the Cavities -> Clean room Class 10!
- Installed in XFEL Prototype Accelerator Modules
- Series Production (80 Pieces) will start in 2010
Cold Re-entrant Cavity BPM

- About 1/3 of cold BPMs will be cold re-entrant cavity BPMs
- Operation at 4K
- Monopole mode around 1250 MHz and Q around 24
  Dipole mode around 1725 MHz and Q around 59
- Single bunch measurement
- Signal processing electronics uses a single stage down conversion to obtain $\Delta/\Sigma$
- RF front-end electronics based on a Printed Circuit board
- $\Sigma$ signal uses by a direct detection using a Schottky diode detector
- $\Delta$ signal uses an I/Q demodulator
- Digital electronics designed by PSI
Cavity & Button BPM Electronics (PSI Designs)

Undulator RFFE
- 3.3GHz (cavity BPM)
- IQ demodulation
- Requirements: Sub-\(\mu\)m resolution & drift

ADC Mezzanine
- Six 16-bit ADCs
- 160Msps

FPGA Carrier Board
- Virtex-5 FPGAs
- Flexible interfaces: 1-5Gbit Rocket IO, VME, VXS, Ethernet
- Two mezzanines: 500-pin connectors

Modular BPM Unit
- Crate: customized power, backplane & cooling: low noise, high temp. stability

Low-cost version of IBFB carrier board (no DSPs, ...), used for all E-XFEL BPMs

2 cavity BPM or 4 button BPM RFFEs

FPGA/ADC board

Slide by B. Keil, PSI
BPM Electronics by PSI (and CEA)

- RF Front Ends
  - Cavity: 2nd Prototype iteration
    beam test: Q3/2010
  - Reentrant: PCB Prototype
    beam test: Q3/2010
  - Button: Circuit layout
    beam test: Q3/2010

- ADC Mezzanine for GPAC
  - 16 bit: first prototype works well
  - 12 bit: test with button RFFE in Q3/2010

- GPAC: Prototype production
  test with 16 bit ADC in Q3/2010

- MBU: first components in house
  prototype test in Q3/2010
Go to µTCA Standard with double Size Boards and the RTM Extension

Try to restrict to few Standard AMC Boards
- DESY AMC02: Multipurpose Board with VIRTEX5 and 4 optical Links
- Struck 8300: 10x16 Bit, 125 MHz ADC with VIRTEX5 FPGA

Customize by application specific RTM

Establish common “Firmware” Framework for these few boards
Technical Issues: Charge

- DESY Style Toroid:
  - about 40 devices required
  - charge range < 1 nC
  - min. bunch spacing 222 ns
  - arbitrary bunch pattern
  - Prototypes of Ceramics ordered, delivery in July

Ferite core (Transformer)
2ndary Coils not visible

Ceramic Gap

Beampipe with Gap
Toroid Readout will base on µTCA DESY AMC02 Board

Use Powerful FPGA for Charge Processing
- Connectivity to other Toroids via up to 4 digital links
- Comparison of charge values for fast transmission interlocks
- Check of Time Structure possible
- Provide digital data stream with Charge Information to LLRF

with custom made Rear Transition Module
- Analog Signal Conditioning
- 108 MHz ADC
- Connection to the Machine Protection System
Dark Current Monitors

- Gun Dark Current: main reason for losses and activation
- Need to control and collimate Dark Current
- DC Monitors: 1.3 GHz Cavities with moderate Q(200)
- Sensitivity $\sim 0.5V$/mA
- Option for Small Charge Operation
- Prototypes installed at FLASH (and PITZ)
- First Beam Tests during FLASH startup (now
### Hotspots for Screens/WS

4 stations with known phase advance for optics characterization

### XFEL uses OTR and fast Wire Scanners

- to check and detect beam at critical places
- to match the optics and to measure Emittance at
  - Injector (OTR)
  - Bunch Compressor B1 and B2 (OTR)
  - in the Collimator (OTR/WS)
  - before the Undulator (WS)
- to measure slice parameters in combination with a transverse mode structure in
  - Injector
  - Bunch Compressors B1 and B2

<table>
<thead>
<tr>
<th>Section</th>
<th>OTR</th>
<th>OTR Off Axis</th>
<th>Wire-scanners (WS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>BC1</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>BC2</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Collimator</td>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Beam Distribution</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undulator Lines</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Dump</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24</strong></td>
<td><strong>12</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>
Requirement: Record On-Axis and Off-Axis (kicked/streaked) Profiles

Resolution 10 µm

Idea: Use “Scheimpflugs” Principle from large format photography

Get a sharp image of an entire plane, if focus, image, and object plane cut in a single line

picture by Linhof
- Design a new scanner based on Linear Motors
- Proof of principle Experiment: Success! Trigger Jitter < 10 µs
  - Go for this system!
- Electronics (Commercial + µTCA)
  - Commercial Linear Motor with (customized) commercial Controller
  - µTCA based readout of Wire Positions + Interlocks (Board 1)
  - µTCA based Detector (BLM) Readout, independent from Scanner (Board2)
Wire-Scanner Impressions

- Acceleration/Deceleration 16.5 mm, const. Velocity: 20 mm/s
- 53 mm Stroke, max speed 1 m/s

Titan
TI-Bellow

Scanner vertical DN50
Scanner horizontal DN50
Viewport DN40
Strahl
OTR-Mover/Screen

hor. Fork in / vert. Fork out
Forks cannot hit

Dirk Nölle, DESY, BIW2010, Santa Fe
Beam Loss Monitor System for XFEL

Beam Loss Monitor
- Scintillator
- PMT

micro-TCA crate
- Readout Electronics
- HV Power supply

~300 Beam Loss Monitors (More than half – in undulator area)

BLMs: IHEP Protvino
Readout Electronics, HV: DESY
Beam Loss Monitor Prototype Based on R5900

28 mm *Hamamatsu R5900* PMT:
- 30 mm scintillator and light-guide
- 100 uA continuous anode current (maximum)
- $2 \times 10^6$ gain (at 800 V), 900 V maximum
- “old” HV-divider (HERA-B)
- 4 PMT anodes connected together
- differential signal output (with transformer)

Test with signals from losses at FLASH:
- signal shape and amplitudes →
  input for readout electronics development and
  new HV-base (larger capacitors)

Next tests:
- BLM based on Cherenkov light measurement →
  BLM with lower sensitivity for places with
  larger expected beam losses (collimation section)
Currently the focus is on items produced in bigger numbers

First Activities
- Dosimetry System: Investigation of Detector Types

No work on
- Special OTR Stations for the BC and Dumps
- E-BPM Mechanics and BAM
- Synchrotron Radiation Ports (High Energy)
- Gun Diagnostics (want to clone recent PITZ/FLASH)
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