Beam Instability Investigations at DELTA

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DELTA
DELTA

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Content:
• Status of the Facility
• Instability Investigation
• EU-Cavity Beam Test
• Summary
BL12: Methods (II): Soft X-Rays
- Photoemission
- Photoelectron Spectroscopy
- Fermi-Surface Mapping

L = 115,2 m
E = 1.5 GeV
Full energy booster BoDo

full energy 1.5 GeV
ramped storage ring
~ 0.1 Hz rep. rate
Linear Injector

- Thermic electron gun
  - 50 keV, 2 A
  - Single bunch mode, few bunch mode

- 3 GHz - klystron

- Output energy: 75-80 MeV
- Total length: 6.4 m
- Old SBTF-structure from DESY, Hamburg

- 40 MW loss power
  - (Ohmic losses in copper)
- 4 μsec RF-pulses
  - @ a few Hertz repetition rate

RF-Section with DORIS-type-Cavity

Single cell cavity @ DELTA

400 kV @ 500 MHz
RF-power 50 kW cw
loss power cavity 27 kW
energy transfer to beam 20 kW
shuntimpedance 3 MΩ

2nd RF ??????
no decision yet
depends on DELTA upgrade philosophy
(lifetime vs. current vs. frequent injection)
### Maschine Parameters DELTA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum beam energy</td>
<td>1.5 GeV</td>
</tr>
<tr>
<td>circumference</td>
<td>115.2 m</td>
</tr>
<tr>
<td>nominal beam current</td>
<td>130 mA multi bunch @ 1.5 GeV; 25 mA single bunch @ 550 MeV</td>
</tr>
<tr>
<td>beam lifetime</td>
<td>&gt; 8 h multi bunch @ 1.5 GeV; &gt; 20 min single bunch @ 542 MeV</td>
</tr>
<tr>
<td>horizontal emittance</td>
<td>16 nm rad @ 1.5 GeV</td>
</tr>
<tr>
<td>natural coupling</td>
<td>3 %</td>
</tr>
</tbody>
</table>
Operation 2004/2005:
30 weeks (3000 h)
2000 h user operation.
1000 hours machine optimisation
and machine physics

Performance 2004/2005:
Average availability during 20 user weeks 94/89 %.
Max. beam current 120 mA.
Average lifetime ~ 7hrs

Availability during user weeks 2005

Performance 2006:
availability ~ 90%
Max. beam current 130 mA.
Average lifetime ~ 8-10 hrs

Only minor vacuum openings
Insertion devices @ DELTA

U55 permanent magnet undulator
ACCEL Instruments

SAW superconducting 5.3 T asymmetric multipole wiggler
ACCEL Instruments

U250 electromagnetic undulator
in house fabrication, also acting as FEL undulator
Brilliance

photons/s/mA/mm²/mrad²/0.1%BW

Photon Energy [eV]

Synchrotron Radiation Sources at DELTA
D. Schirmer, University of Dortmund

Superconducting 5.3 T asymmetric multipole wiggler @ DELTA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dipole</th>
<th>Wiggler (sym. mode)</th>
<th>Wiggler (asym. mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field [T]</td>
<td>1.51</td>
<td>2.79</td>
<td>5.30</td>
</tr>
<tr>
<td>Critical current [A] @ 5T and 4.2 K</td>
<td>471</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of periods</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Beam stay clear [mm]</td>
<td>40</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Horizontal opening angle θ of radiation [mrad]</td>
<td>±13</td>
<td>±25</td>
<td></td>
</tr>
<tr>
<td>Critical energy εC [keV]</td>
<td>2.26</td>
<td>4.18</td>
<td>7.93</td>
</tr>
<tr>
<td>Critical wavelength λC [Å]</td>
<td>5.49</td>
<td>2.97</td>
<td>1.56</td>
</tr>
<tr>
<td>Power P [W/mrad]</td>
<td>4.30</td>
<td>166.89</td>
<td>317.04</td>
</tr>
<tr>
<td>Vertical integrated photon flux @ εC [photons/s/mrad/0.1%BW]</td>
<td>4.61·10^{12}</td>
<td>6.86·10^{13}</td>
<td>2.16·10^{13}</td>
</tr>
<tr>
<td>Type of radiation (off-plane)</td>
<td>elliptical polarised</td>
<td>linear polarised high intensity</td>
<td>great fraction of circular polarisation at high intensity</td>
</tr>
<tr>
<td>Liquid He consumption</td>
<td></td>
<td></td>
<td>~12 liters/day with beam</td>
</tr>
</tbody>
</table>


first superconducting multipole wiggler worldwide

serving 3 hard-X-ray beamlines
### SR-Beamlines @ DELTA

<table>
<thead>
<tr>
<th>Beamline</th>
<th>Experiments</th>
<th>Photon energy</th>
<th>Present status</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL 2 / dipole</td>
<td>X-ray fluorescence spectroscopy</td>
<td>white beam</td>
<td>user operation</td>
</tr>
<tr>
<td>(ISAS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 5 / U250</td>
<td>photoemission, spectroscopy</td>
<td>5 - 400 eV</td>
<td>user operation</td>
</tr>
<tr>
<td>(FZ Jülich)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 8 / SAW 3</td>
<td>material science, EXAFS, diffraction</td>
<td>2 - 30 keV</td>
<td>under commissioning operational end 2006</td>
</tr>
<tr>
<td>(U Wuppertal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 9 / SAW 2</td>
<td>grazing incidence X-ray diffraction, SAXS, XSW, inelastic X-ray scattering</td>
<td>4 - 30 keV</td>
<td>user operation</td>
</tr>
<tr>
<td>(U Dortmund)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 10 / SAW 1</td>
<td>EXAFS</td>
<td>4 - 30 keV</td>
<td>under construction operational 2007</td>
</tr>
<tr>
<td>(U NRW)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 11 / U55</td>
<td>photoemission spectroscopy, photoelectron diffraction</td>
<td>55 - 1500 eV</td>
<td>user operation</td>
</tr>
<tr>
<td>(U Dortmund)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL 12 / dipole</td>
<td>valence band spectroscopy, Fermi-surface mapping</td>
<td>6 – 200 eV</td>
<td>under commissioning operational end 2006</td>
</tr>
<tr>
<td>(U Dortmund)</td>
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</tr>
</tbody>
</table>

**Wiggler Beamlines**
Fast Beam and Instability Investigation

- filling pattern measurement bunch by bunch, turn by turn
- postmortem analysis of beam loss due to coupled bunch mode CBM instabilities
- real time longitudinal CBM instability detection
so far: CBM-detection via synchrotron side band analysis

BPM

P/2

3dB hybrid couplers

Orbit diagnostics

Spectrum analyser 1

Spectrum analyser 2

Epics

Tcl/Tk frontend

10-20 min
new: Bunch by Bunch Beam Analysis

- sampling of BPM sum signal at 2 GS/s, bandwidth 1 GHz
- oversampling technique using shift between RF frequency and sampling frequency
Set up

Acqiris DP214
- 2Gs/s sampling rate
- 8 Bit resolution
- 1Ghz bandwidth

BPM
Power Combiner (500 - 5000 MHz)
EPICS-control-system
Oscilloscopecard (2 GS/s with 1 GHz bandwidth)
RF-Generator
Frequency divider (factor 1/192)

Filling Pattern from bunch by bunch signal
(averaged over 7 turns)

Injection into specified buckets
injection control
FFT of phase modulated signal
(appr. 700 revolutions)

real time (~ 1 s delay)
FFT of phase modulated signal (appr. 700 revolutions)

longitudinal CBM @ mode 52
filling pattern analysis after partial beam loss induced by longitudinal CBM
CBM Investigations @ DELTA
DORIS type cavity

E = 1.5 GeV

T = 40-60 °C
I = 87 mA

$I_{\text{th}} \approx 75\text{mA}$

$L_{16}$

Coupled Bunch Mode No. 1 - 192
full understanding of filling pattern induced mode spectra

Spectrum measured with DORIS cavity @ 542MeV

Filling pattern:
144/192 buckets filled

R. Heine, thesis, Dortmund University 2006
another comparison with a simulated spectrum

Spectrum measured with DORIS cavity @1.5GeV

- 144/192 buckets filled
- induced synchr. frequency spread
- Landau damping
CBM Investigations @ DELTA
DORIS type cavity with damping antennas

E= 1.5 GeV

Coupled Bunch Mode No. 1 - 192

Threshold CBM 22

Threshold CBM 52
The HOM-Damped EU-Cavity

- Single Trapped Mode Resonator
- Plunger
- Nose cones
- Ridged waveguides
- RF window

- Waveguide cut-off between fundamental and first HOM frequency
- HOM energy is dissipated in external RF loads

Cavity design: F. Marhauser & E. Weihreter, BESSY, Berlin
Residual Longitudinal Impedance

- complex time domain calculations for a very complex geometry
- full validation of calculations by bead-pull measurements (o)
- effective damping also of transverse Z

Z|| < 5 kΩ

EU-Cavity Test @ DELTA

CBM Characterisation of EU-Cavity

Spectrum measured with EU cavity @1.5GeV

CBM 52 not induced by cavity, also seen with the DORIS-type cavity
responsible $Z_{||} \approx 10^{-100}$ kΩ

reason still unknown:

candidates:

- strip line kickers
- broken RF-contacts in bellows, valves
- resonant vacuum chambers and tapers
HOM-Damped Cavity Installed


- The cavity was preconditioned up to 30 kW (thermal load, CW) at BESSY and delivered to DELTA (17.May `04).
- Reconditioning within one day (0-30 kW, 5% duty cycle) (02.Jun. `04)
- 28 kW CW were reached the next day.
- 28.Jun. `04: First beam stored with EU-cavity up to 25 mA
- 29.Jun. `04: Vacuum limited 60 mA stored
- 30.Jun. `04: 100 mA stored.
- 14.Jul. `04: 130 mA stored. ($I_{\text{max}}$ of DELTA)
- Sep. 2004 taken out due to leakage in one HOM-damper
Characterisation at 1.5 GeV

Threshold at 95 mA. not related to a cavity HOM. No hints for cavity induced CBM instabilities

27. & 28. Jul. 04 (user week)
HOM-Damped Cavity Installed


- standard operation as single DELTA cavity
- beam characterisation @ 1.5 and 0.542 GeV
- look to cavity impedance via HOM-damper signal
- no hints for CBM-instabilities caused by the cavity
- LCBM at mode 55 detected with threshold currents \(~90\) mA (1.5 GeV) down to 1 mA (542 MeV). Reason for instability not found yet. Instability may hide other instabilities caused by cavity (impedance \(~10 \text{ to } 100\) kW). But no hints.
- Loss power capability of the prototype limited to 20 kW due to non sufficient RF contacts between HOM-dampers and body.
- New HOM-damper design with in vacuum ferrites will solve this problem (see presentation of E. Weihreter)
LCBM-Spectrum @ 542 MeV
EU-Cavity
200 - 1 mA
mode 55 not cavity induced
spectrum analyser

30 dB attenuator

$U(\omega) = Z(\omega) I(\omega)$

HOM-damper signal compared with long. impedance @542 MeV few bunch

20 MHz bandwidth
HOM-damper signal compared with long. impedance @542 MeV few bunch signal normalized to beam frequency spectrum

few kHz bandwidth at revolution frequencies
Summary

- DELTA is operating 3000 h/a with an availability of ~ 90%...
- ..... within a wide range of photon energies (eV – 30 keV).
- DELTA exhibits longitudinal CBM above ~90 mA. Source of impedance (10 – 100 kΩ) not found yet.
- Development of a fast broadband instability monitor.
- The EU-HOM-Damped-Cavity has been tested with beam at 1.5 GeV and 524 MeV for more than one year. Prototype limited to 20 kW cavity loss. No cavity induced instabilities found.
- The cavity impedance can be deduced from the HOM-signal (first steps done, no complete understanding however)
Thanks for the Attention

Acknowledgments

EU-cavity collaboration colleagues from: BESSY, Daresbury CLRC, MaxLab, NTHU

DELTA machine and accelerator physics group

Help from colleagues from ESRF, ALBA, SLS