Damping Wigglers in PETRA III

WIGGLE2005, Frascati 21-22.2.2005
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Introduction
Damping Wiggler Parameters
Nonlinear Dynamics with DW
Operational Aspects
Summary
DESY and its Accelerators

HERA:
6.3 km
27 GeV e⁺ / 920 GeV p

PETRA:
2.8 km
12 GeV e⁺ / 40 GeV p

TTF-2:
300 m
1 GeV

DORIS:
300 m
7 GeV e⁺
Parameters:
- energy: 6 GeV
- current: 100 mA
- emittance: 1 nmrad
- straight sections: 9
- undulators: 13
- undulator length: 2, 5, 20 m
# PETRA III Parameters

<table>
<thead>
<tr>
<th></th>
<th>Without Wiggler</th>
<th>With Wiggler</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tune</strong></td>
<td></td>
<td>35.87 / 31.25</td>
</tr>
<tr>
<td><strong>Nat. Chromaticities</strong></td>
<td></td>
<td>-45 / -47</td>
</tr>
<tr>
<td>I2</td>
<td>6.3e-2</td>
<td>2.6e-1</td>
</tr>
<tr>
<td>Energy Loss/turn</td>
<td>1.15 MeV</td>
<td>4.66 MeV</td>
</tr>
<tr>
<td>Hor. Emittance</td>
<td>4.65 nm rad</td>
<td>1.2 nm rad</td>
</tr>
<tr>
<td>Energy Spread</td>
<td>0.083 %</td>
<td>0.0126%</td>
</tr>
<tr>
<td>Bunch length</td>
<td>8.3 mm</td>
<td>12.7 mm</td>
</tr>
<tr>
<td>Damping times</td>
<td>80/80/40 ms</td>
<td>20/20/10 ms</td>
</tr>
<tr>
<td></td>
<td>10400/5200 turns</td>
<td>2600/1300 turns</td>
</tr>
<tr>
<td>Rev. Frequency</td>
<td></td>
<td>130.118 kHz</td>
</tr>
<tr>
<td>Acceptance</td>
<td>30 µm / 2.2 µm / 1.5 %</td>
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</tbody>
</table>
Emittance Constituents

\[ \varepsilon \propto \frac{I_5}{I_2 - I_4}, \quad I_5 = \int \frac{H}{\rho^3} dl, \quad I_2 = \int \frac{1}{\rho^2} dl \]

For small emittance you need:

- Large bending radius
- Small bending angle per cell
- Small horizontal beta-functions

Forcing: Given by user constraints
Wiggler Requirements

\[
\varepsilon_{x,\text{ring}} = \frac{1}{I_{2,A} + I_{2,N} + I_{2,W} + I_{2,U}} \left( I_{2,A} \varepsilon_{x,A} + I_{2,N} \varepsilon_{x,N} + I_{2,W} \varepsilon_{x,W} + I_{2,U} \varepsilon_{x,U} \right)
\]

\[
I_{2,W} \propto \int B^2 dl
\]

- Total field integral:
  \[\int B^2 m : \approx 98 \ T^2 m\]
- Maximum field and period length
  \[B^3 \lambda^2 : \approx 0.2\]

\[\varepsilon_{x,W} \cong 3.5 - 13 \times 10^{-2} B_{\text{max}}^3 \lambda^2 \langle \beta \rangle \ [\text{nm}]\]

depends on wiggler field shape
PETRA 3 Damping Wigglers

Period: 20 cm
Field amplitude: 1.56 T
Field quality @ 1 cm: <10^-3
Total length: 80 m
Total radiation power: 887 kW
Magnetic symmetry leads to magnetic potential of wedge-like plate equals zero
- No coupling between poles
Wiggler Field

longitudinal field versus y,z

vertical field versus y,z

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Wiggler Treatment

- Linear Optics, Emittance Calculations, Closed Orbit Simulations:
  - Hard-edge dipole model in MAD
  - Linear 6x6 matrix based on field data
- Nonlinear dynamics
  - Field calculations with RADIA, …
  - Field fitting (Halbach formulae) with usually 9 harmonics
  - Symplectic integration of analytical field description
  - Generating function (G. Wüstefeld) for tracking studies
  - End field not yet implemented
  - Field errors as additional multipoles based on field integral measurements
Nonlinear motion after 1 wiggler/7 undulator periods
Wiggler and Undulator

No Wiggler

Wiggler

Wiggler + Undulators

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Resonances

tune scan with initial status x=5mm y=1mm delta=0.1%

Wigglers and undulators

No Wigglers and undulators
DA with/without all insertion devices

Transverse

Longitudinal
Operational Issues: Emittance Control

<table>
<thead>
<tr>
<th>Section</th>
<th>$D_x$ [mm]</th>
<th>$D_y$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wiggler section</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Undulator section</td>
<td>33</td>
<td>7</td>
</tr>
<tr>
<td>FODO arcs</td>
<td>58</td>
<td></td>
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<tr>
<td>DBA arcs</td>
<td>22</td>
<td>31</td>
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</table>

Combined orbit & dispersion correction

$$\left( \frac{\alpha \bar{u}}{(1 - \alpha) D_x} \right) + \left( \frac{\alpha R}{(1 - \alpha) S} \right) \bar{\theta} = 0$$
Operational Issues: Wiggler SR Power Absorbers (BINP)

440 kW @ 200 mA, $E_c=36$ keV
Opening angle: 5 mrad horizontal, 0.085 mrad vertical

Cu, 200 W/cm
2004: TDR published
2004-2006: Finalize technical design
   Procure hardware
   Continue machine studies at PETRA II
2007: End of HERA HEP
   Reconstruction of PETRA
2008: Commissioning of PETRA III
2009: Beam to users
Summary

- PETRA III closes the gap between DESY’s DORIS III and existing high energy 3rd generation light sources, Ideal partner for the X-FEL project

- Ideal test bed for LC damping ring issues
  - Wiggler dominated
  - Large injected beam with frequent injection
  - Small vertical emittance
  - State of the art beam stability
  - State of the art diagnostics
  - $e^+ / e^-$ possible

- BUT: Synchrotron radiation facility