Commissioning of the APPLE II undulator

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Radsynch 13, 05/08/2013
PETRA III at DESY

- Conversion between 2007 and March 2009
- 1/8 completely rebuilt
- 14 undulator beamlines
- All components are designed for 200 mA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PETRA III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy / GeV</td>
<td>6</td>
</tr>
<tr>
<td>Circumference / m</td>
<td>2304</td>
</tr>
<tr>
<td>Total current / mA</td>
<td>100</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>960 / 40</td>
</tr>
<tr>
<td>Emittance (horz. / vert.) / nm</td>
<td>1 / 0.01</td>
</tr>
<tr>
<td>Number of insertion devices</td>
<td>14</td>
</tr>
</tbody>
</table>
PETRA III at DESY – Top view

- 9 straight sections with separation of 5°
  - 1 ID with 20 m (now 5m + 5m)
  - 3 IDs with 5 m device length
  - 5 straight sections with canted undulators (5 mrad, 2 m device length):
    → 14 separate undulator BLs

max. BL-length 103 m (from the source)
Spectral characteristics of PETRA III undulators

Figure 1: Spectral characteristics of PETRA III undulators

Figure 2: Brilliance and onset of the 1st harmonics in various operation modes of the APPLE II undulator

<table>
<thead>
<tr>
<th></th>
<th>Standard Undulator</th>
<th>Spectroscopy Undulator</th>
<th>APPLE II Undulator</th>
<th>In Vacuum Undulator</th>
<th>U-23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period length</td>
<td>2.9 cm</td>
<td>3.14 cm</td>
<td>6.56 cm</td>
<td>1.9 cm</td>
<td>2.3 cm</td>
</tr>
<tr>
<td>Number of Periods</td>
<td>172</td>
<td>158</td>
<td>73</td>
<td>210</td>
<td>87</td>
</tr>
<tr>
<td>Magnetic strength</td>
<td>0.81 T</td>
<td>0.91 T</td>
<td>1.1 T</td>
<td>0.86 T</td>
<td>0.91 T</td>
</tr>
</tbody>
</table>
APPLE II undulator with variable polarization

**APPLE-2 undulator:**
- 4.9 m long
- 65.6 mm period ($\lambda$)
- 72 periods
- 11 mm minimum gap

**with first harmonic:**
- linear hor. approx. 220–3000 eV
- circular approx. 240–3000 eV
- linear ver. approx. 280–3000 eV
- linear ±90° approx. 470–3000 eV

\[ P_{tot} = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0} \]

- Advanced Planar Polarized Light Emitter
  - linear horizontal polarization
  - $S_1 = 1$, shift = $0$
  - linear vertical polarization
  - $S_1 = -1$, shift = $\lambda/2$
  - circular polarization
  - $S_3 = 1$, shift = $\lambda/4$
  - variable linear polarization
  - $S_{1/2}$ variable, shift antiparallel

$B = 1.1T$
The variable polarization soft x-ray beamline at PETRA III will provide highest brilliance and flux in the spectral region from 500 eV to 2.5 keV. BESSY II, ELETTRA and ALS up to 500 eV in the first harmonics for circular polarization. SLS, SOLEIL up to 700 – 900 eV.

Beamline Performance:
- Photon energy range: (<100) 250 – 3000 eV
- Resolving power: > 10^4 (up to > 3 * 10^4 @ 1 keV)
- Photon flux: > 10^12 photons / s (up to 5 * 10^12)
- Spot size at sample: 10 * 10 µm^2
- SMU collimates the photon beam and deflects it horizontally by 2°
- Plane Mirror diverts the central ray to the grating
- Final focusing on the sample with two plane-elliptic mirrors
Energies above 2 keV (3 keV) are cut off → No shielding after the optic hutch.
P04 Variable polarization XUV Beamline

Top view of the P04 optics hutch
Fixed Aperture ES XL P04

To reduce the power density and the heat load on the SMU a fixed aperture is installed in the front-end

Requirements:

• Off-axis option for the single beam
• Absorption of the dipol- and undulator radiation in front of the vertical slit system except for an exit diameter of 4 mm, 17 m away from the source
• Water cooled aperture
• Absorption of the scattered radiation by tungsten shielding
• Temperature control

Figure 1: Watercooled fixed aperture of P04 in the Frontend
The APPLE Undulator has 3 modes:

Total emitted power on the watercooled fixed aperture:

Linear horizontal = 13.7 kW
Linear vertical = 10.3 kW } 100 mA, closed GAP (11 mm)
Circular = 12.1 kW

Behind the watercooled fixed aperture:

Linear horizontal = 3.1 kW
Linear vertical = 2.6 kW } 100 mA, closed GAP (11 mm)
Circular = 12 W

→ The ring-shaped power density of the higher harmonics is totally absorbed in the circular mode
Fixed Aperture ES XL P04

Power density at 17 m [kW/ m rad^2]

Figure 1: vertical polarization at 17 m
Gap 11mm, 100mA

Figure 2: horizontal polarization at 17 m
Gap 11mm, 100mA

Figure 3: circular polarization at 17 m
Gap 11mm, 100mA

Calculations by Mr. Tanaka (Spring 8)
Spectra 9.0
P04 Variable polarization XUV Beamline

Beamline Performance:
- Photon energy range: (<100) 250 – 3000 eV
- Resolving power: > 10^4 (up to > 3 * 10^4 @ 1 keV)
- Photon flux at sample: > 10^12 photons / s (up to 5 * 10^12)
- Spot size at sample: 10 * 10 µm^2

Figure 1: Photon flux of the APPLE II undulator with circular polarization, 100 mA, 11 mm GAP

Figure 2: Photon flux of the APPLE II undulator with linear horizontal polarization, 100 mA, 11 mm GAP
Shielding calculations of the optics hutch

**FLUKA – 2005:**
Bremsstrahlung, Neutrons calculations by Mr. Leuschner

Loss of primary electron beam is excluded
Loss: $10^{15}$ electrons per year

<table>
<thead>
<tr>
<th>Symbol</th>
<th>FLUKA</th>
<th>Few-Bunch</th>
<th>Multi-Bunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running time</td>
<td>T</td>
<td>6000 h</td>
<td>6000 h</td>
</tr>
<tr>
<td>Beam current</td>
<td>I</td>
<td>7.4 pA</td>
<td>100 mA</td>
</tr>
<tr>
<td>Length undulator section</td>
<td>L</td>
<td>6.5 m</td>
<td>14.5 m</td>
</tr>
<tr>
<td>Pressure</td>
<td>p</td>
<td>100000 Pa</td>
<td>3.3 µPa</td>
</tr>
</tbody>
</table>
Shielding calculations of the optics hutch

Loss:
$1 \times 10^{15}$ electrons equivalent to

$200 \text{ mA} \times 6000 \text{ h}$

$14.5 \text{ m straight}$

$1.7 \mu \text{Pa air}$

PLANNING GOAL: 3 mSv per year
Shielding calculations of the optics hutch

**STAC8 v.2.3:**
Synchrotron radiation calculations by Mr. Asano

**Spectroscopy beam line**
Multi bunch mode: 200 mA

<table>
<thead>
<tr>
<th>Name</th>
<th>Spec-U</th>
<th>Apple-U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>6 GeV</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>200 mA</td>
<td></td>
</tr>
<tr>
<td>Period length</td>
<td>3.14 cm</td>
<td>6.56 cm</td>
</tr>
<tr>
<td>number of periods</td>
<td>159</td>
<td>73</td>
</tr>
<tr>
<td>magnetic field</td>
<td>0.91 T</td>
<td>1.1 T</td>
</tr>
<tr>
<td>max. radiated power</td>
<td>18.8 kW</td>
<td>26.6 kW</td>
</tr>
</tbody>
</table>

Abbildung 6: Äquivalentdosis durch elektro-magnetische Strahlung hervorgerufen durch 1200 Ah und 1.7 μPa Luft in der Undulatorsektion.
Shielding calculations of the optics hutch

PLANNING GOAL: 3 mSv per year

<table>
<thead>
<tr>
<th>Position</th>
<th>Bremsstrahlung</th>
<th>Synchrotronradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gamma</td>
<td>Neutrons</td>
</tr>
<tr>
<td>D1</td>
<td>0.1 mSv</td>
<td>0.6 mSv</td>
</tr>
<tr>
<td>S1</td>
<td>0.3 mSv</td>
<td>1.6 mSv</td>
</tr>
<tr>
<td>D2</td>
<td>1.0 mSv</td>
<td>0.3 mSv</td>
</tr>
<tr>
<td>B1</td>
<td>2.2 mSv</td>
<td>0.2 mSv</td>
</tr>
<tr>
<td>Goal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Baryte shields synchrotron radiation, Bremsstrahlung and Neutrons, Current = 200 mA
Radiation Measurement at P04

• Stationary dose rate monitor LB 112 (Berthold technologies)
  - Compact measuring device for wall installation made of stainless steel with IP65 tightness
  - Connection of up to two dose rate probes or other detectors (single or dual probe operation)
  - Low dose / high dose rate system
  - Radioactive gas monitor
  - Ratemeter or scaler timer mode
  - Electrically separated in- and outputs
  - Data transfer and communication in local and large area measuring networks
  - Measuring station with alarm signals for local warning functions

• Low Dose Rate Probe LB 6360 H*(10)
  - The LB 6360-H10 is a proportional counter tube for Low Dose Rate measurements used in various radiation protection applications. The measured quantity is ambient dose equivalent H*(10) and ambient dose rate equivalent Ḣ*(10).
  - Energy range: 35 keV – 1.3 Mev, angular responses +/- 45°
  - Dose rate range: 30 nSv/h – 20 mSv/h
Figure 1: Radiation level inside the optic hutch
Current = 1 mA, Gap = 13 mm, linear polarization

Figure 2: Radiation level inside the optic hutch
Current = 100 mA, Gap = 13 mm, circular polarization
Radiation Measurement at P04

Linear Polarization
Gap 13 mm,
Current = 1 mA

Position 1: 0.3 µSv/h
Position 2: <0.1 µSv/h
Position 3: <0.1 µSv/h
Position 4: <0.1 µSv/h
Position 5: 0.3 µSv/h
Expected weak spots in the shielding of the OHs

- Tolerances of few mm (concrete)
- May be slightly reduced by Pb frame
- Groundshine detected at P10
- Could not be shielded by door frame
  Pocket of 3 mm Pb-Al sandwich

- Media trace along sector
- Short path to components desired
- Stiff tubes for liquid nitrogen
Thank you for your attention