Status of In-Vacuum undulators at ESRF

1- Installed IDs
2- In-Vacuum undulators
3- Magnetic design
4- Magnetic measurements
5- Future

ESRF ID group & Technical services
November 2003: 68 ID segments installed
- 5 in-vacuum undulators (8 in January 2004)
- 9 wigglers & asymmetric wigglers
- 6 helical undulators
### Status of in-vacuum undulators

<table>
<thead>
<tr>
<th>SS</th>
<th>Period [mm]</th>
<th>L [m]</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID11</td>
<td>23</td>
<td>1.6</td>
<td>Jan 99</td>
</tr>
<tr>
<td>ID22</td>
<td>23</td>
<td>2</td>
<td>July 01</td>
</tr>
<tr>
<td>ID9</td>
<td>17</td>
<td>2</td>
<td>July 01</td>
</tr>
<tr>
<td>ID29</td>
<td>21</td>
<td>2</td>
<td>Dec 02</td>
</tr>
<tr>
<td>ID13</td>
<td>18</td>
<td>2</td>
<td>July 02</td>
</tr>
<tr>
<td>ID11</td>
<td>22</td>
<td>2</td>
<td>Dec 2003</td>
</tr>
<tr>
<td>ID30</td>
<td>23</td>
<td>2</td>
<td>Dec 2003</td>
</tr>
<tr>
<td>ID30</td>
<td>23</td>
<td>2</td>
<td>Dec 2003</td>
</tr>
</tbody>
</table>

- 5 devices in operation: min. gap 6 mm (5 mm for ID11)
- 3 devices ready for installation in December 2003
Operation of installed In-Vacuum IDs

- Low field Integrals ($\approx 20$ G.cm) for all gap settings are confirmed by regular COD measurements $\Rightarrow$ No correction coils.
- Very small ($\approx 5.0\times 10^{-4}$) tune shift in multi bunches, 16 bunches, Hybrid user operation
- Some small impedance or tune shift effects observed with all in-vacuum undulator closed in high current single bunch (to be investigated with additional devices).
- Gaps under full user control

<10 % lifetime reduction @ gap 5 mm (uniform & 2/3 filling mode)

Acceptable for future operation @ gap 5 mm
Magnetic Designs

6 devices based on P.P.M. technology
Periods 17, 18, 21 & 23 mm

1 hybrid device constructed - Period 22 mm

Higher peak field than p.p.m
≈ 15-20% for Gap/period= 0.25-0.3 (6/22)

Development of dedicated field correction methods

Permanent magnet material : Sm$_2$Co$_{17}$, Br=1.03 - 1.05 T
Hybrid U22

- Excellent agreement between calculations (RADIA) and measurements (≈ 1%)
- $K = 2.14$ @ gap 5 mm

Gain = $(B_h - B_p)/B_p$

$B_h$: hybrid effective peak field ($n=1$)

$B_p$: P.P.M peak field ($≈ n=1$)
Field integral correction:

- more complicated than p.p.m devices but workable
- many improvements identified (design & field processing)
- Ambient field in SR ≠ in ID lab
  -- change field integrals vs gap
  -- need active correction (steerer)

Graphs showing field integral correction on-axis and 2nd field integral vs gap for Hybrid U22 and P.P.M U23.
Magnetic measurements (4)

Hybrid undulator
Period 22 mm
L=2 m
Gap 6 mm

Phase shimming

Correction of phase error:
- Methods for p.p.m. & hybrid are similar
- the results are also similar
Summary

Hybrid technology for in-vacuum undulators

- higher peak field than p.p.m is confirmed
  -> 20 % @ gap/period= 0.25

Field integral shimming & phase shimming are accessible but can be optimized with:

- modifications on the mechanical design of the magnetic assembly
- implementation of dedicated numerical tools for hybrid devices

--> room for numerous improvements
ESRF In-Vacuum undulators: tomorrow (1)

Permanent magnet devices

1- Update hybrid design for in-vacuum undulators
   - mechanical parts of magnetic assembly
   - field processing & numerical simulations

2- Construction of 2 new hybrid devices
   - U20 (ID9, 2nd in-vacuum device)
   - U22 (ID6, test undulator)

Purpose of ID6 U22

Evaluation of potential radiation damage on Sm$_2$Co$_{17}$ material

- operate permanently @ gap 5 mm
- record regularly spectrum on high harmonics (n=9,11) sensitive to radiation damage
ESRF In-Vacuum undulators: tomorrow (2)

Superconducting devices

Higher peak field-smaller period

Test of a prototype at ESRF foreseen

Partial funding by EC under negotiation

- Magnetism
  - field calculation
  - Field correction …

- Cryogenic aspects
  - Heat budget …

- Low vessel pressure when both cold and warm
  - Baking ..

- Electron Beam Dynamics, routine operation

Measurement
Anka & Accel
R. Rossmanith et al, EPAC2002

Max. Field Computed
NbTi @ 4.2 Deg K
Gap = 5 mm

In-vacuum Undulator
Gap = 5 mm

Rossmanith et al. ANKA/ACCEL PAC03