STATUS OF ESRF INSERTION DEVICES

1. Installed IDs
2. Conventional IDs
   • Vacuum chambers
   • Revolver undulators
   • Helical undulators
3. In vacuum undulators
   • Room temp. P.M IVUs
   • R&D cryogenic IVUs
4. ESRF long term strategy
   • ID straight section
   • Canted undulators
Installed Insertion Devices

November 2006: 73 devices in the storage ring

- 5 wigglers
- 6 helical undulators
- 62 undulators & in-vacuum undulators
- ~100% permanent magnet devices

Major trend over the past years

- Gap & period reduction
- 62% of devices with period ≤ 35 mm
  - $K_{\text{max}} < 2$ (1-1.5)
Permanent magnet undulators

\[ \frac{\Delta B}{B} \sim 17\% / \text{mm gap for a 20 mm period} \]

Min gap = beam stay clear 
+ Material thickness 
+ alignment tolerances 
\( \approx 10 \text{ mm} \)

Min gap = beam stay clear + NiCu sheet 
\( \approx 5 - 6 \text{ mm} \)
Large International development 
following success at Spring8
Conventional undulators connected to the ongoing replacement of ID vacuum chambers
Gap 16 mm -> 11 mm

ESRF type Chamber
- Cheap extruded Al profile
- Int/ext gap = 8-10 mm, L=5 m
- In house NEG Coating, Ti-Zr-V, 1 µm
- Activation @ 200 °C.
- Low Photon Induced Desorption
- Rapid Conditioning

Present situation:
- 10mm Al NEG coated
- 10mm Stainless steel
- In-vacuum
- RF cavity
- Other

Applied at ESRF, ELETTRA, MAXLAB, SLS, SOLEIL (10 m), DIAMOND,…
Revolving undulators

Typical Revolver Undulator:

- K=2.2, Continuously Tunable
  Period ~ 35 mm @ 11 mm

+ K=1-1.5 High Brilliance but limited tunability
  Period ~ 18-27 mm @ 11 mm
Revolving undulators

Measured photon flux on ID18 (A. Chumakov, R. Rueffer)

Key points:
- Length: 1.6 m
- Interchangeable with standard IDs
- Compatible with all vacuum chambers

2 different undulators on the same support:

4 devices installed
4 devices in construction

Switching time between the 2 undulators ~ 1 mn
Circular Polarization: APPLE II undulators

Why so popular?:
- High linear/helical magnetic field
- Generating any polarization (linear, elliptical, ..)

Several Devices in the last years
- Maxlab, Soleil, Diamond, …
Variable polarization at ESRF

2 dedicated beamlines

**ID12** (2-10 keV) 3 segments of 1.6 m
- ESRF helios type (HU52)
- APPLE II HU38
- Electromagnet/permanent magnet device (HU80)
  - 2 Hz, switching time 150 ms

**ID8** (0.3-2 keV) 2 segments of 1.6 m
- 2 Apple II (HU88)
- Phasing section between undulators

APPLE II + Electromagnet types

>90% of helical devices recently constructed worldwide
Experience with helical IDs at ESRF

APPLE II undulators

Machine & ID side:
- complicated field shimming but workable
- tune shift vs phase as predicted -> corrected with “L” shims
- Some effects on vertical emittance (non reproducible)

Beamline side:
- Transient heat load at zero phase when switching between left and right circular polarization is problematic (ID12) ---> New Helios device under design
- APPLE II Ok in ID8, but still photon flux limited

Electromagnet/permanent magnet device:

Machine & ID side:
- stable and transparent until replacement of vacuum chamber
  - Stainless steel -> aluminium (higher conductivity)
  - New correction scheme --> ok since then

Beamline side:
- Left & right x-ray spectra exactly the same
- Very low level circular dichroism (1.0e-4)
- higher photon flux would be welcome
In -Vacuum undulators

High photon energy: > 40 keV at ESRF
ID11, ID15, ID27 high energy beamlines

Initially covered with wigglers (W70, W125, W150)

Conventional “in air” undulators not well adapted
- min. gap 11 mm
- use harmonics ≥9

Reduce gap with in-vacuum Undulator technology
- use harmonics ≥3
- K ≥ 1.5
  (U23 @ gap 6 mm)
- small residual phase error <3 deg

Electron beam
E = 6 GeV
I = 200 mA
Emittances: 4 & 0.03 nm
Minimum gap for IVUs

1: Beam lifetime versus gap

ID11:
\( \lambda_0 = 23 \text{ mm} \)
L = 1.6 m
(hybrid)

ID22:
\( \lambda_0 = 23 \text{ mm} \)
L = 2 m
(p.p.m)

-> minimum gap 6 mm for ESRF IVUs
Pure Permanent magnet

Higher field with hybrid structure:

$\approx 20\%$ (U22 @ gap 6 mm)

But more complicated field correction
### Status of In-vacuum undulators

<table>
<thead>
<tr>
<th>ID</th>
<th>Period [mm]</th>
<th>Type</th>
<th>Peak field @ 6 mm [T]</th>
<th>p.m material</th>
<th>Rms Phase Error [deg] @ 6 mm</th>
<th>Installation date</th>
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<tbody>
<tr>
<td>ID11u</td>
<td>23</td>
<td>Hybrid</td>
<td>0.96</td>
<td>Sm$<em>2$Co$</em>{17}$</td>
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<td>23</td>
<td>PPM</td>
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<td>PPM</td>
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<td>Sm$<em>2$Co$</em>{17}$</td>
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<tr>
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<td>PPM</td>
<td>0.6</td>
<td>Sm$<em>2$Co$</em>{17}$</td>
<td>&lt; 5</td>
<td>July 02</td>
</tr>
<tr>
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<td>22</td>
<td>Hybrid</td>
<td>0.93</td>
<td>Sm$<em>2$Co$</em>{17}$</td>
<td>&lt; 2.5</td>
<td>Dec 2003</td>
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<td>PPM</td>
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<td>PPM</td>
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<td>&lt; 2</td>
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<td>22</td>
<td>Hybrid</td>
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<td>Sm$<em>2$Co$</em>{17}$</td>
<td>&lt; 3.5</td>
<td>Jul 2007</td>
</tr>
</tbody>
</table>

Nominal length: 2m
Cryogenic IVUs (R&D)

Superconducting devices:

• New attractive SCU concept proposed at ANKA (Rossmanith et al.)
  • 10 period prototype build by ACCEL
  • Dry cooling based on cryocooler
• Workshop on superconducting IDs at ESRF (2003)
  • Worldwide interest
• January 2004, contract between ACCEL and ESRF
  • SCU, period 15 mm, Lmag=1.35 m, K=1.5, NbTi conductor
• January 2005, project cancelled at end of design phase
  • Too high risk of damaging an insulated Cu foil in case of large vertical mis-steering of e-beam

Experience with a CuNi sheet locally not in thermal contact with permanent magnet assembly

Cryogenic permanent magnet IVUs:

• R&D is going on
• more details in tomorrow’s talk
Long Term Strategy (LTS)

- Reconstruction of ~ 1/3 of beamlines
- Extension of ~ 1/3 of Experimental Hall
  - 120 m long beamlines for nano-meter and nano-radian beams
- Development of new SR instrumentation
- Upgrade of accelerator complex
  - Higher beam current $\geq 300$ mA
  - Longer ID straight
  - Canted undulator capacity (more beamlines)
ID straight sections in LTS

5 m for IDs

Present new lattice

I=0

6 m

Long quadrupole replaced by short (modified) quadrupole

7 m

Feasible for high beta straights but will need new short quads for low beta straights
Canted undulators

Permanent magnet dipole

6 mrad

An option for the ESRF beamlines

• included in the machine upgrade study
• More beamlines
• ~ 11 beamlines concerned (1st round)

Entry & exit angle ( +3 mrad)
  - quadrupole with hor. offset
  - steerer integrated in sextupole

Permanent magnet dipole (-6 mrad)
  - iron free device under design
  - minimum longitudinal size
Concluding remarks

In air devices conventional IDs
  • Refurbishment almost completed (2 ID straights remaining)
  • Existing designs fit well the 7 m ID straights foreseen in LTS
    • 3 segments in 5 m -> 4 segments in 7 m (2x2 in canted option)
  • growing demand for revolver type devices

In vacuum undulators:
  - The installed devices operate with excellent reliability
  - The existing design (2m long) is not well adapted for 7 m ID straights (LTS)
    - new design(s) will be required
  - R&D presently focuses on CPMU

Helical undulators:
  - New devices will be needed within LTS
    - ID12 will be completely revisited
    - Additional devices for ID8