European Synchrotron Light Source workshop XIX

ESRF Operation and Upgrade status report

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On behalf of the Accelerator & Source Division
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Design of the Super-ACO FEL

1986: ESRF: Head of the Insertion Device Group

2001: ESRF: Director of the Accelerator & Source Division

19/03/2011: Accidental death in the French Alps at 55

Pascal was the initiator of the accelerator upgrade
ESRF Upgrade 2009-2018

Funding for a first phase (from 2009 to 2015) secured to deliver:

- Eight new beamlines, with an extension of the experimental hall.
- Refurbishment of many existing beamlines
- Upgrade of the X ray source for availability, stability and brilliance
- Developments in synchrotron radiation instrumentation

While maintaining an operational facility
New buildings

Longer beamlines
Increased capacity

Beginning of works:
October 2011
New buildings

Started !!!
With a long winter shutdown
Accelerator Upgrade

• Upgrade of BPM electronics
  • Improvement of the beam position stability
  • Coupling reduction
  • New position feedback
• 6 m long straight sections
  • No change in magnet lattice
  • Canted straight sections
• 7 m straight sections
  • Lattice symmetry breaking
  • New magnets necessary
• Cryogenic in-vacuum undulators
• Diagnostics developments
• New RF Transmitters
• New RF Cavities
Upgrade of BPM Electronics

**Sum signal of the 4 buttons:**
- Lifetime monitor
- Instant Fractional-Beamloss monitor

**Turn by Turn**
(355 kHz, for lattice studies)

**First Turn mode**
(For injection tuning)

**Slow Acquisition**
(10 Hz, orbit correction)

**224 Libera Brillance**

**Fast Acquisition**
(10 kHz)
For fast global orbit correction

**Post-Mortem**
(on trigger, now operational)
Coupling reduction

• Achieving lower coupling
  • Better resolution of the response matrices \(\Rightarrow\) improved model
  • New correction method: minimization of Resonance Driving Terms
  • Increased number of skew quad correctors: 32 \(\Rightarrow\) 64
    
    Down to 3.5 pm

• Maintaining small coupling
  • ID gap variations with magnetic field errors induce varying contributions to coupling (in-vacuum undulators)
  • Local correction of ID magnetic field errors
    • 2 skew quad correctors, lookup table
  • Automatic periodic retuning of the correction

  \[4 \text{ pm} < \varepsilon_z < 5 \text{ pm}\] on medium term (1 week)
Coupling reduction

- Maintaining low emittance during USM: 1 week delivery
New orbit feedback

• Present
  • Slow feedback: 224 BPMs, 96 steerers, every 30 s
  • Fast feedback uses fewer monitors and steerers, (32 dedicated BPMs, 32 dedicated steerers)
  • Combination of the 2 systems is delicate

• Under commissioning
  • Single system from DC to 200 Hz
    • 224 Libera BPMs
    • 96 standard steerers up to 200 Hz (integrated in the sextupoles)
    • New power supplies
    • 10 kHz operation
  • Much better correction of the orbit distortion induced by IDs
One of the 224 Beam Position Monitors

Group of 7 Libera BPMs per cell

4 cabinets each containing 18 corrector channels

One of the 8 Feedback Processors

One of the 96 sextupoles housing the correctors

100µs cycle

Fast Network
First tests of Fast Orbit Feedback

27/09/2011
224 BPMs / 96 steerers
Average over 224 BPMs

Horizontal OFF

Horizontal ON

Vertical OFF

Vertical ON
6 m sections

- 6 m section no canting
  - Standard
    - ID18, ID20, ID14
    - ID 24 full 6m operational with 4 carriages
  - With New 2.5 m in-vacuum undulator
    - ID6
- 6 m Large Angle canting
  - ID30 ($\pm 2.2$ mrad)
  - ID16 ($\pm 2.7$ mrad)

No change in optics
New vacuum chambers
✓ Modification of cabling, piping,

✓ Transfer of valves, pump transition chambers, bellows, BPM in place of the quadrupoles.

✓ Replacement of upstream and downstream chambers.

✓ Installation a 6 metre ID chamber (pre-conditionned)
5 metre Section standard

4 straight sections already converted to 6 metres.
5 sections to be done in 2012
Steerers for Canted Straights

Permanent Magnet Steerers

- Homogeneous field integral
- Low fringe field
- 11 Steerers manufactured

Steering angles in [mrad]

<table>
<thead>
<tr>
<th>ID</th>
<th>Angle 1</th>
<th>Angle 2</th>
<th>Angle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID16</td>
<td>-2.70</td>
<td>5.40</td>
<td>-2.70</td>
</tr>
<tr>
<td>ID18</td>
<td>-1.2</td>
<td>2.71</td>
<td>-1.51</td>
</tr>
<tr>
<td>ID23</td>
<td>-0.75</td>
<td>1.5</td>
<td>-0.75</td>
</tr>
<tr>
<td>ID30</td>
<td>-2.2</td>
<td>4.4</td>
<td>-2.2</td>
</tr>
</tbody>
</table>

Collimators:
- dipole x-ray
- on axis beam stop

Double slit

double photon shutter
• New girders
• New quadrupoles
• Individual power supplies
• New vacuum chambers
• 1st symmetry breaking

Goal: Redistribute RF cavities to gain useful straight sections
7 m straight sections
High gradient quadrupoles

- 12 units manufactured by ANTEC
- Needed for 7 m straight sections
- Gradient 26 T/m
- Diameter 66 mm
- Delivered
- Magnetic measurement at ESRF
Stretched wire bench

**Measurements**
- Fiducialization
- Multipole analysis

**Applications**
- Lattice magnets
- Insertion devices
- Steerers and correctors
Magnetic measurements

Field integral

- Permanent magnet steerer

Multipoles

- Least square analysis
- Accuracy of $\sim 10^{-4}$ of the main multipole
Cryogenic permanent magnet undulators

Low temperature magnets

25% Higher field

Increased brilliance at high energy

**CPMU-II**
18 mm period / 6 mm gap
0.99 T @ 150 K
3.0 deg RMS phase error @ 150 K (2.7 deg @ RT)
Beam Diagnostic Developments

Dipole C25-1  X-ray lens  Monochromator  Scintillator

4.41 m  12.4 m

ID25-XRL

02/Feb/2011
USM (7/8 +1)
32 skew correctors
ID25-b  6.6 pm
ID25-xrl  6.2 pm
IAX  6.4 pm

01/Feb/2011
MDT (7/8 +0)
64 skew correctors
ID25-b  3.6 pm
ID25-xrl  3.7 pm
IAX  4.2 pm
• 300 mA stored during MDT for validation of the accelerator developments and also for tests with some beamlines.

• No user mode at 300 mA before the end of Upgrade phase 1.
Measuring extremely low current detection

1 hour of injection @ 1Hz (3600 injections) : 11 electrons accumulated

- PCTs
- BPMs Liberas
- simple CCD + visible dipole light
- cooled CCD + visible dipole light

N electrons

4 electrons
3 electrons
2 electrons
1 electron
New RF transmitters

Booster RF : 4
150 kW amplifiers

2 five-cell cavities
x 2 couplers

Directional couplers

4 Waveguide switches to
4 water loads

SY: Booster Synchrotron

Existing transmitter room
SYRF

75 kW tower
New RF cavities

Based on 500 MHz BESSY, MLS, ALBA design
[E. Weihreter et al.]
But while preparing the upgrade...

The priority is still machine operation:

795.5 hours (33.1 days) of delivery without a single failure
Filling modes

<table>
<thead>
<tr>
<th>Energy</th>
<th>GeV</th>
<th>6.04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multibunch Current</td>
<td>mA</td>
<td>200</td>
</tr>
<tr>
<td>in 7/8+1</td>
<td></td>
<td>4 (single)</td>
</tr>
<tr>
<td>Horizontal emittance</td>
<td>nm</td>
<td>4</td>
</tr>
<tr>
<td>Vertical emittance</td>
<td>pm</td>
<td>3.5</td>
</tr>
</tbody>
</table>

91 % of Beamtime available for Timing Experiments
### Machine statistics

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability (%)</td>
<td>99.04</td>
<td>98.78</td>
<td>98.83</td>
</tr>
<tr>
<td>Mean time between failures (hrs)</td>
<td>75.8</td>
<td>67.50</td>
<td>103.2</td>
</tr>
<tr>
<td>Mean duration of a failure (hrs)</td>
<td>0.73</td>
<td>0.82</td>
<td>1.21</td>
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*In 2010:*
- 5538 hours of beam
- 2000 Research proposals
- ~6300 Users, 1500 Experiments
- ~1800 Referred publications
ESRF brilliance record

Reduction and maintenance of the vertical emittance from 35 pm to 3.5 pm.
Lifetime maintained in excess of 45 hours in multibunch (7/8+1)

- Reduction of the lifetime in multibunch limited to less than 10 hours despite a reduction of the coupling by an order of magnitude
  ==> Still no topping-up envisaged

- The other modes do not benefit from the coupling reduction because the emittance is vertically blown up to get a reasonable lifetime
  ==> Topping up would be valuable
MANY thanks for your attention