Diagnostics during the ALBA Storage Ring Commissioning

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1. Introduction: ALBA Facility
1. Introduction: ALBA Facility

- Synchrotron Light Source in Barcelona
- Up to 30 beamlines (7 on day one)
- Full energy Booster for Top-up injection
- 3 GeV Storage Ring, 268m circumference
- Designed emittance: 4.3nm*rad
- Maximum design current: 400mA

- SR Commissioning started 8 March 2011
- BeamLine Commissioning Autumn 2011
- First Users: Spring 2012
1. Introduction: SR Commissioning

March 8th: Commissioning Start. (Shifts from 7am - 10pm)
March 9th: 1st Turn
March 13th: Stored Beam
March 16th: Beam Accumulated
March 16th: Synchrotron Light out to Diagnostics Hutch
April 1st: Stored 100mA
1. Introduction: Di components

Standard components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Acronym</th>
<th># units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent Screen “In-air”</td>
<td>FS</td>
<td>5</td>
</tr>
<tr>
<td>Fluorescent Screen Horizontal</td>
<td>FSH</td>
<td>2</td>
</tr>
<tr>
<td>Beam Position Monitors</td>
<td>BPM</td>
<td>123</td>
</tr>
<tr>
<td>DC Current Transformer</td>
<td>DCCT</td>
<td>1</td>
</tr>
<tr>
<td>Fast Current Transformer</td>
<td>FCT</td>
<td>1</td>
</tr>
<tr>
<td>Annular Electrode</td>
<td>AE</td>
<td>1</td>
</tr>
<tr>
<td>Stripline BPM</td>
<td>SBPM</td>
<td>1</td>
</tr>
<tr>
<td>Scraper (Hor &amp; Ver)</td>
<td>SCRH &amp; SCRV</td>
<td>1 &amp; 1</td>
</tr>
<tr>
<td>Beam Loss Monitors</td>
<td>BLM</td>
<td>128</td>
</tr>
<tr>
<td>X-Ray Pinhole Camera</td>
<td>Pinhole</td>
<td>1</td>
</tr>
<tr>
<td>Visible Light Monitor</td>
<td>BL34</td>
<td>1</td>
</tr>
</tbody>
</table>
1. Introduction: Di location

At S12: FS

At S04: FS

At S08: FS

At S04 - Di Section:

BSM

BLM

At Injection Straight:

SCRV

FSH

At S2 - Di Section:

Stripline

DCC
AE
FCT
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2. Fluorescent Screens

- Conventional “in-air” model*
  - YAG:Ce screen is kept inside a closed shaft that keeps it away from vacuum
  - Inserted vertically with a pneumatic actuator
  - Screen center, Optics and CCD camera (Ethernet Basler Scout) are in the same axis

2. Fluorescent Screens

- Essential element to perform the 1\textsuperscript{st} turn

\begin{align*}
\sigma_x &= 833\,\text{um} \\
\sigma_y &= 685\,\text{um} \\
\sigma_x &= 545\,\text{um} \\
\sigma_y &= 429\,\text{um} \\
\sigma_x &= 243\,\text{um} \\
\sigma_y &= 555\,\text{um} \\
\sigma_x &= 779\,\text{um} \\
\sigma_y &= 430\,\text{um}
\end{align*}
2. Hor Fluorescent Screens

- Located at Injection Straight
- Inserted horizontally with a motor
- Beam centroid inferred after beam analysis, adding calibration offset of YAG screen wrt stored beam
- Screen center, Optics and CCD camera are in the orbit plane

- Location:
  FSH1: downstream septum
  FSH2: downstream kicker
2. Hor Fluorescent Screens

- Very useful during all commissioning to optimize injection efficiency through the calculation of injected and kick angle.

FSH1

FSH2, Ki OFF

FSH2, Ki ON

X₀ = -22.6mm

X₀ = -21.5mm

X₀ = -16.2mm
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3. Current Monitors

Fast and DC Current Transformers (FCT & DCCT):

- Mechanical design for ALBA SR in-house
- Coils: off-the-shelf products (Bergoz)
- Air-cooling circuit installed to prevent overheating
- Available from day-1 w.o. problems

Bergoz NPCT Card
6-1/2 Digit PXI Multimeter
Adlink SMX-2040

1 turn = 896ns
3. DCCT Performance

DCCT Performance:

- DCCT rms noise: +/- 2uA
- DCCT sensible to dipole cycling and Ta drifts (+/- 30uA)
- No overheating problems (so far, 100mA injected)
3. Current Monitors:

- Continuously used to check machine performance
- Example of analysis of a vertical instability:

SCRV closed from 10mm to 0.28mm produces beam losses (16mA) mainly in the last bunches of the train (suspected to be Fast Ion Instability)
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4. BPMs

- 7 or 8 BPM/cell (120 BPMs): orbit control and interlock system
- 2 BPMs for Bunch-by-Bunch Feedback System
- 1 spare BPM for Beam Dynamics (Tune measurements)

- BPM block is composed by 7mm diameter button type feedthroughs
- Small electrode size and button-shell gap to reduce buttons heating

- Semi-Rigid PEEK cables as transition from feedthrough to RF coax cables
- Low-loss phase matched (<10deg) RF cables of wide variety of lengths [15m – 45m]

![Image of BPMs and related equipment]
4. BPMs

• Reading Electronics: Libera Brilliance
• Non-controlled temperature area/rack
• Digital conditioning (DSC) and calibration not yet applied
• BPMs used from SR commissioning day-1

Raw position meas during 40min @20mA:

- Not yet proper temperature regulation inside tunnel (+/- 0.1deg) neither on service area (+/- 1deg)
4. BPMs

- BBA routine partially ran on BPMs (90/120 Ver, 96/120 Hor)
- Most of the offsets inside +/- 200um (some BPMs to be measured again or crosschecked by alignment team)

No slow orbit correction for the time being (use Orbit Correction Application from MML -> beam within +/-0.5mm)
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5. Tune Measurement System

Function Generator

Splitter-Combiner
rf multiplexer

Choose excitation plane

50W Amplifier
(Kick = 0.15 urad*)

λ/4 stripline
(@tunnel)

FG: Function Generator
Tek. AFG3102

Δ: 180° Split. Comb.
MiniC. ZFSCJ-2-2-S

S: 0° Split. Comb.
MiniC. ZFRSC-42-S+

MUX: Multiplexer
NI PXI-2593

AMP: Power Amplifier
IFI ML50, 50W

* U. Iriso, et al. Design of the stripline kickers
for ALBA, Proc. DIPAC09
5. Tune Measurement System

- Oscillations produced by a white noise signal around tune freq.
- Excitation are produced continuously → no trigger or synchronization is required
- Very useful for beam dynamics applications (chromaticity measurements)
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6. X-Ray Pinhole Camera

- Transverse beam sizes $\rightarrow$ emittance measurements
- To avoid diffraction limit, use x-rays from a bending magnet
- Magnification factor: 2
6. X-Ray Pinhole Camera

Water cooling for the 1mm thick Al-Window:

Max Heat Load: 4.7 W/mm²
Max Tᵃ: 129°C
Max Stress: 79 MPa

Pinhole construction*:
Two arrays of 4 W-bars, with slits spaced by [10, 50, 100μm]

Placed perpendicular one to another

Four motors allow controlling pinhole position and chose the desired hole

*Thanks to K. Scheidt & F. Ewald (ESRF)
6. X-Ray Pinhole Camera

- Pinhole Commissioning took 1-day after stored beam.

<table>
<thead>
<tr>
<th>Date</th>
<th>Conditions</th>
<th>X-ray Images</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011.03.25</td>
<td>one QP polarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>swapped</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25mA, $X_V=0$</td>
<td>$\sigma_x=121\text{um}$, $\sigma_y=218\text{um}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25mA, $X_V=+3$</td>
<td>$\sigma_x=108\text{um}$, $\sigma_y=103\text{um}$</td>
<td></td>
</tr>
<tr>
<td>2011.03.28</td>
<td>QP polarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>corrected during</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20mA, $X_V=0$</td>
<td>$\sigma_x=86\text{um}$, $\sigma_y=186\text{um}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20mA, $X_V=+3$</td>
<td>$\sigma_x=89\text{um}$, $\sigma_y=105\text{um}$</td>
<td></td>
</tr>
</tbody>
</table>
6. X-Ray Pinhole Camera

2011.05.11: After BBA and correct coupling

30 mA, $X_v=0.2$

$\sigma_x=72\mu m$

$\sigma_y=124\mu m$

20 mA, $X_v=0.2$

$\sigma_x=74\mu m$

$\sigma_y=41\mu m$

2011.05.11: Ver and Hor Beam size continuously monitored

![Graph showing beam size over time](image-url)
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Radiation wavelength from a dipole emitted at different vertical angles.

- Select the visible range by placing the mirror at different vertical position.

- Mirror position (in-vacuum) controlled with thermocouples.
7. Visible Light Monitor

- At the Diagnostics Hutch:
  - CCD:
    Reference beam image
  - Streak Camera:
    Precisely infer longitudinal time bunch structure
    Slow sweep unit not yet working
    (image is integrated over 1ms)

Sigma = 33ps (\(V_{rf}=200\text{kV}\))
7. Visible Light Monitor

FIRST SYNCHROTRON LIGHT!!

U. Iriso

Diagnostics during ALBA SR Commissioning
7. Visible Light Monitor

FIRST SYNCHROTRON LIGHT!!
7. Visible Light Monitor
7. Visible Light Monitor
8. CONCLUSIONS

• Diagnostics components at ALBA combine off-the-shelf products with ad-hoc designs → Easy Di Commissioning
• FS, FSH, FCT, DCCT, BPMs worked since day-1 of commissioning without problems
• Diagnostics FE (pinhole and visible light) worked right after beam was accumulated
• Diagnostics components at ALBA eased an efficient commissioning

• Future plans:
  • Fine adjustments to increase Di performance
  • Implement Slow and Fast Orbit Correction
  • Install Fast Feedback Kickers to correct CBI
  • Streak camera measurements
Acknowledgements

→ thanks to the rest of the Accelerator Division (M. Pont, G. Benedetti, Z. Marti, M. Munoz, D. Einfeld...)
→ thanks to people in other divisions: J. Pasquaud (Engineering Div.), and D. Fernandez, S. Blanch, J. Moldes (Computing Div.)

→ Thanks for the advices from many colleagues in other machines:
G. Rehm and C. Thomas (Diamond), J.-C. Denard and L. Cassinari (Soleil), V. Schlott (SLS), K. Scheidt and F. Ewald (ESRF), P. Kuske (BESSY)
Extra slides
XSR or pinhole camera

- Transverse beam sizes $\Rightarrow$ emittance measurements
- Simple pinhole system (no need for pinhole array)
- Pinhole material: Tungsten
- Magnification factor: 2
- Al vacuum window + Cu sloped block to filter x-rays ~ 18 keV
Visible Sync. Rad. front end

- Need to build a **mirror** with thermocouples to reflect just the visible part
- Light analysis is done in the optical hutch
- Bunch length measurements with **streak camera**
- Qualitative beam image with **CCD** camera

*K. Scheidt, UV and Vis. Light diagnostics at the ESRF, Proc. of EPAC'96*
### BPM Buttons

<table>
<thead>
<tr>
<th></th>
<th>SR</th>
<th>Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hor. Sensitivity (mm$^{-1}$)</td>
<td>0.080</td>
<td>0.093</td>
</tr>
<tr>
<td>Ver Sensitivity (mm$^{-1}$)</td>
<td>0.075</td>
<td>0.093</td>
</tr>
<tr>
<td>Capacitance (pF)</td>
<td>2.7</td>
<td>3.2</td>
</tr>
<tr>
<td>Intrinsic resolution (μm)</td>
<td>11 (@0.1 mA and 4kHz)</td>
<td>45.5 (@0.1 mA and 1.2 MHz)</td>
</tr>
</tbody>
</table>

**First 20 BPM buttons & Blocks just manufactured**

**BPM block welded to vac. chamber**
BPM electronics

- One type of electronics for one type of monitor
- Contract signed with I-Tech for all BPMs (SR, Booster, LTB, BTS)
  Keeps system simple, eases maintenance...
- Sub-micron resolution, stability depending on current, temperature...
- Slow & Fast Orbit Correction schemes
- BPMs equipped with data acquisition for:
  -> Turn By Turn (1.1MHz)
  -> Fast Orbit Correction (4 kHz)
  -> Slow orbit Correction (4 Hz)
  -> Post Mortem buffer
  -> Other data acq. options on demand

TESTS STATUS:

- 30 Libera units & 4 Clock Splitters arrived for tests in Jan. 2007
- Res. around -40 dBm was out of the specs due to a wrong gain scheme → Corrected in 2 weeks → Acceptance Tests for approved for all units