ALBA
Synchrotron Light Source
Commissioning

D. Einfeld, CELLS-ALBA
on behalf of the Commissioning Team
Contents

1.) The project ALBA
2.) Commissioning results
   2a.) Linac
   2b.) Booster Synchrotron
   2c.) Storage Ring
Contents

2.) The project ALBA

2.) Commissioning results
   2a.) Linac
   2b.) Booster Synchrotron
   2c.) Storage Ring
The ALBA - Building

- Warehouse
- Parking
- SR and Boo Tunnel
- Workshop
- Electricity
- Offices
- Cooling, HVAC
- Size of the ground: 250m *450m

Dieter Einfeld, CELLS-ALBA

IPAC-2011, 5th September 2011
Accelerator complex of ALBA: We followed the concept of the SLS to have the booster and the storage ring in the same tunnel. The preinjector is a 100 MeV Linac.
The lattice is a TME-structure.
The ALBA synchrotron should have the smallest emittance in the world.

Design working point: $Q_x = 12.42$, $Q_y = 7.38$, emittance $\epsilon = 9$ nmrad.
Booster Installation

- Straight
- Detail
- Booster Arc
- Extraction
- Injection

Dieter Einfeld, CELLS-ALBA

IPAC-2011, 5th September 2011
4 long straights with a length of 7.8 m
12 medium straights with a length of 4.3 m
8 short straights with a length of 2.3 m

Circumf. = 268.8 m
4 fold symmetry
Emitt. = 4.5 nmrad
There are: 8 foc. and 3 def. families of quadrupoles
4 foc. and 5 def. families of sextupoles
New developments:

- Normal conducting HOM damped cavities.
- Watrax, transition from WG to Coaxial
- CaCo, cavity combiner of 2x80 kW IOTs
- Digital LLRF

Check posters today:

MOPC045
MOPC046

RF Voltage: 3600 kV, beam current: 400 mA, losses: 1.3 MeV/turn, beam power: 520 kW
RF Voltage: 3600 kV, beam current: 400 mA, losses: 1.3 MeV/turn, beam power: 520 kW

New developments:

- Normal conducting HOM damped cavities.
- Watrax, transition from WG to Coaxial
- CaCo, cavity combiner of 2x80 kW IOTs
- Digital LLRF

Check posters today:

MOPC045
MOPC046
ID’s, Front Ends and Beam Lines

17 ID beam ports
17 BM beam ports

Phase I
7 Beamlines (6 ID + 1 BM)
2 Diagnostic FEs
1 test FE (for future beamline)
Storage Ring in the Tunnel

Cavities

Storage ring

Booster

Unit cell

Straight section

Storage ring arc
Contents
1.) Introduction
2.) The project ALBA
3.) Commissioning results
   3a.) Linac
   3b.) Booster Synchrotron
   3c.) Storage Ring
Summary: Some specifications of the Linac are much better as given by the specifications (for example the emittance is by a factor 1.5 smaller). The Linac operation is very reliable for the different modes: long bunch, small bunch, single bunch, large charge (4 nC), small charge (0.5 nC), etc.
Contents
1.) Introduction
2.) The project ALBA
3.) Commissioning results
   3a.) Linac
   3b.) Booster Synchrotron
   3c.) Storage Ring
Booster Commissioning

22.12.2009, 3:00 first beam in the booster

1. Phase: 10th to 24th of January 2010
   The goal was to cross check all the sub-systems. We reached a beam up to 600 MeV and later to 2.8 GeV

2. Phase: July 2010
   We have had problems with the Linac, the booster power supplies and also the injection elements. No success and progress.

3.) Phase: September - October 2010
   We changed the philosophy: tunnel open in the morning for storage ring installation and tunnel closed in the afternoon for booster commissioning. We could characterize the booster and got a 3 GeV beam at the 4th October 2010. 28th of October a beam of 3 GeV into the BTS transfer line
Dispsrsion Functions (DC)

Good agreement with the model
Results of the ALBA Booster commissioning

**LOCO: Beta Functions (DC)**

\[ \beta - \text{function (Tune} \,= \, 12.271 / 7.356) \]

\[ \beta_x \, [\text{meters}] \]
\[ \beta_y \, [\text{meters}] \]

*Good agreement with the model*
4th October 2010: beam accelerated up to 3 GeV

- First beam to 3 GeV: injection on w.p. (12.42, 7.38)
- Large drop of Qx at the start due to nonlinear magnet calibration
- Vertical tune is flat: most of the vertical focusing is provided by the gradient bending
Correcting the orbit while ramping

orbit corrected to ± 3 mm along the ramp
Beam in the Booster Synchrotron

Dieter Einfeld, CELLS-ALBA

Accelerator Division

- Bad shots
- Increase transmission
  - LINAC
  - LT: 70% 70-85%
  - BO: 100%
  - BT: 50 - 60%

110 MeV
3 GeV
200 MeV
We are 30 % off to the theoretical emittance and have a coupling factor of roughly 20%.

\[ \sigma(x) = 0.86 \text{ mm}, \sigma(y) = 0.19 \text{ mm} \]

\[ \varepsilon(x) = 13 \text{ nmrad}, \varepsilon(y) = 2,6 \text{ nmrad} \]
Contents
1.) Historical remarks
2.) The project ALBA
3.) Commissioning results
   3a.) Linac
   3b.) Booster Synchrotron
   3c.) Storage Ring
Recabling Quads:

- Sectors 1&2
- Quadrant 1
- Quadrant 2
- Quadrants 3&4

19h35: 1st turn!
13th March, 9h38: 1 second stored beam

SR FCT

Maximum

Average

Vacuum
13 - 14 March: First measurements

Lifetime

Synchrotron light at pin hole camera

Energy = 2.92 GeV
16th of March 2011: a historical day of the ALBA – project: the first accumulated beam at ALBA.

Beam within the storage ring

Beam within the booster
16th of March 2011:
A historical day of the ALBA – project,
The Accelerator Division is celebrating this success.
First measurements of beta function with LOCO: there is an asymmetry in the machine.

Result: QF1 and QD1 in sector 8 are swapped.
Beta functions reconstructed by LOCO after recabling QF1 and QD1

Result: It looks much better, but there is still an asymmetry in the machine (vertical)
Once the MPS was operational…
Normally working with (+2, +2)
**Beam Based Alignment**

**BBA : Results**

- **Horizontal offsets:**
  - +1.0 mm to -1.1 mm

- **Vertical offsets:**
  - +0.9 mm to -1.1 mm
**Raw orbit without correctors**

Offsets of BBA included and RF frequency adjusted

Storage Ring Orbit (Difference from the Offset Orbit)

- Horizontal orbit < 3mm
- Vertical orbit < 2 mm

Good alignment
Dieter Einfeld, CELLS-ALBA

**Orbit Correction: Reproducibility**

**Raw orbit with correctors**

Storage Ring Orbit (Difference from the Offset Orbit)

- Horizontal rms error: 32 μm
- Vertical rms error: 29 μm

Long straight sections

Accelerator Division

Raw orbit with correctors to reference orbit

*IPAC-2011, 5th September 2011*
Tune during the commissioning:  
Accelerator Division

\[ \begin{align*}
Q_y(\text{nom}) &= 8.37 \\
Q_x(\text{nom}) &= 18.18
\end{align*} \]

Normally working with chromaticity: +2, +2
- 7 or 8 BPM/cell (120 BPMs): orbit control and interlock system
- Low-loss phase matched (<10deg) RF cables of wide variety of lengths [15m - 45m]

Example: raw position meas during 40min @20mA

110 Minutes
Horizontal Dispersion: the deviations to the model are +/- 5 mm. This is a good agreement.

Vertical Dispersion: +/- 15 mm the vertical dispersion is given by the cross talk of the BPM’s. With the introduction to LOCO, it could be decreased to 1 mm.
The maximum differences after the LOCO fitting are +/- 2%.

In the vertical direction there are 32 peaks and we have 32 bendings.
Injection Efficiency

Injection efficiency ~ 95%

SR DCCT

I = 21 mA

t = 40 s

Booster DCCT

<|l|> = 0.55 mA
 Beam Size / Emittance

Pinhole camera

Quite ok with model:
Emittance X = 6.07 nmrad
Coupling = 0.4 %

Emittance Y = 0.03 nmrad
Coupling = 0.5%

71 um
31 um

Accelerator Division

Dieter Einfeld, CELLS-ALBA

IPAC-2011, 5th September 2011
Three insertion devices have been installed and closed:

- EU62
- EU71
- MPW80

Without much influence in the machine:

<table>
<thead>
<tr>
<th>MPW80 - BL22</th>
<th>Gap (mm)</th>
<th>tunes</th>
<th>RMS Orbit Distortion (um)</th>
<th>tunes change (10^-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN</td>
<td>275</td>
<td>0.229, 0.375</td>
<td>0 , 0</td>
<td>---</td>
</tr>
<tr>
<td>1/2 CLOSED</td>
<td>50</td>
<td>0.229 , 0.377</td>
<td>11 , 57</td>
<td></td>
</tr>
<tr>
<td>CLOSED</td>
<td>12.7</td>
<td>0.229 , 0.377</td>
<td>15 , 9</td>
<td>0 , 2</td>
</tr>
<tr>
<td>OPEN</td>
<td>275</td>
<td>0.229 , 0.376</td>
<td>14 , 14</td>
<td>0 , 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EU71 - BL29</th>
<th>Gap (mm)</th>
<th>Phase (um)</th>
<th>tunes</th>
<th>RMS Orbit (um)</th>
<th>tunes change (10^-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN</td>
<td>273</td>
<td>0</td>
<td>0.229, 0.376</td>
<td>0 , 0</td>
<td>---</td>
</tr>
<tr>
<td>HORIZONTAL (0)</td>
<td>15.5</td>
<td>0</td>
<td>0.230, 0.376</td>
<td>15 , 14</td>
<td>+1 , 0</td>
</tr>
<tr>
<td>CIRCULAR (π/2)</td>
<td>15.5</td>
<td>21181</td>
<td>0.228, 0.377</td>
<td>15 , 14</td>
<td>-1 , +1</td>
</tr>
<tr>
<td>VERTICAL (π)</td>
<td>15.5</td>
<td>35650</td>
<td>0.228, 0.377</td>
<td>16 , 15</td>
<td>-1 , +1</td>
</tr>
<tr>
<td>CIRCULAR (-π/2)</td>
<td>15.5</td>
<td>-21181</td>
<td>0.228, 0.377</td>
<td>15 , 15</td>
<td>-1 , +1</td>
</tr>
<tr>
<td>VERTICAL (-π)</td>
<td>15.5</td>
<td>-35650</td>
<td>0.228, 0.377</td>
<td>16 , 15</td>
<td>-1 , +1</td>
</tr>
<tr>
<td>OPEN</td>
<td>273</td>
<td>0</td>
<td>0.229, 0.376</td>
<td>15 , 16</td>
<td>0 , 0</td>
</tr>
</tbody>
</table>
• Visible Radiation from a dipole is extracted using a mirror
• Mirror position (in-vacuum) controlled with thermocouples

**Example: Bunch Length Measurement**

Bunch length vs. RF voltage

- **Effective RF voltage (kV)**: 1050, 1100, 1150, 1200, 1250, 1300, 1350
- **Bunch length sigma (ps)**: 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

- **Experimental**
- **Calculated**

---

**Streak Camera**

Accelerator Division

Visible Light  CCD

STREAK CAMERA
The commissioning could only be done with 3 to 4 cavities with a maximum current of 200 mA.
7th of June: 170 mA at ALBA

Dieter Einfeld, CELLS-ALBA

Beam current, mA

DCCT
Hor Size
Ver size

Xh=0.6  Xv=3.9
Xh=0.6  Xv=4.4
Xh=1.1  Xv=4.4
Xh=1.6  Xv=4.4
- Average pressure without beam = $4 \cdot 10^{-10}$ mbar.
- With 4.5 A.h. dose, the average pressure was $3.2 \cdot 10^{-9}$ mbar with 80 mA of beam current (multi-bunch filling mode).
- Vacuum Clean-up rate estimated 0.68.

![Pressure Profile](image)

Average pressure normalized to current vs. beam dose

Photon-stimulated desorption yield (PSD) vs. beam dose.
Summary of Measurements

- Tune
- Chromaticity
- Beam Based Alignment
- Orbit correction, including frequency adjustment
- LOCO measurements:
  - Beta functions, dispersion and beating correction
- Beam size, emittance
- Bunch length
- Vacuum performance
- Closing IDs
- Slow orbit correction system

(Most of these measurements were done with 10~20 mA)
Thank you very much

This was not only a success from the commissioning team, it was a success of the whole CELLS staff.

The machine is ready to serve as a source for the experiments.
[1] M. Pont et al., "Operation of the ALBA injector",