Installation, commissioning and performance of IDs installed at ALBA

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Abstract. The new synchrotron light source ALBA is currently starting regular operation. Up to 6 beamlines are using light produced by Insertion Devices. There are up to four types of IDs: 2 Apple-II undulators (EU62 and EU71) operating at low energies, one conventional wiggler (MPW80) operating in the range of 2 – 20 keV, two in-vacuum undulators (IVU21) operating in the range 5 - 30 keV and a superconducting wiggler (SCW30) operating in the range of (up to) 40 keV. The main IDs characteristics, their influence on the beam dynamics and a first characterization of their light will be presented.

1. Introduction

The Insertion Devices (IDs) installed at ALBA synchrotron light source are summarized in Table 1. We described them in detail elsewhere [1].

| Table 1. IDs at ALBA. “H”, “V” and “C” stand for horizontal, vertical and circular polarization. |
| Beamline (name) | Spectral range (keV) | ID (name) | B_{max} (T) | \lambda_u (mm) | N |
|-----------------|---------------------|-----------|------------|--------------|---|
| BOREAS          | 0.08 - 3            | EU71      | H          | 0.93         |    |
|                 |                     |           | V          | 0.7          | 71.36 |
|                 |                     |           | C          | 0.56         | 22  |
| CIRCE           | 0.1 - 2             | EU62      | H          | 0.87         |    |
|                 |                     |           | V          | 0.625        | 62.36 |
|                 |                     |           | C          | 0.508        | 27  |
| CLAESS          | 2.0 – 20            | MPW80     |            | 1.782        | 80.0 |
|                 |                     |           |            |              | 12.5 |
| XALOC           | 5 – 21              | IVU21     |            | 0.806        | 21.6 |
|                 |                     |           |            |              | 92  |
| NCD             | 6.5 – 13            | IVU21     |            | 0.806        | 21.6 |
|                 |                     |           |            |              | 92  |
| MSPD            | 8 – 40              | SCW30     |            | 2.15         | 30.15 |
|                 |                     |           |            |              | 58.5 |

Three IDs were outsourced to private companies through international tendering process: in-vacuum undulators IVU21 [2]; and multipole wiggler MPW80 [3]. The rest were made collaborating with public institutions: elliptical undulators EU71 and EU62 Apple-II type with ELETTRA [4], and SCW30 superconducting wiggler with BINP [5]. Installation was done in two steps: first step lasts from January the 10th to February the 2nd of 2011, and was dedicated to installing the out-vacuum devices, including the removal of dummy vacuum chamber at the straight sections and substitution by extruded aluminium NEG coated vacuum chamber with small vertical aperture (8 mm inside, 10 mm
outside). These devices have been commissioned with beam between May the 20th and June the 8th. Second step lasts from June 1 the 4th to August the 5th of 2011. It was dedicated to the bake-out and mechanical installation of the two in-vacuum undulators and the superconducting wiggler, along with the upstream and downstream vacuum chambers completing the involved straight sections. Commissioning with beam was done between September the 13th to October the 12th.

2. Commissioning of IDs without beam
Prior to the installation, all IDs passed the Site Acceptance Tests (SAT). In the case of out-vacuum devices, they were remeasured at ALBA magnetic measurement laboratory.[6] Magnetic field, phase error and field integrals were measured, and we found good agreement with manufacturer data acquired during Factory Acceptance Tests (FAT). Also fiducialization was successfully tested using SAT magnetic measurements, showing that shipment did not have big impact in ID performances.

Elliptical IDs were compliant with specifications, even producing specified peak field at higher gap values than expected. With respect to the intrinsic large quadrupole term observed by several groups, for EU62 maximum quadrupole was 7·10^{-3} T (skew) and for EU71 was 1·10^{-2} T. Specified maximum quadrupole from optics tolerance was in both cases 1·10^{-2} T, so no specific action has been needed to correct it. In the case of MPW80 wiggler, we found higher sextupole component than specified, but this can be compensated by ALBA Storage Ring sextupoles. In addition, upper array was found to be longitudinally displaced 250 µm with respect to lower array, without consequences for its performance. Finally, also in this case, first and second integrals were higher than specified at one of the given working gaps. This forced us to build new correction coils, because those initially manufactured did not give enough compensation power. Regarding in-vacuum undulators, SAT consisted only of vacuum tests (leak and Residual Gas Analysis). Because of that, FAT follow up was stressed, especially regarding magnetic measurements. Devices were compliant with specifications, with phase errors lower than 2.5º, first field integrals lower than 30 µT·m, and second field integrals lower than 55 µT·m² (both without correction). In order to account for the field degradation because of bake-out, the second device was disassembled after a first bake-out at 120°C and was magnetically characterized again. Initially, at 6 mm gap, peak field was B0= 0.7571 T, phase error 2.4º, first field integral 25 µT·m and second integral 52 µT·m². After bake-out the corresponding figures were B0 = 0.7533 T, phase error 2.6º, first integral 40 µT·m and second integral 70 µT·m², and consequently the device was re-shimmed. New bake-out made at ALBA before installation took place at lower temperatures (internal girders < 80º C). Finally, SAT of superconducting wiggler SCW30 was carried out by BINP personnel assisted by ALBA staff. All specifications were fulfilled.

3. Commissioning of IDs with beam
During the commissioning of out-vacuum IDs with beam, they three were operated with correction coils powered according to a feed-forward table calibrated using magnetic measurements. Circulating beam showed small influence of IDs on ALBA performance for any gap and phase of elliptical devices. A small increase of pressure was observed during the emission of first light, because of desorption in Front Ends. Original vacuum levels were recovered after some minutes.

Commissioning with beam included the full calibration of feed-forward tables using closed orbit deviations along the Storage Ring measured with BPMs. For each value of gap and phase, the combination of correction coils was chosen to minimize the deviation of closed orbit. This correction has some problems in real-time operation, because of a non-perfect synchronism between the gap and/or phase changes and the power supplies feeding the correction coils. This leads to some distortion of the closed orbit especially in horizontal plane when changing the gap or the phase, mainly in MPW80 wiggler (Figure 1). Main problems come from wiggler, but this has no impact in ALBA operation because it is operated at fixed gap. With respect to in-vacuum devices, they were easily commissioned with beam in just one week. In the case of undulators, the activation of correction coils
is not needed, and their influence on closed orbit is minimal. After installation, we used lifetime measurements to align them vertically, and corrections of 400 \( \mu \text{m} \) and 700 \( \mu \text{m} \) were needed to maximize lifetime. In the case of superconducting wiggler SCW30, its influence on the closed orbit was higher than expected, and the built-in correction of 1\(^{st}\) integral was not enough to minimize closed orbit distortions, mainly in the horizontal plane. Using slow orbit feedback the distortion can be reduced to submicron in vertical plane (Figure 1), but not in the horizontal, with distortions up to 10 \( \mu \text{m} \) (Figure 1). However, SCW30 is operated at fixed field, so in practice it does not influence Storage Ring operation. Dedicated correction coils are being build and will be installed at the end of 2012.

We observed also a decrease in the injection efficiency when the gaps of IDs were closed. This issue should be addressed and can be attributed to a change in the closed orbit affecting the injection section. Therefore, an improvement of correction schemes will lead to overcome this effect.

![Figure 1](image_url)

**Figure 1.** Vertical (top) and horizontal (bottom) orbit measured with BPMs placed upstream and downstream of each ID, when closing their gap one after other. For SCW30, field ramped to operation value (2.1 T). For Apple-II devices, phase is scanned from maximum to minimum as well. Slow orbit feedback and correction coils for EU62, EU71 and MPW were switched on all the time.

4. **First light**
The first light from IDs at ALBA was obtained on May the 20th and corresponds to the elliptical undulator EU62 operating in planar mode (horizontal polarization). Some pictures corresponding to the first light coming from EU62, EU71 and MPW80 are shown elsewhere [1].
Regarding the in-vacuum undulators, we obtained some spectra (Figure 2) using an ALBA-made XBPM, consisting on a photomultiplier tube linked to a Cr foil.[7] This allowed us to cross check both the undulator and storage ring parameters using real measured light. Using the magnetic measurements done in the laboratory as well as the measured spectra, we could certify the energy of the Storage ring to be 2.9977 GeV and its energy dispersion to be $1.0 \times 10^{-3}$.

![Figure 2](image_url)

**Figure 2.** 1st full spectrum recorded from an in-vacuum undulator at ALBA, at XALOC beamline, using a photomultiplier tube and a Cr foil as detector, on December the 22th. Black dots are measured data, and red line the fitted spectrum. Vertical axis is in arbitrary units. Horozontal axis in eV.

5. Conclusions
First round of Insertion Devices has been received and measured at ALBA. In general, Site Acceptance Tests confirm the characterization made in the factories, thus indicating that transport is not a big issue affecting the IDs performance. All of the IDs have been installed in the Storage Ring. Installation has been done in two campaigns, first one dedicated to out-vacuum devices, and a second one dedicated to in-vacuum devices, including superconducting wiggler. Out vacuum IDs are delivering light to the beamlines from day one. The effect of such IDs on Storage Ring performance is small except for MPW80. In-vacuum IDs have been also delivering light from day one. The effect of in-vacuum undulators on electron beam is negligible and they are operated without need of using correction coils. With respect to superconducting wiggler, it has strong impact on horizontal closed orbit during powering on and off, and we are currently manufacturing dedicated correction coils to compensate its effect.

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