# FIRST TESTS OF THE APPLE II UNDULATOR FOR THE LOREA **INSERTION DEVICE AND FRONT END**

J. Campmany, J. Marcos, V. Massana, L. García-Orta, M. Quispe, and Z. Martí, ALBA-CELLS, Barcelona, Catalonia, Spain

## Abstract

title of the work. publisher. and DOI. ALBA synchrotron is currently installing the new s), beamline LOREA (Low-Energy Ultra-High-Resolution Angular Photoemission for Complex Materials at ALBA). It operates in the range of 10 - 1500 eV with polarized 2 light. To produce the light for the beamline (BL), an Apg ple II undulator with a period of 125 mm has been cho- $\underline{5}$  sen. It can operate as an undulator at low energies and as a wiggler at high energies, providing a wide energy range. The device was built by company KYMA, delivered on February 2017 and installed in August 2017. We present the magnetic measurements made during SAT as well as the simulations of the influence of the Insertion Device (ID) in the electron beam dynamics and the first measmust urements with beam. On the other hand, the high demanding characteristics of the BL lead to a device providing high power and wide beam in some working modes. This E situation has been a challenge for the Front End (FE) thermal load. It has been built by the companies RMP and 5 TVP, and the FE modules have been installed in the tunadopted, especially in terms of mechanical design and used materials. Anv

## ACCEPTANCE TEST RESULTS

2018). ID has been built by KYMA. Once received, it has been O measured using ALBA Hall probe bench. Results of Site

3.0 licence (© 2	<ul> <li>measured using ALBA Hall probe bench. Results of Site</li> <li>Acceptance Test [SAT] agree with those obtained in Factory Acceptance Tests [FAT], published elsewhere [1]. In</li> <li>Table 1 we show the measured parameters.</li> </ul>						
C BY	Table 1: Measured LOREA ID Features						
Ŭ	Magnitude	Design	Measured				
the	Period [mm]	125.00	124.98±0.02				
s of	Magnetic length L [mm]	2153.20	2157.00±1.5				
rm	Max $B_0$ vertical (V) [T]	1.1400	$1.0934 \pm 0.000$				
e te	Max $B_0$ horizontal (H) [T]	1.0594	$1.0598 \pm 0.000$				
the	Max $B_0$ Circular (C) [T]	0.7734	$0.7610 \pm 0.000$				
der	Max $B_0$ Diagonal (D) [T]	0.5299	$0.4501 \pm 0.000$				
iay be used un	The ID was installed in ALBA Storage Ring (SR) in August 2017. During October 2017 several tests at low stored current have been conducted in order to determine						

stored current have been conducted in order to determine the influence of the device on the about from this work

## **EFFECTS ON BEAM DYNAMICS**

For mechanical reasons, the separation between both magnetic arrays of the upper and lower girder has been set at 2 mm. The consequence of such design, added to Content the high field and period, is that the local multipoles in-

```
TUPMK002
```

1488

duced by each period are high, and thus its influence on SR dynamics is not negligible. This is characterized through the so-called kickmap [2]. Its determination has been simulated with RADIA [3] code. The main influence of the second order kicks is in the tune shift, as shown in Fig. 1, and worst case happens at minimum gap and vertical polarization. Also, we made real measurements on the beam to determine the beta-beating and tune shift induced by the device, from which a semiempirical kickmap is assumed. Measurements and simulations have a high degree of coincidence, as seen in Fig. 2.



Figure 1: induced tune shift for various phase configurations. Peak to peak beta-beat is within brackets.



Figure 2: Green (Meas) is the measured effect on tunes. Red (fit) is a linear fit of semiempirical kickmap calculated from response matrix of Storage Ring (SR) at each gap and phase. Blue (RADIA) is the effect on tunes simulated adding the kickmap to SR model. Black (NL fit) is the non-linear fit of semiempirical kickmap calculated response matrix of SR at each gap and phase.

**02 Photon Sources and Electron Accelerators** 

Although the agreement with RADIA is not absolute, it should be noted that the coincidence between measured and non-linearly fitted tune is solid evidence that the semiempirical kickmap has been calculated correctly.

Figure 3 shows the effect on dynamic apertures (DA).



Figure 3: On/off-energy DA calculated with 500 turns. Top: bare lattice. Bottom: ID LOREA effect (worst case).

The tune shift also has an effect on energy acceptance (EACC). Regarding physical apertures, the on-energy aperture is not affected, but the EACC reduces approximately from 4% to 3%. Although this is quite significant, nowadays the RF system is still limiting the EACC to 2.6%, so the effect is not critical. Moreover, considering the combined effect of all the existing IDs, it turns out that the optics beating effect of ID is partially canceled. As an example, the horizontal beta beating is reduced from 10% to 8%. This has an effect on the off-energy DA which gets partially restored at  $\pm 3\%$ . Besides the beam dynamics effects, the beam-lines (BL) suffer from machine functions variations. Being the beta-beating at the BL source points similar to the maximum beta-beating, the ID induces up to 10% beam size variation and 15% beam divergence variation. These effects clearly require some kind of optics correction scheme.

Similar effects on beam optics have already been reported at DIAMOND and BESSY [4-5]. In order to tackle with it, we have designed a correction scheme as proposed and used by DIAMOND, BESSY and CLS [4-6].

### **CORRECTION SCHEME**

In order to correct at least the influence of the device at first order, the proposed correction is based in the placement of a small multi-wired planar belt through which different currents are circulated. The current intensity circulating through each wire will depend on the gap/phase settings, as shown in Fig. 4, and they will be operated according to a feed-forward scheme.

We decided to use commercial cables. Typical crosssection of each wire is 0.76 mm high x 1.57 m wide. We will install the belt along the whole Al vacuum chamber, with a length of  $\sim$ 2.5 m. After optimization, we concluded that a correction using 8 power supplies is enough. Maximum currents to be applied are listed in Table 2. It should be noted that the belt is replicated above and below the vacuum chamber, so despite the power supplies used are only 8, the number of acting wires is 16 (8 above, 8 below), placed at regular positions, separated by 2.54 mm



Figure 4: Currents applied on each wire to correct at 1<sup>st</sup> order the effect of 2<sup>nd</sup> order kicks, at minimum gap and with phase vertical (V), horizontal (H), circular (C) and diagonal (D).Black line marks maximum currents applied.

Table 2: Maximum Current Applied to Each Cable

Wire	Position	Current (A)	Power (W)	
1	-8.89	2	1.32	
2	-6.35	5	8.25	
3	-3.81	11	39.93	
4	-1.27	13	55.77	
5	1.27	13	55.77	
6	3.81	11	39.93	
7	6.35	3	2.97	
8	8.89	1	0.33	

As can be seen, the total power generated by this device is 408.54 W. This is a non-negligible value, and therefore the thermal impact (both on magnets and on the vacuum chamber) but also on the belt itself, should be studied. To this end, we performed some thermal simulations. the scheme of correction wires on vacuum chamber is shown in Fig. 5. As said, pitch is 2.54 mm. 9th International Particle Accelerator Conference ISBN: 978-3-95450-184-7



Figure 5: correction belt on vacuum chamber (top side).

Using Finite Element Analysis, we determined the maximum temperature that the vacuum chamber and the belt itself will achieve. This is shown in Fig. 6. According to the thermal analysis, maximum temperature will be less than 30°C, which is within the working range of magnets, vacuum chamber and belt.



CC BY 3.0 licence Figure 6: Simulation of maximum temperatures that will achieve the vacuum chamber and the surrounding space.

#### **FRONT END**

The components of the FE, manufactured by the companies RMP and TVP, were delivered during the period panies RMP and TVP, were delivered during the period July-October 2017. The main innovation in the manufac-turing of the FE with respect to the already existing ones  $\frac{1}{2}$  has been the usage of CuCrZr for the manufacturing of the Movable Masks that define the dimensions of the P. photon beam delivered to the BL. This material allows pu machining the mask block with integrated conflat flanges machining the mask block with integrated conflat flanges g in a single piece, eliminating the need of brazing [7]. In 2 addition, it displays a thermomechanical behaviour not as ⇒ good as Glidcop®, but better than that of OFHC copper. Model and stress and temperature distribution obtained work from FEA are shown in Fig. 7.

this The FE was installed in ALBA tunnel in October 2017 rom but, given that the modifications in SR vacuum system described in [1] have not been implemented yet, the FE Content has not received any photon so far

maintain



Figure 7: Movable mask model (top) and maximum stress, 242 MPa (bottom, left) and maximum temperature, 123.9°C (bottom, right) achieved with LOREA for a SR current of 400 mA.

#### CONCLUSION

The ID for new BL LOREA at ALBA has a big impact on the SR dynamics because of its intrinsic characteristics. However, this impact can be minimized using a correction scheme based on wires that correct locally the second order focussing effects. Thermal calculations have proved the suitability of this scheme. Also, a low-cost thermal-resistant material has been used to build part of the Front End, in order to tackle with the high power delivered by the device.

#### REFERENCES

- [1] J. Campmany, J. Marcos, V. Massana, L. García-Orta, "AP-PLE-II undulator and Front End design for the new LOREA Beamline at ALBA", in Proceedings of IPAC2017, p. 2747, Copenhagen, Denmark (2017).
- [2] P. Elleaume, "A new approach to the electron beam dynamics in undulators and wigglers", in Proceedings of EPAC92, p. 661, Berlin, Germany (1992).
- [3] O. Chubar, P. Elleaume, J. Chavanne, "A 3D Magnetostatics Computer Code for Insertion devices", in SRI97 Conference August 1997, J. Synchrotron Rad. (1998). 5, 481-484.
- [4] J. Bahrdt, W. Frentrup, A. Gaupp, M. Scheer, G. Wuestefeld, "Active shimming of the dynamic multipoles of the BESSY UE 112 APPLE undulator", Proceedings of EPAC08, Genoa, Italy, p. 2222.
- [5] B, Singh, R. Bartolini, R. Fielder, E.C. Longhi, I.P. Martin, S.P.Mhaskar, R.P.Walker, "Active shimming of dynamic multipoles of an Apple II undulator in the DIAMOND storage ring", Proceedings of IPAC2013, Shanghai, China, p. 1997.
- [6] Drew Bertwistle, C. Baribeau, L. Dallin, S. Chen, J. Vogt, and W. Wurtz, "EPU Correction Scheme Study at the CLS", Proceedings of the 12th International Conference on Synchrotron Radiation Instrumentation - SRI2015, AIP Conf. Proc. 1741, 020012 (2016); doi: 10.1063/1.4952791.
- [7] F. DePaola, C. Amundsen, S. Sharma, "Manufacturing of photon beam-intercepting components from CuCrZr", Proceedings of MEDSI2016, TUPE31, Barcelona, Spain, p 233.

**02 Photon Sources and Electron Accelerators A05 Synchrotron Radiation Facilities** 

Q

with

B publishe

version is

final

the

preprint

S.