APPLE-II UNDULATOR AND FRONT END DESIGN FOR THE NEW LOREA BEAMLINE AT ALBA

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Abstract

ALBA synchrotron has started the construction of a new beamline LOREA, for Low-Energy Ultra-High-Resolution Angular Photoemission for Complex Materials. It will operate in the range of 10 – 1500 eV and will use polarized light. In order to produce the light to be used in this beamline, several options have been studied, and finally an Apple II design has been chosen.

The device can operate as an undulator at low energies and as a wiggler at high energies, reaching a wide energy range. The high demanding characteristics of the beamline in terms of energies lead to a device providing high power and wide beam in some working modes.

This situation has been a challenge for the Front End design, especially for the vertically polarized mode, with some changes with respect to standard ALBA front ends.

In this paper we present the magnetic design and expected performances of the device that has been built by KYMA as well as the Front End design, that is currently being built by RMP and TVP.

REQUIREMENTS

The requirements of operation of LOREA beamline (BL) in circular, vertical and horizontal polarization modes, have led to adopt the well-known APPLE-II design.

The motion of half-girders has driven the design towards an out-vacuum device, thus limiting the minimum gap to 13 mm, as ALBA standard vacuum chamber in straight sections is 10 mm high.

Undulator has been optimized to deliver flux in the lower part of the spectrum, between 8 and 100 eV. This has led to a high period value, of 125 mm. The result of these requirements is EU125, delivering up to 6 kW in some configurations, with a wide aperture angle, ±2.18 mrad in the worst case, corresponding to vertical polarization mode.

Moreover, EU125 has to deliver polarized flux at high energies, between 1000 and 2000 eV, in order to carry out different experimental techniques with the same sample and the same photon source.

At this range, even in horizontal model, EU125 is delivering more flux operating as a wiggler than as an undulator using high harmonics. A particular gap of 35 mm has been chosen to deliver high degree of circular polarized light.

The large vertical aperture of the emitted photon beam for certain configurations has imposed changes in the standard bending magnet vacuum chamber downstream the Insertion Device (ID), with the redesign of the capacity and dimensions of the absorber.

ID AND FE DESIGN

Regarding the ID, considerations on design can be found elsewhere [1]. Design values are given in Table 1.

Table 1: Characteristics of LOREA ID.

Magnitude	
Period [mm]	125
Block width l_x [mm]	32
Block length l_z [mm]	32
Total magnetic length L [mm]	2153.2
Max. transversal force F_x [kN]	17.75
Max. longitudinal force F_s [kN]	16.42
Max. vertical force F_z [kN]	16.53
Max. horiz. force density D_x [kN/m]	7.7
Max. longit. force density D_s [kN/m]	7.1
Max. vertical force density D_z [kN/m]	7.2
Maximum height [mm]	2500
Maximum width [mm]	1000
Width (beam inwards) [mm]	750
Width (beam outwards) [mm]	250
Electron beam height [mm]	1400
Minimum gap [mm]	13.0
Maximum gap [mm]	300
Maximum phase lineal advance [mm]	±62.5
Number of full blocks	65
Number of end section blocks	3+3

In Figure 1 we show the power density distribution at the entrance of the Second Fixed Mask of the Front End (FE), showing that more of the 70% of the beam power should be absorbed in this FE element.

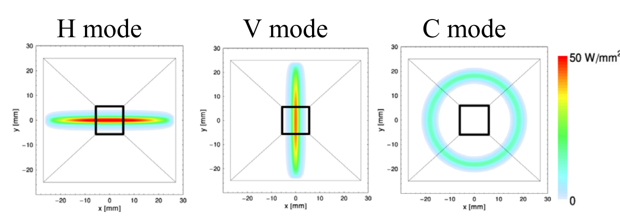

Figure 1: Power density distribution at the entrance of the Second Fixed Mask of the FE, at 11.18m from the source, for the different polarization modes of EU125 at minimum gap. The thick back square indicates the exit aperture of the mask, defining a user aperture of ±0.5mrad in both planes.

In **Figure 2** and **Figure 3** we show the expected flux at lower and high energy ranges, respectively, for both horizontal and circular polarization modes.

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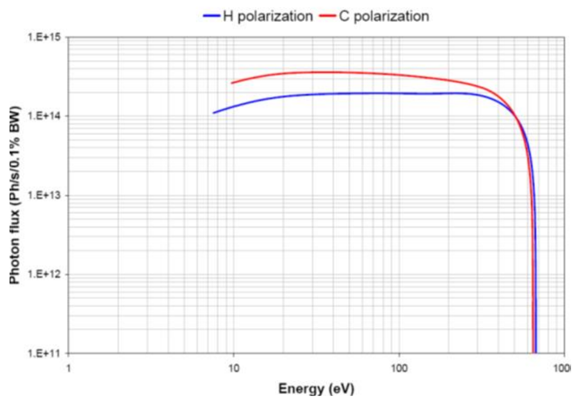

Figure 2: Flux through a slit (1st harmonic) for a slit aperture of 1.0 mradH × 1.0 mradV.

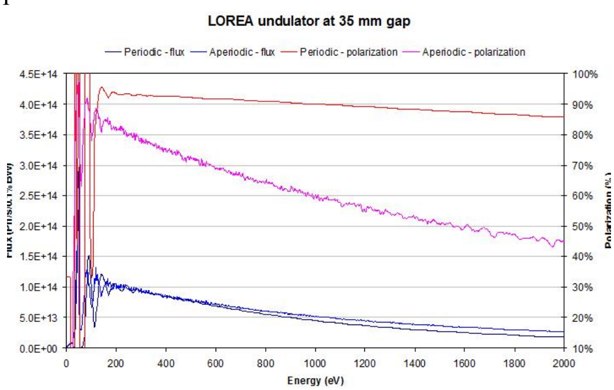

Figure 3: Flux (left axis) and polarization rate (right axis) at circular mode for EU125 at 35mm gap and an aperture of 0.075×0.075 mrad^2 for a periodic (red and light blue) and an aperiodic (pink and dark blue) EU125 undulator.

As said, this device is foreseen to be operated as an undulator at low energies and as a wiggler to reach high energies and make possible the combination of multiple energetic measurements on the same sample.

Figure 4 shows the interference of the photon beam from the EU125 device operating in vertical mode at minimum gap with the downstream dipole chamber, leading to an expected temperature increase of the chamber up to 600ºC, which is not acceptable. Figure 5 indicates the required modifications of the SR vacuum system, affecting both the dipole chamber and some of the crotch absorbers. Figure 6 shows the redesigned crotch absorber as compared to the standard one. More details can be found elsewhere [2].

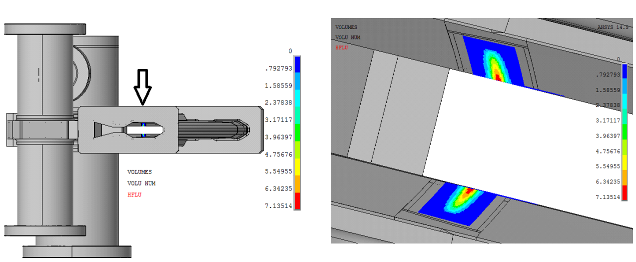

Figure 4: Power deposited on downstream standard dipole chamber by EU125 device in vertical mode. The vacuum chamber has been modified in order to avoid this effect.

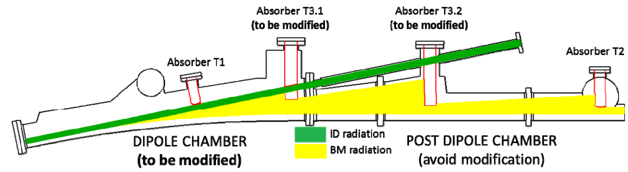

Figure 5: Affected areas of downstream dipole chamber due to the impact of large vertical opening of EU125 radiation.

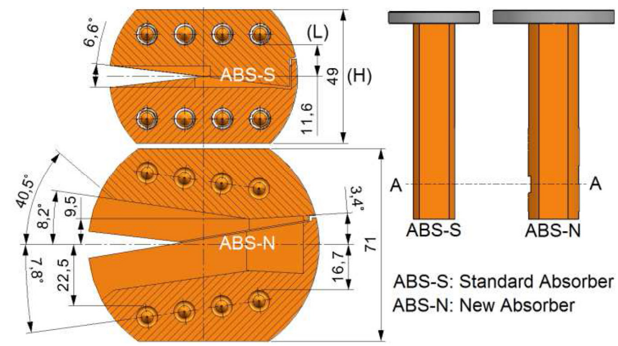

Figure 6: Modified T3 crotch absorber as compared to the standard one. Dimensions are in [mm].

Regarding the FE, we have taken the design of Phase-I FEs as a reference, in particular that of BLs with an APPLE-II undulator as a source [3]. The FE is currently being built by companies RMP srl (Rome, Italy) and TVP S.L.U. (València, Spain), and it is expected to be delivered on June 2017.

ACCEPTANCE TEST RESULTS

ID has been built by KYMA and its performance is in full agreement with the specifications. Once received, it has been measured using ALBA Hall probe bench, as shown in Figure 7. First harmonic behaves as theoretically expected, with a flux in the range of 10^{14} Ph/s/0.1%BW for lineal polarization (Figure 8). In circular mode, flux is 1.8×10^{13} Ph/s/0.1%BW at minimum energy (7.75 eV at 13 mm gap), as shown in Fig. 9.

Figure 7: Elliptical polarized undulator built by KYMA at ALBA magnetic measurements laboratory.

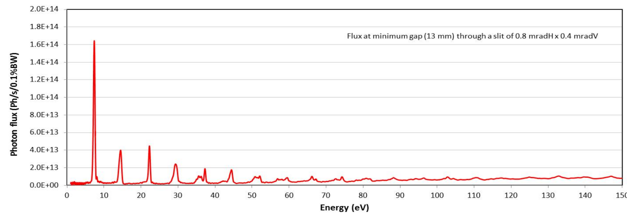

Figure 8: Flux at 13 mm gap for H polarization. E_0=7.37 eV, slit 0.8 mradH × 0.4 mradV and SR current 100 mA.

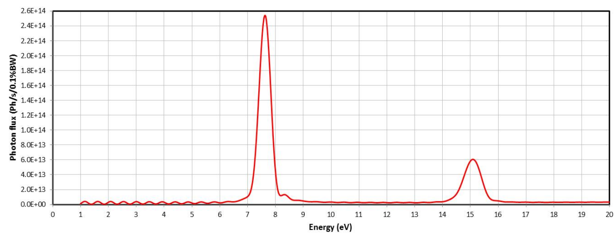

Figure 9: Total flux at minimum gap (13mm) in circular mode, corresponding to E_0=7.75eV, slit size 0.6 mradH × 0.6 mradV and current in SR, 100 mA.

At low energies, flux is concentrated in a cone with an aperture σ~2.25 mrad and circular polarizations close to 100% are reached (Fig. 10 and 11), whilst at high energies, operating the device in wiggler mode, the circular polarization degree reaches up to 85% (Fig. 12 and 13), high enough to perform the experiments foreseen in the beamline scientific case.

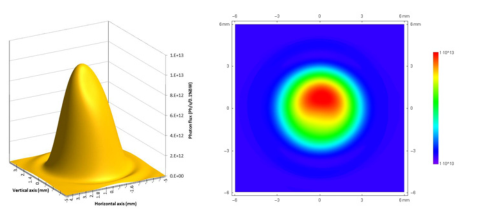

Figure 10: Spatial distribution of photon flux at E_0 = 7.75 eV and 10 m of source in circular mode at minimum gap.

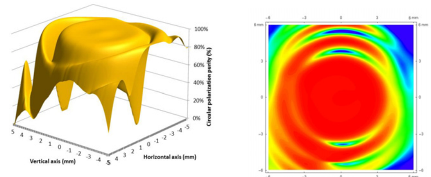

Figure 11: Circular polarization rate at minimum gap (13 mm) in circular mode, corresponding to E_0 = 7.75 eV

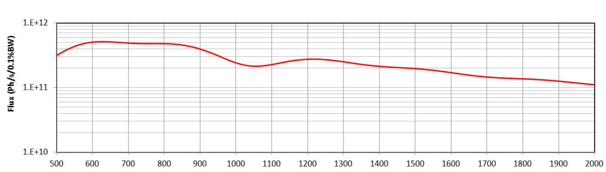

Figure 12: Total flux at 35 mm gap in circular mode is in the range of 10^{11} to 10^{12} Ph/s/0.1 BW. Aperture is 0.075 mradH x 0.075 mradV and Storage ring current 150 mA.

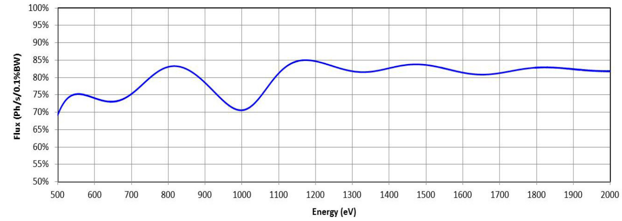

Figure 13: Polarization degree at 35 mm gap in circular mode. Between 1100-2000 eV it is >80%. SR current is 150 mA and aperture 0.075 mradH x 0.075 mradV.

Another important feature of the ID is the rejection of the high order harmonics. Possibility of transforming the current periodic device in an aperiodic device is open, and KYMA has supplied the magnets and the tools to make it possible. However, at low gaps, the native spectral structure shows already a rejection rate of more than 80%, as can be seen in Figure 14.

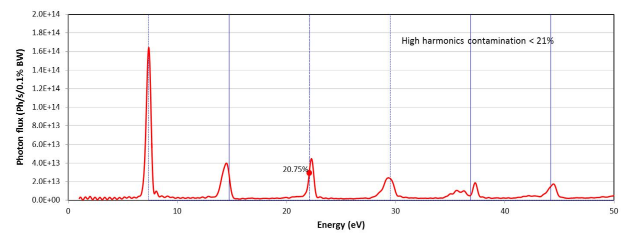

Figure 14: Detail of Figure 8 showing the peak of 3rd harmonic being less than 21% of fundamental.

CONCLUSIONS

LOREA beamline has already a tested insertion device able to make experiments at high and low energies, with polarized light. This feature is achieved thanks to an APPLE-II device, operated as an undulator at low energies and as a wiggler at high energies.

REFERENCES

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