ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB085

DESIGN AND FABRICATION OF A SHORT MULTIPOLE WIGGLER AND THE FRONT END FOR THE NEW ALBA BEAMLINE FAXTOR

J. Campmany†, J. Marcos, V. Massana, ALBA-CELLS, Barcelona, Catalonia, Spain

Abstract

FAXTOR is a new hard XR tomography beamline that is being built at ALBA to fulfil the needs that cannot be currently covered by the MISTRAL VUV and soft XR beamline. This new beamline needs a source size smaller than 310 μm horizontal and 25 μm vertical, as well as a high flux in the energy range 5-60 keV. The contract for the manufacturing of the ID has been awarded to AVS-US company. In this paper we present the conceptual model for the insertion device developed at ALBA and the implementation proposed by the manufacturing company.

INSERTION DEVICE REQUIREMENTS

FAXTOR beamline is aimed at performing fast X-ray microcomputed tomography at high resolution. The beamline is foreseen to operate in both absorption and phase-contrast regimes. The scientific requirements include a small source size in order to attain a high spatial resolution, better than 0.7 μm, a large divergence, and a high photon flux in the range between 30 and 50 keV. In particular, at an energy of 30 keV the specification is to obtain a flux of at least 4×10^{13} ph/s/0.1%BW through an angular opening of 1×0.4 mrad^2 for an electron beam current of 400 mA.

In order to fulfil these scientific requirements the initially proposed source was a wavelength shifter with a central pole achieving 3 T and two satellite poles to compensate the field integral. However, upon further development the proposal was changed into a short multipole wiggler in order to enhance the photon flux while keeping the source size small enough.

The resulting device was an in-vacuum wiggler of hybrid type with only 5 periods and a period length of 50 mm. The peak field achieved in that model using RADIA [1] simulation was 2.5 T, enough to fulfil the requirements.

AVS-US MAGNETIC DESIGN

The tender to manufacture the device was awarded to AVS-US company on October 2020. This company proposed a modification in the design in order to avoid demagnetization of the magnet blocks during the vacuum bake-out at 100ºC: the originally intended magnetic material grade has been replaced by one with an enhanced coercivity (at the cost of a reduced remanence), and the period has been accordingly increased from 50 up to 54 mm. This modified design is shown in Fig. 1 and the device parameters are summarized in Table 1.

Table 1: Main Parameters of FAXTOR Insertion Device

Device type	wiggler
Magnetic configuration	Planar hybrid
Technology	In-vacuum
Period length	54±0.02 mm
Number of periods	5.5
Maximum magnetic length	362.5 mm
Magnetic minimum gap	5.2 mm
Minimum physical gap	5.0 mm
Gap range (magnetic)	5.2 mm to 30 mm
B_0 value at minimum gap	2.5 T
K value at minimum gap	11.5

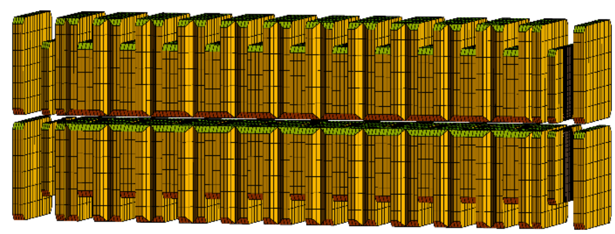

Figure 1: AVS-US Magnetic model generated by RADIA [1]. Yellow parts are NdFeB magnets. Overall length is 0.3625 m, total width is 72 mm, overall height is 125.2 m (including gap) and minimum gap is 5.2 mm.

Block and Pole Shapes

Magnet blocks are box-type with chamfers in edges allowing clamp fixations to prevent demagnetization. Mechanical tolerances have been assumed to give changes in the peak field smaller than 0.1%. The selected magnetic material has been NdFeB Vacodym 974 DTP, with a minimum remanence Br=1.25 T and coercivity μ0HCJ ≥ 2.6 T. Poles will be made of high permeability Vanadium Permendur (Vacoflux 50).

The AVS-US model of central and side blocks, and pole dimensions are specified in Tables 2 and 3. The corresponding blocks and pole shapes are shown in Fig. 2. The magnetic structure generates a peak (effective) field of 2.5 Tesla (2.14 Tesla) at minimum gap.

At both ends the magnetic structure is equipped with optimized geometry sections in order to minimize field integrals. On top of this the device will incorporate magic fingers to minimize integrated multipoles and correction coils for an active compensation of residual field integrals.

† campmany@cells.es

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB085

Table 2: Magnetic Block Proposed by AVS-US

Main block	
Width	72.0 ± 0.05 mm
Height	60.0 ± 0.05 mm
Length	8.5 ± 0.02 mm
Side block	
Width	17,521 ± 0.02 mm
Height	245.0 ± 0.02 mm
Length	170 ± 0.02 mm
Magnet characteristics	
Grade	VACODYM 974 DTP
Remanent field	1.25 T
Permeability on axis	1.06
Transversal axis permeability	1.17

Table 3: Iron Pole Characteristics

Width	30.0 ± 0.05 mm
Height	45.0 ± 0.05 mm
Length	9.9 ± 0.02 mm
Iron type	Vanadium permendur

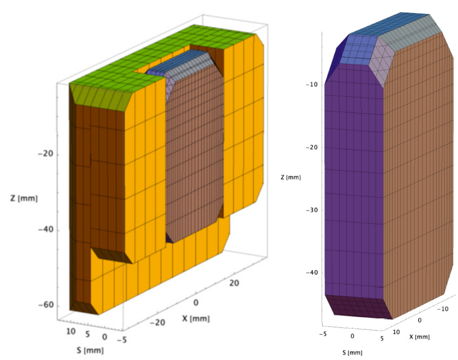

Figure 2: Shapes of blocks and poles.

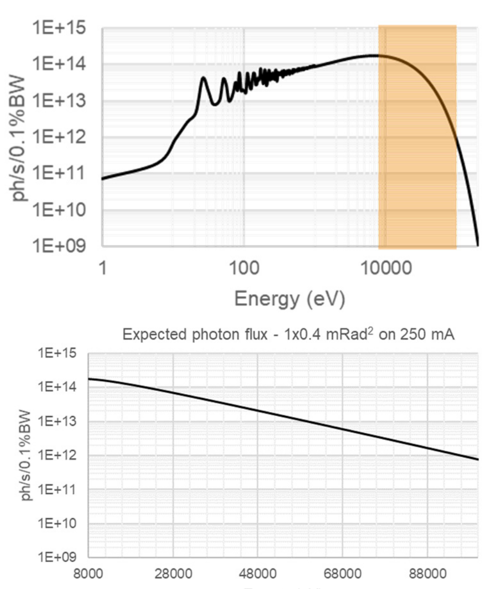

Figure 3: Photon flux of FAXTOR ID through an aperture of 1×0.4 mrad^2 for a beam current of 250 mA calculated using Spectra.

With this magnetic structure, the requirements in terms of flux at high energies can be achieved, as shown in Fig. 3, calculated with SPECTRA code [2].

Forces

This device, due to its large peak magnetic field produces a very significant force of almost 10 kN between both magnetic arrays at minimum gap. So, the mechanical design of such a device is a challenge, because it should be movable within the range from 5 up to 30 mm with an accuracy of ~5 µm.

The support structure will consist of a very stiff C-shape that will carry most of the force arising from magnetic forces. The total mass of this structure will be reduced by means of triangular openings on the side plates. Each magnet girder will be connected to the corresponding moving carriage out of vacuum by means of two pairs of rigid rods placed at Bessel points along the beam propagation direction. The final mechanical design is shown in Fig. 4.

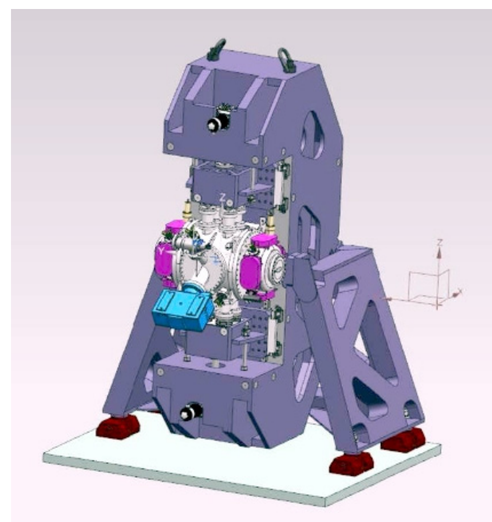

Figure 4: FAXTOR mechanical structure.

Vacuum

Magnet girders will be installed inside a 400 mm-long cylindrical chamber with a DN400 CF flange at each end.

The connection to the storage ring will be done by means of to end cans at both sides of the main chamber via DN160 spigot flanges. These end cans will also house the correction coils and ports for cooling and instrumentation. The total flange-to-flange distance of the whole device will be 829 mm.

The pumping needs of the system will be covered by a 600l/sec ion pump and a 1200l/sec NEG pump.

Manufacturing

Currently (June 2021) the device is being built in AVS-US premises in Lansing, New York. Delivery of the device is expected during the first half of 2022.

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB085

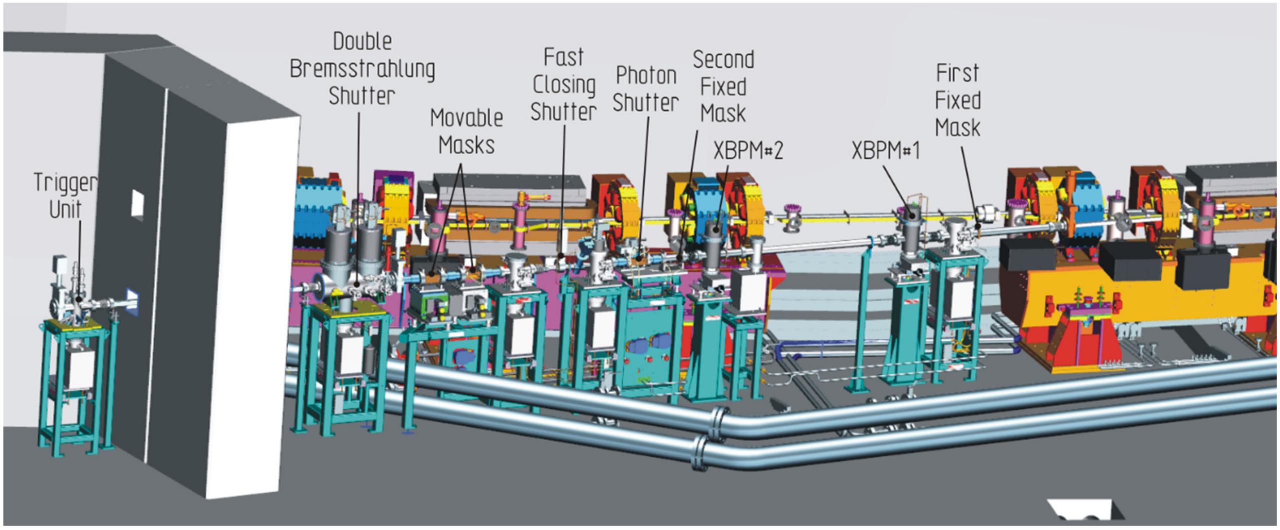

Figure 5: Layout of FE for FAXTOR.

FRONT END

For the structure of the Front End (FE) the standard configuration used at existing ALBA beamlines [3] has been adapted to the aperture and power requirements of the wiggler source. The limiting aperture of the FE has an entrance acceptance of 3.56×1 mrad^2, and delivers to the beamline a photon beam with a maximum divergence of 1×0.4 mrad^2, as requested. As for the power load, the FE masks and shutters are designed to withstand a total power of 3.4 kW and a peak power density of 5.0 kW/mrad^2 (calculated for an electron beam current of 400 mA). An innovation with respect to previously installed FEs at ALBA is that it will be equipped with two X-ray Beam Position Monitors (XBPMs), thus providing information not only on the photon beam position but also on its steering angle. The distance between the 2 XBPMs has been maximized taking into account the geometrical constraints inside the FE, and it will be equal to 2 m. A layout of the FE is shown in Fig. 5.

The FE is currently being manufactured by company FMB-Berlin GmbH (Germany) and will be delivered on June 2022.

CONCLUSIONS

The presented device will allow to fulfil the flux requirements of the beamline at high photon energies avoiding the usage of cryogenics, while keeping at the same time the source size small.

REFERENCES

[1] P. Elleaume, O. Chubar, and J. Chavanne, “Computing 3D Magnetic Fields from Insertion Devices”, in *Proc. 17th Particle Accelerator Conf. (PAC'97)*, Vancouver, Canada, May 1997, paper 9P027, pp. 3509 - 3511.

[2] T. Tanaka and H. Kitamura, “SPECTRA: a synchrotron radiation calculation code,” *Journal of Synchrotron Radiation*, vol. 8, no. 6, pp. 1221–1228, Oct. 2001. doi:10.1107/s090904950101425x.

[3] J. Marcos, J. Campmany, D. Einfeld, and J. Pasquaud, “Front Ends at ALBA”, in *Proc. 2nd Int. Particle Accelerator Conf. (IPAC'11)*, San Sebastian, Spain, Sep. 2011, paper THPC055, pp. 3017-3019.