UPGRADE OF THE INSERTION DEVICES AT THE ESRF

J. Chavanne, G. Le Bec, L. Goirand, C. Penel, F. Revol, ESRF, Grenoble, France

Abstract

An important upgrade of the ESRF is planned from 2009 to 2016. The upgrade is mainly driven by the improvement of beamline performance and capacity. On the storage ring side, the length of the straight sections will be increased from 5 m to 6 m with a possible further extension to 7 m. These long sections will provide a higher photon flux, and will allow the installation of canted undulators. The length of the insertion devices (ID), such as the revolver and in-vacuum undulators, will be modified to fit the first upgraded beamline sections. The subsequent implications for the length of new IDs will be presented. The concept of canted undulators is a proposed optional feature. This will rely on a novel permanent magnet steerer providing a maximal separation angle of 5.4 mrad while keeping a short distance between canted undulators. Magnetic chicane magnets with low fringe field and homogeneous longitudinal field integral have been designed. The magnets which have been developed will be presented.

INTRODUCTION

The present layout of the ESRF storage rings includes 28 available straight sections (SS) with 5 m free space for the installation of Insertion Device (ID) segments. The length of ID segments was standardized to 1.6 m for in-air devices (IA) and 2 m for in-vacuum undulators (IVUs). Typical ID layouts in a SS correspond to three IA segments or two IVUs. In the framework of the ESRF upgrade, the length of the SSs will be extended to 6 m. A further extension to 7 m is foreseen later on [1]. The extension will be primarily used for the installation of new RF cavities between IDs in the same SS. The lengthening to 6 m requires the definition of additional standard lengths for ID segments if one wants to optimize the magnetic length in the available space. Canted undulators will be installed in several sections. This will requires space for the installation of a steering magnet in the middle of the SS which will therefore have an impact on the selected ID length.

Table 1: First 6 upgraded straight sections

Beamlines	type	Number of IDs	Installation date
ID6	straight	1 IVU + 2 IA	Dec. 2012
ID16	canted	1 IVU+ 2 IA	Dec. 2012
ID18	canted	3 IA	Sept. 2011
ID20	straight	4 IA	Mar. 2012
ID24	straight	4 IA	Oct. 2011
ID30	canted	4 IA	Apr. 2012

A set of 6 sections will be upgraded before the end of 2012 as shown in Table 1. Half of the sections will include canted undulators. The canting strategy relies on optimized permanent magnet steerers, further detail of which follows.

NEW INSERTION DEVICES

In-Vacuum undulators

For a 6 m section, IVUs with a magnetic length of 2.5 m were needed to fill the free space with two independent devices. The IVUs will be operated with a minimum gap of 6 mm. The design of a new support structure was recently achieved using our experience of the 2 m versions (see Fig. 1). The total length of the device is 2.878 m from flange to flange. The stiffness of the support frame was improved due to higher magnetic forces. The gap drive assembly includes a motorized gap tapering (± 90 micrometers) mechanism to compensate for the mechanical imperfections in the gap motion. A new cooling layout was adopted to ensure higher compatibility between water cooling for room temperature operation and cryogenic cooling with liquid nitrogen for the Cryogenic Permanent Magnet Undulator (CPMU) option. A first version will be constructed in 2010.

The first IVU will include a hybrid magnetic assembly with a period of 26 mm. It will be installed in ID16.

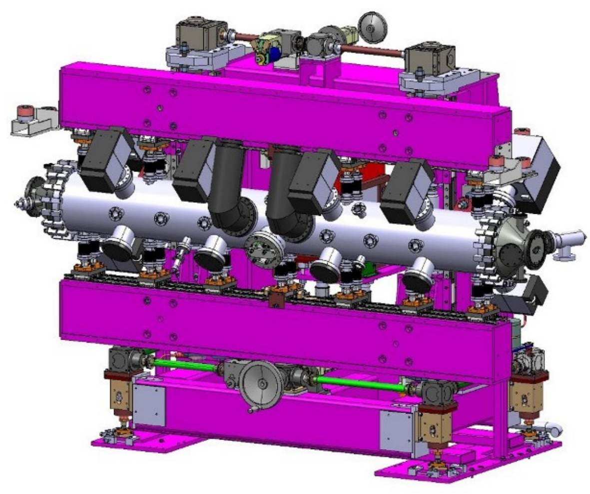

Figure 1: New 2.5 m in-vacuum undulator.

Cryogenic Permanent Magnet Undulators

Cryogenic Permanent Magnet Undulators are being developed in some facilities [2, 3]. Following the successful operation of a first CPMU prototype at the ESRF, a second 2 m device with a period of 18 mm is presently under construction. It will replace the first IVU prototype installed in the ID11 straight section in 1999. This CPMU is based on high remanence NdFeB permanent magnet material (B_R = 1.39 T at room temperature). The undulator will be magnetically corrected to obtain low phase errors (below 2.5 degrees r.m.s) at an operational temperature of 150 K. The performance of the device at high X-ray energies (above 50 keV) will be carefully investigated. Based on this experience, other CPMUs may be considered for the future upgrade of high X-ray energy beamlines.

In-air insertion devices

The existing IA devices consist of 1.6 m long standard undulators and revolver undulator. For the 6 m SSs, new 1.4 m long devices were needed taking into account the use of existing segments and the canting. Several ID layouts in 6 m straight sections are possible:

- 4 x 1.4 m devices with canting (ID30)
- 2 x 1.6 m and 2 x 1.4 m (ID20, ID24)
- one 2 m IVU and 2 x 1.6 m (ID6)
- one 2.5 m IVU and 2x 1.4 m with canting (ID16)

For straight sections with IA segments only, new 6.1 m long aluminium vacuum chambers have been developed. The chambers include a NEG coating performed in-house and will allow a minimum gap of 11 mm .

The 1.4 m long standard supports will consist of recycled 1.6 m versions. The aluminium girders supporting the magnetic assemblies will be shortened and all electrical components will be refurbished. Four devices will be needed for the ID30 canted section.

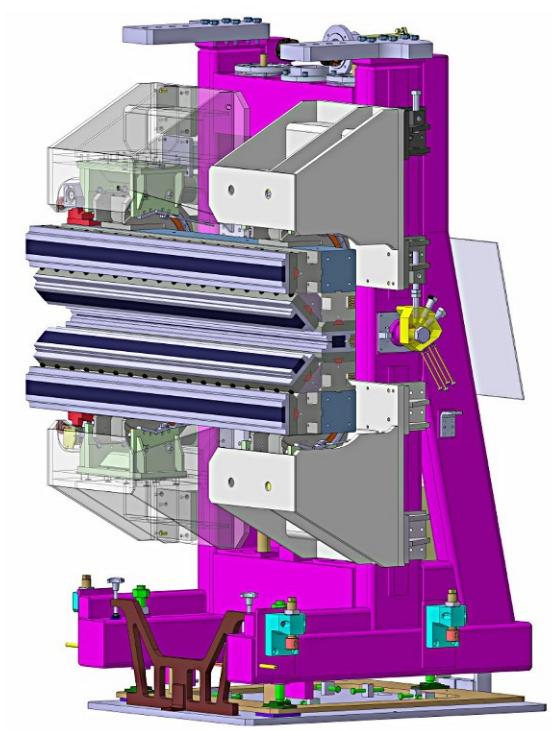

Figure 2: New 1.4 m revolver structure equipped with three undulators.

Revolver undulators have become very popular at the ESRF over the past years. The existing structures allow the implementation of two undulators. A typical revolver includes a tunable multi-purpose undulator (period 32 mm to 35 mm) and a second smaller period assembly dedicated to optimum operation in limited photon energy ranges (period 17 mm to 27 mm). A new 1.4 m long revolver design was completed in 2009. It was derived from the previous 1.6 m concept with two different undulators at 90 degrees on a rotational girder. The new version can include an optional third undulator at 45 degrees (see Fig. 2). A total of six units will be needed for ID20, ID24 and ID16.

CANTED SECTIONS

Chicanes

Improving beamline capacity is an important objective of the ESRF upgrade. Splitting some beamlines into two experimental stations could be a solution, especially if the photon flux does not restrict performance. This can be done by forcing the electrons to make a chicane in the ID straight section. Canted undulators based on this concept have already been implemented in some synchrotron radiation facilities (see for instance [4]).

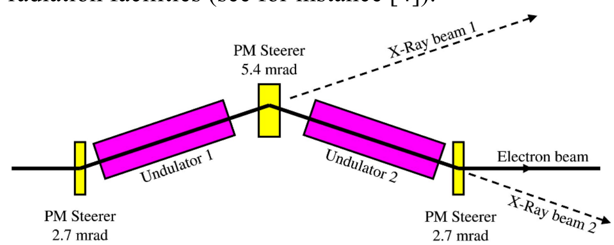

Figure 3: ESRF standard canted undulators.

A sketch of the layout of a standard ESRF canted section is shown in Fig. 3. The maximum separation angle has been fixed at 5.4 mrad due to the vacuum chamber and front end geometry.

The Permanent Magnet Steerers (PMS) used to bend the electron beam must fulfil the following design constraints:

- The available space is around 40 cm in the middle of the canted section and 20 cm at the ends.
- The PMS must not interact with the undulators.
- The transverse homogeneity of the magnetic field integral must be good enough to avoid any reduction in the dynamic aperture.
- The temperature variations of the canting angle must not affect the beamline.

Two kinds of magnetic interaction between PMS and undulators can occur. The first is the modification of the field integral versus undulator gap. The second, an extra deflection of the electron trajectory in the undulator leading to additional optical phase errors and a reduction in the brightness of the high harmonics of the X-ray spectrum. One must take into account these interactions when designing PMS.

Magnetic Design

A hybrid steerer design has been proposed. It combines Sm_2Co_{17} magnets and iron poles. A standard 2.7 mrad extremity steerer is shown in Fig. 4. The 5.4 mrad PMS placed in the middle of the chicane has a similar design but a lower gap.

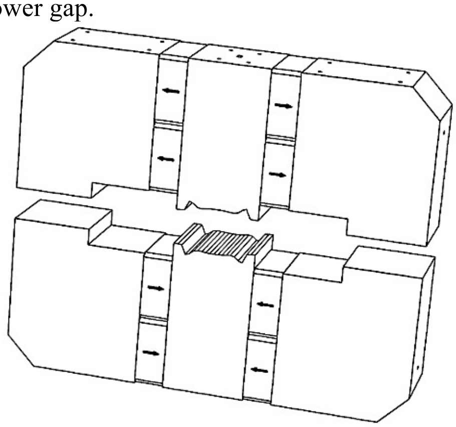

Figure 4: Magnetic design of a 2.7 mrad extremity PMS.

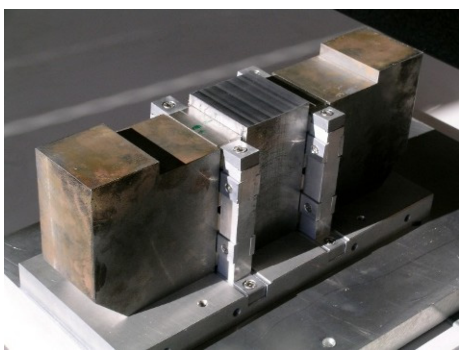

Figure 5: Half part of a prototype PMS.

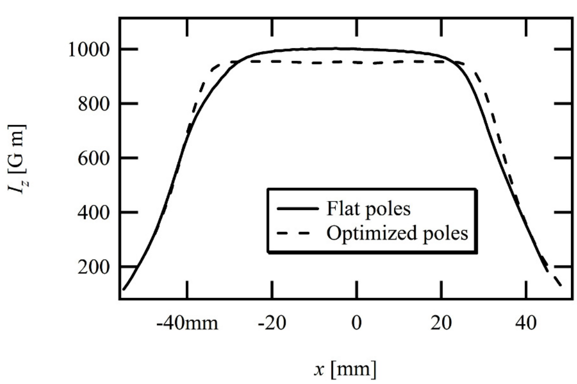

Figure 6: Measured field integral with two different pole shapes.

One notices two auxiliary lateral gaps which are used to control the steerer's magnetic fringe field. The shape of the main iron poles has been optimized in order to improve the transverse homogeneity of the field integral. The optimization process has been performed with RADIA software.

Prototype and measurements

A prototype of a small gap, middle position PMS has been built (see Fig. 5). The vertical field integral of this steerer has been measured with a stretched wire bench. Measurements have been performed with flat iron poles, and then with optimized poles (see Fig. 6). This shows the significance of pole optimization in terms of transverse field integral homogeneity.

The PMS's fringe field and its effect on the phase error of a 35 mm period, 10 mm gap undulator have been measured with a Hall probe bench. No phase error increase was noticed when the prototype PMS was placed at a distance of 16.5 cm from the undulator end magnet.

Serial Permanent Magnet Steerers

The nominal steering angles of the PMS depend on the beamlines (see table 2). Steerers with eight different canting angles have been designed and are currently being manufactured.

Table 2: Canting angles at the ESRF

Beamlines	**Steering angles in [mrad]**			
ID16	–2.70	5.40	–2.70	
ID18	–1.20	2.71	–1.51	
ID23	–0.75	0.75	0.75	–0.75
ID30	–2.20	4.40	–2.20	

CONCLUSION

The design work for new IDs and PMS to be used for canted undulators was completed in 2009. 2010 corresponds logically to a construction phase for magnetic assemblies (11 undulators), different types of support structures (7 units) and also PMS (11 units). The magnetic field measurements of the first undulators are expected to start in late 2010.

REFERENCES

[1] J.C Biasci et al., "Upgrade of the ESRF Accelerator Complex", EPAC'08, Genoa, pp 2004-2006.

[2] T. Tanaka et al., "Status of Cryogenic Permanent Magnet Undulator developments", Proc. PAC09, Vancouver, May 2009.

[3] J.chavanne et al., "First Operational Experience with a Cryogenic Permanent Magnet Undulator at the ESRF", Proc. PAC09, Vancouver, May 2009.

[4] P. K. Den Hartog et al., "Dual Canted Undulators at the Advanced Photon Source", PAC'03, Portland, May 2003, pp 833-835.