STATUS OF THE ESRF INSERTION DEVICES

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Abstract

The ESRF insertion devices are the object of a continuous refurbishment in order to follow the changing needs of the beamlines and increase their performances. The successful development of the narrow aperture aluminum chambers pumped by non evaporable getter has resulted in the reduction of the minimum gap from 16 mm to 11 mm . A new set of undulator magnetic assemblies with shorter magnetic periods are being prepared that make use of the lower gap. .A prototype of a new type of revolver undulator support has been completed and successfully tested. Such a structure allows the beamline user to switch between two different undulator periods in less than a minute. Three additional devices will be constructed in 2004. Three new in-vacuum undulators have been installed on the ring. One of them is based on an hybrid magnetic structure and achieves a peak field 20% higher than a pure permanent magnet undulator of identical period. Their main magnetic measurements results and interactions with the stored beam are presented.

INSERTION DEVICES UPGRADE

Figure 1 shows some historical aspects about Insertion Device activities at the ESRF since the installation of the first ID segment on the storage ring in June 1992. It presents the evolution versus time of the number of installed segments (blue dotted curve) and the average minimum gap (red curve). It essentially reveals a permanent task focussing on the ID gap reduction and consequently the improvement of performances for the ESRF beamlines. Presently, as far as conventional IDs are concerned, it consists in the migration from minimum gaps of 16 mm to 11 mm. The ESRF is now equipped with a Non Evaporable Getter (NEG) coating facility for the routine preparation of 10 mm extruded aluminium chambers.

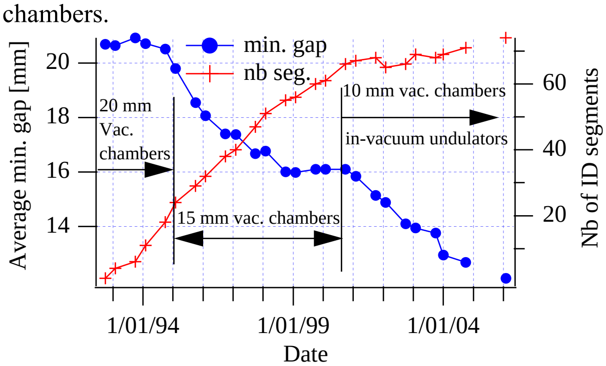

Figure 1: Number of installed ID segments and evolution of the average minimum gap since 1992.

The reduction of the minimum gap involves obviously a reduction of the undulator period keeping in mind that the target is to increase photon intensities. Consequently, new magnetic assemblies have been constructed for the replacement of obsolete devices. It concerns mainly a period reduction from 42 mm (U42) to 35 mm (U35). Table 1 presents the status of the ongoing upgrade for four beamlines. In each case, the upgrade involves the installation of three independent segments with a standard length of 1.6 m. The advantage of this segmentation is the possibility to proceed to a very smooth upgrade. All new undulators are systematically processed with a high level of magnetic passive corrections: low residual integrated mutipoles and r.m.s optical phase errors lower than 2.5 degrees. For the last beamline in Table 1 (ID10) the upgrade includes a novel revolver support equipped with two undulators (see section 2).

Table 1: Upgrade status for four beamlines

ID	Position in straight section			Completion date
	Up	Middle	Down	
26	U40	U35	U35	Jan. 04
20	U35	U35	U32	May 04
32	U35	U35	U42	Jul. 04
10	U35	U35/U27	U27	Oct. 04

DEVELOPMENT OF REVOLVER UNDULATORS

The concept of revolver undulators is not new, a few devices were constructed in the early 90s [1][2]. More recently, this has been the subject of new developments at SPRING 8 with the construction of a double undulator revolver structure [3] and also mini gap in-vacuum revolver undulators [4]. At the ESRF, a new prototype of revolver support structure has been constructed (Figure 2).

Figure 2: ESRF revolver prototype before installation in the ID18 straight section, the support is equipped with a U32 and a U20.

It is equipped with two 1.6 m long undulators of period 32 mm and 20 mm. The design integrates a very rigid 90 degree angular motion of the main girders using high precision circular bearing systems. The switching between the two undulators takes less than 1 minute. As a very important point, this device is interchangeable with standard ID segments installed in the ESRF storage ring. The main interest for such a device is the combination of a multi-purpose undulator (U35 with minimum gap 11 mm) and a dedicated shorter period undulator providing higher photon flux on the fundamental in a limited energy range (beamline specific). The first prototype was installed in the ID18 straight section in December 2003. It has been optimized for operation at photon energies of around 14keV with the U20 device. Figure 3 shows the measured photon flux in a very narrow pinhole (20µm x 20µm) at 30 m from the source. The gaps of both undulators have been tuned for maximum flux at 14.4 keV on the fundamental (third harmonic) for the U20 (U32). At this energy, the U20 provides twice the flux produced by the U32.

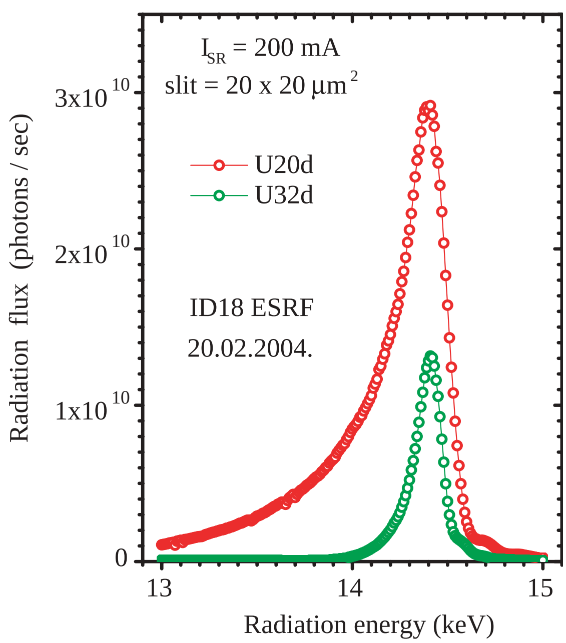

Figure 3: Measured flux output for the two undulators installed on the revolver support.

Three additional revolver supports were constructed and delivered in 2003 . They are committed for three beamlines and adopt the same strategy concerning the magnetic assemblies.

Table 2: Status of revolver undulator development, the cells with two undulators indicate a revolver device.

ID	Position in straight section			Installation status
	Up	Middle	Down	
18	U32	U32	U32/U20	Dec. 03
10	U35	U35/U27	U27	Oct. 04
28	U32	U32	U32/U18	Mar. 05
16	U35	U35	U32/U26	Mar. 05

Table 2 summarizes the situation regarding the development of revolver undulators at the ESRF. It defines in particular the undulator combination adopted for each beamline as well as the installation status.

IN-VACUUM UNDULATORS

In December 2003, three in-vacuum undulators were installed. Their main characteristics are summarized in Table 3.

Table 3: Main parameters for the three in-vacuum undulators recently installed

ID	Period [mm]	Techno.	Length [m]	p.m material
27_1	23	p.p.m	2	Sm_2C0_{17}
27_2	23	p.p.m	2	Sm_2C0_{17}
11	22	hybrid	2	Sm_2C0_{17}

Technology

The two devices installed in the ID27 straight section are identical. They are based on the pure permanent magnet technology (p.p.m). The third one, as part of a development programme, has been constructed in order to establish a comparison with usual p.p.m structures in terms of field performance and magnetic correction methods. Figure 4 shows a view of the hybrid U22 device during assembly.

Figure 4: Hybrid magnetic structure of the U22 in-vacuum undulator.

Magnetic measurements

As for p.p.m devices the magnetic structure is based on short modules which are individually measured [5]. A dedicated stretched wire bench has been developed for this purpose. It has the capacity of measuring 6 modules at the same time, each module being characterized by a field integral scan with typically 41 points over a total horizontal distance of 100 mm. The vertcial distance from the magnet to the wire is in general fixed at 2.5 mm.
The 400 modules of the U22 undulator were measured in less than two days. The mechanical design includes the option to easily extract modules from the assembly. This has been used for additional field corrections based on

module exchanges in the assembly or when using extra modules. This process proved to be relatively efficient because no additional shimming has been necessary. Figure 5 present the horizontal and vertical field integral variation versus gap for the U22 hybrid device and a U23 p.p.m undulator (ID27_1). The measurements are taken at the beam axis.

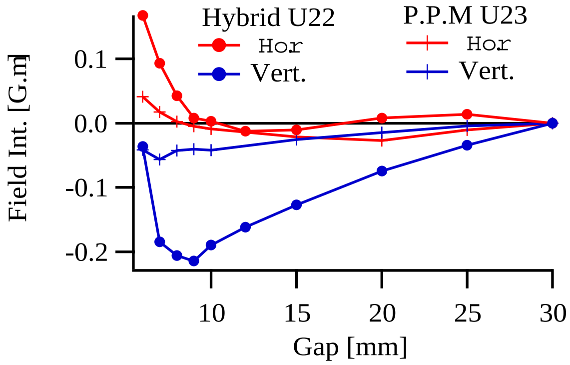

Figure 5: Field integral variation versus magnetic gap for the hybrid U22 and a p.p.m. U23.

As far as peak field is concerned, the measurements agree very well (within 2%) with RADIA computations. The measured peak field as a function of gap is presented in Figure 6. For hybrid undulators, the peak field is assumed to be the amplitude of the first harmonic in the field (effective peak field). The comparison with the peak field of a p.p.m undulator with the same period indicates a net gain of about 18 % (22%) at the gap of 6 mm (5mm).

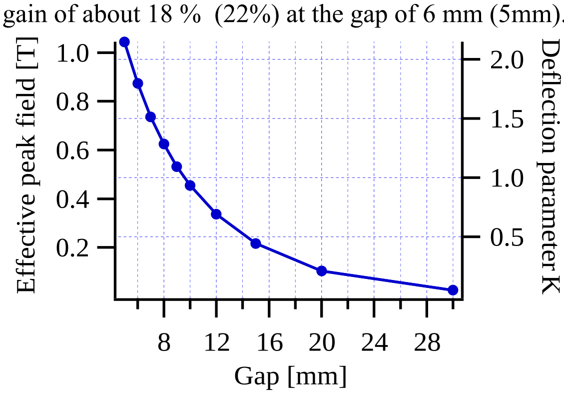

Figure 6: Peak field versus gap for the hybrid U22 in-vacuum undulator.

In order to make use of the high harmonics of the x-ray spectrum, the optical phase error needs to be corrected. Figure 7 shows the gap dependence of the phase error (r.m.s value) for the two undulators compared above. The results are relatively similar and indicate also a possible need for additional correction at low gap for the hybrid device.

Interaction with the stored beam

As for all installed insertion devices, the Closed Orbit Distortions (COD) induced by in-vacuum undulators are recorded on a regular basis. For the two p.p.m devices installed in ID27 the COD data confirm the field integral measurements. In the hybrid undulator case, the COD results show a different behaviour at small gaps. This was expected because, as observed in many cases for hybrid IDs, the ambient field existing in the ring tunnel can induce small changes in the magnetization of soft iron poles and consequently a modification in the field integral dependence versus gap. Nevertheless, for this hybrid undulator, the induced beam displacements remain smaller than 10% of the beam size without any active correction.

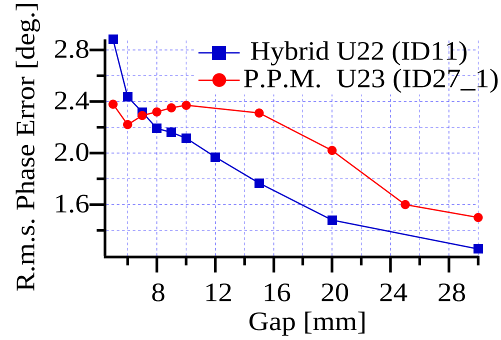

Figure 7: R.m.s optical phase error versus gap for hybrid and p.p.m in-vacuum undulators.

For the three last devices installed, it has not been possible to detect any tune shift or modification in the beam coupling connected to higher integrated multipole errors. In terms of beam lifetime reduction, these three devices behave very similarly to in-vacuum undulators previously installed: the reduction is lower than 10% in mutibunch filling pattern (200 mA, uniform filling).

In order to maintain constant heat load in the beamlines, the injection with front end open has been successfully implemented at the ESRF. The in-vacuum undulators remains the only IDs for which the gap is opened to 8 mm during this phase. This gap value corresponds to a compromise between minimization of heat load variation and magnet protection against possible radiation damages.

In 2005, two additional in-vacuum undulators (period 20 mm and 18 mm) will be built. They will be based on the hybrid technology which is now the new standard adopted for in-vacuum devices.

ACKNOWLEDGEMENTS

The authors thank the ESRF vacuum group for the strong support in in-vacuum undulator activities. We also greatly appreciate the feedback from the ID18 scientists concerning the revolver undulator prototype tests.

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