RECENT PROGRESS IN INSERTION DEVICES AT THE ESRF

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Abstract

Insertion Device activities at the ESRF are presently driven by the upgrade of more than ten beamlines. The concept of canted undulators is part of the requirements in a number of cases. Permanent Magnet Steerers (PMS) will be used to create canting angles of up to 5.4 mrad. The magnetic structure of PMS was fully optimized to minimise space occupancy and magnetic perturbations induced on neighbouring undulators. The measured field quality of PMS recently constructed is presented. The development of undulators dedicated to high photon energy is still pursued. Leading on from the successful operation of a first Cryogenic Permanent Magnet Undulator (CPMU) installed in the ID6 beamline since 2008, a second device was constructed. This 2 m long device has a period of 18 mm and will be operated at 145 K. The field measurements at cryogenic temperature are discussed.

ESRF UPGRADE

ID Straight Sections

The activity of the ESRF Insertion Device group is presently largely focused on the ESRF upgrade. For the Upgraded Beamlines of the first phase, the length of the straight sections is increased to 6 m [1]. Different Insertion Device arrangements along the straight section can be achieved including canting in some cases. The approach has been to keep the flexible segmentation concept adopted since the early stages of the ESRF. In most of cases, existing 1.6 m long segments are mixed with new 1.4 m segments to fully occupy the 6.17 m long free space. The 1.4 m support structures consist of either shortened 1.6 m standard supports (S) or new revolver supports (R). A typical configuration involves one or two revolvers so that two long undulators can be used in the same straight section. The ID segments used in ID24 (recently completed) illustrate the concept as shown in Table 1. A 4.4 m long U27 and a 3 m long U32 can be used from four segments including one 1.4 m long revolver support. The total length covered by the magnetic assemblies is 6.04 m .

Table 1: ID segments Installed in ID24.

position	Period [mm]	Length [m]	Type
1	27	1.6	S
2	27	1.4	S
3	27/32	1.4	R
4	32	1.6	S

All undulators in use or planned include specific end field structures which allow optimum optical phasing at any gap with non zero air gap between consecutive segments [2]. The space (face to face) between two phased undulators depends on the period of the undulator. It varies monotonously from 2 mm (period 18 mm) to 5 mm (period 35 mm).

A total of 17 new undulators will be needed to complete and install the Insertion Devices for the first five upgraded beamlines before the end of 2012. This includes a new 2.5 m long in-vacuum undulator. A number of existing segments will need to be modified also. This mainly concerns the shortening of undulator from 1.6 m to 1.4 m. This has been found to be easily feasible due to the modular approach used for all magnetic assemblies. All necessary new support structures have already been fabricated and the necessary magnet blocks have been delivered (12 devices) or are under manufacture (5 devices).

ID Field Quality

Over the last three years, the vertical emittance of the stored beam has been dramatically reduced at the ESRF. The storage ring operates routinely with a vertical emittance as low as 3 pm in multibunch filling patterns. Such ultra small emittance fixes new requirements on integrated skew multipoles. In particular, the integrated skew quadrupole should be kept lower than 10 G to avoid any perturbation of the vertical beam size during gap changes. The multipole shimming of the new undulators must be compatible with this requirement. In addition, a number of existing in–air segments in operation will be progressively re-visited prior to their relocation on new upgraded beamlines. However, for some devices, an active correction scheme is required. This concerns some old wigglers or in-vacuum undulators. The method consists of using the existing iron free steerers placed at either side of the straight section. Each of these steerers includes two pairs of coils for the correction of the first and second field integral in the horizontal and vertical planes when needed. The steerers can be configured in a skew quadrupole scheme either by modifying the existing wiring or by powering each coil separately. A feed forward method can be used to produce a gap dependent integrated skew quadrupole. This approach was successfully tested on two straight sections [3]. Due to the capacity of the steerers, it can be used to correct integrated skew quadrupole lower than 150 G.

STRETCHED WIRE BENCH

A stretched wire magnetic measurement bench has been developed at the ESRF. It can be used for the measurement of magnetic field integrals and for multipole analysis of lattice magnets.

Arbitrary wire motions can be performed and analyzed. One can design wire trajectories which erases the contribution of the main harmonic: the basic idea is to build trajectories which are parallel to the main field multipole. The measured field integral $\mathbf{B_{MEAS}}$ can be expressed as

$$\mathbf{B_{MEAS}} = \mathbf{MC}.$$

where the vector $\mathbf{C}$ contains the multipole coefficients and the coefficients M_{mn} of the matrix $\mathbf{M}$ depend only on the position and angle of the wire at point m and on the multipole order n. The multipole coefficients can be obtained from the measured field integral and from a pseudoinverse of the matrix $\mathbf{M}$.

The bench is based on two groups of Newport linear stages M-ILS250CC driven by an XPS motion controller. The wire voltage was measured with a 2182A Keithley nanovoltmeter. The linear stages and the measured magnet are supported by a 60 x 60 cm^2 cross-section granite table. A 4 feet FARO Platinium measuring arm can be fasten on the bench for mechanical measurements. It can be used for the fiducialization of multipole magnets. This stretched wire system has been validated on quadrupole and sextupole magnets. The field multipoles obtained for a sample quadrupole magnet are given in Fig. 1.

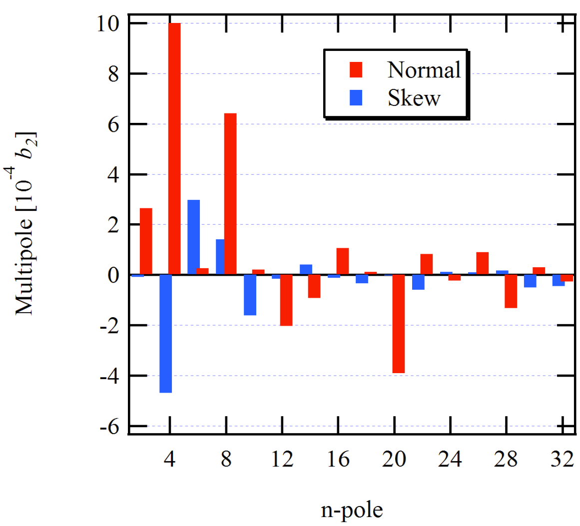

Figure 1: Multipole content of an ESRF high gradient quadrupole.

PERMANENT MAGNET STEERERS

Permanent Magnet Steerers (PMS) have been designed for the ESRF canted sections. An optimized design has been presented last year [1]. The on-axis fringe field of the PMS was minimized in order to avoid additional undulator phase errors. The shapes of the main poles were optimized numerically for obtaining a flat field profile. The canting angles of the first ESRF canted sections are given in Table 2. The serial PMSs were received in the Autumn of 2010. Figure 2 shows a PMS which will be installed in one extremity of the ID16 section. The serial PMSs have been characterized with the stretched wire bench described above. Field integral measurements are given in Figure 3.

Table 2: Angles of the first ESRF canted sections.

ID 16	–2.70	5.40	–2.70	
ID 23	–0.75	0.75	0.75	–0.75
ID 30	–2.20	4.40	–2.20	

The field profiles of all the PMSs are very flat between ± 25 mm, even for the –2.2 mrad and –2.7 mrad large gap PMSs placed at the extremities of the ID sections. The phase error of a 35 mm period undulator has been measured in presence of a 5.4 mrad PMS (Figure 4). The nominal distance between the undulator and the PMS is roughly 16 cm. At this distance, the PMS has no impact on the undulator phase error

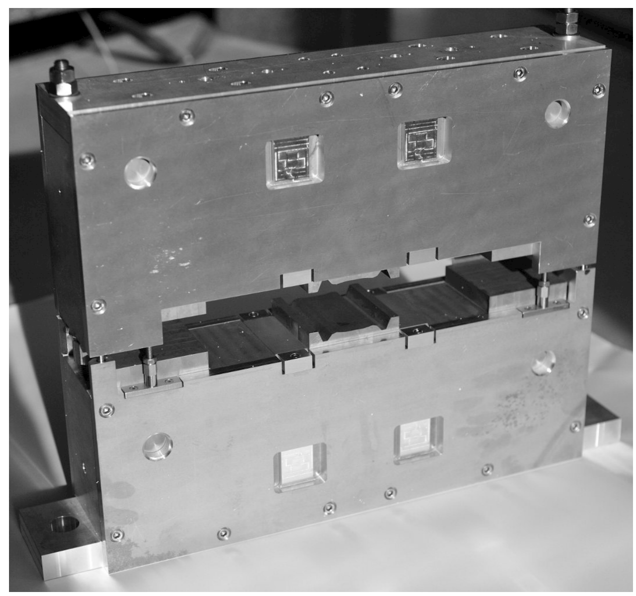

Figure 2: Extremity PMS with 2.7 mrad.

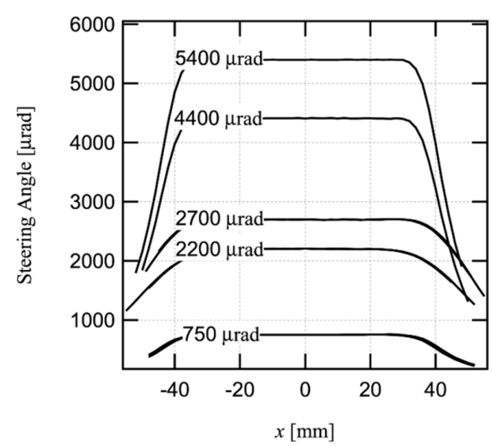

Figure 3: Measured PMS canted angles.

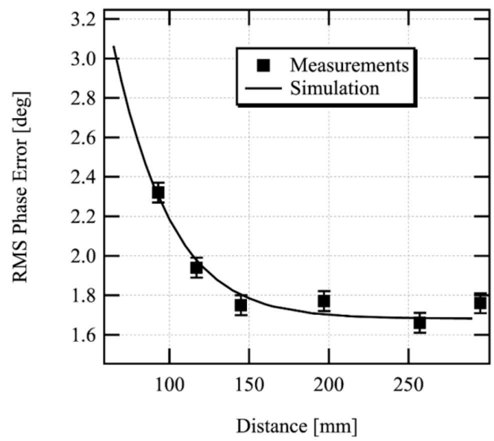

Figure 4: Undulator phase error in presence of the PMS. The distances are from the face of the PMS to the extremity of an undulator. The undulator period is 35 mm.

DEVELOPMENT OF CPMUS

A second Cryogenic Permanent Magnet Undulator (CPMU) was recently constructed at the ESRF. The main parameters of the undulator are presented in Table 3: As opposed to the first prototype [4], this device is based on high remanence NdFeB material (Vacodym 764 [5]). The measured remanence Br is 1.383 T at 20 deg. C.

Table 3 Main Parameters of the second CPMU.

Period [mm]	18
Length [m]	2
Min.gap [mm]	6
Peak Field @ 297 K	0.907
Peak Field @ 150 K	0.99

The magnetic measurements where carried out with the same system used for the first prototype [4].

Figure 5 shows the measured peak field of the undulator at different temperatures. The measurements were taken during the first cooling. At 150 K the field reaches a maximum of 0.99 T, close to the simulated field of 1T. A linear model can be used for the NdFeB material at 150 K in the different simulations. The remanence is 1.5 T at 150 K while the magnetic susceptibility parallel and perpendicular to the easy axis is 0.04 and 0.18 respectively.

The device was corrected at room temperature to reach a RMS phase error of 2.9 deg at the minimum gap of 6 mm. At low temperature (150 K) the RMS phase error was 3.8 degree at the gap of 6 mm. To allow further correction of the phase error a verification of calibration of the hall probe bench is found to be necessary in order to eliminate systematic errors originating from the hall motion. This is expected to be done during September 2011. A stretched wire was used to measure the field integral, preliminary measurements show that the on axis field integral components remain lower than 30 G·cm at any gap and temperature. Further measurements of higher order integrated multipoles are also expected to be done.

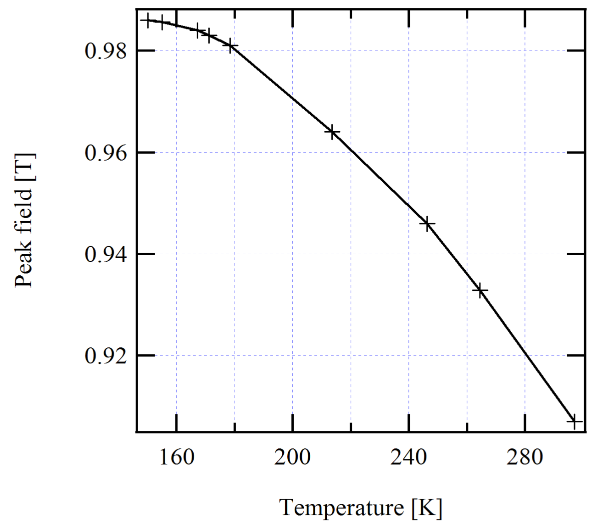

Figure 5: Peak field versus temperature at a gap of 6 mm for the second CPMU constructed at the ESRF.

CONCLUSION

In 2012, a significant number of new Insertion Devices will be constructed and installed for the first upgraded beamlines. For canted sections, an innovative concept of PMS was designed. It combines a high field quality and minimum space occupancy. All required PMSs were constructed and magnetically qualified. A second CPMU was constructed in 2011. Detailed magnetic measurements of the device will be completed in September 2011. CPMU will be considered for the upgrade of high energy beamlines at the ESRF. This will be the subject of the second phase of the upgrade.

REFERENCES

[1] J. Chavanne, G. Le Bec, L. Goirand, C. Penel, F. Revol, Upgrade of the Insertion Devices at the ESRF, in: IPAC10, Kyoto, 2010, pp. 3105-3107.
[2] J. Chavanne , P.Elleaume, P. Van Vaerenbergh, Segmented High Quality Undulators, PAC95, Dallas,1995, pp. 1319-1321
[3] A. Franchi, J.Chavanne, F. Ewald, L.Farvacque, T.Perron, K.Sheidt, Vertical emittance reduction and preservation at the ESRF storage ring, TUODA1, this conference.
[4] J.Chavanne, M. Hahn, R.Kersevan, C.Kitegi, C.Penel, F.Revol. Construction of a cryogenic permanent magnet Undulator at the ESRF, EPAC08, Genoa, 2008, pp. 2243-2245
[5] http:// www.vacuumschmelze.com/