Status of the ESRF Insertion Devices

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Abstract

I. INTRODUCTION

The ESRF is a third generation synchrotron radiation source being built in Grenoble, France. It is optimized to generate high brightness hard X-ray radiation. The main source of the radiation will be Insertion Devices (ID) of undulator or wiggler type. The machine presents 29 straight sections each 5 m long.
Phase I consists in a series of 17 Beamlines presently being built out of which 9 will use the radiation from an ID. Commissioning of the IDs will start end of 1992.

II. Design Considerations

The presently planned IDs are optimized for a 20 mm magnetic gap with magnet blocks placed on both sides of a vacuum chamber in the air. The magnetic assemblies are placed on a support structure which allows a precise adjustment of the magnetic gap under a load as high as 6 tons/meter. For reasons of flexibility and ease of construction, a segmentation policy has been adopted resulting in the full occupancy of one straight section by three segments each 1.6 to 1.7 m long. Such segmentation allows the placement of up to three similar or different IDs on the same straight section. In order to accommodate an ID segment of any kind, a standard support structure has been designed, prototyped and tested. An arrangement of three support structures placed over a 5 m long straight section is shown in the next figure.

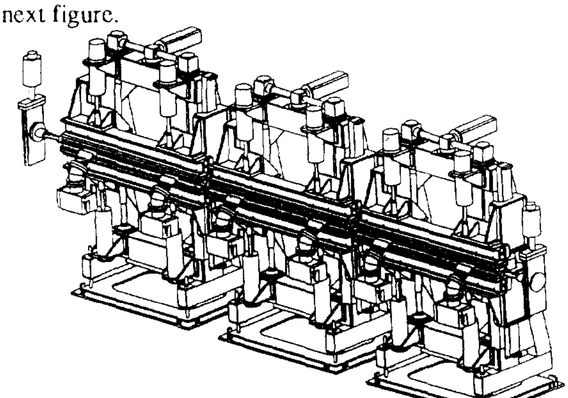

Figure 1. Three Undulator and wiggler support structures assembled over a straight section.

They are driven by open loop controlled stepper motors allowing a resolution of 2 μm and a speed of gap variation as high as 10 mm/second. The gap setting is monitored by absolute encoders. These supports are C shaped and can be installed on the storage ring without braking the vacuum. The control is made through a VME crate running OS9 operating system which is interconnected to an HP 700 Unix machine.

A revolving support structure has been designed and is presently being manufactured. It allows the placement of up to four different undulator assemblies over a single segment.

All magnetic assemblies have been further subsegmented to allow easy handling. The mechanical interface between the magnet assembly and the rigid girder of the support structure has been standardized with a dovetail profile in order to allow an easy interchange of any magnet assemblies over any one of the support structure.

III. List of IDs

The following table presents the list of the Phase I IDs:

Beamline Number	Scientific Application	Field [Tesla]	Period [mm]	N.of Period
ID2	High Flux	0.48	46	36
ID3	Microfocus	0.48	46	36
ID6	Machine Diagnostic	0.50	48	32
ID9	High Energy	1.8	230	7
ID10	Dichroism	0.3	85	18
ID21	Open ID	0.48	46	36
ID25	Material Diffraction	1.2	125	12
ID27	Surface Diffraction	0.4	44	38

The following table presents the list of the Phase II IDs:

Beamline Number	Scientific Application	Field [Tesla]	Period [mm]	N.of Period
ID22	Mossbauer	0.12	22.8	72
	Mossbauer	0.27	34	48
ID26	SEXAFS	0.5	48	32
ID9	High Energy	4	100	1.5
ID8	EXAFS	0.37	40	42

ID12	Magnetic Scattering	0.9	210	8
ID19	Topography	1.5	150	5.5
ID2	High Flux	0.16	26	64

All IDs listed in these tables, with the exception of the 4 Tesla wiggler, are presently being manufactured out of permanent magnet blocks. The majority are conventional IDs with a vertical sinusoidal magnetic field. There are two asymmetric wigglers namely the 1.8 T wiggler for the High Energy Beamline and the 0.9 T wiggler for the magnetic scattering beamline. The undulator for the Dichroism beamline is a helical undulator device of a novel kind[1] which is sketched on the following figure.

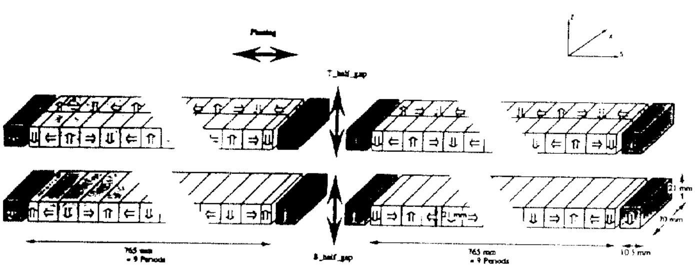

Figure 2. The helical undulator for the ID10 dichroism beamline.

Nearly all undulators are made of pure permanent magnet material without any iron pole while most of the wigglers make use of the hybrid technology combining iron poles and magnet blocks.

IV. Field Measurements

The characterization of the magnetic blocks when received from the supplier is made by the combined use of a Helmhotz coil and a magnetometer of fluxgate type. In order to ensure a RMS closed orbit displacement smaller than one tenth of the RMS beam sizes, the vertical (horizontal) field integral fluctuations must be left smaller than 5 10^{-5} Tm (3 10^{-5} Tm) and even lower if one wants to tune several undulators simultaneously. These are very demanding tolerances. Two kind of benches were developed: a field integral and a local field measuring bench. The field integral measuring bench is based on the flipping coil and harmonic analysis technique. The solid coil usually used in such benches has been replaced by a multifilar Litz wire held under tension. It is rotated from both extremities simultaneously by means of synchronous stepper motors. With such a bench, the field integral can be measured over long distances (as long as 3.5 m has been tested so far) within a magnetic gap as low as 10 mm. At this time the absolute precision is estimated to be better than 1 10-5 Tm for a typical ESRF segment (1.6 m length, 48 mm period, o.5 T field). The local magnetic field is measured by means of a set of Hall probes scanned longitudinally inside the magnetic gap of the ID. To insure minimum noise, high repeatability and fast measurement, the motion is made at a constant velocity and the field is measured on the fly from a voltmeter triggered by a linear encoder fixed on the moving carriage holding the probes. A typical scan of both the horizontal and the vertical fields for a single undulator segment consists in 2* 2000 data points which are recorded within 1 minute.

The initial measurements on both hybrid and pure permanent magnet undulator segments have shown a very large residual integrated dipole, quadrupole, sextupole (of normal and skew type) which varies with the setting of the magnetic gap. Such behavior was present even after a careful pairing of the magnetic blocks. It originates from non uniform magnetization of the magnet blocks. Consequently, we have ben forced to develop a new correction based on a two dimensional shimming of both magnetic jaws. The method consists in placing thin iron rectangular pieces(typical 10*20*0.2 mm) at specific longitudinal and transverse positions on the surface of the magnetic assembly. The force occurring in the iron under the presence of the magnetic field holds the shim in place while its magnetization adds a small correction to the magnetic field and compensates for the non uniform magnetization of the blocks. The next figure presents the horizontal and vertical field integrals measured before and after the shimming process. The measurement is made versus the horizontal position x inside the magnetic gap. x=0 corresponds to the symmetry axis of the field.

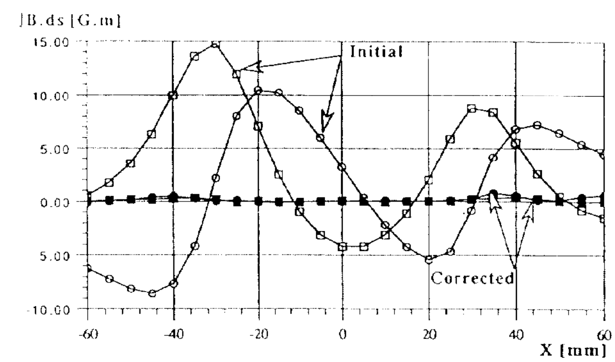

Figure 3. Horizontal and Vertical field Integrals versus the horizontal position x measure on the symmetry plane in the middle of the gap. The flat curves are measured after shimming.

The flatness of the field integral versus x results in extremely small quadrupole, sextupole... The measurement of field integral versus the magnetic gap is well inside the above stated specifications. The next figure presents a typical undulator trajectory before and after shimming.

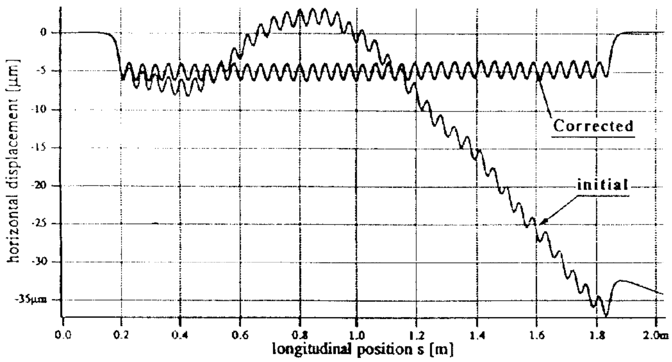

Figure 4. Electron trajectory in an undulator segment before and after shimming.

At this time the shimming has been routinely applied to the first 6 segments of Phase I. Its price is the loss of magnetic gap due to the iron thickness which has been limited to a total of 0.4 mm.

V. Computational Tools

The IDs were designed using various software tools such as POISSON[3] , Hybrid[4] and Flux3D[5] . A special software called RADIA[6] has been designed by the ESRF ID group. It allows the computation of 3D magnetostatic field from rectangular magnet blocks and iron pieces. It is at the moment the essential tool for designing all new IDs of undulator or wiggler type. One of the originalities of this software is that it is interfaced to the commercially available spreadsheet Wingz[7] . It currently runs under macintosh and HP workstations series 300,400,700 and 800. The latest version allows also the computation of bending magnet, undulator and wiggler radiation. Periodic magnetic field of any kind are allowed including planar, helical and elliptical or asymmetric undulators. The 4 Stokes components of the polarization of the radiation are systematically computed and integrated inside a rectangular aperture located somewhere in the beamline. Electron beam sizes and angular spread are fully taken into account. Heatload computations are available which have been used to optimize the beryllium window, filters and photon position monitors. A direct link exists between the 3D magnetostatic routines and the radiation routines allowing a rapid investigation of a large number of magnetic structures by a full simulation of the radiation characteristics in order to suit the particular figure of merit of the beamline.

VI. Vacuum Chamber

A prototype vacuum chamber has been built and fully tested. Its useful length is only 1850 mm. 9 of these chambers are presently under production to be used for Phase I. The pumping is provided by two isolated 707 NEG ribbons placed in an antechamber. A transverse cross-section of this chamber is shown in the next figure:

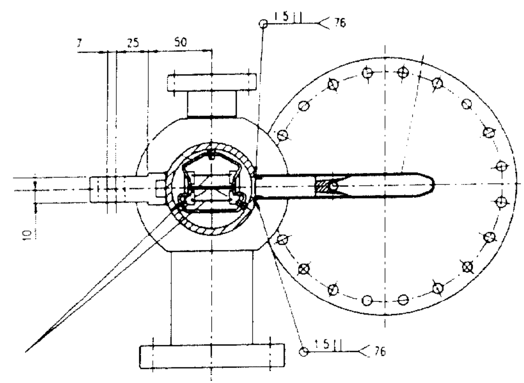

Figure 5. Cross-section of the ID vacuum chamber to be used for Phase I

A 5m long 20 mm chamber has been designed and will soon be prototyped. It contains a single NEG ribbon which will be activated when baking at 250 deg C. This chamber will replace the short 1850 mm unit and will authorize the installation of the full three segments.

VII. References

[1] P. Elleaume, J. Chavanne, A New powerful flexible linear/helical undulator for soft X-rays, Nucl. Instr. and Methods. A304, (1991) 719-724.

[2] POISSON, Los Alamos Accelerator Code Group, LA-UR-87-115.

[3] hybrid, developped by Tor Meinander, VTT Finland.

[4] Flux3D, Magsoft Corporation, 1223 People's Avenue, Troy, New York 12180. Cedrat, 10 chemin du pre carre, ZIRST, 38240 Meylan (France).

[5] J. Chavanne, P. Elleaume, RADIA Version 2.0, A software running under Wingz to compute Synchrotron Radiation and Magnetic fields, Report ESRF-SR/ID-90-46 (1990).

[6] WINGZ, Informix Software Inc., 16011 College Boulevard, Lenexa, Kansas 66219.