A NOVEL FAST SWITCHING LINEAR/HELICAL UNDULATOR

J. Chavanne, P. Elleaume, P. Van Vaerenbergh
ESRF, B.P. 220, F-38043 GRENOBLE Cedex France

Abstract

A new fast switching linear/helical undulator has been built and its field has been measured . It consists of 19 periods of 80 mm with a field slightly less than 0.2 T . The vertical sinusoidal field is produced by a coil and laminated yoke while the horizontal field is produced by an array of permanent magnets. A fast reversal of the circular polarization rate is induced by flipping the current in the coil within a time which can be a short as 6 ms. The magnetic design of the central section and extremities is presented. The result of local field as well as field integral as a function of the magnetic gap and coil current are detailed. The field integrals are corrected in real time using a DSP I/O board operating with a 5 kHz cycle.

1 INTRODUCTION

The production of circularly polarized radiation from insertion devices has always been a high priority at the ESRF. The hard X-ray range (20-500 keV) is covered by three asymmetric wigglers installed on ID15A (1.8 T, 7 poles) , ID15B (4 T, 1 pole)[1] and ID20 (1 T, 8 poles) while the low energy range (0.5-10 keV) is covered by three variable polarization helical undulators installed on ID12A, ID12B and ID16. These undulators are made of permanent magnets and allow an independent setting of the vertical and horizontal field components and of their phase allowing any elliptical polarization to be produced[2]. During the four years of user operation of these undulators , it appears that the most frequent adjustment is a phase inversion which flips the circular polarization between left and right. Such a flip takes a few seconds which is too long if one wants to detect a dichroism signal as low as 10^{-4}. To overcome this limit a new variable polarization helical undulator has been built. It will be installed very soon on the ID12 beamline dedicated to dichroism measurement. It is described in this paper.

2 MAGNETIC DESIGN

Figure 1 presents a 3D view of the undulator. The vertical field is produced by a coil and a laminated iron structure. The horizontal field is produced by an array of Sm_2CO_{17} permanent magnets located between the poles. The spatial period is 80 mm and its length is 1600 mm. The horizontal magnetic field is varied by changing the magnetic gap between the upper and lower magnet arrays placed on both side of the vacuum chamber. At the minimum magnetic gap of 16 mm and for the highest current of 250 A , an almost purely helicoidal field is generated. The flipping of the helicity of the magnetic field is obtained by inverting the current in the coil.

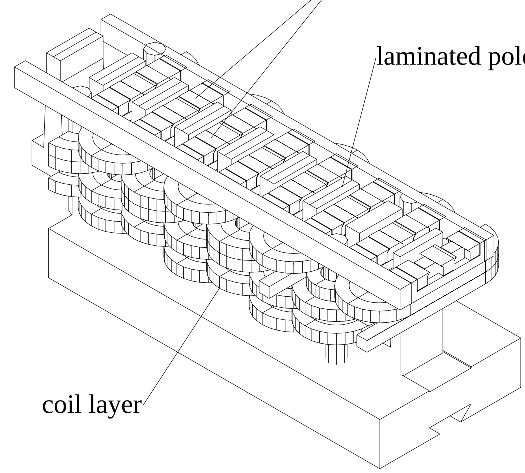

Figure 1: 3D view of the termination of the undulator.

The magnetic design is largely dictated by the operation of the vertical field at the highest frequency as possible (up to 100 Hz). The choice of Sm_2CO_{17} as opposed to NdFeB magnets was made to avoid any possible thermal demagnetization of the magnets due to the eddy current.

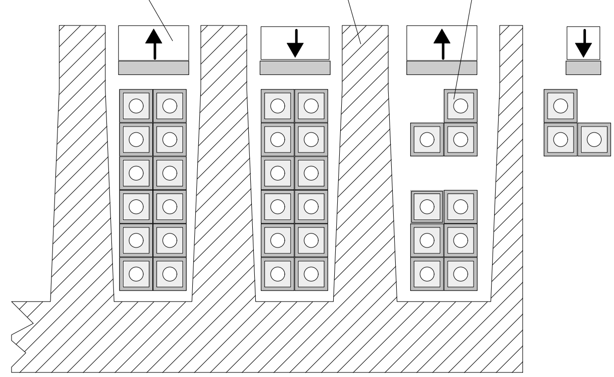

Figure 2: Longitudinal cut of the yoke and coils around the extremity.

The yoke is made of 0.35 mm laminations of Silicon Iron (STABOCOR V270-35A) similar to those used in

50 Hz current transformers. To reduce the total inductance (and simplify the design of the power supply), the coil is made of a conductor with large cross-section (7.5 x 7.5 mm with 4 mm diameter hole for water cooling) operated with a maximum current density of 5.7 A/mm^2. The conductor is wound in and out around the poles from one extremity of the undulator to the other as a single piece. A longitudinal cut of the yoke and coil is presented in Figure 2. Such a winding is simpler and more economical than using individuals coils around each poles. However, due to the large cross-section of the conductor, a single layer of conductor produces an undesirable uniform horizontal field in addition to the sinusoidal vertical field. To minimize this horizontal field, the 6 layers have been interlaced as shown in Figure 1 where the 2nd, 3rd and 5th layers contributes to the horizontal field with the same sign while all other layers contribute with the opposite sign. The field in the upstream and downstream terminations is symmetric (anti-symmetric) for the vertical (horizontal) field components. As a consequence of this choice, one observes a much larger residual field integral in the vertical plane than in the horizontal plane (see section 4). The vertical field integrals are corrected using small coils placed at each extremities. To minimize the mutual inductance between the main and correction coils, the correction coils are placed below the yoke. The horizontal field integrals should be zero by design except for non uniformity of the magnetization in the Sm_2CO_{17} and positioning or machining errors of the yoke and magnets. Residual horizontal field integrals are corrected by winding two long loop extending along the whole undulator in the vertical plane. The 3D magnetic design of the central part as well as the extremity has been made at the ESRF using Radia[3]. The yoke and coil has been manufactured by DANFYSIK. All field measurements and shimming were made at the ESRF.

3 CONTROL SYSTEM

The upper and lower magnet arrays are fixed on two rigid aluminum girders which are part of the standard ESRF support structure used for all conventional permanent magnet undulators allowing a gap change between 16 and 300 mm. The main bipolar power supply is made by HAZEMEYER. Its maximum current is ± 250 A and maximum voltage ±250 V. The vertical and horizontal field integrals corrections are provided by two 4-quadrant power supplies with a maximum current (voltage) of 12 A (32 V). The shortest flipping time between +250 A and -250 A was observed to be 6 ms. Within such a short transit time, eddy currents develop in the yoke and coils resulting in field integrals transients of short duration (see below). It is therefore essential, if one wants to precisely control the field integral in the AC mode of operation to drive the correction power supplies synchronously with the current in the main power supply. To do so, a DSP VME card is used which allows a precise real time synchronization of the current in each three power supplies (main, vertical and horizontal corrections) with a time resolution equal to 200µs. Since this insertion device is going to be used as an undulator , the energy of the fundamental depends on the main current. Therefore , in an AC mode of operation, the current versus time must have some *trapezoidal shape* and cannot be a pure sinus. The data acquisition in the beamline is triggered during the flat part of the trapeze where the current is constant. The repetition rate will extend between DC and 10 Hz. At 10 Hz and a 6 ms flipping time of the main current, the Fourrier components extentds to 100 Hz. The vacuum chamber is made with 2 mm thick stainless steel sheets.

4 MAGNETIC MEASUREMENTS

4.1 Local Field

Figure 3 presents the measured vertical field and horizontal field as a function of the longitudinal coordinate for the minimum gap of 16 mm and the maximum current of 250 A. Figure 4 presents the variation of the peak fields as a function of the magnetic gap.

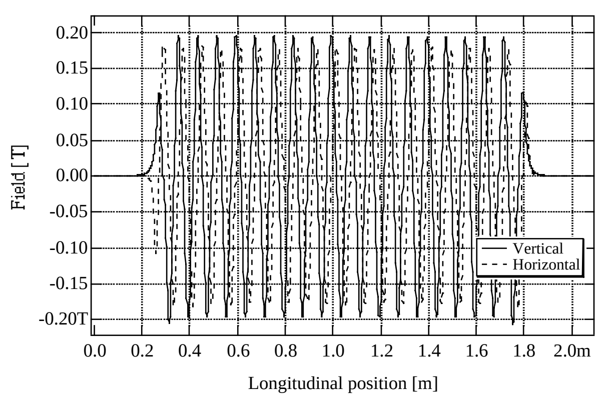

Figure 3 : Horizontal and vertical field components as a function of the longitudinal coordinate for a gap of 16 mm and a current of 250 A.

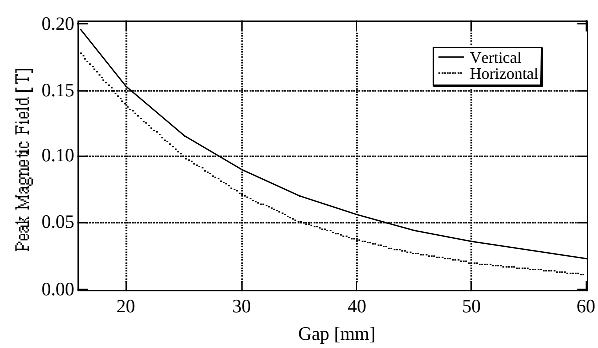

Figure 4 :Peak horizontal and vertical fields as a function of the magnetic gap for a current of 250 A.

4.2 Field Integrals

Some multipole shimming has been applied to both the permanent magnet and yoke in order to flatten the field integral as a function of the horizontal coordinate. The shimming of the Yoke consisted in fixing thin pieces of steel with screws on the horizontal outer side of some poles . Figure 5 presents an hysteresis cycle of the measured field integral as a function of the main current in the coil for a magnetic gap of 16 mm.

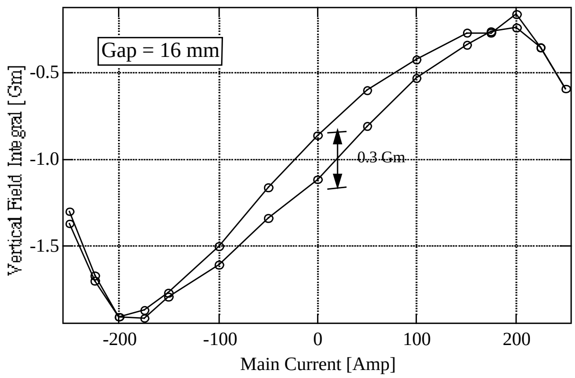

Figure 5 Hysteresis cycle of field integral vs. Current in the coil for a magnetic gap of 16 mm.

The current is cycled between -250 A and +250 A. The maximum thickness of the hysteresis cycle is 0.3 Gm . Thinner cycles have been observed for larger gaps and lower currents. As a result, a vertical field integral correction is applied as a function of the magnetic gap and current but no correction is made for the hysteresis effect. Figure 6 presents the vertical field integrals observed as a function of current and averaged over the hysteresis cycle.

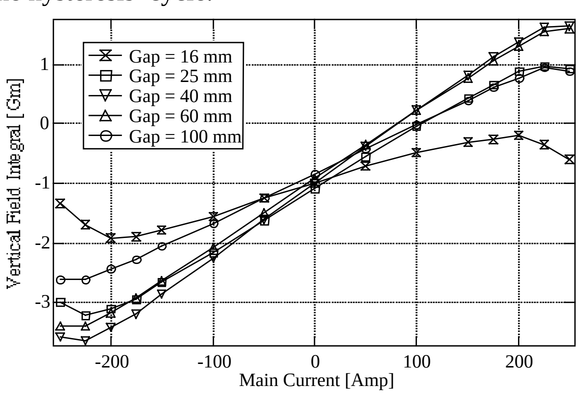

Figure 6 : Average vertical field integral measured as a function of the main current and magnetic gap.

The horizontal field integral variations with current and gap measured in the laboratory are smaller than 0.1 Gm and no correction is applied. Nevertheless, due to the different ambient field in the storage ring tunnel compared to the laboratory, one may need a further tuning of both the horizontal and vertical field integral correction tables when the device is operated on the storage ring. Such phenomena has been observed on all hybrid permanent magnet insertion devices [4].

As one suddenly flips the vertical field to flip the polarization, one observes some time dependent field integrals during the transition. They originates mainly from eddy currents. The shorter the flipping time, the larger the field integral during the transient. They are corrected by applying a vertical field integral proportional to the derivative of the main current with a 25 ms exponential delay. The results are illustrated on Figure 7 for the worst case corresponding to the highest current (250 A) and minimum gap (16 mm). The residual field integral excursions peaks around 0.5 Gm (0.2 Gm) for a 20 ms (200 ms) flipping time. The eddy current in the stainless steel vacuum chamber accounts for a 0.3 Gm for a 20 ms flipping time. These periodic change of field integrals will be seen by the users of the ESRF beamlines as a small growth of the horizontal emittance. Some limitations will be placed on the flipping time that will be determined following the first operation in the storage ring in July 98.

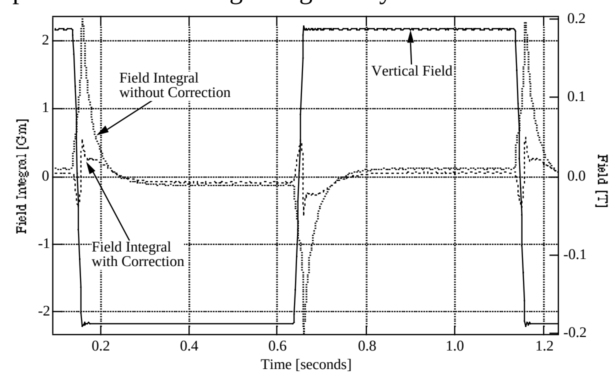

Figure 7 : Vertical field and field integrals as function of time for a 1 Hz repetition rate. The current is flipped between -250 A and 250 A within 20ms. The magnetic gap is 16 mm.

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[3] The Radia code is freely available for download from « http://www.esrf.fr/machine/support/ids/Public/welcome.html ». Details have been published in : P. Elleaume, O. Chubar, J. Chavanne, PAC97 Conference May 1997, Vancouver. see also O. Chubar, P. Elleaume, J. Chavanne, proceedings of the SRI97 Conference August 1997, Himeji, Japan.

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