CONSTRUCTION OF AN APPLE-II TYPE UNDULATOR AT DARESBURY LABORATORY FOR THE SRS

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Abstract

A new variable polarisation undulator of the APPLE-II type has been designed and constructed at Daresbury Laboratory. Testing of the 56mm period device has recently started in the new Magnet Test Facility at Daresbury Laboratory. This paper presents the magnetic and mechanical design of the undulator, and the first magnetic measurement results.

INTRODUCTION

There are currently 5 insertion devices in routine operation on the SRS, a 2GeV second-generation light source. The prime motivation for installing a new polarising undulator is to provide greater flux of circularly polarised photons in the soft x-ray region, an energy range of 265 to 900 eV. This will give 50 times the flux available from other SRS sources. Due to the large horizontal beam dimensions in the SRS an APPLE-II type undulator [1] was chosen as it could provide the necessary horizontal magnetic fields from magnet arrays above and below the vacuum vessel [2]. An inherent feature of helical undulators is that they only produce on-axis emission in the first harmonic. To cover the required energy range it will be necessary to use the 2nd and 3rd harmonics also. Fortunately this will be possible due to the large emittance in the SRS, with the trade off of slightly degraded degree of polarisation.

This device is currently assembled and undergoing magnetic measurements in the new Magnet Test Facility, and will be installed in straight 5 of the SRS in the 2004 autumn shutdown. Initially it will be commissioned to operate in the variable elliptical mode, but will subsequently also be commissioned and used in the variable linear mode of operation.

MAGNETIC DESIGN

The APPLE II type helical undulator is a pure permanent magnet structure, composed of four arrays (Figure 1). The arrangement of the blocks is such that there are four blocks per period. By moving two opposing magnet arrays with respect to the other two longitudinally (a phase shift) the strengths of the vertical and horizontal magnetic field components can be varied, and hence the polarisation of the radiation produced. It is foreseen that the undulator will have two modes of operation. First a variable elliptical mode where the two arrays are moved mutually together with respect to the static arrays and as the phase is shifted from zero to half a period the radiation produced goes from pure horizontal, through elliptical to pure vertical. The phase between the horizontal and vertical fields remains at $\pi/2$ so the ellipse remains upright. The second mode is the variable linear, where the two arrays are moved the same distance but in opposite directions to each other. In this situation the phase between the two magnetic fields is zero, and so the radiation is always linear, going from horizontal to vertical over half a period phase shift.

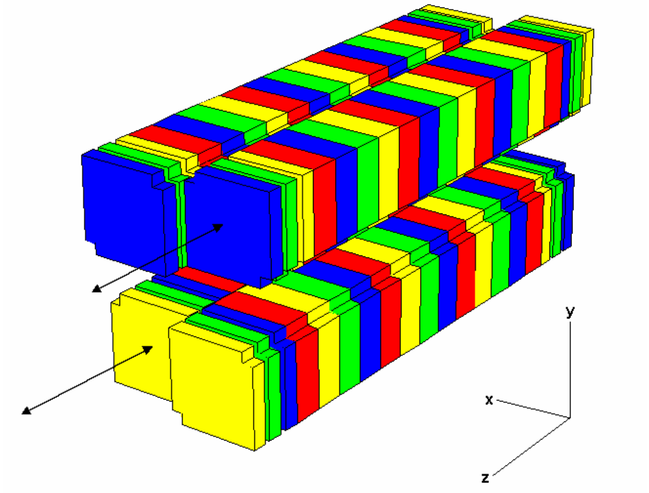

Figure 1: Schematic of an APPLE II Undulator.

The undulator design parameters are given in Table 1. The RADIA software [3] was used to calculate the magnetic fields and estimate the forces acting between the arrays.

Table 1: Undulator Parameter List.

Magnet Period (mm)	56
Number of Periods	17
Nominal Magnet Gap (mm)	21
Nominal Length (m)	1.09
Number of Blocks per Period	4
Max Gap between Adjacent Arrays (mm)	0.5
Magnet Remanent Field (min) (T)	1.25
Magnet Block Material	NdFeB
Magnet Block Height (mm)	40
Magnet Block Width (mm)	40
Longitudinal Movement (mm)	+/- 28

The mounting notches and end block configuration (Figure 2) were optimised to minimise the fringe fields and the horizontal and vertical first and second field integrals over the operating range of gaps and phase shifts. The results of the RADIA modelling are shown in Table 2. The maximum horizontal and vertical on-axis first (and second) field integrals calculated are 0.003 Tmm (50 Tmm^2) and 0.035 Tmm (0.42 Tmm^2) respectively.

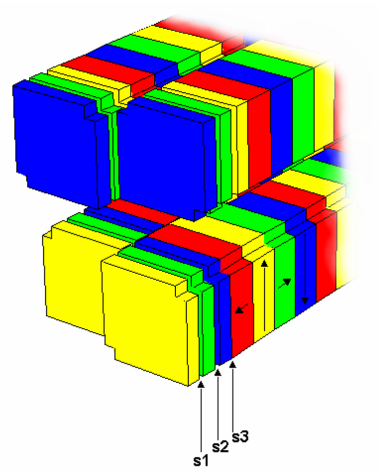

Figure 2: End Block Configuration and Mounting Notches.

Table 2: Results of Modelling.

Peak Vertical Field, B_y (T)	0.65
Peak Horizontal Field, B_x (T)	0.40
Max Circ Poln Field B_x=B_y (T)	0.33
End Block Dimensions (mm)	40 x 40 x 6.95
End Block Spacing S1, S2, S3 (mm)	2.4, 3.2, 0
Peak Horiz. Force on one array (kN)	10
Peak Vert. Force on one array (kN)	3
Peak Long. Force on one array (kN)	9
Notch dimensions (mm)	5 x 5

The effect of this undulator on the stored electron beam in the SRS has been calculated as a function of horizontal position, Figure 3. This effect is predicted to be small due to the fairly low magnetic fields, and can be corrected for using 8 trim coils and local quadrupoles in the undulator straight. The variation of tune with phase has also been calculated and found to be a small effect.

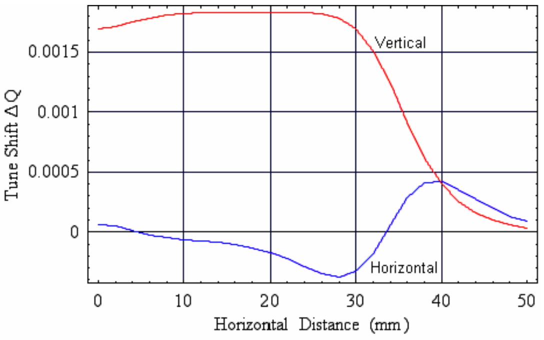

Figure 3: Horizontal and Vertical Tune Shift Calculated as a Function of Horizontal Position for Zero Phase Shift.

The magnetic modelling assumed that there would be no variation in field strength or magnetisation direction between blocks, which of course does not reflect reality. To improve the performance of the undulator in the SRS both a Monte-Carlo and a simulated annealing block-sorting algorithm were used with the real magnet block data to minimise transverse field integrals and optical rms phase error [4]. Once sorted the blocks were assembled into their holders and onto each array.

MECHANICAL DESIGN

The support structure for this undulator is a standard SRS design, which has been slightly modified to cope with the additional forces from this type of undulator, and includes a phase shift mechanism for the arrays, as shown in Figure 4.

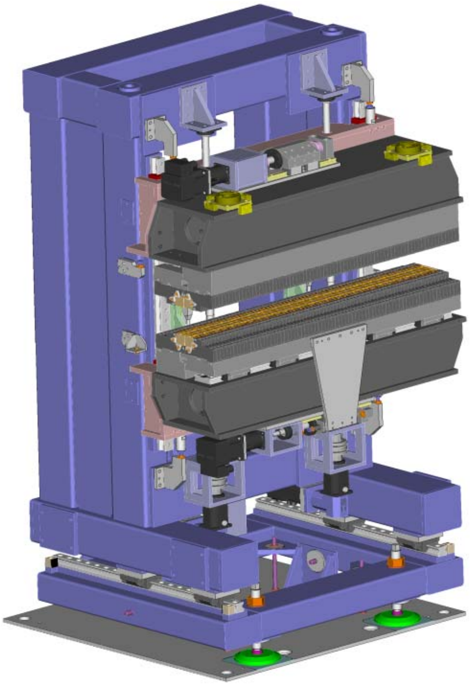

Figure 4: Mechanical Assembly.

Gap Drive System

The arrangement for the drive system consists of two precision leadscrews shafts, each with a right hand and left-hand thread. Two left-hand nuts are attached to the upper carriage and two right hand nuts are attached to the lower carriage. As the two leadscrews are rotated in synchronism the magnet gap is adjusted symmetrically about the electron beam axis. Each leadscrew is attached through a coupling with high torsional stiffness to a low backlash gearbox, which is driven by an electric AC motor.

The control system for adjusting the magnet gap is a closed loop servo control with two linear encoders attached directly between the upper and lower support beam carriages at a position close to each leadscrew.

To prevent any possible damage to the motors, magnet arrays or vacuum chamber, the following safety features have been included:

- Tilt sensors on each magnet array.

- Adjustable end of travel switches at maximum gap settings.
- Adjustable end-stop switches at minimum gap settings with 1μm repeatability.
- Adjustable mechanical fixed stops at the min. and max. gap settings.
- Limit switches between the mechanism and vacuum chamber to detect any errors in alignment between the chamber and the magnet arrays.

Phase Shift Drive System

The arrangement of the two phase shift drive systems consists of a precision ball screw shaft per moving array, the moving nut is attached to an aluminium block that is mounted onto a linear guide system. A plate provides a rigid link between the driven block and magnet array requiring the motion, which is mounted on a second linear guide. Each ball screw is again attached through a coupling to a gearbox and is driven by an AC brushless motor.

The control system for adjusting the phase change is a closed loop servo control with a linear encoder attached directly between the stationary beam and the moving array. Additional resolvers are also attached directly to the back of the motor. End of travel limit switches have been added to prevent possible damage to adjacent equipment in the storage ring

The gap and phase required by SRS users will be derived from look-up tables giving gap versus harmonic energy and associated phase for each polarisation. These tables will be produced through characterising the undulator by scanning the gap and phase whilst monitoring the output through the beamline.

MAGNETIC FIELD MEASUREMENT

The two top and bottom arrays have been mounted onto the undulator carriage and mechanical drive tests successfully completed. Magnet measurements have now started and Figure 5 shows the first measured data of the vertical field at the minimum gap, compared with the predicted field.

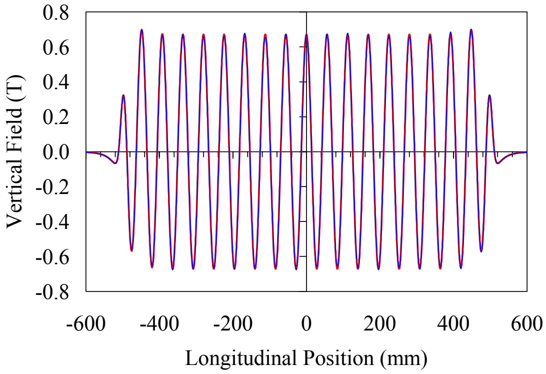

Figure 5: On Axis Vertical Magnetic Field at 21mm Gap at Zero Phase Shift. Red - Measured, Blue - Modelled.

The peak vertical field vs gap at zero phase has also been measured and this is shown in Figure 6. A detailed program of measurements will now commence in conjunction with the shimming process. The magnet block holders are designed to allow transverse position adjustment and it is hoped that this will be the primary method used to adjust the fields locally.

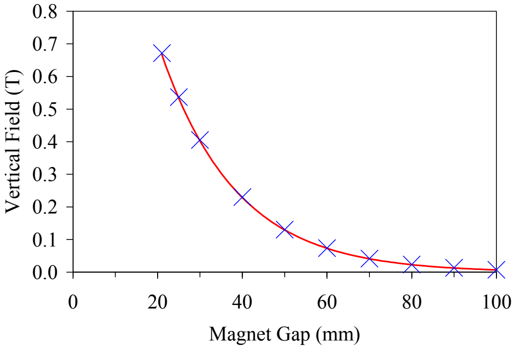

Figure 6: Peak Vertical Magnetic Field as a Function of Magnet Gap at Zero Phase Shift. Red - Measured, Blue - Modelled.

CONCLUSION AND OUTLOOK

A new variable polarisation undulator of the APPLE-II type has been designed and constructed at Daresbury Laboratory. The device is designed to operate in both the elliptical and arbitrary linear modes.

Following block sorting, based upon both Monte Carlo and simulated annealing algorithms, the arrays have been assembled and mounted onto the undulator carriage. To date the magnetic field measurements show good agreement with prediction. The mechanical acceptance tests have shown smooth and precise movement operation, and that the structure does not flex with the varying load from the magnets.

The undulator will be installed in the SRS during the autumn shutdown of 2004 and will be commissioned for first use soon after.

REFERENCES

[1] Sasaki, S., "Analyses for a Planar Variably-Polarizing Undulator", NIM A 347, 1994, p310.

[2] Clarke, J.A., "A Planar Helical Undulator for the SRS", EPAC, 1996.

[3] RADIA software homepage http://www.esrf.fr/machine/groups/insertion_devices/Codes/Radia/Radia.html.

[4] Scott, D.J., "Permanent Magnet Block Sorting for APPLE-II Type Variably Polarising Undulators", these proceedings.