A PLANAR HELICAL UNDULATOR FOR THE SRS

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Abstract

A proposal for a soft X-ray undulator source of variable polarisation has been generated for the SRS. The insertion device will be a pure permanent magnet planar helical undulator made up of four standard arrays. Control of the polarization state will be possible through a longitudinal translation of the arrays relative to each other. This paper details the design parameters of the undulator and the reasons for their choice.

1 INTRODUCTION

The SRS is a 2 GeV second generation light source facility. At present the majority of the beamlines are based upon dipole sources although there are 3 insertion devices in operation. A major upgrade is also planned that will provide two more insertion device beamlines [1]. A further proposal is now being assembled for a soft X-ray beamline with variable polarization control. This paper explains why a planar helical undulator would be an excellent choice for this beamline and gives the anticipated design details for such a device.

2 OUTPUT SPECIFICATION

The proposal is for a soft X-ray spectroscopy beamline that will utilise high degrees of linear polarization in both horizontal and vertical planes for the study of liquid surfaces and interfaces. Circularly polarised light will also be used to study magnetic and organic samples.

The photon energy range required must cover the Carbon, Nitrogen and Oxygen edges which specifies a range of 265 eV to 600 eV. Since the beamline will need to handle liquid samples it is essential for the polarization state to be variable between linear in the horizontal and vertical planes. The degree of polarization required is better than 95%, although some experiments may choose to sacrifice this high degree of polarization for increased flux. Very fast polarization switching is not necessary for the experiments planned.

3 MAGNET CHOICE

There are several possible insertion device sources of variable polarization that could meet some of the specifications given in Section 2. A detailed review of the possibilities is given in [2]. Since the SRS horizontal aperture is relatively large it is difficult to create a significant horizontal magnetic field with poles either side of the axis. It is more effective to create a horizontal field from above and below the aperture. The vertical field for the device must also be created from above and below the aperture but needs to be independently variable on-axis with respect to the horizontal one to be able to produce the desired polarization states. This leads to the so-called planar helical type of undulator, of which there are several variations [2]. The most appropriate planar helical design for the SRS is the APPLE-2 variation developed in Japan [3]. This generates horizontal and vertical magnetic fields on-axis that are always out of phase by $\pi/2$ regardless of the relative array positions. The advantage of this fixed phase difference is that the continuously variable polarization ellipse is always upright, thus ensuring that linear polarization can be generated both vertically and horizontally. Most other accepted designs produce linear polarization that is inclined to the axis.

A view of the proposed device is given in figure 1.

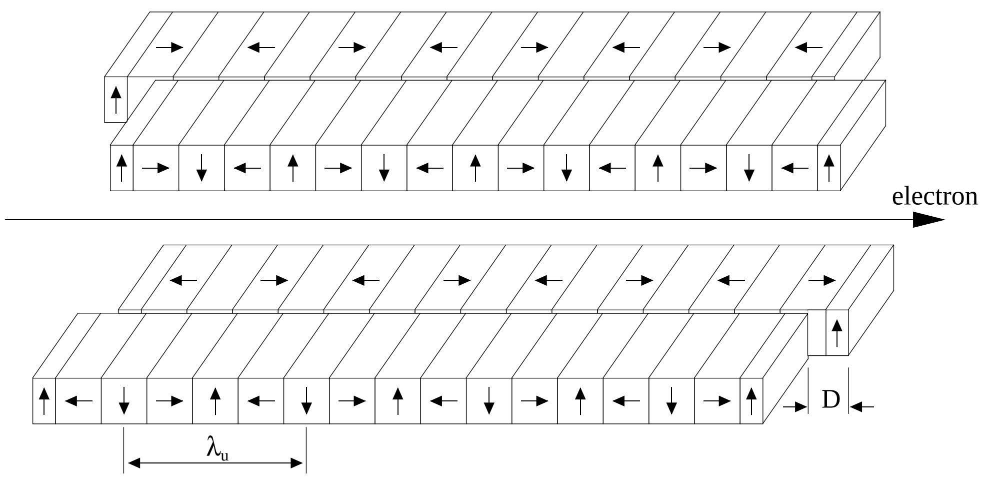

Figure 1. Sketch of the Planar Helical Undulator

The undulator consists of four conventional arrays of permanent magnet, two below the beam and two above. The relative strengths of the horizontal and vertical magnetic fields are varied by sliding the arrays with respect to each other. The upper front and lower back arrays move together with respect to the other two. The vertical magnetic gap is also varied as in a conventional undulator to tune the device to the required photon energy range.

4 DETAILED DESIGN

The choice of parameters for the undulator is determined by the assumptions made for the magnet gap and the remanent field of the permanent magnet material. Recent studies on the SRS [4] have shown that a vertical beam aperture of 15 mm is needed operationally so a magnet gap of 20 mm appears to be sensible. The latest generation of permanent magnet materials (NdFeB) have remanent fields in excess of 1.3 T. For this study a field of 1.27 T has been used.

The spectral property which defines the peak magnetic fields required is the condition of circular polarization at 265 eV. To find the optimum period for the SRS undulator it is useful to plot the peak magnetic field required that gives the first harmonic output at 265 eV. This can then be compared with the peak magnetic fields attainable with the chosen type of planar helical undulator. Several conditions have been applied to generate figure 2. The magnet gap has been fixed at 20 mm, the width of each array at 40 mm and the height of each block is one-quarter of the period (ie blocks of square cross-section). To make most efficient use of the space in the SRS straight section the smallest possible period has been chosen, in this case the period is 56 mm.

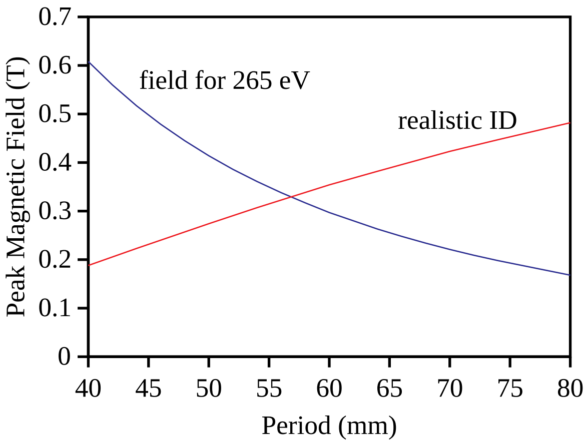

Figure 2. Plot showing the peak magnetic field required to reach 265 eV with the first harmonic and the realistic fields achievable from an APPLE type device.

A period of 56 mm gives a peak vertical field for generating horizontal polarization of 0.584 T which will give a first harmonic at 120 eV. The peak horizontal field is 0.386 T which gives a first harmonic at 223 eV. The relative position of the magnet arrays (D) required to set the circular polarization condition at minimum gap is 0.282 period. A summary of the undulator design parameters is given in Table 1.

The transverse field profiles in a planar helical undulator can vary quite substantially near the beam axis. The field profiles for the proposed SRS undulator are shown in figures 3 and 4, for the circular polarization case at minimum gap. Clearly precise steering of the electron beam in both planes will be important to provide optimum spectral output. The effect of these strongly varying magnetic fields on the non-linear dynamics of the electron beam have not yet been assessed. The calculations have assumed that the adjacent arrays are touching although the results are very similar with a transverse gap of 1 mm.

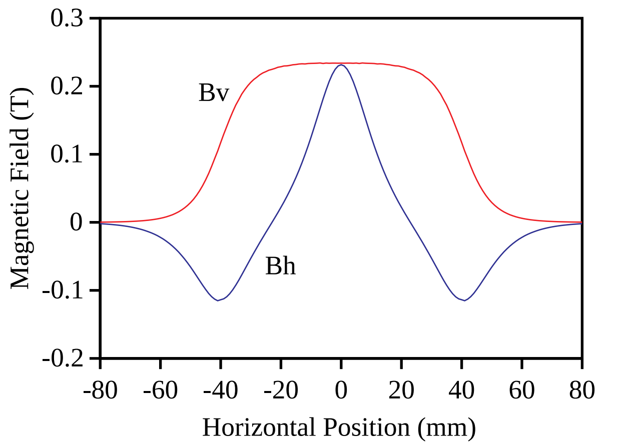

Figure 3. Horizontal and vertical magnetic fields along the x-axis assuming the arrays touch each other.

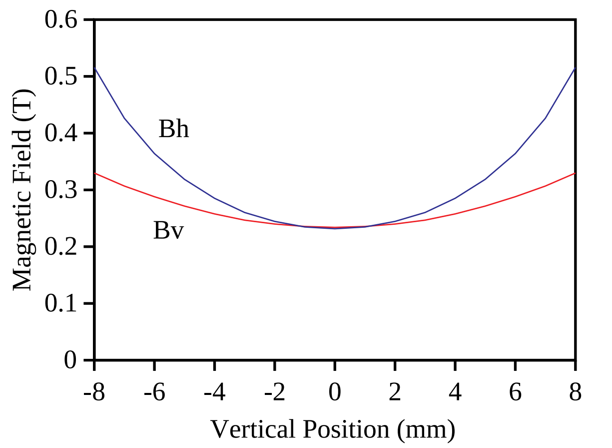

Figure 4. Horizontal and vertical magnetic fields along the y-axis assuming the arrays touch each other.

Table 1. Undulator parameters.

Period Length	56 mm
Number of Periods	17
Blocks per Period	4
Magnet Material	NdFeB
Remanent Field	1.27 T
Peak Vertical Magnetic Field	0.584 T
Peak Horizontal Magnetic Field	0.386 T
Peak Field for Circular Polarization	0.322 T
Magnet Block Dimensions	14 x 14 x 40 mm
Minimum Vertical Gap	20 mm
Longitudinal Movement	±30 mm

5 SPECTRAL OUTPUT

The spectral output from the undulator has been calculated using the code URGENT [5]. The flux in the first harmonic at K_v = 1.5 (310 eV, horizontal polarization) through a square aperture has been calculated as a function of the aperture width. The results are given in figure 5 together with the percentage of horizontal polarization.

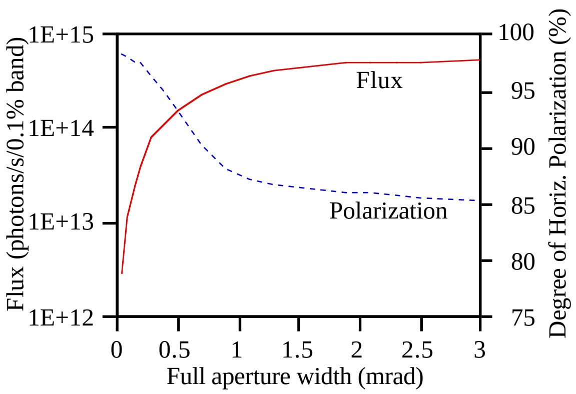

Figure 5. Flux and degree of horizontal polarization in the first harmonic through a square aperture at K_v = 1.5.

As expected the degree of polarization at small apertures is very high. The polarization level decreases as the aperture size increases but the flux also increases substantially. Even with a 3 mrad aperture the polarization is about 85 % which is much better than that achieved from a bending magnet beamline working about the horizontal plane (typically 60% for a 1 mrad aperture at the SRS).

The tuning range of the undulator is shown in figure 6 for the horizontal polarization case. The required photon range of 265 eV to 600 eV is covered by the first harmonic although there will be some advantage in using the third harmonic above about 500 eV.

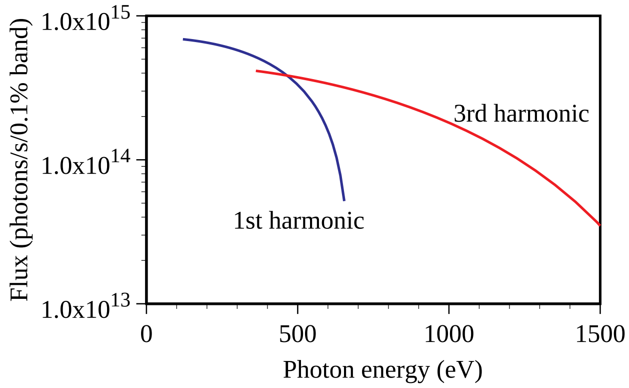

Figure 6. Undulator tuning curve.

Figure 7 shows the flux transmitted through a 0.2 mrad by 0.2 mrad square aperture when the undulator is set to produce circular polarization at minimum gap. The degree of circular polarization is also shown. The broadness of the harmonic peak is due to the relatively large emittance of the SRS.

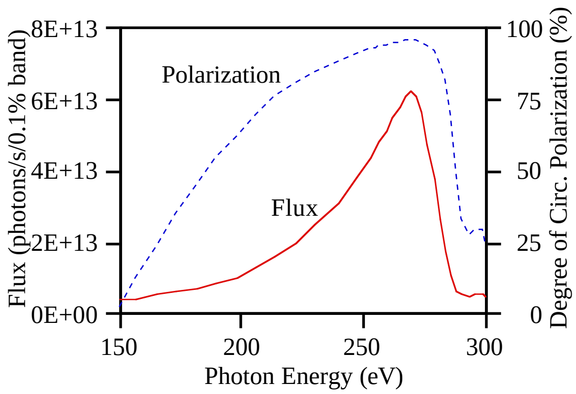

Figure 7. Integrated flux and degree of circular polarization for minimum gap condition. Beamline aperture is 0.2 mrad x 0.2 mrad square aperture.

REFERENCES

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