THE MAGNETIC DESIGN OF A HIGH FIELD PERMANENT MAGNET MULTIPOLE WIGGLER FOR THE SRS

J. A. Clarke, CLRC Daresbury Laboratory, Warrington, WA4 4AD, UK

Abstract

Two new insertion devices will be installed as part of the Daresbury SRS upgrade project. The devices are multipole wiggler magnets with a peak field of 2 T. This paper describes the complete magnetic design of these permanent magnet devices which has been carried out in both 2 and 3 dimensions. The design has been optimised to generate the highest fields with the shortest possible period to fully utilise the limited space available in the SRS.

1 INTRODUCTION

The SRS is a 2 GeV, 2nd generation synchrotron radiation source operating in the UK. It was designed to use the main dipole magnets as the primary source of radiation. Nevertheless during its life three insertion devices have been installed, two superconducting wavelength shifters [1,2] and one undulator [3]. An upgrade project has recently been funded that will add two more insertion devices to the lattice [4]. These two identical insertion devices will be hybrid multipole wigglers designed to provide high flux levels at about 10 keV. The free straight section available for the IDs is just over one metre so there is great pressure to reduce the period of the MPWs as much as possible to give the greatest flux output for the beamlines. With this in mind the vertical aperture has been assessed in detail with beam scrapers [5] and it has been concluded that the total internal beam stay clear region in the straight section could be reduced from the present 36 mm to 15 mm without reducing the beam lifetime by more than about 15%. The insertion device vacuum vessel has been designed so that the gap between the steel poles is minimised [6]. A prototype titanium vessel has been built and measured that will allow the magnet gap to reach 19.2 mm.

The peak magnetic field specified for the MPWs is 2.0 T since this provides a high critical energy of 5.3 keV and also provides enough angular spread in the electron beam to allow 2 stations to be built on each beamline. An initial assessment quickly concluded that an electromagnetic device was feasible but with a longer period than would be possible from a permanet magnet hybrid device. The specification for the MPWs is given in Table 1.

Table 1. Specification of the Multipole Wigglers

Peak Field on axis	2 T
Minimum Gap	19.2 mm
Period	200 mm
K value	37.4
Number of full strength poles	9
Maximum length available	1.1 m

2 MAGNET DESIGN

The magnet design has been carried out in both 2 and 3 dimensions to give as accurate a model as possible. The computing time is much shorter for 2D studies and so as much of the design as possible has been carried out in this regime and then final checks made with a full 3D simulation. Typical execution time for the complete 3D simulation is about 30 hours with 150,000 nodes on a Unix workstation. The 2D models have been generated with Opera-2D [7] and Pandira [8], the 3D models were created with Opera-3D running Tosca [7].

2.1 Longitudinal Design

Simple ¼ period models were initially investigated to check the feasibility of the specification. These concluded that the specification required would be challenging but possible if the highest grade materials were assumed. High saturation field strength vanadium permendur steel has been chosen for the pole pieces, in common with other projects requiring very high field strengths. A high remanent field permanent magnet material has also been assumed (NdFeB with Br=1.35 T, Hc = 1020 kA/m). An optimum geometry for the steel and permanent magnet material has been found by manual iteration. The main permanent magnet block extends beyond the steel pole piece by 34 mm to increase the on-axis field. The vertical gap between the pole pieces is 19.2 mm but the gap between the permanent magnet blocks must be larger than this to provide room for strengthening ribs on the vacuum vessel (see figure 1). The permanent magnet blocks are separated by a vertical gap of 27.2 mm. An additional permanent magnet piece was initially placed on top of the steel but it was concluded that this only had a small effect on the peak field. The corner of the steel pole is chamfered at 45 degrees to reduce steel saturation in this area. More

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complicated steel profiles have not been found to be necessary.

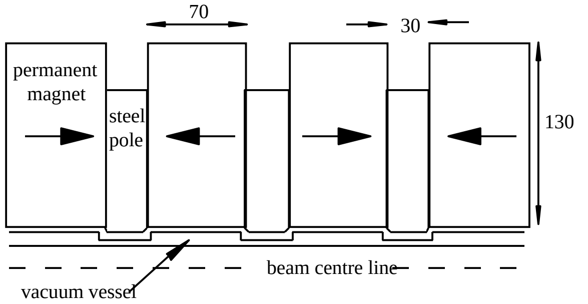

Figure 1. Longitudinal cross-section though a part of the top array. The arrows indicate the direction of magnetisation. Dimensions are in mm.

2.2 Transverse Design

Although the extra permanent magnet material above the steel was found to be inefficient, additional permanent magnet material side pieces do provide a significant contribution to the field on axis. These extra side pieces are found to reduce the flux leakage in the transverse plane. This is seen in figure 2 where the effect of leaving out the side pieces is illustrated. The width of the main permanent magnet blocks is extended well beyond that of the steel in common with most hybrid designs. As with the longitudinal profile, the steel corner is removed in the transverse plane with a 45 degree chamfer to reduce steel saturation problems.

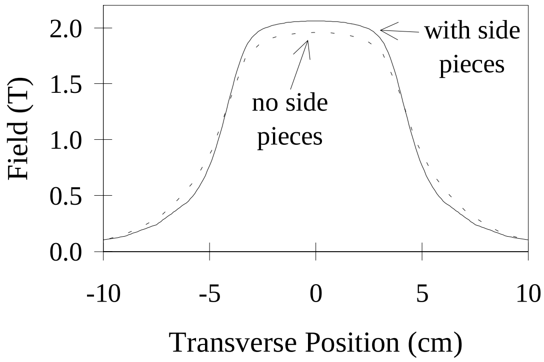

Figure 2. The on-axis vertical magnetic field as a function of transverse position underneath the pole. The dotted line shows the effect of not using permanent magnet side pieces.

2.3 End Design

Since the number of main poles is only 9, the 2 end poles can make a significant contribution to the photon output. For this reason the field in the end poles has been forced to be as high as possible whilst still terminating the magnet correctly with zero angle and displacement of the electron beam. A slim steel end pole and half main permanent magnet block are found to give a peak field of about 1.8 T. No side permanent magnet pieces were included as they were unnecessary. The vertical magnetic field along the electron beam axis is given in figure 3. An air-cooled trim coil will be wound around each array to provide fine tuning of the electron beam steering through the MPW.

A view of one complete array of the MPW assembled onto a backing beam is given in figure 4. A summary of the design parameters for the MPW is given in Table 2.

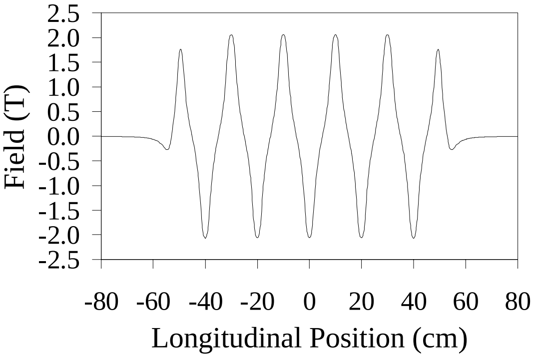

Figure 3. The on-axis vertical magnetic field through the MPW.

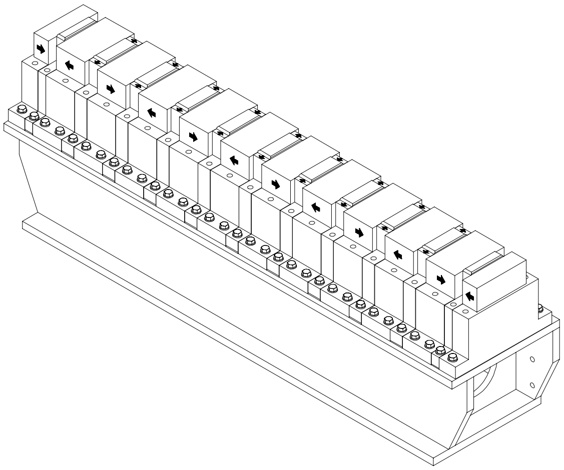

Figure 4. A complete magnet array of the MPW. The arrows indicate the direction of magnetisation.

Table 2. Design parameters for the MPW.

Pole Material	Vanadium Permendur
Permanent Magnet Material	NdFeB
Remanent Field	1.35 T
Pole Dimensions	100 x 80 x 30 mm
Main PM Block Dimensions	130 x 120 x 70 mm
Side PM Block Dimensions	96 x 10 x 30 mm
Total Length of Magnet	1.078 m
Gap Setting Accuracy	< 10 μm
Gap Resolution	< 5 μm
Parallelism of Two Arrays	< ±40 μm
Force at Minimum Gap	50 kN
Trim Coil Ampere Turns	450 At

3. PHOTON OUTPUT

The magnetic field model has been used to calculate the synchrotron radiation output from the multipole wigglers. The most interesting feature is the influence of the non-sinusoidal longitudinal field shape. This has the effect of decreasing the angular spread of the radiation in the horizontal plane from what would be expected of a pure sinusoidal field. The photon flux at 10 keV has been calculated as a function of horizontal angle from the beam centre line. This is compared with an ideal sinusoidal device in figure 5. The power levels from the devices are also significantly affected by the non-sinusoidal field shape, these are summarised in Table 3.

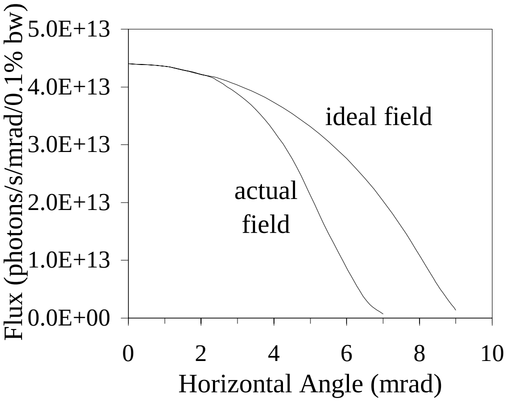

Figure 5. Photon output as a function of horizontal angle. A beam current of 300 mA has been assumed.

Table 3. Predicted power levels form the multipole wiggler assuming a beam current of 300 mA.

Total Power	2.4 kW
Vertically Integrated Power	220 W/mrad
Peak Power Density	1130 W/mrad^2

4. FUTURE WORK

A new magnet measurement facility is now being assembled to make detailed measurements of the two devices. Two measurement benches will be available in an air-conditioned environment. The first will provide point by point field measurements using a Hall plate and the second will provide integrated field measurements with either a rotating coil or a scanning wire.

The design of the multipole wigglers is now complete and it is intended that manufacturing should start in the Summer of 1997 with the two devices available for magnet testing in the Summer of 1998. It is intended to install the two devices at the start of 1999 and to have operational beamlines later that year.

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