FRONT ENDS AT DIAMOND

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Abstract

Diamond is a 3GeV, 3rd Generation Synchrotron Light Source currently under construction on the Harwell Science and Innovation Campus, Chilton, Oxfordshire. This paper describes the three different types of Front end that have been designed to transmit the intense synchrotron radiation generated by the Undulator, Multi-Pole Wiggler and Bending Magnet sources in the Diamond storage ring to the experiments. The functions of the main components and their location in the layout are described. The Finite Element Analysis (FEA) that has been carried out to verify the performance under the high heat loads generated by Diamond is also described along with the limits on temperature and stress that have been employed in the design.

INTRODUCTION

The Diamond storage ring has a six-fold symmetry made up of 24 cells. Each cell consists of a straight section followed by an arc section containing two bending magnets. 18 of the 24 straight sections are 5 m long, and 6 are 8 m long. Four of the 8 m straight sections are available for insertion devices, as 2 are required for the injection and RF straights. There is therefore a capacity for 22 Insertion Device Front ends and 23 Bending Magnet Front Ends to be installed. Only the bending magnet immediately after the injection straight cannot be used.

Seven beamlines are being built as part of Phase I of the Diamond project while the first beamline of Phase II is also being built at the same time. All of these 8 beamlines use Insertion Devices (ID) as sources. Three of the beamlines are for Macromolecular Crystallography (I02, I03, and I04), the others are for Nanoscience (I06), Extreme Conditions (I15), Magnetism and Materials (I16), Microfocus Spectroscopy (I18), and Non-Crystalline Diffraction (I22). Table 1 summarises the source parameters.

Table 1: Source parameters at 3.0 GeV and 500mA

Beamline	Period mm	Period No.	Field T	Power kW	Density $kW/mrad^2$
I02 04	23	85	1.01	5.83	41.5
I03	21	95	1.06	6.4	39.8
I06	64	66	0.94	12.5	28.5
I15	60	24	3.5	52.5	36.9
I16 18	27	73	1.14	7.3	36.5
I22	25	80	1.10	6.9	38.2

FRONT END LAYOUT

Front ends at Diamond are divided into three types: Undulator, Multi-pole Wiggler, and Bending Magnet. The Undulator type front ends are further subdivided into Single Undulator and Canted Undulator types. This is because beamlines I02, I03 and I04 are designed to have two undulators in their straights producing two ID beams which are separated by 1 mRad.

Undulator Front ends

The Undulator Front ends are 10.4 m long, and run from a pneumatic isolation valve on the crotch leg of the storage ring through to a pneumatic isolation valve just inside the optics hutch. The crotch leg of the storage ring is designed to allow a maximum 7mRad horizontal by 1mRad vertical fan of ID radiation to enter the Front end from the centre of a 5 m straight, although in this case only 2 mRad is required. Figure 1 shows the layout of the Canted Undulator Front end.

The main components of the Canted Undulator Front end are: (1) 1st Aperture, (2) 1st X-ray Beam Position Monitor (XBPM), (3) 1st Absorber, (4) All-metal isolation valve, (5) All metal fast shutter, (6) Access pipe, (7) 2nd XBPM, (8) Beam splitter, (9) 1st customised aperture, (10) 2nd customised aperture, (11) 2nd Absorber, (12) Twin Port Shutter, (13) Ratchet shield wall and (14) All-metal isolation valve.

The Single Undulator Front end shares many of its components with the Canted Undulator Front end. The main components are: (1) 1st Aperture, (2) 1st X-ray Beam Position Monitor (XBPM), (3) 1st Absorber, (4) All-metal isolation valve, (5) All-metal fast shutter, (6) Access pipe, (7) 2nd XBPM, (9) 1st customised aperture, (11) 2nd Absorber, (12) Twin Port Shutter, (13) Ratchet shield wall and (14) All-metal isolation valve.

Multi-pole Wiggler Front end

The Multi-pole Wiggler Front end is 10.7 m long, and runs from a pneumatic isolation valve on the crotch leg of the storage ring through to a pneumatic isolation valve just inside the optics hutch. The component arrangement of the Multi-pole Wiggler Front end is: (1) 1st aperture, (2) Pinhole array (provision), (3) 1st Absorber, (4) All-metal isolation valve, (5) All-metal fast shutter, (6) Access pipe, (7) CCD camera arrangement (provision), (8) 1st customised aperture, (9) 2nd Absorber (provision), (10) Twin Port Shutter, (13) Ratchet shield wall, (14) Collimator and (15) All-metal isolation valve. The main differences between the component arrangement of the Multi-pole Wiggler Front end and the Undulator Front ends are the XBPM arrangement, 2nd absorber, and collimator. There are no XBPMs in the Multi-pole

Wiggler Front end, instead there is provision to retrofit a pinhole camera array and CCD screen to view the source [1]. The Multi-pole Wiggler Front end has space for a 2nd Absorber although none is currently fitted as this space may be required for photon filters and a tungsten alloy collimator has been fitted just inside the Optics hutch to reduce the radiation levels propagating through the beamline.

Bending Magnet Front Ends

The Bending Magnet Front end is 14.4 m long, and runs from a pneumatic isolation valve on the crotch leg of the storage ring through to a pneumatic isolation valve just inside the optics hutch. The component arrangement of the Bending Magnet Front end is: (1) 1st aperture, (2) 1st Absorber, (3) 1st XBPM (4) All metal isolation valve, (5) All-metal fast shutter, (6) 2nd XBPM, (7) combined 1st customised aperture and collimator, (8) Access pipe, (9) 2nd Absorber, (10) Twin Port Shutter, (13) Ratchet shield wall and (14) All-metal isolation valve. The main differences between the component arrangement of the Bending Magnet Front end and the Undulator Front ends are that the order of the 1st XBPM and 1st absorber have been reversed, and the access pipe is in a different location due to space constraints.

FEA criterion

All components of the Front end subjected to a heat load were designed using Finite Element Analysis (FEA) criteria. In the case of the Canted Undulator Front end this comprises of: (1) 1st aperture, (2) 1st Absorber, (8) Beam splitter (9) 1st customised aperture and (10) 2nd customised aperture.

These components were designed with 4mm and 6mm bore diameter cooling channels and pressure drop calculations were undertaken to ensure that a flow rate of 4.5 – 5 m/sec through the cooling channels was obtained giving an optimum heat transfer co-efficient of 20 $mW/mm^2/°C$ [2].

Thermal FEA was performed utilising ANSYS 10 and adopting strain based criteria. For Oxygen Free High Conductivity Copper (OFHC) strains of 0.1% in the main body with peak strains of up to 0.5% in a localised area are considered acceptable. Because OFHC has such a low yield stress (<50 MPa) a strain based criteria was adopted. For Glidcop® strains of 0.1% (125 MPa) in the main body with peak strains of up to 0.35% (400 MPa) in a localised area are considered acceptable.

COMPONENT DESCRIPTION

1st Aperture (1)

The function of the 1st aperture is to remove any dipole radiation that is not in the ID fan, and to protect downstream components in the case of beam mis-steer. It reduces the beam aperture to 2 mRad horizontal, but does not affect the vertical aperture which is reduced to 1 mRad vertical by the radiation slot in the dipole magnet vacuum vessel within the storage ring.

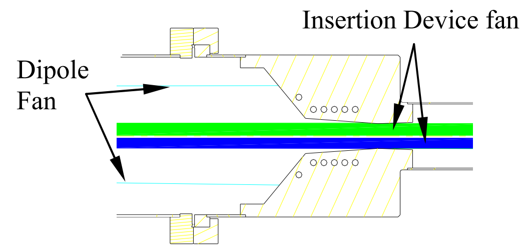

Figure 2: Section through 1st Aperture.

The first aperture is angled at 3° in close proximity to the Undulator beams due to the intensity of any mis-steered beam, and at 45° where only dipole radiation will impinge. Two PT100 temperature transducers have been installed to monitor the components temperature.

XBPMs (2) and (7)

The XBPMs are used to monitor the position and stability of the photon beam. They do this by monitoring the current drawn through tungsten vanes that project into the photon beam. In the case of the Canted Front end each XBPM has 8 vanes and uses 4 to monitor each ID beam, hence these can monitor the position of both Canted Insertion devices simultaneously. The beam is measured in two positions to determine position and angle. A large distance between the XBPMs allows the the angle of the photon beam to be accurately measured thus the XBPMs are separated by a minimum of 4m on the Undulator Front ends. The XBPMs were procured from FMB [3]. In normal operation no components come into contact with the beam between the 1st and 2nd XBPMs.

1st Absorber (3)

This pneumatically operated absorber is used to protect the all-metal isolation valve in the event of a vacuum failure downstream. It is made of OFHC, and is based on the European Synchrotron Radiation Facility (ESRF) high powered absorber design [2].

Fast shutter (5)

This is a series 77 all-metal fast shutter supplied by VAT [4], and designed to shut in less than 10 milliseconds. Two pairs of pressure sensors are used to trigger the device. When the shutter is triggered, the electron beam in the storage ring is interrupted to avoid damage to the fast shutter as the absorber cannot close quickly enough to protect it.

Access pipe (6)

Access is required for installation, maintenance and operation of the Personnel Safety System (PSS) search buttons. The main access route to the far side of the Front end is under this length of vacuum pipe.

Beamsplitter (8)

The Beamsplitter in the Canted Undulator Front end prepares the beam before the Customised Apertures by reducing the incoming fan to well defined 7mm diameter cylinders, that can then be further reduced.

Customised Apertures (9) (10)

The Customised Apertures are used to define the beam to each beamline. They are on an X-Z stage which allows them to be co-aligned to the SR beam. The Customised Aperture on the Canted Undulator Front ends have a range of +/-2.5 mm, and on the Single Undulator Front ends they have a range of +/-5 mm. The resolution of the X-Z stage is 5 µm and repeatability better than 10 µm. Table 2 summarises the aperture parameters for each beamline.

Table 2: Beam sizes defined by Customised Aperture Horizontal by Vertical

Beamline	Beam 1 size (µrad)	Beam 2 size (µrad)	Beam 3 size (µrad)	Aperture Shape
I02 03 04	130x80	130x80	-	Rectangular
I06	300x250	-	-	Rectangular
I15	50x40	50x40	50x40	Rectangular
I16	150x75	-	-	Rectangular
I18	150x75	-	-	Rectangular
I22	150x75	-	-	Rectangular

2nd Absorber (11)

The 2nd Absorber is used to protect the Twin Port Shutter. In combination with the twin port shutter it allows access to the Optics hutch whilst keeping both the XBPMs, and the Customised Apertures illuminated.

This allows the position of the beam to be continuously monitored and the apertures to maintain a constant temperature for positional stability whilst the optics hutch is accessed.

Twin Port Shutter (12)

The Twin Port Shutter is used for radiation safety purposes. Protection is provided by 315 mm long tungsten alloy blocks. The upstream shutter is called the Port Shutter and is under control of the machine, the downstream shutter is called the Optics Shutter and is under beamline control.

CURRENT STATUS

ACCEL[5] were awarded the contract to carry out the detailed design and construction of the Front ends from the DLS reference design. All 7 Undulator Front ends have been tested, delivered, and installed. The Multi-pole Wiggler Front end is due to be delivered in July.

All Front ends are to be fully commissioned, ready for 3GeV, 300mA storage ring operation in September and the transmission of synchrotron radiation to the beamlines.

REFERENCES

[1] K. Holldack, J. Feikes and W.B. Peatman, “Review of Emittance and Stability Monitoring using Synchrotron Radiation Monitors”, BESSY Berlin Germany.

[2] Jean Claude Biasci, Bernard Plan and Lin Zhang “Design and performance of ESRF high-powered undulator front-end components” J. Synchrotron Rad. (2002). 9, 44-46.

[3] FMB Feinwerk- und Meßtechnik GmbH, Friedrich-Wöhler-Strasse, Berlin, Germany, http://www.berlin-fmb.de/

[4] VAT Vakuumventile AG, Seelistrasse, Haag, Switzerland, http://www.vatvalves.com/

[5] ACCEL Instrument GmbH, Friedrich-Ebert-straße, Bergisch, Gladbach, Germany, http://www.accel.de/

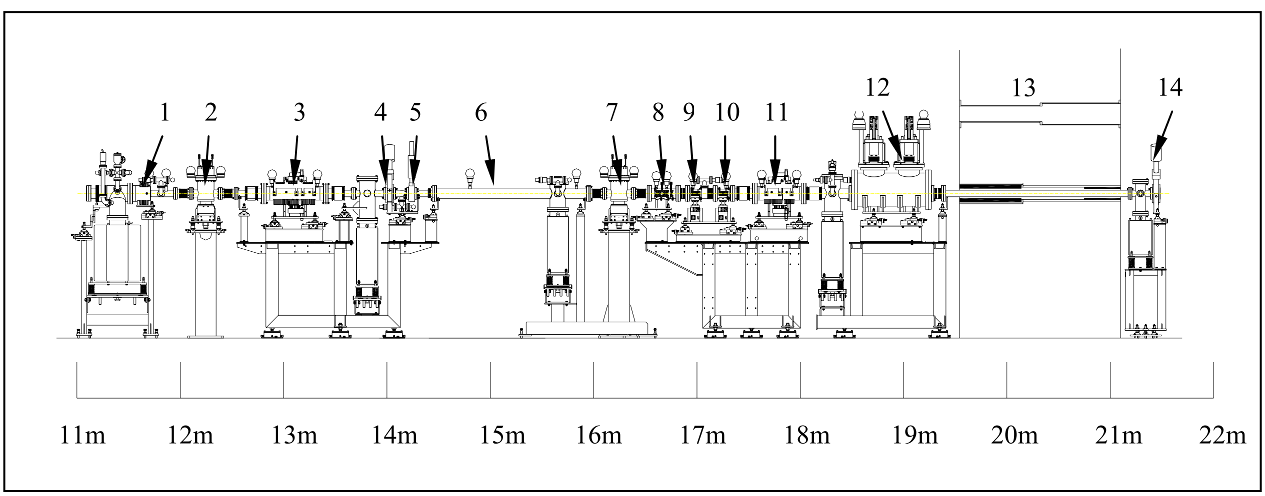

Figure 1: Layout of Canted Undulator Front end.