RADIATION SHIELDING DESIGN FOR DREAM-LINE BEAMLINE AT SSRF

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Abstract

Dream-line beamline at Shanghai Synchrotron Radiation Facility, SSRF, is an under construction soft X-ray beam line with wide energy range and super high energy resolution. It is required to allow online operation beside optical components in experiment hutch at this beamline when synchrotron light is running. This requires more careful radiation shielding design for the beamline. The radiation shielding design for the beamline are considered to shield gas bremsstrahlung and synchrotron. Ray trace was carried out according to the beamline structure and optical components layout. The residual gas bremsstrahlung with optical components and the induced dose rate distribution were simulated with Fluka code. The synchrotron radiation scattering at optical components was calculated with STAC08 code. With the simulated results, the specifications of shielding collimators, safety shutters and hutch wall are given for the beamline. The normalized dose rate results by gas bremsstrahlung are consisted with the measurements or calculations results in other facilities in the world very well.

INTRODUCTION

The shanghai synchrotron radiation facility (SSRF) is a 3.5GeV, 300mA third-generation light source. The storage ring is 432m in circumference and can provide more than 60 beam-ports to give access to insertion devices (ID) or bending beamlines. Seven user beamlines in Phase I are currently in operation, and other beamlines are being developed. Dream-Line is an under construction soft X-ray ID beamline with wide energy range and super high energy resolution.

The shielding design criteria of Dream-line beamline is set to 1.2μSv/h in the experimental hall. Gas bremsstrahlung (GB) and synchrotron radiation (SR) are mainly considered in the shielding design. Gas bremsstrahlung is generated due to electron beam scattering from the residual gas molecules in vacuum chamber. In the straight section, it adds up to produce a narrow peak forward beam, which is called primary GB, can come through the ID beamline along with synchrotron radiation [1, 3]. Electromagnetic cascade and photon-neutrons are generated by interactions of GB with optical components. Primary GB and scattered GB are all very important issues of radiation shielding and safety of ID beamlines. The primary GB must be shielded by a heavy metal shutter in the front end and also by main stoppers or collimators on the beamline. The scattered GB should be taken into consideration in the beamline hutch or local shielding. The intensity of synchrotron radiation ID beamline is closely related to the parameters of inserted device and accelerator. Synchrotron radiation are scattered mainly on three targets: slits, reflecting mirror and monochromator.

LAYOUT OF DREAM-LINE BEAMLINE

Dream-line beamline has double APPLE Ⅱ type EPU to satisfy its design goals: energy range from 20~2000eV, and ultra-high resolution 10000 at 1000eV. A Schematic layout of main optic components should be concerned in radiation design is shown on Fig.1.

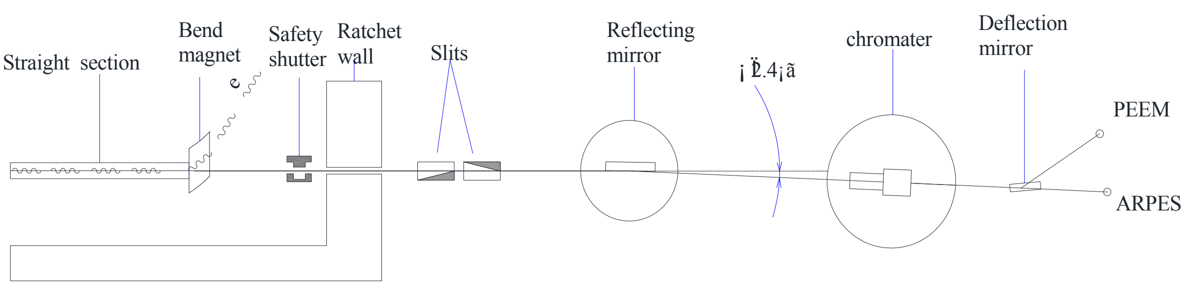

Figure 1: Schematic layout of main optical components concerned in radiation shielding design.

As shown in Fig.1, from left to right, in the ratchet wall, there are 12.5m long ID straight section, 1.27T bend magnet and safety shutter etc. Out of the ratchet wall, there are slits, 1.2 degree grazing anger reflecting mirror, plane-grating monochromator, deflecting mirrorand after that are two branch beamlines: photoemission electron microscope (PEEM) and Angle resolved photoemission spectrum (APPES). Differing from general ID beamlines, Dream-Line needs on-line commissioning for monochromator. The leakage from the upstream by scattered GB must be concerned for the shielding design of the beamline.

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SHIELDING FOR PRIMARY GAS BREMSSTRAHLUNG

The Monte Carlo simulation code FLUKA (version 2.11) is used for the primary gas bremsstrahlung study because it known as a fully integrated particle physics Monte Carlo simulation package, which includes whole hadronic and electromagnetic interactions, charged particle tracking, low-energy neutron transport and full tracing of secondaries[4,5]. In the present study, primary gas bremsstrahlung was studied with the 3.5GeV electrons travel in a 12.5m long chamber of the normal straight section at SSRF. The residual gas filled in the chamber is given in table 1. Out of the straight section chamber the electron is deflected to vain region by a 1.27T bend magnet. Primary GB then strike on different targets.

Table 1: Residual Gas in the Typical ID Straight Sections at SSRF

Atomic Number (Z)	Residual Gas Composition	Mole Fraction (%)	Weight Percent (%)
2	H_2	70	15
10	H_2O	13	26
14	CO	13	40
22	CO_2	4	19

For comparing the GB source with other facilities, a 30cm×30cm×30cm tissue phantom target is selected which is 10m distance to the end of straight section. Bremsstrahlung spectrum incident on target are statistic and integrate to get the normalized bremsstrahlung power 166.7±2.2nW/nT/mA. At a 100mm^2 cross-section 150mm depth position of the phantom, normalized absorbed dose rate results are 0.56mSv/h/nT/mA. The comparisons of dose rate normalized to the corresponding gas bremsstrahlung power were given in table 2 for the ID beamlines at several synchrotron radiation facilities. The results of ESRF and APS were measured using lead-glass electromagnetic calorimeter [1, 3], and results of Spring-8 was measured by using scintillator PWO (PbWO4)[2]. The dose rate normalized to the corresponding bremsstrahlung power for the ID beamline at SSRF is consistent with the other facilities'.

Based on the source of the gas bremsstrahlung simulated, a 20cm×20cm×30cm lead target with density of 11.35g/cm3 and a 20cm×20cm×25cm tungsten alloy (heavymet) target with density of 18.5g/cm3 were designed for shielding. The equivalent dose rate was calculated as a function of target thickness, as shown in Fig.2. According to the results, collimator was designed to be 30cm thickness of lead and the shutter to be 20cm thickness of tungsten alloy for the Dream-line beanline.

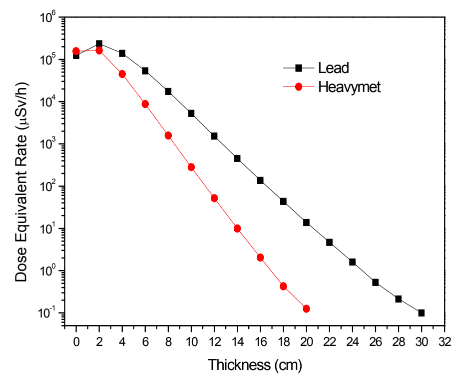

Figure 2: The dose rate simulated as a function of target thickness.

Table 2: Comparisons of Dose Rate Normalized to the Corresponding Gas Bremsstrahlung Power for ID Beamlines

Facility	Straight Section Length (m)	StoredBeam Energy (GeV)	Gas Atomic Number (Z)	Bremsstrahlung Power (nW/nT/mA)	Absorbed Dose Rate (kGy/h/nT/mA)	Normalized Dose Rate (kGy/h/W)
ESRF	15	6	3.2	68.9～1000	2.13～35.9×10^{-7}	3.1～3.6
APS	15.38	7	-	3.4×10^{-6}	1.1×10^{-5}	3.3
Spring-8	16.54	8	8.1	343.1±1.1	1.24×10^{-6}	3.6
SSRF	12.5	3.5	5.4	166.7±2.2	5.6×10^{-7}	3.4

SHIELDING FOR SCATTERED GAS BREMSSTRAHLUNG

The gas bremsstrahlung ray trace for the Dream-line beamline is given in Fig.3. Collimator 1 with aperture 20mm×20mm behind slits and collimator 2 with aperture 20mm×20mm behind the reflecting mirror are optimized on their position and configuration, aimed to enclosure the primary gas bremsstrahlung, and to shield about 10 degree opening angle on scattered GB generated at slits and mirror to let more zone out of hutch end wall in the shadow of collimator shielding. By setting primary GB strike on a 2cm radius and 20cm long copper cylinder as a target, the thickness of FOE hutch wall was determined according to the dose resulted from the target calculated by the FLUKA code.

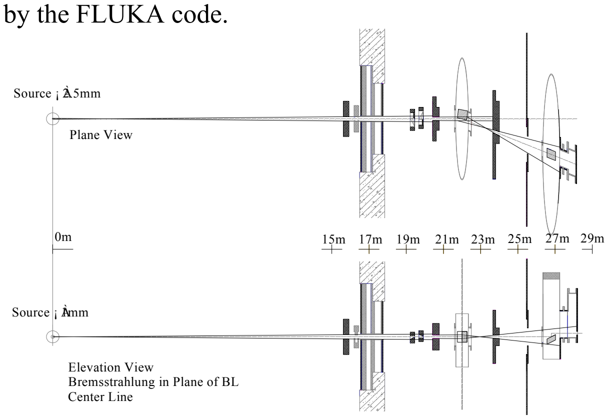

Figure 3: The gas bremsstrahlung ray trace for the Dream-line beamline.

For satisfying the design goal of dose limits, 18mm thickness of lead is designed for the hutch wall, and 50mm thickness of lead in the end wall of the hutch. The end wall locates at 3.5 m far from the reflecting mirror and 2.0m from the collimator 2. For estimating the leakage radiation arrived at the monochromator, each component in the ray trace was considered in the simulation with Fluka code. The average dose rate calculated from scatted GB through the collimator 2 and the end wall exceeded 10μSv/h. It means that the photons in the leakage radiation still have enough energy to strike on silicon crystal in the monochromator to generate next scattering cascade. Consequently, 50mm thickness of lead local was designed to be a local shielding around the monochromator cylinder chamber. With the local shielding, the dose rate both from gamma and neutron induced by GB is illustrated in Figure 4 as a plane view. As seen from the figure 4, the dose rate out of beamline FOE is less than 1.0μSv/h.

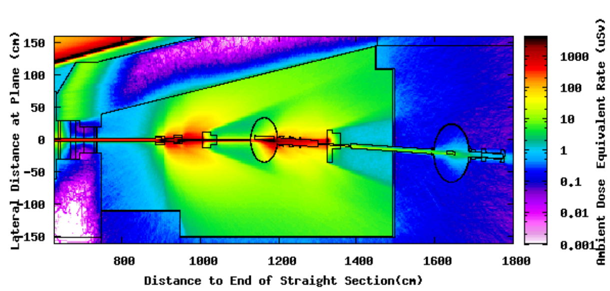

Figure 4: The dose rate both from gamma and neutron induced by GB after the setting local shielding on monochromator chamber(plane view).

SHIELDING FOR SYNCHROTRON RADIATION

With parameters of two ID of Dream-line shown in Table 3, calculation for shielding synchrotron radiation were carried out by using STACK08 code [6].

Table 3: Synchrotron Radiation Beam Parameters for SSRF Dream-Line Beamline.

Magnetic Field (T)	Effective Number of Poles	Critical Energy Ec (keV)	SR Power (W/mradH)	Fan Width (mrad H×V)
0.79	168	6.4	7204	0.6×0.6
0.63	64	5.13	2189	0.6×0.6

The calculation results showed that 8mm thickness of lead for FOE lateral wall and end wall are enough to achieve the dose rate limits design required. As described above, 18mm thickness of lead in lateral wall and 50mm thickness of lead in the end wall were designed for shielding the scatted GB. It is thick enough to shield the synchrotron radiation. It's the same for the dose rate introduced by SR out of monochromator chamber. The synchrotron radiation after the reflecting mirror is only several keV in energy whereas the monochromator chamber is made of 5mm thickness stainless steel.

SUMMARY

Careful shielding design for the Dream-line beamline at SSRF was carried by using Monte Carlo simulation method, performed by using the Fluka code combined with complex ray trace for the GB, and the stack08 code for the synchrotron radiation. The Shielding calculations for the primary gas bremsstrahlung, the scatted gas bremsstrahlung and the synchrotron radiation were performed. The ray trace of the Dream-line beame was also presented. Based on the calculation, bulk shielding design for the hutch, the local shielding for the end wall of the hutch and the monochromator was obtained. With the shielding design, the dose rate can be less than the shielding criteria level 1.2μSv/h for the Dream-line beambine at SSRF. Experimental measurement of the dose rate is considered to confirm the shielding design during the beamline commissioning in the future.

REFERENCES

[1] M. Pisharody, P. K. Job, Nucl. Instr. And Meth. A 401 (1997) 442-462..
[2] Y. Asano, T. Matsumura, Nucl. Instr. and Meth. A 451 (2000) 685-696.
[3] M. Pisharody, P. K. Job, Radiat. Phys. and Chem. 59(2000) 459-466.
[4] A.Ferrari, P. R. Sala, G. Guaraldi, F. Padoani, Nucl. Instr. And Meth. B 71 (1992)412.
[5] A. Fasso, A, Ferrari, P. R. Sala, in: Proc. 8th Int. Conf. Radiation Shielding, Arlington, Texas, 24-28 April 1994, Vol.2, p.643.
[6] Y. Asano, JAERI-Research-2001-006, March 2001.

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