National Synchrotron Light Source

Building 743, National Synchrotron Light Source
Brookhaven National Laboratory
Upton, NY 11973-5000
Phone 631 344-2117
Fax 631 344-3238
zhong@bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

Date: March 8, 2018
To: Milinda Abeykoon, Edwin Haas, Eric Dooryhee and Julian Adams, and Paul Zschack
From: Zhong Zhong (chair), Photon Science Radiation Safety Committee
Subject: Review of the radiation safety design of the PDF beamline

Dear Milinda, Ed, Eric, Julian, and Paul,

The Photon Science Radiation Safety Committee (RSC) conducted review of the design of the PDF beamline, at 28-ID, on February 13, 2018 with a follow-up review by the RSC ray-tracing subcommittee occurring on February 28, 2018 . Subjects reviewed include synchrotron max-fan and Bremsstrahlung drawings, Secondary Bremsstrahlung and synchrotron radiation shielding analysis, top-off safety analysis, and aspects of thermal management that relate to radiation safety.

Written documents

The following documents and drawings were reviewed:

1. XPD and PDF assembly drawing, PD-XPD-RAYT-0001 rev. A, by A. Desantis, sheet1, "28-ID, XPD/PDF Beamlines Raytrace Layout" showing plan and elevation views of both the existing XPD beamline and the new PDF beamline.
2. XPD/PDF Bremsstrahlung ray-tracing drawings, PD-XPD-RAYT-0001 rev. A, sheets 5 and 6 for horizontal and vertical projections, respectively. Details for Bremsstrahlung collimator and stop are included on sheet 7.
3. XPD/PDF max. synchrotron ray-tracing drawings, PD-XPD-RAYT-0001 rev. A, sheet 2 for horizontal projection, sheet 3 for vertical projection Additional details for the chamber and beam-pipe cross sections are shown on sheet 4.
4. PDF max. synchrotron ray-tracing drawings, PD-XPD-RAYT-0001 rev. A, sheet 8 for horizontal projection, sheet 9 for vertical projection Additional details for mis-steering of the monochromatic beam by the one-bounce Silicon monochromator are shown on sheets 10 and 11, respectively, for the horizontal and vertical projections. These drawings are specific to PDF beamline.
5. Ray-tracing assuming that FMK2 fails, sheet 12. This is used as input to the FEA simulation demonstrating radiation safety in the case of FMK2 failure.
6. Powerpoint presentation "PDF Radiation Safety Review" presented by Milinda Abeykoon, February 2018.
7. Report "XPD FMK2 failure consequences", Rev.0, by PDF beamline working group including M. Abeykoon, E. Dooryhee, E. Haas, S. O'Hara, and C. Stelmach.
8. Report "Finite Element Analyses of the XPD BRC2 Collimator", by S. O'Hara.

9. NSLS-II technical note number 278 by M. Benmerrouche entitled "28ID1-PDF Beamline Radiation Shielding Analysis". The tech. note presents analysis results of Gas Bremsstrahlung (GB) as well as Synchrotron Radiation (SR) at 500 mA.

Oral Presentation

Attendance for final RSC review: Andrew Ackerman, Milinda Abeykoon, Andi Barbour, Mo Benmerrouche, Eric Dooryhee, Sunil Chitra, Ray Fliller, Ed Haas, Steven Hulbert, Cherno Jaye, Robert Lee, Wah-Keat Lee, Steve O'Hara, Boris Podobedov, Chuck Schaefer, Chris Stelmach, Lutz Wiegart, Emil Zitvogel, and Zhong Zhong

Attendance for follow-up meeting: Andrew Ackerman, Milinda Abeykoon, Eric Dooryhee, Ed Haas, Steven Hulbert, Wah-Keat Lee, Steve O'Hara, Chuck Schaefer, Chris Stelmach, and Zhong Zhong

Milinda Abeykoon gave the presentation entitled "PDF Radiation Safety Review". Following the guideline from the memo by Paul Zschack to the RSC on May 29, 2014, the following were discussed:

1. PDF, located at 28-ID, is a high-energy x-ray diffraction beamline using the damping wiggler as x-ray source. PDF beamline shares the same FOE as the XPD beamline that has been in operation since late 2014. It was noted that the PDF uses a portion of the white-beam that passes through the bent-Laue first crystal of the XPD monochromator.
2. The beamline optics consists of a bent-Laue Silicon crystal one-bounce (horizontal) monochromator and a vertical-focusing mirror, all located in the FOE. A shielded beam pipe transports the monochromatic beam to the experimental enclosure, hutch B, on the experimental floor. The bent-Laue monochromator allows selection of 111, 022, 311 and 511 reflections by changing the crystal. At fixed two-theta, the output energy range is 39 to 117 keV depending on the reflection chosen. The white-beam stop is located outside of the monochromator in a separate vacuum chamber.
3. The preliminary PDF ray-tracing drawings were reviewed by the ray-tracing sub-committee a few times before, with the most recent review in August last year. The comments/recommendations from that review are attached for completeness.
4. As with the XPD beamline, the white beam for the PDF beamline is controlled by the front-end shutter. The monochromatic beam for PDF is controlled by standard NSLS-II photon shutter located at the downstream end of the FOE.
5. Shielding for the primary Bremsstrahlung x-rays is designed using ray-tracing method. A collimator (Tungsten BRC2 at 33.37 m) and beam-stop (Lead BRS at 36.66 m) combination, with a vertically offset double-Laue monochromator in between, stops the primary Bremsstrahlung in the FOE. The Lead Bremsstrahlung beam-stop, at 36.66 m, intercepts all possible primary Bremsstrahlung radiation. It was noted that the current Bremsstrahlung shielding is the same as the XPD Bremsstrahlung shielding which was reviewed by the RSC in 2014.
6. Shielding and control of secondary Bremsstrahlung radiation is designed by ray-tracing from possible secondary scattering sources in FOE, and verified by FLUKA analysis performed by Chitra and Benmerrouche. The chamber wall of the PDF one-bounce monochromator provides additional shielding to reduce the simulated dose rate to below 0.05 mrem/hr at the downstream wall of the FOE.
7. The XPD transport pipe between the FOE and the downstream wall of the B-hutch is shielded with 7 mm thick lead (the PDF transport pipe between the FOE and B-hutch

has 13 mm thickness lead shielding). The PDF monochromatic beam, when mis-steered by the one-bounce monochromator, could strike the shielded monochromatic beam transport pipe. Analysis by Benmerrouche (item 8) shows that this condition is safe.

8. Thermal protection of the beamline shielding components is designed using ray-tracing method. The design is supported by synchrotron ray-tracing drawings assuming maximum possible synchrotron fan and mirror alignment errors. FEA analysis for white-beam mask FMK and stop (STW) were presented to show that they are adequately designed to handle the power load. The simulation does not take credit for the Diamond windows (both being 1 mm thick).
9. The PPS logic diagram for the PDF beamline was reviewed separately by the RSC PPS subcommittee.
10. The PDF front-end is the same as that of XPD, and was previously reviewed by the RSC ray-tracing subcommittee.
11. Configuration control of the radiation safety component was discussed.
12. Milinda and Ed Haas described actions performed by the team to address our recommendations. It was noted that cooling water for the Diamond windows are not interlocked by Personnel Protection System (PPS). The issue of taking credit for the diamond windows was discussed. FEA results assuming no diamond windows reveal that the stress at the fixed mask 2 (FMK2) is too high. The purpose of fixed mask 2 is to protect the Tungsten Bremsstrahlung collimator (BRC2) behind it. The team was advised to perform further FEA for BRC2 assuming presence of neither the diamond windows nor the fixed mask2,
13. The PDF team performed new ray-tracing (sheet 12 of item 5 above) assuming failure of fixed mask2 to determine the worst-case heat load on BRC2. New FEA was performed the result of which was summarized in two reports (items 7 and 8 above). The reports were reviewed on February 28 at the follow-up meeting. The new FEA proves the survivability of the BRC2 in the event of failure of both diamond windows and the fixed mask 2.

Peet's coffee was dutifully served by you-know-who for both meetings – what is new?

Recommendations

As a result of the RSC final review and the follow up meeting, we determined that our prior recommendations are adequately addressed. The RSC has no recommendations for further action.

Conclusions

1. Based on our assessment of the ray-tracing drawings and radiation simulation results, the RSC finds that the PDF beamline shielding design meets the NSLS-II shielding policy. Subject to experimental verification by radiation survey, we believe the installed shielding will provide adequate personnel protection for normal operation and against failures of synchrotron orbit.
2. Based on our review of the max. synchrotron ray-tracing drawings and the FEA results, the RSC believes that the PDF masks, mirror, white- and pink- beam-stops are adequately designed to protect against thermal failure of shielding components.

Comments from preliminary review of ray-tracing in August 2017

Date: September 12, 2017
To: Milinda Abeykoon, Edwin Haas, Eric Dooryhee and Julian Adams
From: Zhong Zhong (chair), Photon Science Radiation Safety Committee
Subject: Recent preliminary review of the ray-tracing design of the PDF beamline

Dear Milinda, Ed, Eric and Julian,

The Photon Science Radiation Safety Committee (RSC)'s ray-tracing subcommittee concluded preliminary review of ray-tracing of the PDF beamline. Subjects reviewed include the synchrotron max-fan and Bremsstrahlung drawings and aspects of thermal management that relate to radiation safety.

We met with the PDF team on August 1 to review the preliminary PDF ray-tracing. We spent about 2 hours discussing issues related to XPD/PDF ray-tracing not being in compliance with the latest ray-tracing guidelines.

The following were discussed:

1. XPD and PDF layout drawings.
2. XPD (commissioned in late 2014 and is currently operational) and the new PDF beamline share the same front-end. Both beamlines actually share the same white-beam, with PDF re-using the white-beam that has passed through the XPD bent-Laue monochromator. Thus it makes sense for the new PDF beamline ray-tracing drawing to also include that of XPD components.
3. In the FOE, the following issues were identified:
    a. Fixed mask and lead Bremsstrahlung collimator 1 (FMK &BRC1): the collimator tube-to-photon beam clearance, 0.945 mm inboard & outboard, is less than suggested 1.00 mm.
    b. Fixed mask 2 and Tungsten Bremsstrahlung collimator (FMK2 & BRC2): the edge of mask aperture to photon beam clearance, 0.60 mm inboard and 0.66 mm outboard is less than the recommended 2.00 mm clearance; the collimator tube-to-photon beam clearance, 0.52 mm top and 0.54 mm bottom, is less than the suggested 0.75 mm clearance.
    c. Synchrotron white beam stop (WBS): edge of WBS to white beam distance is 2.1 mm top/1.88 mm bottom, less than the 3.0 mm suggested. Also the white beam to the chamber housing the WBS is 0.77 mm on the inboard side, less than the recommended 1 mm.
    d. The PDF monochromatic beam under mis-steering, less than 0.2 W in power, could strike the vacuum chamber in the FOE.
    e. The monochromatic beam of the XPD beamline, under mis-steering, could strike the shielded beam transport pipe in hutch B.
    f. The PDF mirror-mis-steered monochromatic beam could strike the FOE downstream wall.

The above issues (a-f) were discussed in detail. As a result of our review of the drawings and the discussion, we recommend the following:

a. Fixed mask and lead Bremsstrahlung collimator 1 (FMK &BRC1): Since the 0.945 mm clearance is very close to the recommended 1.0 mm, and the distance between the collimator tube and fixed mask is very small, less than 1 m, we recommend granting exception.
b. Fixed mask 2 and Tungsten Bremsstrahlung collimator (FMK2 & BRC2): The recommended edge of mask aperture to photon beam clearance should be 2 mm. Please supply FEA results demonstrating survivability of the mask in worst-case scenario. Due to the small distance between the fixed mask and Bremsstrahlung collimator 2, and the higher accuracy with which the Tungsten collimator can be surveyed compared to lead components, we recommend granting exception to the collimator-tube to photon-beam clearance.
c. Synchrotron white beam stop (WBS): the WBS was recently surveyed in 2016 and the survey results were presented to the management. Due to the small difference between the actual clearances (2.10 mm top and 1.88 mm bottom) and the recommended clearance of 3 mm, and the proximity of the WBS and Bremsstrahlung shield, we concur with the management decision to grant exception. The consequence of the beam striking the WBS chamber was discussed. We believe it is not a PPS issue since the chamber is in the FOE. Thus we recommend exception for the 0.77 mm clearance for inboard chamber wall.
d. Due to the negligible power of the monochromatic beam, this is not a thermal issue. Since the beam-pipe is in the FOE, this scenario does not pose a radiation issue. Thus we believe it is safe for the PDF monochromatic beam to strike the vacuum chamber and photon shutter in the FOE.
e. The shielded beam pipe should provide adequate shielding for monochromatic beam. Nevertheless, please provide radiation simulation. This could be calculation of the transmission of the highest possible energy beam through the shielding, or Mo's simulation results.
f. We believe that the monochromatic beam under mis-steering striking the 50 mm thick downstream wall of the FOE does not pose a safety risk.

Radiation Safety Committee

Name	*Expertise*	*Directorate*
Andrew Ackerman	Deputy ESH Manager	PS
Andi Barbour	Beam Line Physicist	PS
Mohamed Benmerrouche	Nuclear and Radiation Physics	PS
Scott Buda	Personnel Protective Systems	PS
Ray Fliller	Accelerator Physicist	PS
Wah-Keat Lee	Beam Line Physicist	PS
Boris Podobedov	Accelerator Physics	PS
Chuck Schaefer	Accelerator SME	ESH
Lutz Wiegart	Beam Line Physicist	PS
Zhong Zhong	Beam Line Physicist	PS
Emil Zitvogel	Accelerator Operations	PS
Ashley Shoemaker-Skokov	Administrative Support	PS

Ray-tracing sub-committee

Andrew Ackerman	Deputy ESH Manager	PS
Steven Hulbert	Beamline Scientist	PS
Wah-Keat Lee	Beam Line Physicist	PS
Chuck Schaefer	Accelerator SME	ESH
Christopher Stelmach	Designer	PS
Lutz Wiegart	Beam Line Physicist	PS
Zhong Zhong	Beam Line Physicist	PS

PPS sub-committee

Mohamed Benmerrouche	Nuclear and Radiation Physics	PS
Scott Buda	Personnel Protective Systems	PS
Robert Lee	ESH manager	PS
Zhong Zhong	Beam Line Physicist	PS

RSC checklist sub-committee

Andi Barbour	Beam Line Physicist	PS
Mohamed Benmerrouche	Nuclear and Radiation Physics	PS
Ray Fliller	Accelerator Physicist	PS