REPORT:

XPD FMK2 FAILURE CONSEQUENCES

Revision 0

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PDF beamline working group, including;

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Introduction:
This preliminary report considers the consequences of failure for XPD Fixed Mask 2 (FMK2; reference Design Review, June 09, 2014 [1]) located inside enclosure 28-ID-A at Z = 33.11 m from the damping wiggler source point, just downstream of the XPD Double Laue Monochromator (DLM). It is a follow-up to the Radiation Safety review that took place on 2/13/2018 and is a response to Andrew Ackerman's email dated 2/14/2018. Two action items were requested:

1. Re-do the ray traces without taking credit for Fixed Mask 2 to determine if beam can propagate past the Tungsten collimator and illuminate something downstream.
2. Complete Finite Element Analysis (FEA) for Bremsstrahlung collimator 2 (BRC2) to assure the tungsten AND the mechanical attachment for that collimator can handle the XPD beam heat load without the diamond windows and fixed mask 2.

This document addresses both of these actions. The results herein were presented to the Radiation Safety Committee on 2/28/2018.

Status:
1. The XPD Ray Trace drawing (PD-XPD-RAYT-0001) was updated to show rays not trimmed by FMK2. As of 28 February 2018, this drawing is in review.
2. XPD Bremsstrahlung collimator 2 (BRC2) was analyzed using the as-built configuration supplied by FMB/Oxford for the XPD beamline assuming Fixed Mask 2 (FMK2) is not trimming the XPD Maximum Synchrotron Fan. The preliminary findings are provided herein. A more complete FEA report is being filed by Steve O'Hara in Vault (reference PD-XPD-BL-FMB_AZM0008-FMB_AZM0008_Rev3-CALC-AZM0008).

Findings:
1. The XPD/PDF Ray Trace drawing now includes a view showing the path of the Maximum Synchrotron Horizontal fan without mask FMK2. Mask FMK2 only trims the XPD white beam horizontally; it does not trim the Vertical Maximum Synchrotron fan. Under these conditions, most of the additional beam hits the BRC2 large tungsten block. A small amount of beam proceeds to the white beam stop, some of which hits the white beam stop vacuum vessel. Figures 2, 3, and 6 show the projections and effects of the Max Synchrotron Fan on BRC2 and on the white beam stop vacuum vessel.
2. Analyses were performed to consider the effects of the added heat load. The following assumptions are made:

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[1] Supporting documentation for 'Design Review for CSX and XPD PPS Masks', Monday, June 09, 2014 is posted at https://ps.bnl.gov/phot/BeamlineSupportDocs/Forms/AllItems.aspx?RootFolder=%2Fphot%2FBeamlineSupportDocs%2FXPD%2FXPD%20PPS%20Mask. FMK2 was hydrostatically pressure tested to 150 PSI, but not helium vacuum checked.

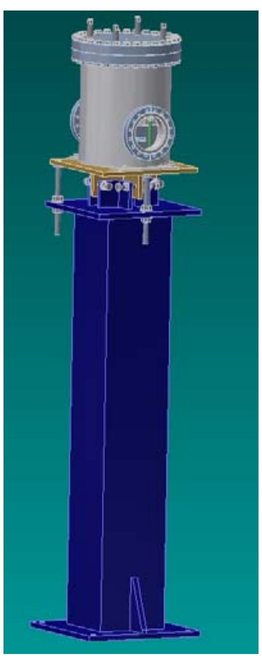
- Synchrotron beam is fully mis-steered horizontally within the PPS max fan envelope to the worst-case location
- both of the diamond windows located upstream of the FMK2 are fully destroyed (without tripping vacuum or thermal sensors)
- the five SiC window (total thickness = 7.4mm) are fully destroyed (also without tripping vacuum or thermal sensors)
  <u>Note</u>: these actuated filters are forced into the beam path by the PLC software, based on the value of the ring current.
- the first DLM crystal is destroyed (also without tripping vacuum or thermal sensors).
- XPD white beam is not trimmed by FMK2 (i.e. FMK2 is damaged, also without tripping any vacuum sensors).

The occurrence of these five failures allows 1.6 kW of white beam to impact the large tungsten Bremsstrahlung Collimator 2 (BRC2) block which is located just downstream of the DLM (Fig. 2). Also, a small amount of this additional white beam proceeds downstream to the white beam stop (STW) and its' vacuum vessel. Assuming beam impact continues long enough to reach steady state conditions, the preliminary analyses show:

- the large tungsten collimator block reaches a maximum temperature of ~1750°C and the tungsten plate reaches a maximum temperature of ~707°C (melting point: ~3400°C) (Fig. 3). Material certification was provided by FMB-O and is included herein (Fig. 7). The BRC2 tungsten materials meet the 18 g/cc density requirement and LT-C-XFD-SPC-XPD-BLC-001 specifications (i.e. no porosity or high vapor pressure elements).
- the 304/316 stainless steel support plate (AAC0170) reaches a maximum temperature of 747°C (melting point: ~1400°C) (Fig. 4)
- the 6082-T6 aluminum block (ACC0078) directly above the large tungsten block (which does not support the large tungsten collimator block) experiences melting
- the 5083/6082 aluminum upper plate (AAC0170) that holds the tungsten plate in place reaches a maximum temperature of ~600°C and experiences partial melting (melting point: 570/555°C respectively)
- one of the four stainless steel rods supporting the large tungsten collimator block is significantly damaged (not shown; structural analyses *conservatively* consider three threaded support rods whereas thermal analyses use four rods for maximum heat transfer). The case where beam hits both the tungsten block and a stainless steel rod was not analyzed due to the poor thermal conductivity (163-173 W/m-K for tungsten versus 12-45 W/m-K for stainless steel) and smaller cross-sectional area for the support rods. The most conservative cases only were considered. Once the conduction paths are not providing full heat transfer, the temperature in the support plates is expected to drop, thus enough structure should be retained to hold the upper tungsten plate.

– The lower BRC2 tungsten collimator block continues to be supported if either one of the two stainless steel support rods is fully destroyed.
– Minimal movement (~0.02 mm) of the large BRC2 tungsten block occurs if either one of the two upstream stainless steel supports rods is completely destroyed.
– the outer surface of the BRC2 vacuum vessel heats up to 381°C at a location that is largely inaccessible. (Fig. 5)
– The small amount of white beam passing BRC2 and not impacting the white beam stop conservatively raises the white beam stop (STW) upstream vacuum vessel flange temperature locally to 929°C. (Fig. 6)

Conclusion:
A final and more detailed FEA report is being issued, however based on the above results, we believe it is safe to operate the XPD and PDF beamlines using the present FMK2 to trim the Maximum Synchrotron fan at 500 milliamps ring current. Although the analyses show the aluminum plates above the BRC2 large tungsten collimator experience melting, the large collimator block would continue to be supported and therefore remain functional. In the accidental scenario presented in this document, all beam-power-mitigating components are assumed to fail without tripping any vacuum or thermal sensors; therefore the first crystal of the DLM would also be destroyed. Hence there can be no XPD monochromatic beam passing 50 mm above the XPD white beam through the tungsten plate opening just above the large tungsten block.



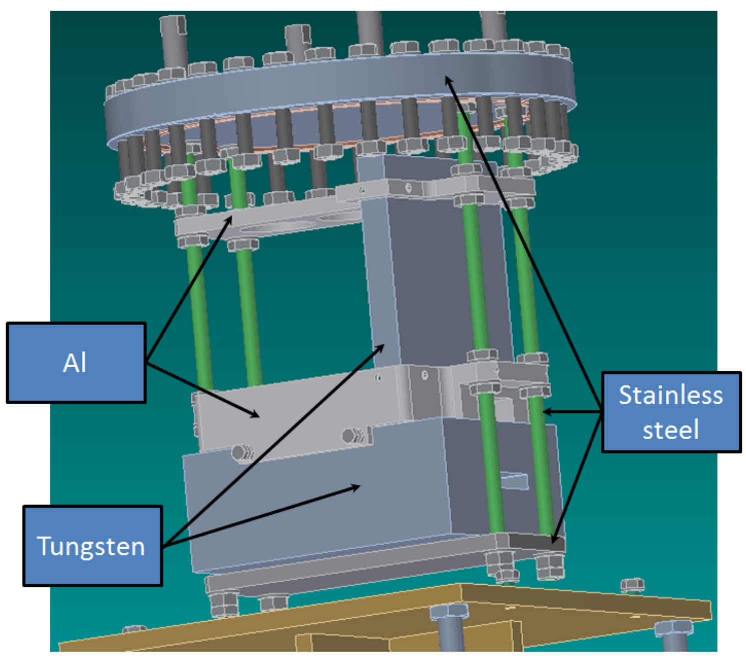


Figure 1: BRC2 (a) external view with support stand and (b) showing internal components

Finite Element Analysis Results

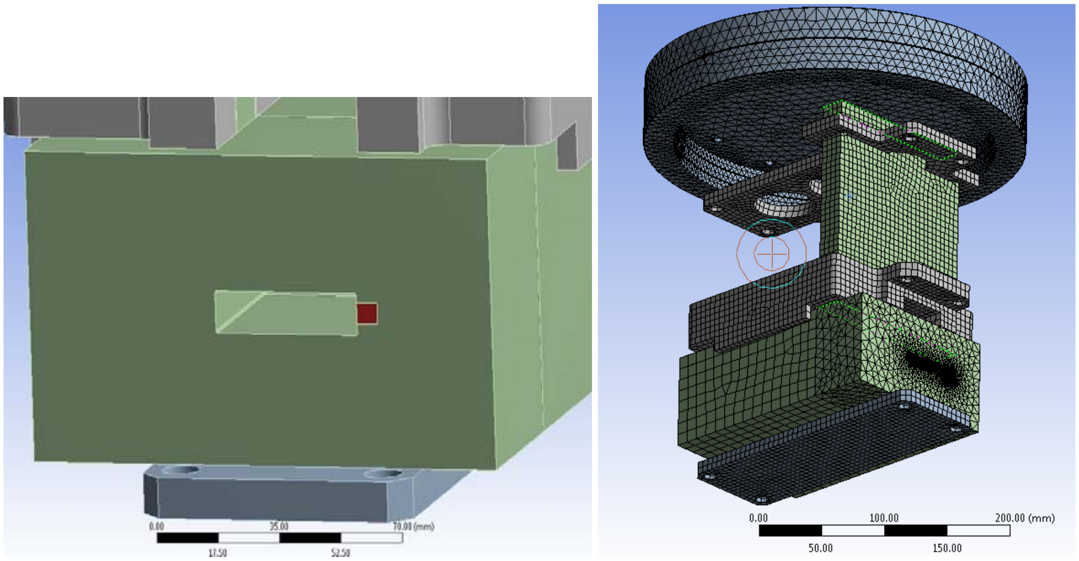


Figure 2: Views (a) looking downstream at XPD BRC2 (AZM0008 Rev3) showing white beam impact without FMK2, and (b) meshed elements (both views have the BRC2 vacuum vessel removed)

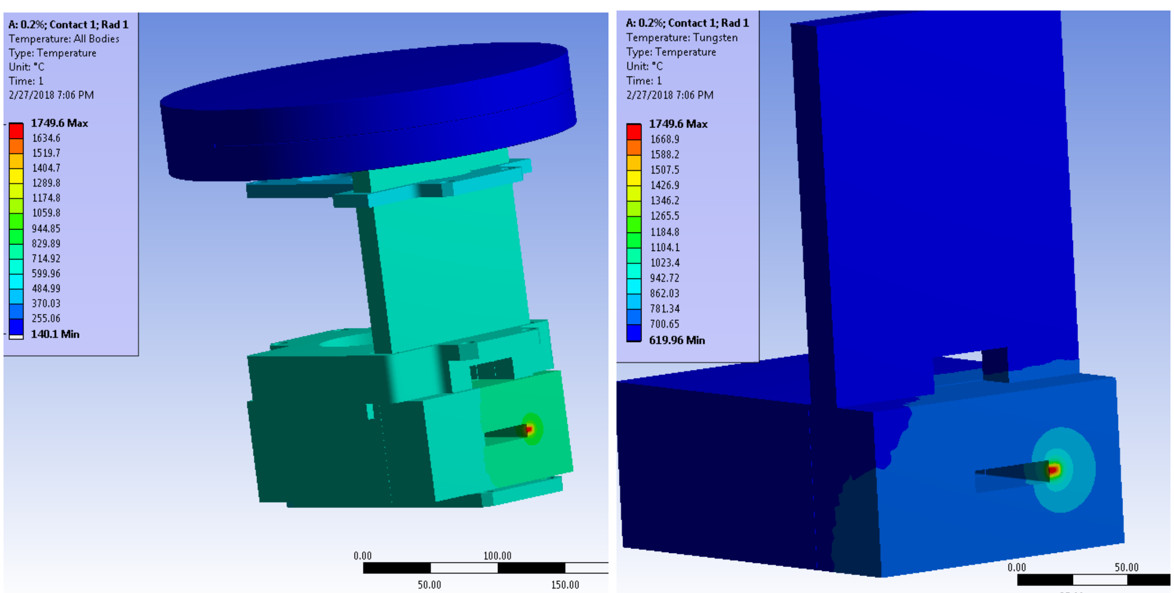


Figure 3: Thermal Analysis results of XPD BRC2 (AZM0008 Rev3) internal components, (vacuum vessel removed)

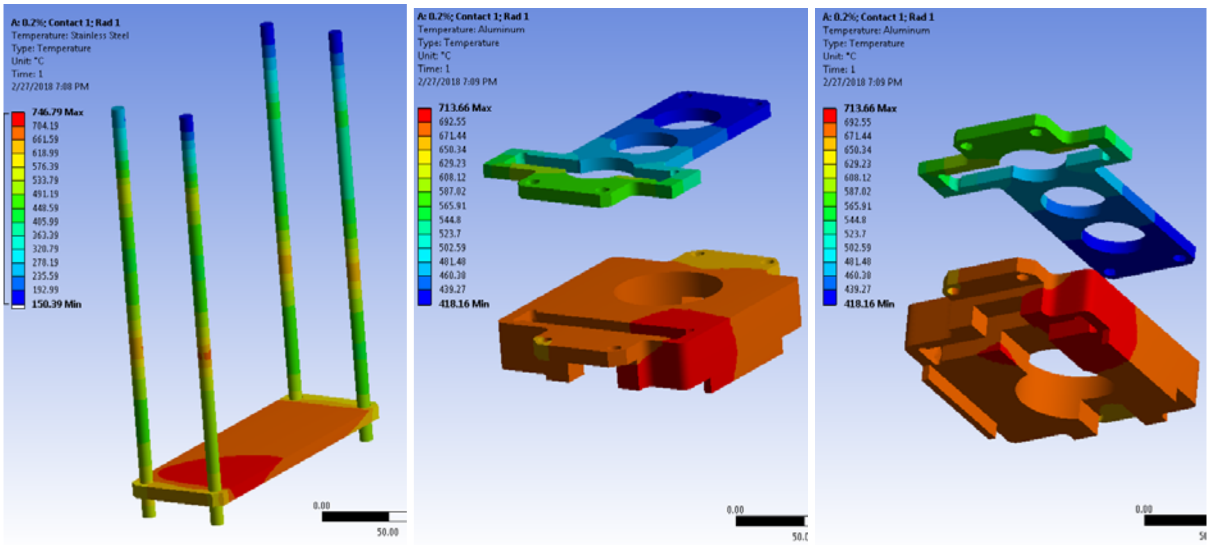


Figure 4: Thermal Analysis results of XPD BRC2 (AZM0008 Rev3) internal plates, (vacuum vessel removed)

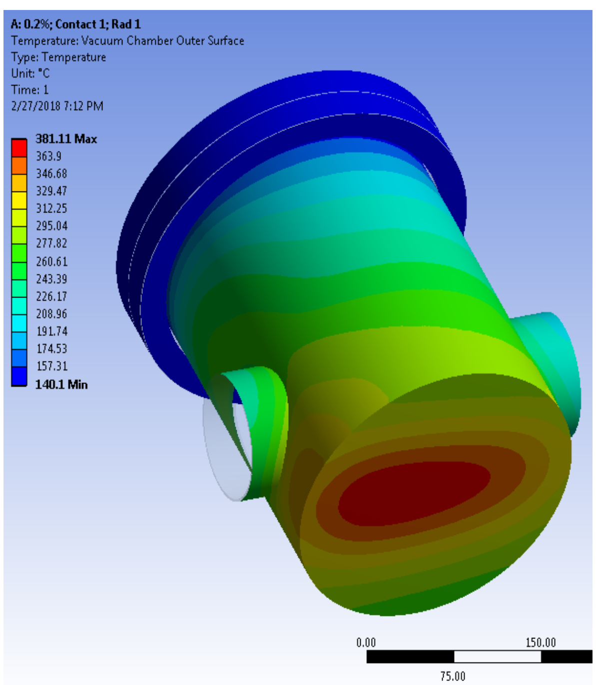


Figure 5: Thermal Analysis results of XPD BRC2 (AZM0008 Rev2) vacuum vessel outer surface

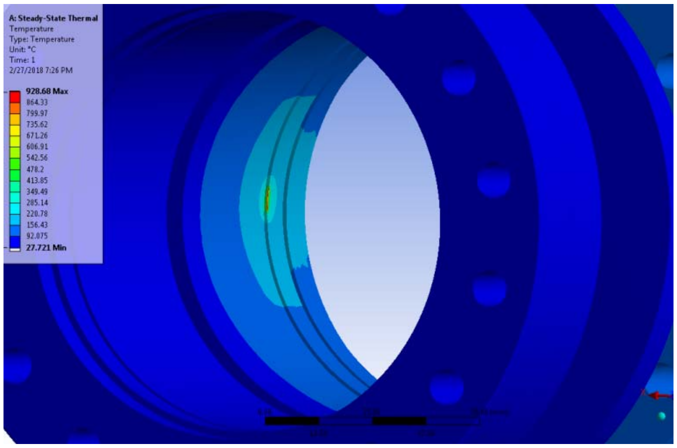


Figure 6: Thermal Analysis of STW vacuum vessel

MC0090

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CERTIFICATE OF CONFORMITY

Certificate No: TACOC 05166
Your O/No: 5084
Our O/No: 8175 W001265

Despatch No: TAD 05166
Despatch Date: 14 August 2013

ITEM	DESCRIPTION	QTY ORDERED	UNIT	QTY DESPATCHED	BATCH NO
	TAM 2000 - 95% W - 4% Ni - 1% Cu 18g/cm³				
1	TAM 2000 - XPD BRC2 Tungsten Block ACC0031 Rev02	1	ea	1	8175/072270
2	TAM 2000 - XPD BRC Tungsten Shield ACC0077 Rev02	1	ea	1	8175/072270

REMARKS

Certified that the whole of the materials and/or parts detailed hereon furnished against this purchase order, unless otherwise stated above, were manufactured and supplied in conformance with all applicable requirements and/or to your drawing.

Signed: ____________
For and on behalf of Tungsten Alloys

14 August 2013

Figure 7: Certificate of Conformance for Tungsten material