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COHERENT SOFT X-RAY EPU VACUUM CHAMBER THERMAL ANALYSIS FOR SYNCHROTRON RADIATION PROTECTION*

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Abstract

The purpose of this study was to determine the effect of beam mis-steering, on the temperature of the vacuum chamber. The chamber used for this study was for the Coherent Soft X-Ray (CSX) Elliptically Polarizing Undulator (EPU). Finite Element Analysis was conducted on the vacuum chamber to determine the temperature distribution on the chamber for set values of beam mis-steer, for NSLS-II. These results were then compared with on-site temperature measurements taken using RTD's, as well as thermal sensitive cameras. The accuracy of these results was analyzed and further FEA studies were proposed for steeper beam mis-steers and beam offsets.

INTRODUCTION

The Coherent Soft X-Ray (CSX) Elliptical Polar Undulator (EPU) beam line has two EPU's at a canted angle of 0.16 mrad. The effect of synchrotron radiation of the upstream device was studied on the vacuum chamber downstream. A single vacuum chamber made of Aluminum, as indicated in Fig. 1, covers the entire length of both the EPU's. The maximum aperture of the vacuum chamber is 8 mm as indicated in Figure 2.

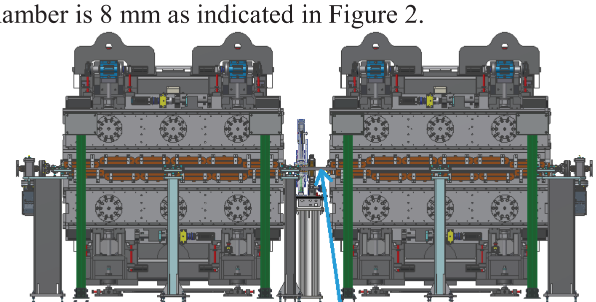

Figure 1: CSX EPU Vacuum Chamber.

The total on axis power of both the devices is around 10.1 KW [2].

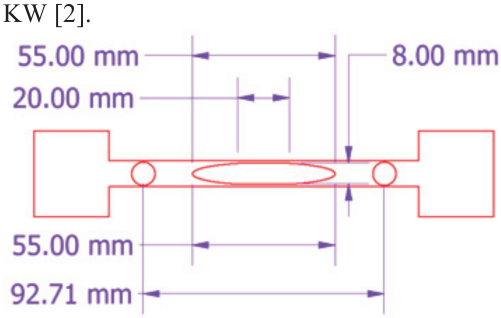

Figure 2: CSX EPU Vacuum Chamber Cross Section.

Since the effect of beam mis-steer of the upstream device is studied on the vacuum chamber, heat fluxes for 0.05 mm beam offset and 0.2 mrad angle beam mis-steer were studied. These offset and mis-steer limits were obtained from the maximum allowable active interlock limits set. After determining the close correlation of the FEA results to the actual measurements, FEA analysis of larger beam mis-steer angles were determined. The maximum beam mis-steer studied was 0.7 mrad.

HEAT LOAD CALCULATIONS

SRW code was used to compute the heat load on the wall of the vacuum chamber. Figure 3 shows the magnetic structure of the CSX EPU.

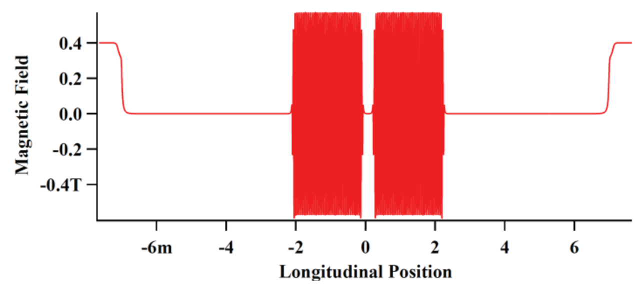

Figure 3: Magnetic Structure of CSX EPU.

The straight section has two EPU's of magnetic length 2 meters placed next to each other with a canting magnet in-between.

Table 1: CSX EPU Parameters Used for Heat Load Calculations

CSX EPU Properties	
Length	2x2 meters
Canted Angle	0.16 mrad
K_{eff}	4.34
Power Total	10.1 KW
Straight	Low Beta
Fan angle (V)	0.79 mrad
Fan angle (H)	0.76 mrad

Table 1 indicates the characteristics of CSX EPU [1]. Figure 4 indicates the power density (heat flux) in SRW code (using Igor-Pro) for synchrotron radiation, on the wall of the vacuum chamber, using a 0.2 mrad mis-steer.

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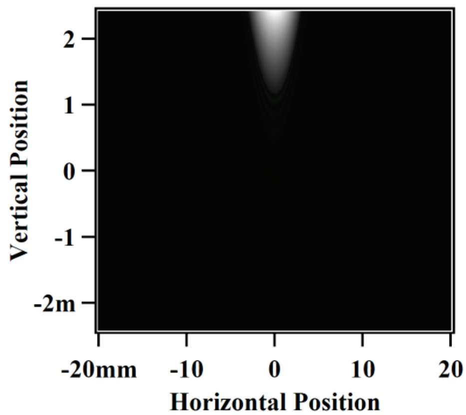

Figure 4: Heat Flux Distribution for 0.2 mrad Mis-steer.

This was the maximum allowable beam-mis-steer angle proposed, before active interlock gets activated and dumps the beam. Figure 5 indicates the heat flux distribution for the 0.2 mrad beam mis-steer [1].

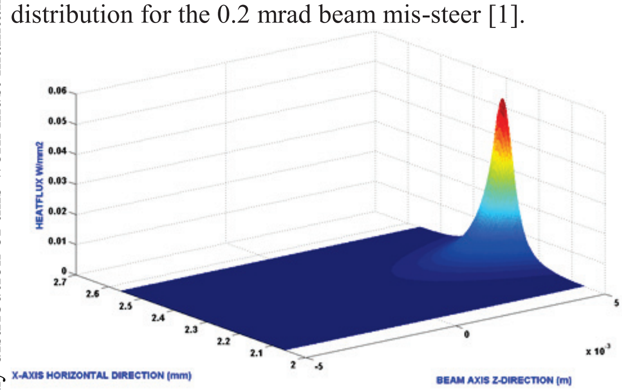

Figure 5: CSX EPU Heat Load for 0.2 mrad beam mis-steer.

After measuring the temperature on the vacuum chamber and correlating it to the FEA analysis, the SRW code was run for a mis-steer angle of 0.25 mrad and beam offset of 1.5 mm. In order to run this case, the active interlocks installed in the NSLS-II ring at the CSX EPU straight section would have to be de-activated.

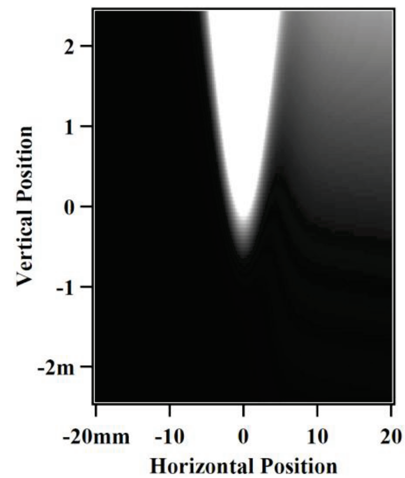

Figure 6: Heat Flux Distribution for 0.25 mrad Mis-steer and 1.5 mm Offset.

FEA ANALYSIS

The chamber was defeatured to improve the mesh quality. The devices are not centered at the center of the straight section. The upstream device is 1.125 meters upstream of the center of the straight and downstream devices is 1.2 meters downstream of the center of straight. Using SRW the heat flux distribution on the walls of the vacuum chamber was calculated. As indicated in Figure 2, the chamber minimum aperture is 8 mm, with the wall thickness of 0.95 mm. FEA was conducted using Ansys 16.2. Figure 7 indicates the temperature distribution on the Aluminum vacuum chamber for this case. The Ring temperature is 25.56 degree C. As indicated in figure 7, the maximum temperature on the walls was 25.8 degree C. A rise of approximately 0.4 degree was determined on the vacuum chamber as per FEA analysis.

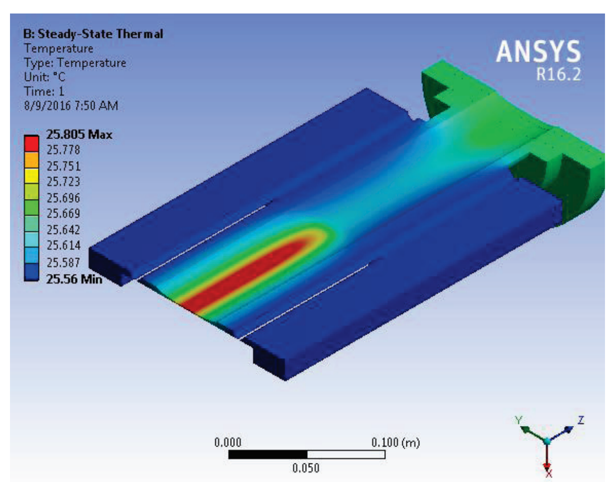

Figure 7: Thermal Analysis of the vacuum chamber for 0.2 mrad mis-steer.

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For a 0.25 mrad beam mis-steer, along with a 1.5 mm offset, the temperature distribution, calculated as per FEA analysis was 128 degree C., as indicated in figure 8.

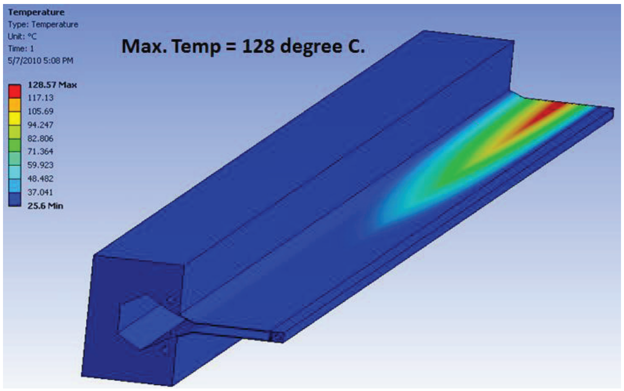

Figure 8: Temperature Distribution for 0.25 mrad Mis-steer and 1.5 mm offset.

MEASUREMENTS

RTD's and thermal sensitive cameras were set to determine the correlation of the FEA results with the vacuum chamber temperature measurements. There was a spike of about 0.125 degree C in the measured value. Since the RTD's were attached on the vacuum chamber wall away from the actual hot spot, the peak temperatures were not captured. In future we intend to conduct physical measurements on the CSX EPU vacuum chamber for the 0.25 mrad beam mis-steer and 1.5 mm beam offset. The heat flux distribution for a 0.25 mrad beam mis-steer and 1.5 mm offset is indicated in figure 6. We intend to attach RTD's at the locations where the hot spots were indicated in the FEA analysis as indicated in Figure 8 and compare analytical and practical results.

ACKNOWLEDGEMENTS

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[2] J. Skaritka, et al, "The Design and Construction of the NSLS II Magnets", MO6PFP008, PAC '09.