ISBN: 978-3-95450-188-5 doi:10.18429/JACoW-MEDSI2016-TUPE19

APLICATION OF A NEG COATED CHAMBER AT THE CANADIAN LIGHT SOURCE

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Abstract

In the Fall of 2015 a 4800 mm long NEG coated chamber was installed in the Canadian Light Source in cell 9 straight section. The chamber will occupy to majority of the straight length. The chambers vacuum has been monitored for +1 year and no obvious issues has been found.

The chamber body is 10 mm thick and the aperture is an ellipse with an 8 mm height and a 65 mm width. A design feature of the chamber is a lack of support in-between the ends of the chamber. This is due to the double elliptically polarizing undulator (54 mm, and 180 mm period). This proceeding details the following: Structure design and Deflection and strength Finite Element Analysis (FEA); Heat loads and cooling calculation; Supports design and deflection correction; Current strips installation and activation.

INTRODUCTION

The Canadian Light Source (CLS) is constructing a new phase III Beamline – the Quantum Material Spectroscopy Centre (QMSC). QMSC is designed to cover the energy from EUV radiation to soft X-ray (15 - 1000 eV) with arbitrary polarized light. Two APPLE II type undulators are designed to fulfil this energy range. The 180 mm period Low Energy Elliptically Polarizing Undulator (LE-EPU) covers the photon energy ~15-200 eV while the 55 mm period High Energy EPU (HE-EPU) covers the energy range of ~200-1000 eV. Each of the EPUs are 4 meters in length. The minimum gap for the high energy EPU is 14.5 mm. This double-EPU design required considerable engineering and analysis for the support structure and straight section vacuum chamber.

1. There was no possibility of a middle absorber so the vacuum chamber needed to be capable of absorbing roughly 900 Watts of bend magnet power deposited and an additional 700 Watts heat load from the EPU along the length of the chamber.
2. The chamber could not have a support in-between the two ends, due to the requirement of being able to switch between the HE- and LE-EPU's.
3. The chamber thickness between the magnets was limited to 10 mm, with an aperture of 8 mm. The chamber sag was limited to 0.3 mm. A regular chamber and ion pumps would not be able to be accommodated with the above restrictions.

FMB Berlin supplied a non-evaporable getter (NEG) coated chamber and CLSI designed the two ends supports and put the current strips on the chamber surfaces. Figure 1 shows the chamber assembly.

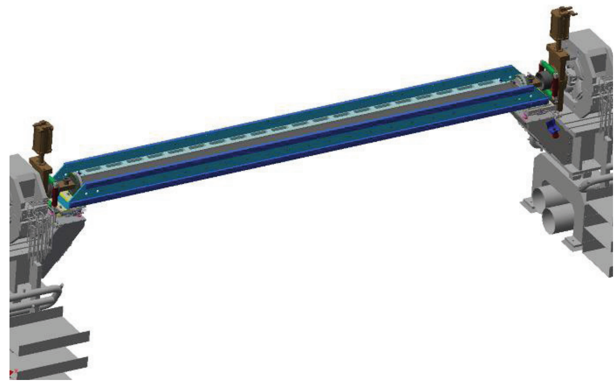

Figure 1: QMSC NEG Coated chamber.

STRUCTURE, STRENGTH, AND DEFLECTION

Due to the limited space, an H-style structure was required. Both the H-beam width and height were strictly limited by the double-EPU. To ensure the maximum sag was less than 0.3 mm, stiffening bars were attached to the side flanges. The end supports were also designed in such a way that the unti-sag torque could be applied to the chamber. Figure 2 shows the chamber structure. A series of FEA analyses were performed with positive results. Figure 3 and 4 (a), (b) and (c) show the FEA results at different conditions.

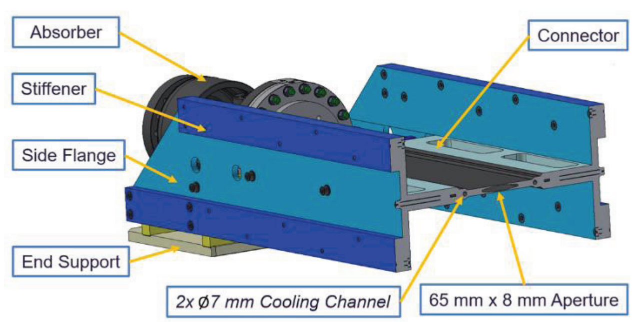

Figure 2: The chamber structure.

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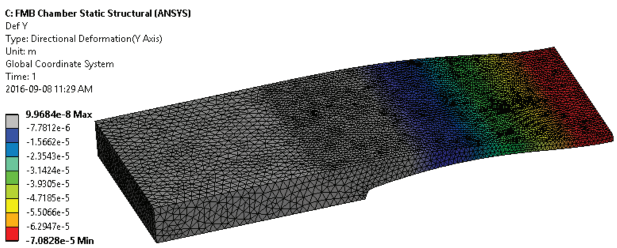
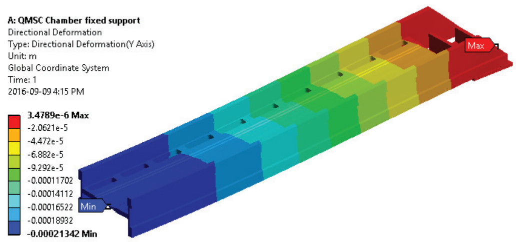
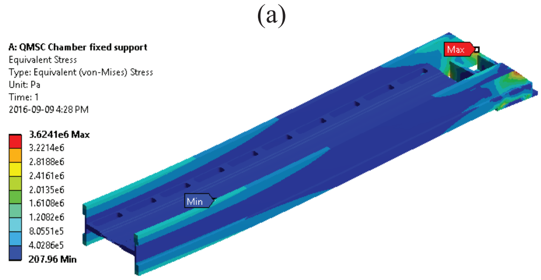


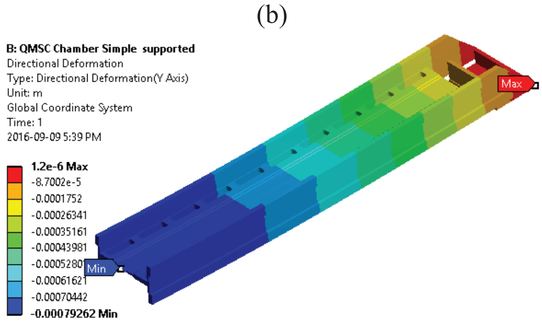
Figure 3: The chamber thin wall deflection and Von-Mises stress results at vacuum pressure.



(a)



(b)



(c)

Figure 4: (a) Chamber deflexion at the gravity force and end fixed supported condition. (b) Chamber Von-Mises stresses at the gravity force and end fixed supported condition. (c) Chamber deflection at the gravity force and end simply supported condition.

SUPPORT DESIGN AND SAG COMPENSATION

The two end support pieces were designed to be attached to two quadrupole magnet girders, with connections for water cooling channels near the ends. For NEG coating activation the chamber needs to be heated to 180 °C. The aluminium chamber length will extend 16.38 mm. For the chamber position stability, one end support was designed to be fixed along the beam direction, while the other end has a custom designed M/V rail stage. This stage allows this end free movement in the beam direction, while a unti-sag correction torque can be transfer to the chamber. Each support has full 6-degree adjustment during chamber installation. Figure 5 shows the two end supports.

Unfortunately, when the real chamber was installed, the chamber sag due to gravity was more than 2 times of the calculated value. The maximum surveyed sag was 0.88 mm. At each end three adjusting jacks were used to compensate for this chamber sag. Figure 6 (a) shows the surveyed chamber sag along the length. Figure 6 (b) shows the chamber's top surface flatness after installation and be adjusted in the Storage Ring.

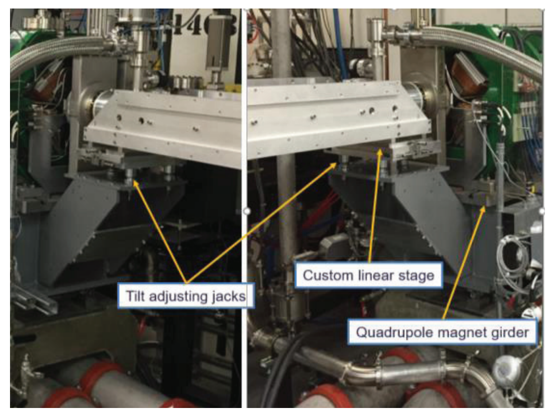
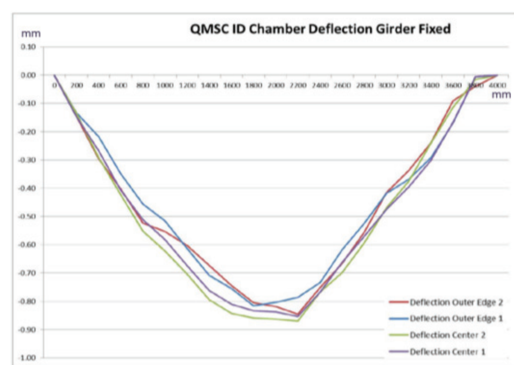
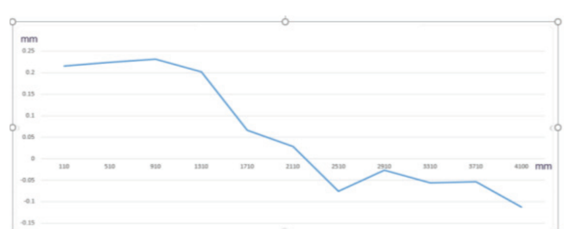


Figure 5: The chamber two end supports.



(a)



(b)

Figure 6: (a) Chamber tested deflexion. (b) Chamber top face flatness after correction.

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HEAT LOADS & COOLING CALCULATIONS

The chamber takes the upstream bend magnets heat load and also the heat load from the EPU in the straight section.

The bend magnet heat load was calculated using the following CLS storage ring parameters: electron beam current of 500 mA; beam energy of 2.9 GeV; magnetic field 1.354 T, and a bending angle of 15°. The calculated normal linear power density is 69.76 W/mrad and the normal peak power density is 259.6 W/mrad^2. The total bend magnet heat load on the chamber is 900 W. This heat load is primarily distributed on the upstream half of the chamber. See Figure 7 for details.

At the worst case scenario, with the low energy EPU at a minimum gap of 15 mm, and the electron beam is offset from the chamber centre (1.25 mm, 1.25 mm) in the X and Z (out-board, upper) directions. The downstream chamber receives 700 W of heat from the EPU. 603 W impinges evenly on the upper half inner channel surface. The remaining 97 W hits the bottom half of the inner surface evenly. The heat loads are shown in Figure 7, 8.

The heat transfer coefficient 'h' is calculated to be 12003 W/m^{2}·°C. This is using both of the available Ø7 mm cooling channels, with a flow rate of 2.5 m/s for the cooling water. The pressure drop is 58 Pa, and the cooling water temperature rises 2 °C.

Figures 9 and 10 show the temperature profile on the upstream and downstream chamber halves. Further calculations show that increasing the water flow rate does not reduce the chamber temperature significantly.

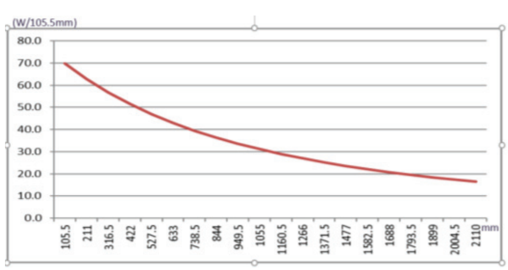

Figure 7: Heat load on upstream half chamber.

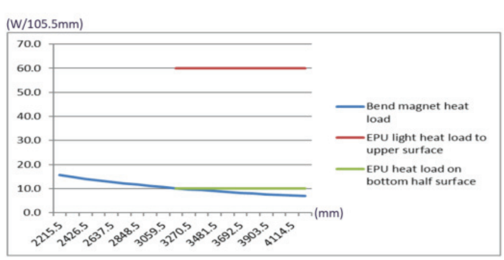

Figure 8: Heat load on downstream half chamber.

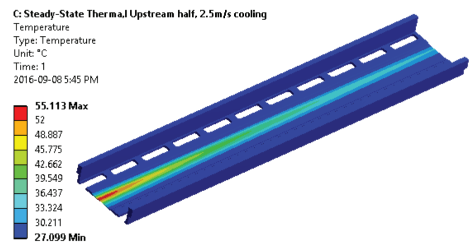

Figure 9: Upstream half chamber temperature.

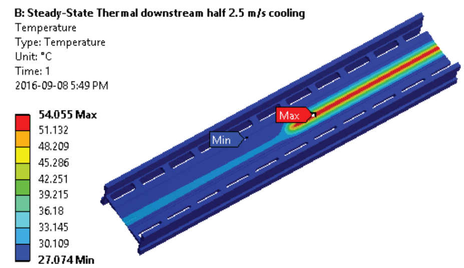

Figure 10: Downstream half chamber temperature.

CURRENT STRIPS INSTALLATION

The current strip array was adopted from the approach BESSY took for one of their insertion devices (ID). It makes use of two regular 12-strip arrays of conductors mounted flush with the EPU vacuum chamber. The independently powered current strips allow for compensation of dynamic multipoles during the EPU's operation.

The challenge was to find appropriate current strips and attach them on the chamber with a position tolerance of 0.1 mm. Several different engineering approaches were considered and tested. The end result was adapted from the NSLS-II solution for their ID. Two 4-metere flexible printed circuit boards were glued on the chamber surfaces. The accurately placed pin holes on the circuit board can be used for positioning the current strips. A jig for gluing the pins and aligning them on the chamber was designed. Figure 11 shows the alignment process.

Figure 11: Alignment jig.

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ACTIVATION

Due to the severe space limitations, the straight section has no ion pumps installed. There is a roughing port and a vacuum gauge on the absorber at each end of the chamber. During the activation process, both ends are pumped on. The activation procedure was supplied by FMB Berlin and Figure 12 illustrates the activating process and pressure results.

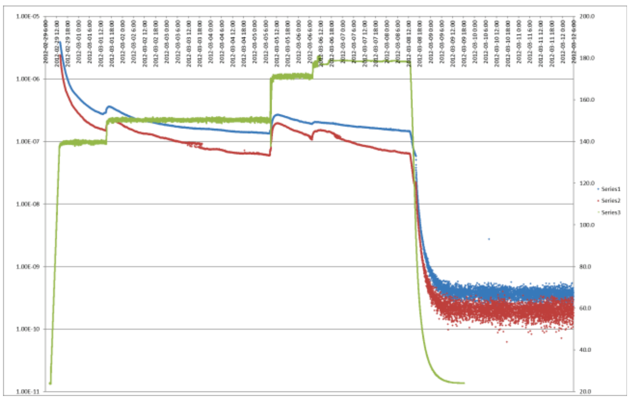

Figure 12: Activating temperature & vacuum levels versus time

CONCLUSION

The QMSC vacuum chamber is the second NEG-coated chamber in use at the CLS. It also has the longest span and uses the thinnest walls out of any chamber at the CLS. The current strips are the first to be installed and used at the CLS. The chamber has been installed in the storage Ring for over 1 year, with no vacuum or cooling issues to date.

ACKNOWLEDGEMENTS

A special thanks goes to Charles Hetzel at NSLS-II for sharing their current strip installation knowledge.