VACUUM MODIFICATIONS FOR THE INSTALLATION OF A NEW CESR-C FAST LUMINOSITY MONITOR*

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Abstract

In order to improve luminosity tuning and maintenance for the CLEO-c high energy physics (HEP) program at the Cornell Electron Storage Ring (CESR), a luminosity monitor using photons from radiative Bhabha events has been installed in the CESR ring. Over 8 meters of CESR vacuum chambers near the interaction region were modified to accommodate this new device. The vacuum modifications were designed to meet two criteria. First, the new vacuum chambers had to provide sufficient horizontal and vertical aperture for photons originating from the interaction point (IP) over a wide range of colliding beam conditions. Secondly, the new vacuum chambers required adequate safety margins for operation at beam energies up to 5.3 GeV for Cornell High Energy Synchrotron Source (CHESS) running. In order to be certain that the vacuum modifications would not give rise to any localized pressure bumps, a detailed calculation of the expected vacuum pressure distribution due to synchrotron radiation flux was carried out. Careful design and planning enabled a successful installation and resumption of CESR operations in record time.

INTRODUCTION

After successful CESR-c conversion [1] to extend the energy reach of the Cornell Electron Storage Ring (CESR), a time-sharing operation mode has been adopted to support both the CLEO HEP program (at lower beam energy ~ 2GeV) and the synchrotron radiation (SR) users (at higher energy, ~5.3 GeV) for CHESS. To improve luminosity tuning for the HEP program, a fast luminosity monitor (FLM) was proposed [2] to be integrated in CESR. In this paper, we describe the vacuum system modifications for the FLM installation.

VACUUM MODIFICATIONS

It was determined that the optimum location of the FLM was at ~16.1 meters from the interaction point (IP). The vacuum modifications in this region need to meet the following basic requirements.

- Adequate aperture with uniform material profile, to reduce systematic error to the FLM signal.
- Sufficient operational safety margin in the vacuum chamber design to handle SR power at CHESS runs (maximum 300mA per beam @5.3 GeV).
- Acceptable vacuum pressure level with existing vacuum pumping.

CESR vacuum chambers from 12 to 20 meters were modified for the FLM installation. Figure 1 shows the comparison of vacuum system layout in the affected region before (a) and after (b) the installation. The modifications included replacing two dipole chambers, B3W and HB4W, and adding a short quadrupole chamber, Q3W. A FLM window made of 6061-T6 aluminum alloy was part of the modified HB4W chamber. The modified chambers were opened up horizontally to provide sufficient aperture to accept photons originating at the IP with crossing angles of the colliding beams ranging from -7 to +2 mrad [2].

The SR power density on the walls of vacuum chambers at 5.3 GeV CHESS runs did not change significantly after the modification, except at the FLM window. Thus built-in cooling in the new chambers, which is similar to the old chambers, is adequate. The aluminum FLM window intercepts significant SR power from both bend magnets and superconducting magnets near the IP. The design and thermal analysis of the FLM window is presented separately in this proceeding. [3]
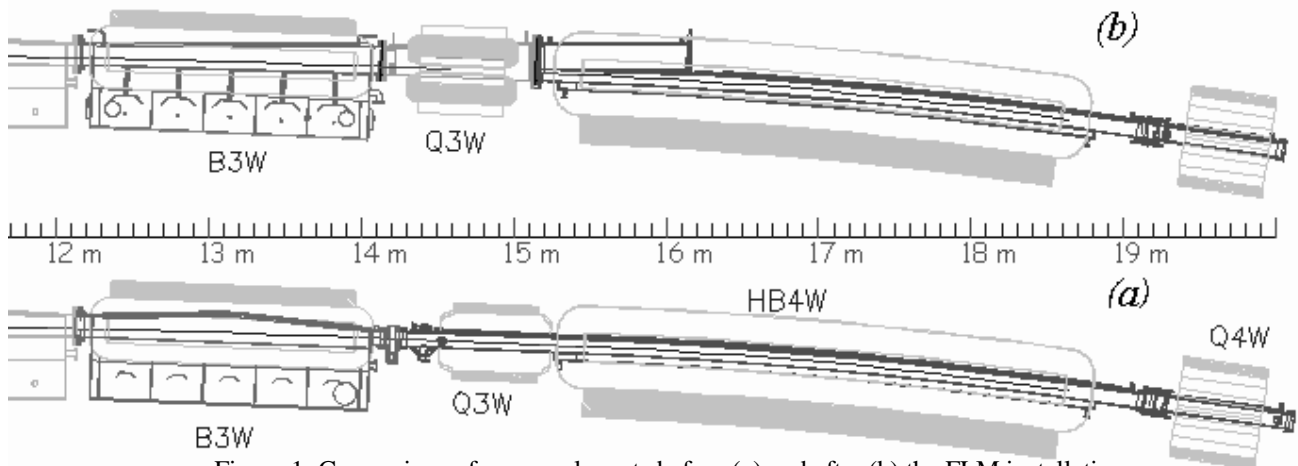

Figure 1: Comparison of vacuum layouts before (a) and after (b) the FLM installation.

The B3W chamber, as shown in figure 2, consists of a beam pipe and a titanium sublimation pump (TiSP) ante-chamber. The chamber is made of mostly OFHC copper sheet, with a water-cooled copper bar as its outer wall to absorb the SR power. The TiSP ante-chamber is partitioned into five compartments to increase pumping speed and capacity. The inner surface exposed to TiSP filaments is ~10^4 cm^2, providing total installed pumping speeds [4] of 2.6×10^4, 3.5×10^4 and 8.2×10^4 l/s for H_2, N_2 and CO, respectively. The TiSP ante-chamber is connected to the beam chamber through a slotted stainless steel screen. The slot pattern is designed in such a way to maximize the gas conductance between the pumping and the beam chambers while keeping sufficiently low impendence for the stored beam. The gas conductance of the beam screen at room temperature is ~2100 for CO/N_2 and ~7700 l/s for H_2. A 60 l/s ion pump is attached to the TiSP ante-chamber to remove non-gettable gases.
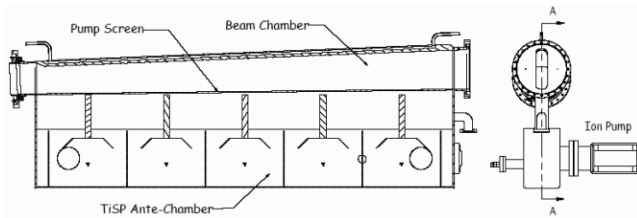

Figure 2: B3W Chamber for FLM Installation.

The short Q3W chamber, shown in figure 3, provided flexibility in the installation of the modified chambers and a new Q3W quad magnet. The beam pipe is constructed from two L-shaped 3-mm thick copper plates welded along the seam and a water-cooled copper bar as its outer wall to absorb SR power. The welded beam pipe is in turn welded to two stainless steel collars and then the end flanges. The 3-mm thickness of the beam pipe plates was dictated by required vertical beam aperture and clearance for the Q3W quadrupole pole tips. A pair of stiffening plates and bars was tack-welded to the beam plates to provide adequate strength while maintaining sufficient clearance to the pole tips.
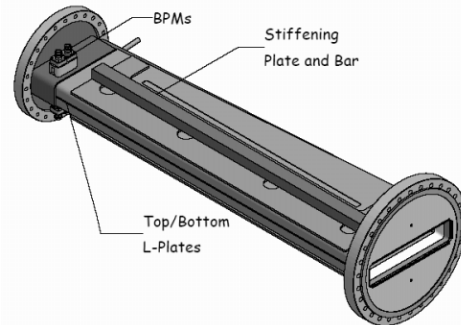

Figure 3: Q3W quadrupole vacuum chamber.

The hardbend dipole chamber, HB4W, was the most challenging chamber to modify in this project. It was modified from a fully finished spare 6.2-m long hardbend dipole chamber with installed distributed ion pump (DIP) elements. As shown in the exploded view in figure 4, one end of the dipole chamber was first cut to length, and a precision cut was then made by dry-machining along outer wall of the extrusion to attach the FLM photon beam box, to provide required aperture for the FLM signal. Extreme care was taken during the machining to avoid contamination of the inner surfaces of the dipole chamber. DIP pumping slots were shielded by a thin SST strip during the machining to prevent metal chips from getting into the DIP channel. The FLM beam plates B & C were first welded to the dipole chamber as shown. The FLM window D and an explosion-bonded SST/Al bi-metal transition were then welded to the ends of the FLM beam box. A 13¼" ConFlat flange was welded to the SST/Al transition to finish the chamber.

PRESSURE PROFILE CALCULATION

The vacuum modification unavoidably altered the SR flux distribution, with concentrated SR flux impinging on the FLM window. To ensure an adequate vacuum level in the modified region, the pressure profile between 9 and 23
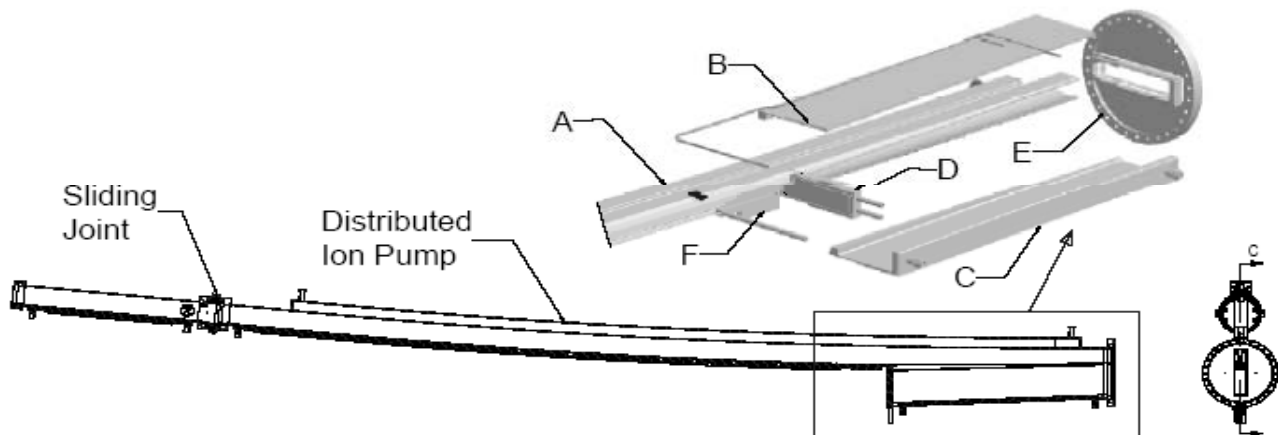

Figure 4: Modification of HB4W chamber for FLM installation. A – extruded aluminum beam pipe with distributed ion pump; B – Top plate and C – Bottom plate for FLM beam box; D – FLM window; 13¼" ConFlat flange with an explosion-bonded stainless steel/aluminum transition piece; F – Water cooling block for the chamber.

from IP was calculated (using a one-dimensional finite-element method [5]) by dividing the vacuum system into 10-cm cells. We only consider the pressure profile at CHESS runs, as the pressure is much lower at CESR-c energies. Figure 5 shows calculated pumping speed and gas conductance of each cell.
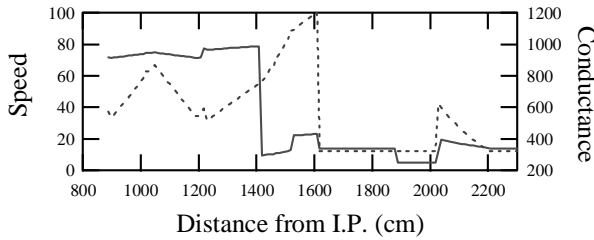

Figure 5: Pumping speed (solid line) and gas conductance (dashed line) per unit cell, all in liter/sec.

The gas load consists of a static thermal desorption (Q_{th}) and SR photon-induced desorption (Q_{PID}),

$$Q_{th} = q_{th} \cdot A_{cell} \qquad (1)$$

where A_{cell} is the surface area of each cell, and $q_{th}=10^{-11}$ torr·l/sec·cm^2 is used for aluminum.

$$Q_{PID} = 2.83 \times 10^{-20} \eta_{SR} F_{SR} \qquad (2)$$

where η_{SR} is the PID yield. With beam conditioning of the chamber, the PID yield decreases with photon dose D:

$$\eta_{SR} = \eta_0 D^{-\alpha} \qquad (3)$$

We considered only the SR flux originating from the dipole and IR SCQ magnets. Almost all of the SR from the SCQ magnets ends on the FLM window. Figure 6 shows the calculated SR flux (a) of each cell for 300mA×2 beams at 5.3 GeV and the gas load (b), with $\eta_0=5.61 \times 10^{14}$ and $\alpha=0.85$ [6]. As shown in figure 7, the projected vacuum level in the affected region is very acceptable after a brief beam conditioning. The high SR flux on the FLM window does not induce a local pressure bump due to large gas conductance and local pumping.
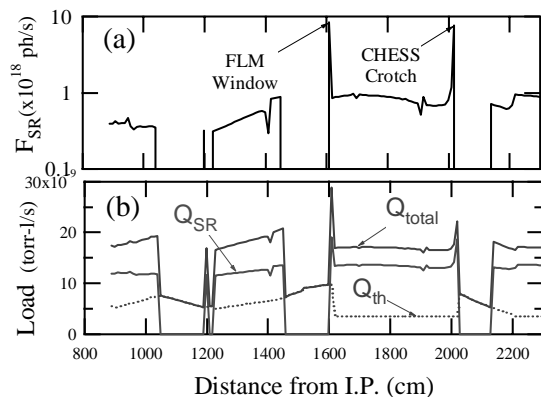

Figure 6: SR flux (a) and gas load (b) after 100 A·hr beam dose per unit cell in the pressure profile calculation.

CONCLUDING REMARKS

The modified vacuum chambers were successfully installed during a very brief accelerator shutdown in the summer 2004 for the FLM, owing to the well thought-out

design and careful planning. After only ~25 A·hr beam conditioning at 5.3 GeV, the vacuum level in the affected region was rapidly recovered to allow the resumption of CLEO-c HEP running. An example of the vacuum beam conditioning after the installation is given in Figure 8. Operational experiences verified that the vacuum system design fully satisfies the aperture requirement for the HEP runs and the mechanical and vacuum requirements for the CHESS runs.
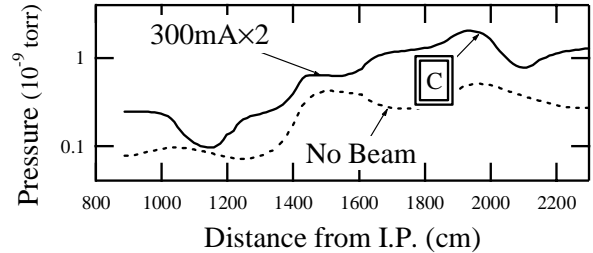

Figure 7: Calculated pressure profile at a total beam current of 600 mA at 5.3 GeV, after 100 A·hr beam dose.
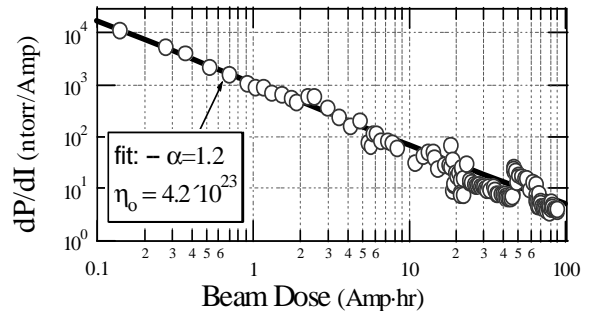

Figure 8: Example of vacuum beam conditioning, measured by a vacuum gauge at location C (as marked in Figure 7). Changes in beam energy from 5.3 GeV to CESR-c energy at 25 A·hr, and back to 5.3 GeV at 50 A·hr are visible>.

ACKNOWLEDGEMENTS

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