ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME059

CONCEPTUAL DESIGN OF A STORAGE RING VACUUM SYSTEM COMPATIBLE WITH IMPLEMENTATION OF A SEVEN BEND ACHROMAT LATTICE AT THE APS*

B. Stillwell, B. Brajuskovic, H. Cease, D. Fallin, J. Noonan, and M. O'Neill, ANL, Argonne, IL 60439, USA

Abstract

A conceptual design is presented for a storage ring vacuum system at the Advanced Photon Source (APS) which is compatible with a multi-bend achromat (MBA) lattice under development for the APS Upgrade (APS-U) project [1]. Together, the interface with the magnets, required quantity and stability of beam position monitors, synchrotron radiation loading, and beam physics requirements place a demanding set of constraints on the vacuum system design. However, the requirements can be satisfied with a hybrid system which combines conventional extruded aluminum chambers incorporating "antechambers" with a variety of simpler tubular chambers made variously of copper-plated stainless steel, NEG-coated copper, and bare aluminum. This hybrid system has advantages over an all NEG-coated copper system with regard to overall project risk, required installation time, and maintainability.

INTRODUCTION

As presently envisioned, an upgraded APS storage ring will store 200 mA of electron current at an energy of 6 GeV. The MBA lattice will improve x-ray brightness substantially with innumerable benefits to our users [1]. X-ray beam extraction will be essentially unchanged with perhaps only a 1 cm shift of the bending magnet beamline position. However, a three-pole wiggler is being considered as a replacement to the bending magnet source. A sector assembly of the storage ring vacuum system is shown in Fig. 1 with and without magnets. The sector is divided into nine sections of four types named according to the functions of the magnets there.

VACUUM CHAMBERS

Quadrupole Doublet Sections

To limit the impact of eddy current shielding on fast steering correction fields, vacuum chambers in that area will be made of stainless steel alloy 904L which has an exceptionally low electrical conductivity. The interior surface, however, will be plated with copper to minimize beam impedance effects. To further minimize distortion of the fast corrector fields, the chambers will be simple round tubes with no cooling channels. The chambers are short and shielded from radiation so thermally-induced motion is of little concern.

L-bend Sections

"L-bend" sections will have C-shaped dipole magnets with a longitudinal gradient. The C shape provides unlimited space outboard of the magnet. Chambers here will have a 22 mm circular aperture for the particle beam and antechambers to allow discrete absorbers to intercept bending magnet radiation away from the stored beam (Fig. 2). In addition, dual NEG strips ensure excellent vacuum pressure performance. Experience at Argonne

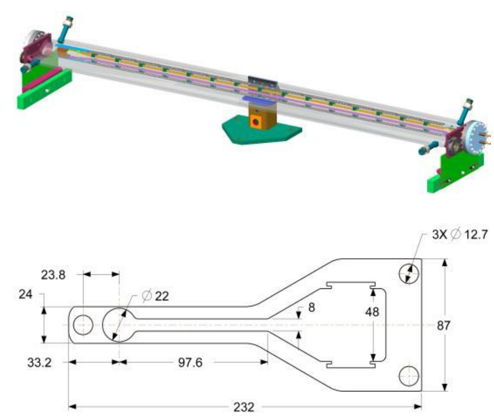

Figure 2: L-bend vacuum chamber model and section.

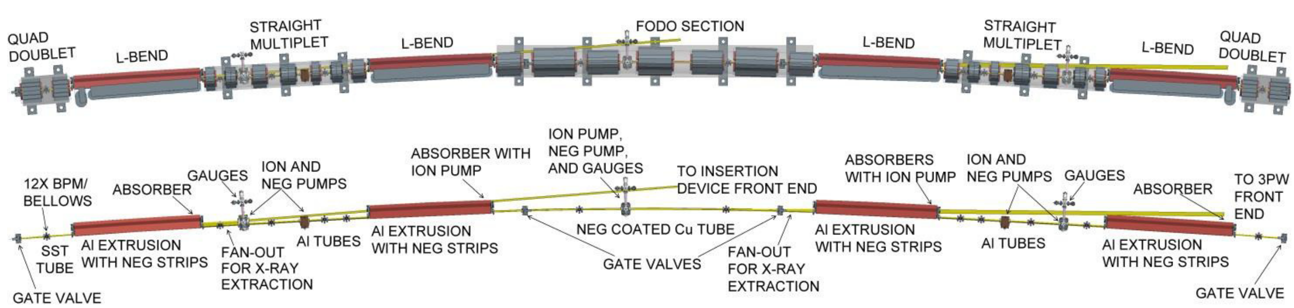

Figure 1: Vacuum system layout for a typical storage ring sector.

* Work supported by U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME059

building this type of chamber for the APS and many other synchrotron facilities gives us confidence that the fabrication will meet design specifications.

Straight Multiplet Sections

The configuration of magnets in the straight multiplet sections does not permit the use of antechambers there. However, ray traces indicate that a simple tube in these locations will see little bending magnet radiation so heating and photon stimulated desorption are manageable without an antechamber. The chambers will be straight aluminum extrusions with a 22 mm internal diameter particle beam chamber and an adjoining water channel. Two relatively large gaps between magnets in each multiplet section permit placement of cross chambers onto which ion pumps, NEG cartridge pumps, gauges, and rough pumping valves will be located.

FODO Section

In the central "FODO" section (so-named for the focus-drift-defocus-drift magnetic pattern) photon power and flux densities are higher than in any other part of the sector. Due to space limitations, the vacuum chambers are designed to accept the synchrotron radiation power load on the outboard wall similar to the MAX-IV design [2]. Either work-hardened high-purity copper or silver dispersion-strengthened copper will be used to simultaneously maximize thermal conductivity and mechanical strength. Water channels will adjoin the outboard wall to remove heat as close as possible to the radiation-incident surfaces. Most of the chambers here will also be NEG-coated to minimize photon stimulated desorption and provide distributed pumping. To minimize risk of NEG saturation or contamination during bake-out of adjoining sections, gate valves will be used to isolate the NEG-coated chambers during such operations. The gate valves also permit installation of chambers in the tunnel in an activated state, preassembled with magnets.

BEAM POSITION MONITORS

Beam position monitors (BPMs) will be RF pickup-type and integrated with a pair of shielded bellows which serve to decouple the BPMs from thermal and vibrational motion on adjacent chambers (Fig. 3). The BPM support structure is designed to be sufficiently rigid such that vibrational mode frequencies are well above those of known mechanical sources. The BPM housing is stainless steel with ceramic feedthroughs for the electrodes, similar to some commercially available double-sided flange BPMs. Flanges will use chain clamps to minimize required installation time and space.

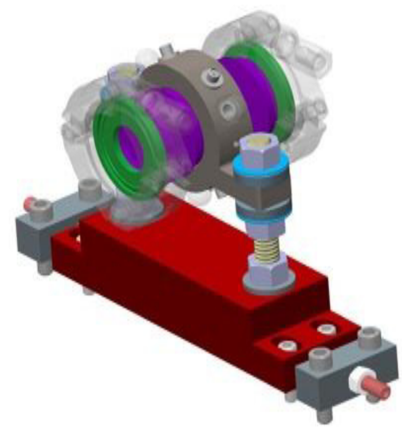

Figure 3: Beam position monitor assembly.

RAY TRACE ANALYSIS

A ray trace analysis (Fig. 4) illustrates how synchrotron radiation-based heat loads and photon stimulated absorption informs the vacuum system design. Incident power densities are generally highest for source points

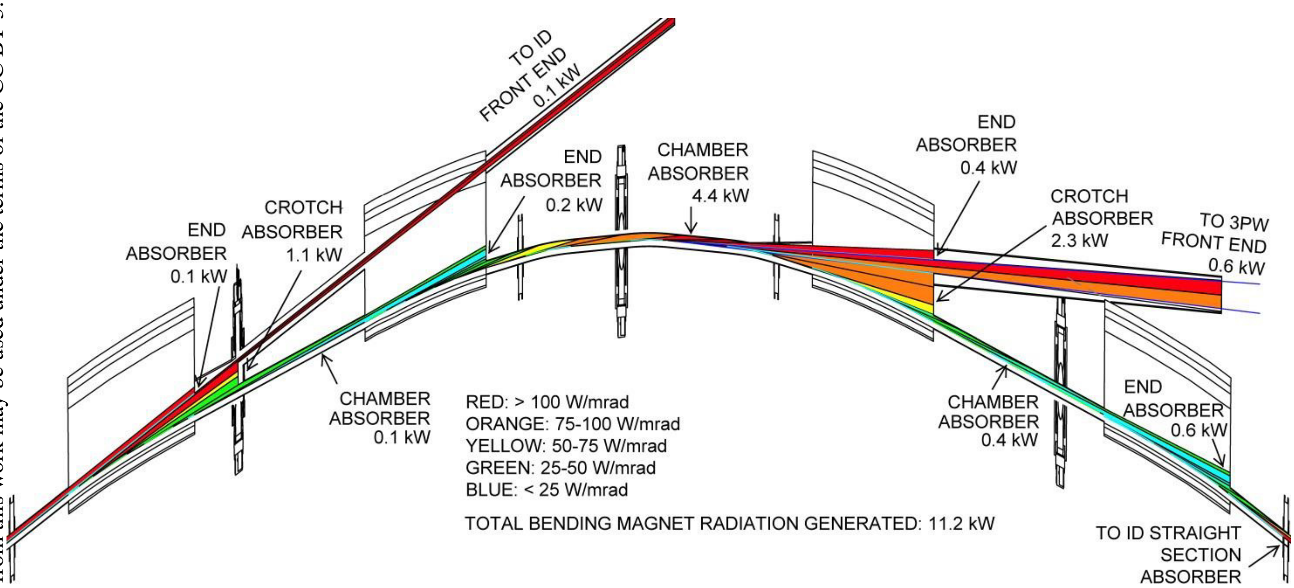

Figure 4: Distribution of bending magnet radiation for a typical storage ring sector.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPME059

near the insertion device straight section and FODO section. FODO vacuum chambers receive more than one third of the total bending magnet radiation power. Most of the remainder is intercepted by discrete absorbers. Radiation absorbed on chamber walls in the straight multiplet sections is small and easily managed.

ABSORBERS

The insertion device x-ray beam extraction crotch absorber is expected to be similar to that developed for ANKA [3]. The crotch absorber needed for extraction of the three pole wiggler x-ray beam will see lower incident power densities and so may be similar to storage ring chamber end absorbers presently in use at the APS. The ends of the L-bend chambers will also be protected by an absorber similar to what is presently used at the ends of APS insertion device vacuum chambers. Small absorbers needed to protect RF liners inside bellows, pumping crosses, and gate valves will be incorporated into the adjoining flange of the vacuum chamber upstream of those components as is planned for MAX-IV [2].

VACUUM ANALYSIS

Calculated one dimensional pressure profiles give us confidence that the goal of less than 2 nTorr average pressure during full-current operation will be met. Figure 5 shows what is expected to be a typical operating pressure profile over a full sector excluding the insertion device straight section. The gas load due to photon-stimulated desorption was calculated assuming radiation power determined by the ray traces and the power-weighted average of photon energy in each section. Vaccalc [4], a computer program which employs the finite difference method, was used to generate the profile.

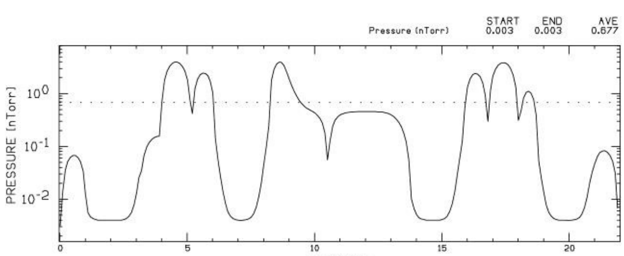

Figure 5: Typical 1-D pressure profile during operations.

THERMAL-MECHANICAL ANALYSIS

Finite element analysis (FEA) was used to calculate the mechanical and thermo-mechanical stresses in vacuum chamber walls. For the chamber segments that are to be exposed to synchrotron radiation heating, a thermal analysis was first performed to compute temperature distribution and then a structural analysis was conducted which accounted for thermal stresses due to the thermal gradients in addition to the stresses caused by atmospheric pressure and gravity. The results of the FEA analyses were used in material selection and the optimization of the design. The results of thermal and thermo-structural analysis of the vacuum chamber segments in the FODO section confirmed that high purity copper, due to its superior thermal conductivity and thus minimal thermal gradients, is the optimal material for these segments (Fig. 6).

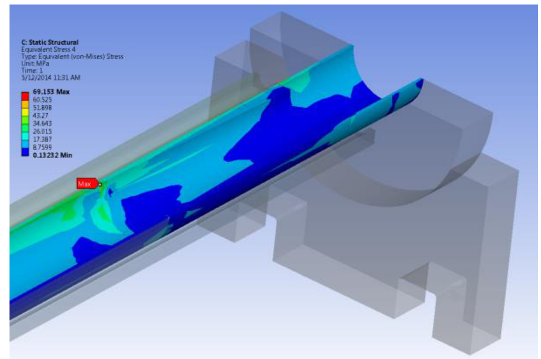

Figure 6: Thermal-mechanical stress in FODO chamber.

CONCLUSION

A conceptual design has been developed for a storage ring vacuum system at the Advanced Photon Source that will serve the implementation of a new seven-bend achromat magnetic lattice. Chamber designs and pumping schemes are optimized for the four types of magnet arrangements and have been tailored to the spatial allowances and bending magnet radiation present in each. Concepts for radiation absorbers and BPMs are largely based on previously demonstrated designs and commercial components. Thermal-mechanical and vacuum analyses corroborate the validity of the design relative to mechanical integrity and vacuum performance respectively.

ACKNOWLEDGMENT

The authors gratefully acknowledge the guidance and constructive feedback offered to us by George Goeppner (ANL), Glenn Decker (ANL), Roberto Kersevan (CERN), and Marek Grabski (Max-lab).

REFERENCES

[1] E.S. Reich, Nature 501, 148-149 (2013).
[2] E. Al-Dmour, D Einfield, J. Pasquaud, M. Quispe, J. Ahlbäck, P. Fernandes Tavares, M. Grabski, "Vacuum System Design for the MAX IV 3 GeV Ring," IPAC '11, San Sebastian, September 2011, p. 1554 (2011); http://www.JACoW.org
[3] S. Hermle, D. Einfield, E. Huttel, "Layout of the Absorbers for the Synchrotron Light Source ANKA," PAC '99, New York, March 1999, p. 1360 (1999); http://www.JACoW.org
[4] M. Sullivan, Stanford Linear Accelerator Center (SLAC), Internal Note AP 94-6 (1994).