

# PROGRESS ON THE DESIGN OF THE STORAGE RING VACUUM SYSTEM FOR THE ADVANCED PHOTON SOURCE UPGRADE PROJECT\*

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## Abstract

Recent work on the design of the storage ring vacuum system for the Advanced Photon Source Upgrade project (APS-U) includes: revising the vacuum system design to accommodate a new lattice with reverse bend magnets, modifying the designs of vacuum chambers in the FODO sections for more intense incident synchrotron radiation power, modifying the design of rf-shielding bellows liners for better performance and reliability, modifying photon absorber designs to make better use of available space, and integrated planning of components needed in the injection, extraction and rf cavity straight sections. An overview of progress in these areas is presented.

## SYSTEM DESIGN

The sector vacuum layout (Fig. 1) is generally as previously reported [1] with the most significant changes being the use of two pumping crosses instead of one in the multiplet sections, making these crosses of aluminum and integrating them with adjacent tubular chambers, and use of copper-plated Inconel instead of stainless steel at four, rather than two, fast-corrector locations. The new lattice that has been adopted for the APS-U storage ring requires that the vacuum system accommodate six reverse-bends in the sector arc [2]. Impact on the vacuum system is mostly associated with the roughly 20% increase in bending magnet radiation power that must be managed and, because of the use of reverse-bending magnets, locally higher power absorption on photon absorbers from overlapping radiation fans (Fig. 2). Increased photon flux will also result in greater outgassing, but simulations with MolFlow+ [3] indicate that the system as-designed should still meet the given average pressure requirement of 2 nTorr after 1000 Ahr of operation (Fig. 3).

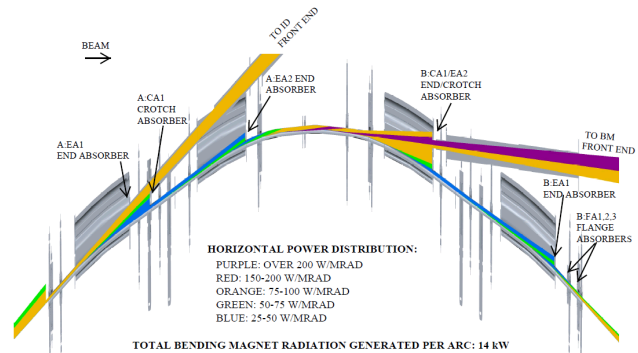


Figure 2: Ray trace showing overlapping bending magnet radiation fans.

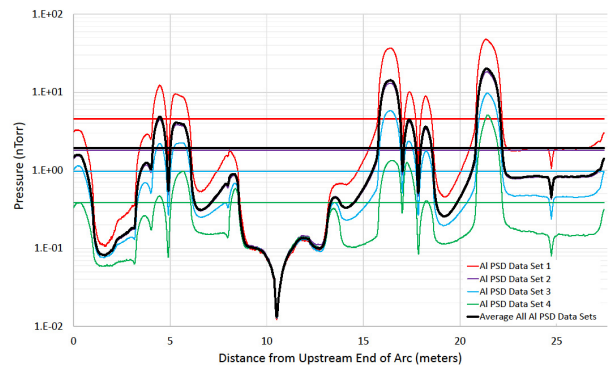


Figure 3: Results from a series of pressure profile simulations assuming 1000 Ahr of conditioning.

The particle beam follows a more complicated trajectory on account of the new lattice, but reasonable compromises have been made to the chamber geometry to avoid bending additional chambers. In the areas where

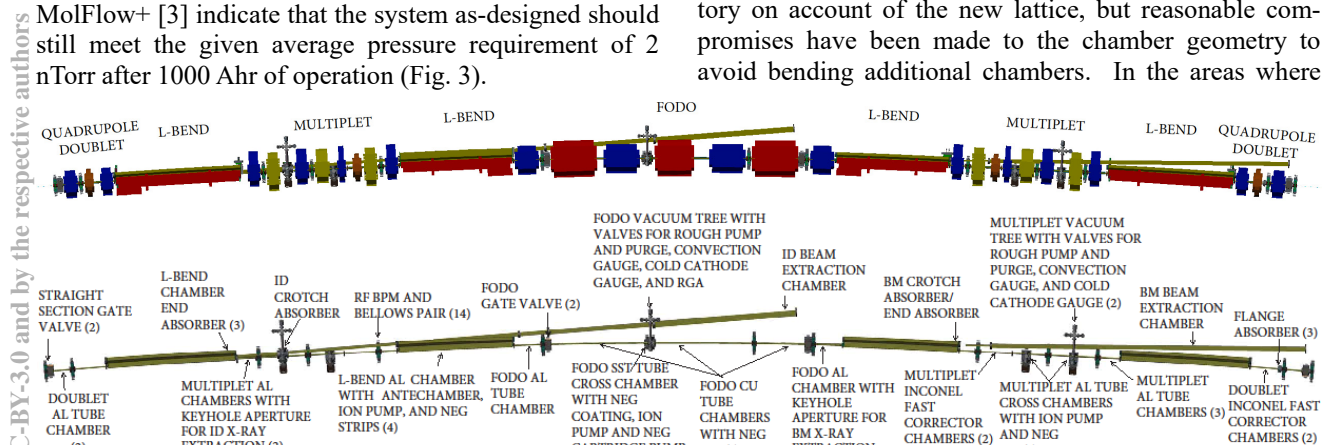


Figure 1: Vacuum system layout for a typical sector arc shown with magnets (top) and without (bottom).

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reverse bends are located, the chambers follow a path along straight line segments which terminate on the particle beam at adjacent BPM locations. Midway along the offset quadrupoles which provide the reverse bending fields, where the offset of the chamber center line relative to the beam is the greatest, the offset is no more than 0.3 mm in the multiplet sections and 0.9 mm in the FODO section. Figure 4 shows the geometry in the upstream multiplet section where the central two quadrupoles are offset to provide the reverse bending field.

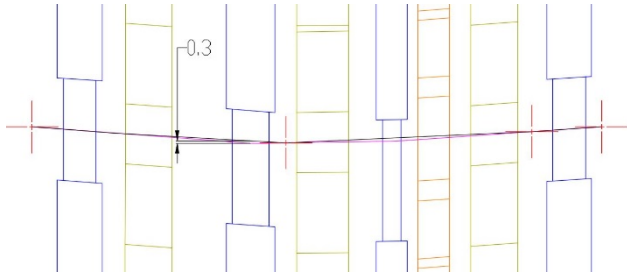


Figure 4: Alignment of particle beam (magenta) relative to chamber center (black) and BPMs (red cross-hairs) in the upstream multiple section where the central two quadrupoles (blue) are laterally offset to create reverse-bending fields.

## COMPONENT DESIGNS

### FODO Section Chambers

High resolution numerical ray tracing reveals “hot spots” in FODO section where, due to geometry and overlapping of bending magnet radiation fans, absorbed heat loads spike at two locations. To ensure adequate mechanical strength, chambers are designed with segments in these areas made of GlidCop [4] (Fig. 5). While doable, use of GlidCop for this application is not ideal as the material is expensive, available only in rod form, and challenging to weld. Options to retain or recover work-hardened properties in C10100 (OFE) and C10700 (OFS) copper which would eliminate the need for GlidCop are being investigated.

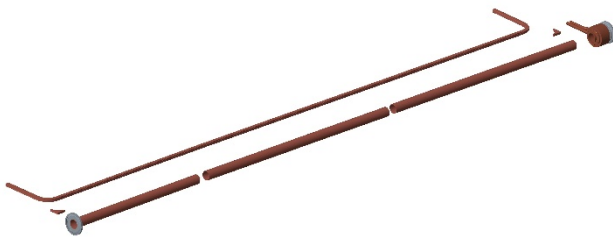


Figure 5: Major components of FODO chamber with central GlidCop segment for locally-high power loads.

### BPM RF Shielding Bellows Liners

The design of the liners for bellows integrated into BPM assemblies has been modified to an “outside finger” configuration by which the fingers make sliding electrical contact on the outside surface of the chamber and contact

force is provided by an external set of springs (Fig. 6). This type of design has been used to ensure tolerance to heating from induced electrical currents at PEP-II [5] and other high-current machines. Such a scheme is also less likely to fail catastrophically than one by which the fingers make contact on the inside of the chamber whereby they can be caused to deform into the beam path under overheating conditions. Furthermore, less BPM signal distortion is expected with outside fingers as bellows are compressed in operation since the location of the sliding contact is static with this design. A design by analysis using finite element simulation ensures that the flexible fingers, made of GlidCop due to its excellent thermal and mechanical properties, and with variable thickness to distribute stresses away from the root, will have sufficient strength. Under worst-case conditions, a 6 mm compression of a bellows with 1 mm lateral offset, stresses in the fingers are close to yield strength of non-work hardened material.

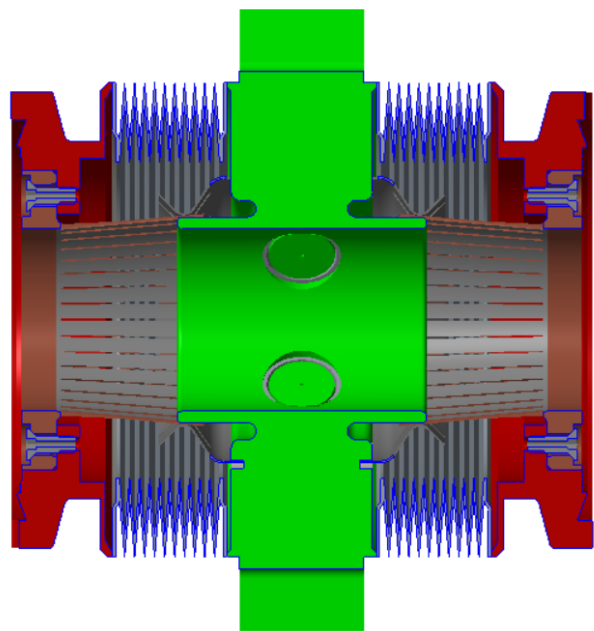


Figure 6: Cross section view from CAD model of BPM showing improved bellows shielding scheme.

### Photon Absorbers

In addition to the “inline” absorbers built into the downstream flange of many of the vacuum chambers, demountable photon absorbers are needed at both crotch locations and at the downstream end of each L-bend chamber. Preliminary designs have been established for these and analysis is underway to determine required materials, detailed geometry, and cooling water flow. To make best use of limited space inside magnets, many of the photon absorbers will have hollow bodies machined using die sinker EDM and brazed-in baffles to direct water flow (Fig. 7). CFD simulations are being done using COMSOL Multiphysics [6] to ensure adequate heat transfer.

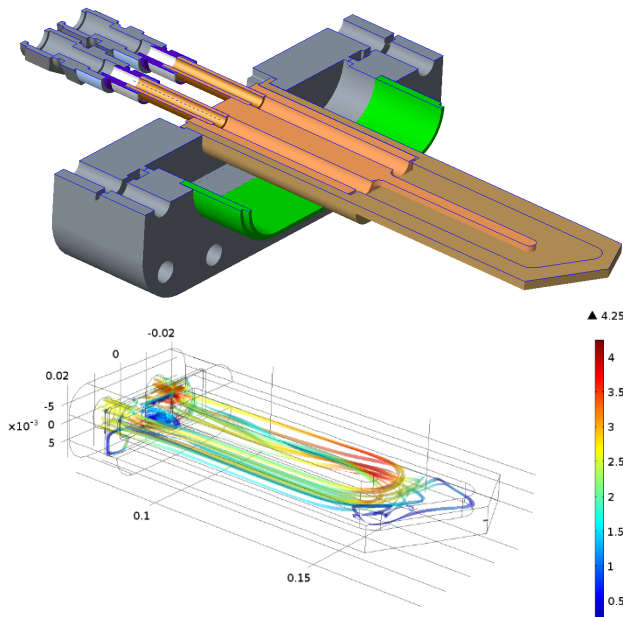


Figure 7: Cross section view from CAD model of a typical photon absorber with pocket and baffle scheme for cooling water circulation (top) and example of velocity field results from a CFD simulation (bottom).

## VACUUM SYSTEM INTEGRATION IN SPECIAL-PURPOSE STRAIGHT SECTIONS

Five straight sections in “Zone F” of the storage ring house injection and extraction systems, rf cavities, diagnostics, and feedback systems. CAD layouts (Fig. 8), and ray traces have been generated to best understand space constraints for new equipment, locate and design photon absorbers, and determine what other vacuum hardware is needed. Protection of narrow horizontal apertures is a particular concern, particularly at the upstream ends of these sections where shadows cast by absorbers are found by ray tracing to be relatively short on account of the sharply curved beam trajectory in the preceding portion of the arc.

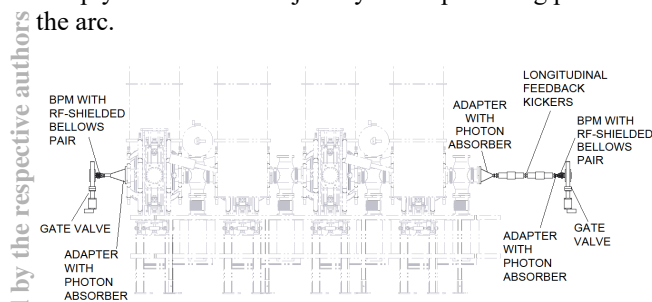


Figure 8: Example layout being used to plan new hardware in one of the five special-purpose straight sections.

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