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DISCLAIMER

STATUS OF NSLS-II STORAGE RING VACUUM SYSTEMS*

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Abstract

National Synchrotron Light Source II (NSLS-II), being constructed at Brookhaven National Laboratory, is a 3-GeV, high-flux and high- brightness synchrotron radiation facility with a nominal current of 500 mA. The storage ring vacuum system will have extruded aluminium chambers with ante-chamber for photon fans and distributed NEG strip pumping. Discrete photon absorbers will be used to intercept the un-used bending magnet radiation. In-situ bakeout will be implemented to achieve fast conditioning during initial commissioning and after interventions.

INTRODUCTION

NSLS-II storage ring, with a circumference of 792 m, has 30 double-bend-achromatic (DBA) cells [1]. In each cell, there are five magnet/chamber girders, and one straight section, with alternating length of 9.3 m and 6.6 m, for insertion devices, radio frequency cavities and injection. Due to the low bending field of 0.4 Telsa, the critical energy of the bending magnet radiation is only 2.39 keV. The radiation power from each bending magnet at the design current of 500 mA is 2.4 kW with a power density < 88 W/mrad^2. Therefore the unused bending magnet radiation can be intercepted by discrete absorbers at normal incidence. The insertion device photon fans, due to their high power density, are only trimmed at front ends.

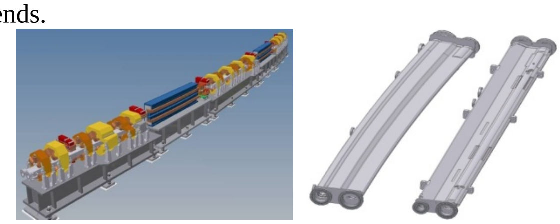

Figure 1: Models of NSLS-II DBA cells with a length ~ 20 m (excluding straight sections), dipole and multipole chambers.

The storage ring vacuum systems will be divided into 60 vacuum sectors with RF-shielded gate valves mounted at the ends of each straight section. The designed average pressure with beam is < 1×10^{-9} mbar. The beam lifetime due to beam-gas inelastic scattering is > 30 hr, much longer than the 3-hr Touschek lifetime. However, localized pressure bumps will produce bremsstrahlung radiation and damage the downstream beam line components, and have to be suppressed.

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VACUUM SYSTEM DESIGN

The design of the storage ring vacuum systems has to use proven, reliable and cost-effective technology already employed at other 3rd generation light source vacuum systems. The choice of the vacuum chamber materials depends on the machine requirement and, to a large extent, the expertise available. Aluminium has been the preferred material for a few light sources in the U.S and Asia, while stainless steel is widely used in Europe.

Due to the low bending field of 0.4 T in NSLS-II, the photon fan from the bending magnets has a small dispersion which allows a narrow chamber geometry design. Therefore, the cell chambers can be made of extruded aluminum with uniform cross sections. Extruded aluminum chambers have low impedance, good thermal properties, high mechanical strength, low magnetic permeability and reasonable cost. The need to accommodate the exiting photon fans and to provide NEG strip distributed pumping also favors extruded aluminum since an ante-chamber configuration can be incorporated.

Cell Aluminum Chambers

There are five aluminium chambers of < 4 m in length in each DBA cell with two cross sections as shown in Fig. 2. The two dipole chambers fit inside the bending magnet gap and the three multipole chambers are surrounded by quadrupole, sextupole and corrector magnets. The straight sections, prior to the installation of insertion devices, will also use the multipole chamber cross section. The electron beam channel has an elliptical shape beam-stay-clear (BSC) envelop of 76 mm (H) x 25 mm (V). The horizontal width of the dipole and multipole extrusions are 320 mm and 280 mm, respectively. The inner heights of the photon exit gaps are 15 mm for dipole and 10 mm for multipole. The ante-chamber geometries are a balance among the photon fan requirements, the minimum wall thickness, the pumping conductance, and to minimize magnet radii.

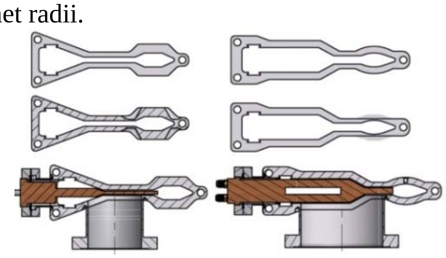

Figure 2: Extruded cross sections for multipole (left) and dipole (right) chambers; those after machining (middle) at sextupole location and in the dipole gap; and those at absorbers (bottom) with pumping ports.

The beam channel walls are machined after extrusion to accommodate the magnet poles. The minimum wall thickness of the dipole chamber is 3 mm, and the multipole chamber 2.5 mm at the sextupole pole locations while still maintaining a minimum spacing of > 2 mm between the chamber and the magnet poles. Finite element analysis of the stress and deflection gives a safety factor of > 2 in stress and maximum deflection of 0.3 mm x 2 at the photon exit gap. The extrusion ends are precision machined for welding to the machined adapter plates, and then on to the bi-metal (aluminium to stainless) Conflat flanges. Additional ports are added for beam position monitors (BPM), absorbers, ion pumps, vacuum gauges, etc. The cleaning and welding is carried out at APS vacuum facility by APS staff using their robotic welding machines.

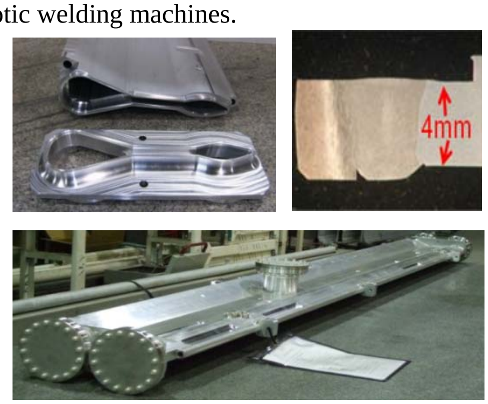

Figure 3: Machined extrusion end and the mating adapter plate (top left). Micrograph of the welds (top right), and the completed multipole chamber.

Weld development has been successfully carried out at APS for both cross sections using short extrusion pieces, and with different adapter plates, flanges and geometries. The most critical welds are those at top and bottom of the beam channel where excessive under-beading and over-beading will increase impedance and HOM heating. Figure 3 shows the micrograph of the weld zone cut out, with steps less than 0.5 mm. A multipole chamber was successfully completed and being tested for BPM mounting, alignment, thermal and mechanical stability, NEG strip activations and in-situ bakes.

Photon Absorbers

Due to the soft bend, both power and power density of the bending magnet radiation are relatively low as compared with other light sources. Therefore, the unused bending magnet radiation can be intercepted by discrete absorbers at normal incidence to shield and protect un-cooled downstream flanges and bellows. There are two types of absorbers; the crotch absorbers at end of dipole chambers with opening for the exiting ID photon fan, and the stick absorbers which trim the edge of the bending magnet fan. Both types of absorbers are made of GlidCop [2] and inserted horizontally from the ante-chamber side into the photon exit gap with tips of the absorbers ranging from 22 mm to 32 mm from nominal beam center. The absorbers will protect chambers from abnormal beam steering (up to ± 0.5 mm and ± 0.25 mrad), and the mechanical alignment/tolerances (up to ± 1.5 mm). The crotch absorbers will intercept less than 1.5 kW with power density < 12 W/mm^2 and T < 200^o C at the tip, while the stick absorbers intercept less than 800 W with power density < 3 W/mm^2 and T < 70^o C at the tip, well within the allowable limits for GlidCop. Additional absorbers or masks will be implemented at downstream end of each insertion device to shield vacuum components from abnormal beam steering. Ion pump and titanium sublimation pump are mounted directly underneath each absorber with ~ 200 l/s speed to pump the desorbed gas. Nominal pumping speed of over 100,000 l/s is provided by ion pumps, titanium pumps and NEG strips for the ring.

Using the photon flux intercepted by the absorbers, the chamber geometry and the pumping locations, pressure profiles inside the beam channel are calculated using MOLFLOW Code [3] for two scenarios, with and without canted damping wigglers (DW). The high radiation power and wide fans from DW with large canting angles require trimming ~ 20 kW off DW fans at the beginning of the front end (downstream of the photon exit port), as shown in Fig. 4. The desorbed gas from the DW absorber creates a localized high pressure zone in the beam channel. However, the average ring pressure is little affected since only two long straight sections will have canted DWs. The calculated pressure profiles shown in Figure 5 do not include contribution from scattered photons or vertical photon fans from certain insertion devices. They hit on less-conditioned surfaces which have much higher photon stimulated desorption (PSD) yields.

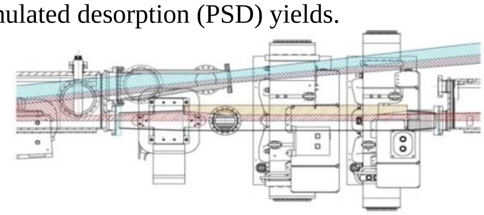

Figure 4: Top view downstream of 1st dipole, showing photon fans from bending magnet and canted DWs, which are trimmed by DW absorber, before entering front end.

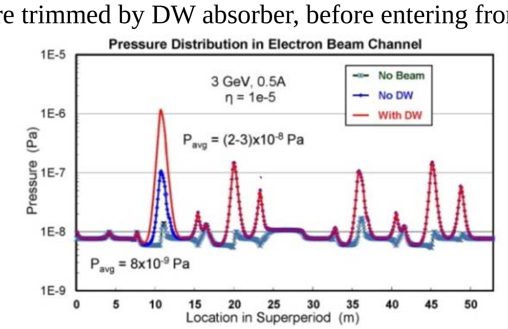

Figure 5: Pressure profiles with and without canted DW, with PSD yield of 1x10^{-5} after 100 A.hr beam conditioning. Average pressure of < 1x10^{-9} mbar is achievable since only two sets of DW will be canted.

RF Shielded Bellows

RF shielded bellows will join the adjacent cell chambers to form the complete vacuum sectors. The RF bellows has to accommodate the following requirements: lateral offset of ± 2 mm, compression & expansion of + 15 mm & - 10 mm, and angularity of ± 15 mrad. They allow for the manufacturing tolerances, flange assembly, BPM alignment and thermal expansion during in-situ bake. More importantly, the RF bellows has to have low impedance and losses with the intense electron beam under these adverse mounting conditions. We have studied bellows employed at other light sources, with inside and outside RF fingers [4, 5]; and concluded that bellows with outside fingers should offer lower impedance with the above lateral and angular offsets. Models of RF bellows with wider (and fewer) fingers were generated and a prototype made as shown in Fig. 6. Impedance calculation [6] gives a loss factor of less than 4×10^{-2} V/pC even with ± 2 mm offset, five times less than that of inside fingers with same offset condition. Thorough mechanical testing will be carried out for its ease of assembly, flexibility and reliability.

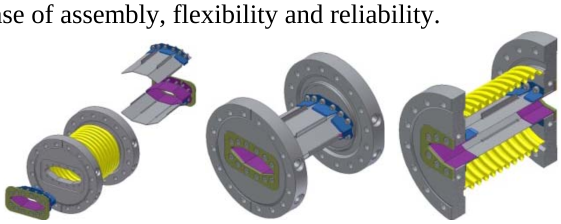

Figure 6: Prototype RF bellows with wide outer GlidCop fingers (gray), captured between outside inconel springs (blue) and inner stainless sleeves (purple).

NEG Strips and Supports

NEG strips of St707 alloy from SAES Getters will be mounted at the top and bottom of the ante-chambers, as shown in Fig. 7, to provide distributed pumping for active gases. The NEG strips with pre-punched holes are riveted with alumina insulators at 10 cm intervals, on to stainless steel carrier plates which ride in the extruded channels in the ante-chamber. The prototype support system has been successfully tested in the prototype chamber through many activation cycles.

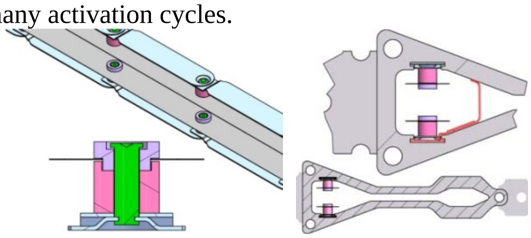

Figure 7: Top & bottom NEG strips with stainless rivet (green) and alumina bushings (pink and purple) on stainless carriers (light blue) at 10-cm intervals; and the proposed BPM RF shield (red at right) using modified NEG support carrier plates, positioned at 150 mm from beam center.

In-Situ Bake

The cell vacuum chambers and other appendage components will be in-situ baked to ~ 130^{o} C for fast conditioning during initial commissioning and after interventions. After extensive survey of various bakeout options, such as the high pressure, high temperature water system used at APS and SPring8, we have elected to use long cal rod type heaters of 10-mm ϕ inserted into one of the 12-mm ϕ unused cooling channels at ante-chamber side. More than 1 kW/m power can be attained with these low cost commercial heaters and temperatures over 120^{o} C can be achieved without thermal insulation around the chamber. Additional heaters will be installed at ion pumps, RF bellows and large flanges to achieve overall temperature uniformity.

Mitigation of BPM Rouge Modes

Some BPM signals at APS have been compromised by the transverse electrical (TE) mode type resonances. Similar resonance frequencies ranging from 400 MHz to 1.5 GHz have been measured in NSLS-II multipole chambers [6]. Simulation using GdfidL Code has identified these resonance modes are those due to the electric field inside the photon exit gap into ante-chamber volume. One possible remedy is to provide partial RF shields in the ante-chamber, thus shifting the starting frequency to over 550 MHz, the NSLS-II RF frequency. A schematic of the proposed BPM shields using modified NEG strip carriers is shown in Fig. 7. The distance of the modified carrier plates/shields to beam center is 150 mm, well outside the path of the SR fan. The modified carrier plates will be grouped into 50cm long sections and equally spaced with regular plates. Simulation indicates that the starting frequency will be higher than 540 MHz. Full models and prototypes will be fabricated for evaluation and measurement to ensure their adequacy with beam and with repeated NEG activations.

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REFERENCES

[1] S. Krinsky, et al., "Accelerator Physics Challenges for NSLS-II Project", this conference.
[2] GlidCop is a registered trademark of OMG Americas Corp., Research Triangle Park, NC, USA.
[3] R. Kersevan, "MOLFLOW User's Guide", Sincrotrone Trieste Tech Report, ST/M-91/17 (1991).
[4] J. Jones, S. Sharma, D. Bromberek, "APS SR Flexible Bellows Shield Performance", PAC99, New York, p3095 (1999).
[5] M.E. Nordby, N. Kurita, L-K. Ng, "Bellows Design for PEP-II High Energy ring Arc Chambers", PAC95, Dallas, p2048 (1995).
[6] A. Blednykh, et al., "Suppression of Rogue Modes in Multipole Vacuum Chambers", NSLS-II Tech Note, May 2009.