APS-Upgrade Storage Ring
Vacuum System Design

APS Upgrade Accelerator Vacuum Group
October 15, 2014
Outline

- APS Upgrade
- APS-Upgrade Vacuum System Design
- Ray tracing
- Vacuum chamber design
- Vacuum pressure simulations
- R&D plans for a vacuum chamber sector mockup
The Upgrade is evaluating a completely new DLSR (Diffraction Limited Storage Ring) magnet lattice and vacuum system.
APS Upgrade Vacuum System - Scope

- APS Upgrade Multi Bend Achromat Magnet Lattice
  - 1104 meters circumference
  - 40 sectors, each sector is the same lattice
  - 35 sectors have both an ID and BM photon source
  - 5,000 scientists per year

Comparison inspired by C. Steier

Dramatically enhance the performance of the APS as a hard x-ray source

Particle Beam Profiles

1 mm
Preliminary APS MBA fill patterns

- Total beam current is expected to be 200 mA at 6 GeV
- Fill patterns with 48 to 324 bunches will be possible
- Various timing patterns should be possible with up to 4.2 mA/bunch
- Parameters subject to change

### 6 GeV

<table>
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<tr>
<th></th>
<th></th>
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<th>mA</th>
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<tr>
<td>Total current</td>
<td>$I$</td>
<td>200</td>
<td>200</td>
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<tr>
<td>Number of bunches</td>
<td>$N_b$</td>
<td>48</td>
<td>324</td>
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<tr>
<td>Bunch current</td>
<td>$I_b$</td>
<td>4.2</td>
<td>0.6</td>
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<tr>
<td>Bunch rate</td>
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<td>88</td>
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<td>Rms bunch duration</td>
<td>$\sigma_t$</td>
<td>70</td>
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Basic Design Scheme, typical sector

- **27 Beam chambers**
- **Vacuum pumps**: 7 Discrete active pumps, NEG strips in L-Bend ante-chambers, NEG coating in FODO section between gate valves.
- **Quad doublet**: Chamber is a simple spool. Magnets incorporate fast correctors.
- **L-bend**: Magnet is C-shaped, we can use APS-style Al extrusions with antechambers.
- **Multiplet**: Space is tight except for two ~250 mm gaps between adjacent magnet per section. There is also a light synchrotron heat load (~100 W/m). Simple spools with water cooling are used except where x-ray extraction requires a wider “key-hole” geometry.
- **FODO**: Distributed absorber, and cooling. Average thermal load (~1–1.5 W/mm). Required thermal performance suggests high-strength Cu chambers.
- **ID Chambers**: Aluminum extrusions, ante chambers, NEG strips, design by ID group. May be a long-term interest in small diameter chambers -6 mm round.
Synchrotron Radiation Ray Trace: Heat Loads

- Ray traces initial performed with CAD program and analytically.
- Total thermal load due to radiation per sector is 11.2 kW.
- Bending magnet radiation power is concentrated in the center (FODO) section and at the ends (close to the ID beam), distributed power in FODO section is 4.5 kW.
  - Glidcop in-line absorbers needed in FODO section to shadow downstream flanges and bellows.
  - Maximum power density on the FODO section chamber wall is ~20 W / mm².
  - Maximum power density on an in-line absorber is ~50 W/mm².
- In addition we need BM crotch absorbers. These discrete absorbers will receive 2.2 kW of power and will be located in the antechambers of L-bend chambers.
Vacuum chamber design

- Example chamber design for high thermal loads.
  - 6 FODO chambers per sector, chambers between 500-1600mm length
  - Radiation load is 1-1.5 W/mm length or ~11 W/mm^2
  - Straight and bent chambers: 3/6 chambers have a curvature
  - Current plan is 4/6 chambers NEG coated (central 4 chambers)
  - OFS copper and or Glidcop stubs at each end,
  - Joining methods: brazing or welding TBD
  - CF/QCF flanges
  - Inner Diameter: 22mm, 2 chambers have key hole geometry for photon extraction.

VC18 vacuum chamber
1.6 m long
Vacuum design and implementation

- 3-D Vacuum simulations
  - Parameterized Solid model for Design
- Flange tests and evaluation of flange to chamber bonding techniques
- Sector mockup
  - Fabrication of a sectors worth of vacuum components for testing
    » Quad doublet, stainless steel chamber
    » Multiplet chambers, extruded aluminum with water channel
    » L-Bend chambers with waters channels and ante-chamber for NEG strips
    » FODO chambers, NEG coated copper
    » BPM assemblies, supports, photon extraction to front ends
    » Assembly and testing procedures
- Impedance bench measurements
- Impedance measurement with beam – NEG coated ID chamber
Vacuum design and implementation

3-D Vacuum simulations to develop sector pressure profiles

- Working with SynRad and MolFlow+ from CERN.
  - Developing detailed 3-D simulations for the entire sector.
  - Parameterized CAD model is used to define the chamber and absorber geometries.
  - SynRad generates power loads at absorbers and chamber walls.
  - MolFlow used for pressure analysis at absorbers and the entire sector.

Power deposited on Absorber
ID chamber Pressure
Sector pressure profile
Vacuum pressure profile with 3-D simulation tool

After 20 days less than 1 nTorr
Vacuum design and implementation

- Parameterized solid model design.
  - Parameterized Solid model for Design

Leveraging Parametric Computer-Aided Design (CAD) for Efficient Optimization of a Storage Ring Vacuum System Design for the APS Upgrade (19109)
Vacuum design and implementation

- Flange tests and flange to chamber bonding techniques.
  - Chamber material to Stainless Steel 316L Flange bonding techniques.

<table>
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<tr>
<th>Qty</th>
<th>Flange Ends</th>
<th>Tube 1</th>
<th>Tube 2</th>
<th>Tube-Tube Bond</th>
<th>Tube-Flange Bond(s)</th>
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<tr>
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<tr>
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<td>Bi-metal Al 2219</td>
<td>TIG (Al to Al)</td>
<td>TIG/TIG (SST to SST)</td>
</tr>
</tbody>
</table>

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Vacuum design and implementation

- Sector mockup
  - Fabrication of a sectors worth of vacuum components for testing
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