IPAC21

Poster THPAB085

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STATUS OF INSERTION DEVICE TUNING FOR THE APS UPGRADE*

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ABSTRACT

The Advanced Photon Source Upgrade (APS-U) project is developing a multi-bend achromat (MBA) lattice at 6.0-GeV beam energy to replace the existing APS storage ring lattice operating at 7.0 GeV. One of the key components of the project is to design, fabricate, and install optimized insertion devices (IDs) for 35 beamlines. A plan was developed to standardize on four new undulator period lengths for 44 new undulators and to reuse 23 existing undulators with four more different period lengths

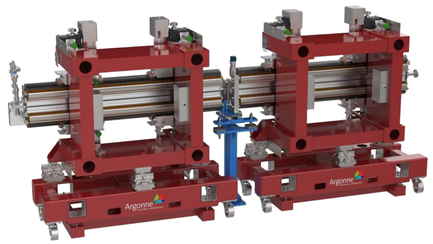
Early in the Upgrade project we anticipated there would be large challenges in meeting the tight fabrication and tuning schedules so that all undulators would be ready for installation in the upgraded storage ring prior to beam commissioning. With recent developments and techniques used in the magnetic measurement laboratory, we have successfully tuned many of the new and reused undulators to demanding magnetic field requirements. We will report on the tools and techniques used and on results to date.

INTRODUCTION

- New Hybrid Permanent Magnet Undulators (HPMUs) were designed and fabricated for about two thirds of the beamlines
- A combination of legacy (old) undulators and new undulators will be used

Magnetic Per. (cm)/Min Gap (mm)	Total	Comments
3.3 / 10.0	3	Existing IDs
3.3* / 10.0	6	Existing canted IDs
3.0 / 9.0	3	Existing IDs
3.0* / 9.0	3	Existing canted IDs
2.7 / 8.5	2	Existing IDs
2.7* / 8.5	3	Existing canted IDs
2.3 / 8.5	2	Existing IDs for 2 revolvers
2.3* / 8.5	1	Existing canted IDs
Existing	**23**	
2.8 / 8.5	3	New IDs
2.8* / 8.5	9	New canted IDs
2.5 / 8.5	9	New for 2 IDs & 7 revolvers
2.5* / 8.5	3	New for 3 canted revolvers
2.1 / 8.5	10	New for 3 IDs & 7 revolvers
2.1* / 8.5	5	New for 2 canted IDs & 3 revolvers
1.4 / 8.5	2	New IDs for 2 revolvers
1.35 / 8.5	2	New IDs
1.35*/ 8.5	1	New canted ID
New	**44**	
Total	**67**	

Model new standalone ID (GSM in gray)



Model new revolver ID (GSM in red)

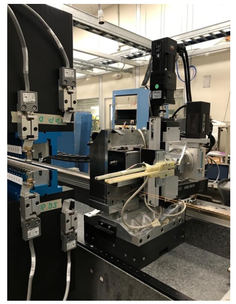
TUNING PHASES

- Phase 1 – Prior to the storage ring shutdown (shut-down planned for April 2023)
- Phase 2 – During the 12-month shutdown (for removal and installation of components and commissioning of the new storage ring)

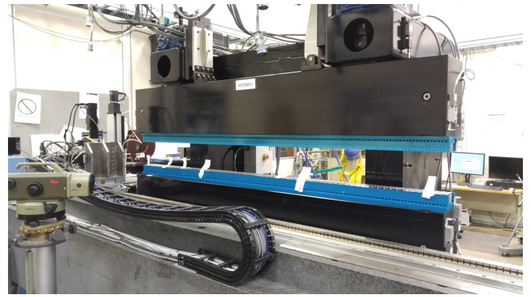
Many of the gap separation mechanisms (GSMs) will be reused due to substantial cost savings and will be harvested at the beginning of phase 2, causing many of the IDs to undergo their final tuning during phase 2.

MAGNETIC MEASUREMENT LABORATORY

- Two granite benches (3 m and 6 m long)
- Capacitec probe systems for pole/magnet height and gap measurements
- Fast scanning 2D Senis Hall probe systems for field measurements
- Coil systems for integrated field measurements



Hall probe and Capacitec probe



APS28#1S on 3 m bench

APS28#7 on 6 m bench

TUNING TECHNIQUES

- Optional gap tuning (from Capacitec scans)
  Uses mechanical shims with placement from Capacitec measurements (if necessary)
- Trajectory tuning (from Hall probe scans vs. gap)
  Uses primarily side shims supplemented with surface shims, if needed. Placement from optimization code
- Phase tuning (from Hall probe scans vs. gap)
  Uses wide surface shims or mechanical shims. Same code for trajectory tuning also works for phase tuning with surface shims. Phase-based optimization code is used for mechanical shimming.
- End angle tuning (from Hall probe scans vs. gap)
  Uses side or surface shims. A search algorithm finds the best combination of shims to correct the end angles
- Integrated field multipole tuning (from translating coil scans vs. gap)
  Uses side or surface shims and the same search algorithm that is used for end angle tuning

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DESIGN FEATURES

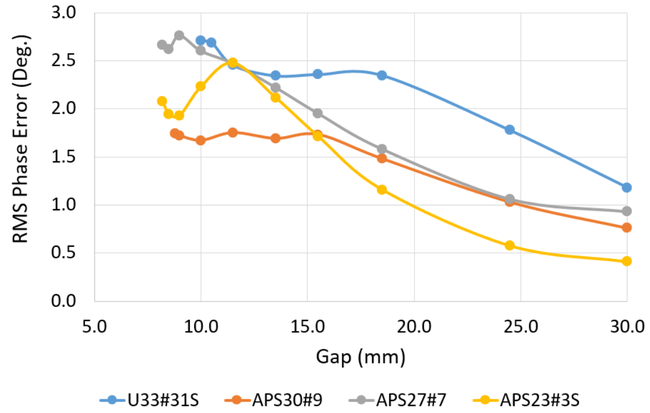
Realistic tuning schedule due to recent tuning technique developments and the following design features and efforts for new IDs.

- 12 new revolver GSMs fabricated
  The revolver IDs undergo final tuning prior to the APS shutdown
- 10 regular GSMs available for swapping magnet structures
  6 new and 4 spare GSMs used for pre-tuning prior to the APS shutdown
- New mechanical design
  Single magnet keepers (mono-keepers) machined with extreme accuracy
  Mono-keepers mounted on either new super-strongbacks or new baseplates (using old strongbacks)
  Magnets and poles fabricated with high accuracy
  Magnetic properties tightly controlled (moments, north/side field difference)
  Narrower magnets and poles → lower forces and gap-dependent deflections
  Design proven because only limited phase error tuning was required for the IDs with super-strongbacks (2 of 12 needed minor phase tuning)
- Phase shifters
  With magnetic shields to isolate them from IDs

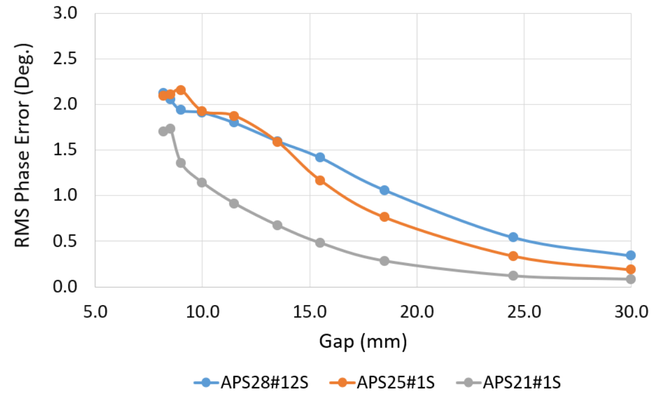
TUNING SCHEDULE

- Tuning completed to date
  Final tuning of 9 legacy IDs
  Pre-tuning all 12 new 28-mm-period IDs (plus one extra), one 25-mm-period ID, and one 21-mm-period ID
- During the five remaining storage ring maintenance periods before the APS shutdown continue to swap out IDs from the ring to complete final tuning of most of the 23 legacy IDs
- Continue to pre-tune the new IDs and complete final tuning of all revolver IDs
- High quality magnets
  Sorting not necessary → provides valuable time saved during assembly
- Measurements scripts developed for automatic gap scans for both magnetic measurement systems → provides valuable time saved during measurements

RESULTS



RMS phase error vs. gap of four tuned legacy IDs with 33 mm, 30 mm, 27 mm, and 23 mm period lengths



RMS phase error vs. gap of three tuned new IDs with 28 mm, 25 mm and 21 mm period lengths

CONCLUSION

- Efficient magnetic tuning procedures and techniques were developed and successfully deployed for both legacy IDs and new IDs
- Estimate tuning takes about one week/device for new IDs and up to two weeks/device for legacy IDs
- Final tuning of a pre-tuned device is expected to take less than one week for either type of device
- Most time-critical period is during the APS shutdown, with about nine months available to harvest the GSMs from the storage ring, install pre-tuned magnet structures onto mated GSMs, and complete final tuning
- With recent developments and experience we are optimistic that the tight tuning schedule can be met