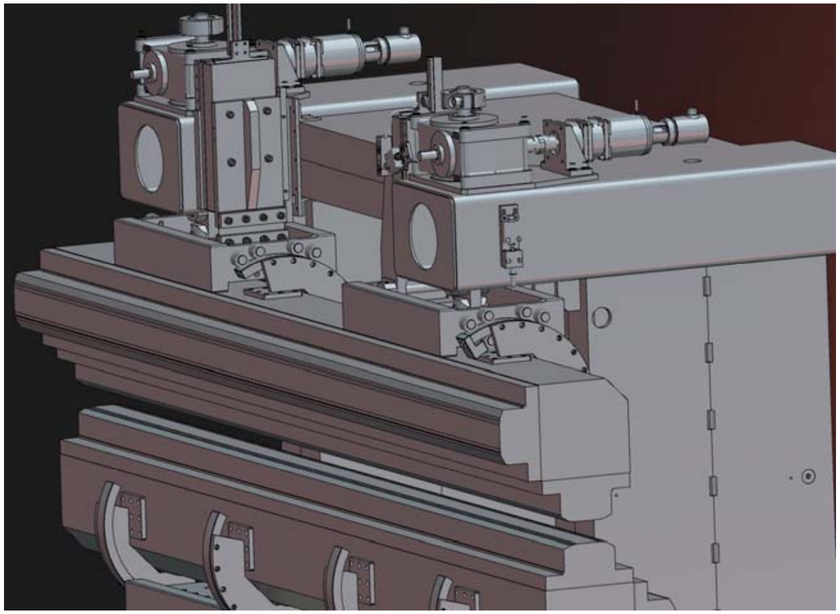
Special Purpose Undulators

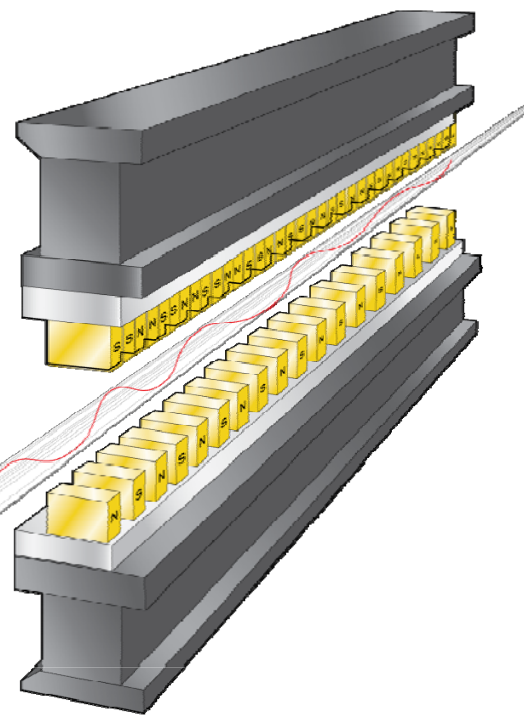
- Overview of Existing APS Undulators
- APPLE II Undulators: What are they, why use them, what are the challenges, project status
- Revolver Undulators: What are they, why use them, what are the challenges, project status
- Acknowledgements



Overview of Existing APS Undulators

Currently Installed at the APS:

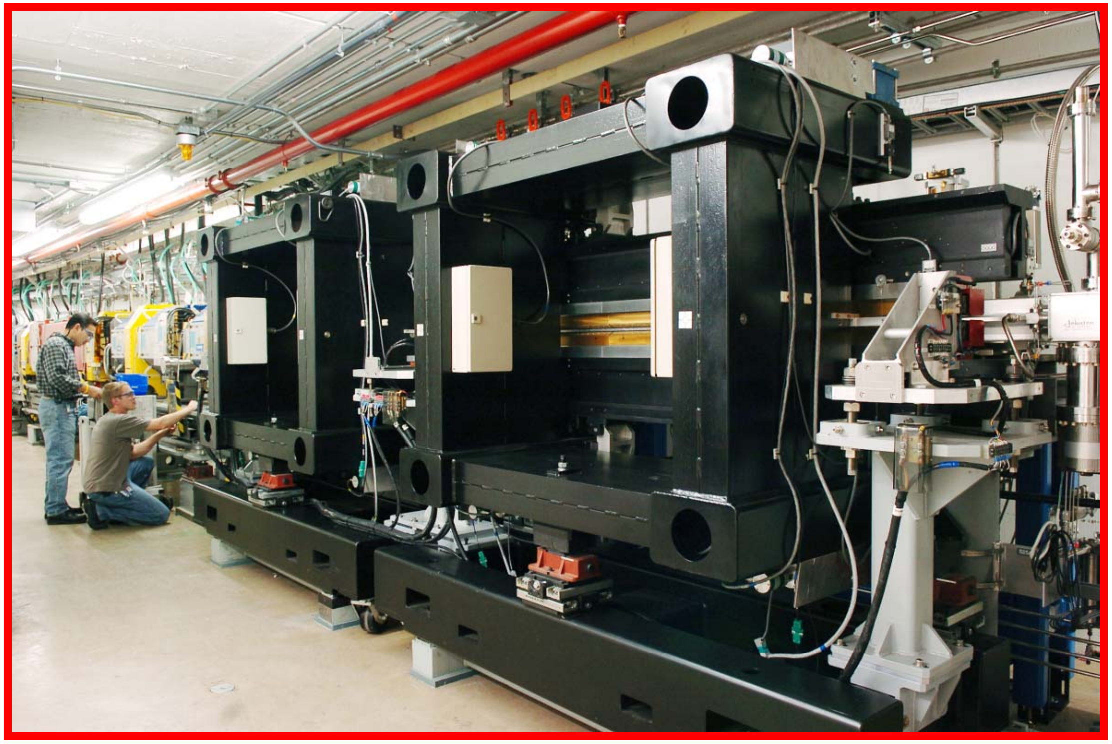
- 46 moving-gap, planar, hybrid permanent magnet undulators are installed.
- 1 fixed-gap, helical, electromagnetic undulator (CPU).
- Two different gap separation mechanisms are used: 20 undulators use a 2-motor mechanism supplied by STI Optronics and 26 use a 4-motor mechanism designed by Emil Trakhtenberg and assembled at the APS.
- Both mechanisms allow the gap to be fully tapered from one end to the other. The usable taper is limited through software to 5mm.
- Admirable record of accurate, safe and reliable operation.



Overview of Existing APS Undulators

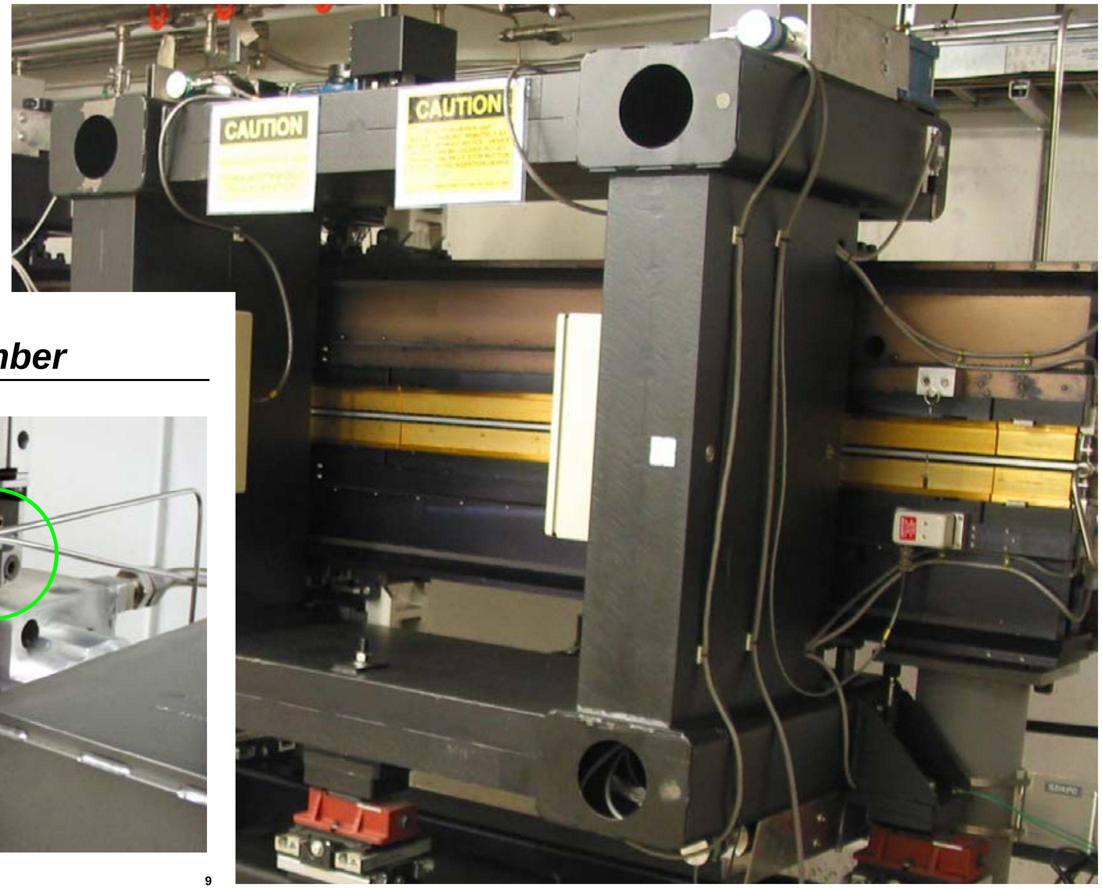
Currently Installed at the APS:

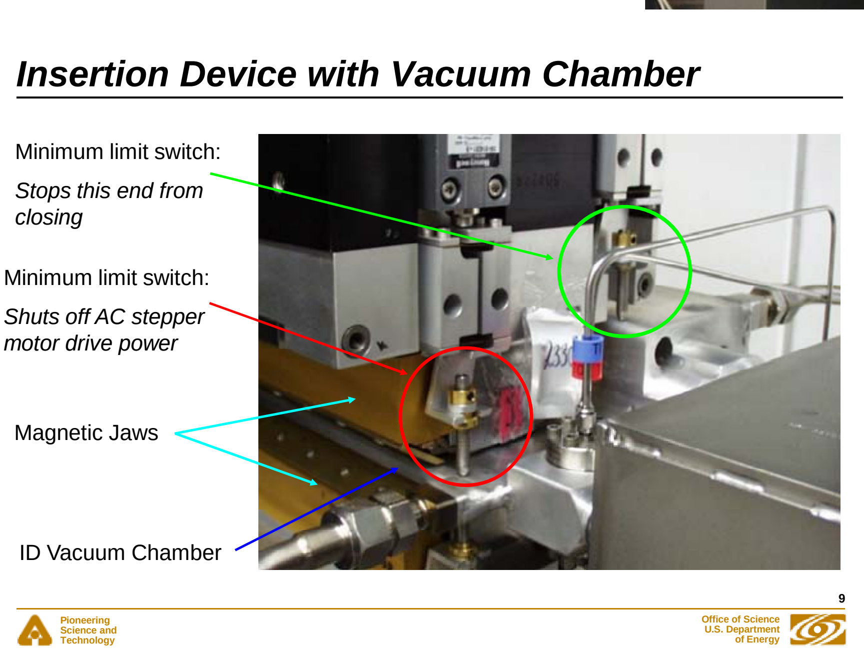
- 35 magnetic structures were designed and built by STI Optronics; 4 different periods; most are 3.3 cm period.
- 11 magnetic structures were designed and built by APS; 4 different periods; modular for use full-length or shortened in dual, canted undulator sectors.



Overview of Existing APS Undulators

Full-length 3.0 cm Period Undulator with 4-motor Gap Separation Mechanism

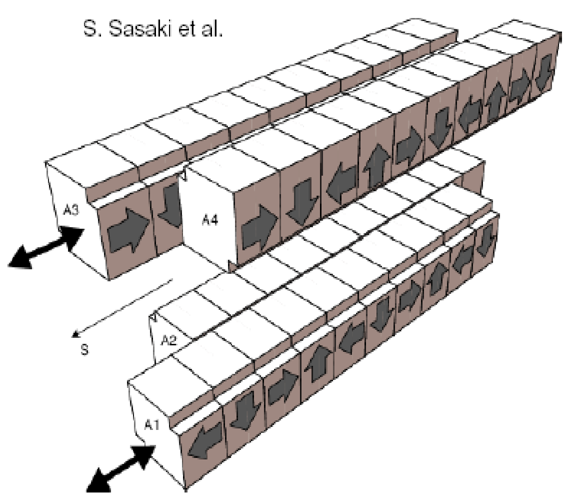


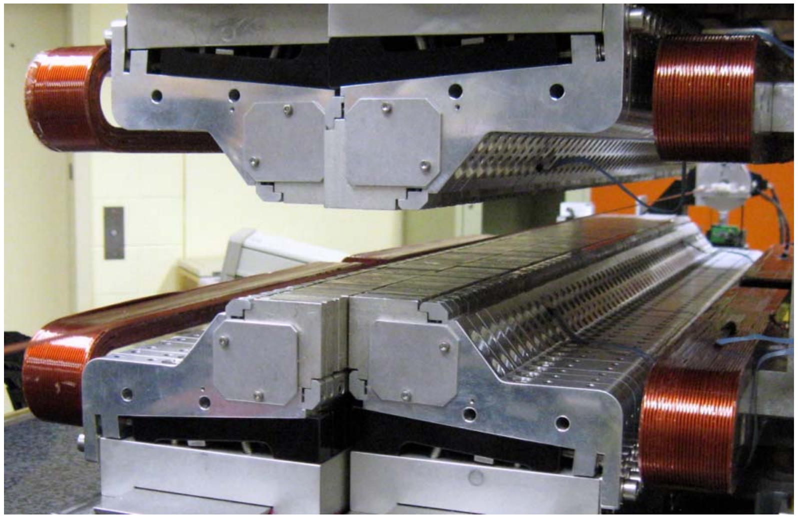


APPLE II Undulators

What's an APPLE II?

- APPLE stands for "Advanced Planar Polarized Light Emitter," which encompasses methods of providing both vertical and horizontal magnetic fields from planar magnetic arrays located solely above and below the electron beam plane
- An APPLE II is the second evolution of magnetic block geometry and direction for an APPLE undulator.

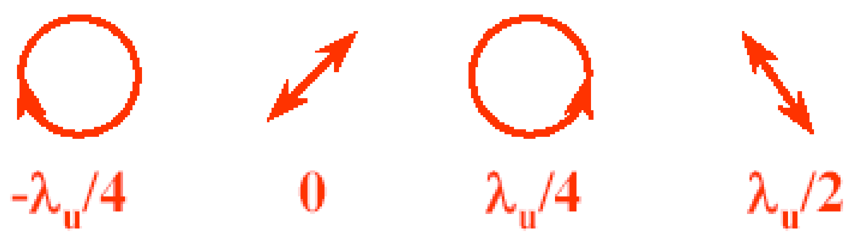




APPLE II Undulators

Why select an APPLE II as a source at the APS?

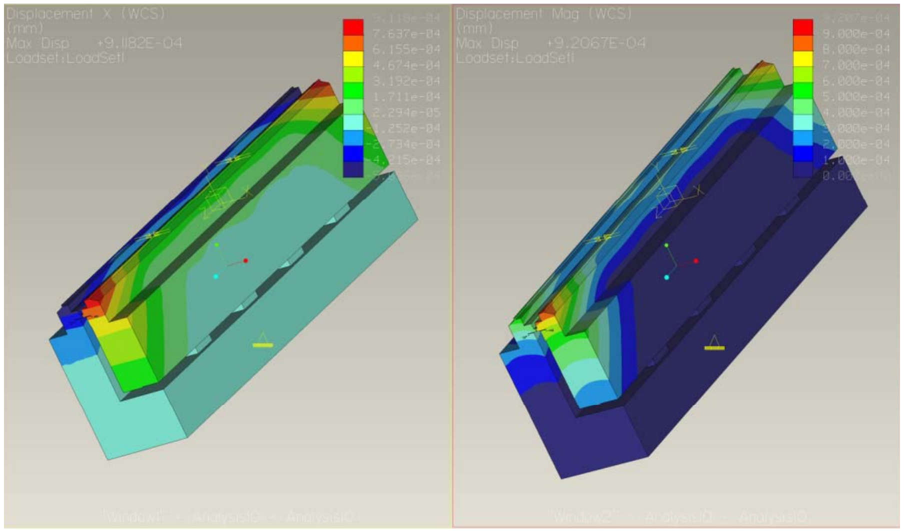
- The user is doing magnetic studies and wants the different polarizations, particularly reversible circular polarization.
- The user wants a circular undulator because the unwanted power is in a ring around the beam axis and can be masked off, reducing the heat load on the beamline. The circularly polarized light is not a factor, pro or con, in the source selection.
- The user wants a single photon energy, without higher harmonics. A circular undulator gives just the first harmonic photon energy on axis.



Challenges of Designing, Building and Tuning an APPLE II Undulator

Mechanical and Alignment Issues

- Magnet and magnet block (holder) design- safety, convenience, alignment accuracy, fit to vacuum chamber, etc.
- Stability and accuracy of phase change over all degrees of freedom
- Empirical verification of magnetic forces; design criteria for structures
- Stability and accuracy of gap and gap change, ideally for all phase positions
- Commonality of gap separation mechanisms with other APS undulators
- Self-locking or low-friction (freely backdriving) phase and gap drives (possibly different from each other)
- Mechanical stops for drive axes
- Gap tapering accommodation?



Challenges of Designing, Building and Tuning an APPLE II Undulator

Controls and Electromechanical Issues

- Open or closed-loop control of phase and/or gap
- Resolution of phase feedback and phase drive motor (if stepper)
- Safety of gap and phase change
- Barebones controls platform for development work vs. final controls configuration
- Control of field correction

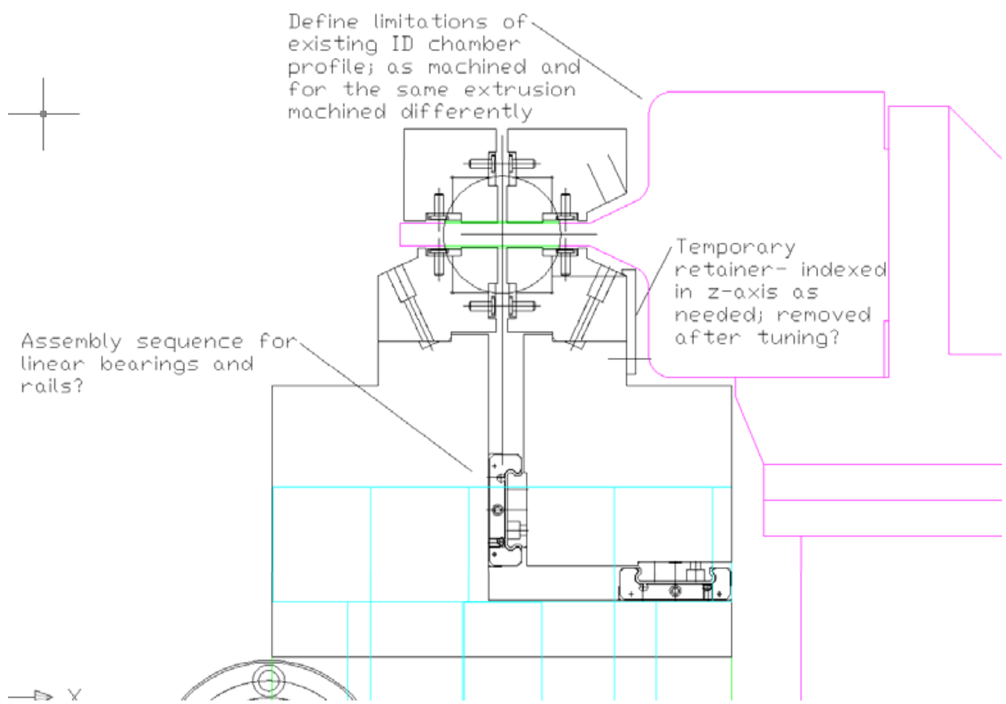
Magnetic Measurement and Tuning Issues

- Magnet swapping
- Field shimming
- End correction/field tapering/magic fingers- likely need active correction for transients
- Ease and accuracy of magnetic measurement for horizontal and vertical field components
- Gap dependency of tuning

APPLE II Prototype Project

The original approach of the prototype envisioned 5 stages:

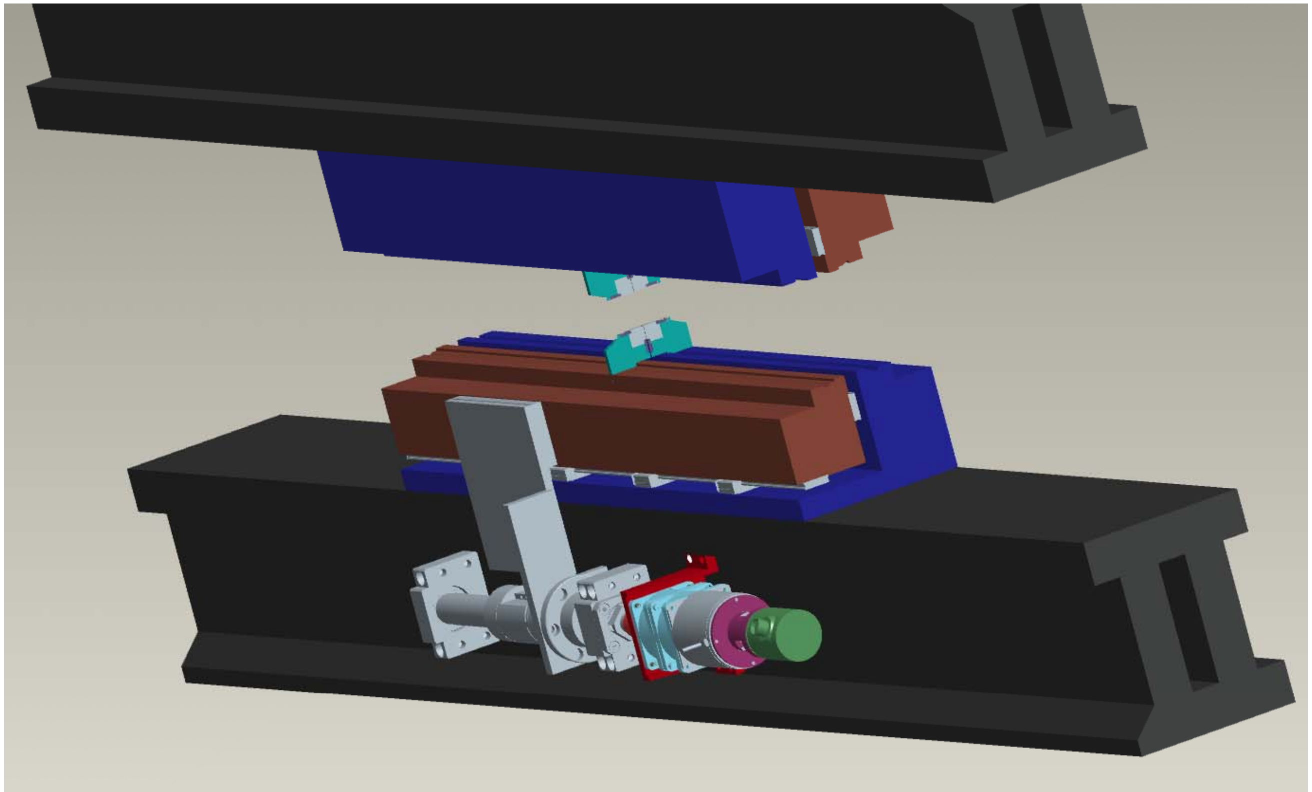
1. Design, procure and assemble magnets, magnet holders and magnet platens for device of ~.1m length; refine design of these components after assembling and measuring/tuning them
2. Add phase guides and non-motorized phase shifters, and fully populate 4 magnetic arrays of ~.2m length set at fixed gaps
3. Add some method of non-motorized gap separation capability
4. Add encoder feedback to stage 3
5. Motorize gap and phase drives



APPLE II Prototype Project

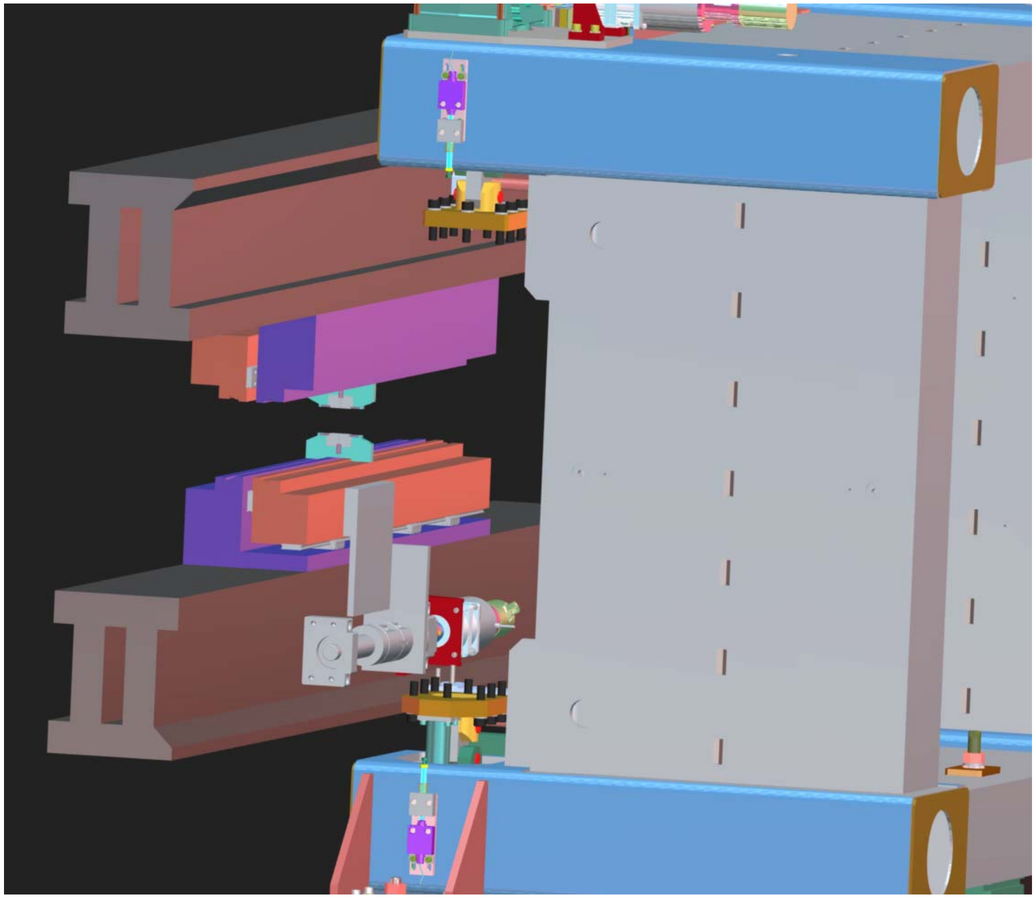
The current approach is to use an existing gap separation mechanism and a set of strongbacks for our planar, hybrid undulators.

- A variation of the normal gap drive and a preloaded ballscrew will be added to each strongback as a phase drive.
- The maximum gap will be limited to ~80-90 mm.



APPLE II Prototype Project

- Prototype can serve as a viable test bed for end correction and field tapering schemes
- We can intentionally weaken the magnet platens, if necessary, to get empirical measurements for design of the actual APPLE II platen, strongback and gap separation mechanism structures.



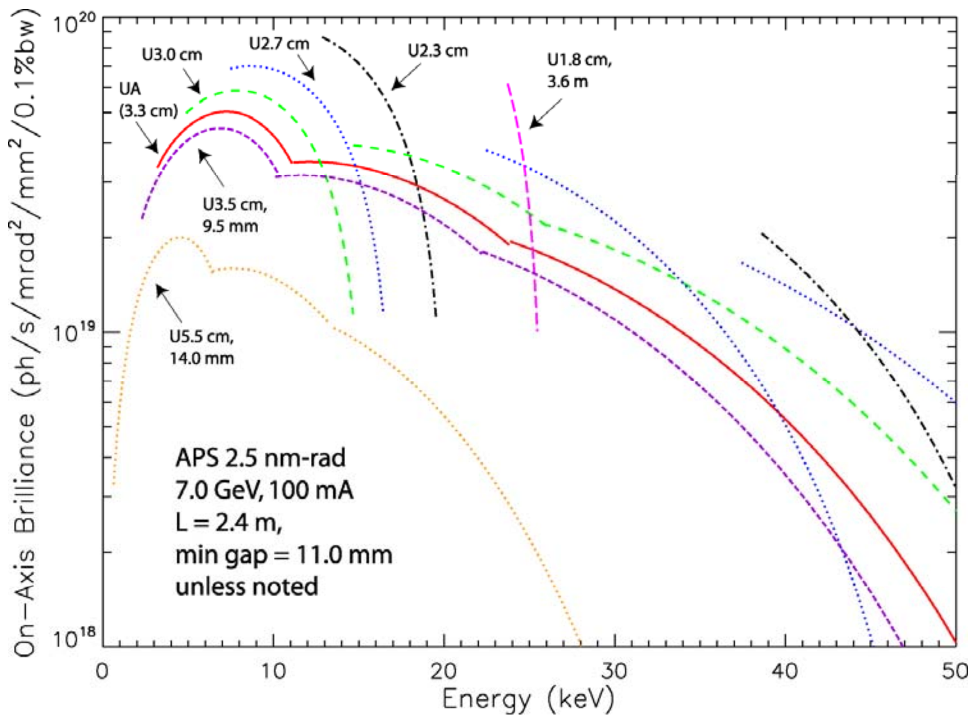
APPLE II Prototype Upcoming Tasks

- Update mechanical design to reflect magnet geometry optimization from recent magnetic design work (3.0cm period, M. Jaski).
- Period for prototype will likely be 2.7cm, so at least one more round of magnetic analysis will be needed.
- Design, procure and assemble magnets and magnet holders for a device of ~.1m length on fixed and phase-shifting magnet platens of ~1m length mounted to strongbacks.
- Refine design of these components after assembling and measuring/tuning them
- Next steps based on results, user priorities and available funding.

Revolver Undulators

What are they and why use them?

- Revolver undulators have 2 or more sets of magnetic structures of different periods arranged radially about an axis parallel to the beam direction.
- Revolver undulators offer a broader tuning range than a single undulator and/or more photons at specific energies than a single undulator.
- As envisioned for the APS upgrade, revolvers would address some requests that would otherwise require long straight sections.



Revolver Undulators

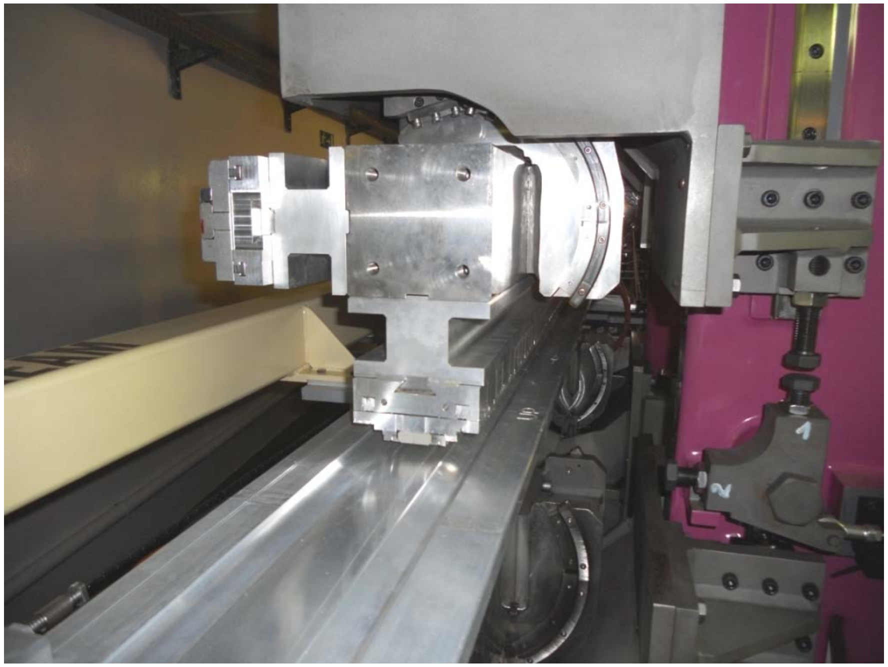
ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

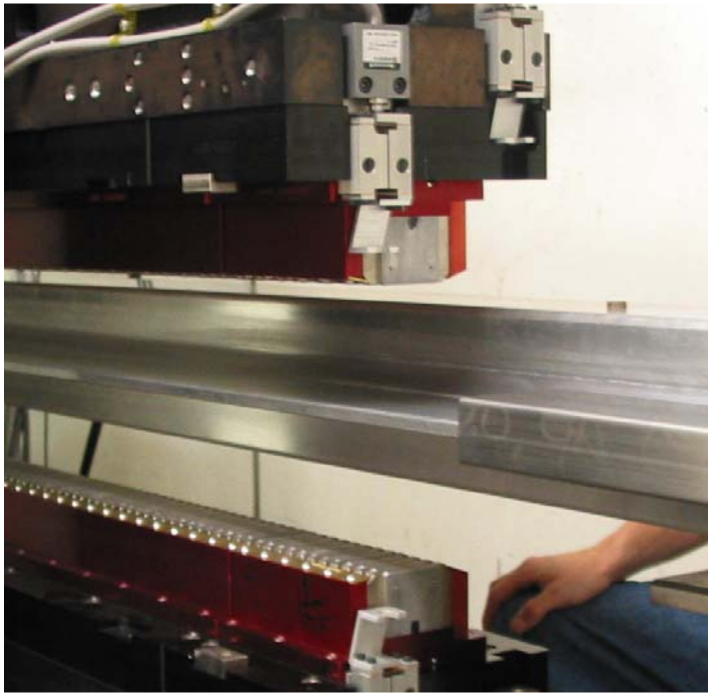
- These first-generation revolver undulator support mechanisms at ESRF used a strongback **supported from the ends**, allowing 4 separate magnet structures.
- This design has been abandoned in favor of one supported at intermediate points to allow longer active ID length and to allow better phasing of adjacent undulators.

Revolver Undulators

ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

- The current ESRF revolvers have 2 separate magnet structures, but an evolution of that design with 3 magnet structures is being built.
- The ID vacuum chamber at ESRF is flatter than the APS design, affording clearance for a revolver with 3 magnet structures.
- The APS ID vacuum chamber has a replaceable NEG material in strip form located in a large antechamber. The ESRF design has the NEG material coated directly on the beam aperture.

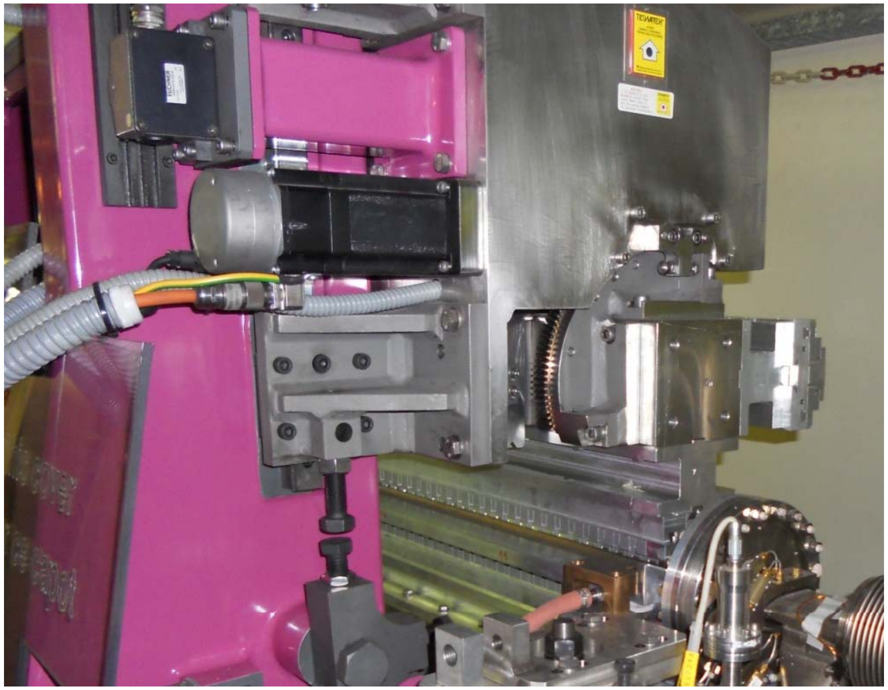




Revolver Undulators

ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

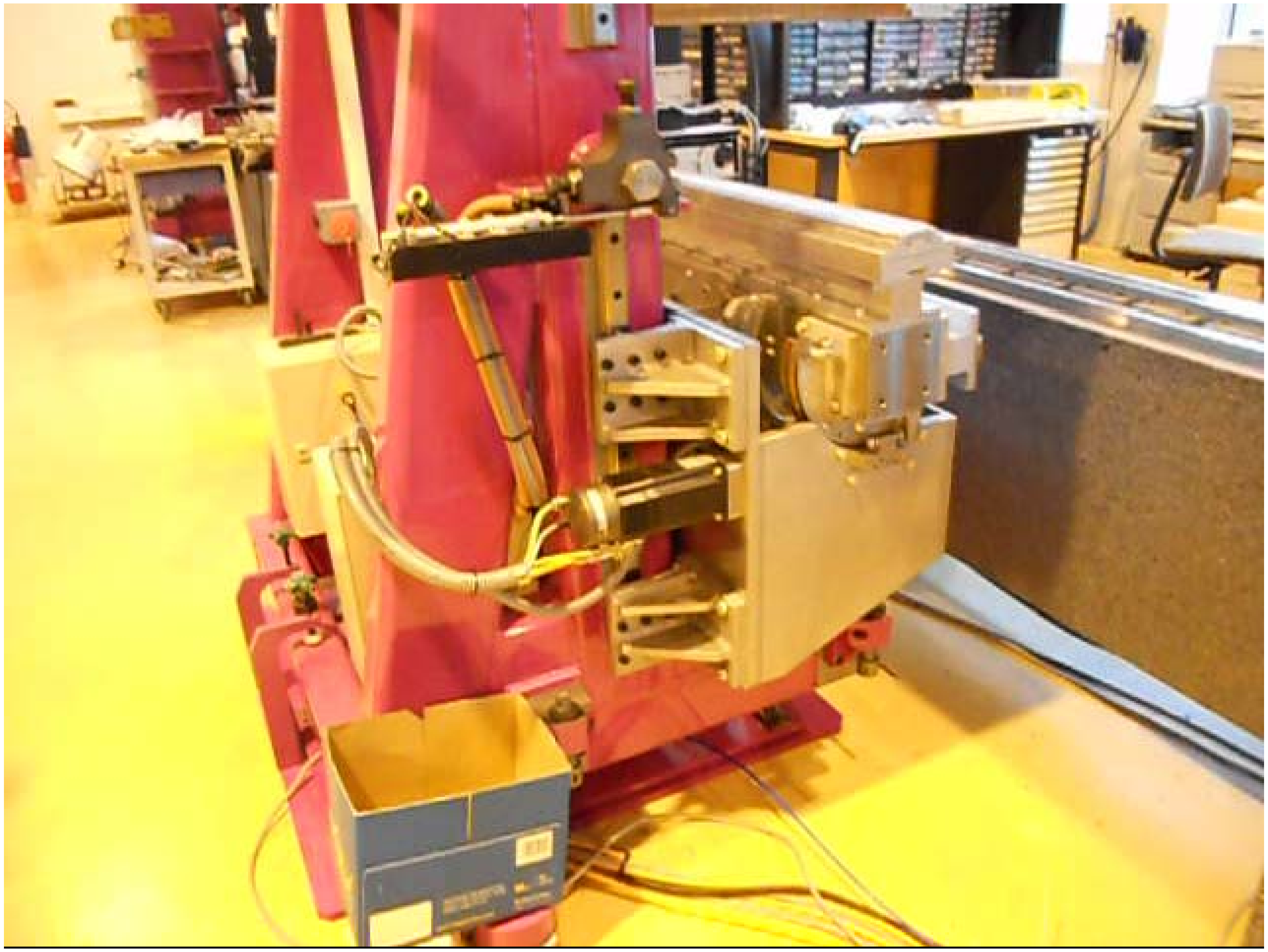
- All of the undulators at ESRF use a single motor for adjusting the gap. Most have another motor for adjusting a small taper (+/- 100 micron). The revolvers **do not have any taper** provision, but do not need one for self-protection (obviously with only one motor).
- The drive for the revolver axis is through a worm gear, with no intermediate position feedback. A stepper motor directly drives the worm gear, and holds position with a failsafe brake.



Revolver Undulators

ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

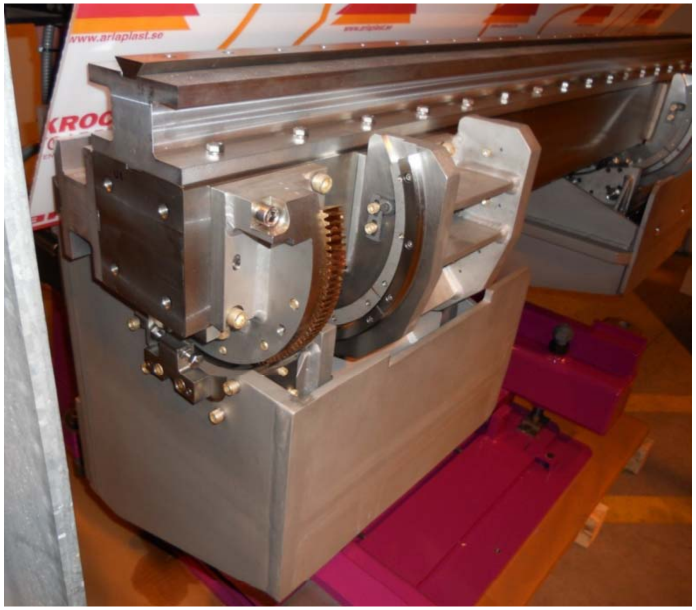
- The revolver motion can only be engaged when the gap is opened to a certain point.
- Inductive proximity switches are used to stop revolver motion. The revolver axis rotates until the switch is made, then, at a slower speed, reverses until the switch condition changes back.

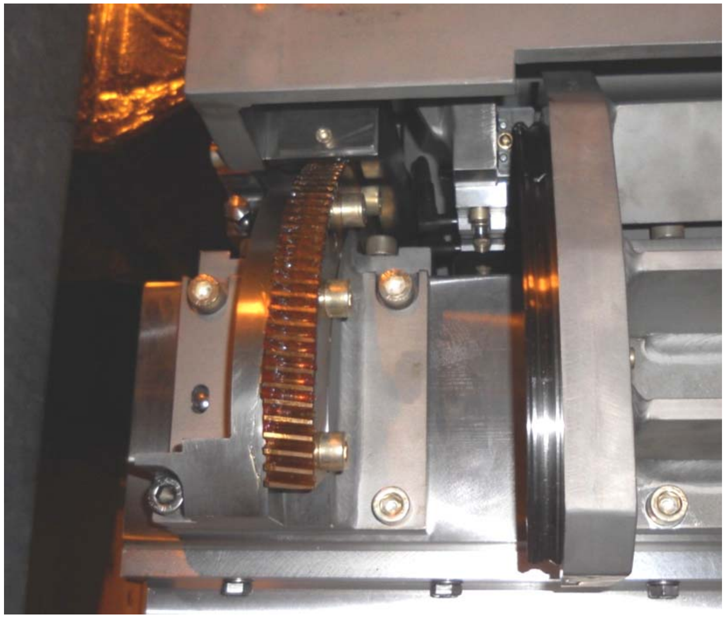


Revolver Undulators

ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

- The worm wheel, which is a bronze alloy, is exposed, with the worm itself and the "pinch point" between the two enclosed.
- A THK bearing/rail system is used for guiding the revolver motion. This is similar to their widely-used linear bearing system, but with a curved (rather than straight) rail. THK models HMG and HCR are available from THK in this configuration.

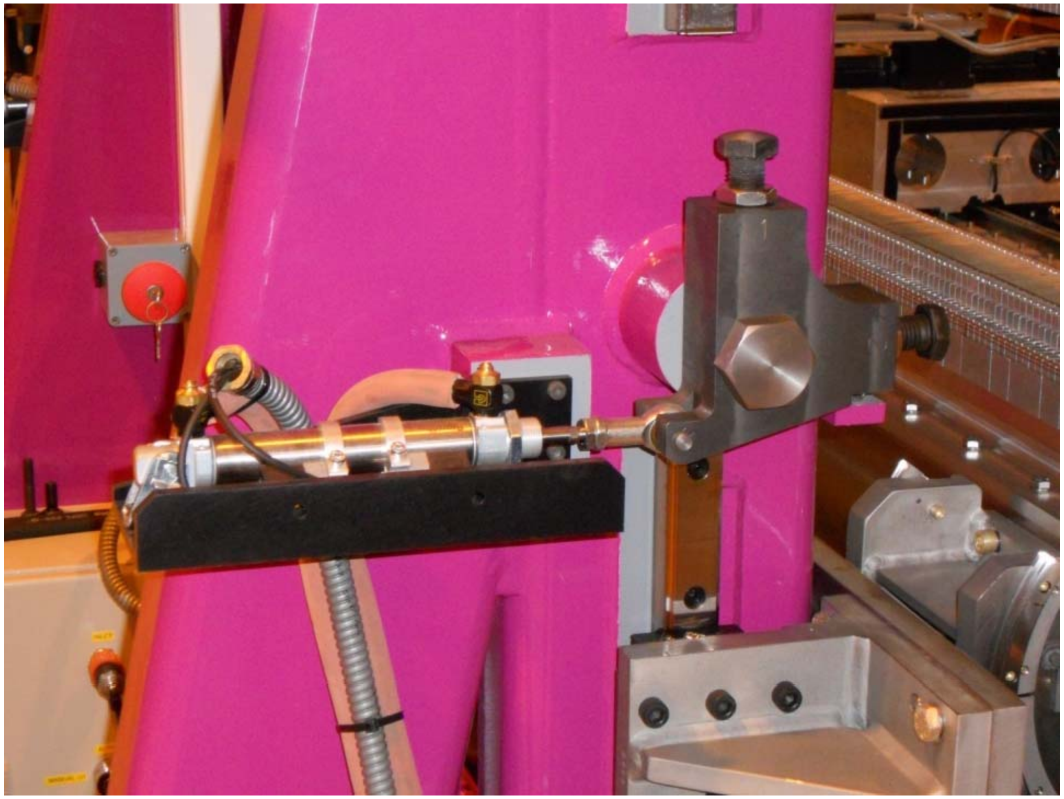




Revolver Undulators

ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

- A pneumatically-indexed gap hardstop is used, due to the difference in height of the magnet structures.
- There are no minimum gap limit switches mounted to the magnet structure and actuated by the ID vacuum chamber, as they are at the APS.



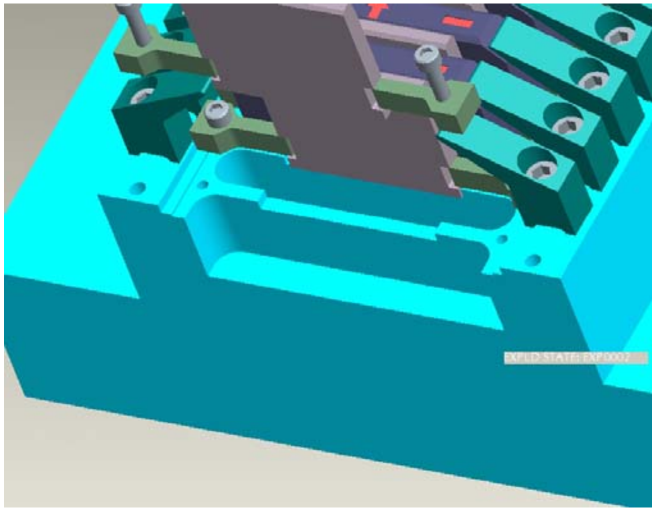
Revolver Undulators

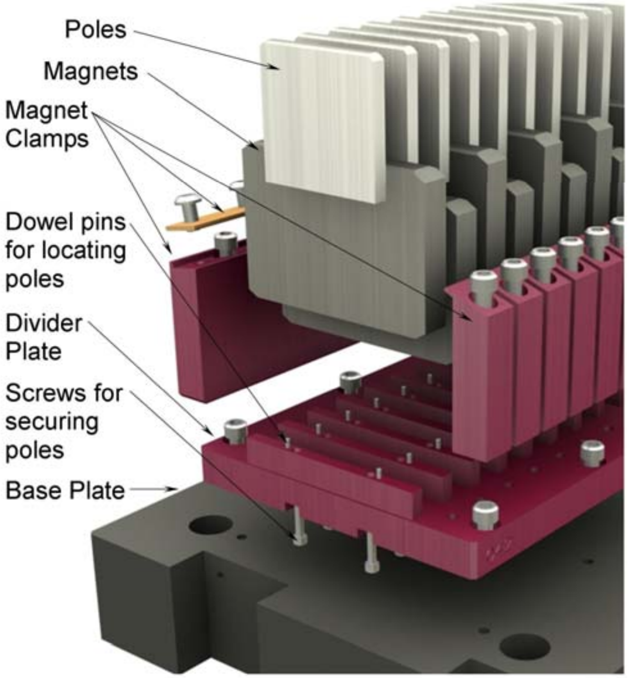
ESRF Revolver Undulators / Relevant Differences Between ESRF and APS

- Their gap separation mechanism guidance and drive screws are offset horizontally from the ID vacuum chamber, while those at the APS are centered on it.
- The ESRF ID vacuum chamber and chamber support was designed to accommodate a revolver . The existing APS ID vacuum chamber can accommodate a 2-position revolver, but the supports need to be modified.

Challenges of Designing, Building and Tuning an Revolver Undulator

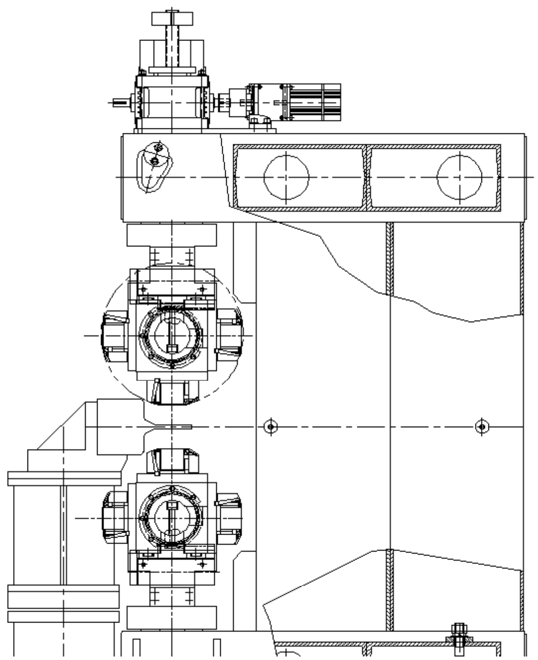
- Minimize the support frame and strongback deflection
- Stability and accuracy of revolver motion
- Define the worst-case future use of the platform
- Stability and accuracy of gap and gap change
- Commonality of gap separation mechanisms with other APS undulators and with shorter or possibly longer undulators
- Failsafe revolver interlock
- Gap tapering accommodation?

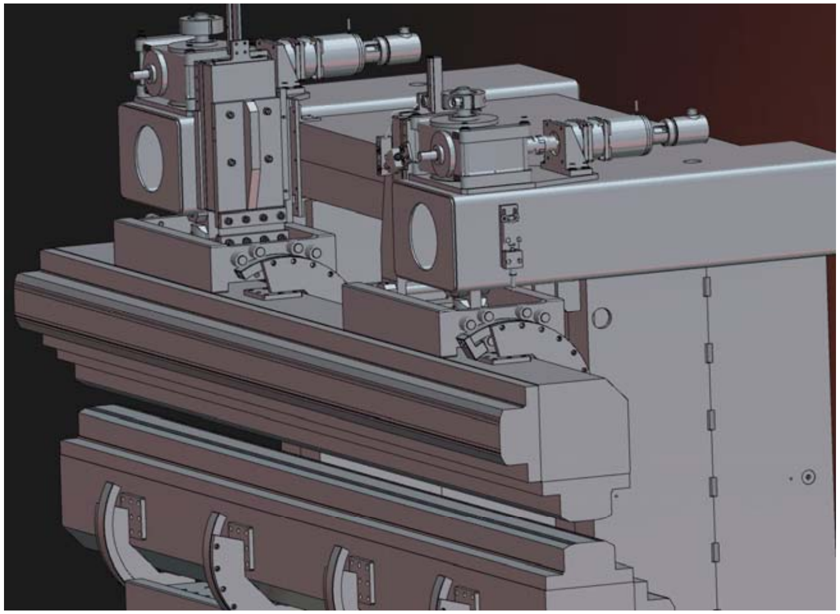




Revolver Undulator Project Status

- Emil Trakhtenberg and I have noodled concepts based on his 4-motor gap separation mechanism, with minor modifications to the frame.
- LDRD project for $200k in deliverables and $324k in effort for current fiscal year.
- Ben Stillwell (AES-MED) is heading an effort to engage an outside engineering firm to design a prototype revolver.
- Project will be multi-year effort: difficulty is quickly determining scope of engineering work for this year.





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- AED-MED
- ASD-DD
- AES-MD

I would thank APS personnel by name but listing anyone by name will mean slighting someone!