Eight-piece quadrupole magnet tolerance analysis*

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Background

Early R&D magnets for the APS Upgrade project were built based on a conventional two-piece quadrupole magnet design. However, the as-assembled magnets showed high multipole errors and magnetic center offsets that were out of specification. An eight-piece quadrupole design and assembly method is developed that produces the desired magnetic field quality and can be manufactured cost-effectively.

Objectives

- Identify the key features that affect the magnetic field quality in both two-piece and eight-piece quadrupole magnet designs.
- Determine the appropriate tolerances for the identified key features in both quadrupole magnet designs.
- Select the design and the proper machining and assembly tolerance level for APS Upgrade storage ring.

Conventional Two-Piece Quadrupole R&D Magnets

- Intrinsically has big tolerance stack-up on final pole tips locations,
- High lower order harmonics
- Big offset between magnetic center from the mechanical center

New Eight-Piece Quadrupole R&D Magnets

- Four pole tips will be symmetry within 25 µm
- The aperture could change
- The gap could change

Conclusions

- The key feature that affects the magnetic field is identified to be the symmetry of the four pole tips around the quadrupole longitudinal axis
- With a conventional two-piece design quadrupole, even 25 µm machining error will result in excessive stack-up tolerances and hence deteriorated magnetic field quality. With eight-piece design, 50 µm standard machining precision is sufficient to make high quality magnet
- Eight-piece design and 50 µm machining tolerance will be selected for APS Upgrade quadrupole magnet

*Work supported by U.S. Department of Energy, Office of Science, under contract numbers DE-AC02-06CH11357