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LCLS Quadrupole First-Articles Acceptance Test

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Outline

- Gradient measurements:
  - Integrated → Hall probe and Translation coil
  - Local → Hall probe
- Measurements of center position
  - Hall probe: local and integrated
  - Stretched wire
- Saturation
- Correctors
- Temperature measurements – power dissipation
- Summary

Introduction

- APS responsibility at LCLS project is an undulator beamline with all components [1] including EM quadrupoles.
- First two articles of quadrupoles have to be measured and tested at APS before going into production.
- Recent paper is devoted to the first test done with quadrupole articles #1 and 2 at APS magnetic measurement facility [2].
- Usual tests of quadrupoles use rotating coils for measurements. No coils with such small diameter (11 mm) are available at APS, and making such a coil is a challenge. so we decided instead to use a magnetic measurement technique that is available for ID measurements and tuning and has very good reliability and accuracy (Hall probes and translation coils).

Introduction (cont)

- The MM1 magnetic measurement system allows measurement of all LCLS quadrupole parameters to within the required accuracy in order to perform acceptance testing on the 1st articles:
  - Integrated and local gradient
  - Hysteresis and center motion
  - Temperature dependence

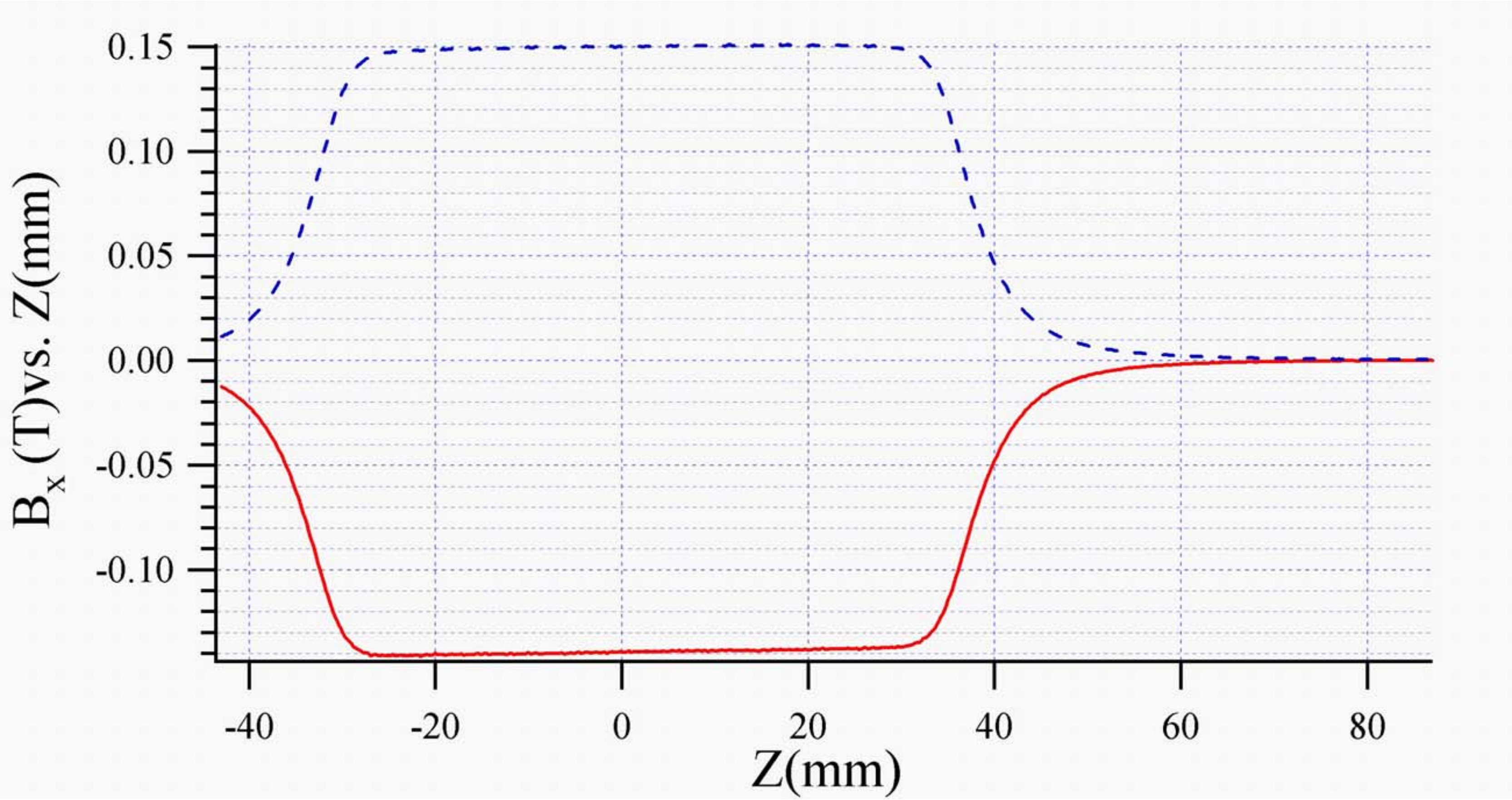
- No additional equipment is required.

- The physical location of the magnetic center will be measured and fiducialized at SLAC using vibration wire.

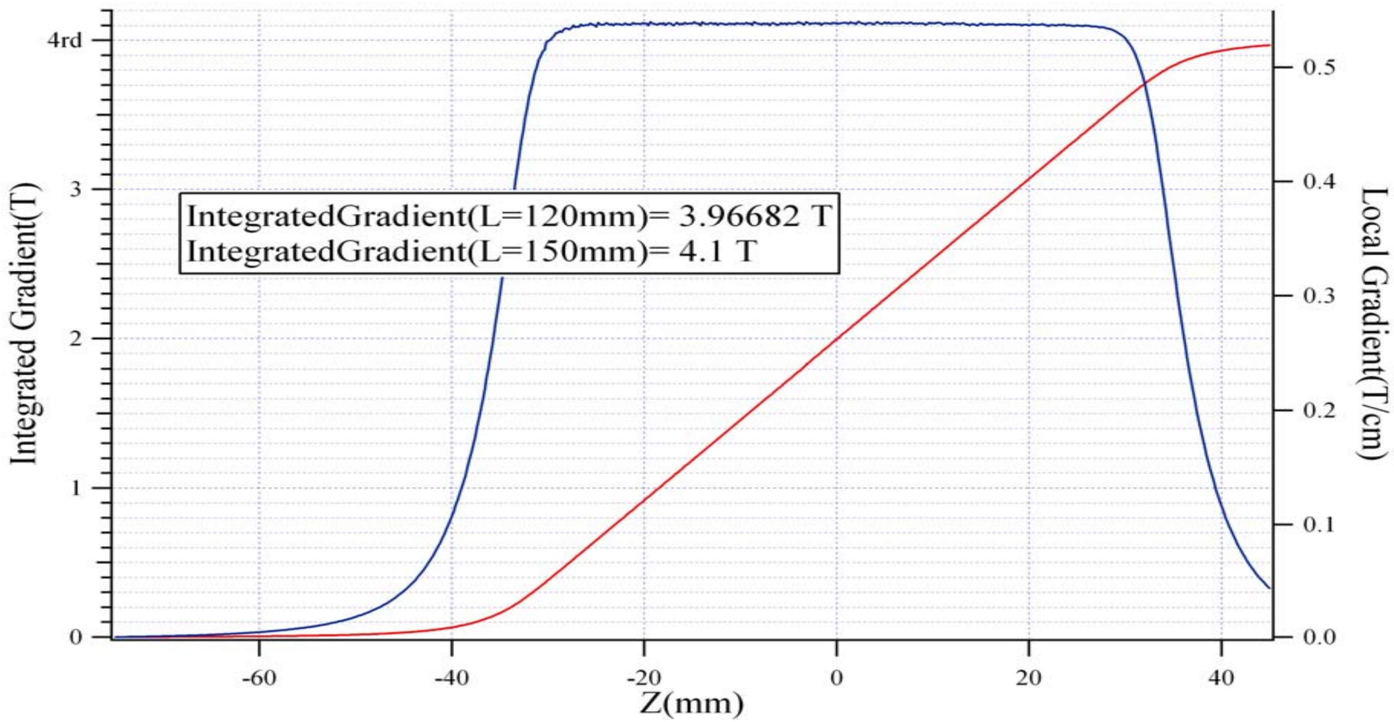
LCLS Quadrupole Parameters

Parameter	*Value*	*Unit*
Nominal integrated gradient	3.00±0.03	T
Maximum integrated gradient	4	T
Integrated horizontal and vertical field	300	G-cm
Magnetic center motion, general	10	μm
Magnetic center motion at 3T±20%	3	μm
Minimum pole gape diameter	11	mm

*Hall Probe Scans in Z for Y=±2.5*mm

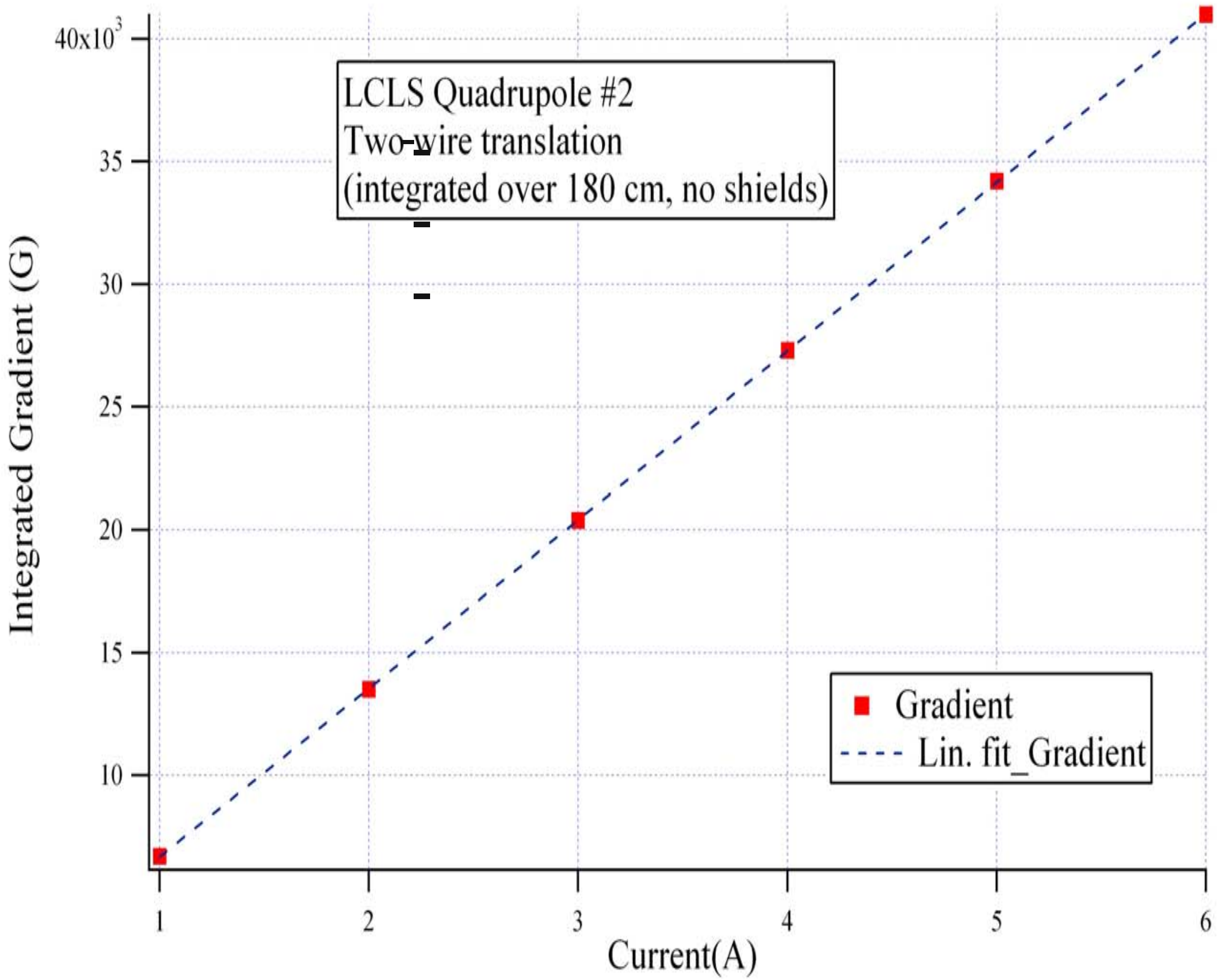


Hall Probe Scan for Quadrupole #2



Integrated quadrupole for L=150 mm was calculated assuming the downstream end is the same as the upstream end.

No Saturation for Quadrupole up to I=6 A



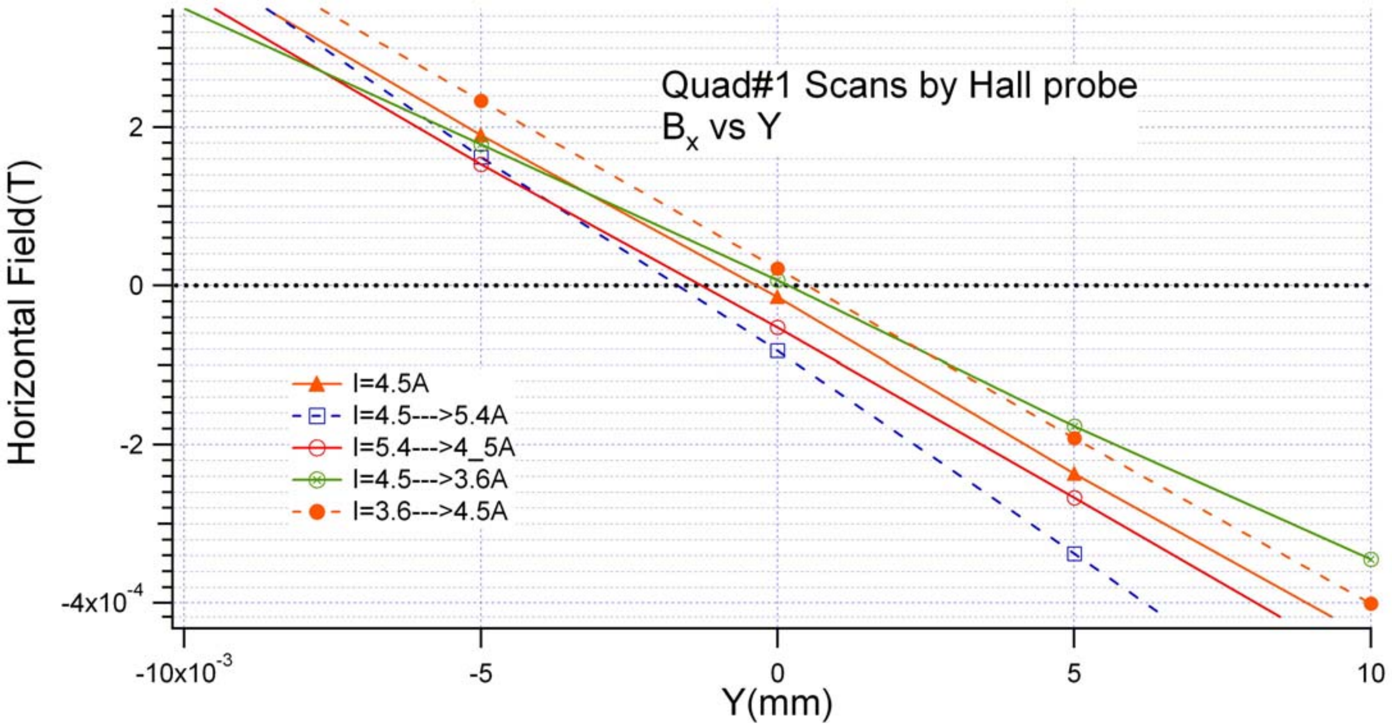
Two-wire translation mode allows us to obtain an integrated quadrupole with good accuracy in a short time

Center Motion

- Integrated nominal quadrupole : 3T
- Field integral at distance from center Y=1μm → $3T*10^{-6}$=3 G-cm

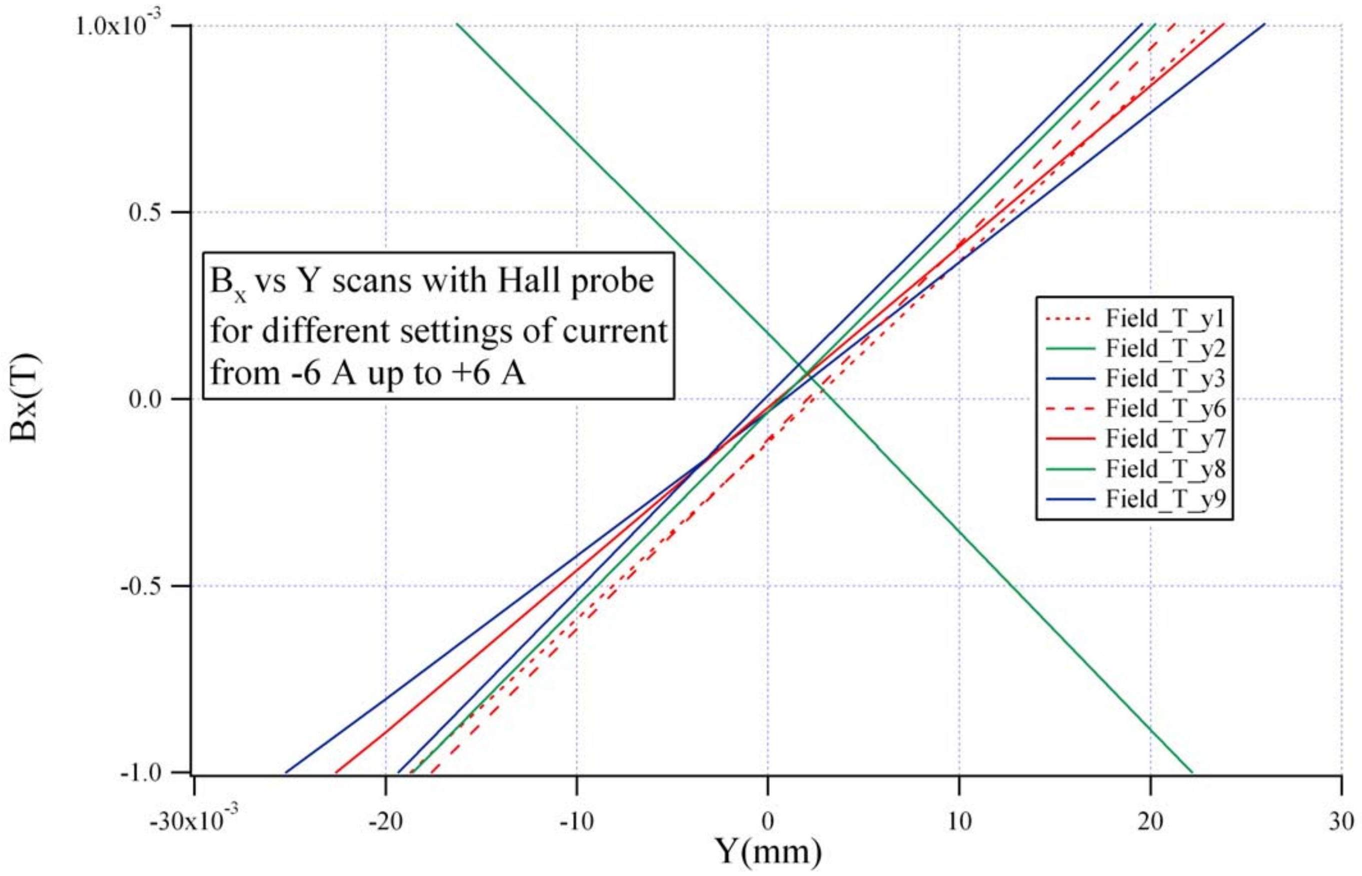
  Such accuracy could be easily achieved by Hall probe measurements, and therefore 1 μm center motion can easily be seen.
- Scan in Y by Hall probe allows us to see the local magnetic center with an accuracy of better than 1 μm.
- An example of a Hall probe scan in Y is shown in the next slide for a quadrupole current setting corresponding to an integrated gradient 3 T±20%. Center motion is less than 3 μm.

Center Motion from Hall Probe Data (Quad#1)

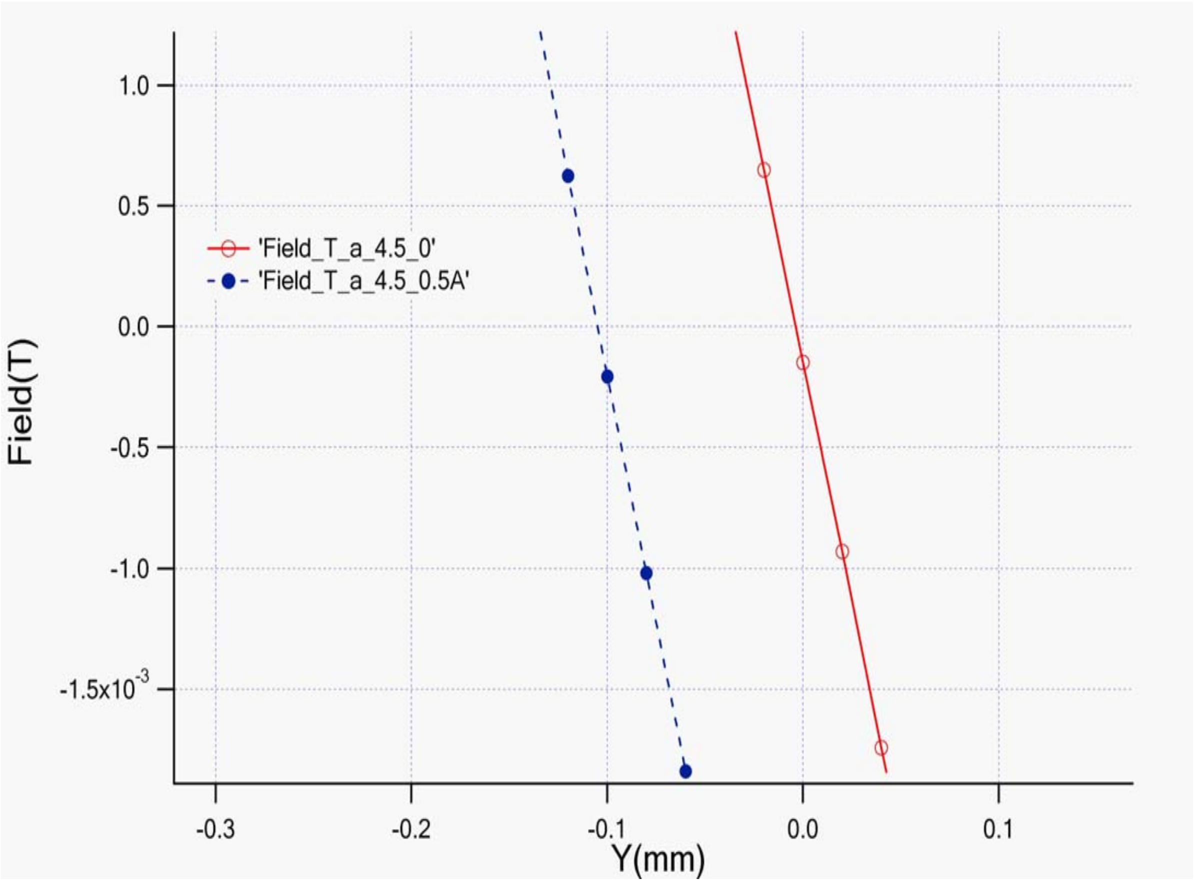


Line B_x=0 corresponds to magnetic center position

Quadrupole #2 Center Motion



Center Motion by Corrector at I=0.5 A (100 μm)



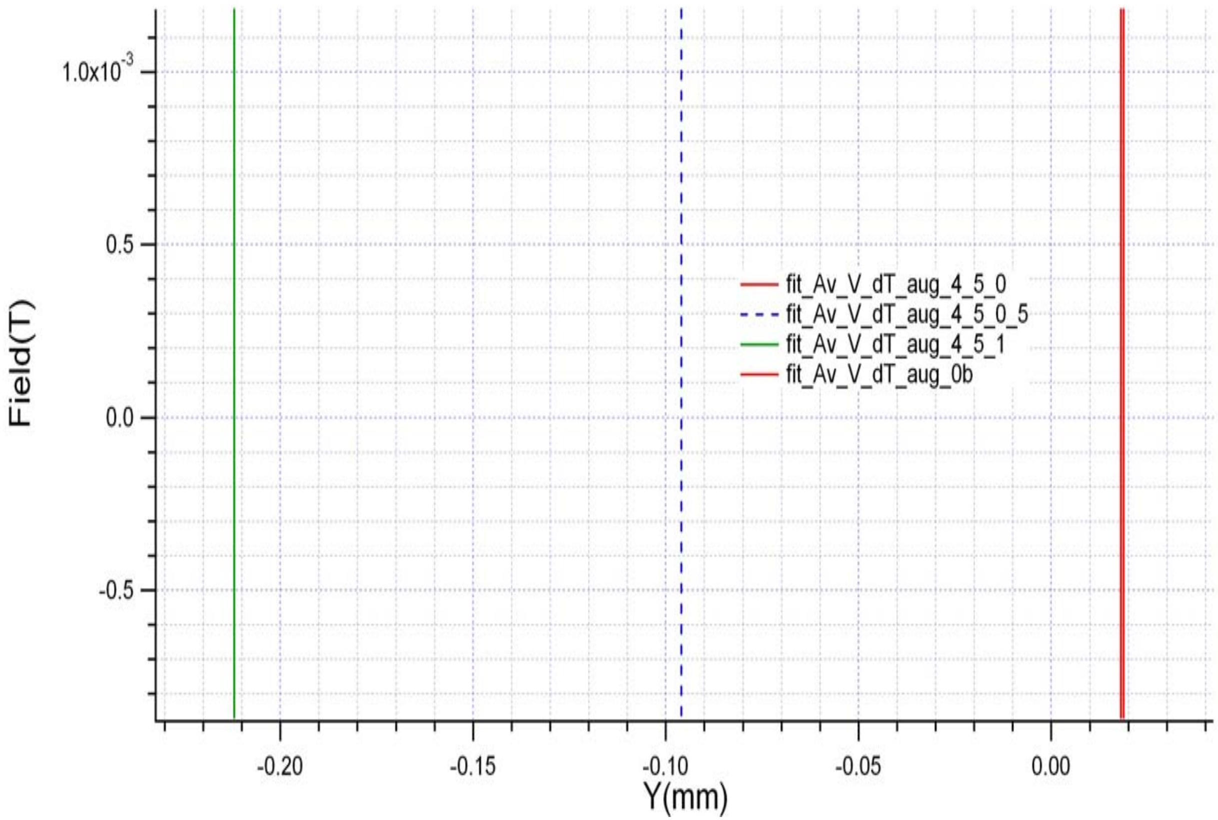
Done by Hall probe scans in Y for I_{cor}=0 and 0.5 A.

Difference of 100 μm is a design value of the corrector field.

Stretched Wire Measurements

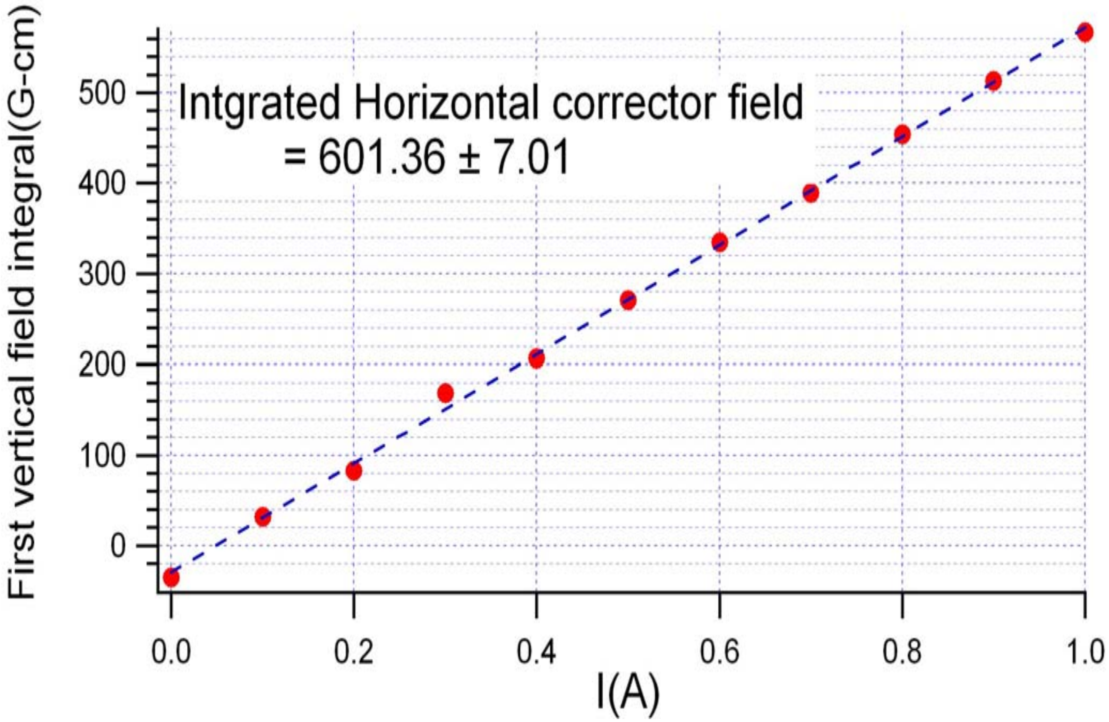
- An attempt was made to measure center motion due to corrector field by using a stretched wire. Unfortunately, this magnetic measurement technique, which works well for IDs with close to zero field integrals, is not appropriate for quadrupoles with strong magnetic fields when high accuracy is required. Due to large errors associated with strong force and vibration of the wire, the results are not reliable.

One Wire Scans in X



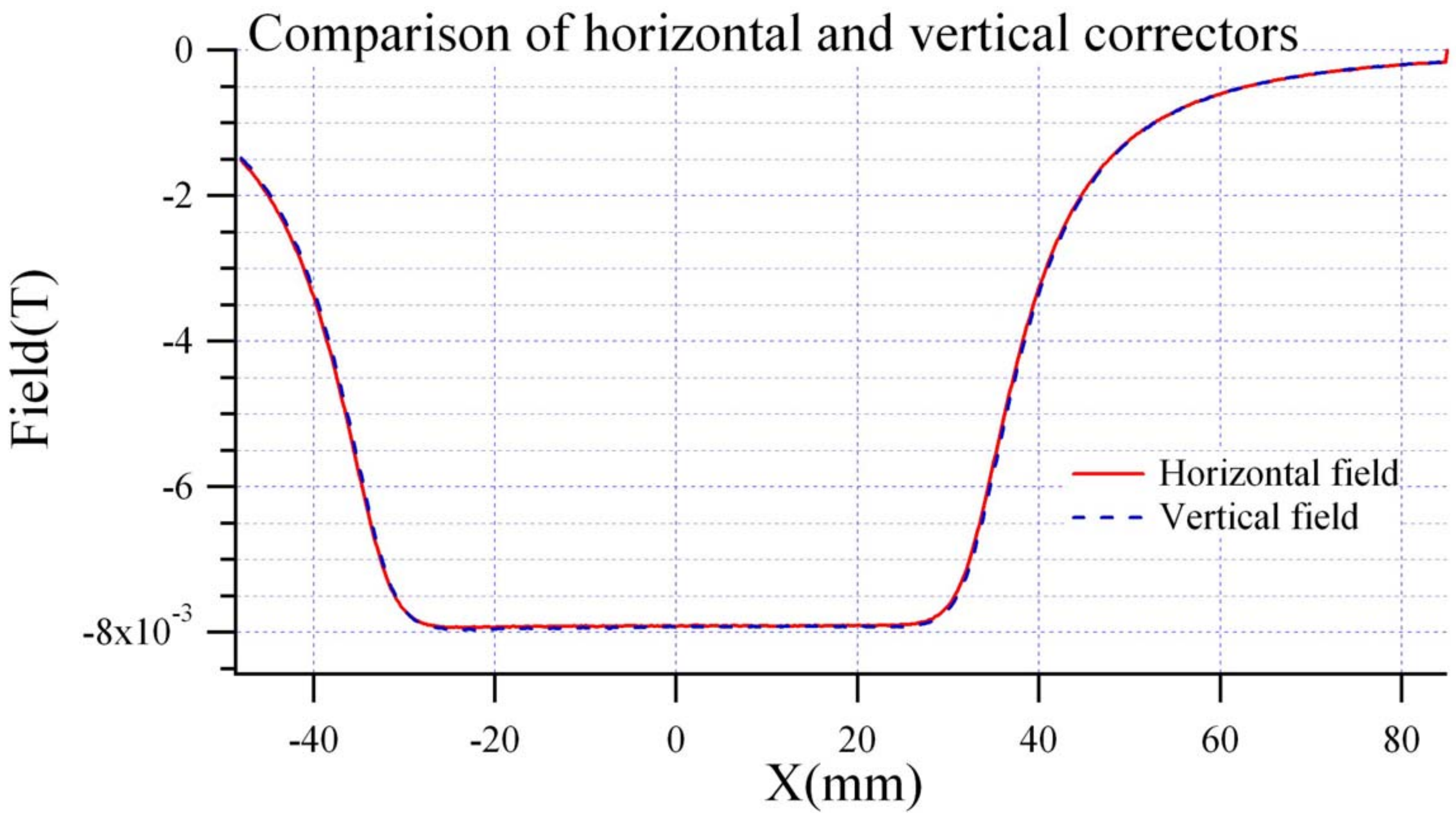
Center motion for corrector settings: I=0A; 0.5A; 1A with quad at I=4.5A

One Wire Scans: Horizontal Corrector Saturation

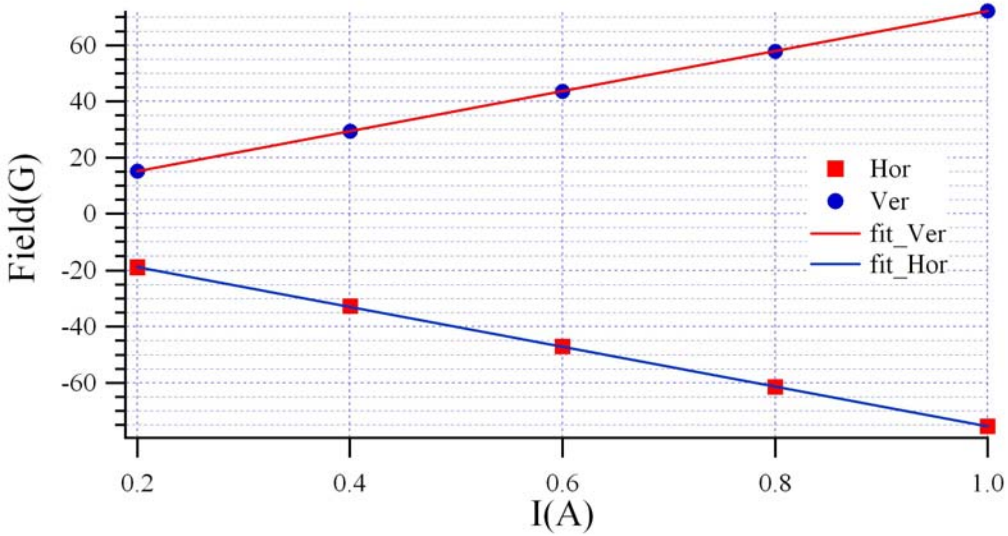


These types of measurements with stretched wire saves time and could be used, if needed.

Hall Probe Data (Hall Probe Scans)



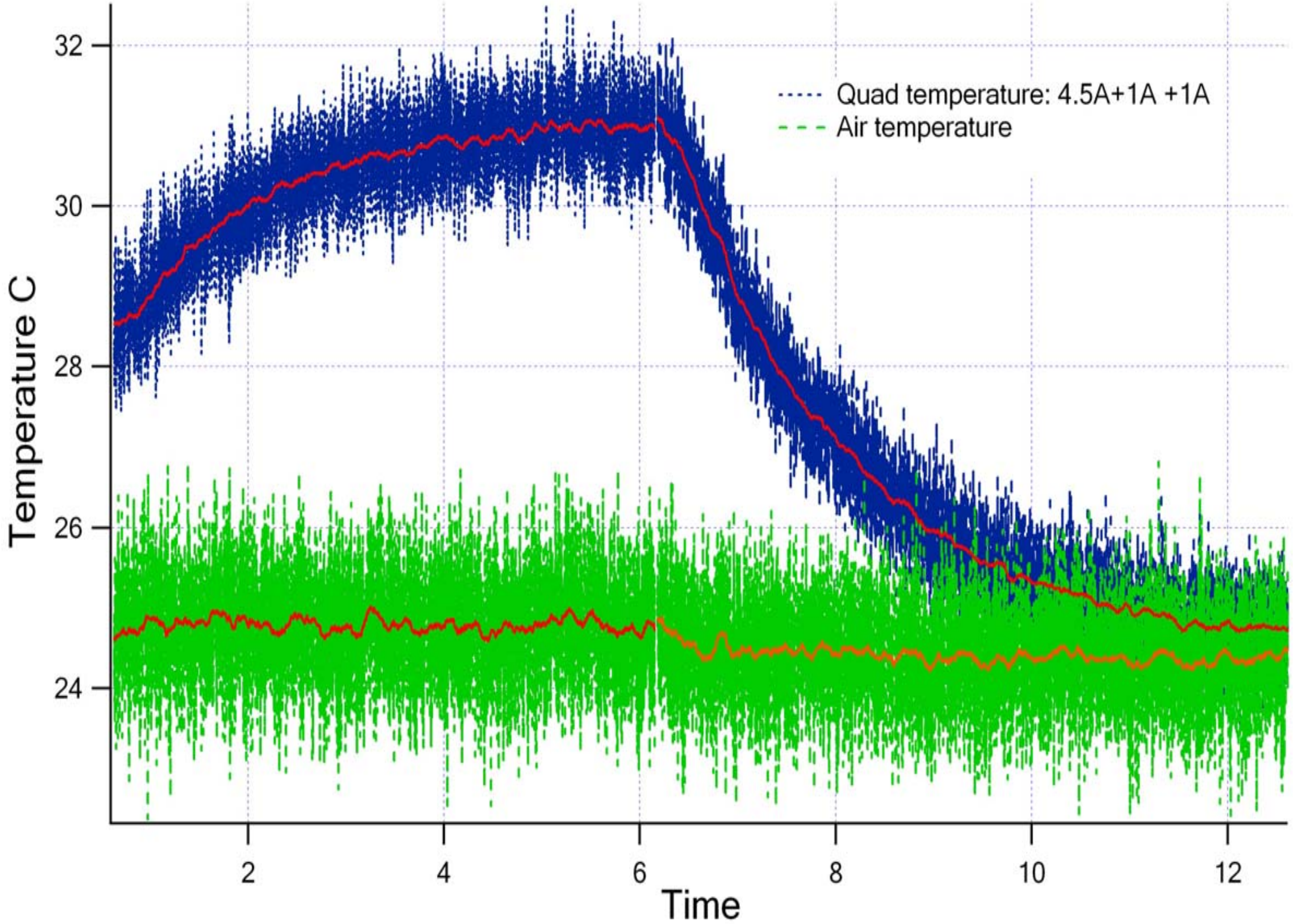
Hall Probe Saturation for Correctors



Hall probe data are more precise than stretched wire but more time consuming.

Quadrupole #1

Temperature Cycle: 4.5A→6A→0
both Correctors on with I=1A   Quadrupole #1



Integrated Gradient vs. Quadrupole Power Cycles

Quadrupole #2 (Translation Wire)

-6A→6A→4.5A	30200
6A→-6A→4.5A	30300
6A→-6A→4.5A	30200
6A→-6A→4.5A	30300
4.5A→5.4A→4.5A	30460
4.5A→3.6A→4.5A	30370

Summary

- Magnetic measurement technique that includes Hall probe and translation coil provides a reliable test of quadrupoles
- Both integrated gradient and stability of magnetic center can be measured with high accuracy in a short time
- Very small aperture quadrupoles up to few mm ID can be measured without problem using this techique

References

- [1] Coherent Light Source Project, SLAC-R-593, April 2002, http://www-ssrl.slac.stanford.edu/lcls/cdr/
- [2] I. Vasserman, J. Xu, “Upgraded accuracy and reliability for insertion device magnetic measurements at the Advanced Photon Source”, IMMW-14, September 2005