STRAIGHTENING OF APS LINAC ACCELERATING STRUCTURES UTILIZING A PORTABLE ARTICULATING ARM CMM

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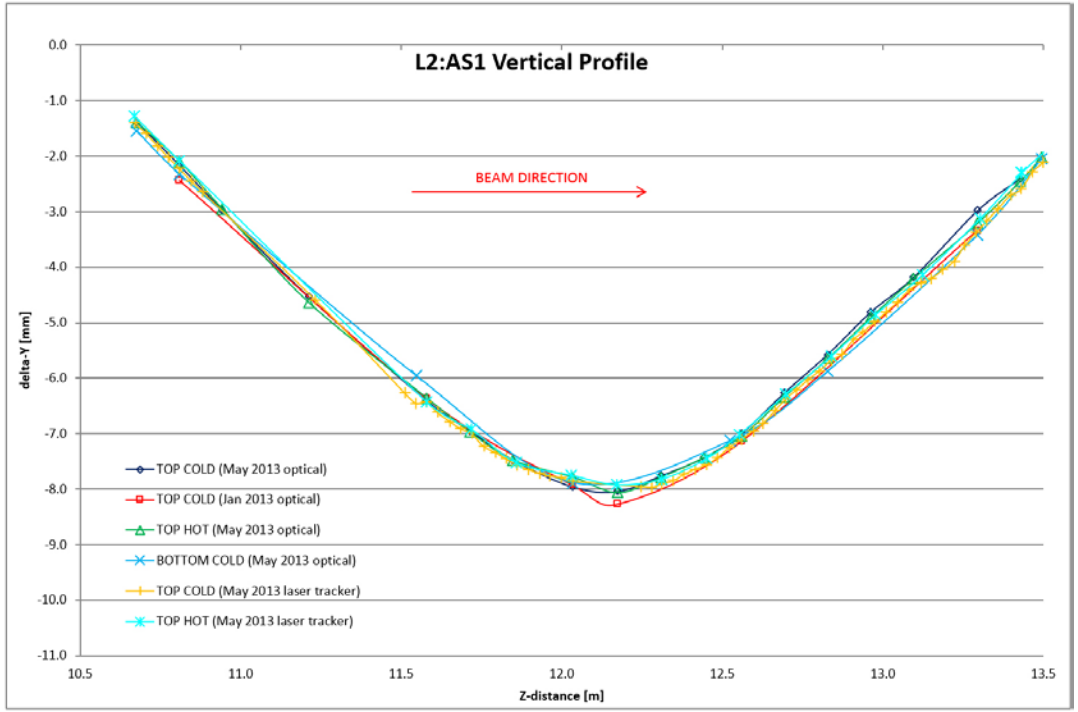
OVERVIEW

- Background
- Project
- Process
- Results
- Conclusion
- Acknowledgement
- Questions

BACKGROUND

- June 2013 survey of the APS LINAC revealed deformation of the accelerating structures.
- Worst case vertical sag of up to 7 mm was detected
- Discovery of deformation prompted initiative to straighten the devices to improve overall performance



BACKGROUND

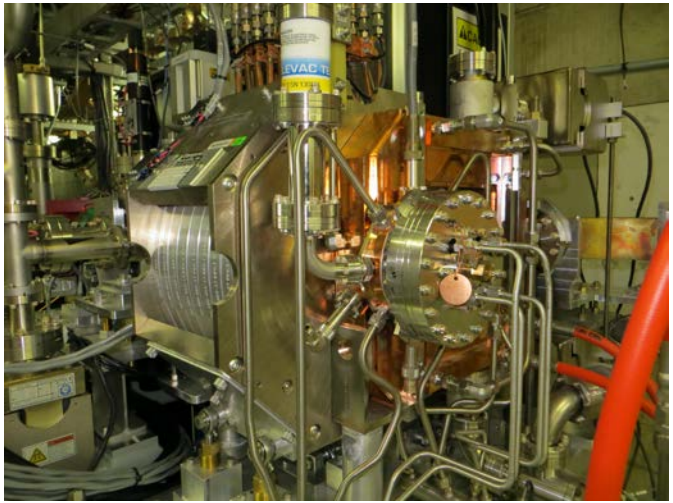
- Similar work done in 2013 at the SLAC National Accelerator Laboratory (SLAC)
- SLAC hardware adopted for straightening nearly identical APS structures.
- Straightness measured at SLAC using a 5 meter coordinate measurement machine (CMM)

BACKGROUND

- Bench CMM not available at APS
- Portable CMM arm was selected.
- PCMM has 2 sigma accuracy of 25 um
- Straightness tolerance +/- 200 um
- SLAC designed strong-back support and halo adjustment system adapted to fit the APS structures.

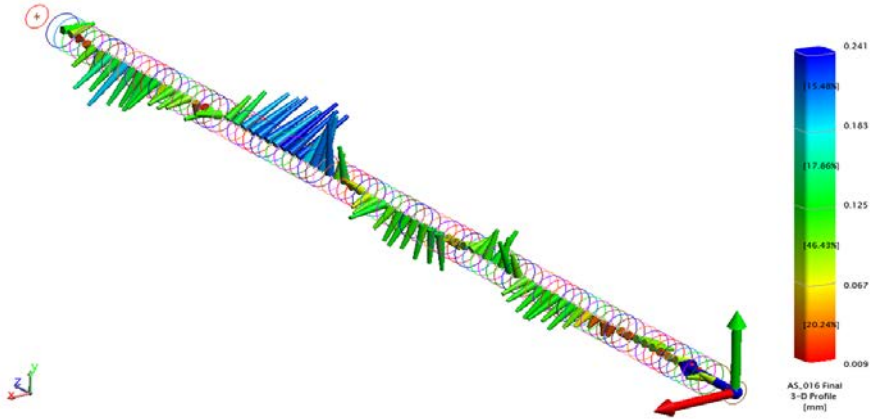
PROJECT

- Long-term project to straighten the APS LINAC accelerating structures implemented in 2015.
- Expected to take 4 years, about 3 structures per year.
- Straightening intended to increase LINAC performance for the APS Upgrade.
- New photocathode RF gun requires LINAC alignment of +/- 200 um for optimal performance.
- Straightening should diminish transverse wakefield effects, reducing emittance enlargement of the beam during acceleration.



PROJECT

- First straightened structure installed in fall of 2015
- Project to continue until all 13 accelerating structures have been straightened.



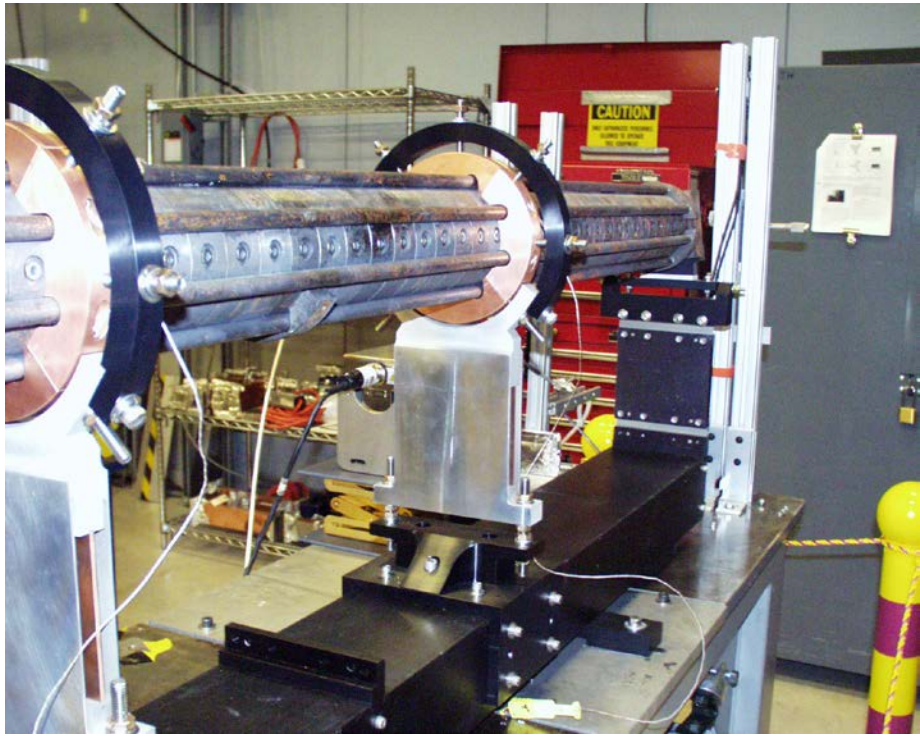
- Second straightened structure installed in May 2016 was damaged by arcing – not related to straightening process
- Replaced with third straightened structure in August 2016.

PROCESS

The process utilizes hardware developed at SLAC, and a measurement procedure developed at APS.

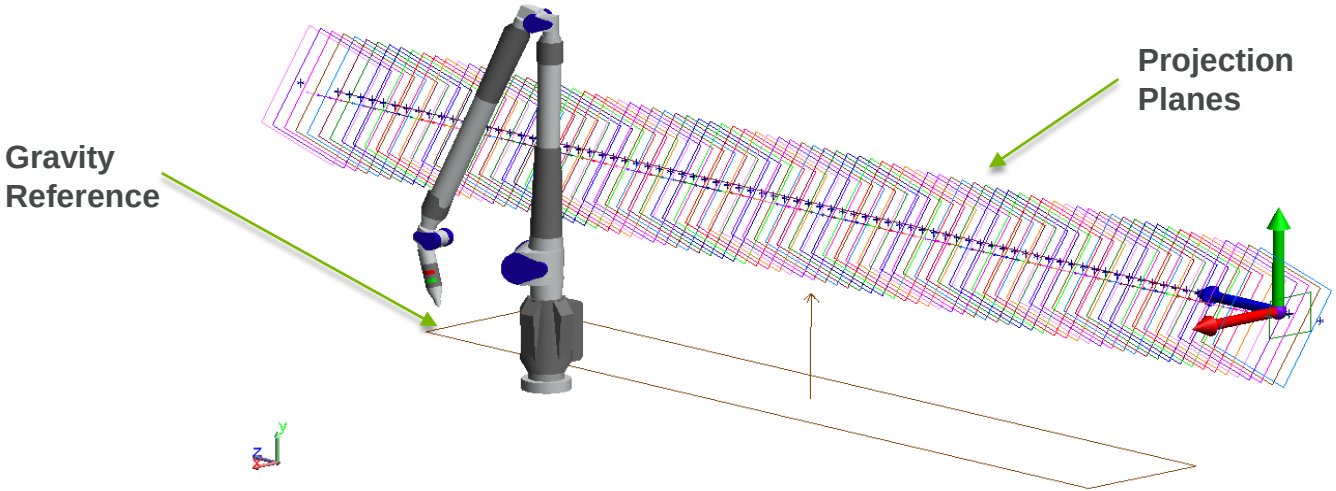
Setup

- Structure mounted to strong-back and secured to work table.
- Upstream end of structure fastened to fixed, rigid support
- Downstream end fastened to adjustable, flexible support to allow expansion
- Ends of the structure levelled to gravity
- Baseline measurement prior to installation of flexible intermediate supports.



Baseline Measurement

- Baseline measurement establishes magnitude and direction of deformation
- Measurement using PCMM arm and 3-D industrial coordinate measurement software
- Nominal gravity plane established on the work bench using a precision optical level is measured with CMM for gravity reference
- Projection planes established normal to the Z-axis through the centre each individual cell.

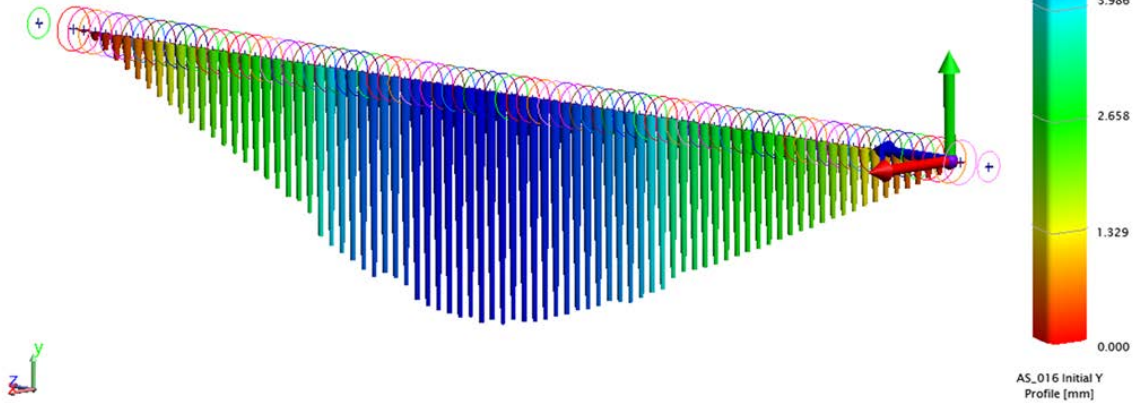


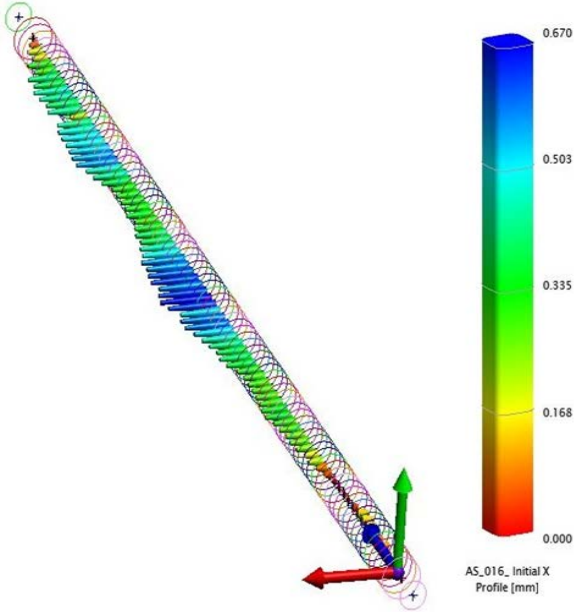
Baseline Measurement

- Circular fit measurements recorded for all 84 cells
- 8 points measured around each cell, projected to established planes
- 2 instrument stations required.
- Best-fit line established though the cell centres
- Query between the centre points and line is computed

Baseline Measurement

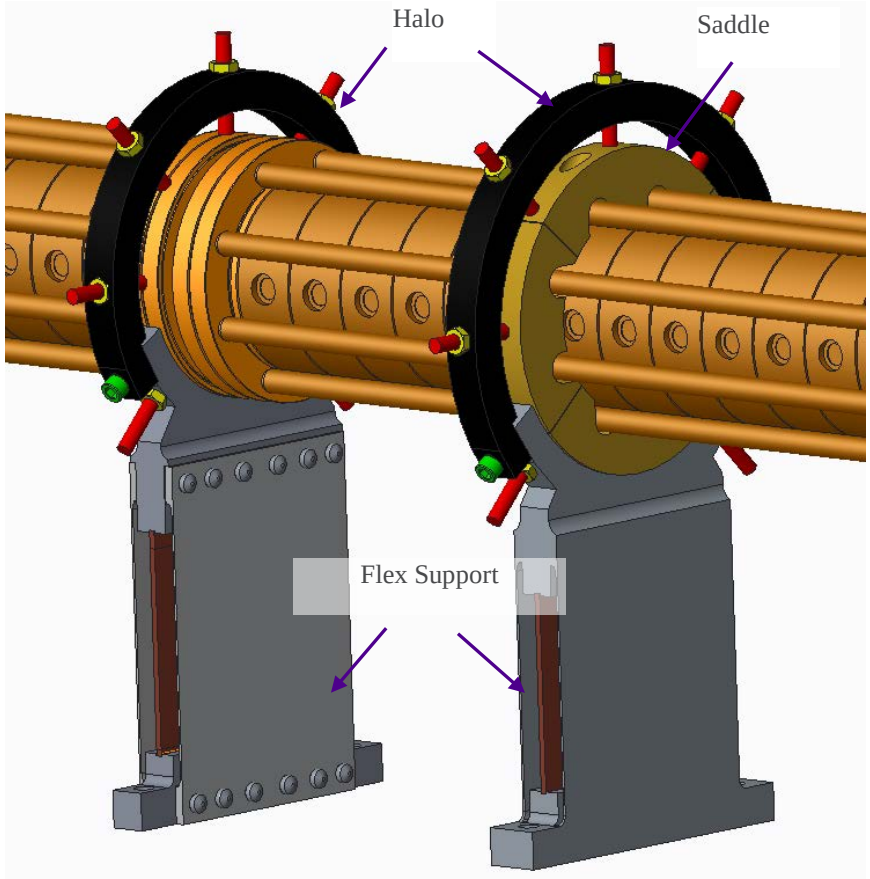
Vertical and Horizontal Baseline Profiles





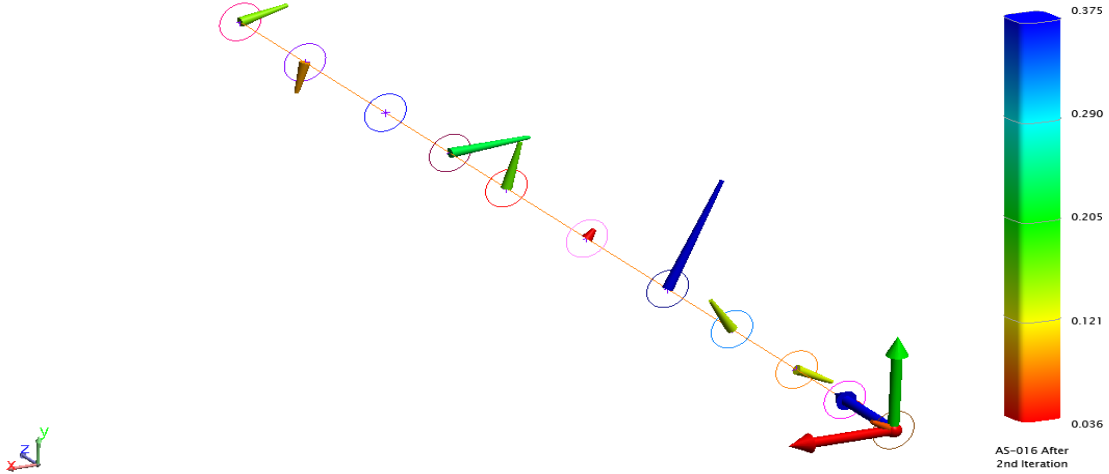
Straightening

- Adjustment halos and copper saddles installed per baseline measurement results, accounting for quadrupole magnet locations.
- Saddles carefully tightened to avoid detuning.
- Coarse adjustment using threaded rods at the base of the intermediate supports
- Fine adjustment by iteratively adjusting the halo push screws, utilizing feedback from the PCMM, until +/- 200 um straightness is achieved.



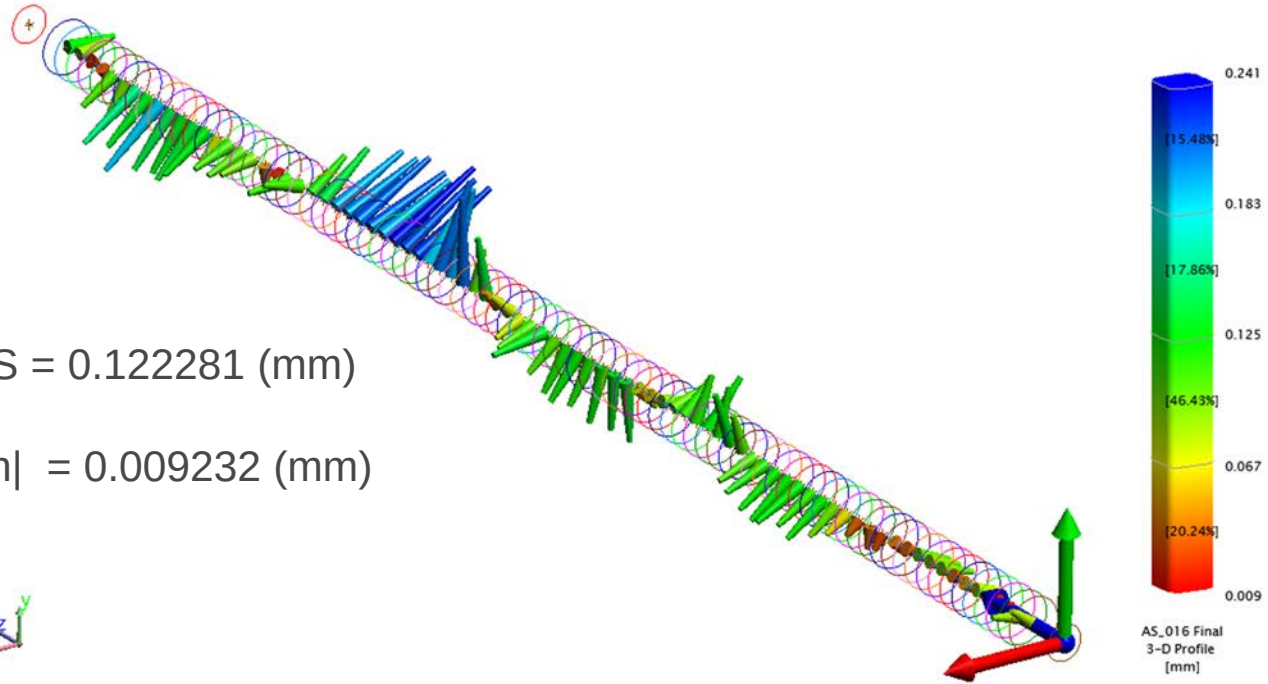
Straightening

- Straightening measurements focussed on adjustment points and mid-points along structure - Not necessary to monitor the position of every cell
- Numerous iterations necessary to achieve the desired straightness tolerance.
- Large, initial moves relatively easy - fine-adjustment increasingly difficult.
- 2 to 3 days of effort to accomplish



Reporting

- Once an accelerating structure has been straightened within +/- 200 um, a complete measurement is recorded. The report data also serves as fiducial information for subsequent alignment in the APS LINAC.



Best-Fit Line Deviations

Mean = 0.109974 RMS = 0.122281 (mm)

Magnitude

|Max| = 0.241214 |Min| = 0.009232 (mm)

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Installation and Alignment

- Structures swapped out during maintenance periods.
- Deformed structure is removed from the LINAC
- Modified mounting pattern is laid out and drilled in the support table.
- Straightened structure is installed
- Best-fit centreline of the structure is aligned collinear with the LINAC beam axis.

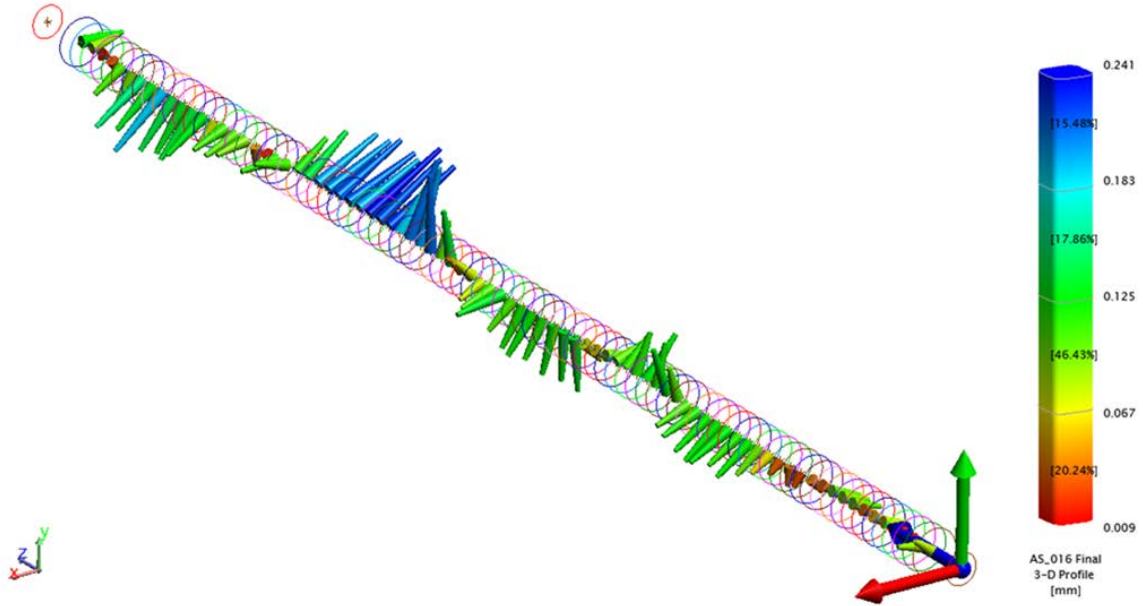
RESULTS

As of this writing, only 3 of the 13 APS LINAC accelerating structures have undergone the straightening process. Initial results are promising, and indicate that the specified tolerance can be met.

Statistic	dX [mm]	dY [mm]	Mag [mm]
Min	-0.194	-0.164	0.011
Max	0.124	0.129	0.195
Average	0.000	-0.001	0.094
RMS	0.077	0.070	0.104

Structure	Straightness Before	Straightness After
1	+/- .98 mm	+/- 0.14 mm
2	+/- 1.2 mm	+/- 0.17 mm
3	+/- 2.7 mm	+/- 0.18 mm
4	+/- 1.9 mm	+/- 0.36 mm*

*0.26mm after straightening, 0.36mm after vacuum bake



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CONCLUSION

- Three APS accelerating structures have been successfully straightened utilizing the process described herein. We are confident the mechanical and metrology methods are sound, and look forward to completing the project over the next 3 to 4 years. Although it is too soon to report, the work described here should produce measurable improvements to electron beam quality in the APS LINAC.

REFERENCES

- [1] Morrison, Leonard H., "*LINAC Accelerating Structures: Deformation and Proposed Straightening*" APS/MED Group Internal Document, Advanced Photon Source, Argonne National Laboratory, October 2013
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- [2] Bromberek, D., Jansma, W., Smith, T., Waldschmidt, G., "*Mechanical Straightening of the 3m Accelerating Structures at the Advanced Photon Source*", 2016 North American Particle Accelerator Conference (NAPAC16), Chicago, Illinois, USA October 2016

ACKNOWLEDGEMENT

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THANK YOU FOR YOUR ATTENTION!

ANY QUESTIONS?