Development of Optical Metrology ENgine (OMEN)

Ben Sheff

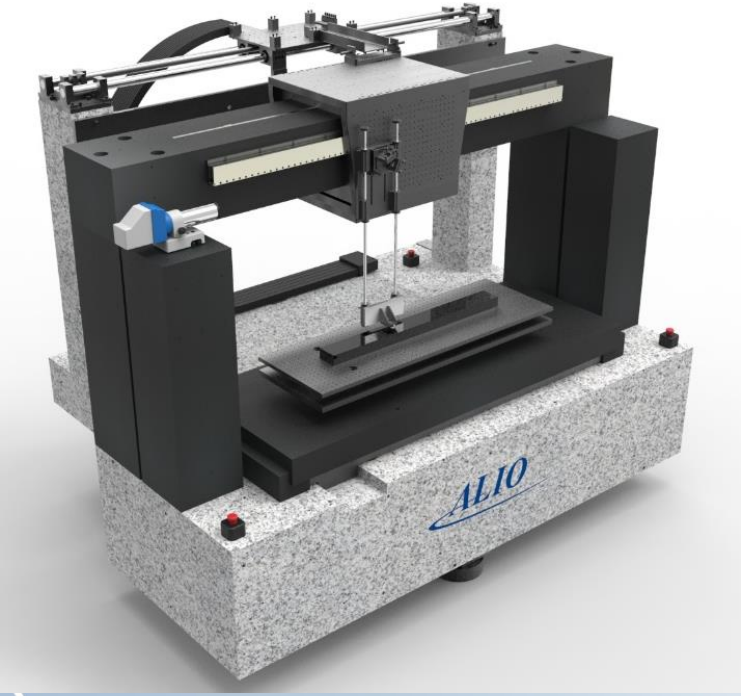
Introduction

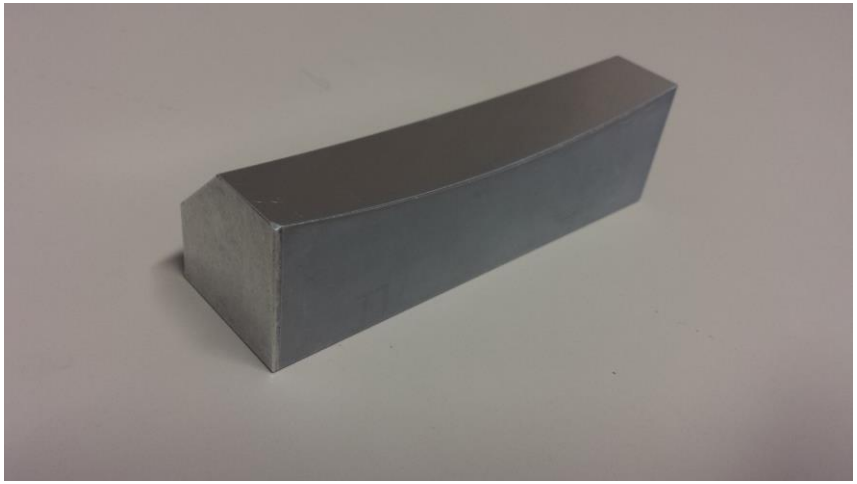
- APS is a 7 GeV, storage-ring-based hard x-ray synchrotron radiation source at Argonne National Laboratory
  - Funded by DOE Office of Science, Basic Energy Sciences
- Produces collimated, intense beams of hard x-ray radiation
  - Useful for a variety of applications
  - Requires advanced optics to manipulate

Image courtesy of https://www1.aps.anl.gov/About/Welcome

X-ray Mirrors

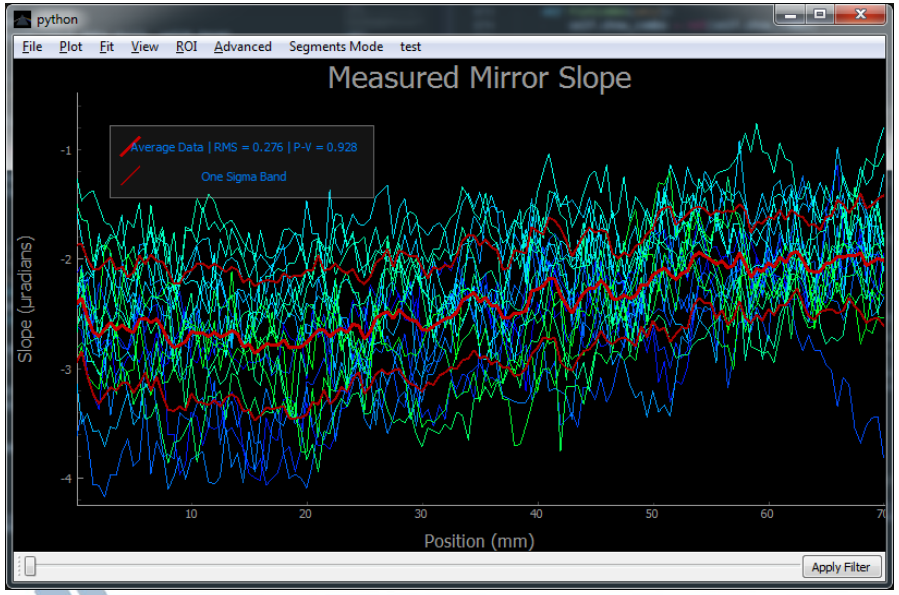
- As beamlines get better, need better mirrors
  - Residual slope error as low as 50 nrad
- Autocollimator-based Long trace profiler (AC-LTP) is a high precision metrology tool[1,2]
  - Measures slope of mirror at each point to within 50 nrad
  - Extremely accurate for small range of angles, but has problems farther out
  - New analysis tools needed to handle this

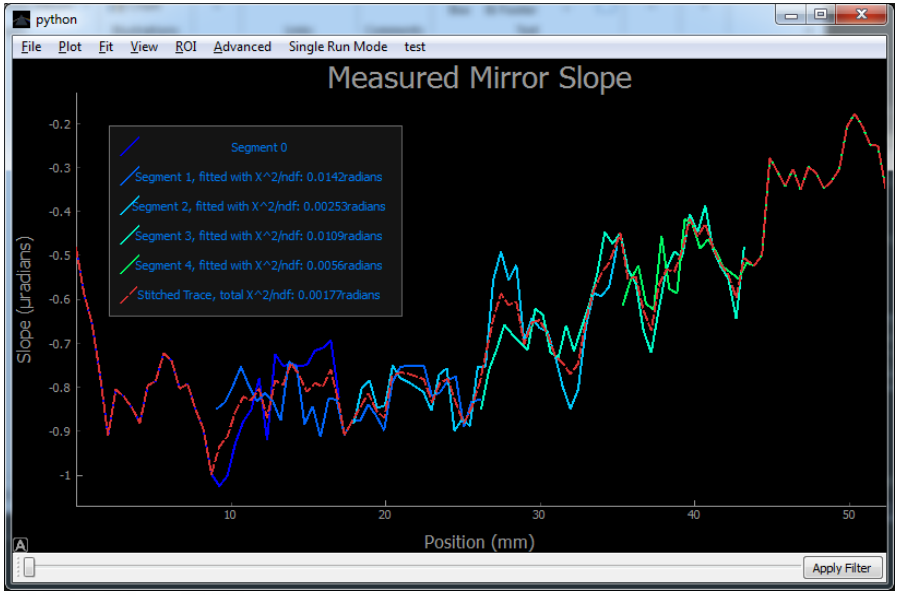




Analysis Software

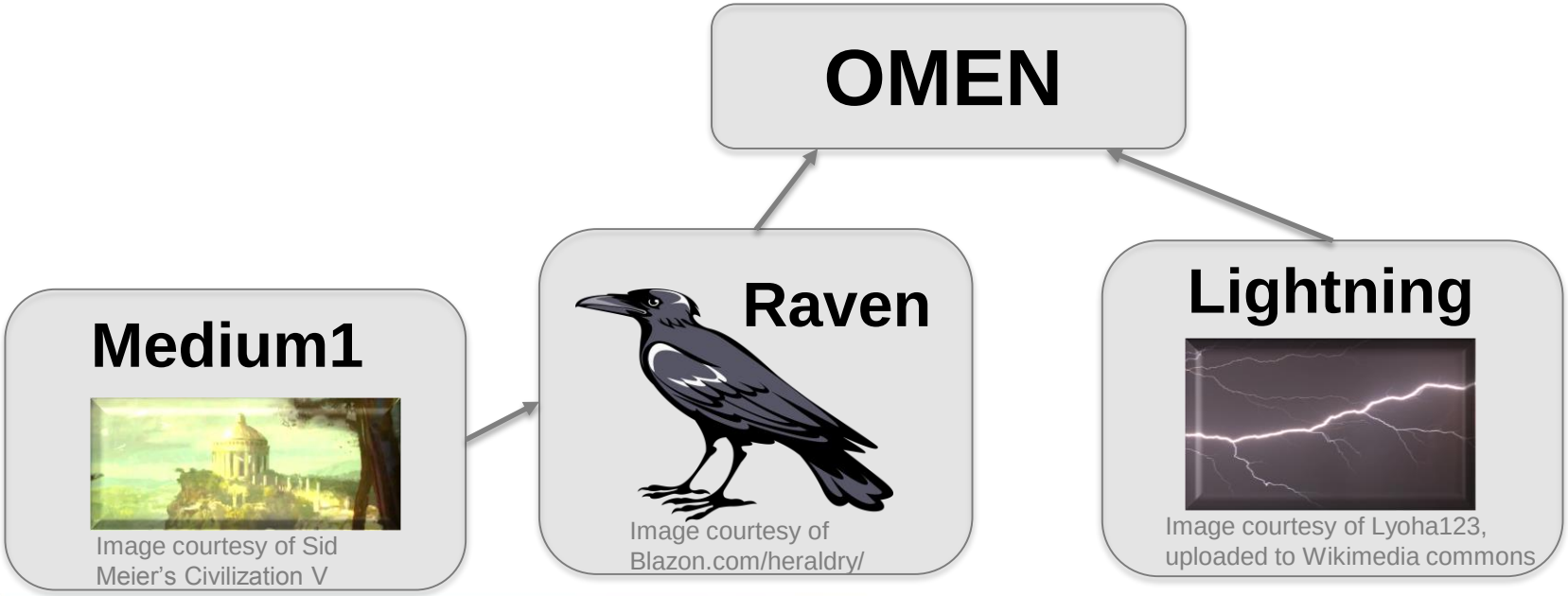
- Developed Optical Metrology ENgine (OMEN) in Python
- Handles standard analysis
  - Easy, dynamic filtering
  - Fitting options, with live-updated residue plot
  - Region-of-interest selection
- Tools to deal with high angles
  - Stitching together overlapped, adjacent scans of mirror segments
  - Adding calibration run



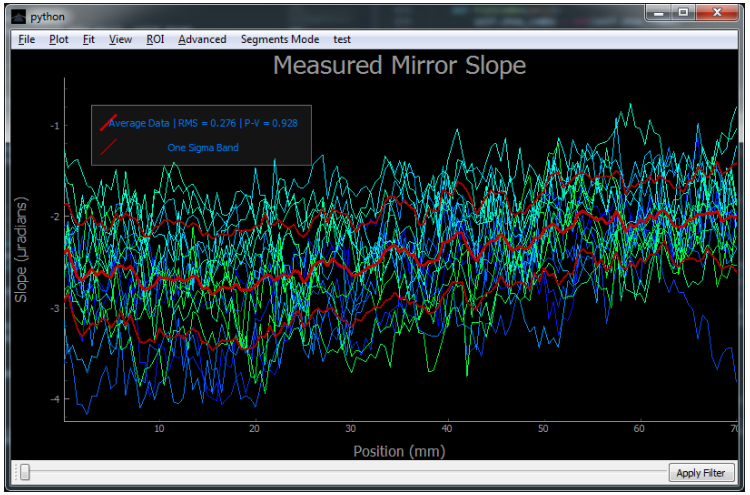


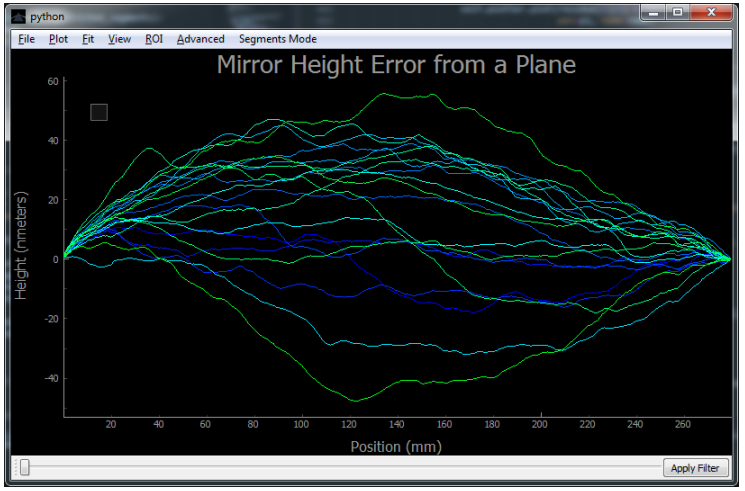
Object Oriented Design

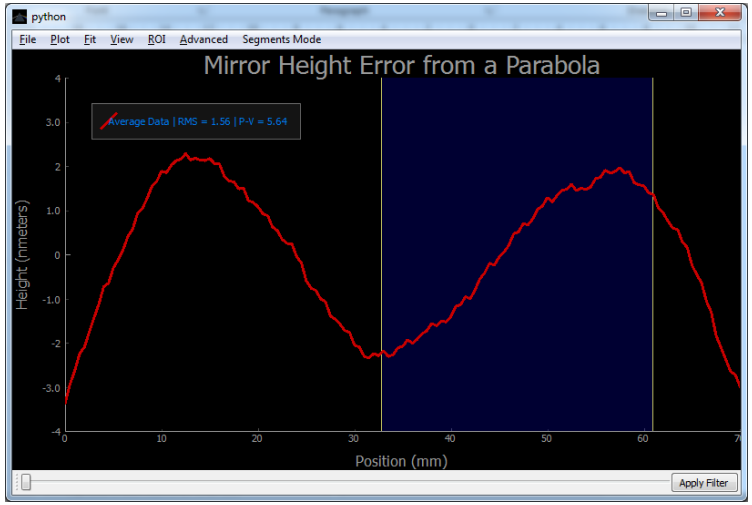
- OMEN class handles GUI and manages companion classes
- Three companion classes
  - Raven handles data collection and most processing
  - Lightning handles stitching and mirror profile comparison
  - Medium handles input/output standard formats
- Easy to modify, and to re-use parts for other purposes

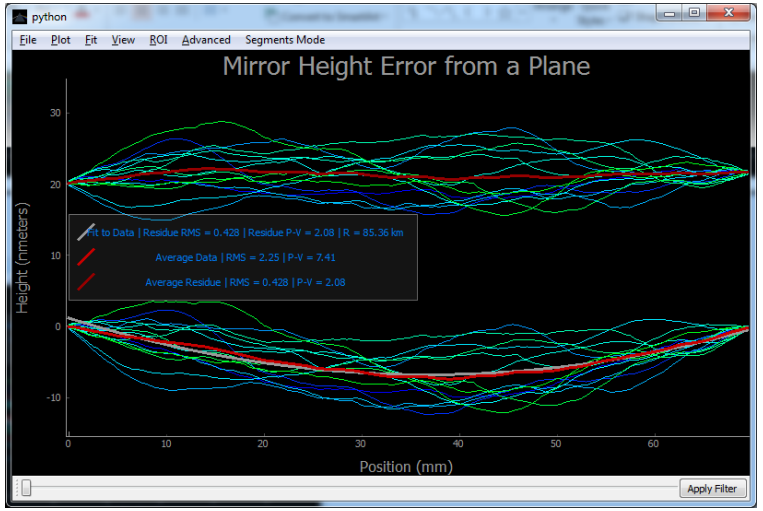


OMEN in Action



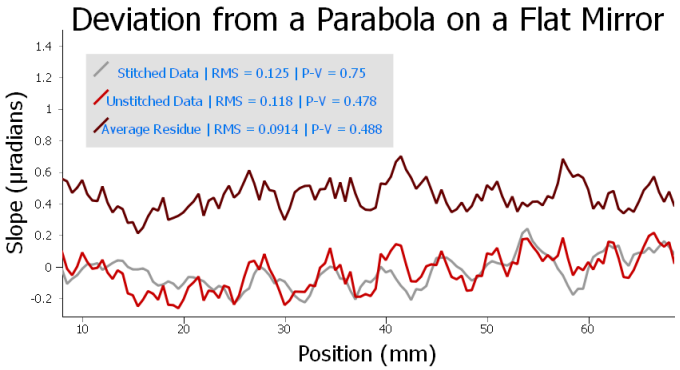


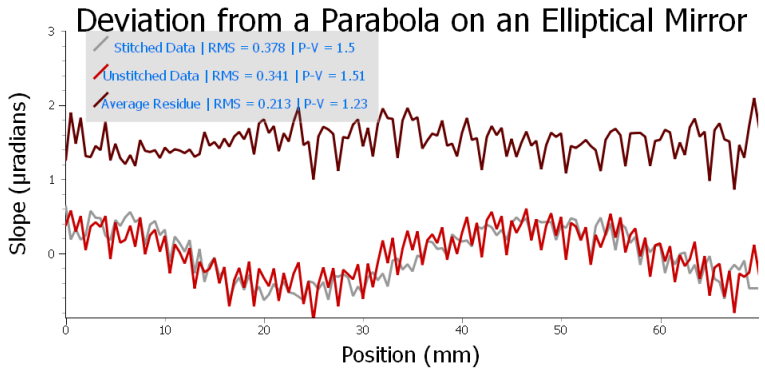


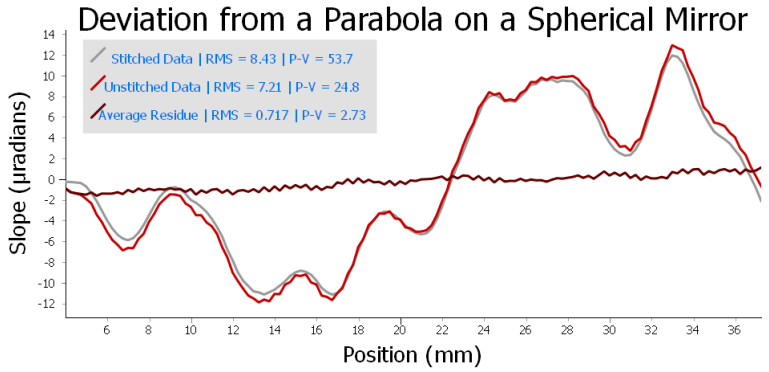


Dealing with Highly Curved Mirrors

- Preliminary Work: Take overlapping partial scans and stitch together
  - Each scan over a small region over which the mirror is roughly linear
  - Tilt mirror so the scan center is horizontal
  - Use Lightning to stitch together partial scans
  - Compare the result with full scan

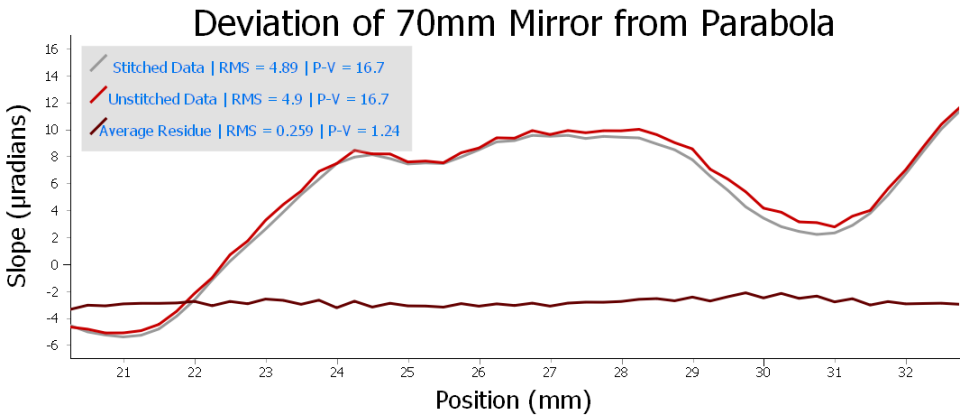


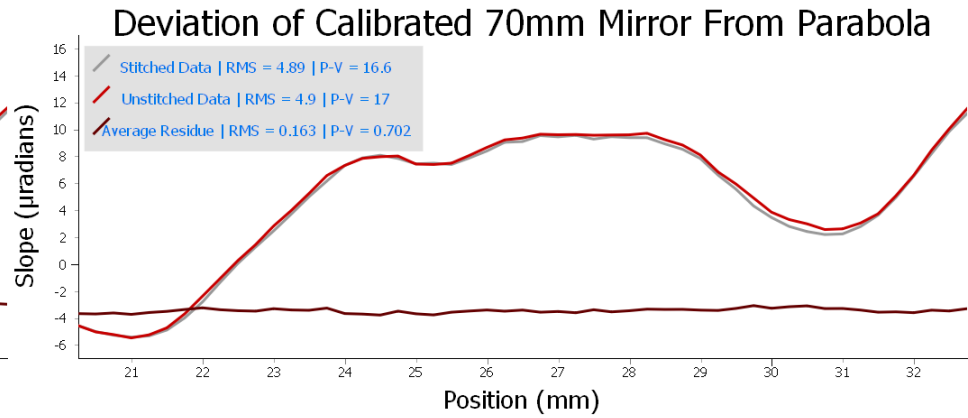




Calibration

- Significant deviation between stitched and non-stitched
  - Seems to correlate with angle measured
- New high precision small angle generator against which to calibrate[3]
  - Accurate on the order of 10 nrad
- Tested small calibration run
  - Inverted and interpolated data to make a look-up table
  - Further investigation warranted, with more accurate measurements





Conclusions and Future Direction

- Code is robust, and will be useful for future analysis
  - Easy to use
  - Rapid analysis
- Stitching code allows for new measurement capability
- Further investigation will be conducted into calibration in the future
  - More accurate measurements needed
- Some known systematic errors introduced by analysis have yet to be corrected
  - eg., All interpolation is simple linear as of yet

http://img2.goodfon.su/original/2048x1360/7/39/doroga-vdal-povorot-izgib.jpg

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- The Optics Group in the X-ray Science Division of the Advanced Photon Source at Argonne National Laboratory, and Argonne National Laboratory itself for hosting me for the summer.

References

- [1] Lahsen Assoud et al., Nucl. Instrum. Methods A 710, 31-36 (2013).
- [2] J. Qian, J. Sullivan, M. Erdmann, A. Khounsary, L. Assoud, Nucl. Instrum. Methods A 710, 48-51 (2013).
- [3] D. Shu, J. Qian, W. Liu, S. Kearney, J. Anton, J. Sullivan, and L. Assoud, Proc. SPIE 9206, Advances in Metrology for X-Ray and EUV Optics V, 920601 (October 7, 2014); doi: 10.1117/12.2084726Proc. of SPIE Vol. 9206

Questions