Characterization of an In-Situ Metrology Setup for the APS Modular Deposition System

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The Advanced Photon Source

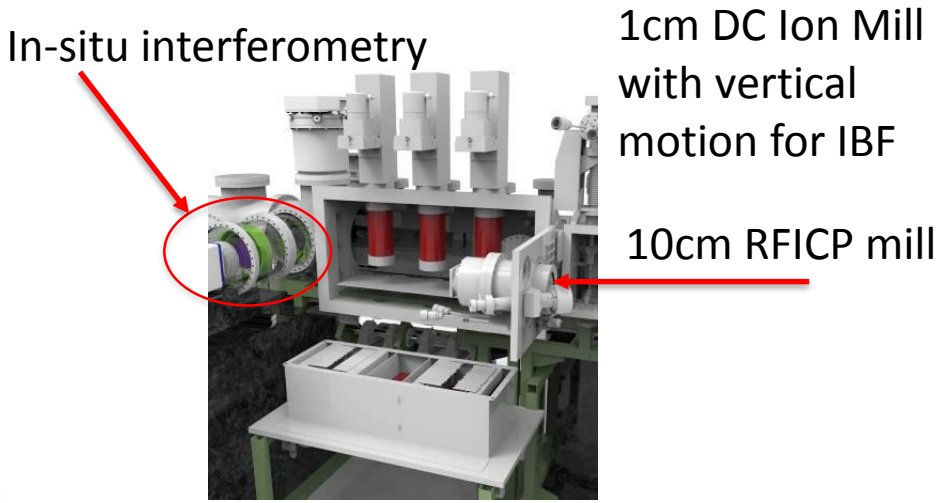
- The Advanced Photon Source (APS) is a premier national research facility that provides high energy x-ray beams to over 5,000 scientists from around the world
- The future APS Upgrade Project will deliver x-ray beam with an emittance a factor of ~50 smaller and coherent flux 2 to 3 orders of magnitude larger compared to the APS today
- Higher energy x-ray beams will require higher quality mirrors with <1 nm figure error and <0.15 nm surface roughness

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

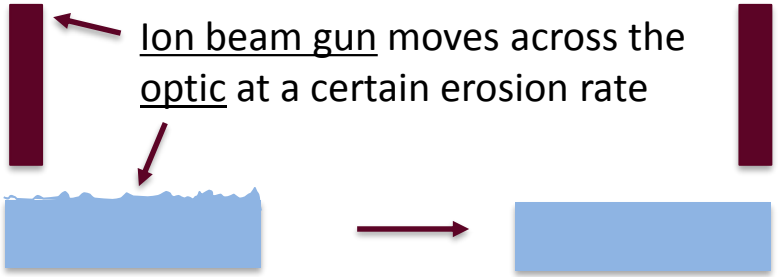
Advanced Photon Source (APS) Modular Deposition System (MDS)

- APS/XSD Optics Group commissioned an advanced modular deposition system (MDS) to develop advanced thin film optics including:
  - Single and multilayer mirrors
  - 3-D thin film optics
  - Focusing mirrors
- The system is equipped with and in-situ metrology and an ion beam figuring system.

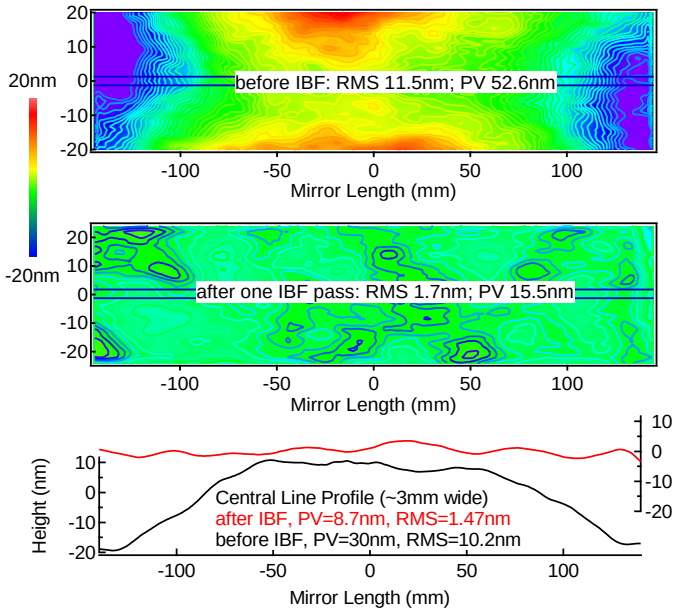
Image courtesy of Ray Conley – "Directors Review" presentation



Mirror Figure Correction Using In-situ Ion Beam Figuring and In-situ Metrology

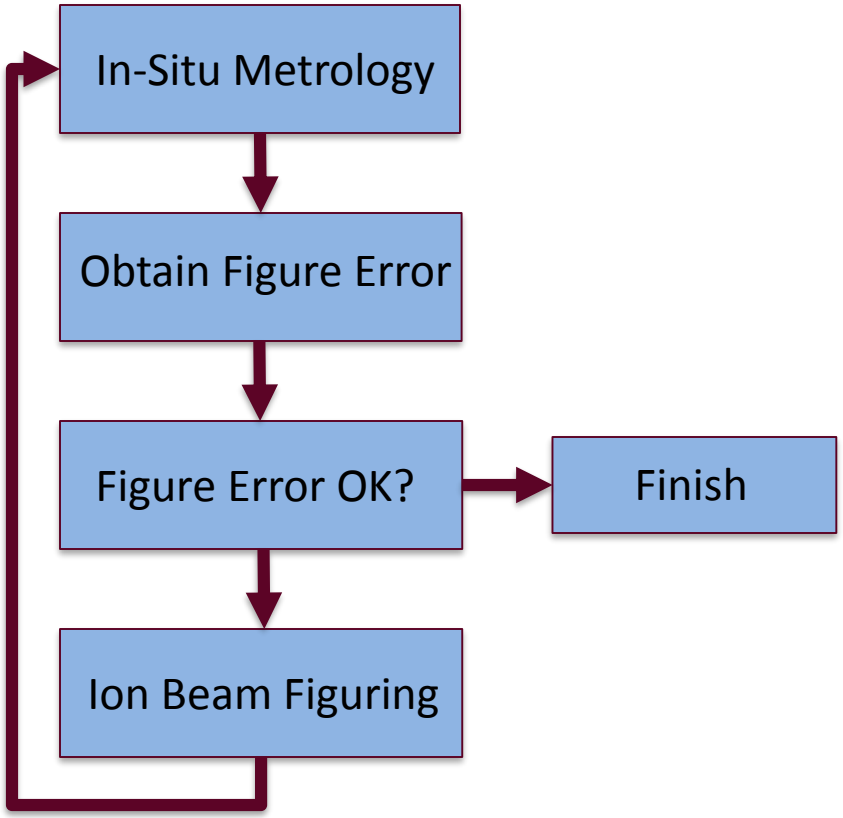


(a)



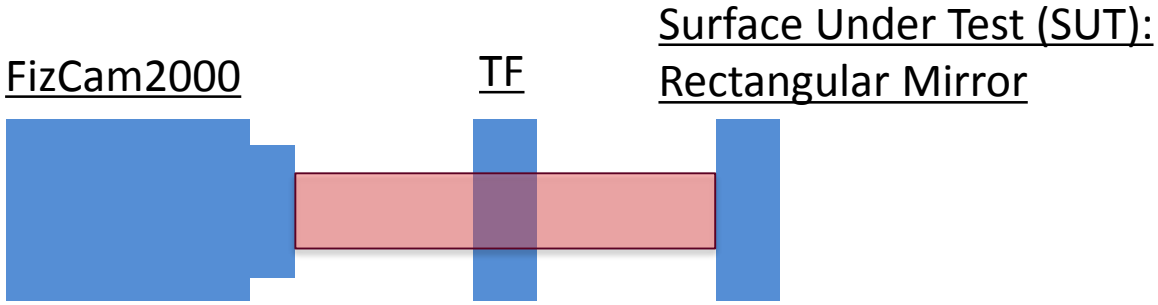
Example mirror figure correction courtesy ZEISS

Basic Work Flow Diagram

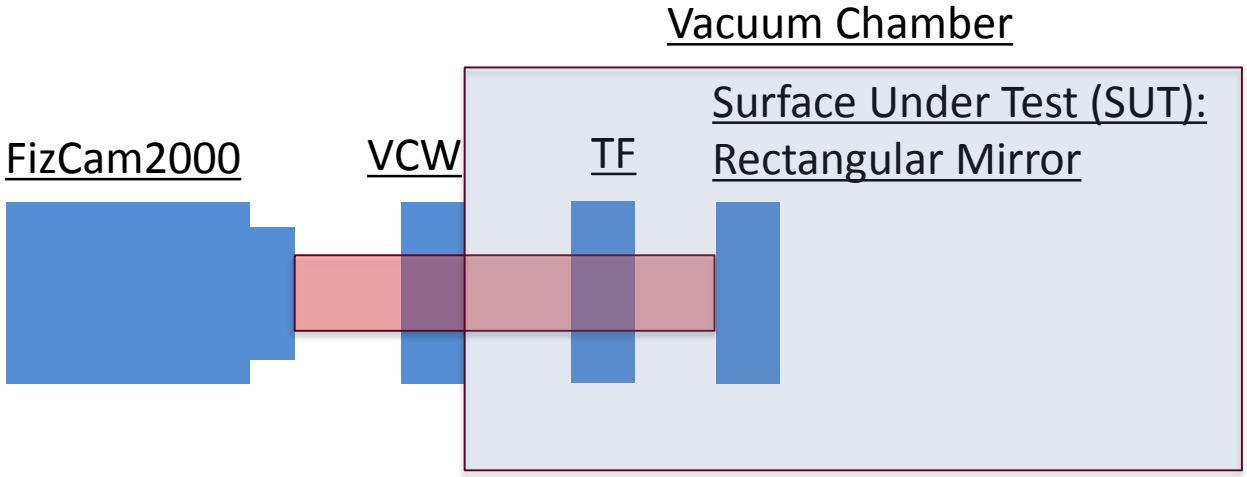


Project Aim

Normally, x-ray mirror metrology uses the following setup with a transmission flat (TF) and surface under test (SUT):



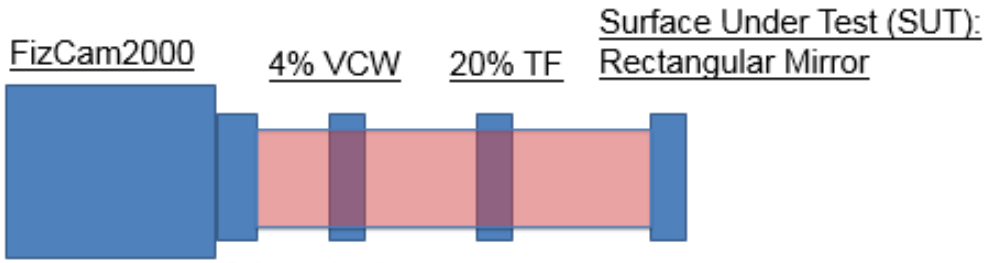
In-situ metrology introduces vacuum chamber window (VCW)in the setup:



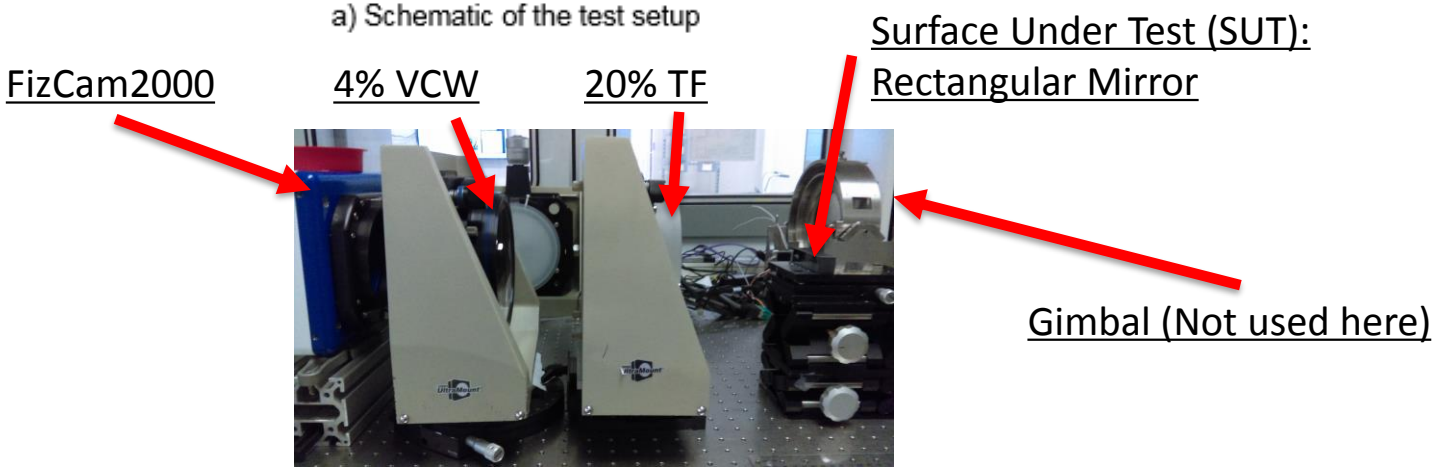
- The aim of the present work is to evaluate the effect of the VCW when measuring the SUT

Experimental Setup

- Basic setup to simulate the effect of the vacuum chamber window
- Preliminary tests to study the effect of the vacuum port were carried out in the APS metrology laboratory. Measurements were performed both in vacuum using a test chamber and at atmospheric pressure. The present work focuses on measurements at atmospheric pressure using the setup



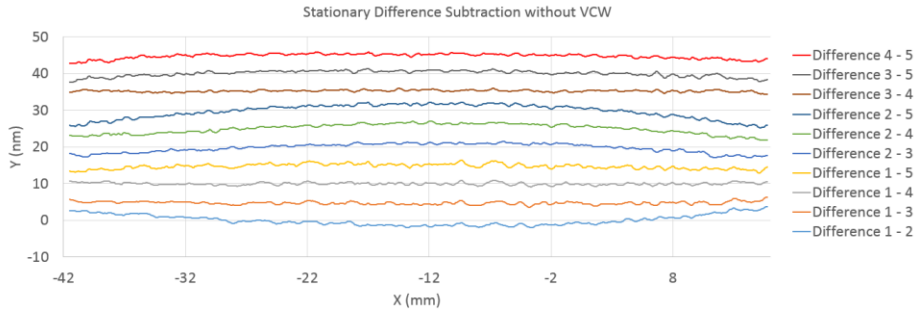
a) Schematic of the test setup

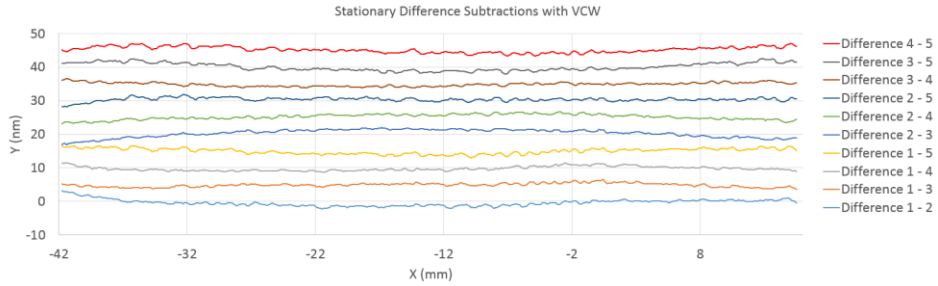


b) A photograph of the test setup

Measurements

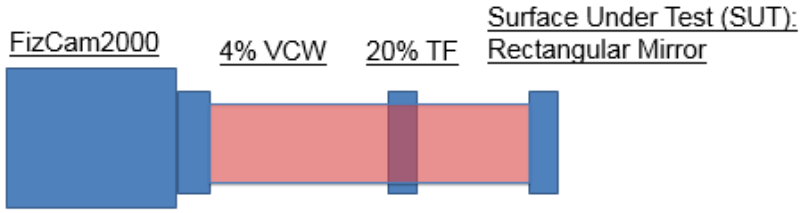
- Types of measurements:
  - Stationary measurements (with/without VCW) taken to gauge stability of the system
  - VCW tilt measurements to observe the effect of tilting the VCW



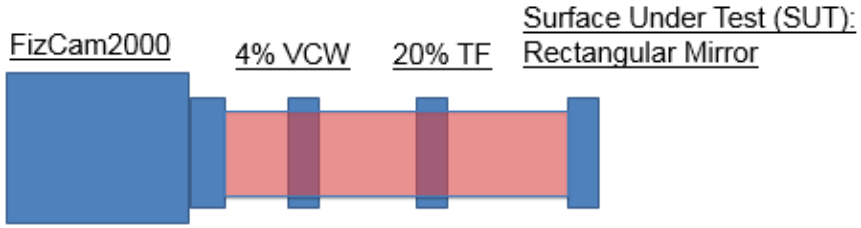


Stationary measurements above show environmental factors contributing to noise

Setup for Stationary Measurements:

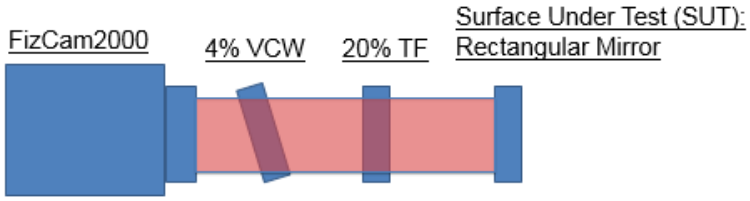


a) Schematic of the test setup without VCW



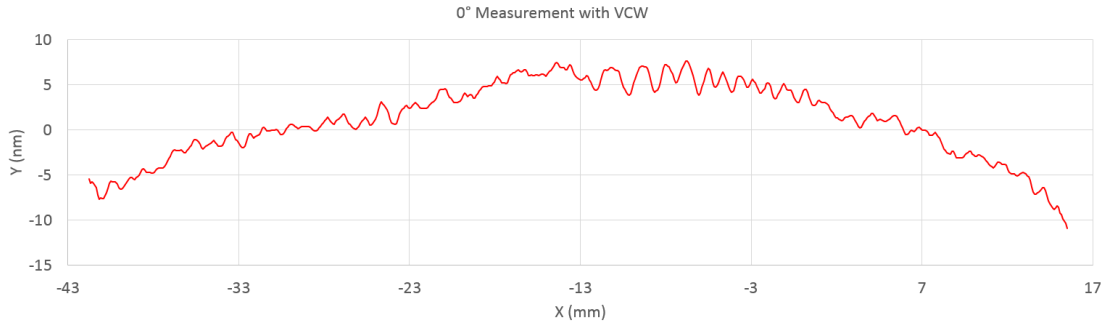
a) Schematic of the test setup with VCW

Setup for VCW Tilt Measurements (top view):



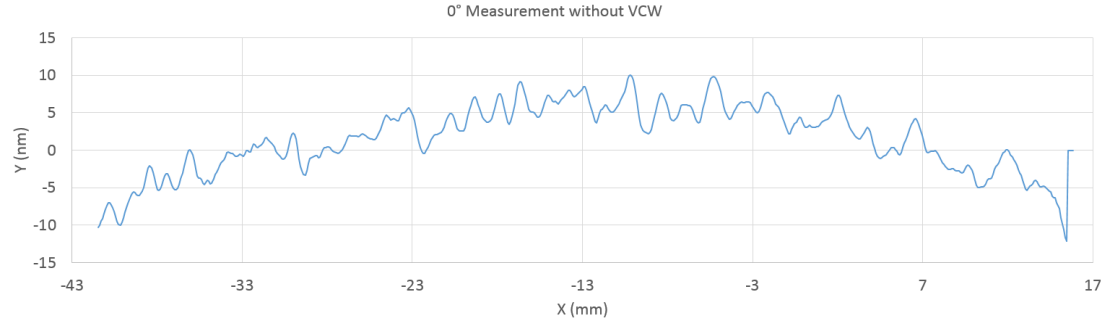
a) Schematic of the tilt setup

Results and Discussion



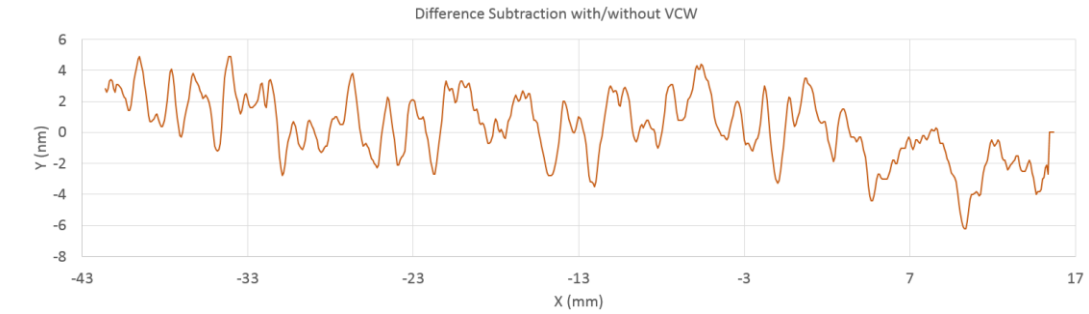
Measurement 1
With VCW
(RMS = 20.55 nm)

Minus



Measurement 2
Without VCW
(RMS = 20.52 nm)

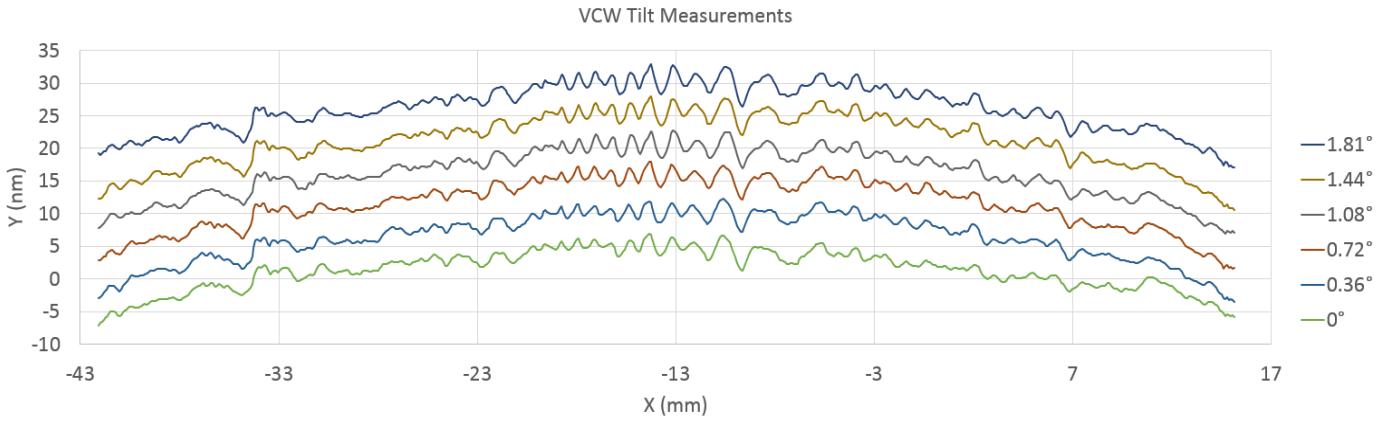
Equals



Difference Subtraction
Profile (RMS = 1.7 nm)

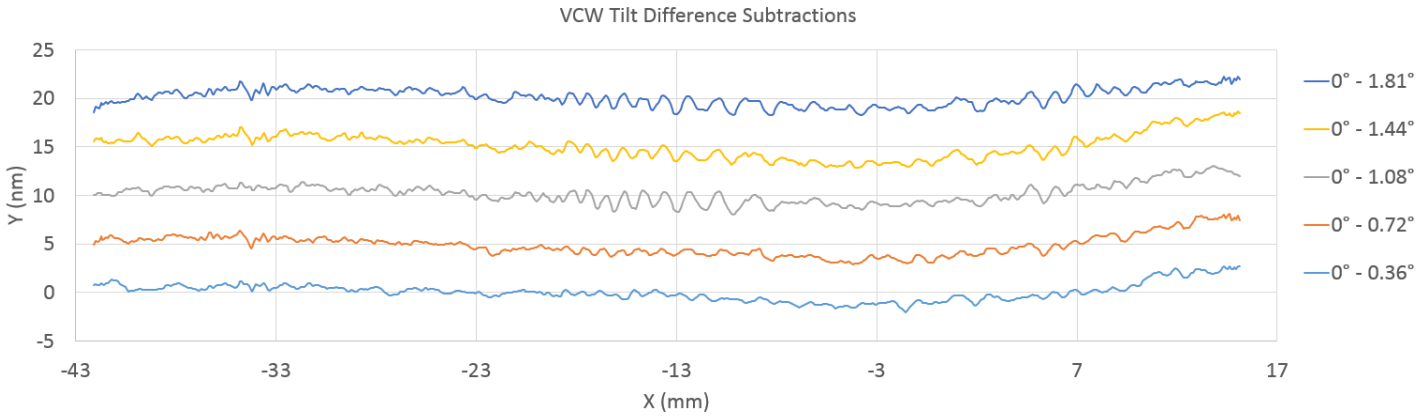
High RMS value most likely due to system's systematic errors

Results and Discussion (cont'd)



The RMS values versus window tilt angle

Tilt	RMS (nm)
1.81°	3.088
1.44°	3.405
1.08°	3.052
0.72°	3.128
0.36°	3.229
0°	3.095



The RMS values versus difference of profiles

Line Subtraction #	RMS (nm)
0° - 1.81°	0.676
0° - 1.44°	0.888
0° - 1.08°	0.784
0° - 0.72°	0.808
0° - 0.36°	0.678

- Overall, there is negligible difference in tilt angles (all RMS are <1nm)

Conclusion and Future Plans

- The measurements show that the VCW has negligible effect on the measurement of the SUT.
- Further experimenting will need to be conducted to verify this finding. Due to the limited amount of time for this project, the work could not be completed.
- Future tests will be conducted in the MDS actual vacuum chamber to obtain more representative results. The reference flat will then mounted inside the vacuum chamber using in-house designed gimbal.
- Noticeable differences between the vacuum and atmospheric environments include the deformation of the vacuum chamber window (becomes curved) when the air is pumped out.

Acknowledgements

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- This work was supported by Argonne and the US Department of Energy, Office of Basic Energy Sciences, under contract No. DE-AC02-06CH11357

References

[1] R. Conley, M. Erdmann, J. Carter, B. Shi, T. Mooney, L. Assoufid, J. Qian and K. Goetze, "Ion Beam Figuring with In-situ Metrology: Diffraction Limited X-ray Optics and Dynamic Aperture for Three-Dimensional Control of Thin-Film Deposition and Ion-Beam Erosion", 2016.

[2] 4Sight User Manual, Version 2.14 Rev B, 4D Technology Corporation, Tuscson, AZ, 2014

[3] D. Malacara, Optical shop testing, third edition. Hoboken, N.J.: Wiley-Interscience, 2007.

[4] R. Conley, "APS Deposition System", Argonne National Laboratory, 2016.

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Questions?