BEAMLINE ALIGNMENT AND CHARACTERIZATION WITH AN AUTOCOLLIMATOR

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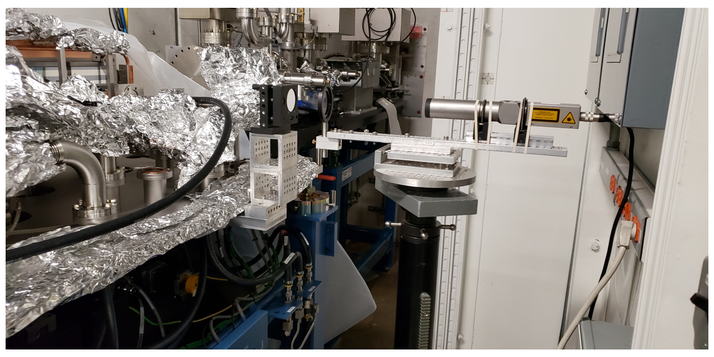
ABSTRACT

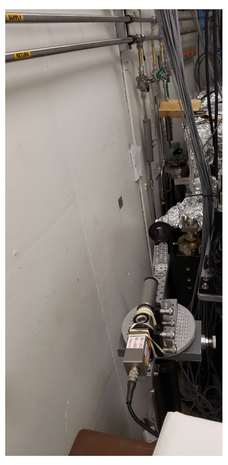
An electronic autocollimator is a valuable tool that can assist in the alignment of optical beamline components such as mirrors and monochromators. It is also a powerful tool for *in situ* diagnoses of the mechanical behavior of such components. This can include the repeatability of crystals, gratings, and mirrors as they are rotated; the parasitic errors of these same optical elements as they are rotated and/or translated; and the repeatability and parasitic errors as bendable mirrors are actuated. The autocollimator can even be used to establish a secondary reference if such components require servicing. This paper will provide examples of such alignments, diagnoses, and references that have been made with an autocollimator on existing and recently commissioned beam-lines at the Advanced Photon Source (APS). In addition, this paper will discuss how this experience influenced the specifications and subsequent designs of the new primary high-heat-load mirror systems (PHHLMS) that are currently under fabrication for six of the APS Up-grade (APS-U) feature beamlines. Each mirror was specified to provide *in situ* line-of-sight access for an autocollimator to either the center of the mirror's optical surface or to a smaller polished surface centered on the backside of each mirror substrate. This line of sight will be used for initial alignment of the mirror and will be available for *in situ* diagnoses if required in the future.

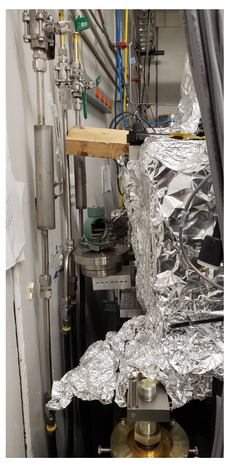
DUAL MIRROR SYSTEM AT 2-ID

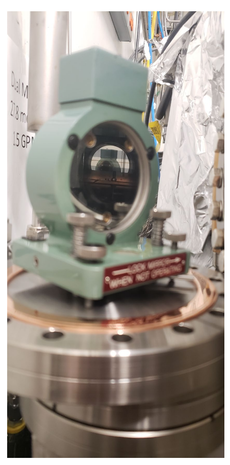
- Dual mirror system installed at 2-ID in late 2019 [2]
- Mirrors are horizontally deflecting and focusing.
- Original roll position of each mirror set with scope viewing downstream edge - > 1mrad error.
- Autocollimator and Vertical Leveling Mirror (VLM) [1] allowed roll to be set better than 100 µrad.
- Water leak developed on upstream/inboard mirror during minimum safe operations, water turned off.
- Repairs occurred a few months later.
- Used autocollimator to establish reference mirror, allowed verification that actual mirror did not change appreciably in pitch and roll due to repair.



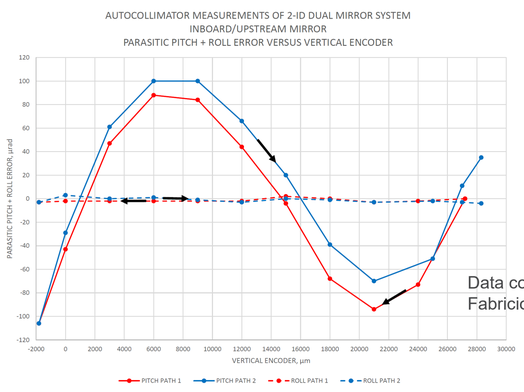
Autocollimator was aligned to upstream/inboard mirror at 2-ID prior to addition of reference mirror. Allowed verification of before/after repair of pitch and roll.







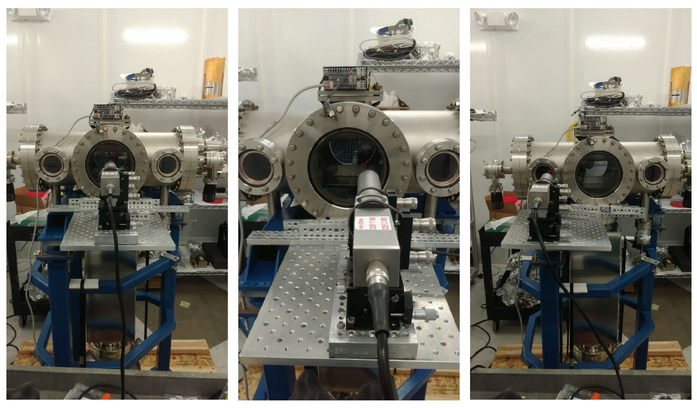
In situ autocollimator readings of both mirrors have been made under normal operating conditions utilizing viewports and a VLM in the case of downstream/outboard mirror which is inward facing.

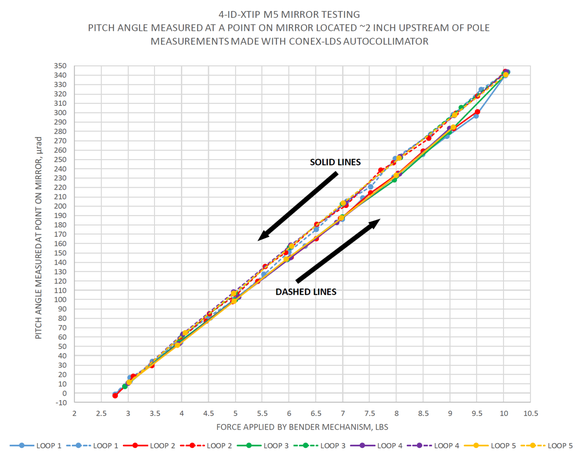


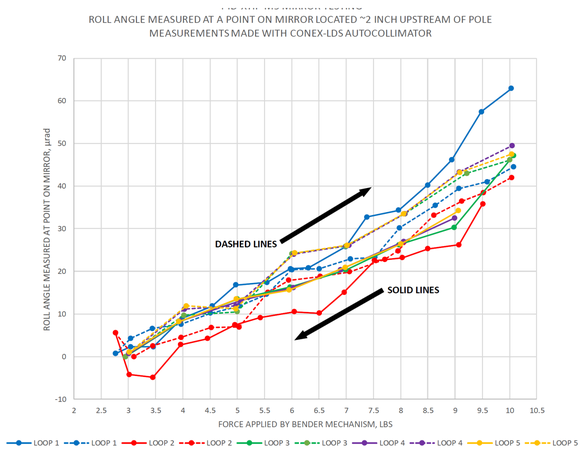
Data courtesy Fabricio Marin

BENDABLE MIRROR AT 4-ID-XTIP

- 4-ID-XTIP branch beamline constructed 2018-19 [3]
- SGM with moveable long travel exit slit required a bendable mirror to focus exit slit to sample position.
- Original plan was to specify and procure a new M5 Mirror with elliptical bender but decided to refurbish an old 011 4m-NIM M0 Mirror from SRC [4] that had been vented, backfilled, crated and sent to APS for possible use after SRC shutdown.
- Autocollimator test were performed on this mothballed mirror system to verify that bender mechanism was still smooth and repeatable after years in storage.
- Autocollimator measurements were made at pole, position 50mm upstream of pole and at downstream end of mirror where bender grips mirror (photos below).
- Test confirmed bender functioned reasonably. Plots below are results form 50mm upstream of pole position.

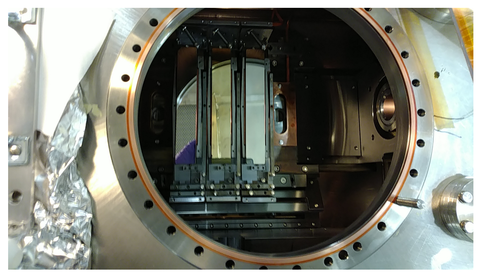




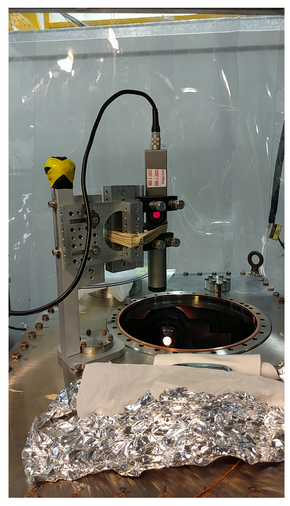


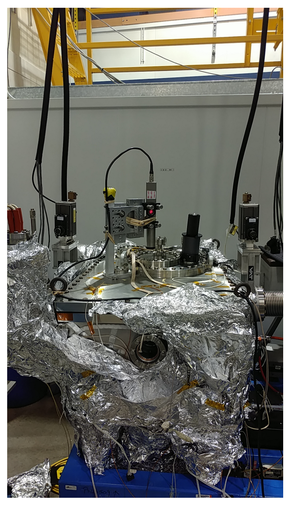
SGM AT 4-ID-C

- Autocollimator was used to install new grating on the 4-ID-C SGM in mid-2017 . Autocollimator allowed new grating to be aligned with same pitch and roll as existing gratings. These are manual adjustments best done while SGM is vented.
- Gratings were also installed into SGM at 4-ID-XTIP and VLS-PGM at 29-ID using similar technique.
- XPS data taken on C 1s binding energy with an in-situ autocollimator tracking repeatability of energy scan. Measurements confirmed theory that SGM performance could be enhanced by retrofitting in-vacuum scan angle encoding. Upgrade was not pursued.

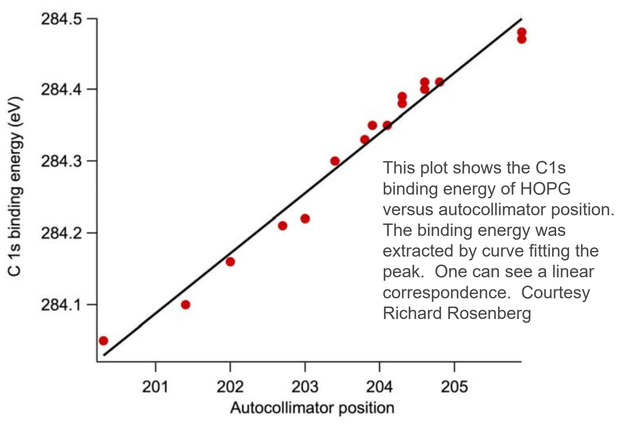


View thru open access port on 4-ID-C SGM showing third grating installed. Photo on bottom right shows how autocollimator was used to set new grating to have same pitch and roll s existing gratings.



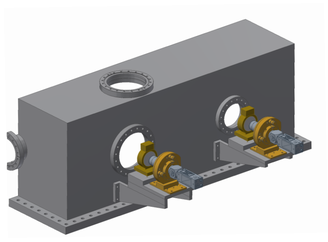


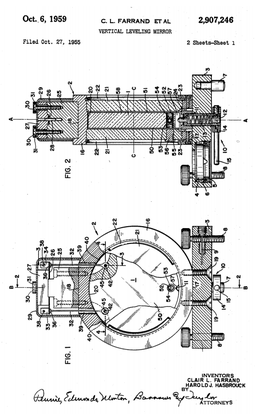
In situ autocollimator setup shown above and to the right was used to correlate XPS and autocollimator readings and verify that scan energy repeatability could be improved with in-vacuum scan angle encoding.



CONCLUSIONS

- Previous experience with autocollimator influenced specifications for PHHLMS on APS-U feature beamlines.
- Mounting feature, viewports and lines of sight to optical surfaces were required on all mirrors except those downward facing.
- Additional polished reference surface required on backside of downward and inward facing mirrors with corresponding viewports and lines of sight.





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[1] C. L. Farrand, "Vertical Leveling Mirror," U.S. Patent No.2907246, Oct. 6, 1959.
[2] D. Capatina et al., "APS 2-ID beamline, upgrade to canted configuration," in Proc. MEDSI'16, Barcelona, Spain, Sep. 2016, paper WEPE18, pp. 342-344, DOI:10.18429/JACoW- MEDSI2016-WEPE18.
[3] V. Rose et al., "XTIP - the world's first beamline dedicated to the synchrotron X-ray scanning tunneling microscopy technique," J. Synchrotron Rad., (2020). 27, pp. 836-843, DOI: 10.1107/S1600577520003689.
[4] T. Kubala, M. Fisher, R. Reininger, M. Severson, "New actively bent plane mirror at SRC," AIP Conference Proceedings 417, 130 (1997), DOI:10.1063/1.54610.

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