MINIMIZING GRATING SLOPE ERRORS IN THE IEX MONOCHROMATOR AT THE ADVANCED PHOTON SOURCE

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MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

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ABSTRACT

- Intermediate Energy X-ray (IEX) Beamline currently in commissioning phase. Energy resolution of the beamline was not meeting specifications by several orders of magnitude.
- Monochromator is an in-focus VLS PGM up to four water side-cooled gratings. Currently configured with a HEG and MEG grating.
- Experimental measurements indicated a systematic problem with gratings which led to venting monochromator to investigate.
- Initially suspected error in ruling density of both VLS gratings, but that was not the case. Eventually determine that original grating holders were causing large surface profile errors in gratings.
- Grating holder modifications eliminated problematic constraints without compromising the rest of the design. Metrology performed on the gratings before and after the modifications showed a 20-fold improvement in surface profile. FEA showed similar improvements.
- Gratings were successfully reinstalled and subsequent measurements with beam show dramatic improvement in energy resolution.

BEAMLINE

- IEX Beamline designed with two separate branches, each with dedicated endstation [1].
  - ARPES: angle resolved photoemission spectroscopy
  - RSXS: resonant soft X-ray scattering
- High energy resolution required by ARPES endstation is achieved with an in-focus variable line spacing plane grating monochromator (VLS-PGM). [2]
- High-line-density grating (HEG) with a nominal 2400 l/mm primarily used for high resolution photoemission experiments on ARPES branch.
- Medium-line-density grating (MEG) with a nominal 1200 l/mm offers higher flux with moderate resolution and can be used by both branches.
- Future plans include a low-line-density grating (LEG) with a nominal 400 l/mm that is optimized for the RSXS endstation.
- ENERGY RESOLUTION PROBLEM - The diffracted beam downstream of the exit slit was observed to shift in energy depending on the size and position of either the synchrotron beam or the aperture located just downstream of the monochromator. As a result, the energy resolution was very poor except for the smallest aperture sizes.

GRATING HOLDER

- The grating substrate design adopted for the IEX monochromator is shown in Figure 1. It has three horizontal through-holes to facilitate clamping of side cooling blocks and three vertical holes to facilitate bolting the grating to a support from below.
- The original grating holder design is shown in Figure 2. The cooling blocks are clamped to the sides of the gratings with three custom bolts that are secured with a nut. These custom bolts have tapped holes through their shanks that allow three vertical screws to pull the grating down against three steady rests.
- A drawing of the modified holder design is shown in Figure 3. The cooling blocks are still clamped to the sides of the grating with the same custom bolts, but now include a Belleville washer. The steady rests have been replaced with spherical washers of the same height that are located coaxial to the three new low profile vertical hold-down screws. A stack of three Belleville washers is placed under the head of the screws and allow for the application of a repeatable, small clamping force that is thermally compliant.

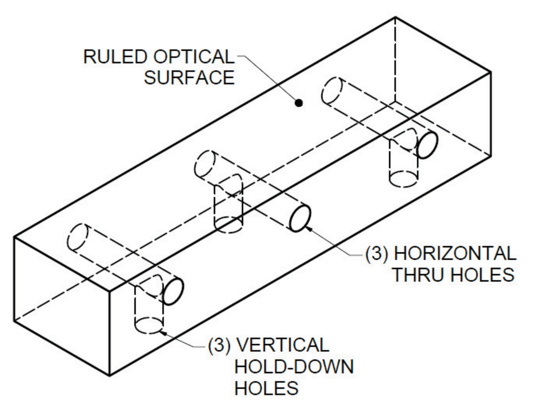

Figure 1: Grating Substrate Mounting Details

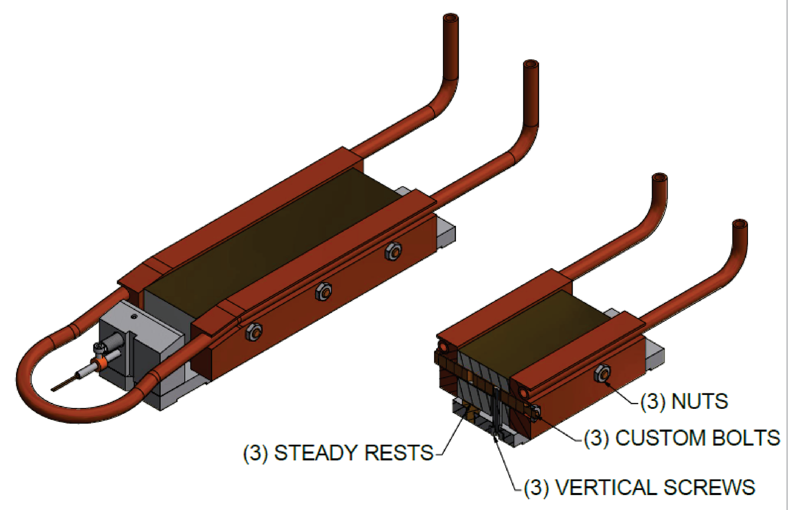

Figure 2: Original Grating Holder

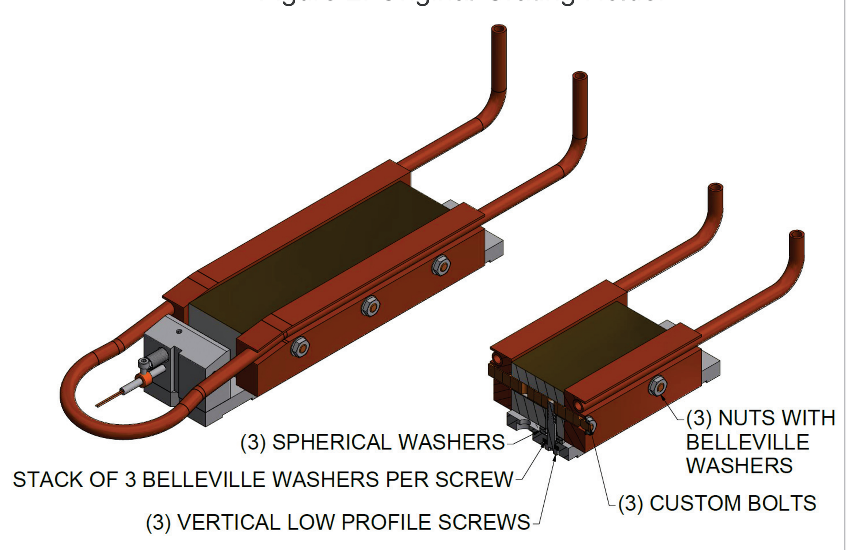

Figure 3: Modified Grating Holder

METROLOGY

- Long trace profilometer (LTP) at the APS was undergoing upgrade.
- Original MEG was sent to SOLEIL Synchrotron for measurement of ruling density using their LTP, measurements confirmed ruling was okay.
- Adopted philosophy that metrology should be conducted at each step along the way to verify surface profile integrity. This entails measuring gratings before and after they are mounted in their holders. [3, 4]
- With APS LTP unavailable, developed methodology to measure surface profile errors with a Wyko 600 Interferometer. This technique was first used with a grating substrate and eventually was perfected for use with the actual gratings. Setup and measurement results shown in Figures 4 and 5.

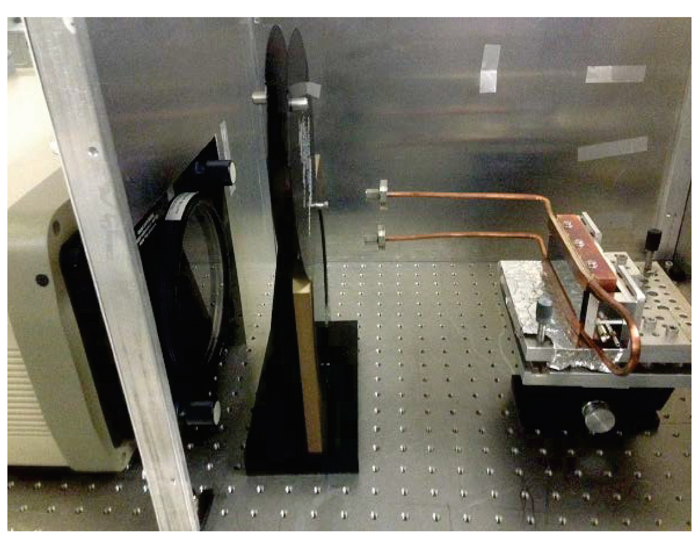

Figure 4: Surface Profile Measurements with Wyko 6000 Interferometer

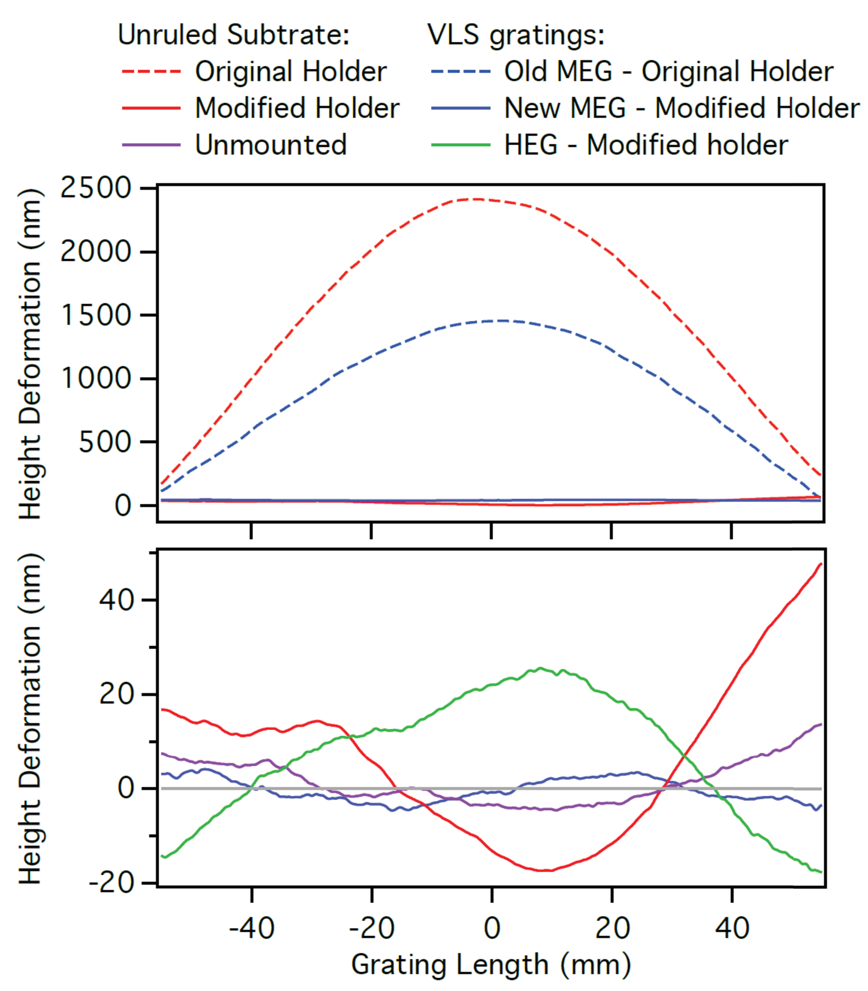

Figure 5: Surface Profile Results

FEA

- An arbitrary loading 10 N per vertical hold-down screw assumed on original grating holder, 1000 N assumed for modified holder in order to normalize to same distortion scale.
- In addition to loads, impose constraints corresponding to original and modified holder.

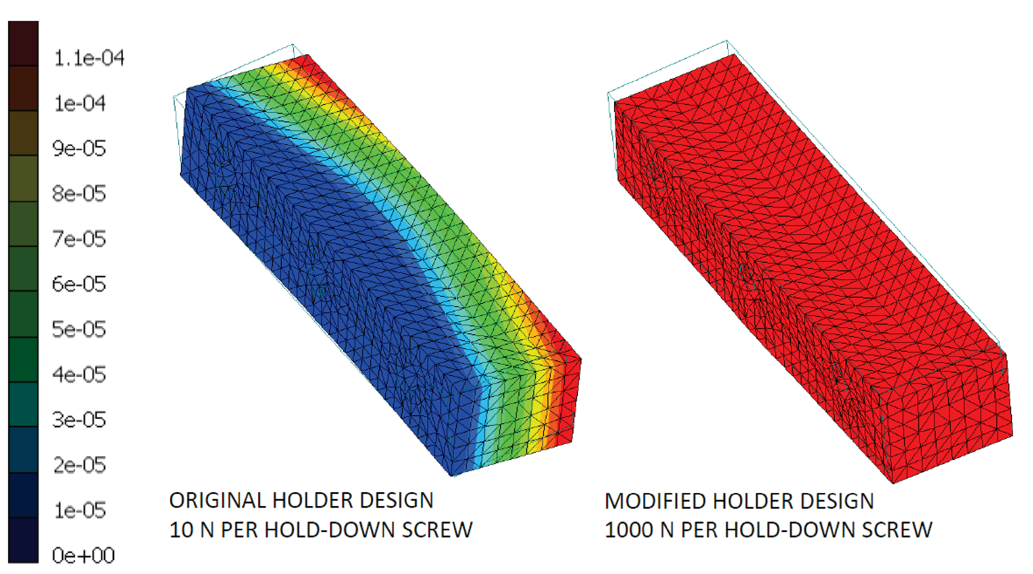

Figure 6: FEA Comparison of Grating Distortions

CONCLUSIONS

- A dramatic improvement in energy resolution as one measures the energy of the Au 4f photoemission peaks and scans the vertical aperture downstream of the monochromator.

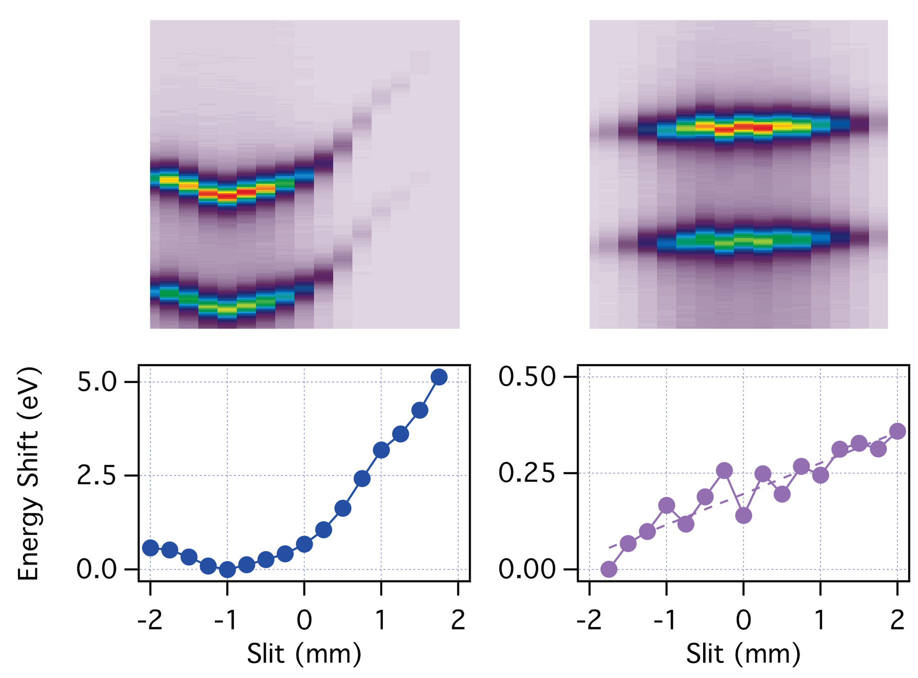

Figure 7: Improved Beamline Performance

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