Fabrication, Assembly, and Metrology Methods to Optimize an Adjustable Exit Slit for a Soft X-ray Beamline

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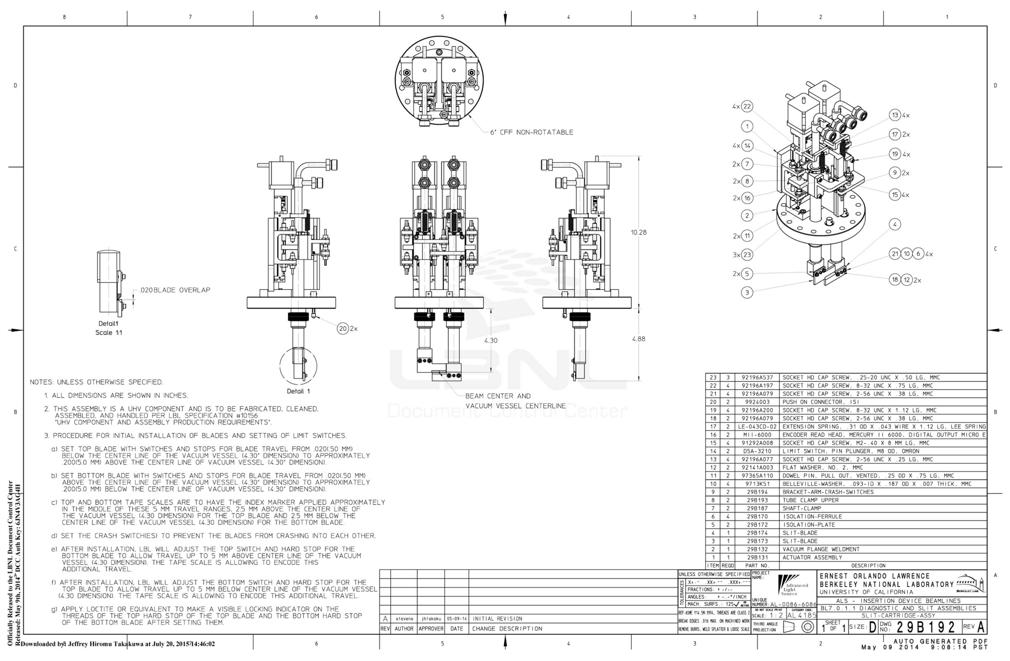
Abstract

Exit slit edge geometry and paired edge parallelism can directly impact performance of a synchrotron beamline. At the same time, maximizing the performance of an existing design is often a financial and logistical necessity. The construction project for beamline 7.0.1 (BL7.0.1, COherent Scattering and MICroscopy (COSMIC)) at the Advanced Light Source (ALS) facility located at Lawrence Berkeley National Laboratory (LBNL) consists of two branch lines, each of which has vertical and horizontal slit assemblies. These assemblies were fabricated from a preexisting design, positively impacting project schedule and budget. Apart from orientation, the slit assemblies are identical. The goal for parallelism is +/- 2 microns over the full 25 mm length. The each slit blade edge can travel +/- 5 mm about the beam center with the resolution of a micron; slits can scan over that range with a nominal size of about 10 microns. A variety of fabrication and metrology techniques were implemented to maximize the performance of the current design and future areas of improvement in fabrication, metrology, and design were identified.

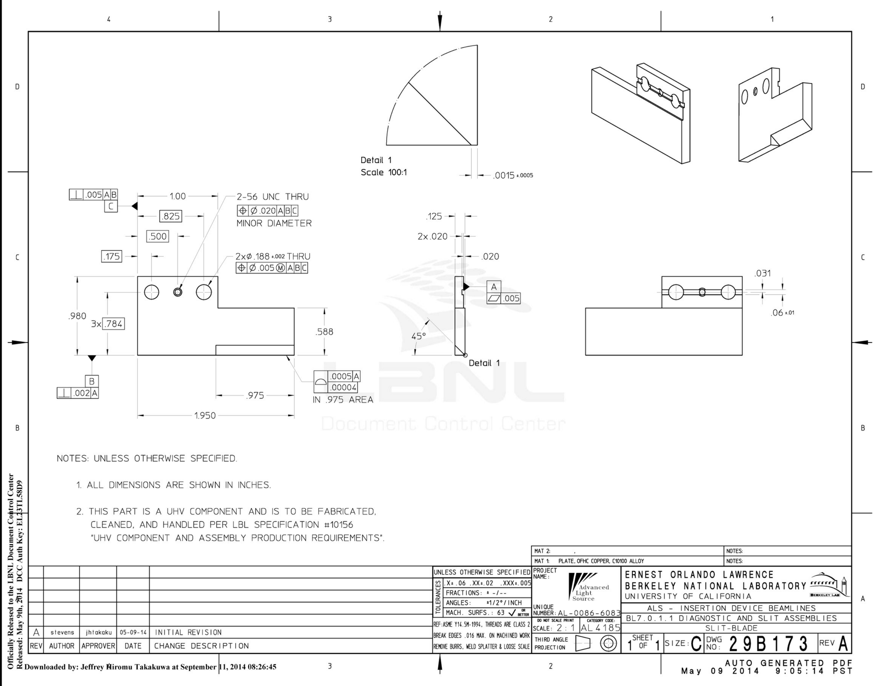
Introduction

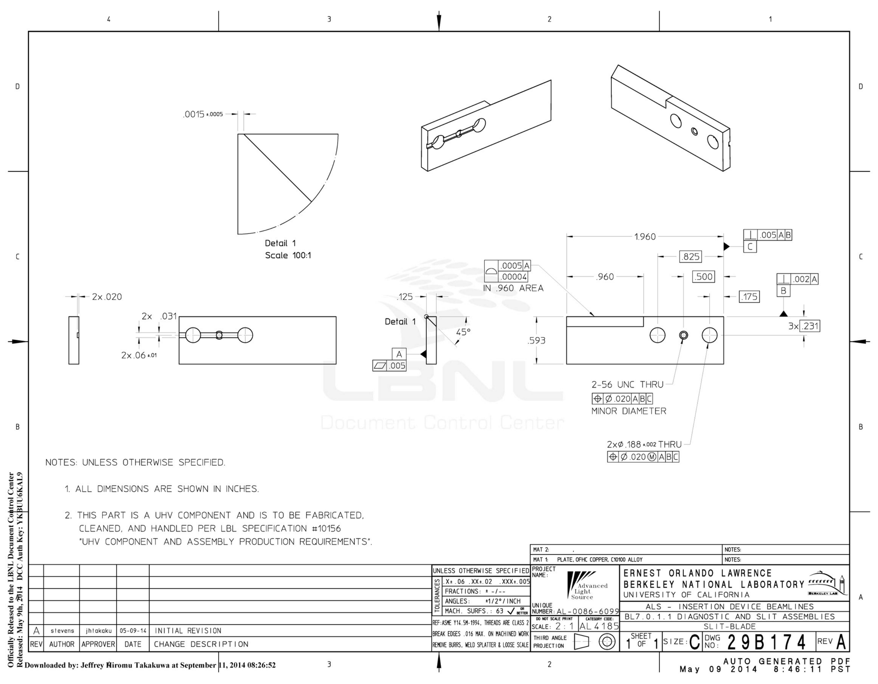


At the ALS beamlines 7.0.1 and 7.0.2, there are eight sets of exit slits used. Each beamline has two branchlines and associated end stations. Branchlines use two exit slit sets where each confines the beam horizontally and vertically. The goal is to have an exit slit parallelism of +/- 2 µm over 25 mm. Perpendicularity between the horizontal and vertical sets are determined by the flange orientations on the welded chamber. During the fabrication process for the 7.0.2 beamline (which predated 7.0.1), each blade edge was measured to be out of the +/- 2 µm specification. Improvements were made to the exit slit edge straightness and parallelism for the subsequent 7.0.1 beamline. These fabrication and assembly improvements and their results are described herein.

Blade Fabrication for Edge Straightness

Exit slit blades were OFHC copper, C10100 alloy, paddle style blades and are water cooled (for temperature stability) and mounted to the end of actuators to create a rectangular exit slit with adjustable dimensions and locations. The GD&T tolerance for the edge was a profile, ⌓, of 0.00004" (1 µm). Goals to meet the tolerance were "best effort" using "standard" fabrication techniques; the bevel feature was produced with a fine wire EDM.



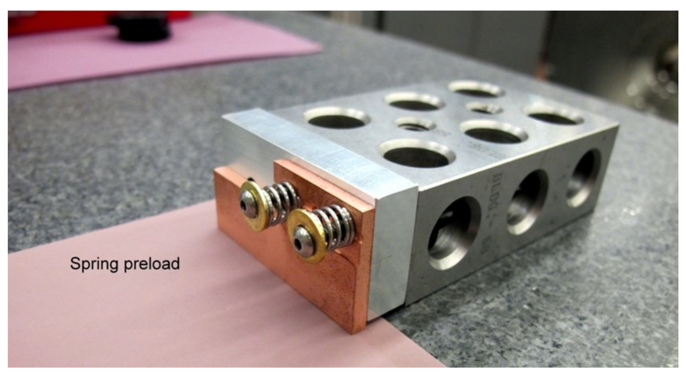


Means of inspection:

Metrology was performed by Bob Connors at Precision Measurement Services at the central shop in building 77. The slit blade edges were measured on the Optical Gaging Products, SmartScope Quest 800. Metrology software used was MeasureMind 3D version 15.1. Measurements were first taken directly following fabrication and cleaning with no additional machining. Typical results yielded a variation of the exit slit blade of +/- 2.5 µm to +/- 7.5 µm depending on the length of the blade sampled, compared to the target of 1 µm. A lapping process was chosen as a secondary operation to improve the edge profile geometry of the blades.

Lapping Process:

Each slit blade was bolted to a fixture maintaining a consistent orientation. Lapping was manual and pressure from the blade to the lapping surface was applied by hand.



A series of grits were used:

- Roughing — 1200 Grit wet dry silicon carbide paper
- Semi finish — 3 Micron (1500 Grit) Aluminum Oxide
- Finish — 1 Micron (2000 Grit) Aluminum Oxide
- Final Polishing — .1 Micron (2500 grit) Diamond

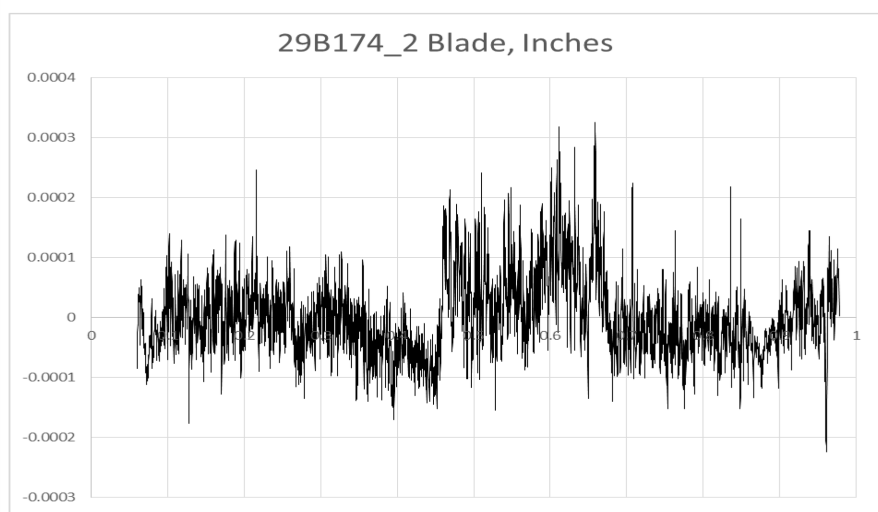
Cleaning:

After all the parts were lapped and placed in a protective insert a final ethanol rinse and drying was performed and the box sealed. The next cleaning steps were done by the LBNL plating shop.

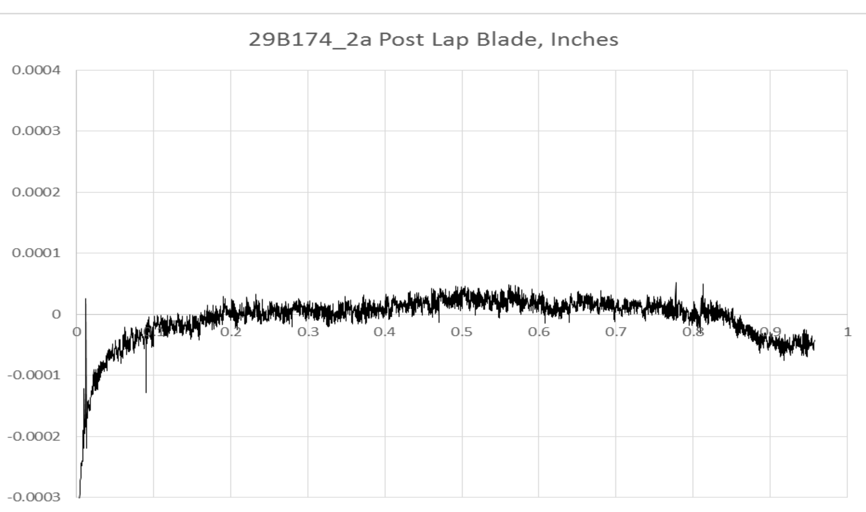
- 909 Cleaner wash
- Electro polish 130 F Time in bath was the start of bubble formation after current applied < 1 min
- Nitric acid rinse dip
- Hot, 180 F deionized water rinse

Edge Straightness Results (Typical)

Initial Inspection:



Post-Lap Inspection:



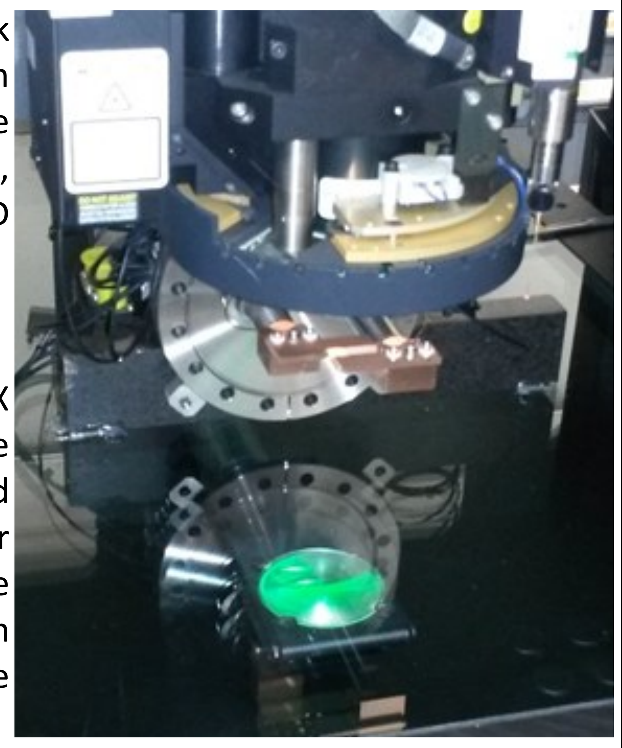
The conclusion after reworking the individual blade edges was that they do not meet the specified 1 µm profile tolerance zone over the length of the blade. However, the results of the rework are an improvement over the original effort and close to the specification over "short" lengths. These blades were expected to function for the 7.0.1 beamline and were installed as-is.

Slit Assembly Parallelism Adjustment

The initial assembly was performed with conventional tools and measuring devices. Blade parallelism was adjusted using dial indicators. So as not to damage the blade edges themselves, indicator stylus contact was to the side opposite the blade chamfer (edge) side. This assumed parallelism between the edge and opposite side.

Means of Inspection and Adjustment:

Metrology and adjustment was performed by Chris Hernikl and Mark Campagna at Precision Measurement Services at the central shop in building 77; overseen by Rick Kraft. As with the exit slit blades' edges, the slit blade edge parallelism was measured on the Optical Gaging Products, SmartScope Quest 800. Metrology software used was MeasureMind 3D version 15.1.



Initial Measurements:

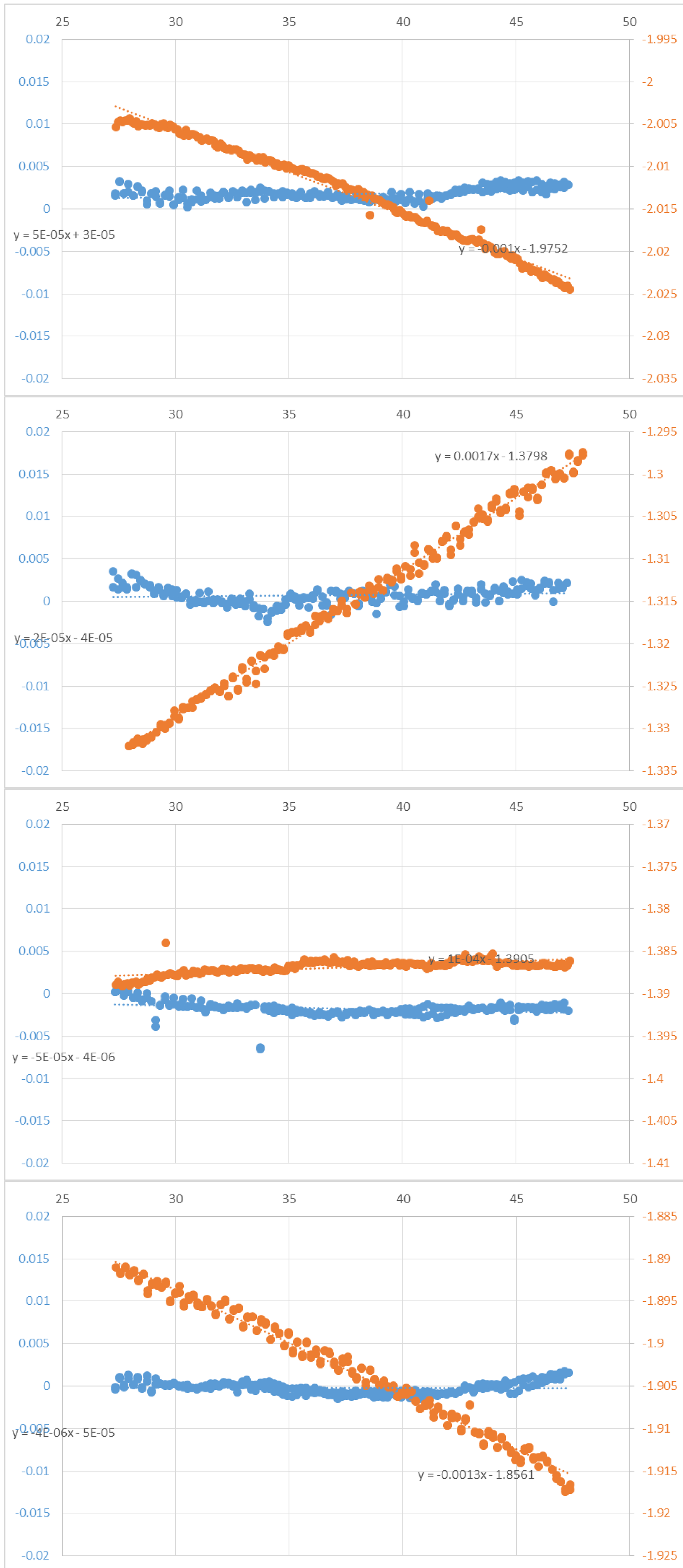
Measurements were over the length of the beveled blade edge, at 33.8 X power (optical), excluding ~2.5 mm from either end of the edge to exclude edge effects. The resultant ~19.7 mm length of blade edge was considered in all the following parallelism data. Best fit straight lines were created for each measured edge and the parallelism of these best fit lines were analyzed; excluding straightness issues of the edges themselves. Parallelism for each slit set ranged from 3 µm to 34 µm. This does not compare favorably with the specification of +/- 2 µm parallelism over 25 mm.

Adjustment:

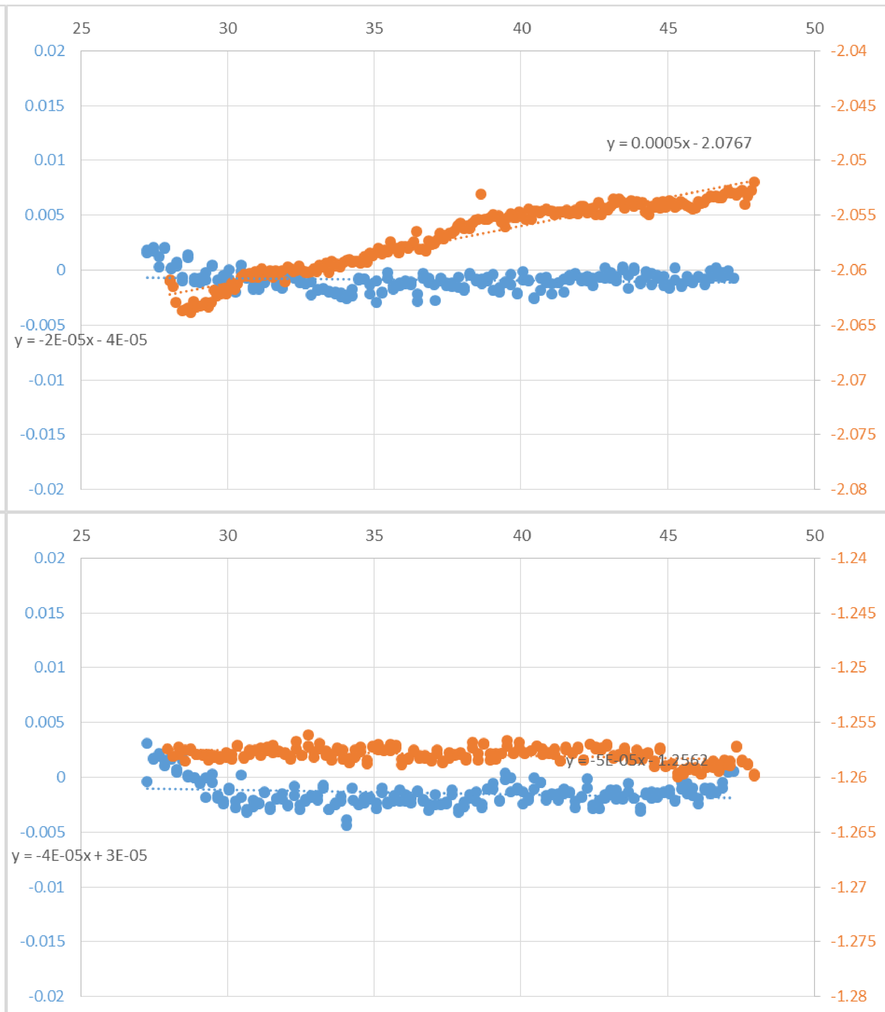
Adjustment of parallelism was accomplished by moving only the blade that was furthest from the flange. Adjustments were made by hand using the optical machine as feedback. Slit# 3 was accepted with no adjustment.

Parallelism Before/After Results For Each Slit Set (pair)

Before:

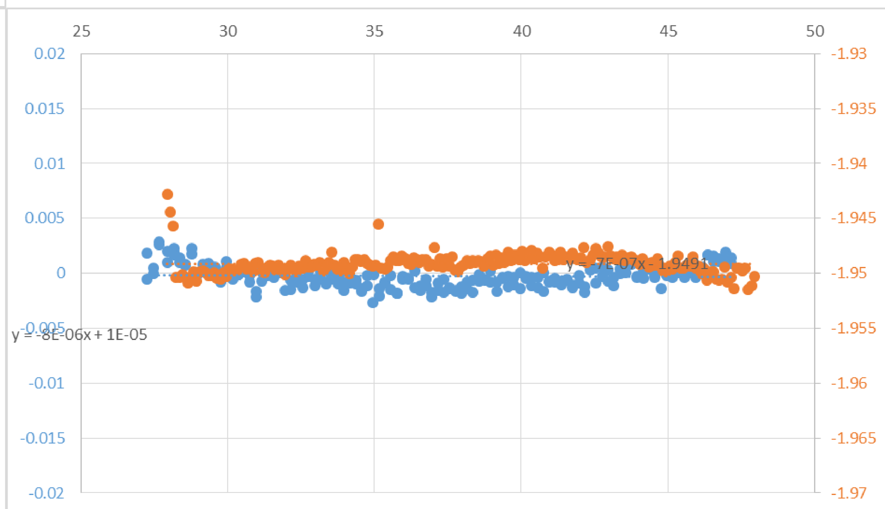


After:



The table describes the calculated parallelism results between best fit lines. The parallelism results constitute a "best effort". It is not possible to claim that the original specification of +/- .002 mm parallelism over 25 mm was achieved.

(mm)	Preadjustment	Postadjustment
Slit# 1	0.021	**0.010**
Slit# 2	0.034	**0.000**
Slit# 3*	0.003	**0.003**
Slit# 4	0.026	**0.000**



Conclusion and Future Design Considerations

It was not possible to claim that the specification of +/- 2 µm parallelism over 25 mm was achieved. However, the results of the rework were a significant improvement over the original effort. Financial and schedule impacts of a redesign were avoided. Within the constraints of a beamline construction project, this fabrication was a success. The exit slit assemblies are expected to function for the beamline 7.0.1 and were installed. Performance will be gauged during/after commissioning in early 2017.

Possible design changes that may improve performance would be:

- Add symmetric "lands" about the blade at the lapping surface to eliminate the lapping "fall-off"
- Add lapping fixture specific mounting points, symmetric about the blade for even pressure application
- Add flexures for parallelism adjustment, possibly from outside of the vacuum envelope
- Improve measuring edge straightness and parallelism over the 10 micron scan length
- Include metrology after installation and vacuum loading
- Change linear translation (ball screw) stage to a flexure for consistent blade edge insertion and retraction
- Add physical anti-clash hard stops

Acknowledgements

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