The Ninth International Conference on Synchrotron Radiation Instrumentation
May 28 – June 2, 2006, DAEGU, EXCO, KOREA

Pink-Beam, Highly-Accurate Compact Water Cooled Slits

Aaron Lyndaker, Alex Deyhim, Richard Jayne, Dave Waterman, Dave Caletka, Paul Steadman*, Sarnjeet Dhesi*

Advanced Design Consulting USA, 126 Ridge Road, P.O. Box 187, Lansing, NY 14882, USA
**Diamond Light Source Ltd, Rutherford Appleton Laboratory, UK*

Abstract. Advanced Design Consulting, Inc. (ADC) has designed accurate compact slits for applications where high precision is required. The system consists of vertical and horizontal slit mechanisms, a vacuum vessel which houses them, water cooling lines with vacuum guards connected to the individual blades, stepper motors with linear encoders, limit (home position) switches and electrical connections including internal wiring for a drain current measurement system. The total slit size is adjustable from 0 to 15 mm both vertically and horizontally. Each of the four blades are individually controlled and motorized. In this paper, a summary of the design and Finite Element Analysis of the system are presented.

Keywords: Slits, Current measurement, Water Cooled
PACS: 07.85.Qe, 41.50.+H

INTRODUCTION

Advanced Design Consulting USA, Inc. (ADC) in collaboration with Diamond Light Source (DLS) has developed a new secondary slits to define the beam after the first collimating mirror before the light reaches the plane mirror of the monochromator. The light is produced by an APPLE II undulator with 66 periods and period length 64mm. The total power from this undulator is 11kW at 500mA ring current. Shown in the table below are the details of the slits and optical elements that the beam meets before it reaches the secondary slits. The total power at the position and the power density is also given. These quantities are worked out for a 500mA ring current with the primary slit fully open at 6x6mm^2.

	Distance from Source (m)	Maximum Size of Aperture (mm)	Power at Position (kW)	On Axis Power Density (W/mm^2)
Frontend Aperture	17.3	5.25mm (H) x 4.4mm (V)	11	88.5
Primary Slits	21	6mm (H)x6 mm (V)	1.5	54.5
Secondary Slits	24.8	15mm(H) x 15mm (V)	0.15	6

	Parameter	Value
Horizontal Slit Blades	Range	10mm
	Min. incremental movement	≤3 μm
	Repeatability	≤5 μm
	Backlash	≤10 μm
Vertical Slit Blades	Range	10mm
	Min. incremental movement	≤3 μm
	Repeatability	≤5 μm
	Backlash	≤10 μm

DESIGN PRICIPLES

This unit consists of vertical and horizontal slit mechanisms, a vacuum vessel which houses them, water cooling lines connected to the individual blades, stepper motors, limit switches, electrical connections for a drain current measurement system and a stand for the vacuum chamber to attach to. Each of the four blades are individually controlled and motorized. The range of travel for each blade is –12.7 mm (-0.5”) to +12.7 mm (+0.5”) from the nominal beam axis. The vacuum vessel, a custom cylindrical chamber, contains ports for an ion pump, roughing pump, fluorescent screen, cold cathode gauge, feedthroughs for drain current measurement, feedthroughs for temperature sensors and spare ports for future use. The slits system is designed in such a way that each of the blades can withstand power loads as high as 300W total with power density up to 5W/mm^2 referred to a screen perpendicular to the beam propagation axis. As shown in figure 1 there is a large DN160 flange for a fluorescent screen diagnostic. The electrical, vacuum and water connections were all housed on custom designed interface units, making attachment to the beamline simple and straightforward.

A spring-extended linear encoder with built-in home position is provided for each individual blade. The accuracy of the linear encoder is better than 1 micron. An easily-visible linear scale for each blade is attached to its translation system to provide an alternate way of reading the blade position. Limit switches and hard stops prevent damage by over-travel. The four blades are electrically conductive and insulated from the vacuum vessel. Each blade is connected to a feedthrough with a standard BNC connector. The drive assembly uses stepper motor actuation and crossed-roller bearings. Two fiducial marks are provided per slit unit as well as height references on the vacuum chamber. All UHV sections are vacuum tested to better than 5x10^{-10} torr and have a leak rate of less than 2x10^{-10} mbar 1^{-1}s^{-1}. A test report, shipped with each unit, includes a residual gas analysis of each section showing the sum of all partial pressures for masses larger than 46 AMU is less than 10^{-11} torr. The slits system sits on a steel base structure. This structure has holes in the steel tubes so it can easily be filled with sand for added stability. Kinematic mounts on the base offer fine adjustment when lining up the slits to the beamline.

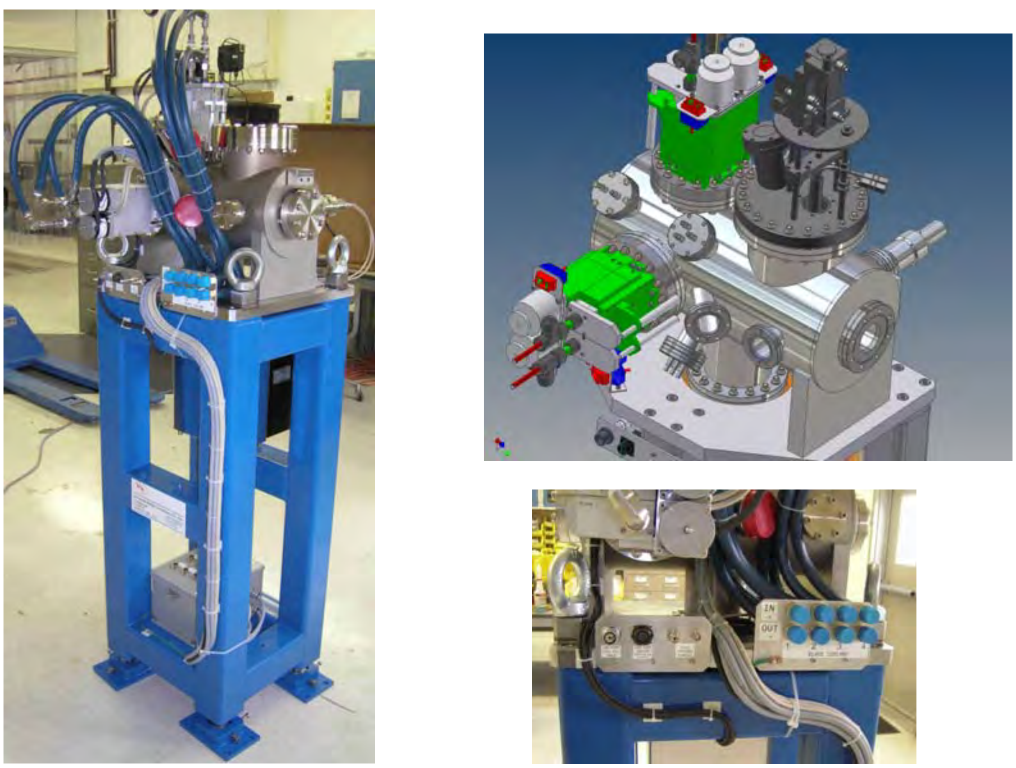

FIGURE 1. Pictures above shows the final assembly, labeling, and the CAD model.

Linear Encoders

The linear encoders used are Heidenhain ST 3078. They have a system accuracy of 1 micron. They each have a measuring step of 0.5 microns. The overall measuring range is 30 mm. The output is standard TTL quadrature, differentially driven, with an index pulse 5 mm from the least extension. Each encoder has a standard 1.5 meter cable length, different lengths are available up to 30 meters.

Blade Polishing

The process begins with a grinding operation designed to minimize the amount of material that must be removed during polishing. An edge and one of the faces are ground to an interior angle of 88° and then a second grinding operation relieves the face. Grinding produces an edge that is straight and true, but with pits and scratches that must be removed by polishing. Fixturing the slit is critical when polishing. The fixture must be extremely hard so that material is removed only from the blades, otherwise the knife-edge can become rounded. Two or more blades are usually polished together in a matched set to maintain parallelism. Both surfaces must be accessible without removing the blade as repositioning is impossible within the necessary tolerances.

Scratches are removed using a Buehler low-speed polisher with silicon carbide paper and polycrystalline diamond suspensions on fabrics of differing knaps. As finer grits are used the blades and fixturing must be thoroughly cleaned in an ultrasonic bath to remove larger particles. A final polish with colloidal silica is used when surface finish is critical. Wheel speed, applied force and polishing time varies with each step and is critical to the final quality. Too large a force leads to grain pull-out with Tungsten, which is extremely soft (Vickers hardness of 873). Relatively large force and long polishing time are required for Tantalum (Vickers hardness of 3430) yet overpolishing results in "orange-peel" that destroys the knife-edge.

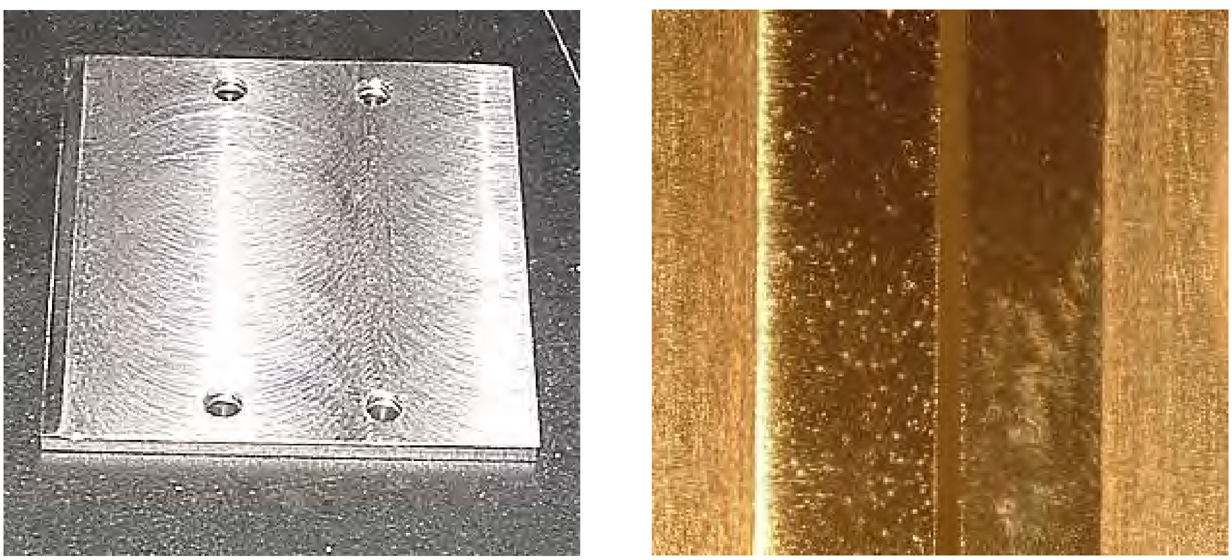

FIGURE 2. Face of blade after grinding operation.

FINITE ELEMENT ANALYSIS

A thermal / mechanical analysis has been performed on the water cooled secondary slits for Diamond Light Source. Results show that, for a nominal power density of 5 W/mm^2, applied evenly over an area of 28 mm^2 between upper and lower slit edges, the deformation of the upper and lower slit edges is less than 2.5μ. The slit edge deformation is essentially constant for water flow rates ranging from 1 gpm to 10 gpm. There is also a translation and rotation of the slit edges, that will affect the true position of and anticipated gap between the two opposing blade edges. This deviation from true position of the blade edges is due to the temperature distribution and subsequent thermal expansion within the copper blade mounts and tungsten blades resulting from the incident radiation. For a minimal water flow rate of 1 gpm, the magnitude of the blade edge translation is 32.7μ (upper blade) and 40.9μ (lower blade). The consequence of these translations tends to reduce the expected blade gap. Blade rotation is calculated to be 41 μ-rad (upper blade) and 7.2 μ-rad (lower blade). The combination of translation, rotation, and deformation results in a 10-14μ reduction in the anticipated gap between blade edges at a 1 gpm cooling water flow rate. At a flow rate of 10 gpm, the reduction in anticipated gap is between 8.5-12 μ. At a flow rate of 10 gpm, the blade edge translation is 29.1μ (upper blade) and 34.7μ (lower blade). As suggested by Dr. Eric Johnson, the greatest contributor to this gap reduction and deviation from true position can potentially be controlled via strategic temperature measurement on the copper blade holders and subsequent compensation.

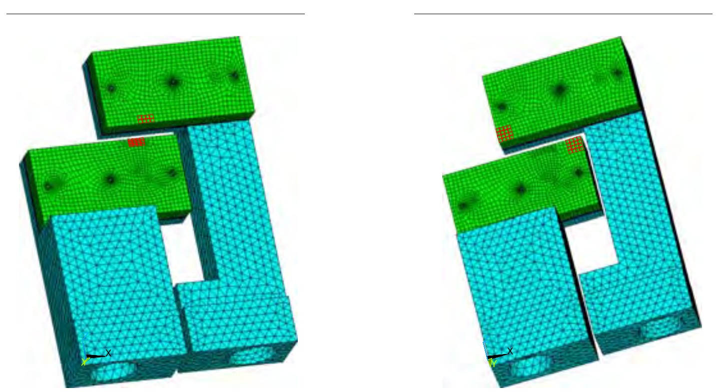

FIGURE 3. Finite element model depicting areas of applied heat flux (5 Watts/mm^2); (a) – Nominal condition, 70 watts per blade centered on blade overlap, (b) – worst case condition, 140 watts per blade applied furthest from cooling channel

ACKNOWLEDGMENTS

This work was supported in part by the Diamond Light Source Ltd. under Contract No. DLS0547. We would like to thank all the staff, engineers and scientists at CHESS for helpful comments and support they provided for developing ADC's slits blades polishing process.