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Development of Ultra-High Precision Optical "Nano Slit"

Alex Deyhim, Joe Kulesza, Eric Van Every
Advanced Design Consulting USA, 126 Ridge Road, P.O. Box 187, Lansing, NY
Karl Smolenski
Cornell University, Ithaca NY

Abstract

In this paper ADC will discuss the design and development of Ultra-High Precision Optical Slits designed for super accurate slits applications where high accuracy is required. The system consists of vertical and horizontal slit mechanisms, a black anodized aluminum housing, Ultra High Precision actuator , 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 1000 microns both vertically and horizontally. The actuation is such that the blade pairs move symmetrically about a central point. The design for this Nano-Slit is patent pending. The design for the Nano-Slit was based off of an existing water cooled in-vacuum slit [1]. This design also used a flexure for blade actuation and can be seen in the below picture.

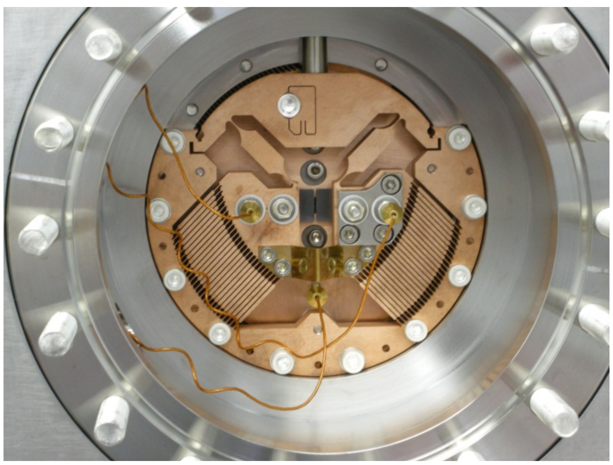


Figure 1: Flexure used in SL-800 Slit

Motion Description

Flexure

The heart of the Nano Slit, which is responsible for moving the blades, is a monolithic flexure made from copper which allows for a small range of blade movement and meets the required accuracy of travel, (Fig.1). Two parallelogram linkages provide a simple design for parallel movement of the slit blades. The 45 degree angle of flexures produces a one-to-one ratio between actuator movement and change in the slit opening. This relationship minimizes the bending angle required of the flexures and provides symmetric motion of the blades in both horizontal and vertical directions. The flexure was designed and then displacements and stresses were verified using Finite Element methods.

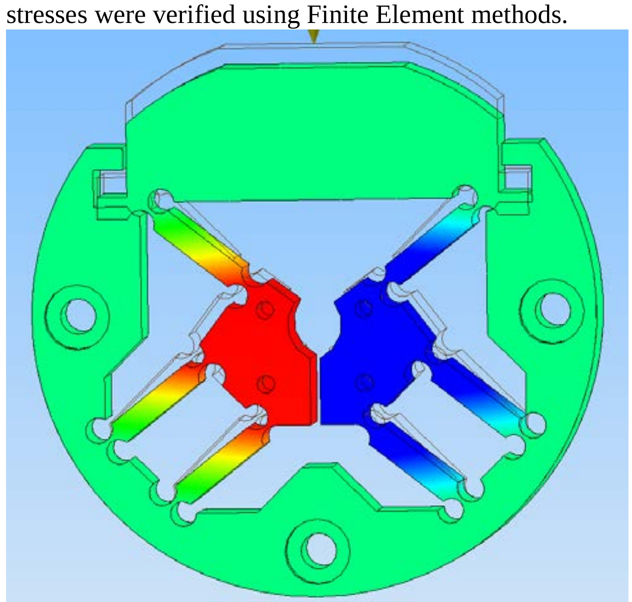


Figure 2: Nano Slit Flexure

Above is an image of the flexure with a vertical force of 10N being applied. The colors represent the displacement of the slit blades in the x direction (horizontally in this case). The green color is zero deflection, while the red and blue colors are symmetric displacements about the centreline of the slit which represents zero motion in the x direction.

Lever

The slit blades move once a force is applied at the top of the flexure. The force is provided by a lever driven by a Ultra-High Precision actuator. The "L" shaped lever has a bearing on either side which allows the lever to pivot. This lever combined with the pivot of the bearing provides mechanical advantage to the actuating motion. This mechanical advantage allows the slit to reach its full potential of 1000 μm aperture horizontally as well as vertically. The lever is guided by linear bearing to ensure the repeatable motion by the lever.

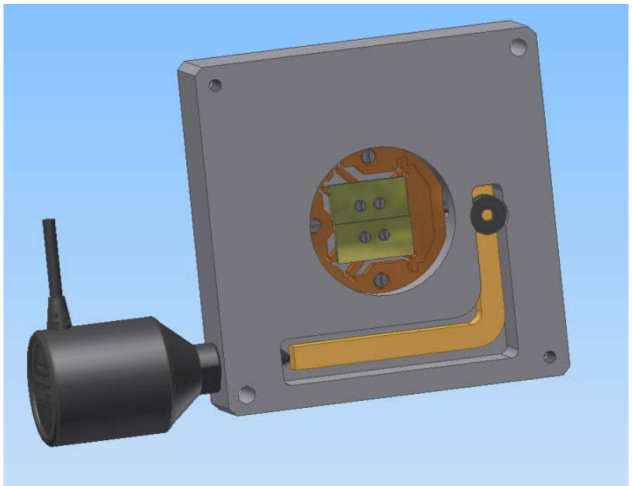
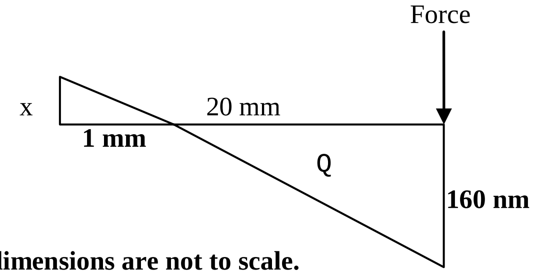


Figure 3: Nano Slit Vertical Blade Half



Note: dimensions are not to scale.

$$Q=\tan^{-1}\left(\frac{0.16\,mm}{20mm}\right)=0.458^{o}$$

$$\tan(Q)=\left(\frac{x}{1mm}\right) \Rightarrow 1mm*\tan(Q)=x$$

$$x=0.008\text{ mm or } x=8\text{ nm}$$

The flexure is designed to have a 1:1 ratio between horizontal and vertical motion. When the flexure is moved 8 nm in the Y direction, the blades close 8 nm in the X direction. This resolution can also be reduced further if a gear box is added to the actuator. If 50:1 gear box is added to the actuator, a mechanical resolution of 0.16 nm is achievable.

Ultra-High Precision Actuator

The Lever is moved by an Ultra-High Precision actuator. This actuator provides a linear motion with an average full step size of 160 nm. This type of precision allows the aperture size of the slit to be adjusted very accurately.

Figure 4: Ultra-High Precision Actuator

Resolution

The slit uses a combination of the Ultra-High Precision Actuator and the lever's mechanical advantage to achieve a very high resolution. The Ultra-High Precision Actuator has an average full step size of 160 nm. This motion is further refined with the lever's 20:1 mechanical advantage ratio. When the Ultra-High Precision Actuator moves 160 nm for a full step the flexure is given a step of 8 nm in the Y direction (Vertical).

Housing

The slit housing is made from two anodized aluminum halves. Each half contains a flexure, two blades, a lever and the Ultra-High Precision actuator. These two halves are bolted together with the motors 90º apart from each other which results in a horizontal as well as vertical blade orientation.

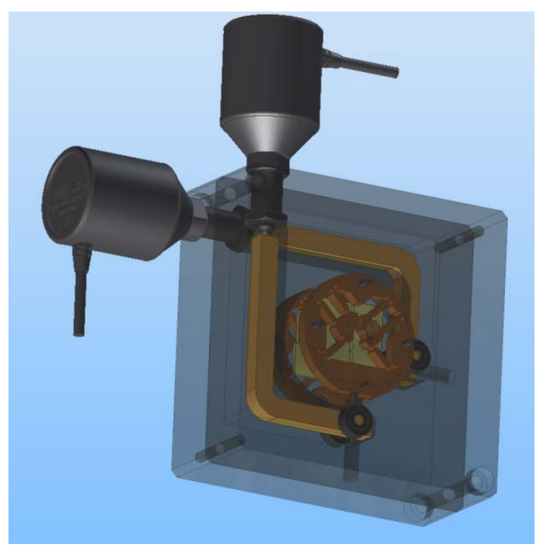


Figure 5: Fully assembled Nano Slit

Vacuum Compatibility

ADC also offers this stage in a vacuum compatible version. An O-ring groove is machined into each half of the housing so there is a seal between the halves. The Nano slit has external tapped holes that allow for connections to the end users beam pipe. The Nano Slit can be used in a vacuum environment of 10^{-7} Torr.

REFERENCES

[1] Dave Waterman, Dave Caletka, Eric Johnson, Alex Deyhim 3nd International Workshop on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (MEDSI04), ESRF, Grenoble, France