Development of 1100 mm Long Silicon Focusing Mirror System

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In this paper we will describe the design of a 1100 mm long silicon mirror system installed at Advanced Photon Source (APS). The APS 20-BM mirror system consists of five primary subcomponents: The mirror optic itself, its positioning system, the bending mechanism, a vacuum chamber, and the support structure all provided as an integrated package. All subsystems were designed to provide the highest positional stability and structural rigidity with precision motions on all axes.

The 1100mm long silicon mirror substrate is ground from a single crystal boule and then polished by a specialist synchrotron mirror vendor with over 20 years of experience. To provide horizontal (sagittal) focusing of a wide bend magnet fan, the substrate is ground with a cylindrical recess in its reflecting surface. Gravity deforms the mirror substrate since it is supported only at its ends, so to compensate for the gravitational forces a series of light springs provide an upward force along the length of the mirror. Both finite element analysis and analytical calculations confirm the adequacy of this compensation scheme which reduces gravity induced deformations to less than 5% of the manufacturing slope errors.

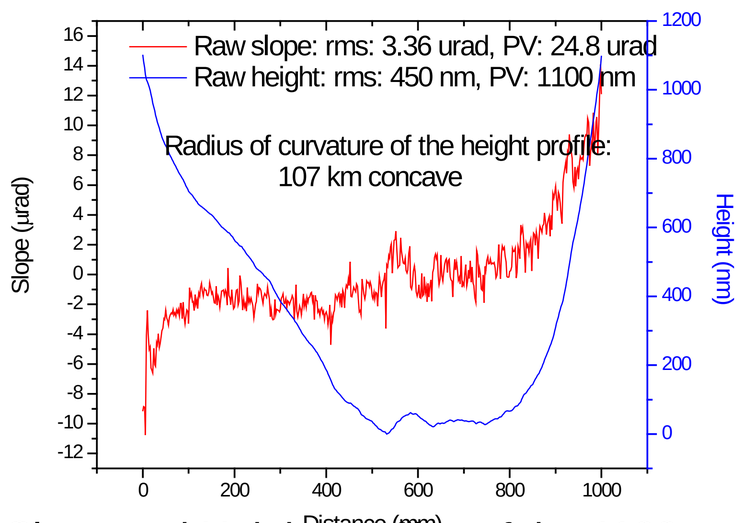
TABLE 1. Mirror Motions

Axis	Range	Precision
X (Horizontal)	5 mm	5 µm
Y (Vertical	10 mm	1 µm
Θ (Tilt about X)	-5 to 10 mrad	2 µrad
Φ (Yaw about Y)	10 mrad	5 µrad
X (Roll about Z)	10 mrad	5 µrad

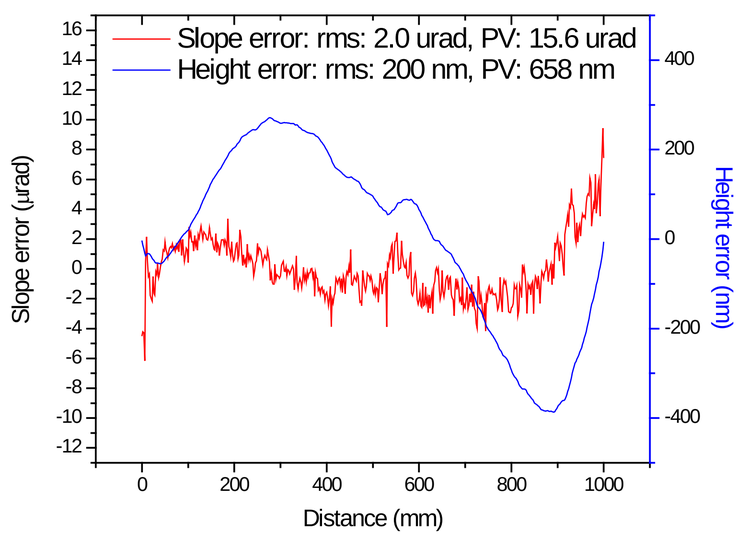
The bender mechanism is driven by linear stepper motors outside the vacuum space, again separated by a floating bellow. The actuator bends a pair of long leaf springs equally via a wiffle tree linkage. The leaf springs impart a pure bending moment to each end of the mirror via a pivoting clamp in the manner of Howells and Lunt [1]. The clamp holds the mirror at each end of its length but outside the optically active surface to avoid local distortions marring the beam quality.

FEA Analysis

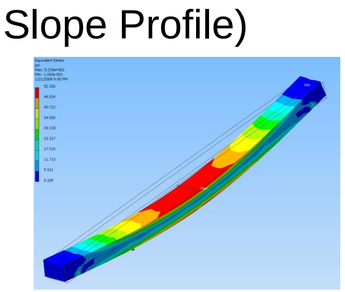
The mirror is assumed to be a rectangular beam of 50mm height, 80mm width, and 1100mm length. The mirror is supported on its neutral plane, 25mm from either top or bottom surface, and is bent about a point 50mm inward from its ends. The useful optical length of the mirror is 1000mm centered on the 1100mm length of the mirror. The mirror is bent by the application of equal and opposite moments imparted by dual leaf springs, one mounted to each end through a clamped block. The clamping is done at the ends of the mirror to preserve the optical quality of the central portion of the mirror. The mirror is mounted such that one end is free to extend in the Z (beam) direction to avoid any thermal stresses on the mirror, while the other is free to rotate about the Z axis to avoid any twists imposed on the mirror due to small manufacturing errors in the mirror, base plate, or supports.

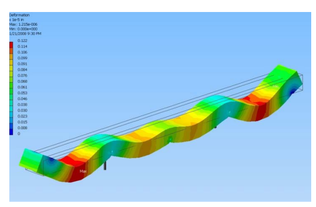


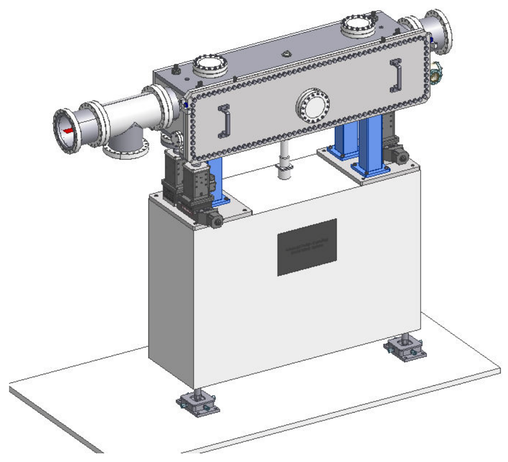
Raw Slope and Height Profiles of the 1100 mm Long Cylindrical Mirror



Slope and Height Error Profiles of the 1100 mm Long Cylindrical Mirror.
(After Subtracted the Best Linear Fit from the Raw Slope Profile)







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