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## An Elliptically Shaped Refractive Hard X-ray Fresnel Lens

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Beamline(s): X13B

**Introduction:** In the pursuit of high quality optical elements for hard X-rays, with photon energies larger than 5 KeV, many avenues have been tried. In the soft X-ray regime ( $1\text{eV} < E < 3 \text{ KeV}$ ), the magnitude of the imaginary part of the refractive index is comparable to the real part. In contrast, for hard X-rays the absorption can be much smaller than the real part of the refractive index, making refractive optics a possibility.

**Methods and Materials:** Using planar micro-electronics technology we have fabricated refractive Fresnel lenses for hard X-rays in single crystal silicon. An elliptically figured profile is transferred to a resist coating of UV113, using a JEOL electron beam writer (JBX-9300FS). The resist profile is subsequently transferred to a 500nm thick oxide hard mask, using an AMAT 5200 magnetically enhanced reactive ion etching tool, with an EMAX plasma source. Finally, using an Advanced Silicon Etcher from STS, the oxide profile is etched 40 microns deep into the silicon substrate. A Fresnel lens is a conventional lens with the minimal amount of material required to provide the curved profile necessary for focussing. The deleted material has to be of a specific thickness and shape, in order to maintaining phase coherence across the lens. An example of such a shape is shown in Figure 1. For a parallel beam, and a lens refractive index less than the surrounding medium, the ideal lens shape is elliptical. Using a knife edge fabricated from a lithographically defined 500nm thick copper film, we have measured the properties of these lenses, by scanning the film across the focussed X-ray beam, and detecting the copper fluorescence.

**Results:** A typical knife edge scan is shown in Figure 2. We have obtained focussed lines with full widths of  $1.01 \pm 0.1$  microns at a photon energy of 12.4 KeV.

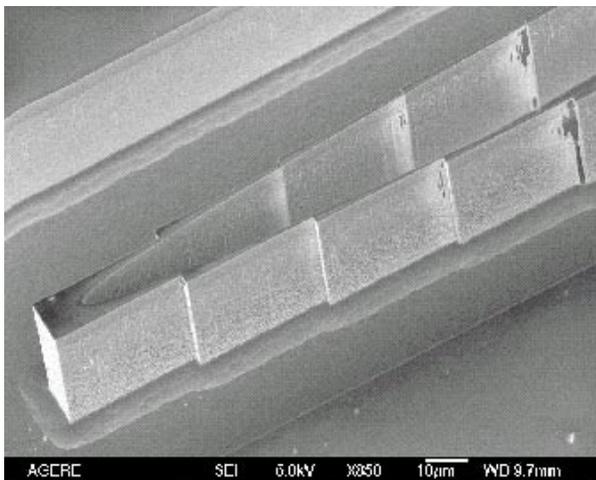


Figure 1 : An Elliptical Fresnel Lens

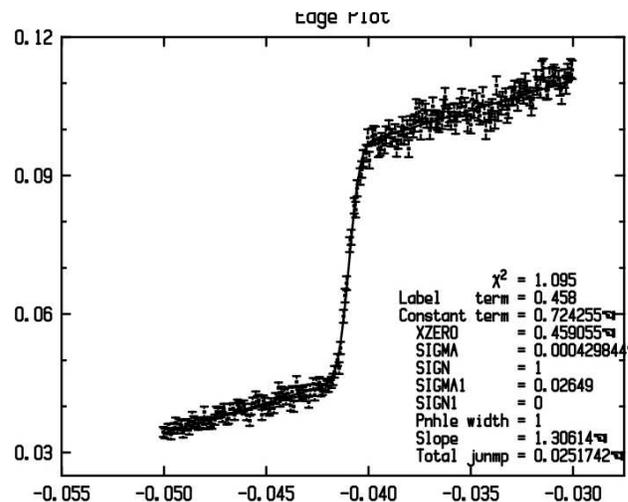


Figure 2: An typical Knife Edge scan. Position in mm.