Abstract No. Evan0581

A Refractive Hard X-ray Fresnel Lens

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Beamline(s): X16C

Introduction: Using planar micro-electronics technology we fabricate refractive Fresnel lenses for hard X-rays in single crystal silicon. A parabolically 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 25 microns deep into the silicon substrate, resulting in a line focus 25 microns long. A conventional refractive optical lens consists of a curved interface that separates materials with different refractive indices. A Fresnel lens is a conventional lens, but with material deleted. The deleted material has to maintain phase coherence for a wave-front propagating across the lens, yet providing the minimal amount of material required to provide the curved profile for focussing. A typical physical implementation of a Fresnel lens shape is shown in Figure 1. A consequence of this phase relationship is that the lens properties are best when the deleted material creates a phase shift of multiples of 2 pi. Shown in Figure 2 is a plot of measured spot size as a function of energy, clearly illustrating the chromatic nature of this type of optic. We have obtain focussed lines with full widths of 5 microns at a photon energy of 8.6 KeV. We suggest that the flat bottom of this curve is the limitation of the finite source size; the minimum measured spot size will be the maximum of the demagnified source size and the ideally focussed spot at the given energy.

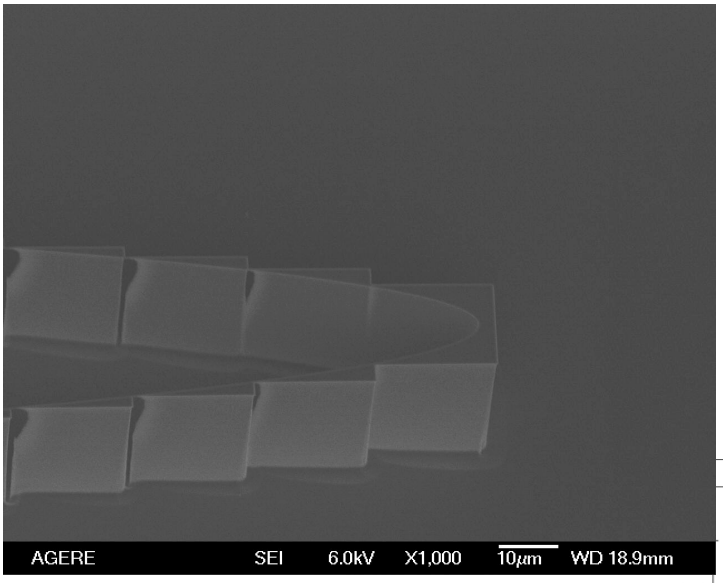

Figure 1: Fresnel Lens with parabolic shape and showing deleted material with step like profile

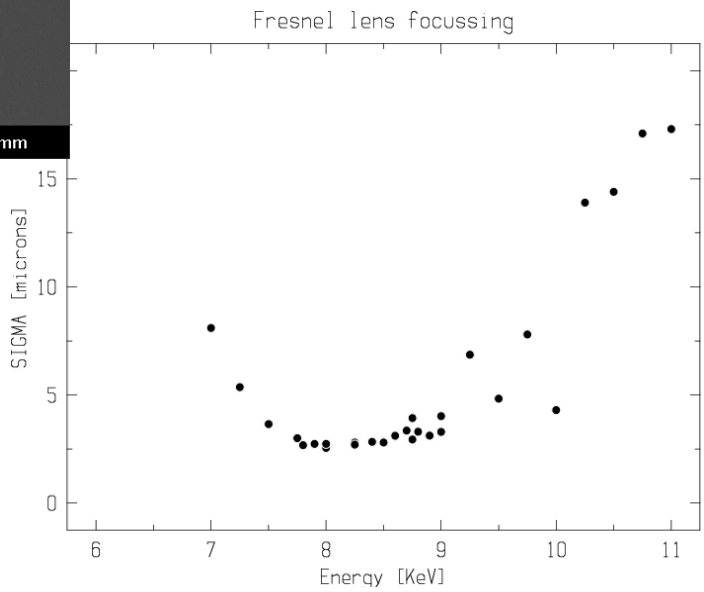

Figure 2: Sigma of line focus at different energies.