Investigation on Crossed Multilayer Laue Lenses for X-ray Point Focusing

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While electron microscopy is a well-established technique of high resolution materials analysis, it suffers from the fact that the samples have to be thinned, polished and hence almost destroyed to allow research. X-ray microscopy on the other hand offers a high penetration depth and allows virtually nondestructive studies but it is limited by the resolution of the used optics that may approach 10 nm resolution \cite{1,2}. Improving the capabilities and resolutions of X-ray optics would directly impact other fields of research with better insight into materials.

An emerging type of lens for x-rays is the multilayer Laue lens (MLL) \cite{2-4}. Substantially it is a kind of linear zone plate where for the fabrication of the zones thin film deposition techniques, such as magnetron sputtering, are used. The thickness of zones follows the zone plate law and they are deposited on a flat substrate starting with the thinnest and ending with the thickest zone. Fresnel zone plates in comparison are produced using electron beam lithography.

The focal size of these kinds of diffractive optics is primarily determined by the smallest zone width and the advantage of thin film deposition for fabrication of these optics is the fact, that much smaller zone widths down to 1 nm can be manufactured. In addition the achievable aspect ratio is much higher and virtually unlimited allowing higher diffraction efficiencies. Theory predicts it is possible to reach 5 nm focal sizes with this type of lens with the current geometry and potentially sub 1 nm foci with an improved geometry \cite{5}.

The preparation of one of those lenses is similar to a TEM H-bar. The lamella, which is the actual lens, is made by focused ion beam milling. To obtain a point focus two of those lamellae have to be placed in series perpendicularly to each other in the beam (see figure 1).

![Figure 1: Geometrical arrangement of the perpendicularly aligned lenses.](image)

The experiments were conducted at the PETRA III P06 beam line in February 2013. Instead of the standard setup with two nanofocusing lenses (NFL), a setup of two crossed MLL was used. The improved deposition PS6359 has a focal length of 12.5 mm at 20 keV. Zone numbers 512 to 7000 were alternately deposited with Si and WSi\textsubscript{2} and have a total deposition thickness of 53 µm. The process took 84 h. This makes it to an MLL with one of the largest apertures so far. The thickness of the lamella was chosen in order to obtain an optimal relative phase shift in the respective zones. The two thin bars with the deposition and the lamellae on top were glue-bonded to each other. In
this way, the distance between the two lens structures is minimized to less than 50 µm. Up to now two different optics holders and sets of stages have to be used to align both lenses individually with respect to each other. Here, only one set of stages is necessary to align the lens assembly with in each case two degrees of freedom for rotation and translation. This significantly reduces the time needed for the alignment. A point focus of a pair of crossed lenses has been reconstructed with ptychography [6-8]. The side lobes correspond to the focusing directions of the respective lenses. Only few significant features outside of these areas can be found.

The size of the beam was determined with 39x49 nm² in the focal plane. With a crossed setup of lenses made from the deposition PS6056 a diffraction efficiency to the first orders of 11.5 % was measured, which corresponds to an efficiency for the individual lenses of 33.9 %.

Figure 2: Intensity of the crossed lens setup of the v2013 version of the lens in the focal plane.

References