EXPERIMENTAL REPORT ON MI404, ESRF MARCH 2000

The beam time application for MI404, was for the characterisation of tri-level Zone Plates, which in theory could yield diffraction efficiencies approaching 50%. The fabrication of these ZPs, requires the accurate overlay of two levels of lithography, which, with the accuracy of present E-beam systems limits the resolution of such optics to 500 nm at best. Following the submission of the application form, and after numerous discussions with active X-ray microscopists world-wide, it became apparent that the usefulness of such tri-level ZPs is rather limited, despite their enhanced diffraction efficiencies. Because of the ever increasing brightness of present sources, diffraction efficiency seems to be less important than enhanced resolution. The relatively low resolution of tri-level ZPs also leads to long focal lengths, often too long to be utilised on a normal beam line set up. The only way to reduce the focal length is to reduce the diameter of the ZP, which then reduces the area of the optic, and consequently the available flux in the focal spot. So the benefit of the enhanced efficiency is lost! The only way to overcome this is to be able to reduce the resolution of these ZPs, but as mentioned earlier, this is not possible at present.

Because of this, for MI404, I concentrated my efforts on "traditional" ZP fabrication techniques, based on single level fabrication in Tungsten, which in principle could yield much better combinations of efficiency/resolution ZPs. In addition, I prepared and carried out some preliminary tests on Nickel ZPs based on the technique proposed in my beam time application MI454, which unfortunately was not given any beam time. These preliminary tests were extremely encouraging, and I am resubmitting essentially the same application, to carry on the tests started in MI404.

Present day fabrication techniques are based on traditional E-beam pattern generation, followed by either Electroplating, or Reactive Ion Etching (RIE), to transfer the E-beam pattern from the resist, into a useful Zone material. For high resolution features (< 100 nm) the aspect ratio is limited to 5:1 at best, in other words a 100 nm zone, can be as high as 500 nm. If such zones were made of Tungsten, the ZP would have an efficiency of

>10% at 3 KeV. If however better resolution is needed, the thickness would have to be reduced, with the inevitable reduction of diffraction efficiency. A ZP with 50 nm outermost zones, will have to be no more than 250 nm thick, with efficiency of the order of 3 % at 3 KeV. Again, the only way to improve on this, is to increase the diameter of the ZP, which increases the area, and leads to more photons in the focal spot. We tested several such Tungsten ZPs during MI404, the best yielding a diffraction efficiency of >8% at 3 KeV, with a resolution of 100 nm, and a diameter of 230 μm. The Tungsten zones were 360 nm thick. If more beam time is allocated, we are hoping to improve the resolution of 360 nm thick ZPs to ~70 nm, and try a few 50 nm ZPs in 250 nm thick tungsten, keeping the diameters to 200 μm or more!

Regarding the experimental Ni ZPs, the aim was to produce optics with good diffraction efficiencies, in both the 1st as well as the 2nd order focal spots, through a process of Spatial Frequency Multiplication – SFM. (Please refer to beam time applications MI454, as well the present MI656.). In order to test the feasibility of the proposed technique, a number of small ZP arrays were constructed (3X3 ZPs), each with slightly different exposure parameters during lithography, as well as different metalization parameters, for each array. In all, more than 30 Nickel ZPs were tested for both 1st and 2nd order diffraction efficiencies, the best yielding 20 % in 1st order and 5 % in 2nd order at 3 KeV, for outermost zones of 160 nm (2nd order, effectively 80 nm.) These results are very encouraging , and if more beam time is allocated, we will use the same technique to fabricate large, useful ZPs. (The ZPs in the arrays that we tested were only 50 μm in diameter, which enabled us to fabricate 9 ZPs on a normal 200 μm square Si3N4 window).