Zone Plate Fabrication at BESSY

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The full-field x-ray microscope installed at the electron storage ring BESSY II is dedicated for applications in life, environmental and material sciences. It covers the photon energy range between 250-750 eV. Currently, the spatial resolution of the zone plate based x-ray microscope is about 20 nm.
At BESSY II we started an in-house fabrication of Fresnel zone plates to supply the x-ray microscope with tailored optics and to improve their spatial resolution in the future. For a future improvement of the spatial resolution new fabrication processes are required as discussed in the following:
State-of-the-art Fresnel zone plates with an outermost zone width of 20 nm can be described by scalar diffraction theory neglecting the three-dimensional shape of the zone structures. According to this theory their diffraction efficiency scales as $1/m^2$ where m is the diffraction order. While keeping the zone height constant, the aspect ratio of the zones increases inversely with decreasing outermost zone width. For photon energies below one keV, it is shown by applying electrodynamic theory that scalar theory is no longer suited to describe zone plates with outermost zone width below 20 nm and aspect ratios of about 10:1 [1,2].
Full electrodynamic theory predicts that the diffraction efficiency decreases continuously if the lateral dimensions of the zone width approach the wavelength used for imaging. This result is obtained for zone structures parallel to the optical axis.
Unlike the diffraction properties of parallel zone structures, rigorous coupled wave theory (RCWT) predicts for zone structures tilted to the optical axis according to the local Bragg condition that the diffraction efficiency can be up to 50 % [3]. In addition, RCTW calculations show that similar diffraction efficiency values can be obtained in any high order of diffraction $m > 1$.
The resolving power of zone plates scales with the order of diffraction m. By applying high orders of diffraction, it is possible to increase the resolution without the need for manufacturing increasingly smaller outermost zone width far below 20 nm.
Applying high orders for imaging requires manufacturing tilted zone structures with aspect ratios of about 20:1 [2]. To overcome the extremely difficult problem of manufacturing tilted zones with high aspect ratios of 20:1, we will work on manufacturing zone plates on top of each other with slightly decreasing zone radii [3]. In good approximation – depending only on the number of layers – the zones can be tilted according to the local Bragg condition and each single layer requires only moderate aspect ratio structures.

[1] J. Maser, in: X-ray Microscopy IV, Bogorodskii Pechatnik Publishers (1994) 523
[2] G. Schneider, Appl. Phys. Lett. 71 (1997) 2242
[3] S. Rehbein, G. Schneider, *Volume diffraction zone plates: A new generation of x-ray optics for sub-10 nm resolution*, in preparation