The focusing limits of Fresnel Zone Plate x-ray optics

F. Pfeiffer[1], C. Bergemann[2], J.F. van der Veen[1],

[1]Paul Scherrer Institut, CH-5262 Villigen PSI, Switzerland,
[2]Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, U.K.

With this contribution we will present the results of a theoretical work in which we investigated the limitations of Fresnel Zone Plate (FZP) x-ray optics. We will in particular address the question: what is the smallest spot size to which an x-ray beam can be focused ?
Based on previous work [1,2], where the focus limit has been investigated in the specific case of a narrowly tapered x-ray waveguide capillary, we have further generalized our approach and developed a theoretical treatment for solving directly Maxwell's equations for more complex boundary conditions, e.g. a linear FZP array. We will show how such a problem can efficiently be reduced to the solution of an Eigenvalue problem similar to frequently occurring problems in quantum mechanics [3]. The solution of the problem, i.e. the complex value of the electrical field as a function of the space coordinates in- and outside of the FZP, is then found by applying basic matrix diagonalization schemes in combination with Fourier space propagation methods.
Based on the results of our calculations we will discuss the dependency of the minimum achievable focal spot size with FZP optics as a function of several parameters. Just like in the case of a single narrowly tapered waveguide we find a minimum focal spot size for hard x-rays of the order of 10 nm (FWHM), the exact value depending only on the electron density of the confining material. Finally, we will discuss whether this limit applies to all x-ray focusing devices.

[1] M.J. Zwanenburg, J.H.H. Bongaerts, J.F. Peters, D. Riese, and J.F. van der Veen, *Focusing of coherent x rays in a tapered planar waveguide,* Physica B **283,** 285 (2000).

[2] C. Bergemann, H. Keymeulen, and J.F. van der Veen, *Focusing X-Ray Beams to Nanometer Dimensions,* Phys. Rev. Lett. **91**, 204801 (2003).

[3] F. Schwabl, *Quantum Mechanics*, Springer, New York, (1995).