

Initial Results from Aberration Correction in STEM

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Aberration correction is an area of research with a long history in electron microscopy, dating back to the discovery by Scherzer in 1936 that the spherical and chromatic aberrations of conventional round lenses will always be positive [1]. The correction of spherical aberration (C_s) is achieved by incorporating a separate aberration corrector, containing non-round elements, into the electron optical system to eliminate the C_s of the round objective lens. We have recently fitted a quadrupole-octupole C_s -corrector [2], to the 100 kV VG501 STEM at ORNL, shown in Fig. 1. The STEM is particularly well suited to the correction of spherical aberration because the high-angle annular dark field (HAADF) image can be directly interpreted as an image of the atomic column positions [3], is relatively insensitive to chromatic aberration and allows the simultaneous acquisition of electron energy loss spectra (EELS).

Once the spherical aberration has been eliminated, the major factors that limit the resolution of a C_s -corrected STEM are the stabilities of the column, both electrical and mechanical, and the so-called parasitic aberrations. At ORNL, the C_s -corrected microscope is isolated from mechanical vibrations by means of a suspension system and sound damping surroundings. Parasitic aberrations can arise because of mis-alignments of the system, or inhomogenities in the magnetic elements (an example is described in [4]). Accurate alignment and the flexibility to cancel any parasitic aberrations are therefore essentials in a C_s -corrected system. In order to achieve a higher resolution, the objective aperture size should be correspondingly increased (Fig. 2). This has the additional benefit of allowing higher current at the same probe size, thereby increasing the signal available for EELS analysis [2]. The increased aperture size also increases the precision with which the parasitic aberrations must be corrected, which requires computer control of the corrector alignment. Because conventional methods of determining the aberration function are not well suited to a STEM, instead our C_s -corrector uses a method based on the analysis of the electron shadow image, also known as the Ronchigram (Fig. 2) [2].

Example HAADF images of silicon “dumbbells” are shown in Fig. 3. Without C_s -correction, the resolution of the 100 kV STEM is approximately 2.2 Å, and the dumbbells cannot be resolved. After C_s -correction the 2 distinct columns, separated by only 1.36 Å are resolved. The correction of spherical aberration in the STEM will allow imaging and microanalysis at higher resolution than ever before.

References:

- [1] O. Scherzer, *Zeit. Phys* 101 (1936) 593.
- [2] N. Dellby et al, *Journal of Electron Microscopy* 50 (2001) 177.
- [3] P. D. Nellist et al, *Ultramicroscopy* 78 (1999) 111.
- [4] V. Beck, *Proc. 35th EMSA* (1977) 90.

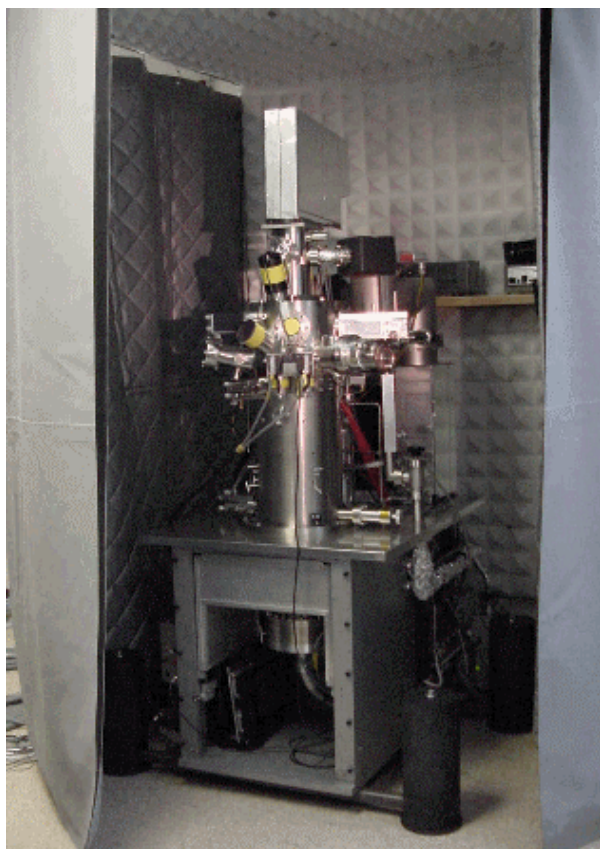


Figure 1. External view of C_s-corrected 100 kV VG501 STEM at ORNL.

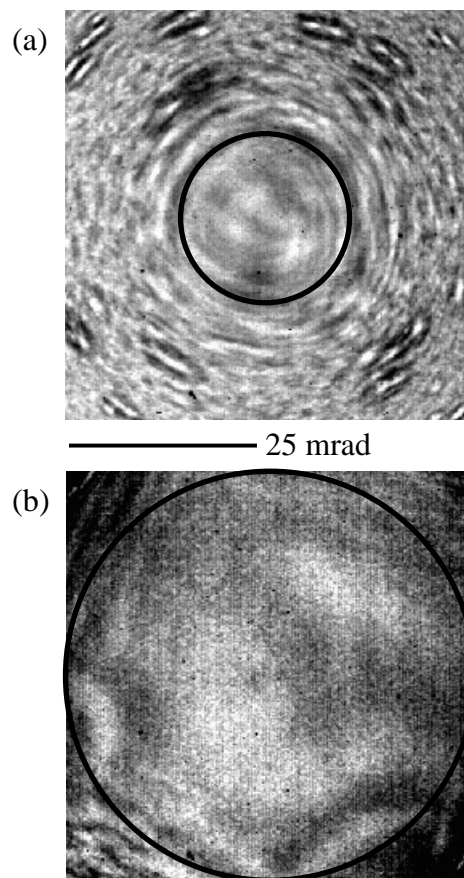


Figure 2. Ronchigrams taken near Gaussian focus (a) before and (b) after the correction of spherical aberration. In both cases the approximate size of the optimal objective aperture is indicated.

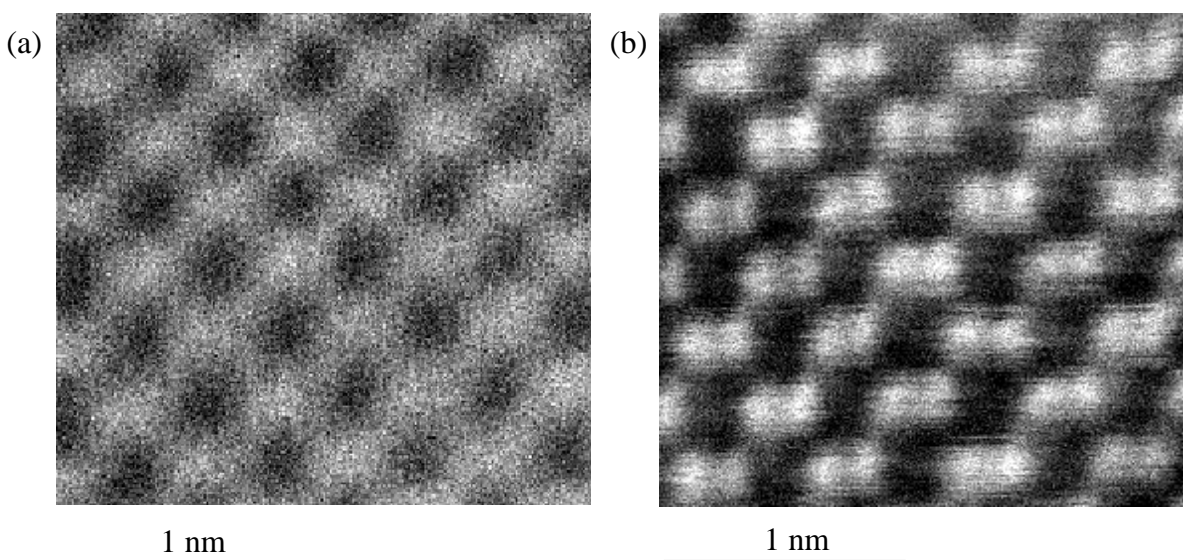


Figure 3. HAADF images of silicon "dumbbells" at similar magnifications taken in a 100 kV VG STEM (a) before and (b) after the correction of spherical aberration.