State of the First Aberration-Corrected, Monochromized 200kV FEG-TEM

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We present first results from the qualification of a new 200 kV FEG-TEM instrument equipped with a Monochromator for illumination and a Cs-Corrector for the imaging system. The **SATEM** (Sub-Ångstrom-Transmission-Electron-Microscope) aims at an ultimate resolution below 0.9 Å.

Recently it has been shown that hardware correction of the spherical aberration of the objective lens of a transmission electron microscope can be successfully implemented [1]. Following a design of Rose [2], the corrector module incorporates two magnetic hexapoles and several additional round lenses. The hexapoles induce a residual rotationally symmetric negative spherical aberration, while the transfer lenses are used to tune and match the specific intermediate optical planes of the ray path. By appropriate excitation of the hexapoles, the spherical aberration of the overall system formed by objective lens and corrector optics can be continously adjusted to a numerical value of the according coefficient C_s down to zero and even to negative values. The Phase Contrast Transfer Function (PCTF) thus can be tuned via C_s up to the fundamental limit given by incoherent damping. Figure 1 shows the PCTF for the uncorrected case (a) and for nearly vanishing C_s (b) in Scherzer Focus. Further improvement is achieved by reducing the damping at higher spatial frequencies due to chromatic aberrations through use of a Monochromator. By narrowing the FWHM of the energy spread from ΔE =0.8eV (inherent FEG value) down to 0.3eV, the envelope function Ec of temporal coherence reaches much further. Therefore a point resolution below 1Å (Fig 1c) is the ultimate goal of this project.

The SATEM instrument (Figure 2) is based on a newly developed highly stable 300 mm column, equipped with a condensor system for Köhler illumination, an high resolution objective lens and a rotation-free projective system with an incorporated in-column energy filter of the in second-order corrected Ω-type [3]. The 200kV FEG Schottky-emitter gun houses an dispersion-free Monochromator of electrostatic Ω-type [4] and the corrector optics are integrated into the TEM below the objective lens adding an additional length of 270 mm to the column. Furthermore in order to obtain highest mechanical stability of the electron optical setup, a “hanging-column concept” has been realized, where the TEM-column is supported like a pendulum in a highly stable frame, which has been optimized for maximum stiffness while providing the necessary accessibility to the column.

We demonstrate performance examples of the instrument. Progress will be reported on the achievement of the ultimate capabilities with respect to the theoretical limits.

References

[1] M. Haider et al., Nature **392** (1998), 768
[2] H. Rose, Optik **34** (1990), 19
[3] G. Lang et al., Microsc. Microanal. **8** (Suppl. 2) (2002), 586CD
[4] F. Kahl & H. Rose, Proc. EUREM Brno/Cz, Vol.III (2000), 1459

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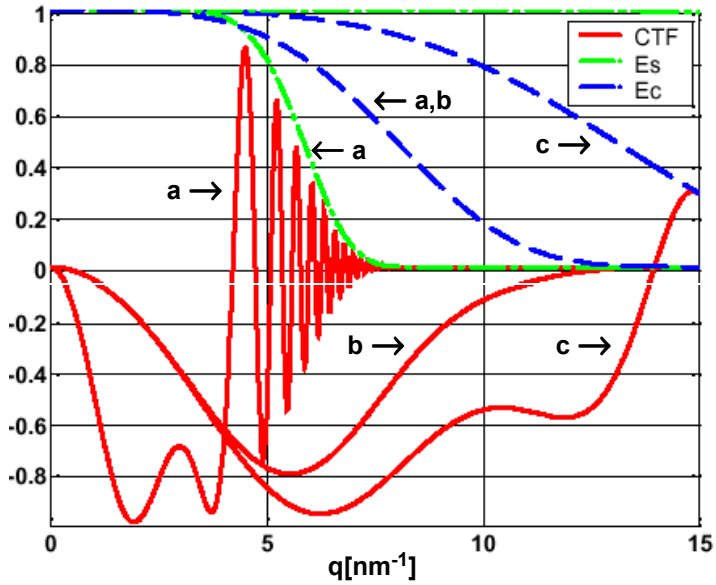
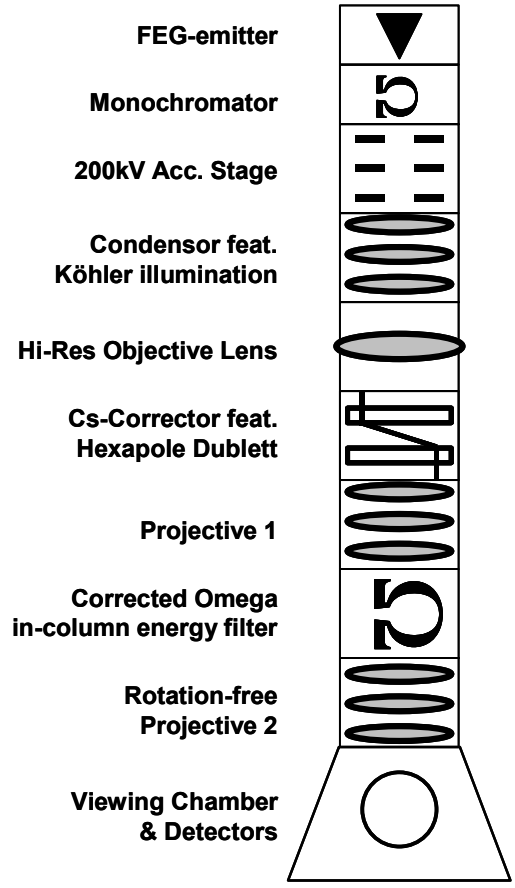
Figure 1:
SATEM PCTFs in Scherzer Focus.
Parameters used:
illumination aperture Θ_c = 0.2 mrad, coeff. of chromatic aberr. C_c = 1.2 mm

a) C_s = 1.2 mm, Df = - 67 nm, ΔE = 0.8 eV;
b) C_s = 0.01 mm, Df = - 6 nm, ΔE = 0.8 eV;
c) C_s = 0,01 mm, Df = - 6 nm, ΔE = 0.3 eV;

Es = spatial coherence envelope,
Ec = temporal coherence envelope





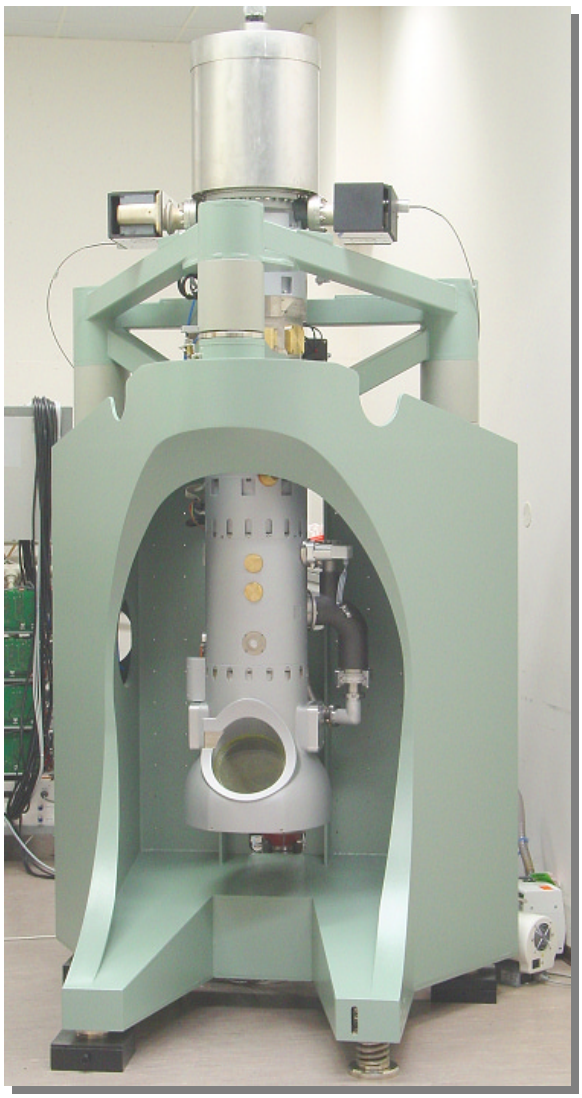


Figure 2:
Schematic setup of the modules forming the **SATEM** instrument. Photograph shows the column after installation in a highly stable support frame.