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New Possibilities for Off-axis Electron Holography by Hardware Aberration Correctors

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Off-axis electron holography provides access to the complete complex image wave hence opens up the opportunity for numerical aberration correction [1]. This allowed "aberration-free imaging" several years before Cs-correctors became commonly accessible for atomic resolution analysis. However, especially at high lateral resolution, the limited signal resolution in the holographically reconstructed wave was not sufficient to apply holography to materials science questions. It was the Cs-corrector that pushed the atomic resolution holography performance beyond hitherto existing limits [2]. Nowadays, off-axis holography, applied in a state-of-the-art aberration-corrected TEM, offers an amazing signal resolution at lateral atomic resolution: Recently, from a single hologram a phase detection limit of 2π/300 was reported, which is close to the phase shift of a single hydrogen atom [3].

The improvement of the holographic performance with respect to lateral resolution and signal resolution is not the Cs-corrector's only benefit to electron holography: The attainable lateral resolution given by the spacing of the hologram fringes and the field of view determined by the hologram width cannot be selected independently, since they are inversely connected with each other by the biprism optics hence have to fulfill several requirements. Therefore, the range of holographic setups within a single TEM is strictly limited. In particular, the sampling of the interference fringes puts very severe constraints on the total magnification of the TEM, so that a wide range of magnifications cannot be used for the holographic recording. This can be solved by the aberration-corrector: As an electron optical add-on with additional lenses, the Cs-corrector opens up a variety of new holographic setups. In our Cs-corrected Tecnai F20-TEM, we achieved a series of holographic setups ranging from fields of view of only a few nanometers at atomic resolution up to even a few microns at corresponding lower resolution. The milestone therein is a continuous magnification series of holographic setups. As an additional highlight, the Cs-corrector is used as an aberration-corrected "pseudo Lorentz Lens" within a part of this series. This allows investigating magnetic specimens without the magnetic field related to the high-resolution objective lens, and furthermore without the giant spherical aberration of the conventional Lorentz Lens.

All in all, the aberration corrector enables a comprehensive holographic analysis at nearly all magnifications within one single TEM column. As an example, Fig. 1 shows a partial magnification series of holographically reconstructed object waves of a carbon grid with Gold-shaded latex spheres. The different holographic setups range from a field of view of microns down to few nanometers with atomic resolution.

References

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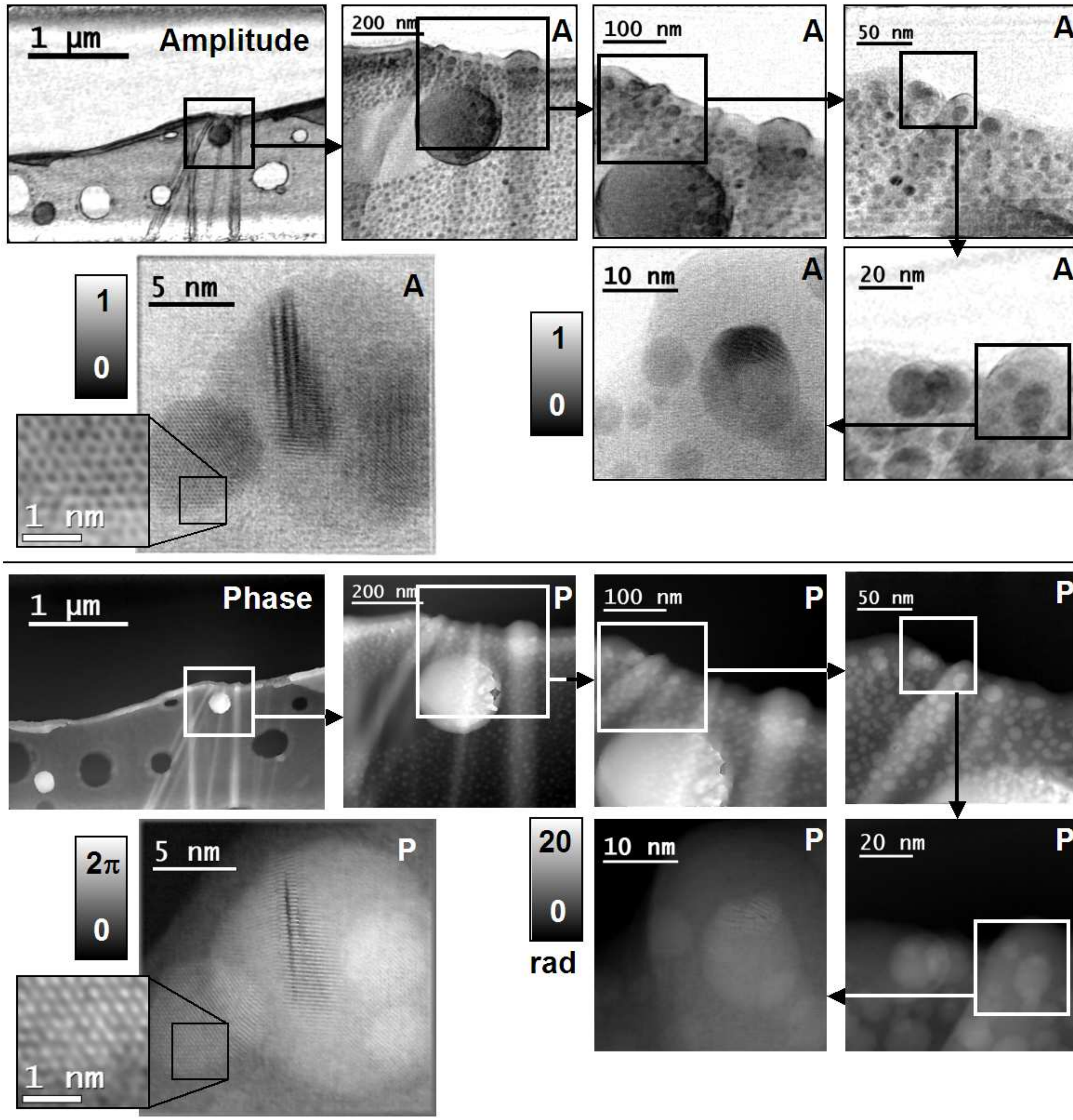

FIG. 1. Holographic magnification series of amplitudes (top) and phases (bottom) of a carbon grid with Gold-shaded latex spheres: A conventional TEM column only offers few holographic setups hence hampers holographic analysis for several materials science questions. The additional electron optics of the Cs-corrector allows recording holograms at a variety of magnifications that have not been accessible for holography before. The holographic setups provide fields of view between few nanometers with real atomic resolution and some microns. As an additional highlight, in the lower magnification regime the Cs-corrector is used as an aberration-corrected pseudo-Lorentz-Lens that is nearly free of the enormous spherical aberration of a conventional Lorentz Lens.

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