Optimum imaging conditions in aberration-corrected TEM for tomography of in-situ microscopy at low voltages

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The contrast transfer function (CTF) in transmission electron microscopy (TEM) is one of the central functions that defines the image formation. In non-aberration-corrected TEM, all parameters in the CTF were given or limited by the specific instrumental layout. The only exception was the defocus value that was freely adjustable. Then, one could optimise the CTF by finding the optimum defocus for any specific instrument and optimise the contrast transfer properties for the largest continuous transfer band for either the real part (Gabor defocus) or the imaginary part (Scherzer defocus) of the coherent CTF (1). The development of medium voltage Schottky electron sources opened the chromatic contrast dampening envelope sufficiently, then, one could push the information limit with optimising the defocus for the lowest spatial dampening (Lichte defocus) (2). Now, in geometrical aberration-corrected instruments, more parameters of the CTF are variable and several properties of the CTF can be optimised in parallel into a single set of adjustable parameters per instrument (Lentzen conditions) (3).

The drawback of the Lentzen conditions is the high demand in respect to parameter precision. While the microscopes nowadays are sufficiently stable for many tasks, this is not necessarily true for all applications. For instance, when performing *in-situ* experiments or obtaining tomographic tilt series at low electron acceleration voltages, the defocus value can often not be held sufficiently stable. For most state-of-the-art instruments, this effect is still masked by the chromatic contrast dampening; only a few highly monochromatised or chromatic-aberration-corrected microscopes working at low electron acceleration voltages face this effect (4).

Here, we report on imaging conditions optimised for a large broad-band depth of view lowering the demand for defocus stability while sacrificing ultimate point resolution. Figure 1, top row, shows the phase contrast transfer function (left) and the frequency-dependent delocalisation (right) each for varying defocus, calculated for Lentzen conditions of a third-order spherical-aberration-corrected microscope with a finite fixed fifth-order spherical aberration. To achieve the maximum point resolution, the contrast transfer band marked with the dashed green line features a pronounced reversed S shape. This in turn means that if one varies the defocus by a small amount, some spatial frequencies will fall into a contrast transfer gap. The bottom row shows the same situation with a different parameter set that effectively straightens the transfer band and thus maximises the depth of view for all transferred spatial frequencies.The reversed S shape in the Lentzen contrast transfer band is pronounced only at low voltages or large higher-order aberration coefficients.

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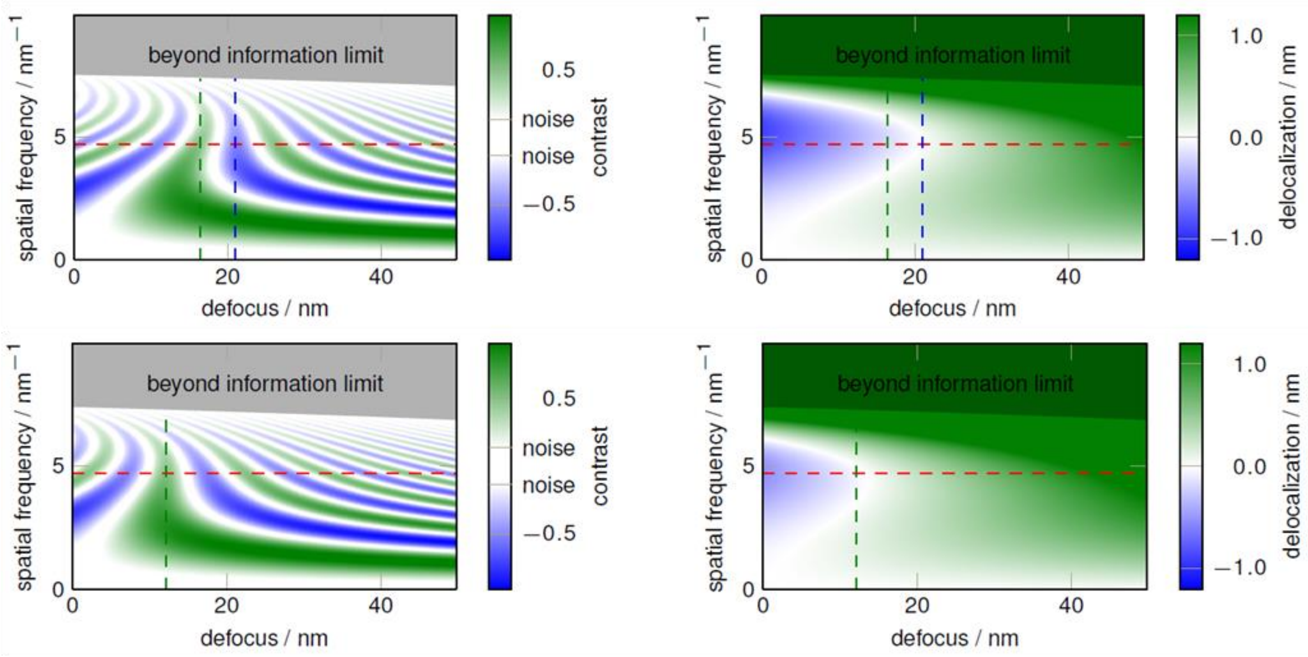

Figure 1. Phase contrast transfer and corresponding delocalisation in dependence of the defocus calculated for the SALVE instrument at 20 kV using *top* - Lentzen conditions (except the defocus) and *bottom* - depth-of-view optimised conditions.