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# ctfExplorer: Interactive Software for 1d and 2d Calculation and Visualization Of TEM Phase Contrast Transfer Function

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The image formation in a transmission electron microscope (TEM) consists of two steps which can be treated separately: electron scattering by the sample and information transfer through the imaging system to the recording device. For the phase contrast, the information transfer in TEM can be conveniently represented by Phase Contrast Transfer Function (CTF). For detailed discussion see for example [1-3]. CTF describes how amplitudes and phases are modulated at the back focal plane of the objective lens and commonly is expressed as:

$$T(k) = -\sin\left[\frac{\pi}{2} C_s \lambda^3 k^4 + \pi \Delta f \lambda k^2\right]$$

where $C_s$ is spherical aberration coefficient of the objective lens, $\Delta f$ is defocus, $\lambda$ is the electron wavelength and k is 2 dimensional vector describing coordinates in the reciprocal space (or *k*-space).

Obviously, the *T(k)* is a complicated curve oscillating between +1 and –1 to the infinity in the *k*-space. In reality, there are instrumental factors which damp the CTF to zero at higher *k* values (at so called *information limit*). These factors are represented by *spatial* and *temporal* coherence envelope functions. Spatial coherence envelope is caused by the finite convergence angle of incidence of the beam. Temporal coherence envelope is caused by the finite focal spread of the beam due to chromatic aberrations, energy spread and instabilities in the high voltage and objective lens systems.

To sum up, CTF describes how the information is transferred through the optical system of a TEM and defines such important parameters as point-to-point resolution and information limit of a TEM.

ctfExplorer is designed to help microscopists to better understand the concept of the CTF by interactively visualizing CTF not only as a 1-dimensional curve but also as a 2-dimensional 'transmittance' map. For example, the defocus or astigmatism (2-fold and 3-fold) can be changed with a slider control and the change in CTF will be immediately displayed. All other parameters defining the CTF can be easily accessed and changed. ctfExplorer allows to select a microscope from a list and also allows edit microscopes or to add new microscopes to the list. ctfExplorer calculates a plethora of important and useful parameters and allows to compare two microscopes by overlaying their CTF curves.

Currently, ctfExplorer can be downloaded from http://clik.to/ctfexplorer (Note: CLIK not click)

[1] D.B. Williams, C.B. Carter, Transmission Electron Microscopy, vol. III: Imaging, Plenum Press, N. Y.,1996, 457-482
[2] D. J. Smith, Rep. Prog. Phys., 60, (1997)1513
[3] M. A. O'Keefe, Ultramicroscopy, 47 (1992)282
[4] Special thanks to my former colleagues at FEI/Philips Electron Optics, Eindhoven, for support and suggestions. Thanks are also due to Dr. Michael O'Keefe (LBNL) for helpful discussions.

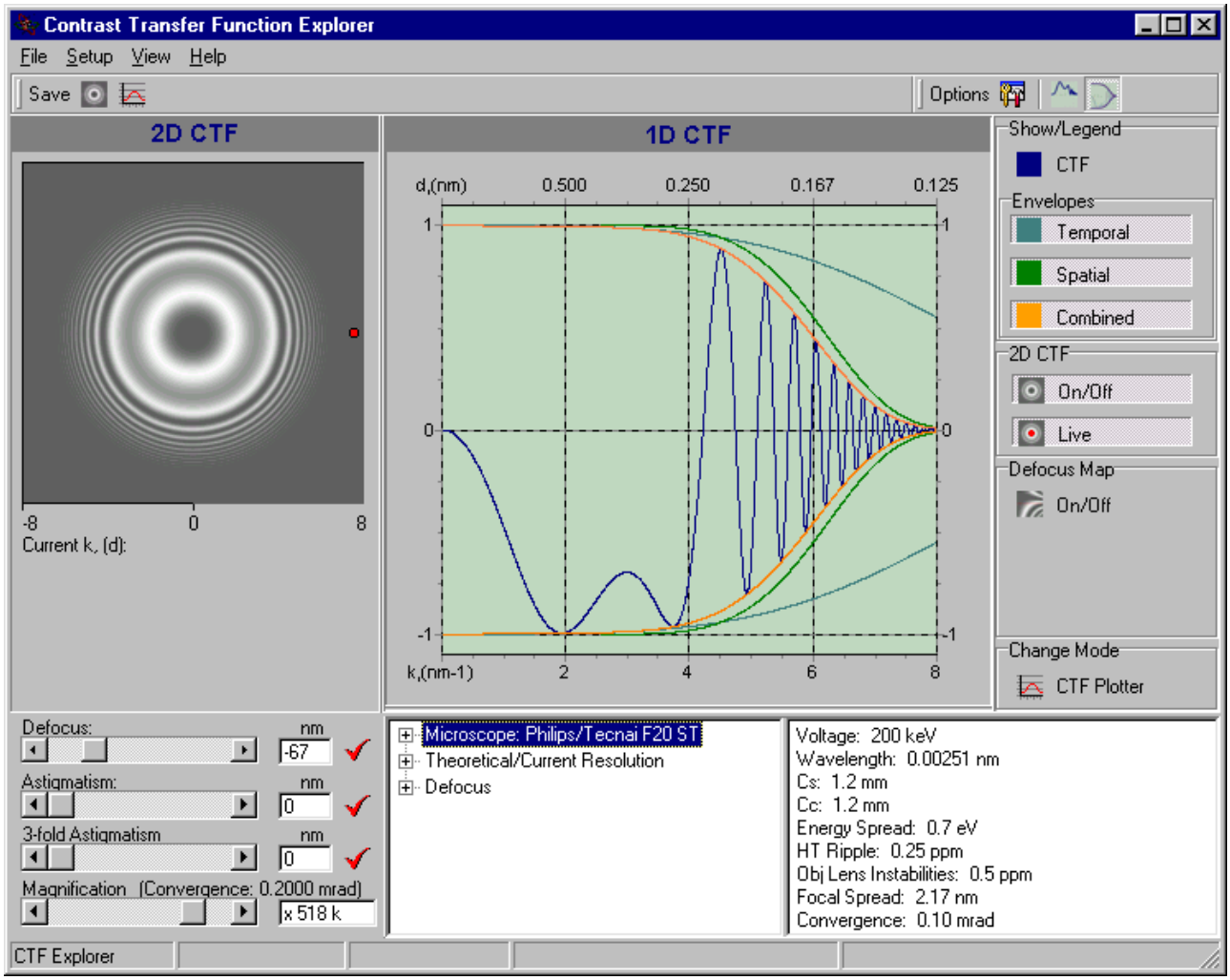


FIG. 1 User interface showing information for Philips Tecnai F20 ST microscope at extended Scherzer defocus with 50 nm 2-fold astigmatism imposed.

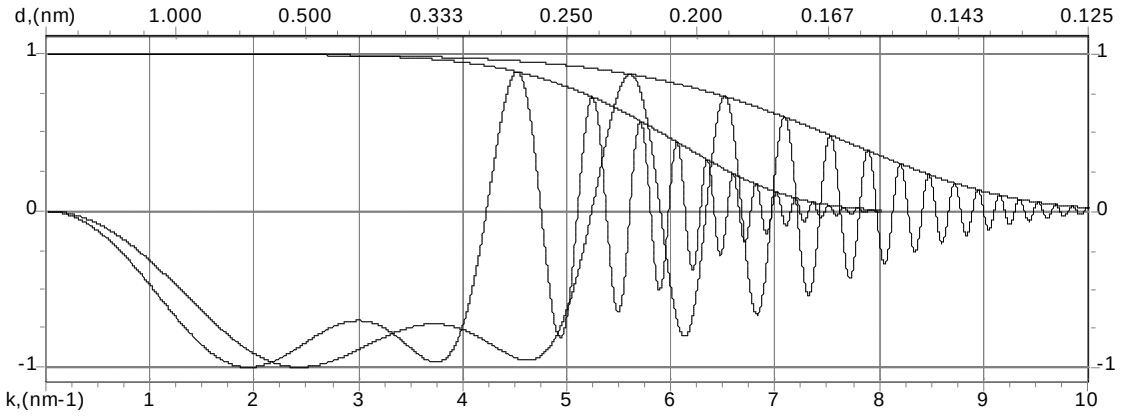


FIG. 2 Comparison of 2 microscopes: Philips Tecnai F20 ST and F20 UT.

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