The resolving power of high-resolution transmission electron microscopes is characterized by the information limit, which reflects the size of the smallest object detail observable with a particular instrument. We introduce a highly accurate measurement method for the information limit, which is suitable for modern aberration corrected electron microscopes. An experimental comparison with the traditionally applied Young’s-fringe method yields severe discrepancies and confirms theoretical considerations according to which the Young’s-fringe method does not reveal the information limit.

The resolving power of a high-resolution transmission electron microscope is ultimately limited by the degree of temporal coherence available for the imaging process. A fundamental benchmark parameter, which reflects the effect of the partial temporal coherence, and which is commonly used to characterize the performance of a high-resolution electron microscope, is the information limit. The information limit $d_{info}$ corresponds to the size of the smallest object detail that can be imaged by the electron microscope in a linear way, and is defined by the spatial frequency $g_{info} = 1/d_{info}$ where the partial temporal coherence causes a contrast damping of $1/e^2 \approx 13.5\%$ compared to the coherent contrast.

Since a long time the Young’s-fringe test is used as a standard method to determine the information limit [1]. The Young’s-fringe resolution test is based on the assessment of the Fourier power spectrum of an image taken from an amorphous object, which is often called a diffractogram, where one tries to identify the highest image frequency that can be undoubtedly discerned from detection noise. In order to distinguish the signal content from the detection noise, two separate images from the same object area are superimposed with a slight real-space displacement, either directly in experiment by a double exposure, or a-posteriori by digital methods. Due to the mutual real-space displacement, a sinusoidal Young’s-fringe pattern appears in the diffractogram of the superimposed images, which helps to distinguish between transferred signal and detection noise (Fig. 1a).

A pragmatic approach to assess the information limit, which is often used due to the lack of a feasible alternative, is to equate simply $g_{info}$ with $g_{max}$, where the latter frequency is the highest detectable signal frequency in a Young’s-fringe pattern. However, this approach is flawed due to a multitude of reasons. Apart from the unjustified neglect of non-linear contrast contributions, which can potentially double the frequency spectrum, this method reveals only a net resolution restriction due to the cumulation of very different effects, such as the coherence properties, the object scattering-function, mechanical vibrations, and the modulation-transfer-function of the detector.

We present a new quantitative method, which allows one to measure directly and separately the information limit of transmission electron microscopes from diffractograms of high-resolution micrographs [2]. The micrographs are recorded from thin amorphous objects under tilted illumination. Our measurement principle is based on the fact that large beam tilts cause an anisotropic deformation of the diffractogram damping envelope and the appearance of an additional “holographic” background contribution (Fig. 2). These two effects are primarily caused by the partial temporal coherence of the electron beam. The information limit is determined by fitting a model function based on a Gaussian focal distribution to the envelope and the background extracted from experimental diffractograms (Fig. 3).

We applied the present method to measure the information limit of two high-resolution transmission micro-
FIG. 2: Series of diffractograms arranged according to the azimuth of the beam-tilt. The large-scale intensity anisotropy of the diffractograms due to the partial temporal coherence, rotating with the beam-tilt azimuth, is clearly visible.

FIG. 3: (a) Large-scale intensity variation extracted from the diffractogram series of Fig. 2. (b) Intensity profiles along the two selected circular paths marked in (a).


TABLE 1: Information limit measured by the present method in comparison to results of Young’s-fringe tests for two microscopes installed at the Ernst Ruska-Centre in Jülich.