Noise Analysis of Amplitude and Phase reconstructed from High Signal Resolution Electron Holograms

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Keywords: electron holography, standard deviation, noise transfer, averaging

In a TEM, the wave and in particular the phase is modulated very sensitively and by electromagnetic fields. Hence the phase reconstructed by means of Electron Holography provides a powerful tool to investigate modulations of electric or magnetic fields in or around solids [1], (Figure 2a). The reconstructed amplitude damped by e.g. inelastic scattering events additionally allows an estimation of the local thickness. This is useful for extracting mean potentials from the phase [2].

Nevertheless the ability to obtain information from amplitude and phase strongly depends on the according signal-to-noise ratios. F. Lenz [3] and A. Harscher, H. Lichte [4] derived analytical expression for the standard deviations of the two mentioned quantities. However, the considerable influence of the scintillator in the detector on the noise was neglected. Hence a more realistic noise model requires the incorporation of the correlation of statistical properties between different pixels in the hologram due to the scintillator before transferring to the three reconstructed channels, i.e. center band, amplitude and phase.

We investigate the noise properties experimentally by evaluating the statistics of amplitude and phase images from a series of N holograms in the same area of magnetic particles. That provides direct access to the local noise in terms of the experimental standard deviation in each reconstructed pixel (Figures 1b and 2b). The thereby obtained standard deviation of the amplitude in the particle is lower than in the vacuum region (Figure 2b), corresponding qualitatively to the prediction of Harscher and Lichte [4]; the analytic behavior however cannot be confirmed in this experiment, due to neglecting the noise correlation by the scintilator. A model including the amplifying and broadening influences of the detector on the noise (i.e. incorporating Noise Transfer Function) will be represented in this contribution.

We will discuss the advantage that averaging over all N reconstructed amplitude and phase images at the same object position reduces the amount of noise for both by a factor of 1/sqrt(N) (Figures 1a and 2a) and provides automatic access to the standard deviation of the mean values, which can be employed as error bars. This is helpful to check the reliability of the reconstructed signals in all applications of holography.

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G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology, DOI: 10.3217/978-3-85125-062-6-008, © Verlag der TU Graz 2009

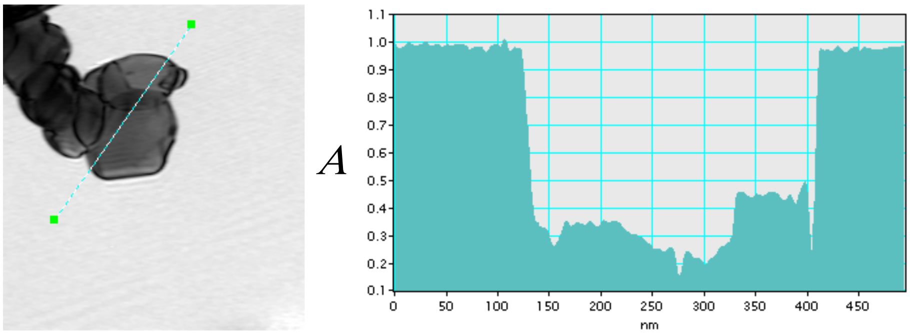

Figure 1a. Mean amplitude of $BaFe_{12}O_{19}$ particles with according profile

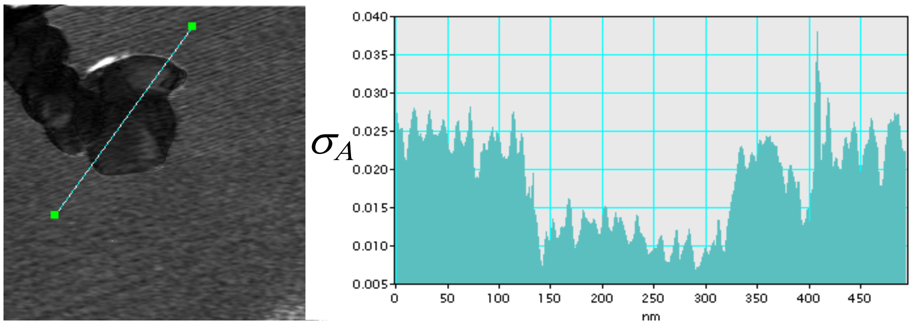

Figure 1b. Standard deviation of mean amplitude of $BaFe_{12}O_{19}$ particles with according profile indicating a decreasing for low amplitude values

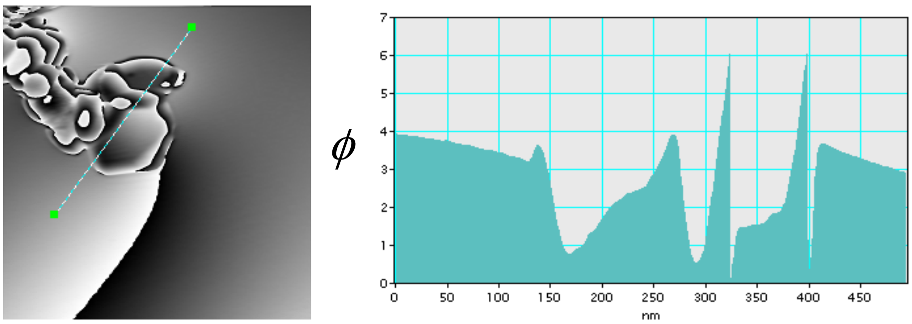

Figure 2a. Mean phase image of $BaFe_{12}O_{19}$ particles with according profile showing phase shifts due to magnetic fields in an around the particles.

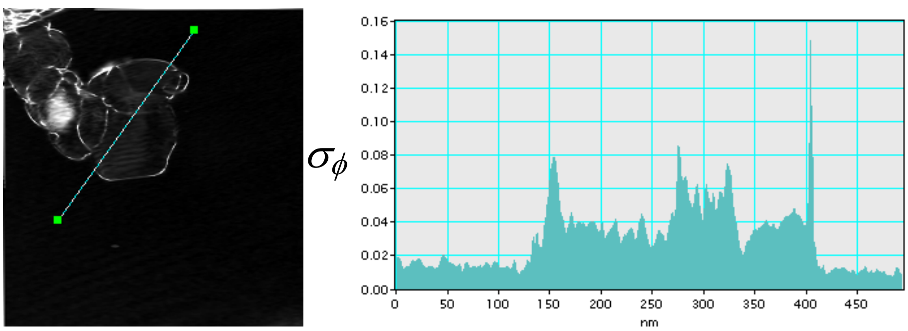

Figure 2b. Standard deviation of mean phase image of $BaFe_{12}O_{19}$ particles with according profile revealing an increase of phase noise in the particle.

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
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