Electron holography with low-energy electrons

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Keywords: electron holography, image reconstruction, phase retrieval.

Holography [1] is a well-known technique to retrieve three-dimensional structural information of an object by reconstructing its hologram. The latter is the interference pattern of a coherent non-scattered reference wave and the scattered object wave.

For holography with low-energy electrons the coherence of the reference wave is accomplished by driving a low-energy electron point source [2] at constant voltage. With a typical wavelength of about 1-2 Å such low energy electrons appear to be suitable for mapping fragile objects such as biological molecules. Our studies of radiation damage to DNA molecules continuously exposed to coherent low-energy electrons for more than 1hour reveal steady interference patterns. Quantitatively, the maximum of the cross-correlation between the initial and subsequent holograms decays from 1 to only about 0.8, see Fig.1.

For structural analysis electron holograms are reconstructed numerically. The reconstruction results in a set of images obtained at different source-sample distances, i.e. in different object planes. By careful mathematical separation of the reference wave and the object wave, such information as phase- and absorption-distribution can be retrieved and provide full information about the recorded object [3]. The mathematics behind the reconstruction algorithm relies on the classical Fresnel/Kirchhoff theory of light wave propagation. However, in case of electron waves some specific effects must be taken into account. For instance, the scattering of electrons, unlike photons, occurs with non-uniformly distributed amplitude. In fact, the maximum amplitude of the scattered wave appears in the direction of the incident beam. In order to account for this strong forward scattering some modifications to the reconstruction routine have been implemented. Their effects shall be addressed.

An intrinsic problem of holography is the so-called twin image problem. Together with the reconstructed image, there is always a twin image present. One possibility to circumvent the twin image problem is the off-axis holography suggested by E. N. Leith and J. Upatnieks [4], where the twin image appears spatially separated from the reconstructed object. Another possibility to separate the object and its twin is to perform the reconstruction iteratively and impose the positive absorption constraint in real space [5]. The algorithm allows retrieving both, absorption- and phase-distributions of the recorded object. This has been tested on high-energy (200keV) electron holograms of polystyrene spheres, recorded in-line as well as off-axis. The results of the reconstructions from both schemes are compared.

In order to improve the resolution stacks of holograms are acquired in a pulsed mode. Thereafter, all individual holograms within the stack are aligned and added up to one single hologram of enhanced signal-to-noise ratio. Lately recorded low-energy electron holograms of individual DNA molecules and their reconstructions, see Fig.3, shall be presented and discussed.

1. D. Gabor, Nature **4098** (1948) p777.
2. H.-W. Fink, W. Stocker and H. Schmid, Phys. Rev. Lett. **65**(10) (1990) p1204.
3. T. Latychevskaia and H.-W. Fink, submitted.

DOI: 10.3217/978-3-85125-062-6-020, © Verlag der TU Graz 2009

4. E. N. Leith and J. Upatnieks, J. Opt. Soc. Am. **53**(12) (1963) p1377.
5. T. Latychevskaia and H.-W. Fink, Phys. Rev. Lett. **98** (1997) 233901.

The aid of Matthias Germann, Conrad Escher and Peter Formanek is gratefully acknowledged. The work presented here is supported by the European Project SIBMAR, part of the “New and Emerging Science and Technology” Programme.

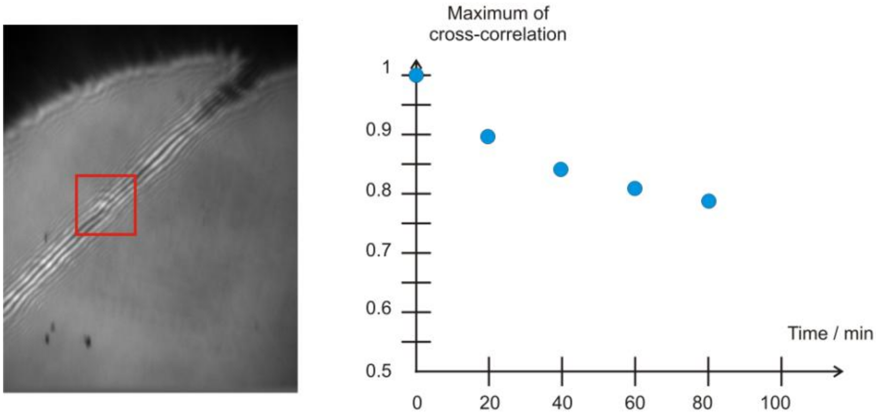

Figure 1. A low-energy electron hologram of DNA molecules and the maxima of the cross-correlation within the area marked with a red square in the first and each consequent image.

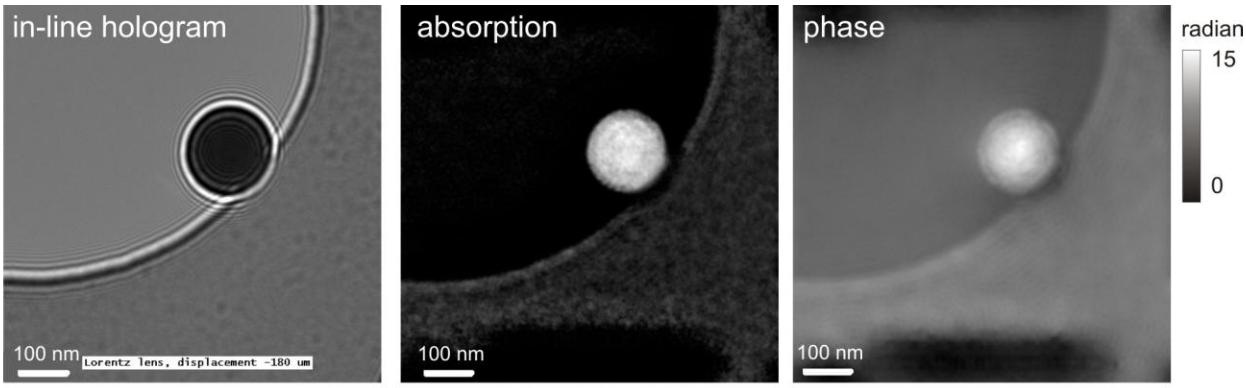

Figure 2. In-line hologram of a styrene sphere recorded with high energy electrons and its absorption and phase reconstruction.

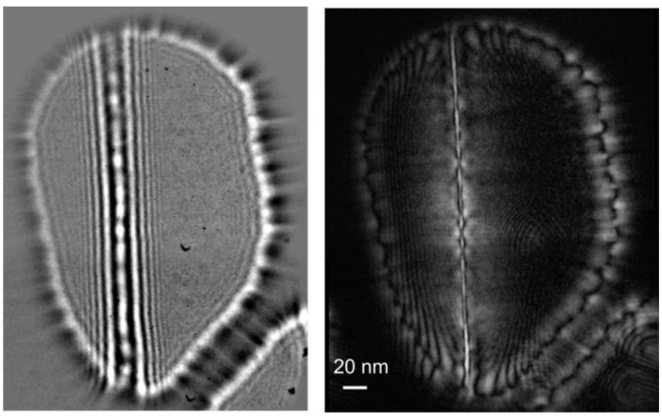

Figure 3. In-line low-energy electron hologram of a DNA molecule and its amplitude reconstruction.

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