Coherent imaging with ultra-low energy electrons

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The current state of the art in structural biology is led by NMR, X-ray crystallography and TEM investigations. These powerful tools however all rely on averaging over a large ensemble of molecules. Low-energy coherent electronswith kinetic energies in the range of 50– 250 eV allow recording holograms and diffraction images of individual molecules. It has been demonstrated [1-2] that individual biomolecules, such as DNA molecules, can withstand low-energy electrons radiation for hours without apparent radiation damage. Two experimental schemes are employed in our group for recording holograms and coherent diffraction images of individual bio-molecules, sketched in Fig. 1. A low-energy electron hologram of an individual DNAmolecule and its reconstruction is shown in Fig. 2. The problems related to numerical reconstruction will be discussed.By combining holography and coherent diffraction imaging [3], assumptions concerning the phase of the scattered wave become needless as the phase information is extracted from the data directly and unambiguously. Performed with low-energy electrons the resolution is just limited by the De Broglie wavelength of the electron wave and the numerical aperture, given by the detector geometry. In imaging freestanding graphene, a resolution of 2 Angstrom has been achieved revealing the 660.000 unit cells of the graphene sheet from one data set at once[4]. Applied to individual biomolecules the method allows for non-destructive imaging and imports the potential to distinguish between different conformations of proteins at atomic resolution.

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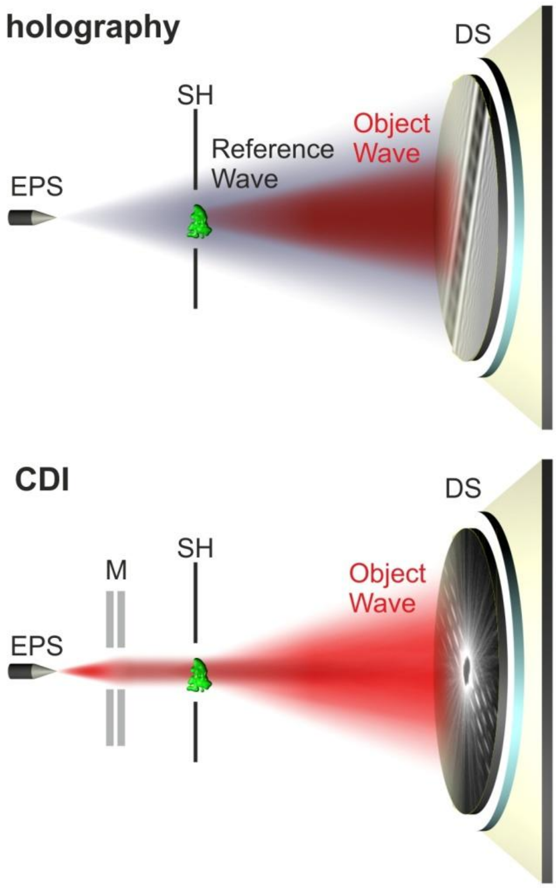

Fig. 1. Schematics of low-energy holographic (bottom)and coherent diffractive (top)imaging of an individual molecule.An electron point-source (EPS) emits a spherical electron wave. For coherent diffraction imaging (bottom), a micro-lens (M) with a bore of 1 micron is employed to form a parallel beam directed towards the sample mounted on a sample holder (SH). The holograms (top), respectively the diffraction patterns (bottom), are recorded at a 70 mm distant detector system (DS), consisting of a 75 mm diameter micro-channel-plate, followed by a phosphorous coated fibre-optic plate and a 8000 × 6000 pixels CCD chip.

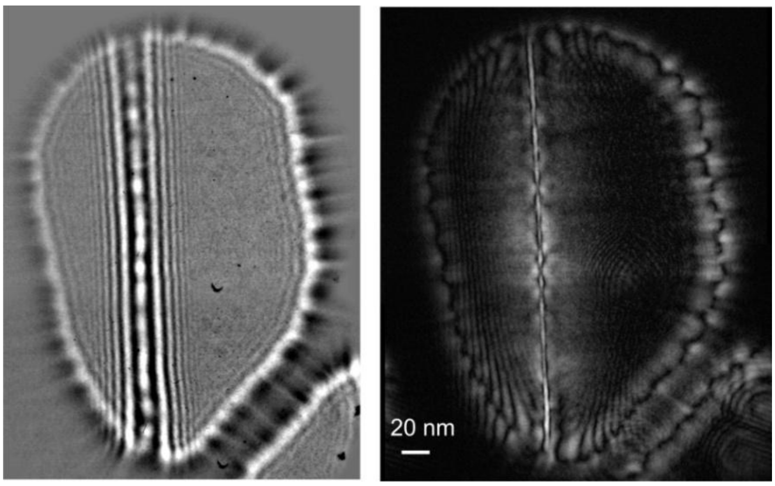

Fig. 2. In-line low-energy (110 eV) electron hologram of a DNA molecule and its amplitude reconstruction.