4D STEM Holography with an Amplitude-Division Diffraction Grating

Yasin, F.[1], Harvey, T.[2], Pierce, J.[3], Ophus, C.[4], Ercius, P.[5], Harada, K.[6], Shindo, D.[7,8], Tanigaki, T.[9], Shinada, H.[10], McMorran, B.[3] and Chess, J.J.[11]

[1] University of Oregon, Japan, [2] Georg-August-Universität Göttingen, D-37077 Göttingen, Germany, Germany, [3] University of Oregon, United States, [4] , United States, [5] National Center for Electron Microscopy, Molecular Foundry, Lawrence Berkeley National Laboratory, United States, [6] RIKEN Center for Emergent Matter Science, Japan, [7] Tohoku University, Japan, [8] RIKEN Center for Emergent Matter Science (CEMS), Japan, [9] Hitachi Ltd. Research and Development Group, Japan, [10] Hitachi, Ltd., Japan, [11] University of Oregon Physics Department, United States

Scanning-Transmission-Electron-Microscope holography (STEMH) was initially developed theoretically and experimentally several decades ago as a phase contrast electron imaging technique [1,2,3]. Due to difficulties in the use of an electrostatic biprism, such as strict coherence requirements and alignment difficulties, as well as the slow throughput of detectors at the time, STEMH was abandoned as an imaging method. Advances in FIB fabrication technologies and fast-readout direct electron detectors (DED) have enabled us to develop nano-fabricated, amplitude-dividing diffraction gratings for use as probe-forming apertures in an experimental demonstration of STEMH as a practical imaging technique.

Amplitude-dividing beam splitters loosen the coherence width requirements of the beam, while also allowing for careful shaping of the electron wave front's phase and amplitude structure [4,5,6,7]. These diffraction gratings form symmetric profile probes at the specimen plane that are absent of any unwanted edge-diffraction artifacts, and have one passive working part the same size and shape as conventional apertures, making them easily installable into commercial electron microscopes. The diffraction grating coherently splits the electron beam into multiple diffraction orders that are sharply peaked at the specimen plane, as shown in Figure 1. These probes are then rastered across the field of view using the scanning (deflection) coils in the microscope. One probe passes through a region of interest (specimen), while the others pass through vacuum, acting as reference beams in parallel interferometers. An interference pattern is focused onto the camera, and the grating fringes shift as the phase imparted onto the interacting probe varies. These images are recorded at each position in the 2D scan, forming a 4D data set, from which the specimen transmission function is reconstructed.

Here we report sub-nanometer resolution phase- and amplitude-contrast imaging of Au nanoparticles on amorphous C using STEMH (Figure 2). Additionally, we propose the addition of multiple electron biprisms into our setup, shown in Figure 3. This new, flexible-STEM holography (fSTEMH) would simplify the exit-wave function reconstruction, while also allowing for larger probe separation in the sample plane, resulting in a larger field-of-view. Additionally, this geometry could allow for new electron wave coherence length experiments. We report initial fSTEMH imaging results and discuss future experiments.

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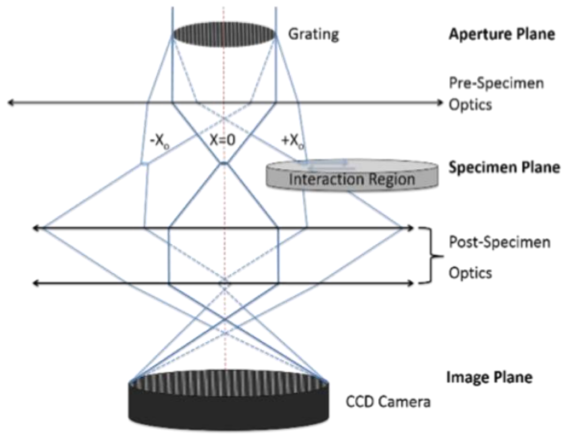

Figure 1 STEM Holography Setup

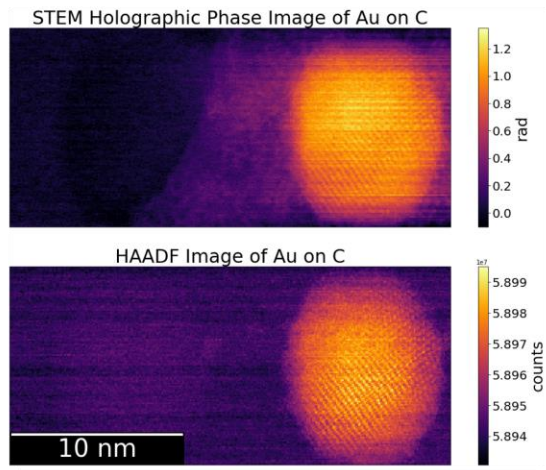

Figure 2 STEMH phase image versus conventional HAADF of Au nanoparticles on amorphous carbon.

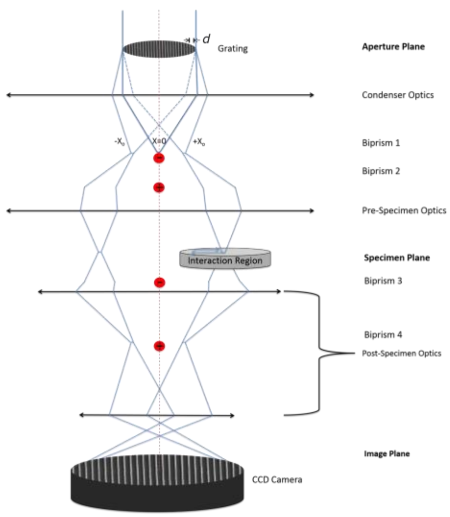

Figure 3 Flexible STEM Holography Setup