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Interference of Inelastically Scattered Electrons by DBI/H Experiments

R. A. Herring, University of Victoria V8N 4T6 Canada

In this paper, it is shown that it is possible to observe the interference of inelastically scattered electrons by using Diffracted Beam Interferometry/Holography (DBI/H), which opens up the possibility of also measuring their coherence. The understanding of inelastically scattered electrons is important for understanding high-resolution lattice images. For many years it has been known that the matching between experimental lattice images and their simulated images [1] do not correspond. The difference is known as the "Stobbs Factor". Electron holography, which also produces lattice images, has been found to be less affected by the Stobbs-Factor [2] since it employs a filtering process by reconstructing the intensity image using a sideband. Since both methods are affected, we need to better understand their role, especially since other explanations such as sample tilt [3] cannot account for the difference.

Recently, Lichte [4] by means of off-axis electron holography, i.e., a wavefront beam-splitter, showed self-interference of the inelastically scattered electrons from the first plasmon energy loss at 15 eV in aluminium but no interference was found for the higher plasmon loss electrons. This showed that inelastically scattered electrons have partial coherence.

Previously DBI/H has been used to precisely measure the relevant parameters of high-resolution imaging, i.e., spherical aberration and lateral spatial coherence [5]. DBI/H involves splitting the primary electron beam by means of a crystal and then interfering the diffracted beams on the back focal plane, i.e., the Fraunhofer plane, by means of a biprism (Figure 1) [6]. The transverse boundary of the interferogram is set by the condenser aperture. Since inelastically scattered electrons deviate from the elastically scattered electrons ray path ($\Delta k/k=\Delta E/2E$ for $\Delta E<<E$), their boundary limits are poorly defined, if at all, and not limited by the aperture. It was sometimes observed in interferograms that the fringes appeared to extend beyond the aperture. The interference limit was measured by overexposing film using the <111> beams of Silicon, with the consequence of increasing the measured intensity of the inelastically scattered electrons outside the boundary of the aperture. Figure 2a shows the observed beams. Interference fringes are clearly seen around the aperture, i.e., extending away from the aperture into reciprocal space, for both the interferograms of [000]/[222] (Figures 2b and 2c) and [111]/[-1-1-1] (Figure 2d]. No fringes were seen inside or away from the [333], which is not an interferogram. In addition, in the [000]/[222], streaks, which appear similar to Kikuchi lines and may be due to contamination on the aperture, emerge radially but they were not see in the lower intensity [111]/[-1-1-1] interferogram. The interference fringes in the [111]/[-1-1-1] are weaker than the [000]/[222] but they are nevertheless clearly seen. Other examples will be presented, and the possibility of Fresnel edge diffracted wave interference, the energy spread of the measured intensities and their carrier spatial frequencies will be discussed.

These results possibly show the interference of inelastically scattered electrons by means of an amplitude splitter, which support the findings of Lichte [5] of their partial coherence. These results should also be considered in light of a theoretical presentation of the subject [7].

Acknowledgement
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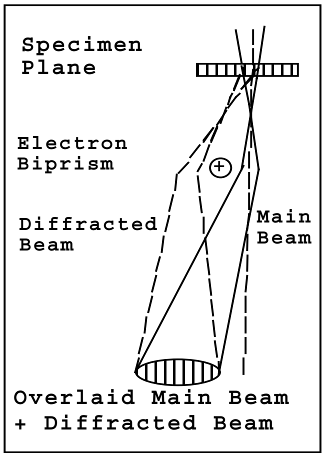
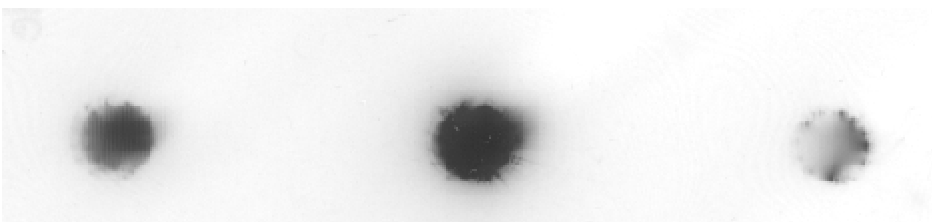
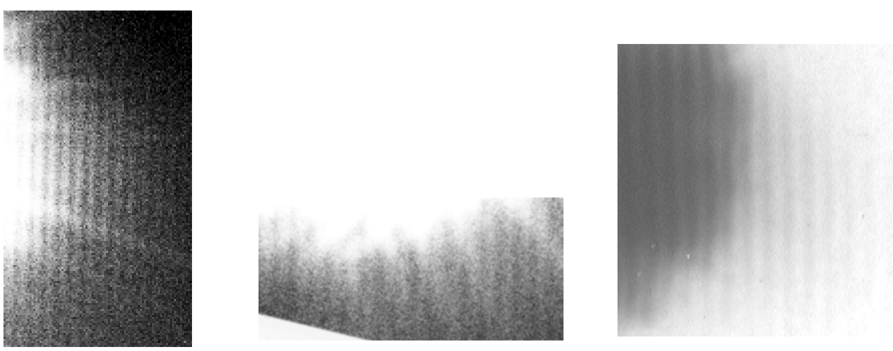


Figure 1 - Simplified ray diagrams of Diffracted Beam Interferometry/ Holography showing the use of an electron biprism to deflect two beams for interference on an observation plane. By increasing the biprism's voltage, the deflection angle increases and multiple beams can be interfered, as given in Figure 2 below.



111/-1-1-1 222/000 333

a)



b) c) d)

Figure 2 - DBI/H interferograms of Si. In a) the main beam [000] has interfered with the [222] beam and the [111] beam has interfered with the [-1-1-1] beam. In a) the [333] beam has not been interfered with another beam and is not an interferogram. The fringes are shown emerging from the right side of the 222/000 interferogram in b), and from the bottom of the 222/000 interferogram in c). In d) the fringes are shown emerging from the right side of the 111/-1-1-1 interferogram.

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