

Electron Holography on Fraunhofer Diffraction Using Double Slit

Ken Harada^{1,2}, Kodai Niitsu³, Keiko Shimada¹, Tetsuji Kodama⁴, Tetsuya Akashi^{5,6}, Yoshimasa A. Ono¹, Daisuke Shindo^{1,7}, Hiroyuki Shinada⁵, and Shigeo Mori²

1. CEMS, RIKEN (The Institute of Physical and Chemical Research), Hatoyama, Saitama 350-0395, Japan
2. Department of Materials Science, Osaka Prefecture University, Sakai, Osaka 599-8531, Japan
3. Department of Materials Science & Engineering, Kyoto University, Kyoto, Kyoto 606-8501, Japan
4. Graduate School of Science & Technology, Meijo University, Nagoya, Aichi 468-8502, Japan
5. Research & Development Group, Hitachi, Ltd., Hatoyama, Saitama 350-0395, Japan
6. Department of Applied Quantum Physics, Kyushu University, Fukuoka, Fukuoka 810-0395, Japan
7. IMRAM, Tohoku University, Sendai, Miyagi 980-8577, Japan

In electron phase microscopy and vortex beam microscopy, the amplitude and phase distributions of wave fields in the reciprocal space, such as diffraction patterns, have been mainly discussed theoretically. Experimentally, however, the phase distribution in the reciprocal space is difficult to detect directly even by using holography technique because intensity of the object wave in diffraction patterns is a few orders of magnitude larger than that of the diffracted waves. In addition, no appropriate reference wave for electron holography exists in the reciprocal space. To overcome these difficulties we developed electron holography on Fraunhofer diffraction utilizing a narrow slit placed at the object plane as a source of a reference wave. In the present study, an electron wave passed through a wider slit was recorded as an object wave while an electron wave passed through a narrower slit worked as a reference wave. The Fraunhofer diffraction wave from the wider slit was recorded in a hologram and the amplitude and phase distributions were successfully reconstructed from the hologram [1].

Figure 1 shows a schematic diagram of the optical system for the Fraunhofer holography. The double-slit with a 120 nm slit width in each (see the inset of Fig. 1) was installed at the specimen position, which was object plane of objective lens. A biprism filament was placed and adjusted at the image plane of the double-slit for creation of an asymmetric double slit [2]. The propagation distance, i.e. the defocus distance Δf , for Fraunhofer condition was controlled by using a magnifying lens.

Figure 2 shows calculated propagation behavior of two waves passed through the asymmetric double slit when the right-slit width are 38 nm in (a) and 5 nm in (b). Although the right-slit width of 5 nm is four orders of magnitude larger than the wavelength of 1.2-MeV electrons, the electron waves passed through the right-narrower-slit spread out quickly just like a plane wave and overlapped with the electron wave passed through the left-slit.

Figure 3(a) shows an electron hologram of a Fraunhofer diffraction from the left-slit at the defocus distance Δf of 23.2 mm, with the right-slit width of 5 nm. Figure 3(b) shows reconstructed phase distribution having a band-shape feature. The phase profile along the red broken line in (b) is given in (c) showing a step-like phase profile with π difference between steps. These observed phase steps are similar to those of microwaves at the back focal plane of an imaging lens reported in the 1950s [3, 4].

We believe the developed interferometry, Fraunhofer electron holography, will be used widely as a new electron holography technique for analyzing electromagnetic properties.

References:

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 [5] The authors would like to thank Dr. Y. Takahashi of Hitachi, Ltd., and Dr. H. Yoshikawa of NIMS for their valuable discussion.
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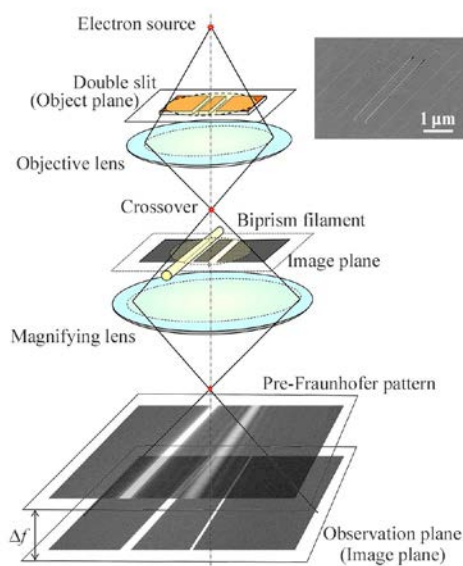


Figure 1

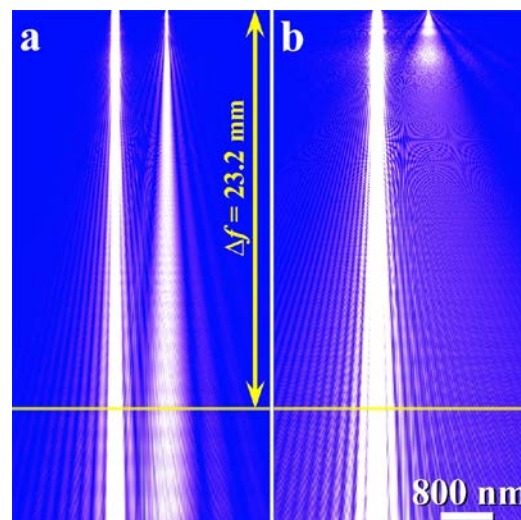


Figure 2

Figure 1. A schematic diagram of the optical system. A double-slit is installed at the specimen position, which is an object plane, and is imaged on an electron biprism filament placed at an image plane. Defocusing conditions are controlled by the magnifying lens below the objective lens. The right-slit width is varied by using the biprism filament. Inset is an SEM image of the double-slit.

Figure 2. Optical simulation on wave propagation from an asymmetric double-slit by changing the right-slit width: (a) 38 nm, and (b) 5 nm. The left-slit width is 120 nm and the wavelength is 0.76 pm.

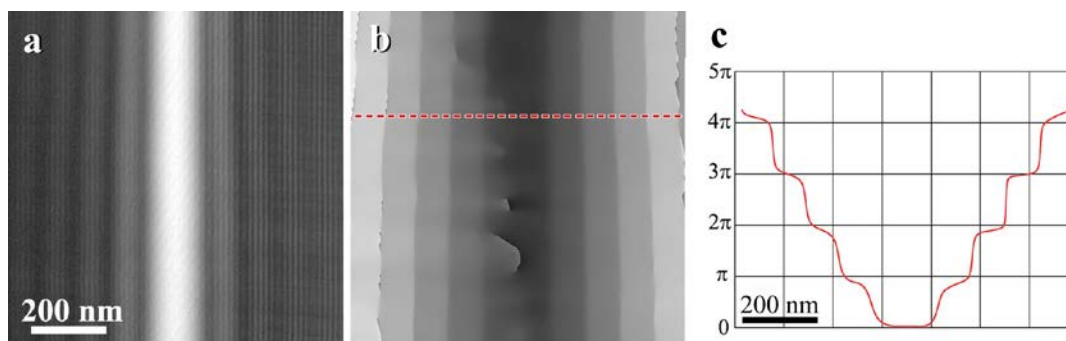


Figure 3. (a) Electron hologram of a Fraunhofer diffraction from the left-slit by using a 1.2-MV field emission TEM, (b) reconstructed phase images, and (c) phase profile along the red broken line in (b). The phase profile shows a step-like structure with π difference between steps.