Type of presentation: Poster

IT-11-P-1673 Observation of Fraunhofer Diffraction Pattern with Electron Vortex Beam using Fork-Shaped Grating with Various Opening Shapes

Harada K.[1], Kohashi T.[1], Iwane T.[1]

[1]Central Research Laboratory, Hitachi Ltd., Hatoyama, Saitama 350-0395, Japan

Email of the presenting author: ken.harada.fz@hitachi.com

Electron vortex beams are considered as probes for next-generation electron beam machines, especially for transmission electron microscopes (TEM), because the vortex beams carry intrinsic orbital angular momentum. We expect that it will bring with it an unprecedented measurement capability.

In order to generate a vortex beam, we fabricated a fork-shaped grating [1] made from a Si_3N_4-membrane with a 200-nm-thickness by using a focused ion beam machine (FB-2100, Hitachi High-Technologies Corp.). The maximum grating size in one direction was 10 μm. Electron diffractions from the gratings were observed with a 300-kV field emission electron microscope [2]. The optical system was constructed for small angle diffraction with a camera length of 150 m and was similar to the twin-Foucault imaging system [3].

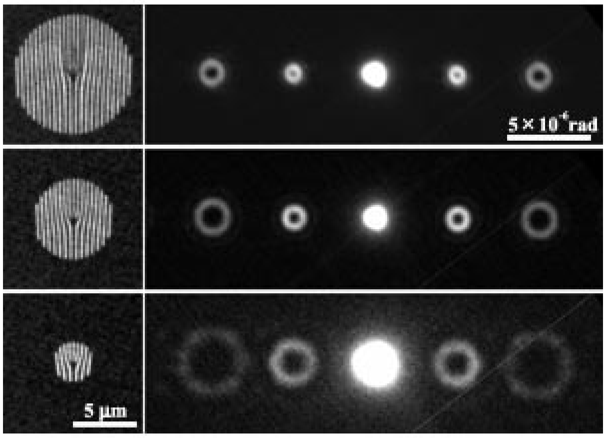
During the experiment, we noticed the shape of the grating openings was superimposed on the ring of diffraction spot, which is a typical shape of the vortex beam. We also noticed the opening size is inversely proportional to the diameter of the diffraction ring. This phenomenon is considered to be due to a combination of Fraunhofer diffractions from the grating and the opening. Figure 1 shows electron micrographs of circular-fork-shaped gratings (left panels) and their electron diffractions (right panels). The smaller the grating opening size, the larger the diameter of the diffraction rings.

The left panels of Fig. 2 show TEM images of fork-shaped gratings with triangular, square, and pentagonal openings. The right panels show electron diffractions whose spot-shapes reflect those of the openings.

The combination of the fork-shaped grating and its opening allowed us to observe the rotational phenomena of the diffraction rings in the through-focus condition. Figure 3 shows diffraction patterns from a fork-grating with a diamond-shaped opening for three different focuses. The diffraction spots on the right are rotated in the opposite azimuth direction to those on the left. Figure 4 plots the rotation angles of the first, second, and third diffraction rings (spots) versus the defocusing distance, Δf. They show the lower order rings rotated more. The phenomenological picture of this rotation is consistent with the phase distribution of the vortex beam. The rotation itself can be explained by the Gouy phase [4, 5].

References:

[1] B. J. McMorran et al., Science, **331**, 192 (2011).
[2] T. Kawasaki et al., Jpn. J. Appl. Phys., **29**, L508 (1990).
[3] K. Harada, Appl. Phys. Lett., **100**, 061901 (2012).
[4] G. Guzzinati et al., Phys. Rev. Lett. **110**, 093601 (2013).
[5] B. J. McMorran et al., Laser Science (Frontiers in Optics, San Jose, CA, USA, 2011), LWL 1.



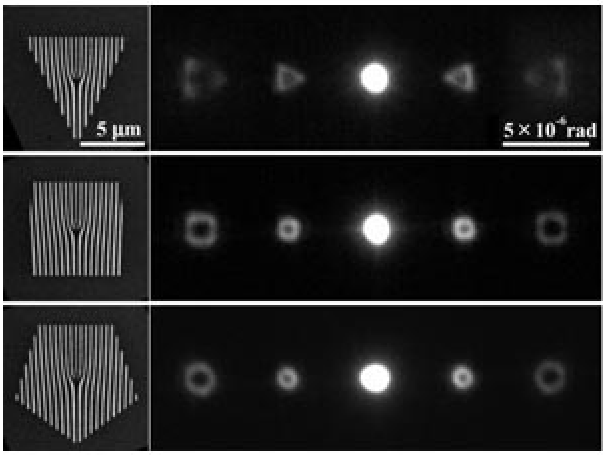
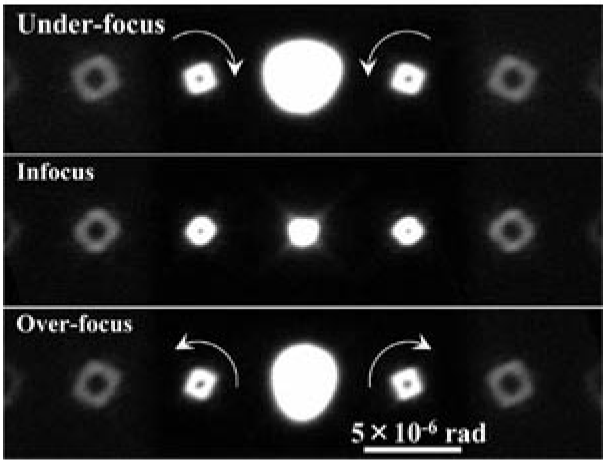


Fig. 1: Ring diameter of diffraction is related to opening size. Contrast of the diffraction pattern of the botom panel is enhanced.

Fig. 2: Opening shape reflects the shape of each diffraction ring.



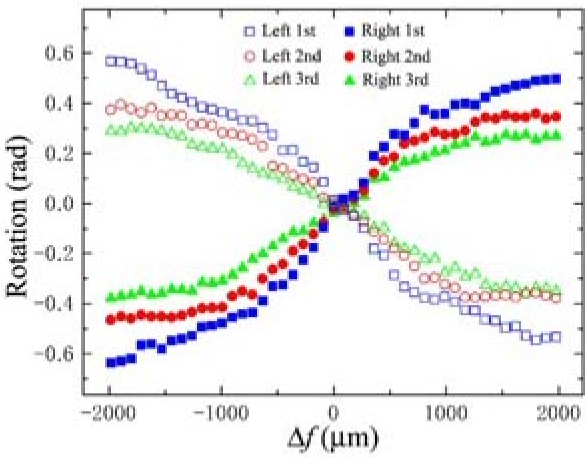


Fig. 3: Diffractions from grating with diamond-shaped opening is rotated by defocusing.

Fig. 4: Rotation angles of the first, second and third diffraction rings on both sides versus defocusing, Δf.