Measuring the orbital angular momentum spectrum of electron beams using a Dammann vortex grating

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Nowadays, orbital angular momentum (OAM)-carrying electron beams can be generated by a variety methods [1, 2]. Both angular and linear momentum can be transferred via various scattering processes between an incident beam and a scatterer, such as an atom and a solid. Emitted and scattered electrons such as secondary electrons could carry OAM. In this context, techniques and devices to measure the OAM of vortex electrons are needed for novel scattering and spectroscopy experiments [3, 4]. Here, we present the measurement of electron OAM by using a Dammann vortex grating (DVG).

Devices that are used to generate electron vortex beams can also be adopted to measure an electron's OAM content. We have proposed electron OAM analyzer (sorter) using a forked grating [3]. DVGs can uniformly distribute electron intensity among all desired diffraction orders [5]. In this work, a binary amplitude two-dimensional DVG with five desired diffraction orders is presented. The theoretical amplitude pattern of a designed DVG with *m*=1 and 4, where *m* denotes the topological charge, is shown in Fig. 1(a). Figure 1(b) exhibits the SIM image of the DVG, fabricated from Si_3N_4 membranes using a focused-ion-beam instrument (Hitachi FB-2100). Experiments for OAM measurement were done using a TEM microscope (JEOL JEM-2100F), operated at an acceleration voltage of 200 kV.

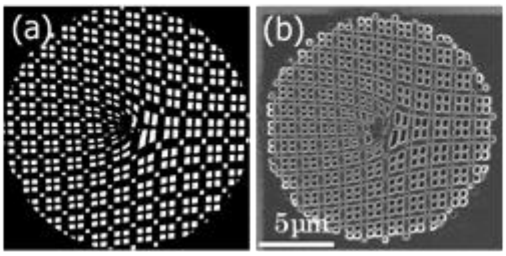

Fig. 1 (a) The theoretical binary amplitude DVG. (b) The SIM image of the fabricated. DVG.

Figure 2(a) shows a diffraction pattern corresponding to the DVG illuminated by a plane wave. The 5×5 equally intense diffraction orders carrying topological charge are clearly observed. The detailed topological charge distribution is presented in Fig. 2(b). The diffracted vortex beam with nonzero OAM has zero intensity at the beam center and the diffracted beam with zero OAM has nonzero intensity at the center. The DVG enables to obtain OAM spectra from10 to 10 at one time. To assess the usability of the present DVG, electron vortex beams from spiral zone plates and electron beams through a monopole magnet [6] were injected to the DVG (Fig. 3). In the case of the the monopole magnet, the resultant diffraction pattern is shown in Fig. 2(c). Central spots at (-2, -1) diffraction order emerge. The results mean that the electron beams carry an OAM value of $6\hbar$. This work supplies a practical approach for OAM detection.

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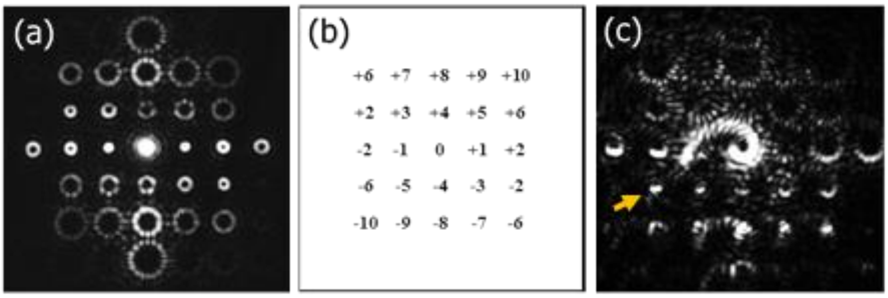

Fig. 2 (a) The diffraction pattern of the DVG illuminated by a plane wave. (b) The distribution of topological charges of (a). (c) The diffraction pattern of DVG injecting electron beams through a monopole magnet (see, Fig. 3). The arrow indicates (-2, -1) diffraction order.

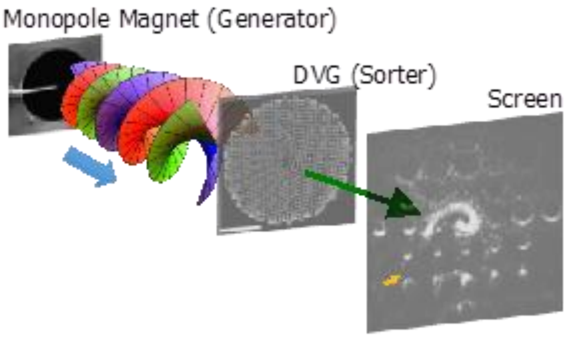

Fig. 3 Schematic drawing of the present experiment. Electron beams through a monopole magnet are injected to the DVG.

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