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Double-Slit Electron Interference Experiment with Zero Propagation Distance Using Electron Biprism

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Yang's double-slit experiments show interferences owing to the long propagation distance from a double-slit to the observation plane. We performed a double-slit interference experiment under the pre-Fraunhofer condition, which corresponded to a short propagation distance from the double-slit to the observation plane: single-slit observations were performed under the Fraunhofer condition and the double-slit observations were performed under the Fresnel condition simultaneously [1, 2]. In this experiment, however, because of the existence of a propagation distance, two waves passed through the right and left slits always overlapped and controlling the waves was difficult. To overcome this difficulty, we devised an optical system for imaging the double-slit on the observation plane under the infocus condition. This experimental condition can be considered as an optically zero propagation distance from the double-slit to the observation plane because of the optical conjugate relation between the object plane and the image plane. Two electron biprisms were installed in the optical system to superimpose the two waves and to control the interference. In addition, we used a V-shaped double-slit (V-DS) of about a 1.3-μm-thick Cu foil made with a focused ion beam instrument to observe in a single image the interference features before, during, and after overlapping of electron waves from the left and right slits.

Figure 1 shows a schematic diagrams of the optical system constructed in a 1.2-MV field-emission transmission electron microscope [3]. The V-DS was placed at the object plane. The biprism I was placed at the image plane of the objective lens and the biprism II was placed at the crossover plane under the magnifying lens [4]. Interference conditions on the observation plane were controlled by the applied voltage to the biprism II to realize the pre-interference condition in Fig. 1(a), the interference condition in Fig. 1(b), and the post-interference condition (no figure given).

The interference conditions from pre-interference to post-interference on the V-DS are shown in Figs. 2(a-e). The interference fringes appeared at the overlapped region of two electron waves, while uniform single electron distributions were obtained in the pre- and post-interference regions. In Fig. 2(c') with the applied voltage of 25.7 V, interference fringes appeared at the center of the V-DS image, and uniform single electron distributions were obtained at the upper and lower parts. This behavior indicates that interference occurred only when no information was obtained on which slit the electrons passed through.

In conclusion, we devised an optical system for zero propagation distance based on the conjugate condition. Using a V-SD we have succeeded in obtaining interference fringes in the overlapped region

and uniform intensity distributions in the pre- and post-interference regions in a single image [5].

References:

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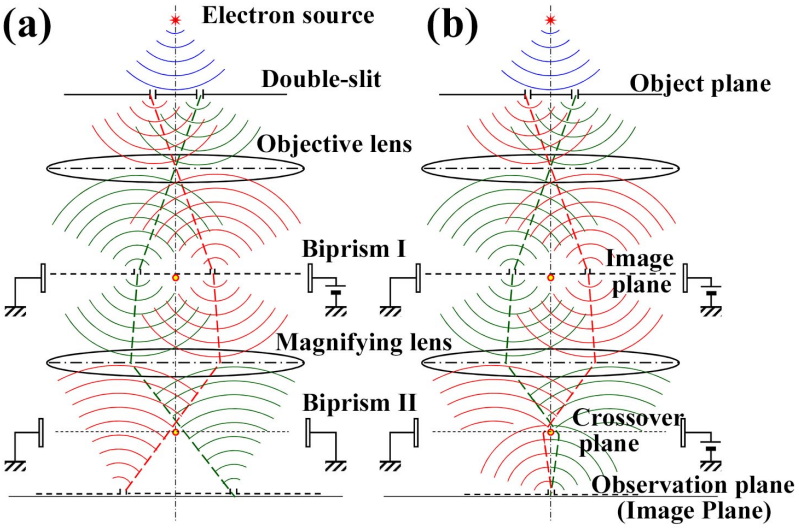

Figure 1. A schematic diagrams of the optical system with electron wave propagation profiles: (a) zero-bias voltage applied to the biprism II, and (b) none-zero bias voltage applied to the biprism II for interference. A V-shaped double-slit is placed at the object plane and is imaged on the biprism I and on the observation plane. The interference conditions are controlled by the applied voltage to the biprism II.

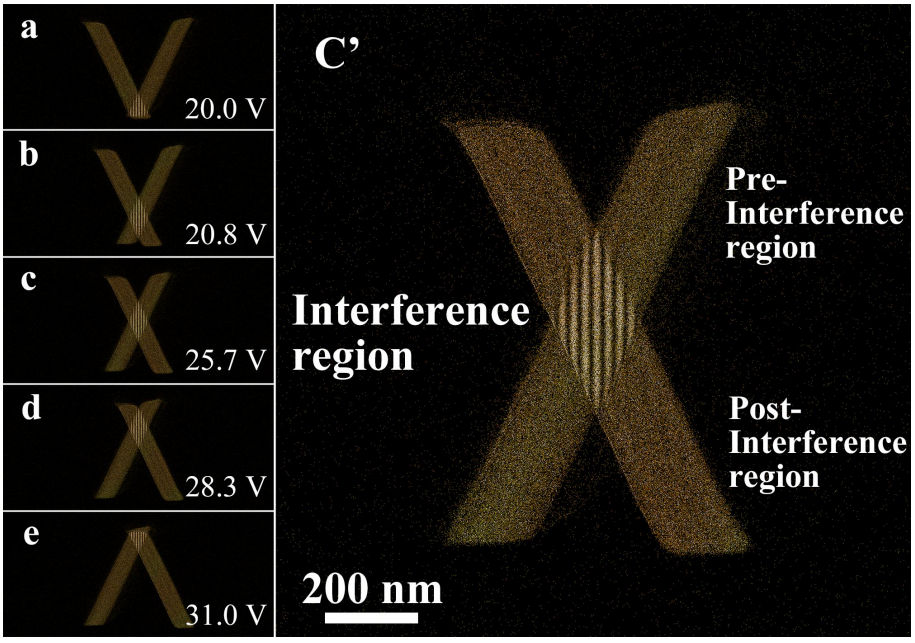

Figure 2. Series of interference patterns on the V-shaped double-slit with different applied voltages to the biprism II: Interference fringes were observed only at the two-wave overlapped region, and uniform intensity distributions were observed in the pre- and post-interference regions.

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