Interference experiment with asymmetric double slit by 1.2 MV-TEM

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Wave-particle duality is one of the fundamental properties of fine particles pointed out by Feynman as one of the mysteries of quantum physics. Various experimental observations, for example by Tonomura *et al.* [1], have been reported on the wave-particle duality of electrons; however, this mysterious "which-way" issue has not been fully resolved yet. Recent technological developments have made it possible to perform double-slit experiments more easily and precisely. We used the following technologies and methods [2]: (1) highly coherent electron beams from a 1.2-MV field-emission transmission electron microscope [3], (2) asymmetric double slits having slit widths that can be varied by using a biprism, (3) measurements under a "pre-Fraunhofer" condition at distances shorter than those in the Fraunhofer condition, and (4) a direct electron detection camera system.

Figure 1 shows a schematic diagram of the optical system for the double-slit experiment. A symmetric double slit was placed at the specimen position. The first and second electron biprisms were set at image planes of the double slit. The first biprism was utilized to control the opening width of one of the slits to be asymmetric. The second biprism was used to shield the beam going through one of the single slits for the alternation between single-slit and double-slit experiments. The pre-Fraunhofer patterns, such as defocused images of the double slit, were recorded by the direct detection camera system in the electron counting mode. Figure 2 shows a composite image of the categorized electrons in three colors: blue corresponds to electrons passed through only the left slit; green corresponds to electrons passed through only the right slit; and red corresponds to electrons passed through both slits simultaneously. Intensity profile is shown above the image. The red electrons form a two-wave interference fringe pattern.

In conclusion, we succeeded in categorizing electrons in three types in terms of the intensity profiles, although we could not completely perform the which-way experiment yet. We hope this trial will contribute to resolve the "which-way" issues.

1. Tonomura, A. *et al.*, *Am. J. Phys.* **57** (1989) 117-120, doi:101119/1.16104.
2. Harada, K. *et al.*, *Scientific Reports* **8** (2018) 1008, doi: 10.1038/s41598-018-19380-4.
3. Akashi, T. *et al.*, *Appl. Phys. Lett.* **106** (2015) 074101, doi:10.1063/1.4908175.

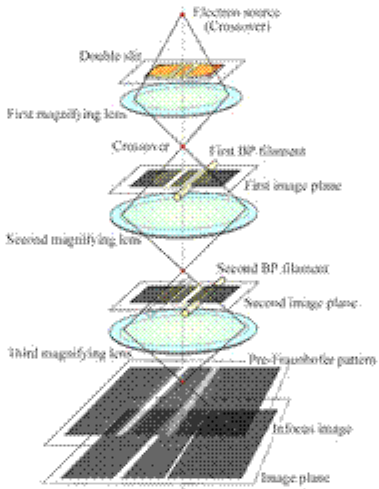

Fig. 1. Schematic diagram of optical system. The double slit and two electron biprisms are placed at the conjugate planes in the system. The resultant asymmetric double-slit image is observed in pre-Fraunhofer condition.

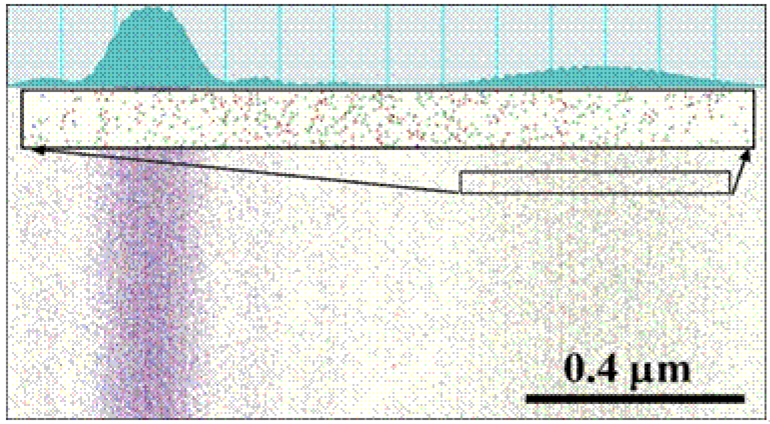

Fig. 2. Composite image of color-coded electrons of present version of the "which-way" double-slit experiment: blue colored electrons passed through only the left slit; red colored electrons passed though both slits simultaneously; green colored electrons passed through only the right slit. Inset is an averaged intensity profile of the pre-Fraunhofer fringe pattern. The second inset indicates an enlarged figure of the data in the rectangle area shown below.