# Electron Phase Microscopy to Observe Microscopic Phase Objects

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Bright beam sources, like lasers and synchrotron radiation, open up new ways of investigating microscopic structures. We have repeatedly developed brighter and brighter electron beams since 1968 to utilize the phase information in an electron beam for microscopy. As it turned out, every time we developed a brighter electron beam, the precision in the phase measurements increased, thus opening up new applications. For example, it has become possible to carry out fundamental experiments in quantum mechanics that were once regarded as thought experiments. Such experiments include single-electron build-up of an interference pattern (Fig. 1) [1, 2] and conclusive experiments on the Aharonov-Bohm effect (Fig. 2) [3]. Also, visualizing magnetic lines of force in h/e flux units by interference microscopy (Fig. 3) [4] and visualizing quantized vortices in superconductors by Lorentz microscopy [5] has become possible. In spring 2000, we completed a 1-MV microscope [6] that has the brightest beam ever obtained, and we have begun obtaining various new results on the vortex behaviors inside high-$T_c$ superconductors, such as the observations of vortices trapped along tilted columnar defects in Bi-2212 film (Fig. 4) [7] and elucidations of the mechanism for forming a special arrangement of vortices, the chain-lattice state [8], that reflects the layered structure of the material.

Keywords: electron microscopy, phase, magnetism, superconductor

References

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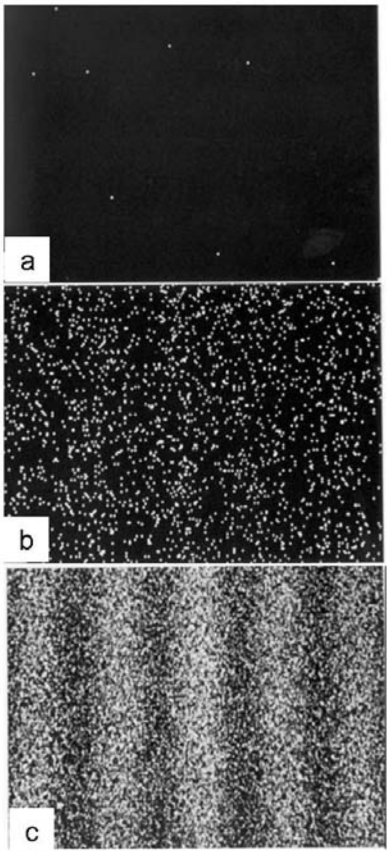


Fig. 1. Single-electron build-up of interference pattern [1].

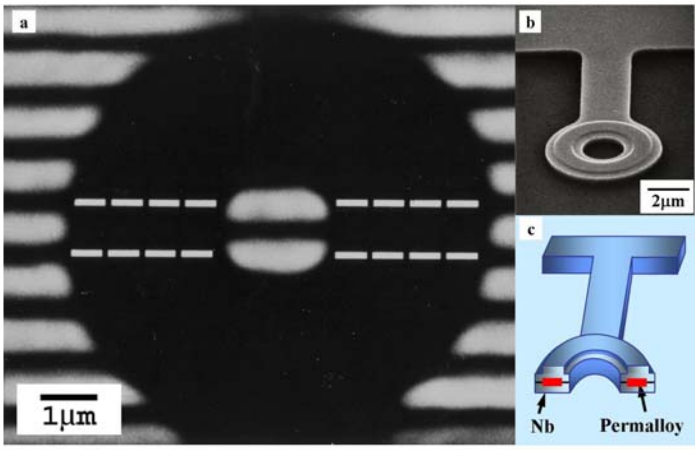


Fig. 2. Confirmation experiment on Aharonov-Bohm effect [3].

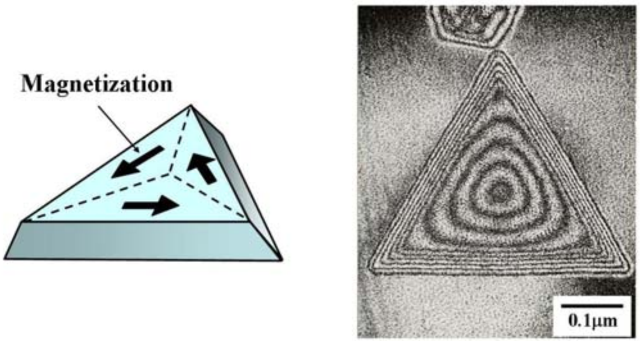


Fig. 3. Observation of magnetic lines of force in Cobalt fine particle [4].

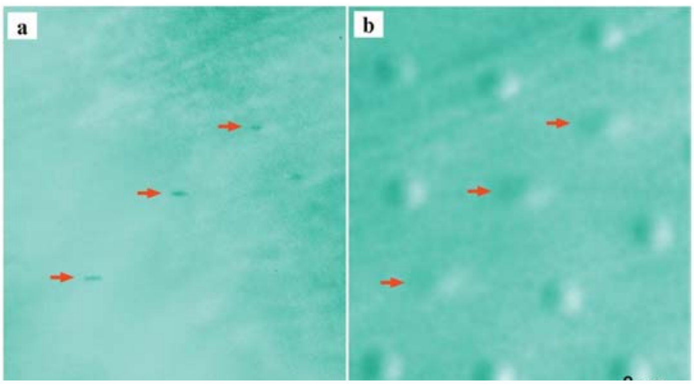


Fig. 4. Observation of quantized vortices trapped along tilted columnar defects [7]: (a) electron micrograph, (b) Lorentz micrograph.

The images of the vortices penetrating perpendicularly to the film plane are circular spots, and the images of the tilted vortices along the columnar defects are elongated spots.