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The Side-Effects Of A Non-Mechanical Shutter In The Gun Area Of A Transmission Electron Microscope For Off-Axis Electron Holography

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There are basically two shutter positions on a standard transmission electron microscope, one above the sample that shutters the illumination off the target, and one below the sample that shutters the image from the detector. The lower shutter is typically electro-mechanical, while the upper shutter could be either electro-mechanical, or employ electromagnetic or electrostatic beam deflection. Use of the lower shutter allows continuous observation of the target, as it closes only when acquiring an image either digitally or on film. Under those circumstances, the total radiation dose for the target is high, and consequently suitable primarily for use in imaging beam-insensitive materials. For radiation sensitive targets, e.g., biological materials, an upper shutter is preferred, as it allows minimizing the total electron dose for the target (the beam is deflected until an image is taken). In the most stringent case, only one image is taken from the target at exactly the dose required for a minimum signal/noise ratio in the image.

There is a lesser reason for preferring the lower shutter. Since it is located at the very end of the imaging chain and because it mechanically intercepts the beam, it has no practical effect on the alignment of the microscope, as might a shutter in the illuminating system or in the gun area. An upper shutter uses beam tilt coils or electrostatic deflectors to deflect the beam from the sample area of interest. It has the side effect that the beam returning onto the target changes slightly between exposures. This is due to, e.g., hysteresis effects of magnetic coils, or thermal effects. In most cases, this effect can be ignored for conventional imaging but not at highest resolution. The effect of the upper shutter on holographic interference fringes however, is a different issue.

In general, the biprism [1] necessary for creating the hologram is positioned either between the back focal plane of the objective lens and the first image plane, or one lens downstream, i.e., between the back focal plane of the diffraction lens and the second image plane. Independent of its exact position, and as displayed in FIG. 1, the biprism splits the electron beam in the plane of the biprism. Downstream, it converges the two beams and an interference pattern forms in the overlap region in the image plane. An observer in the image plane now observes two virtual sources A and B, when looking upstream. A CCD camera is positioned in the overlap area, for observation of the hologram.

As already indicated, the upper shutter physically moves the electron beam. To show the effect, it is assumed for simplicity that the shutter offsets the electron beam in a plane conjugate to the back focal plane (or Fourier plane). Assuming a well-aligned microscope, a shift in the Fourier plane will cause a tilt of the wave front in the image plane, but no shift. As the tilt becomes larger, the beam will eventually be blocked by an aperture and act as shutter. This is ideal for normal imaging. However, with a biprism in a position above the image plane, the following effect would be observed in “slow motion.” In FIG. 2, the shutter has offset the electron beam to the right in the back focal plane. Because the biprism remains in place the virtual sources move to their new positions A' and B'. This immediately affects the position of the fringes with respect to the CCD camera, because the path length difference of beams from the different virtual sources with respect to a given point on the CCD camera changes when the virtual sources move. Therefore, if the shutter acts too slowly, a smearing of the interference fringes will occur and reduce fringe contrast.

A Hitachi HF-2000 FE-TEM was used to compare the effect of the two different shutters on hologram fringe contrast. The lower electromechanical shutter is a special design unique to our instrument, and provides exposure times as low as 10msec. The upper shuttering was done using the electromagnetic horizontal gun deflector coils. Our preliminary results showed a contrast in 1.5Å fringes of 41% using the lower shutter, and 38% using the gun deflector, a statistically insignificant difference. We intend to make use of the upper shutter system for the holographic investigation of radiation sensitive materials.

References

[1] G. Möllenstedt, H. Düker, Naturwissenschaften, **42** (1955) 41.
[2] Research sponsored by Asst. Sec. for Energy Efficiency and Renewable Energy, Off. Of FreedomCAR and Vehicle Technologies, as part of the HTML User Program, ORNL, managed by UT-Batelle, LLC for the U.S. DOE.

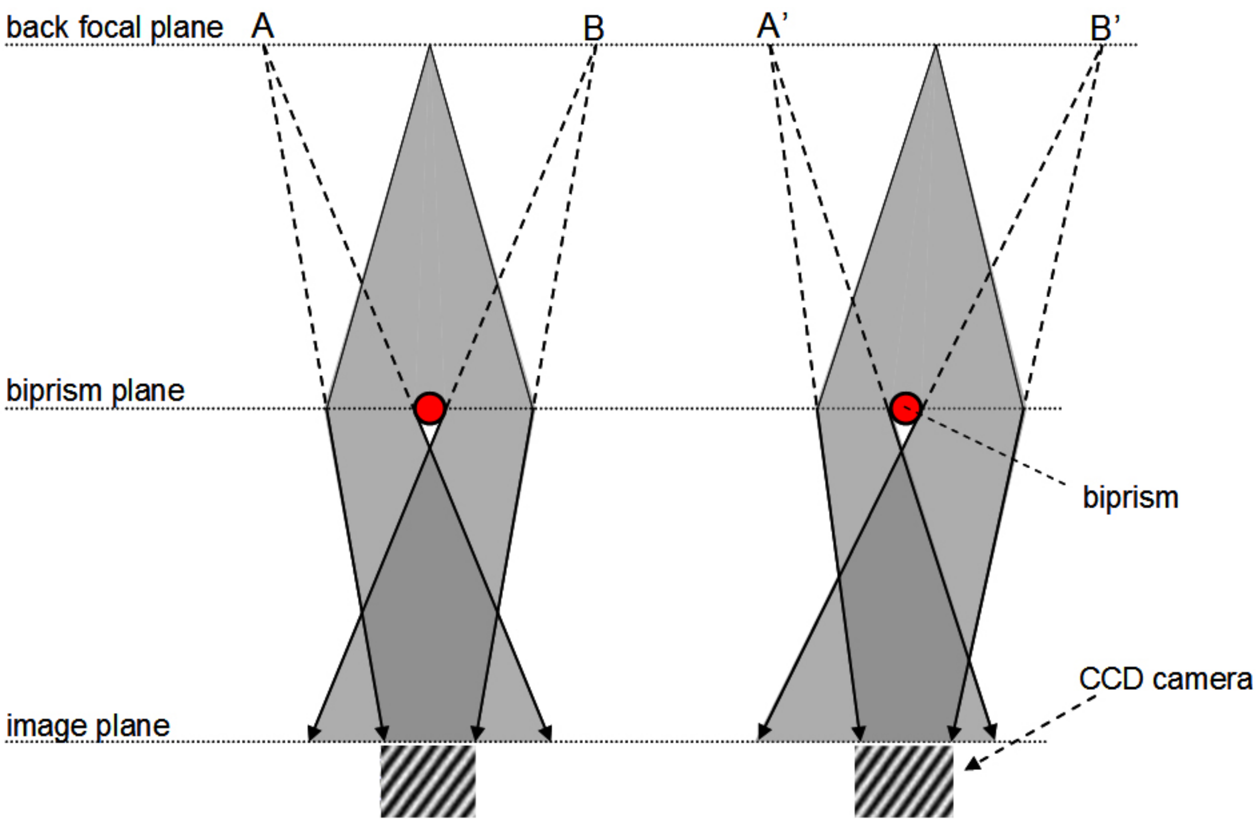

FIG. 1. The positions of virtual sources A and B when using an electrostatic biprism as seen from the image plane.

FIG. 2. A shift of the virtual sources in the back focal Fourier plane to the right moves the interference fringes in the image plane.

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