Time-Resolved Electron Holography by Interference Gating

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With a growing interest in decoding and describing dynamic processes down to nature's smallest components, time-resolved electron microscopy is also becoming increasingly important. Recently, a simple, yet promising approach to realize time resolved measurement in an electron holographic setup by means of an interference gating was presented [1]. The basic idea of interference gating (iGate) is a synchronized destruction of the interference pattern for a defined period of time during an interferometric measurement such as electron holography (EH). The holographic reconstruction process acts as a temporal filter that only retains the information of the undisturbed interferogram outside this period. Originally this synchronized destruction was achieved by a variation of the biprism voltage, which produced an artifact that made only the outer parts of the hologram time-resolved.

Here, a second concept for a realization of an interference gating is demonstrated. In this particular case the needed disturbance of the interference condition is caused by a slight beam deflection through the ac scanning system above the microscope's objective lens (figure 1). This turns out to be an extremely robust switching mechanism which avoids the biprism-induced artifacts, hence allowing acquisition and evaluation of data over the whole field of view. Furthermore, this new switching mechanism produces only a slight redistribution of the intensity underneath the biprism. In comparison to other realizations of time-resolved measurements in a TEM, no gating of the intensity (by means of a shutter or stroboscopic illumination) is needed. This "quasi" constant illumination of the specimen and the detector reduces additional parasitic effects like charge variations or thermic transients.

As test object, the electric field variation of a periodically switched flat capacitor was analyzed. The flat capacitor was milled via FIB into a MEMS heating chip (Denssolutions Wildfire series). With an optimized gating signal for controlling the scanning coils, a rather simple d/a converter like a pc sound card achieves utilizable acquisitions with 50 µs time windows as shown in figure 2. The reconstructed hologram on the left side is obtained without interference gating showing the plateau like phases typical for double exposure electron holography [2], as here both levels of the applied voltage contribute to equal amounts.

The reconstructed phase on the right side was obtained with the new interference gating. With the gating signal applied only stable interference pattern are formed in the indicated fraction of a period. Consequently, only a slope within the phase signal corresponding to the electrical field present between the contacts is observed. This clearly demonstrates the feasibility of the interference gating approach.

References:

[1] T. Niermann, M. Lehmann and T. Wagner, Ultramicroscopy 182 (2017), 54.

[2] V. Migunov, C. Dwyer, C.B. Boothroyd, G. Pozzi and R.E. Dunin-Borkowski, Ultramicroscopy 178 (2017), 48.

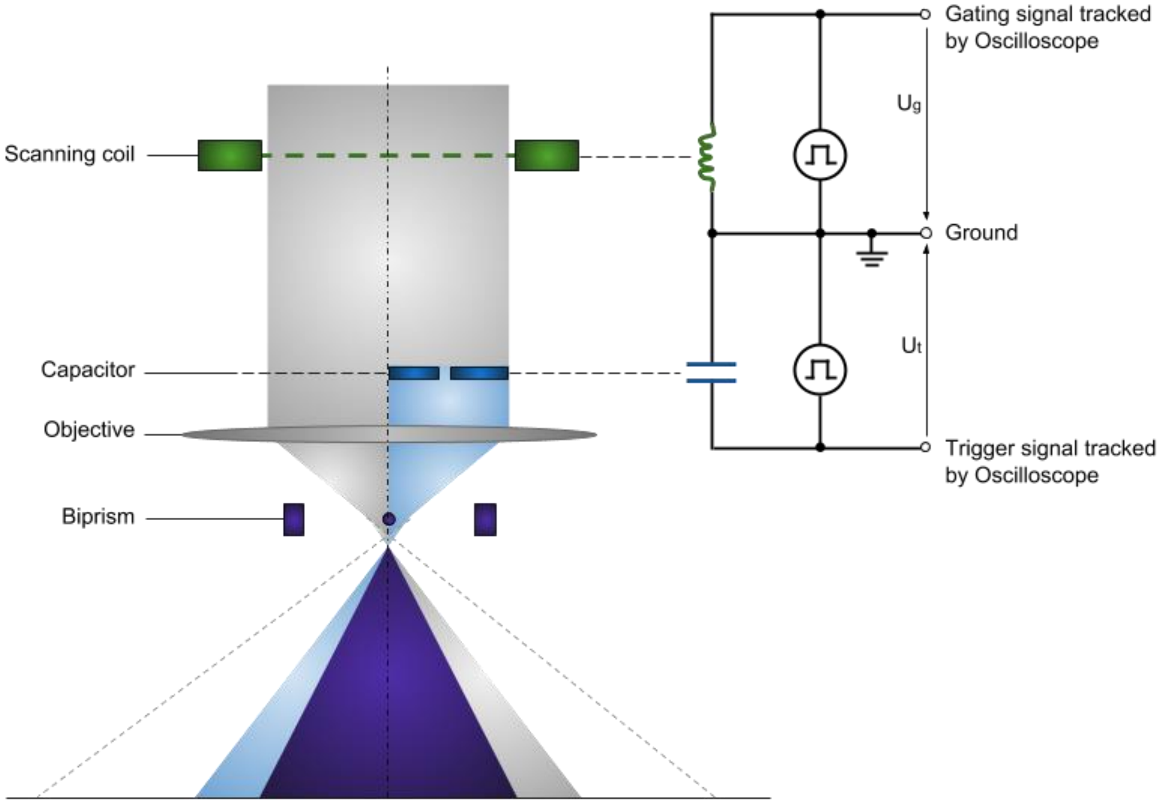

Figure 1: Schematic experimental setup. Left, simplified ray path inside the TEM. Right, electrical wiring of the capacitor and the scanning coil.

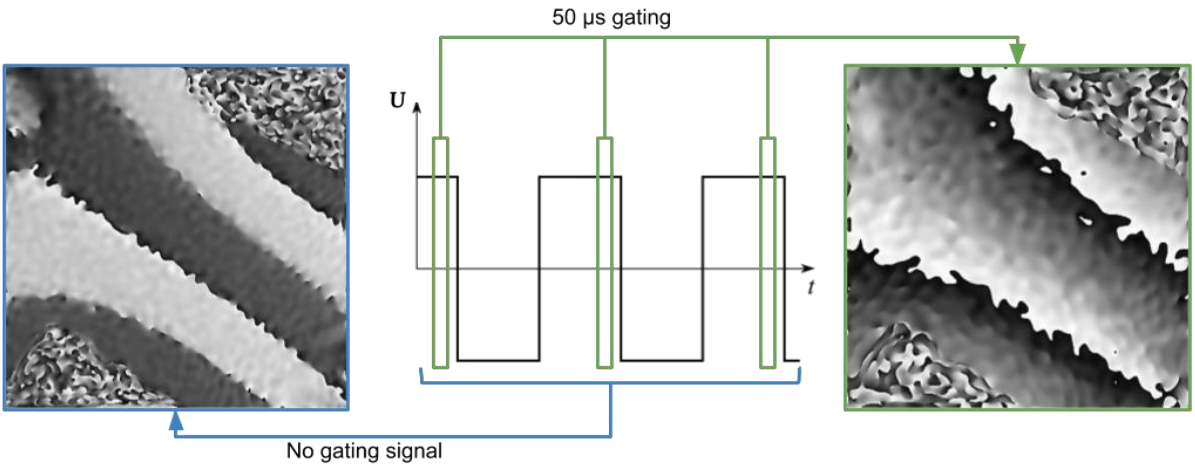

Figure 2: External voltage applied to the test specimen and reconstructed phases of two holograms. Left, normal exposure of a capacitor triggered by a 1.5 Vpp square wave signal at 1 kHz without any gating signal. Right, with optimized gating signal only letting the indicated 50 µs undisturbed.