Characterization of hysteresis within magnetic electron lenses

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1 Electron Microscopy

Reproducibility of settings for magnetic electron lenses is complicated because of hysteresis present in the ferromagnetic material of the lens-yoke. In an electron microscope, an electron beam is positioned on a sample with the help of a magnetic field of which the amplitude is controlled by the current applied to the lens coils. As a first principle, electron optics depend on the magnetic flux density, the velocity of the electrons and the position of the specimen. Hysteresis is characterized by means of experiments on a electromagnetic setup and by analysis of obtained electron microscope images (Fig. 1).

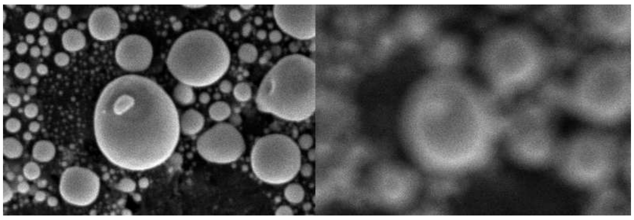

Figure 1: Illustration of the effect of hysteresis on image-quality. Two images obtained with the same lens excitation can be completely different.

2 Hysteresis

Hysteresis can be expressed as a multi-valued input-output relation that depends on its previous trajectory and still holds for quasi-dc inputs [1]. The response to periodic inputs shows transient effects; the minor loops stabilize after a few periods. This effect is often called accommodation [2]. The influence of the history can be wiped out by sufficiently large excitations. However, such a procedure is time demanding.

An illustration of hysteresis (Fig.2) is generated with an implementation of a Duhem-class hysteresis model [1], [3]. Unfortunately, this model does not describe accommodation as observed from experiments [2].

3 Control

Various applications within electron microscopy are involved with repeated variation of the lens excitation between extremes: automated zooming in-out-in, on-off-on with in dual-beam systems. Here accommodation comes into play. It is observed that the response stabilizes within < 10 cycles. In first instance we focus on feed-forward control and do not considerer image-quality and magnetic flux density as possible quantities for feedback control.

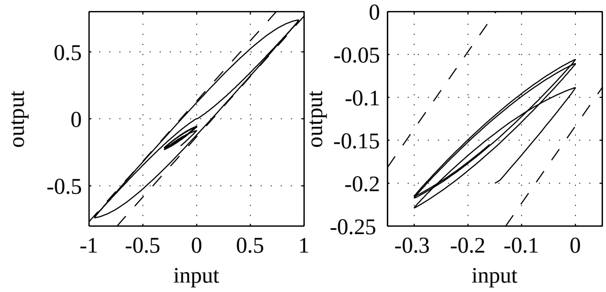

Figure 2: Illustration of hysteresis. **left.** The virgin curve, the stationary response to a periodic oscillation with amplitude 0.95, and accommodation of a minor loop. **right.** Accommodation of a minor loop (zoomed)

The settling-time after single switch is in the order of seconds, but can be reduced by choosing a proper input trajectory. However, dynamics and hysteresis are coupled which means the steady state after overshoot or undershoot will be different. The way to connect dynamics with hysteresis is under study.

4 Acknowledgement

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