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Lecture I: Vortex electron beams: observations and contemplations.

Vortex electron beams were recently produced in a conventional transmission electron microscope. They have many properties in common with the better known optical vortices as both are based on a wave description of either electrons or photons. The matter wavelength of accelerated electrons however is far smaller than the usual wavelengths encountered in optics and this opens many opportunities for applications. On top of this, electrons are charged particles which leads to interesting magnetic effects. Indeed an electron vortex beam with topological charge m will have a magnetic moment of $m\mu B$.

The combination of charged particles and extremely small wavelengths (a few pm) leads to a strong interaction with matter which opens new opportunities for material characterisation techniques on the atomic scale.

In this talk, I will discuss the first experiments demonstrating electron vortex beams and their effect on electron energy loss spectroscopy (EELS). These early experiments already reveal the great potential to obtain magnetic information with electron vortex beams. I will discuss more recent advances in making electron vortex beams with a diameter of approximately 1 Angstrom. Such focussed vortex beams have an extension and angular momentum very similar to atomic orbitals. The main difference is that atomic orbitals are bound states around a nucleus while our electron vortices propagate in free space and converge to a small beam only in a specific plane.

We also use the electron vortex beams to determine the magnetic moment of Fe and Fe_3C nanoparticles which demonstrates their use for the mapping of magnetic moments on the nanoscale. I will briefly discuss the physics behind the effect of topological charge on the EELS spectrum.

In conclusion, electron vortex beams constitute an exciting new field of study in the TEM with a huge potential to obtain previously unavailable information from materials with atomic resolution.

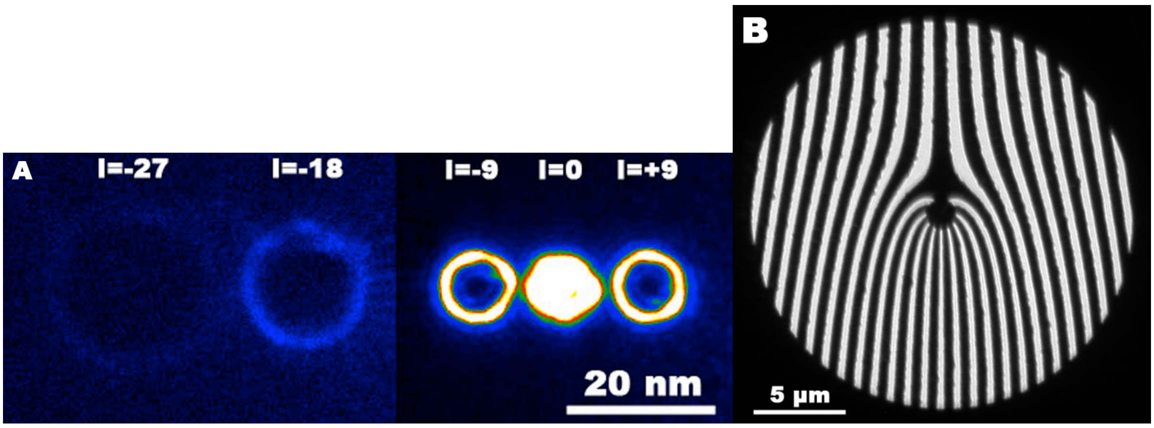

Figure 1 A) Experimental image of an electron vortex beam obtained with a holographic mask (B) designed to produce m=9. Also the higher order beams are faintly visible.