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Towards topological spectroscopy in the electron microscope with atomic resolution

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It has been almost a decade since the first experimental proof that electron beams carrying orbital angular momentum (OAM) can be produced in an electron microscope [1]. Since then, there has been considerable interest, reflected both in the number of publications and the funding of research programs, to utilize sub-nanometer and atomic-size electron beams with OAM for practical imaging and spectroscopy measurements. Yet, so far most of the research in this area has been restricted to describing the possible applications of what could be achieved with electron beams with OAM (also known as vortex beams) rather than performing the actual experiments.

The main limiting factors to bringing vortex beams into the mainstream of the microscopy community is the difficulty of selecting and isolating individual vortex beams. Different approaches have been pursued, such as utilizing holographic masks with dislocations, [2,3] aberration correctors [4,5], and magnetic needles [6]. Images with atomic resolution utilizing vortex beams have been produced [7,8], but the quality of the images indicates that the coherence of the electron beams is not yet optimal, particularly when trying to perform atomically resolved electron magnetic chiral dichroism (EMCD) spectroscopy measurements.

In this talk, I will discuss how and why vortex beams can be utilized to perform novel spectroscopy associated with broken symmetries, such as magnetism. Additionally, I will demonstrate how to produce atomically resolved EMCD measurements utilizing aberrated probes formed by a linear combination of vortex beams (shown schematically in Figure 1) [9]). Finally, I will highlight the current efforts in selecting isolated, atomic-size and coherent vortex beams in ORNL's Nion HERMES [10].

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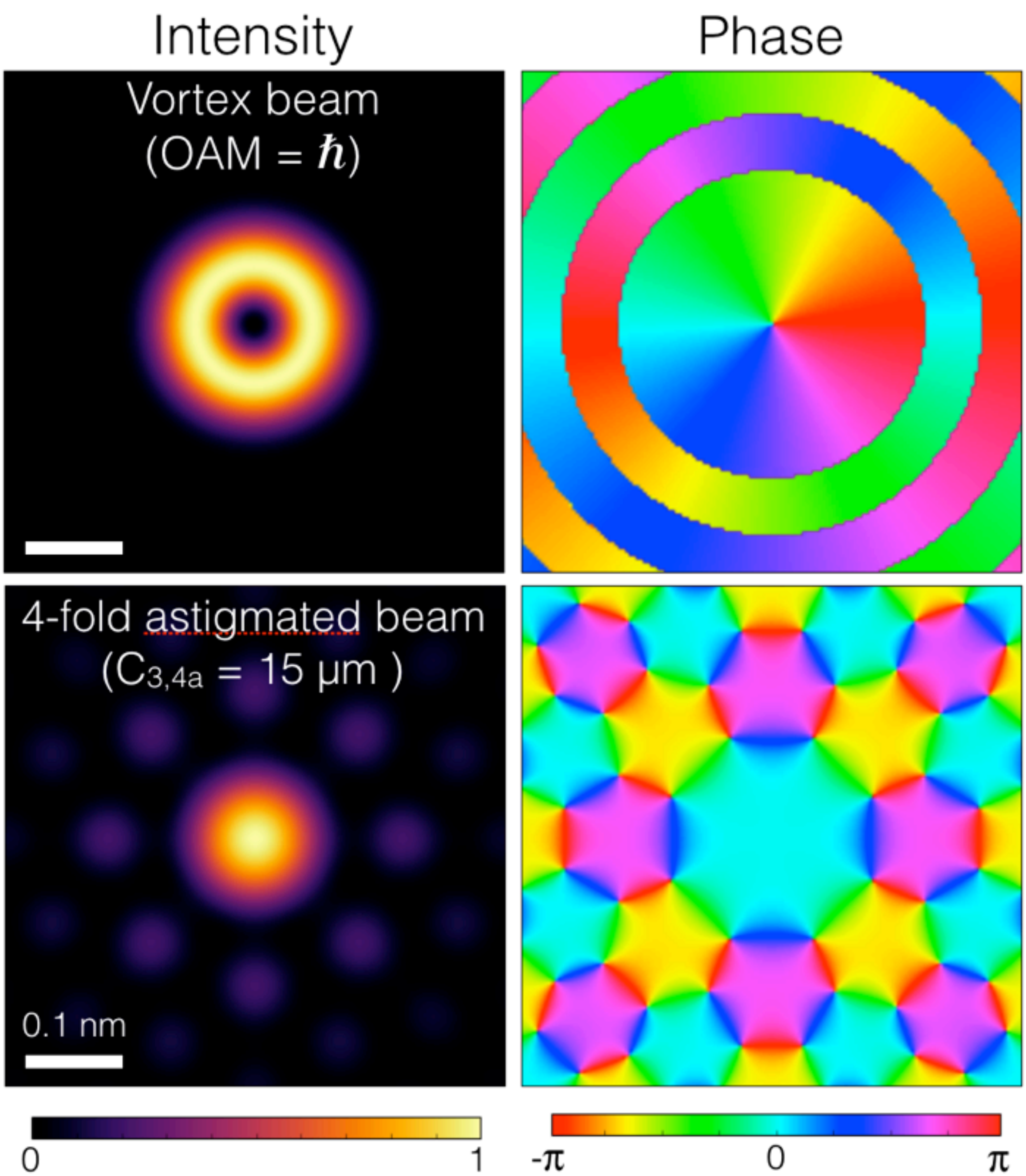

Figure 1. Calculations of an electron vortex beam carrying OAM (top panels) and a fourfold astigmatic electron beam (bottom panels). The calculations were performed using an acceleration voltage of 100 kV and a convergence semiangle α = 30 mrad. Notice that the phase singularity in the vortex beams is also present at the nodes of the fourfold aberrated probe (Figure adapted from Ref. 9).

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