Sensing magnetic ordering, electric fields & isotopes at the atomic and nanometer level: A Glimpse into Electron Microscopy in the Quantum Information Era

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Scanning and transmission electron microscopes (S/TEM) are now ubiquitous in materials and biological sciences laboratories. They have radically enhanced our understanding of organic and inorganic matter with the successful development of aberration correctors [1,2], detectors with film-equivalent dynamical range [3], and more recently, with monochromators capable of achieving sub-10 meV energy resolution spectroscopy [4]. Here, I will present several examples demonstrating how we have exploited these capabilities and solved the pertinent experimental challenges to probe materials behavior at the nanometer and atomic scales. Specifically, I will show how by utilizing the phase of the electron probe one can reveal the magnetic order of complex-oxide materials at the atomic level [5]. I will also explain how the new generation of monochromators, combined with aberration-corrected STEM, can be used (i) as a primary thermometer (without requiring any previous knowledge of the sample) [6]; (ii) to study minute volumes of liquid water [7]; (iii) to detect site-specific isotopic labels in amino acids at the nanometer scale [8]. Additionally, I will show how one can detect the electric field of individual atomic columns of heavy and light elements, at the sub-Angstrom scale, by using an ultra-low noise SCMOS detector in the diffraction plane [9]. Lastly, I will discuss potentially relevant new challenges that electron microscopy will need to resolve as it enters the forthcoming quantum information era. Will it be possible to map orbitals and spins with atomic resolution and with single atom sensitivity? Can we detect a superconducting transition? Can we spectroscopically measure cryogenic temperatures with 10s of mK precision? Can we measure the specific heat and thermal conductivity of materials? Can we detect minute concentrations of isotopic elements and perform radiocarbon dating at the nanoscale? These questions will be addressed and further elaborated during the presentation [10].

References: