MONASH University

Monash Centre for Electron Microscopy and Imaging and Optical Physics

Seminar

Quantum limits of transmission electron microscopy

Thursday March 30, 2023

11.00am

Room 107,

10 College Walk, Monash Clayton Campus

Zoom meeting with the details:

Please click this URL to start or join. https://monash.zoom.us/j/87366577344?pwd=UTJFdGE4eTN5cnRSUkxNVFpPK0kwUT09

Or use meeting ID: 873 6657 7344 and passcode: 897137

Dr Christian Dwyer

RMIT University, Physics &

Electron Imaging and Spectroscopy Tools

Abstract

New-generation transmission electron microscopes (TEMs) are equipped with detectors that approach the shot-noise limit. Hence it is timely to ask: What are the ultimate limits of electron scattering experiments in the TEM? For example, for a given electron dose, what is the ultimate accuracy that can be achieved for the atomic structure of a material? And what determines this accuracy? In this talk, we show how quantum estimation theory can be used to provide quantitative answers to such “big” questions. We report the following: (1) A quantitative prediction of the ultimate precision that can be achieved for the coordinates of atoms within a material. As expected, higher doses allow better precision, and so this prediction is decidedly relevant to radiation-sensitive materials. The prediction also exhibits a strong and unexpected "threshold" effect, which occurs when the dose is high enough for the statistics to become Gaussian. (2) The ultimate (quantum) limit for simultaneous estimation of multiple sample parameters can be achieved under weak scattering conditions, such as when the phase-object or weak-phase-object approximation applies. Zernike phase-contrast imaging combined with maximum likelihood estimation provides a possible experimental realization. (3) This same quantum limit generally cannot be achieved under conditions of strong multiple scattering, due to the incompatibility of the projection measurement. Hence strong multiple scattering precludes the quantum limit - a fascinating result which can be traced back to the quantum-mechanical phase. Finally, while our main focus here is TEM, many of our important conclusions extend to other techniques which utilize the scattering of coherent radiation, such as coherent x-ray scattering and neutron scattering [1].

[1] C. Dwyer. Phys. Rev. Lett. 130, 056101 (2023).

The Presenter

Christian Dwyer is an electron microscopist and physicist. He obtained his PhD from the University of Cambridge in 2004, and he has since held research positions at the University of Oxford, Monash University and Forschungszentrum Juelich, and a faculty position at Arizona State University. He is now an affiliate of the School of Science at RMIT University, and founder of Electron Imaging and Spectroscopy Tools, a company dedicated to the development of advanced software for TEM/STEM. Dr Dwyer's research interests include theoretical and experimental developments in transmission electron microscopy and their application to the nano-, atomic and electronic structure of materials and chemical systems. He has authored well over 100 book chapters and international journal articles on technique developments and applications in these fields.

Imaging and Optical Physics Seminars
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