Location: School of Physical Sciences Room N115
When: 12oc Thursday 29th September
Speaker: Philip Moriarty - Professor of Physics , Nottingham University

Title: Towards 3D Printing, Atom By Atom? (...or **The Trouble With Tips)**

It's now more than three decades since Eigler and Schweizer first demonstrated the controlled positioning of individual atoms with the tip of a scanning tunneling microscope (STM) [1], a landmark experiment in the manipulation of matter that many would argue represents the origin of the entire field of nanoscience. (For the Douglas Adams fans among you, I should also note that next year represents the 42nd anniversary of the invention of the STM.) In the intervening years there have been astounding advances in our ability to push, pull, prod, and poke individual atoms and molecules with not just atomic precision but single chemical bond resolution [2]. The incorporation of machine learning (ML) algorithms into scanning probe microscope control systems [3-5] represents an especially exciting recent development, despite well-placed skepticism about the "black box" nature of a great deal of ML architecture, in the context of automated assembly of custom-designed nanostructures.

And yet the component that makes probe microscopy such a powerful imaging, spectroscopic, and manipulation tool – the tip – also represents an exceptionally frustrating bottleneck in just about every STM or force microscopy experiment; any probe microscopist will attest to the hours, days, or weeks spent coercing the tip into the correct state to enable a particular measurement or modification of the system of interest. When it comes to moving beyond lateral manipulation of atoms and molecules to the assembly of 3D structures, control of the atomistic structure and chemistry of the tip apex becomes even more important, complicated, and infuriating.

I'll discuss our efforts at Nottingham over the last ten years or so to characterise and control the STM/AFM tip state for scanning probe microscopy and spectroscopy of a variety of systems – metals, semiconductors, and molecular assemblies – with a particular emphasis on recent experiments focused on constructing nanoparticles via vertical manipulation, i.e. by dropping atoms one-by-one from the tip.

[1] D. Eigler and E. Schweizer, *Nature* **344**, 524 (1990)
[2] See A. Khajetoorians *et al*., *Nature Reviews Physics* **1,** 703 (2019)
[also https://arxiv.org/abs/1904.11680] for a particularly engaging recent review.
[3] B. Alldritt *et al*., *Sci. Adv*. **6** : eaay6913 (2020)
[4] P. Leinen et al., *Sci. Adv*. **6** : eabb6987 (2020)
[5] OM Gordon and P Moriarty, *Mach. Learn. Sci. Tech.* **1** 023001 (2020)