Band structure at the nanoscale in operating 2D field effect devices

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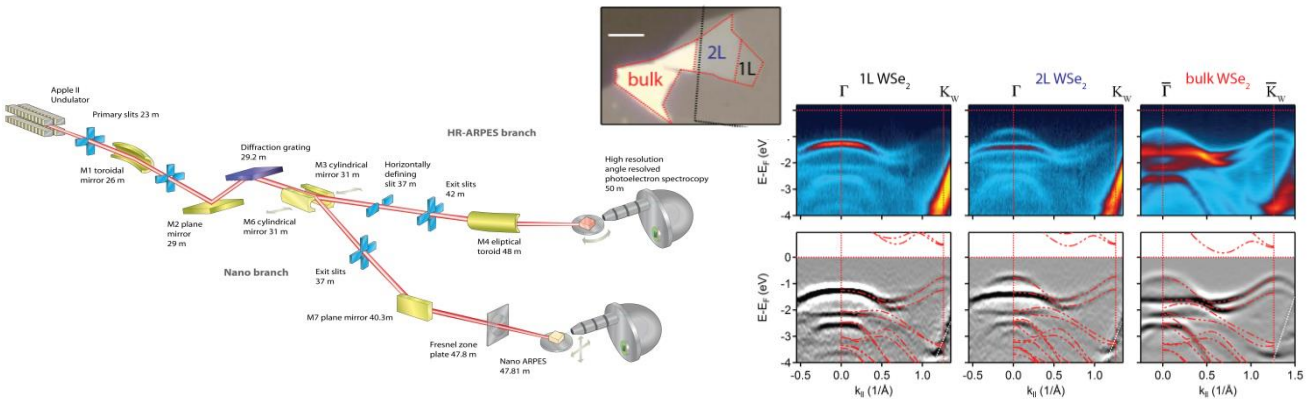
Angle resolved photoemission spectroscopy (ARPES) directly and beautifully reveals the momentum-resolved electronic structure at the surface of crystalline solids. The spectra have both technological and fundamental relevance, providing parameters essential to electronics and giving insight into phenomena like superconductivity. Traditionally ARPES is limited to macroscopic single crystal samples, but with recent advances it is now possible to perform spatially-resolved ARPES with submicrometre resolution (nanoARPES). This is available at only a few beamlines worldwide, exemplified by I05 at Diamond. With spatial resolution comes the tantalising possibility of interrogating microelectronic devices. Such in-operando nanoARPES has recently been demonstrated for the first time. Finally this offers the potential to directly measure the band structure changes that underpin modern electronics, before only accessible indirectly, and to facilitate the development of next generation quantum technologies.

This project will focus on measurements of heterostructures formed from stacking layers of two-dimensional materials. Here, the potential for bandstructure engineering is truly exciting. Layers of metals, semiconductors, insulators, superconductors and more can be combined to design, with atomic-precision, new functional materials. What is more, gate electrodes can control carrier concentrations within the layers, band alignments across them, and even alter band structure within them. The ability to measure gate-dependent electronic structure changes directly in these heterostructures thus presents a timely opportunity to explore a new field.

To do this, the project will combine the world-leading expertise in nanoARPES of the I05 team at Diamond Light Source with the experience of Dr Neil Wilson's group at the University of Warwick, who have demonstrated the first in-operando ARPES measurements of 2D field-effect devices. The aim of the project will be to establish and explore in-operando 2D band structure measurements, from controlling chemical potential in 2D field-effect transistors to tuning correlation effects and phase transitions. Applicants with interest in condensed matter Physics and aptitude for experiment and data-analysis are encouraged to apply.

Funding (stipend plus fees) is available for exceptional UK and EU candidates for 3.5 years, with a stipend above the standard research council rate (see here). The student will spend part of the degree at University of Warwick and part at Diamond Light Source. A broad education in Materials Physics is provided through dedicated modules under the Midlands Physics Alliance Graduate School, and external courses.



(left) Schematic of the I05 beamline at Diamond Light Source; (right) example nanoARPES results from a 2D heterostructure, showing layer-dependent valence band structure in the 2D semiconductor WSe_2.