Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: AI-driven multi-domain sensing

Lead Supervisor: Professor Saverio Russo, S.Russo@exeter.ac.uk

Co-Supervisors:
Prof Monica F. Craciun (Engineering, University of Exeter) email: m.f.craciun@exeter.ac.uk
Prof Y. Wan (Materials Science and Engineering, National University of Singapore) email: wanyi@nus.edu.sg

Webpage: https://experts.exeter.ac.uk/4233-saverio-russo/about

Project details: Spectroscopy has long been one of the most powerful windows into nature, revealing the hidden composition, structure, and dynamics of matter by observing how it interacts with light. From deciphering the chemistry of distant stars to unravelling the quantum properties of new materials, spectroscopy has shaped our understanding of the natural world at every scale. Yet the very instruments that have driven these discoveries remain tied to classical designs.

Traditional spectroscopic systems rely on optical dispersion, where carefully engineered components separate light into constituent wavelengths for detection by large arrays. The achievable spectral resolution is fundamentally constrained by the physical dimensions of these dispersive elements, locking performance to bulk. As a result, these architectures are typically bulky, mechanically complex, and poorly suited to the growing demand for portable, multi-functional, and high-resolution spectroscopy in real-world settings such as healthcare and environmental sensing. Diffraction and dispersion laws impose strict boundaries on the downscaling of these systems, preventing the development of truly compact spectrometers approaching the footprint of a single-pixel detector. Even integrated on-chip spectrometers, though smaller, remain fundamentally limited to amplitude-only responses, leaving untapped vast reservoirs of optical information—including polarisation, phase, time dynamics, and chirality—that could reveal richer insights into complex systems.

The aim of this PhD project is to break this impasse by co-developing a radically new paradigm of light–matter interrogation, uniting physics, materials engineering and computing. At its core is a new generation of multi-domain, single-pixel detectors that collapse the role of entire spectrometers and auxiliary optics into a compact, versatile platform. These detectors will exploit emerging perovskite and their heterostructures with 2D materials, whose unique responses—spectral sensitivity, ultrafast carrier dynamics, polarisation and phase selectivity, and even chirality—can be harnessed. Artificial intelligence (AI)-enabled reconstruction algorithms will act as the unifying layer, actively learning to disentangle and recombine optical signals across multiple domains into meaningful readouts. These devices will not only decode the richness of light, but transform how we explore the world. Despite recent advances, most approaches have demonstrated sensing in only one or two modalities and often rely on hybrid assemblies of multiple components, limiting scalability, reproducibility, and portability.

This PhD project tackles the interdisciplinary challenge of creating truly multi-domain (>3 modalities) single-pixel detectors that condense the functionality of entire spectrometer

systems into compact, versatile devices. The approach leverages on 2D crystals anisotropies, quantum band alignment at hetero-interfaces of 2D perovskites/transition-metal dichalcogenides, and tailored metal contacts. Machine-learning algorithms will be developed to disentangle the non-linear relationships between photocurrent, bias, spectral density, light polarisation, and time, producing responsivity matrices capable of reconstructing rich optical signals in real time. By uniting AI, quantum materials, device physics, and engineering, this project aims to lay the foundation for a new generation of intelligent multifunctional sensors addressing urgent technological and societal priorities.

Project specific entry requirements: A master in Engineering, Materials Science, Chemistry or Physics is a desirable condition

Potential PhD programme of study: PhD in Physics

Department: Physics and Astronomy

Location: Physics

Please direct project specific enquiries to: Prof Saverio Russo email s.russo@exeter.ac.uk

Please ensure you read the entry requirements for the potential programme you are applying for.

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