Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: Miniaturised mid-infrared sensing of environmental exposures using 3D-printed photonic metamaterials

Lead Supervisor: Dr. Calum Williams, C.Williams15@exeter.ac.uk

Co-Supervisors:
Dr Adam Polak ((Fraunhofer Centre for Applied Photonics; adam.polak@fraunhofer.co.uk)
Prof. Geoff Nash, UoE, G.R.Nash@exeter.ac.uk
Prof. Hyun Jung Kim, KAIST
Prof. Juejun Hu, MIT

Webpage: https://experts.exeter.ac.uk/40847-calum-williams

Project details:

Summary: This PhD project will develop next-generation compact mid-infrared (MIR) sensors for real-time detection of chemical and biological exposures in air and water. By combining 3D-printed photonic metamaterials, photoacoustic detection, and computational decoding, the project will overcome current barriers in field-deployable molecular sensing—bringing lab-grade diagnostics into portable formats.

Motivation: Environmental sensing remains slow, sparse, and reactive. In the UK, over 16 million people suffer from pollen allergies, yet national monitoring relies on <10 manual 1950s-era spore traps. Waterborne contaminants like PFAS (synthetic forever chemicals) and E. coli routinely exceed safety thresholds, but are detected too infrequently or too late. MIR spectroscopy is a promising technological alternative—it detects unique molecular vibrations without the need for reagents—but conventional systems are bulky, fragile, and expensive. This project aims to address this gap.

Project Aims: The student will develop, build and evaluate a miniaturised MIR sensor platform for detecting airborne and waterborne analytes. The project will investigate how absorption of MIR light by target molecules can be converted into measurable signals—via either local heating or pressure waves using low-cost, uncooled detectors. Metamaterial-based thermal emitters will be designed through numerical simulation, fabricated using two-photon polymerisation (a nanoscale 3D printing technique), and integrated into a dual-mode sensor platform. The student will also contribute to developing signal decoding algorithms that can identify analytes from a compressed set of spectral measurements. These systems will be tested in lab and field environments, with support from partners

Skillset and training: The research spans fundamental optical physics through to applications, and the student will develop a diverse and sought-after skillset during the PhD project, including: computational optics using machine learning approaches, electromagnetic simulation (incl. Lumerical FDTD and COMSOL), nanofabrication within a state-of-the-art cleanroom (incl. e-beam lithography, physical vapour deposition and two-photon polymerization 3D printing), electro-optic systems characterisation, validation of sensing performance, and advanced data analysis. The student will join the Centre for Metamaterial

Engineering and Physical Sciences Research Council Doctoral Landscape Award

Research and Innovation (CMRI) at the University of Exeter. The CMRI is a community of academic, industrial, and governmental partners that harnesses world-leading research excellence from theory to application, and enables simulation, measurement, and fabrication of metamaterials and metamaterial-based devices. We are home the UK's biggest ever single investment (£19.6million) in metamaterials – MetaHUB. We provide scientific knowledge as well as transferable and technical skills training to all our students to prepare them for careers within and outside of academia. Our breadth of research is our centre's strength: our PhD students, researchers and academics solve multi-faceted research questions and challenges.

Project specific entry requirements: The successful candidate should be completing / have completed their undergraduate degree in Physics, Engineering or related Physical Sciences discipline (2:1 / above). They should be self-motivated, a creative problem solver, and with a strong interest in photonics, electromagnetism and computational optics. Strong analytical and experimental skills are essential. Proficiency in Python / MATLAB programming is desirable, and motivation for experimentally-focused research is preferred.

Potential PhD programme of study: PhD in Physics

Department: Physics and Astronomy

Location: Physics building, Streatham

Please direct project specific enquiries to: Dr. Calum Williams (c.williams15@exeter.ac.uk)

Candidates are encouraged to contact Dr. Calum Williams to discuss the project before applying.

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

To Apply for this project please click on the following link - **APPLY HERE**