PhD PROJECT PROPOSAL

## **PhD Project Title**

Topological Optimisation of Electromagnetic Devices and Structures

## **PhD Supervisory Team**

Principal Supervisor: Dr Stephen Hanham, s.hanham@bham.ac.uk, School of Engineering, Emerging Devices and Technology Research Group

Co-Supervisor/s: Dr Miguel Navarro, M.Navarro-Cia@bham.ac.uk, School of Physics and Astronomy, Metamaterials Research Group

Associated Academic: Prof. Alex Feresidis, a.feresidis@bham.ac.uk, School of Engineering, Metamaterials Engineering Laboratory

## **Project Abstract**

Topological Optimisation (or Inverse Design) is a computational design approach for automated discovery of optical structures based on specified functional characteristics. The technique is currently revolutionising the field of nanophotonics by allowing for the algorithmic design of photonic devices such as resonators, filters, couplers, splitters and diplexers. A summary of this work can be found at https://www.nature.com/articles/s41566-018-0246-9. In this project, the technique of topological optimisation will be broadened to allow the design of electromagnetic devices in all parts of the electromagnetic spectrum (e.g. microwave, terahertz and optics domains) and will be applied to a diverse range of problems such as sensors, 5G antennas, terahertz filters and cold atom traps.

## **Detailed Project Description**

*Project Description*

Topological Optimisation (or Inverse Design) is a computational design approach for discovering optical structures based on specified functional characteristics. The technique is currently revolutionising the field of nanophotonics by allowing for the algorithmic design of photonic devices such as filters, couplers, splitters and diplexers. A summary of this work can be found in [1].

In this project, the student will develop a general framework for topological optimisation of electromagnetic structures which integrates with existing electromagnetic simulation codes, allowing the treatment of two and three dimensional structures with arbitrary conductivity and permittivity distributions. This development will allow the technique to be broadened for the design of electromagnetic devices in all parts of the electromagnetic spectrum (e.g. microwave, terahertz and photonics domains). This could include 5G antennas, metalenses, terahertz filters, sensors, electromagnetic resonators and cold atom traps. There is also an opportunity for the framework to be extended to include modern machine learning techniques.

*Ideal Candidate*

The project is intended for a student who holds an undergraduate degree in Physics or Electrical and Electronic Engineering, or a closely related field. It is ideal for a student with an interest in computational electromagnetics and optical, photonic or microwave systems. The project will involve programming in Python and the use of high performance computing (HPC) facilities. During the course of the PhD programme the student will develop valuable skills and knowledge in writing code and performing numerical computations using high performance computing, microwave and photonic device design, fabrication and test measurement.

Links with Current Research in Research Groups

The proposed PhD project directly links with the current EPSRC funded projects “Anisotropic Microwave/Terahertz Metamaterials for Satellite Applications (ANISAT)” and

“Multi-functional metamaterials and antennas for RF/Microwave communication and sensing devices (MULTIMET)” led by Prof. Feresidis (PI) and Dr Hanham (Co-I) and a current Royal Society-funded project “Experimental demonstration of transmissive-type terahertz digital metamaterials based on microfluidic system” led by Dr M. Navarro-Cía (PI). The Metamaterials Research Group (Dr Navarro-Cia) is a partner in the EU-funded Horizon 2020 Rise project "Non-Conventional Wave Propagation for Future Sensing & Actuating Technologies" and is involved in the recently-awarded EPSRC UK Metamaterials network led by the University of Exeter - the proposed PhD project falls within the remit of both of them.

*References*

[1] S. Molesky *et al*, Nature Photonics, 12, 2018, “Inverse Design in Nanophotonics,” <https://www.nature.com/articles/s41566-018-0246-9>