TEAM-A

The TAILORED ELECTROMAGNETIC and ACOUSTIC MATERIALS ACCELERATOR

3rd Annual Report

QinetiQ Ltd & the University of Exeter

EP/R004781/1: The Tailored Electromagnetic and Acoustic Materials Accelerator (TEAM-A)

Summary: This five-year Prosperity Partnership programme builds upon the successful relationship that exists between the University of Exeter and QinetiQ. TEAM-A is developing advanced materials that can be used to control and manipulate the propagation of electromagnetic and acoustic energy in a highly tailored, bespoke fashion, and focuses to develop innovative techniques for their cost-effective manufacture, thereby working to bolster academia and the technology sector within the South-West of England. The aim of TEAM-A is to create a sustainable, long term partnership, underpinned by revenue created through the licensing of intellectual property, the development of products and the advancement of academic understanding.

Introduction and Background: Materials that have the ability to fully control and manipulate the flow of electromagnetic (e.g. radiated heat, light, radiowaves) and acoustic (e.g. sound, vibration, shock) energy have the potential to transform, and enable, a large and diverse range of technologies. Exeter and QinetiQ have long been at the forefront of the science and engineering of such materials. However, there are still significant challenges prohibiting the widespread take up of these new materials in applications. In particular, concepts developed in the laboratory are often incompatible with commercial manufacture, due to their complexity and the nature of the constituent parts. Instead, the basic science that describes the behaviour of these new materials needs to be combined with a detailed understanding of how such materials could be manufactured, so that new materials can be designed and engineered to tackle specific technological challenges, using commercially viable approaches. The objectives of this Partnership are to bring together leading advanced materials and manufacturing research at Exeter and QinetiQ to address real technology and innovation challenges, to share and disseminate new knowledge and to inspire the next generation of future research and industry leaders. Through the exchange of expert academic and industry leading staff, the shared use of facilities, QinetiQ's unique knowledge of industry challenges and an emphasis on the training of a new generation of entrepreneurial researchers, we work across conventional discipline and institutional boundaries to accelerate the impact of academic research.

Programme achievements:

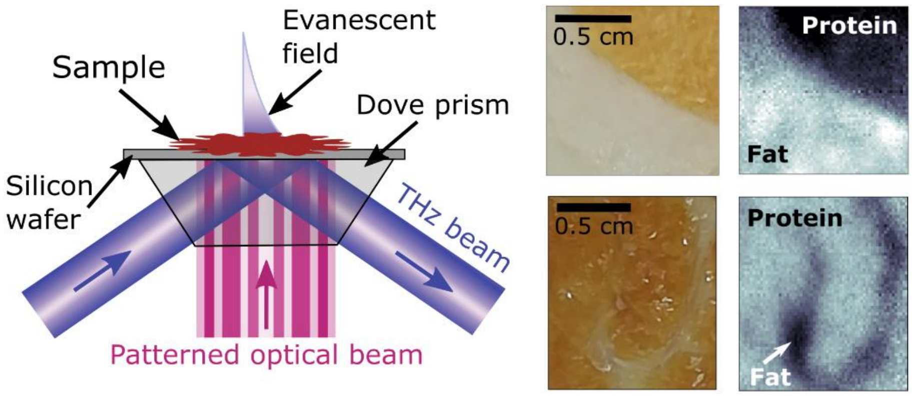
Advancement of academic understanding and technology development:

TEAM-A consists of a portfolio of projects that aim to exploit our comprehensive interdisciplinary capabilities to deliver a number of ground-breaking technologies. The case studies below, and those mentioned in previous years, demonstrate TEAM-A's industry leading and academic excellence, and show how this is translating into outputs such as scientific publications, patents, technology and staff development. A critical objective over the next few years is to establish further partnerships to provide routes to technology exploitation.

Multispectral Imaging: Multispectral imaging finds applications in a host of important fields, from security and defence to environmental monitoring, agriculture, remote sensing, and medical diagnostics. Current multispectral systems are limited in speed and resolution, and TEAM-A is developing new approaches to overcome these limitations, making multispectral imaging faster, cheaper and more effective. This work therefore has the potential for significant economic and societal impact. In particular, we are developing approaches that combines the extraordinary optical transmission (EOT) effect and chalcogenide phase-change materials (PCMs) to deliver dynamically tuneable image capture in the mid and long-wave infrared region of the spectrum. The principal of tuneable filter operation has also been experimentally demonstrated by ex-situ switching (thermal annealing) of EOT filters containing PCMs, an important milestone in the development of reliable and repeatable fabrication and testing procedures for such filters, which are a key enabling technology in advanced multispectral imaging systems.

Terahertz Imaging and Modulators: We have designed what we believe to be the most efficient mm-wave photomodulator to date, which will allow us to create fast and efficient components that can be used for high speed communications and terahertz (THz) imaging. One application we are focusing on is passive THz imaging in the far-field for security, which will allow us to take images in the THz regime without using a THz source, only detecting the faint THz radiation emitted by warm bodies. This would speed up security imaging in airports and other public places, with economic and societal impacts. We are also working on using our near-field imaging system for measuring the thickness of healthy tissue around breast tumours that have been surgically removed (see Figure 1), which will hopefully lead to reductions in the number of surgeries required, saving money, and reducing local recurrence of cancer, saving lives. This work therefore directly addresses the Healthy Nation component of EPSRC's Prosperity Outcomes Framework. To enable future commercialisation, we have filed patent applications relating to the methods and apparatus for imaging an object comprising biological material: GB1908140.5 filed, 7th June 2019, and GB2003820.4 filed 17th March 2020.

Figure 1: Schematic diagram (left-hand-side) illustrating use of a beam of terahertz radiation for the imaging of biological systems (right-hand-side)



Phased-arrays of Thermophones: Thermophones are novel acoustic sources, which convert periodic heating of a thin metallic film into sound, that have the potential to be flexible, transparent, broadband, and physically robust (no moving parts). They could therefore replace traditional sources in a wide range of applications. Recently, in the first work of its kind, we have demonstrated that phased arrays of thermophones can be used to control the shape and direction of the sound field they produce. In contrast to conventional phased array sound source, thermophone phased arrays are cheap and simple to manufacture, have a wide frequency range, have few scale constraints, and have no mechanical coupling by virtue of the fact that the sources do not move (they produce sound directly from heat). The coupling produces a new type of controllable sound source of its own that can be used to simplify phased array design. We show that if we combine this coupling with constrictions in the flow of electrical current, we can create a fully controllable phased array from a single thin metal film. This radical new design of phased array offers a new way to construct simple, cheap phased arrays from sustainable materials, and we are now seeking partners to take this work forward.

New Collaborations:

We continue to collaborate with a wide range of partners, including those shown above. New collaborations, and important updates to existing partnerships, include:

The Centre for Metamaterial Research and Innovation: has recently been established in Exeter, with support from a wide range of academic and industrial partners. Our association with this Centre allows us to tap into a wide range of additional collaborators supporting our aim of making TEAM-A a sustainable partnership beyond 2022.

National Science Foundation Industry-University Cooperative Research Center for Metamaterials (CfM) in the USA: A number of researchers from TEAM-A, including Professors Oana Ghita, Alastair Hibbins, Geoff Nash and David Wright are part of a new collaboration formed with this leading centre in the US**.** This new collaboration resulted in a successful outline proposal being submitted to the EPSRC call for International Centre-to-Centre Research Collaborations

PepsiCo (John Bows): This fully-funded spin-out project continues on from last annum's successes. PepsiCo has committed to funding this project further, with an additional investments of £55k agreed to continue the research into 2021.

CSIC Madrid (Prof. Jan Siegel): There is potential to collaborate with the group of Prof Jan Siegel at CSIC Madrid on upscaling the fabrication of EOT arrays using direct laser writing techniques (which are many orders of magnitude faster in terms of fabrication as compared to e-beam lithography techniques used as present). This would be an important step in demonstrating that this technology could be manufactured cost effectively.
Other Collaborations: Other on-going collaborations include those with the University of Edinburgh, Royal Devon and Exeter NHS Trust, and Technical Composites Ltd.

Staff Highlights:

There have been a number of staff successes, including but not limited to:

1. **Secondment leading to Full-Time Employment:** A core aim of the TEAM-A business model has been to introduce stronger links between the academic and industrial sides of the partnership. In particular, embedded PDRFs have been trained to use QinetiQ's facilities, and exposed to commercial science in a hands-on manner. The PDRFs are now highly employable, as was tested via an eight-week Secondment for Joshua Hamilton onto a QinetiQ customer project. This was a huge success, leading to Joshua being offered full-time employment, but spending at least a day per week on TEAM-A projects as a QinetiQ staff member, a new model for the partners to collaborate on new business opportunities.
2. **Special Presentation:** Dr Lauren Barr (PDRF) was accepted to give an oral presentation at the IRMMW-THz meeting which will run in an online format in November of this year.
3. **IET career mentorship** is taking place (Dr Alexander Boyland of SPI Lasers) to guide Dr Alexander May through the application procedure for chartered engineer (CEng) status.