Bell Burnell Graduate Scholarship Scheme – Physics Project

PROJECT TITLE: Nanoquakes for Pressure Sensing

Lead Supervisor: Professor Geoff Nash

Profile Webpage: https://experts.exeter.ac.uk/18658-geoff-nash

Co-Supervisors: Dr Gregory Chaplain, g.j.chaplain@exeter.ac.uk

Project details: The aim of this project is to investigate the feasibility of creating a new generation of pressure sensors based on one important kind of elastic wave, surface acoustic waves (SAWs), which propagate on the surface of a solid. Although SAWs occur over many length scales, for example as earthquakes, research into devices that utilise SAWs with micron scale wavelengths [1], and nanometre amplitudes, has been a vibrant and active area since the invention of the interdigital transducer in the 1960s.

SAW based devices are key components, for example, in mobile phones and televisions, and in such a device a radio frequency signal is applied to an interdigital transducer, on a piezoelectric substrate to launch a SAW pulse, with an identical transducer used for detection. As the majority of the energy of the wave is confined within one wavelength of the surface, the propagation of the SAW can be dramatically affected by its interaction with the environment. SAWs are therefore also widely used in sensing applications [1] and are particularly attractive for operation in harsh environments due to their robustness and potential for wireless connection.

One of the simplest SAW sensing mechanisms is via mass loading, where a mass on the surface damps the SAW propagation, which includes attenuation by a gas. Over the last few years, we have been investigating whether it is possible to increase the sensitivity of a SAW sensor to changes in pressure by patterning the surface of a SAW device into a metamaterial. Metamaterials are artificial materials that can be designed to have properties that don't exist in nature, and preliminary measurements in Exeter have shown that one type of metamaterial [2, 3], made up of an array of resonators, is extremely promising for use as a SAW pressure sensor, with greatly enhanced sensitivity.

The project will involve a mixture of simulations, experiments and computational analysis, and can be tailored to the interests of the successful applicant. Simulations will make use of the finite-element modelling package Comsol, and measurements will make use of a state-of-the-art laser Doppler vibrometry system that can map out the propagating waves, even though they only have nanoscale amplitudes. There is also potential to incorporate machine learning approaches into the design of the metamaterial.

[1] D. S. Ballantine, R. M. White, S. J. Martin, A. J. Ricco, E. T. Zellers, G. C. Frye, H. Wohltjen, Acoustic wave sensors: Theory, Design, and Physico-Chemical Applications (Academic Press, San Diego, 1997).

[2] B. J. Ash, S. R. Worsfold, P. Vukusic, and G. R. Nash, "A highly attenuating and frequency tailorable annular hole phononic crystal for surface acoustic waves", Nat. Commun. 8, 174 (2017).

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[3] C. Pouya and G. R. Nash, “Sub- and supersonic elastic waves in an annular hole phononic metamaterial”, Commun. Mater. 2, 55 (2021).

Project specific entry requirements: Applicants for this studentship must have obtained, or be about to obtain, a First or Upper Second Class UK Honours degree, or the equivalent qualifications gained outside the UK, in an appropriate area of science or technology such as Physics, Natural Sciences or Mechanical Engineering. Some coding experience is required.

Potential PhD programme of study: PhD Physics

Location: Harrison Building, Streatham Campus, Exeter.

Please direct project specific enquiries to: Please contact Prof. Geoff Nash

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**

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