PHD CONFERENCE 2018 ABSTRACTS

Wednesday 4th July

Alan Harding
Started: November 2013, part-time
Supervisor: Dr Richard Dawson
Title: Recovery of Platinum, Ruthenium and Iridium from Fuel Cell and Electrolyser Membrane Electrode Assemblies Using Iodide

Fuel Cells are gaining prominence as a power source and their growth for transport is expected to steadily increase over the next two decades. A major cost is the electrode catalyst, particularly the platinum content. Recovery of the platinum in an environmentally acceptable way will have a significant impact on the economics of both fuel cells and the electrolysers for hydrogen production. An iodine based chemistry has the required environmental credentials but taking a laboratory scale process to production offers a number of challenges and, potentially, introduces new hazards. This study explores the problem of separating the platinum, ruthenium and iridium catalyst materials and the problems of industrial scale processing of electrode assemblies.

Luc Bouscarrat
Started: October 2016, full-time
Supervisors: Dr Richard Dawson, Dr Nuno Bimbo
Title: MAX phases and MXene materials for electrochemical energy conversion applications

Fuel cells face several challenges to be economically viable, and up to now have mostly only reached really niche markets. One of the biggest disadvantage of fuel cells is currently their cost, mostly due to the use of expensive materials. There are several ways to approach this challenge; first is the use of cheaper alternative to current state-of-the-art electrocatalysts, while keeping good electrochemical performance, another direction is to make the fuel cells more durable, for example by using materials/structures which are more stable under operating conditions. There are a number of different fuel cell types, however, in low temperature variants, alkaline fuel cells have the advantages of allowing a broader range of electrocatalysts for the oxygen reduction reaction (ORR) at the cathode compared to acidic media due to having faster kinetics.
Various issues can arise concerning the durability of an electrode during operation. Indeed, electrode materials are exposed to harsh conditions, leading to degradation of the materials and the fuel cell performance. Diverse electrode degradations mechanisms can occur, such as carbon-support corrosion, electrocatalyst leaching and electrocatalyst particles aggregation. The main line of this project is the synthesis and tailoring of MAX phases and MXene materials for alkaline fuel cell applications, especially as electrocatalysts support for cathodes due to their promising properties, such as good electrical and mechanical properties, their robustness, tunability and processability.

Mohamed Abdelraouf
Started: January 2018
Supervisors: Dr Vesna Najdanovic, Dr Farid Aiouache, Dr Allan Rennie
Title: Novel Applications for the Random Column Packing "Dixon Rings"
Funder: Funded through Centre for Global Eco-Innovation (CGE)

The overall objective of this work is to find new applications for the Dixon rings packing provided by Croft Filters Limited. This will include coating, modelling the flow pattern and validation via experimental designs associated with the Dixon rings. Carbon dioxide emission are considered the most crucial among all greenhouse gases. On a short/medium term basis, fossil fuels are used as source of energy, so the CO_2 emissions from the fossil fuels should be controlled. The first part of the experimental work focuses on capturing carbon dioxide in packed absorption column. This is followed by understanding the flow pattern, wettability and hydrodynamics using three dimensional computational fluid dynamics modelling and simulations on Comsol multi-physics will open the door for further applications. The next phase of the project will investigate coating of the Dixon rings using sol-gel/aerogel techniques and implementing it for different catalytic applications. The coated rings will be tested for a set of applications and will be studied in Comsol using user-defined reaction kinetics models, this will help to understand the effect of the coated layer on the flow pattern.

Sotirios Kottaridis
Started: January 2018, full-time
Supervisors: Dr Emmanouil Papaioannou, Professor Alastair Martin, Dr Timothy Douglas
Title: Recovery of added-value compounds from juice industry waste

Worldwide, fruits and vegetables are processed to juices, adding value to these agricultural products. This juice production generates substantial amounts of solid wastes, which are either disposed of or used as feed/compost with low value. These wastes, however, could be ideal sources for the recovery of added-value compounds, such as polyphenols, polysaccharides and pigments, which could find significant applications in the food, nutraceutical and material sectors. With such uses, these wastes could create additional revenues for companies, also improving their environmental impact. The valorisation of agri-food wastes requires the development of novel processing and analytical strategies. Polyphenols recovery from beetroot pulp waste is a major part of the current work. Polyphenols are mostly entrapped into the complex lignocellulosic structure of the plant cell walls. Therefore, the use of plant cell wall degrading enzymes, such as cellulases and pectinases, prior to extraction, may liberate polyphenols, which would, otherwise, be unavailable for extraction, thus enhancing extraction efficiency. Total polyphenols were quantified spectrophotometrically (Folin-Ciocalteu method) and determined qualitatively by chromatographic methods (HPLC-DAD and LC-ESI-MS). The objectives of this study are: (a) the evaluation of enzymatic pre-treatments of wastes in the recovery of total polyphenols (TP) in comparison to conventional extraction, (b) qualitative/quantitative analysis of individual polyphenols and (c) the investigation of whether new types of polyphenols/compounds could be detected in the enzymatically pre-treated samples as compared to extracts from the untreated pulp. Preliminary results will be presented as well as the analytical problems encountered.

Alejandro Moure Abelenda
Started: October 2017, full-time
Supervisors: Dr Farid Aiouache, Prof George Aggidis, Dr Ben Herbert, and Prof Kirk Semple
Other advisors: Dr Alfonso Lag Brotons, Dr Rachel Marshall
Title: Study about the acidification of the digestate before adding ashes to produce a blended fertiliser
Funder: Natural Environment Research Council (NERC)

The utilisation of the anaerobic digestate and ashes, by-products of the energy industry aiming the valorisation of the residual biomass, has a number of environmental and economic benefits. In addition of representing a key role in the nutrient recovery and recycling, it also reduces the pressure on the producers which could diminish their growing operative capacity and lose their environmental recognitions. The potential of both materials as organic and inorganic amendments, respectively, for soil and agriculture is widely accepted. The production of a blended fertiliser, with both materials, is not straightforward. The results presented in the last conference show a considerable loss of ammonia due the increase of the pH when adding the ashes. In order to prevent the loss of nitrogen, the acidification of the digestates prior to the mixing with the ashes have been tested. The doses used in the industry of the 4 different acids (i.e. sulphuric, hydrochloric, nitric, and lactic acids), hit the target pH (i.e. between 4 and 6) in the digestates, however they are not enough to neutralise the effect of the ashes. Further assessment of the undergoing chemistry is required to determine whether is necessary to increase the doses of the acids.

Louise Cowie
Started: September 2013, part-time
Supervisor: Dr Graeme Burt
Title: Advances towards automated RF conditioning on the CLARA FEL
Funder: Science and Technology Facilities Council

The CLARA FEL is a linear accelerator at Daresbury Laboratory, and will operate at 250 MeV. The S-band RF system will include a 120 MV/m RF photoinjector, four travelling wave linacs, two standing wave dipole mode diagnostic cavities and an X-band travelling wave lineariser.

Automating the high power RF conditioning of these cavities will mean a repeatable, research-lead process is followed. An automated algorithm has been written in Python. A prototype algorithm was used to condition the first CLARA travelling wave linac in October 2017. The linac was successfully conditioned over approximately 12 million pulses up to 27 MW for a 750 ns pulse. A more complex and robust algorithm was used to re-condition the standing wave 10 Hz photoinjector after a cathode change. The photoinjector was conditioned to 10 MW for a 2.5 µs pulse in February 2018 over 2.1 million pulses. Motivation, conditioning method; differences for travelling and standing wave structures; difficulties and interesting phenomena are all discussed.

Thomas Jones
Started: August 2015, part-time
Supervisor: Dr Graeme Burt
Title: Mechanical Engineering for HL-LHC Crab Cavity Cryomodules
Joint funded by the Science and Technology Facilities Council and CERN through the HL-LHC project.

Superconducting RF Crab Cavities are required to rotate the particle bunches within the LHC to an improved crossing angle, therefore increasing the brightness of the machine as part of the High Luminosity upgrade. The Crabbing of High Energy Protons had never been achieved prior to this project. To keep the components at the chosen superconducting temperature (2 Kelvin) a cryomodule is required, which itself is unique due to the demanding constraints of being tested in the Super Proton Synchrotron and later integrated into the LHC tunnel.

This PhD research covers several aspects of the advanced mechanical engineering required for the module, including design of the novel support system for the cavities, optimisation of acid flow during etching of the complex geometries and measurement and optimisation of 3D printed tooling required to assemble the module in an ISO 4 cleanroom environment. This research so far has produced two conference papers which were accepted and presented. In addition the work contributed to the successful testing of the Double Quarter Wave cavity in the SPS which produced world first crabbing of a proton bunch on 23rd May 2018.

Lee Millar
Supervisor: Dr Graeme Burt
Started: October 2017, Full-time
Title: Conditioning and Breakdown in High Gradient Particle Accelerators
Funder: CERN

CLIC (Compact Linear Collider) is a proposed next generation electron-positron collider to be based at CERN. This facility will offer significant fundamental physics insight beyond that available from the Large Hadron Collider (LHC).

For realisation, new high-performance particle accelerators are required. The Xboxes are X-band (12GHz) test stands based at CERN which were constructed to develop and test the main accelerating structures and novel RF components for CLIC at high power. This talk will give an overview of the CLIC project alongside the current state and activities of the X-band test stations.

Additionally, CLARA (Compact Linear Accelerator for Research and Applications) is a next generation FEL (Free Electron Laser) based at Daresbury Laboratory, UK. For the technical portion of the presentation the data from the commissioning and first run of LINAC 1 will be presented.

Amelia Edwards
Started: October 2017, full-time
Supervisor: Dr Amos Dexter
Title: Design and Analysis of RF Upgrade for Improved Phase Measurement on XBOX1 at CERN
Funder: Lancaster University and CERN Doctoral Training Scheme

Since 2012, CERN has been operating high-gradient test stands as a research and test facility for the Compact Linear Collider, CLIC, which is a future electron-positron collider with design energies up to 3TeV. The CLIC design uses 12GHz normal-conducting RF cavities however accelerating gradients of at least 100MV/m are required to keep the design length below 50km.

The Xboxes are klystron-based 12GHz test stands. They are dedicated to the testing and development of normal-conducting high-gradient accelerating structures and high-power RF components for the CLIC design.

The first test stand, Xbox1, was commissioned and built in 2012 and is still in operation. In summer 2018, the 12GHz RF from Xbox1 will be connected to the CERN Linear Electron Accelerator for Research, CLEAR, where it will be tested with a beam-loaded superstructure. In order to make the most of this connection a more detailed understanding of the phase stability of the RF from Xbox1 is required. It is proposed that the RF system be upgraded to allow for convenient sampling and hence better understanding of the RF phase. Two possible designs are being considered and analysed to compare prospective performance.

The first phase measurement system uses a phase locked loop, PLL, to produce the intermediate frequency for down conversion of the RF signals for sampling. An alternative design utilises frequency multiplication and an up-convertor to sample the signals. In addition, two possible sampling schemes are under consideration and a 12GHz filter is being developed to minimize the cost of the upgrade.

James Mitchell
Started: September 2015, full-time
Supervisor: Dr Graeme Burt
Title: Higher Order Mode Coupler Design for a Double Quarter Wave Crab Cavity
Funder: Lancaster University, CERN and STFC

Higher Order Mode (HOM) couplers are devices that extract unwanted power from a resonant cavity at frequencies above the operating electromagnetic mode.
The design of these structures starts with an electrical circuit. This circuit acts as a short to the fundamental operating mode, but gives an ideal broadband transmission at higher frequencies.
The circuit is adapted to a physical device which can be simulated in electromagnetic modelling software. The alterations mean the response is not ‘ideal’ and hence the structure must be optimised with several performance parameters; finding optimal operating points where trade-offs arise.
Finally, physical mechanical and thermal constraints must be considered to ensure operation in the 2 K environment is feasible without harming the device or inducing a thermal run-away.
This presentation will outline the re-design of an existing ‘notch’ coupler to conform to additional performance parameters as well as easing manufacturing processes for batch production. The use of equivalent circuit analysis coupled with electromagnetic simulations will be shown and some example optimisation detailed. Following this a new ‘quarter-wave’ concept will be outlined. This concept aims to provide a structure which is much easier to manufacture than the previous. Finally, the electromagnetic and mechanical operation of both structures will be compared to benchmark the couplers against one-another.

Ahmed Mohamed
Started: January 2018
Supervisor: Dr George Adamopoulos
Title: Solution processed Zinc Sulphide-based semiconductors for TFT applications

The gateway to the Internet of things requires low cost, low power and high performance devices to exploit its full spectrum of capabilities. Several material systems have emerged as potential candidates to address the needs for large-area CMOS technology including metal oxides. At present, however, circuit applications reported so far implement only n-type oxide TFTs.

To tackle this issue, this work aims to the investigation of metal sulphide-based TFTs an alternative to metal oxides semiconductor that could adopt both n and p-type conductivity through appropriate doping.

Besides the electrical performance, the fabrication method constitutes another crucial consideration, as manufacturing costs is equally important in a wide range of emerging technologies. To that end, we are employing a solutions based technique namely the spray pyrolysis for the fabrication of sulphide-based semiconducting films.

The first material of choice under investigation is zinc sulphide (ZnS). This presentation focuses on the methodology to be adopted, including the choice of a suitable soluble precursor and its thermal properties, deposition conditions, as well as the doping elements so that both p- and n-type semiconductors to be manufactured.

Shivaji Pande
Started: January 2013, Part-time
Supervisor: Dr Graeme Burt
Title: Investigation of fast Vacuum Trips in Diamond Super Conducting Cavities
Funded: Diamond Light Source Ltd (75%); Self (25%)

The Diamond storage ring uses CESR type SCRF cavities to provide energy to the the circulating e^- beam. These cavities suffer from fast vacuum trips influencing the reliability of the facility. The trip frequency increases when the cavities are operated at voltage >1.7 MV During the normal user run the cavities are operated 1.1 and 1.4 MV. The operation at lower voltage requires the lowering of Qext of the cavities to match them at higher power with the help of the 3-stub tuners. This enhances the Standing Waves in the coupling waveguide.

The fast vacuum trips are charactrised by a sudden collapse of field in the cavities typically within few ⍰-sec which is considerably smaller than the natural decay time corresponding to the Q_{ext} of the cavity at the time of the trip. These trips are often preceded by a spike on the e^- pick up in the coupling waveguide indicating a strong electronic activity. The signal on the e^- pickup starts several ⍰-seconds before the acual collapse of the field in the cavity. This points towards the existence of multipactor (MP) or some kind of discharge in the coupler region of the cavity.

Multipacting simulations are performed in the coupler region corresponding to different operating conditions and straight waveguide with VSWR as a parameter with the help of CST Studio. Five papers have been presented in the international Particle Accelerator conferences and the SCRF conferences since 2013.

Alisa Healy
Started: October 2015, full-time
Supervisor: Dr Graeme Burt
Title: Electron bunch manipulation using dielectric-lined waveguide structures driven by terahertz pulses

There has been a recent surge in interest in the use of terahertz pulses to manipulate particles, with or without the aid of a modifying structure. Whilst the main focus is acceleration, other uses include as diagnostic tools and bunch manipulation, for example a THz streak camera to measure bunch lengths. Presented here are the initial results of THz spectroscopy measurements of a dielectric-lined waveguide designed for electron deflection. These measurements show the effect of the structure on an incoming THz field and thus verify simulated results. A discussion of a current experiment to use the structure for both deflection and acceleration of 100 keV electrons is also included. Further plans to accelerate 50 MeV electrons at the CLARA facility at Daresbury Laboratory are detailed to highlight key differences in the structure design and experimental setup.

Taylor Boyd
Started: October 2015, full-time
Supervisor: Dr Rosa Letizia and Dr Jonathan Gratus (Physics)
Title: Controlling Electromagnetic Profiles
Funder: Cockcroft student so my funder is STFC

We have developed a method for achieving the control of the profile of longitudinal electric modes within our structure, a dielectric wire medium. This provides us with a way to tailor these modes profile for a given application in a direct manner, without the need for any iterative design process. Using a 1D model to describe our wire medium, we first made predictions about the existence of these longitudinal modes and their dispersion relation. Using numerical simulations, we were able to confirm the validity of these predictions and study the effect of structural parameters on the underlying equations governing the fields supported in the structure. Doing this allowed us to develop our method for linking a desired profile with a function for the variation of the wire radius which will result in the support of our desired profile. We have confirmed the effectiveness of this method for a variety of different profiles and dielectrics in our simulations. Our current work is now focused on extending our results from our initial idealised structures to more realistic finite structures.

Evangelia Delli
Started: February 2016, full-time
Supervisor: Peter Carrington
Title: III-V Mid-Infrared Semiconductor Materials and Devices Epitaxially grown onto Silicon
Co-supervisor: Antony Krier, George Adamopoulos
Funder: EPSRC, Royal academy of engineering, The Joy Welch Educational Charitable Trust

The mid-infrared (MIR) spectral region between 2 to 5 µm is of great interest as it contains the absorption bands of several pollutant and toxic gases such as such as CO_2, CO and NH_3. Strong absorption bands also exist for pharmaceuticals and bio-chemicals allowing highly sensitive detection and/or imaging. III-V compound semiconductor materials are perfect candidates for optoelectronic devices with high performances in the MIR spectral region due to their unique properties. Such devices are of practical interest for a variety of applications including environmental monitoring, biomedical imaging and chemical sensing applications. In addition, there is an atmospheric transmission window exists between 3.6-3.8 µm which enables secure optical communication, thermal imaging and defence applications.
In the present work we will investigate the growth and fabrication of Sb-based III-V compound semiconductor materials and devices onto low cost silicon substrates. Growth onto silicon will lead to a dramatic scaling in the cost and size of the optical systems and will enable the photonic components to be directly embedded into electronic circuits, to enable their widespread application. Implementation of MIR silicon photonics would lead to the production of sophisticated, high operational mid-infrared photonic devices, and the next generation of optoelectronic systems.

Storm Mathisen
Started: September 2016, full-time
Supervisor: Prof Claudio Paoloni
Title: Low Cost Fabrication of mm-Wave Slow-Wave Structures for Wireless Communications Travelling Wave Tubes
Funder: Departmental funding

Data traffic in mobile networks is expected to grow by more than 40% annually until 2021. To handle this increased data traffic, the EU Horizon 2020 projects TWEETHER and ULTRAWAVE propose to exploit untapped spectrums in the mm-wave region. Travelling wave tubes are key to delivering the levels of power needed to effectively exploit

these regions, due to high atmospheric attenuation. Affordable fabrication of these devices present serious challenges due to the required tolerances and assembly. This research is focused on developing and investigating low cost fabrication processes for mm-wave interaction circuits, such as medium-accuracy CNC milling, and ultraviolet lithography and electroforming of copper slow wave structures.
A conference article was accepted and presented as an oral at the International Vacuum Electronics Conference 2018 in Monterey, California. The article presented aluminium interaction circuits fabricated by CNC milling and progress on a new lithography process for fabricating full-size interaction circuits.

Andrew Vint
Supervisor: Dr Rosa Letizia
Started: September 2016, Full-time
Title: Investigation of 2D PBG waveguides for THz driven acceleration
Funder: STFC Studentship

Novel accelerating techniques that overcome the limitations of conventional RF technology are receiving significant interest. Moving from RF to the THz frequency range, higher gradient of acceleration of high energy beams can be achieved in miniaturised structures. Moreover, with respect to the optical frequency range, the THz regime allows for larger structures and better beam quality to be obtained. This project has been investigating the use of a 2D photonic bandgap (PBG) waveguide for THz driven electron acceleration.

In accelerator applications, the properties of PBG waveguides can be exploited to damp higher order modes and offer low-loss dielectric confinement at high frequency. In particular, 2D PBG waveguides offer a good compromise between manufacturability, total photonic bandgap confinement, and ease of parallel illumination. The desire for the structure investigated in this project is optimisation for maximum bandgap and single mode operation. Dispersion characteristics of the accelerating mode are also studied to achieve the best compromise between high accelerating field and effective accelerating bandwidth, given a ~10% bandwidth of the THz driving pulse.

Matthew Bentley
Started November 2016, full-time
Supervisor: Dr Peter Carrington & Prof Anthony Krier
Title: 1.55μm Efficient Temperature Insensitive GaSb-based Lasers for Telecoms Applications
Industrial Partner: Huawei

The telecoms market is amongst the fastest growing and most wide reaching affecting many different areas of modern day life. Currently however lasers used for telecommunications suffer from significant temperature instability resulting in a greater expenditure on controlling the temperature of telecoms lasers than on powering the Lasers themselves, leading to great inefficiencies in telecoms systems. This research aims to improve upon current indium phosphide (InP) based technology by replacing them with more temperature stable, energy efficient gallium antimonide (GaSb) based lasers utilizing strained quantum wells emitting at 1.55μm, which could lead to a significant reduction in telecom infrastructure running costs globally. This presentation will present some motivation as well as basic principles of laser diodes, current technologies, and research outcomes, demonstrating progress with and the potential of GaSb-based quantum well lasers.

Umar Dikko
Started: April 2017, full-time
Supervisor: Dr George Adamopoulos
Title: Solution Processed Tantalum Oxide Films as Alternative High-k Gate Dielectrics

The high-k oxides are considered as alternative gate dielectrics as replacements to SiO_2 due to their high dielectric constants and breakdown voltage. Among those, tantalum oxide is one of the first to be used extensively in capacitors production, however the issues in forming material with a uniform structure has led to variations in its

reported properties such as the dielectric constant as well as the optical band gap. Additionally, tantalum oxide thin films deposition has been monopolised by reactive sputtering and CVD-based techniques inevitably leading to high manufacturing costs.
Here we report the application a solution-based deposition method namely the spray pyrolysis for the deposition of amorphous tantalum pentoxide (TaO_x) films and their implementation in thin-film transistors employing spray-coated ZnO and In_2O_3 semiconducting channels. A variety of methods, including XRD, UV-Vis, and impedance spectroscopy have been applied to assess the structure, dielectric and optical properties of the amorphous tantala films.
Analyses revealed that the optimum substrate temperature to achieve both high relative dielectric constant and high breakdown voltage was 400 °C. Simultaneously, and for the optimum deposition conditions tantala films exhibit wide band gap of about 5 eV consistent with the amorphous phase, and high dielectric constant of about 26. The remarkable finding however was related to the extremely low leakage currents that were found to be on the order of 10^{-10} A. Similarly, thin film transistors implementing TaO_x gate dielectrics and ZnO as well as In_2O_3 channels showed excellent operating characteristics such as high electron mobility in excess of 25 cm^2/Vs, high on/off current modulation ratio ($>10^6$) and excellent high bias stress stability.

Giorgos Antoniou
Started: July 2017, full-time
Supervisor: Dr George Adamopoulos
Title: Solution processed, metal-oxide based p-type thin film transistors

During the last years TTFTs (Transparent Thin Film Transistors) have received much attention, especially the n-channel oxide semiconductors, exhibiting high electron mobility, large on/off ratio, small subthreshold swing and a turn-on voltage very close to 0V. The key ingredient though for the development of high performance transparent TFTs is the p-type channel semiconductors. The latter is considered as the major obstacle for the development of low power, high performance Complementary Metal-Oxide Semiconductors (CMOS) circuits, mainly due to very low hole mobility. NiO is an excellent p-type semiconductor, due to the excellent chemical stability and good electric and optical characteristics. Stoichiometric NiO is considered as perfect insulator, whereas a non-stoichiometric NiO (i.e. creating Ni vacancies) will yield a p-type semiconductor. The fabrication of NiO-based TFTs was achieved using spray coating, in air at moderate temperature (substrate temperatures compatible with flexible glass). NiO has been deposited from solutions of Bis(cyclopentadienyl)nickel(II) in a mixture of toluene and methanol. As-deposited films were characterised by UV-Vis absorption spectroscopy, AFM, X-Ray diffraction, FTIR spectroscopy, spectroscopic ellipsometry and field-effect measurements.

Decio F. F. Alves de Lima
Started: October 2017, full-time
Supervisors: Dr. Hungyen Lin, Dr. Richard Dawson, Dr. Rosa Letizia
Title: Sensing water accumulation and transport in proton exchange membrane fuel cells with Terahertz radiation
Funding: Engineering Department

Proton exchange membrane fuel cells (PEMFC) are electrochemical devices considered as rising alternatives for clean energy generation. A major setback to widespread commercialization lies in its complex water management: membrane dehydration leads to low proton transport and pinhole formation, so proper humidification must be ensured; in contrast, generated water needs to be efficiently purged from the cell to avoid flooding and consequent starving of catalytically active areas. Current techniques on water visualization e.g. NMR, neutron, x-ray, optics/fluorescence, infrared are expensive, not readily available or not suitable enough. Terahertz (THz) radiation consists of electromagnetic waves from 300 GHz to 3 THz, situated between microwave and infrared regions. THz radiation is transparent to most non-conductive materials, such as ceramics, polymers, while being absorbed by polar liquids, such as water, due to rotational motions of the dipoles. THz radiation is also non-ionizing, thereby innocuous to human health. These factors establish the aforementioned technique as a promising alternative for water visualization in PEMFC. The THz imaging is done in standard transmission and reflection setups, using a THz camera, source, lens and custom made rails and carriages. The samples for imaging are mainly non-operating fuel cells, which have been growing in complexity, with the ultimate aim of using fully operating PEM fuel cells.

Juan Socuellamos
Started: January 2018
Supervisors: Prof Claudio Paoloni and Dr Rosa Letizia
Title: Investigation of the meander line structure for traveling wave tubes

Traveling wave tubes are vacuum tubes used to amplify electromagnetic signals as a result of their interaction with an electron beam, which passes some of its energy to the electromagnetic wave while traveling along the tube. A traveling wave tube is basically composed by an electron gun, a magnetic focusing system, a slow wave structure and a collector. So far, this research has been focused on the slow wave structure, which is the most critical part of the tube. For a proper interaction between the beam and the input signal, they both must travel approximately at the same velocity. Therefore, the slow wave structure plays an important role as it slows down the input signal to the velocity of the electrons. The most common slow wave structure is the helix, which provides the best interaction between beam and wave but, nowadays, the attempt to apply this technology to higher frequencies implies that the dimensions of the slow wave structure must be reduced and the helix structure is no longer feasible. One of the alternatives is the meander line structure, a planar structure that allows very small dimensions on the order of hundreds of micrometres, and retains most of the benefits of the helix structure, such as high interaction impedance, broad bandwidth or low phase velocity. A thorough analysis of the available literature regarding this structure has been carried out on this first stage of the PhD in order to find the most appropriate structure for later fabrication.

Rupa Basu
Started: January 2018, Part-Time
Supervisors: Prof Claudio Paoloni, Dr Rosa Letizia
Title: Applied research in the field of millimeter wave vacuum electron devices for future high data rate networks.
Funder: Fee Waiver

Engineering, Lancaster University coordinates an H2020 project 'ULTRAWAVE', in collaboration with seven European partners, proposed to develop an ultra-capacity wireless system beyond 100 GHz, which can provide data capacity of more than 100Gbps per kilometer squared. Aiming at the exploitation of the upper millimeter-wave spectrum for future 5G wireless communication system, a watt-level signal amplifier at D-band is indispensable. Traveling-wave tubes are only viable solution to meet these unique requirements of high power, wide band, reliablity and cost effectiveness. Therefore, the research mainly focuses on design and realization of a powerful TWT meeting the system requirements, by utilizing novel and innovative ideas.
The process involved in building a working prototype of the TWT includes designing the parts and sub-parts, assembling and processing (brazing, diffusion bonding, baking and cathode activation) the TWT and finally electrical and RF testing. The TWT has several parts such as electron gun, electron focusing system, interaction structure, collector and high voltage power system. Each part has a different physics and hence is analyzed through simulation software tools and solvers accordingly. Various prototyping attempts are being carried out to establish the fabrication, assembly and processing steps and come up with the best and most cost-effective method.
Through an in-depth research on addressing and solving the challenges associated with TWT design, this PhD study will come to a conclusion contributing in the demonstration of a working prototype of D-band TWT for the 'ULTRAWAVE' project.

Sean Petley
Started: October 2014, full-time
Supervisor: Prof George Aggidis
Title: Numerical and Experimental Analysis of Pelton Hydro Turbine Injectors
Funder: Gilbert Gilkes and Gordon Ltd

This presentation reports the ongoing results of 3D CFD simulations of the jet – runner interaction in a twin jet horizontal axis Pelton turbine. In previous works the author(s) presented CFD results, which showed that injectors with noticeably steeper nozzle and spear angles 110° & 70° and 150° & 90° respectively, attain a higher efficiency than the industry standard 80° & 55°. Moreover, experimental testing of the entire Pelton system showed gains of about 1% in efficiency can be achieved, however there appears to be an upper limit beyond which steeper designs are no longer optimal. The present work aims at providing further insight by presenting additional CFD analysis of the runner, which has been coupled with the jet profile from the aforementioned injectors. The results are compared by examining the impact the jet shape has on the runner torque profile during the bucket cycle and the influence this has on turbine efficiency.

Alexandros Oikonomou
Started: June 2015, part-time, off-campus
Supervisor: Professor George A. Aggidis
Title: Determination of the optimum weldability of steels which can be used for the construction of welded underwater marine systems (including the submerged parts of Wave Energy Converters and Tidal Energy Converters.

The overall aim of this Ph.D. research is the experimental determination of the optimum weldability of steels which can be used: (i) for the improvement of already existing constructions (including oil platforms) in Greece and (ii) for the fabrication of unfamiliar underwater marine structures (including the submerged parts of Wave Energy Converters and Tidal Energy Converters) in Greece and the experimental investigation of the corrosion rate of the relative steel welds taking into consideration the already existing experience from shipbuilding and submarine constructions. The main academic novelty includes the optimization of the welding values of various welding parameters during the real robotic welding experimental execution of different steels (HY 100, X6CrNiMo17-12-2, S355J2+N) with many specialized applications and the investigation of the corrosion rate of the welding joints of these steels. The optimum weldability of these steels has been already determined by evaluating the non-destructive and the metallographic testing results of the welded joints.

The conference article “Material aspects of underwater marine systems in Greece”, has been accepted for publication and the article “Determination of optimum welding parameters for the welding execution of steels used in underwater marine systems (including the submerged parts of Wave Energy Converters)” will be presented in the relative Conference and it will be submitted for publication. A third article is going to be prepared where the outputs of the investigation of the corrosion rate of the welded joints of the relative steels are analyzed.

Yueqi Wu
Started: October 2016, full-time
Supervisors: Dr Xiandong Ma, Dr Allan Rennie
Title: Intelligent wind turbine condition monitoring
Funder: Department Studentship

With the increasing demand for electricity, wind power is playing a significant role in daily life. However, the wind power resources are often abundant in remote areas and the wind farms are often installed in the place that is far away from cities, which brought inconvenience for turbine maintenances. Both corrective maintenance and preventive maintenance cannot provide cost-effective maintenance strategies. Besides, the fault diagnosis increases the turbine downtime, which increases extra cost for operation and maintenance (O&M). The PhD research is focusing on developing a data-based model-driven wind turbine condition monitoring methodology, which can detect and diagnose the faults on the wind turbines in a more intelligently, accurately and efficient approach.

Two conference articles have been accepted and will be presented. These cover the two aspects of the project, including (i) wind turbine fault detection based on alarm signals incorporating with Kernel Support Vector Machine (KSVM) by building a two-stage classification model to distinguish the fault from the alarms, and (ii) wind turbine fault diagnosis based on Kullback-Leibler Divergence (KLD) and KSVM. The KLD values between healthy and faulty conditions were calculated to determine the variables' contribution to the fault. Both methods were modelled and tested by using Supervisory Control and Data Acquisition (SCADA) data from an operational wind farm. Both methods have been proved their capabilities in fault detection and diagnosis. The next step of the project is to build a Doubly-Fed Induction Generator (DFIG) power electronics test rig and to validate the modelling methods proposed with experimental data.

Jie Ma
Started: January 2017, full-time
Supervisor: Xiandong Ma
Industrial Partner: Entrust Microgrid LLP
Title: Advanced control strategy of the HVAC for microgrid energy management system
Funder: Doctoral Training Scheme: Centre for Global Eco-Innovation

The project is dedicated to developing a real-time energy management controller for the family DC microgrid system. It aims at maximizing the utilization rate of PV panel with immersion heating tank, reducing the peak load demand for the utility and minimizing the electricity bills for the end user. The research is contributing to a wide range of challenging technical and academic issues, involving weather forecasting, power generation estimation, immersion heater modelling, dynamic supply-demand mismatch solution, hardware circuit design, hardware communication and algorithm implementation, and circuit test. The main academic novelty is related to investigating an effective control algorithm for HVAC (Heating, ventilation, air conditioning) system to help management power flow in the microgrid system.
One conference article and a journal paper have been published. The recent work contributes to several aspects of the final thesis: (i) energy management framework for the microgrid system. (ii) local solar irradiance forecasting and power generation estimation for a normal UK family. (iii) Power system modelling of the solar PV model with maximum power point tracking (MPPT) algorithm and grid-connected inverter (iv) consensus control algorithm development for the energy storage system based on the multi-agent system framework and mathematical model of HVAC devices.

Andrew Morrall
Started: January 2017, full time
Title: Numerical and Experimental Investigation of a Vortical Flow Inducing Jet Pump.
Supervisor: Dr M. Sergio Campobasso
Funding: Centre for Global Eco Innovation
Industrial Partner: TCL Cumbria

Jet pumps use a high velocity primary fluid to drive a secondary, lower velocity fluid through entrainment and momentum exchange of the two streams. These pumps contain no moving parts, meaning they are reliable and versatile, able to transfer fluids containing particulates. Thus they are often used in applications where moving mechanical parts would pose problems. Despite these advantages there is significantly less research on the fluid phenomena involved compared to other pumps.
Experimental analyses and CFD simulations are performed on a vortical flow-inducing jet pump which uses high-pressure compressed air injected into a bore through circumferentially distributed nozzles to entrain the secondary fluid. These nozzles are angled axially and radially so that the injected primary and secondary fluids flow in a vortical flow pattern downstream of the pump.

The fluid mechanics involved is complex and Computational Fluid Dynamics (CFD) is used to aid the understanding of the flow physics. This research investigates the use of CFD for the analysis and design of jet pump flows, using the commercial CFD code ANSYS® FLUENT. Simulations are carried out on two jet pump designs replicating experimental analysis, which is used to validate and setup CFD simulations.

Analysis of the pump is considered using single phase, using compressed air to pump atmospheric air. Suction pressure induced by the jets is shown to be highly dependent on the axial angle of the nozzles, which has considerable impact on the radial and tangential components of the resulting flow field, consequently affecting the pump performance.

Thursday 5th July

Inam Ullah Khan
Started: January 2018, full time
Supervisors: Dr Xiandong Ma and Prof James Taylor
Funder: Lancaster University, UK and COMSATS University Islamabad, Lahore campus Pakistan
Title: Scope of demand side management (DSM) as virtual power plant in Smart Grids

In most countries of the world, the amount of energy produced is relatively less as compared to the energy consumed. With the increased population and economic growth, high demand for energy is expected. The imbalance between electricity demand and supply has created an undesirable situation, which may cause power blackout.

In a smart grid network, demand side management (DSM) has promising effects on minimizing demand supply gap. DSM encapsulates those techniques and decisions, which are taken at user premises. It engages end users to make informed decisions about their energy consumption. By participating in DSM programs, users are encouraged to shift their loads from peak hours to off peak hours. In this way, overall consumption is not much effected whilst energy peak shaving is achieved. DSM focuses on reducing peak load demand instead of enlarging the generation capacity or reinforcing the transmission and distribution network. The primary objective of DSM techniques is to reduce peak load demand and operational cost.

We propose an improved energy consumption scheduling scheme for household appliances under the supply-demand framework of residential smart grid. Three types of appliances are considered: Interruptible, uninterruptible and base appliances. Simulation results show that the proposed demand-side energy consumption schedule can provide an effective approach to reducing user total energy costs, total energy demand and reduction in peak to average ratio (PAR).

Simeon Doyle
Started: October 2017, full-time
Academic Supervisor: Professor George Aggidis
Industrial Partner: Waves2Watts Ltd.
Industrial Supervisors: Colin Vicars, Adam Kyffin, William Kyffin
Title: Development of the Waves2Watts Wave Energy Converter
Funder: Centre for Global Eco-Innovation

The oceans contain the largest renewable energy source yet to be taken advantage of. The advancement of wave energy in particular lags behind most other forms of renewable energy despite decades of research and development worldwide. Even though there are over one thousand wave energy converter patented, few have progressed into development, let alone ocean testing or commercialisation. The aim of this project is to develop the patented multi-oscillating water column device known as the Waves2Watts device. Oscillating water column technology in its current state is yet to be proven as a worthy investment for full-scale commercialisation; hence, investigation into multi-OWC concepts is crucial in order to progress with wave energy development.

The first and current stage of this development includes verification of the concept. The work carried out as part of this initial stage includes extensive literature research into the relevant technology under investigation in the field, preliminary small-scale wave tank experiments and frequency domain numerical modelling. Focus thus far has been predominately aimed toward understanding the complex hydrodynamics involved and predicting wave interaction to achieve the desired functional output as described in the patent. By successfully validating a numerical model for the device, additional analysis tools can be utilised as well as significant time saving during optimisation stages. Experimental and numerical modelling will continue to play a significant role throughout the current concept verification stage and beyond.

Federico Attene
Started: September 2017, Full-time
Supervisors: Dr Sergio Campobasso, Prof George Aggidis, Dr Denes Csala
Title: CFD Assessment of tidal stream rotor loads due to Wave-type Inflow Unsteadiness
Funder: Faculty Studentship

The present study focuses on assessing the predictive capabilities of Navier-Stokes CFD for steady TST loads and unsteady TST loads due to surface waves perturbations at the rotor inflow. This study builds on the preliminary analyses of [1]. The CFD analyses of [1] used a 120 degree-grid sector to model the turbine steady and unsteady flows, and did not include any blockage. The agreement between measured and computed steady torque, thrust, in-plane and out-of-plane bending moment was found to be quite good at 73 RPM, but notably worse agreement was reported at 96 RPM [1]. It is here assumed that the worse agreement at 96 RPM may be due to the lack of blockage modelling in the CFD simulations of [1], and the aim of this work is to validate this assumption by performing new CFD analyses including blockage effects. It is also noted that it was already reported in the literature that blockage effects depend of the rotor speed (tip-speed ratio λ, more generally), and this work aims at quantifying the dependence of the numerical performance prediction on λ. The study will also look at the impact of modelling tank blockage on the improvement of the unsteady load predictions. The considered test case is the towing tank experiment of [2], in which steady flow conditions were obtained by towing a model TCT rotor with a track-sliding main carriage, and wave-like inflow conditions were achieved by using a secondary carriage between the main carriage and the rotor to impose an additional harmonic axial velocity component of the rotor. CFD simulations of the steady and unsteady flow regimes of the same flow regimes analysed in [1] will be carried out. Unlike the CFD analyses of [1], however, the new simulations will include the tank blockage and the rotor hub. To do so, the physical domain will consist of the whole tank. To reduce computational costs, frozen-rotor simulations will be used.

Jainil Shah
Started: January, 2018, full time
Academic Supervisor: Professor George Aggidis
Industrial Supervisors: Dr Audrius Zidonis, Dr Matthew Simpson
Funder: Centre for Global Eco-Innovation
Industrial Partner: Typhon treatment system Ltd
Title: Hydraulic Optimisation of UV water treatment system.

Clean water is a basic requirement for all human beings around the world. One of the key stages in the water treatment process utilises Ultra Violet (UV) light to remove viruses, such as Cryptosporidium. Current UV treatment is dependent on the use of mercury lamps; however, one key disadvantage is the high electricity consumption, highlighting the need for research and development of LED's as a new source of UV. The aim of the PhD research is to develop a design, which is suitable to treat water with the same level of capability as the current mercury-based system. In order to achieve this hydraulic optimisation of the state of the art device currently offered by the industrial partner, Typhon Treatment System Ltd is required. This will be carried out using Computational Fluid Dynamics (CFD) as an analysis tool to identify the area for optimisation of the water treatment reactor. Currently, the analysis has been focussed on a single reactor. CFD is used to determine the water flow inside the reactor. This analysis will be the basis for the future scope of research in terms of developing multi reactor capabilities.

Hasan Hasan
Started: September 2015, full-time
Supervisor: Prof Mohamed Saafi and Professor Jianqiao Ye
Title: Engineered Nano Cementitious Composites for Sustainable Concrete Structures

Ordinary Portland Cement (OPC) production is one of main contributors to CO_2 emissions and counts for about 8% of global CO_2 emissions. The production of OPC is expected to increase in the next 30 years because there are no cost effective binders on the horizon that can replace it. This will result in more CO_2 emissions. There is a growing need for new OPC-based materials that have smaller ecological footprint and exhibit improved mechanical and durability characteristics. Therefore, the objective of this PhD project is to develop novel high performance cementitious composites. To do this, new hybrid and self-assembled nanoparticles consisting of bio nano platelets-multi wall carbon nanotubes (BNPs/MWNTs) will be employed as additives. The BNPs material are derived from sugar beet industrial waste and will be used to i) control the local packing and growth in C-S-H gels, ii) integrate nano water reservoirs and a short-circuit diffusion functions thereby amplifying the formation of C-S-H products and iii) create a steric stabilisation effect for improved workability and hydration. The MWNTs will i) improve the cracking and toughness properties of cement. First, the hybrid BNPs/MWNTs particles will be designed and evaluated using state-of-art multiscale characterisation tools to examine their dispersion characteristics in aqueous solutions. Second, the effects of BNPs/MWNTs hybrid particles on the hydration kinetics of the designed cementitious nanocomposites will be elucidated.

Gabriel Lau Sin Hock
Started: March 2016, full-time
Supervisor: Andrew Pinkerton
Title: Laser Direct Metal Deposition

Laser Direct Metal Deposition (LDMD) is one of the additive manufacturing (AM) processes. By using a laser as the heat source, metal powder conveyed by inert gas is melted and deposited onto a substrate's surface to form a deposition layer. The LDMD process is capable of producing a complex geometry structure by depositing multiple layers of materials on top of previously deposited layers.

The objective of the current project is to increase the understanding of the role of melt pool flow within LDMD and its effect on the track produced during the process. Initially the project is examining the similar, but slightly simpler, laser melting process. A finite element model is being created and refined to improve the simulation of the melt pool generated during the process. Temperature dependent material properties will be used to calculate the initial pool shape and then conductivity enhancement factors, used to adjust the conductivity of the material in each axis to allow for flow within the pool and thus generate a more realistic melt pool profile.

Experimental work to verify the model is in progress. The profile of the laser beam has been measured to understand the relation between the beam diameter and the offset of the laser head from the surface of the substrate. Then, a series of melting experiments have been carried out to establish the relation between the cross section of the melt tract and the parameters used during the melting experiment.

Bo Huang
Started September 2016, full-time
Supervisor: Professor Mohamed Saafi
Title: Development of Bio-Engineered Cementitious Composites for Sustainable Construction
Funder: Self-funded

The construction industry in the UK faces serious challenges as the EU attempts to curb its carbon emissions by 2050. A key issue is reducing the overall demand for ordinary Portland cement (OPC). OPC production is one of the main contributors to carbon dioxide (CO_2) emissions, counting for about 8% of the total global CO_2 emissions. Because there are no other alternative cementitious materials currently available that can replace OPC, the production of OPC is forecast to double in the next 30 years to meet the rising global demand. This will result in more CO_2 emissions. Therefore, there is an urgent need for new approaches to dampen OPC consumption in the concrete industry.

The objective of this work is to develop a new generation of sustainable cementitious composites with low embodied carbon. The proposed strategy involves increasing the formation and enhancing the nanoscale properties of calcium silicate hydrate (CSH) phase, the main building block that controls the overall performance of concrete materials using multifunctional nanoplatelets derived from vegetable materials such as carrot and sugar beetroot. By increasing the performance of concrete, smaller size structural members can be designed which in return reduces the volume of concrete thus reducing the overall demand on OPC.

Currently, I am working on the following test 1) understand the interaction of cement of cement with the bio-nanoplatelets during curing using Electrochemical Impedance Spectroscopy (EIS), 2) study the effect of the bio-nanoplatelets on the hydration and microstructure of the cementitious composites, 3) determine the mechanical properties of the cementitious composites.

Matthew Pilling
Started: December 2016, full-time
Supervisor: Dr Allan Rennie, Prof Nicholas Dunn (LICA), Dr Daniel Richards (LICA)
Title: What are the Social Futures of 3D Printing?
Funder: EPSRC through the Lancaster Institute of Social Futures

In 2012, ‘3D printing’ became a cultural buzzword and the technology continues to receive a significant amount of media attention. The fundamental premise of printing objects in an additive ‘layer-by-layer’ process (i.e. in contrast to traditional construction methods that tend to subtract material, e.g. milling) has potential to radically transform how we will manufacture many things in the future, ranging from consumer goods to aeroplanes. However, whilst there is undoubtedly real potential in additive manufacturing processes (such as 3D printing), there is also a significant amount of hype which glosses over the major challenges that must be addressed to unlock the potential of these manufacturing methods. Many of these challenges are technical in nature, requiring engineers and scientists to make the technology cheaper, faster, and more robust. However, there are also an array of important social and cultural challenges that are central to widespread adoption and exploitation.

This PhD research seeks to look beyond the hype and address the important social challenges for futures of additive manufacturing. This research will provide further understanding of what society wants of this technology and describe the key barriers that need to be addressed to achieve this. Then describe how design fiction can be used to explore and speculate on what the possible futures for additive manufacturing. Ultimately, this research aims to position this design research agenda and illustrate how and why it is critical that we address the social futures associated with advanced manufacturing technologies.

Armin Yousefi Kanani
Started: January 2017
Supervisors: Dr Xiaonan Hou and Prof Jianqiao Ye
Title: Determining Adhesive Property

At present, the concept of lightweighting is a hot research topic in the manufacturing sector. One of the most effective methods to achieve lightweighting is to use advanced lightweight materials instead of conventional materials. In practice, this necessarily results in the use and fabrication of multi-material structures for which proper joining techniques are critical to the performance of the overall structures. In this study, material tests such as bulk test, fracture energy tests have been carried out in order to find the material properties such as young modulus, cohesive parameters in order to use them as inputs for finite element simulations.

Beth King
Started: January 2017, full-time
Supervisor: Dr Allan Rennie
Title: Rotational Rectilinear Scan Path Generation for Selective Laser Sintering
Funder: ERDF Centre for Global Eco-Innovation, LoCal-I Project

The Selective Laser Sintering (SLS) process is an established technology with history dating back to the 1990s. While offering a significant improvement in both time and cost for prototyping applications, success in production for the mass market, although sought after, has been largely unsuccessful. The project focuses on the improvement of SLS in three categories: cost, time and resultant parts lack of desired material properties, through four key areas of research: waste reduction, improved machine control methods for efficiency, enhanced pre-processing software and techniques to improve part quality.

Thermal stresses in selective laser sintering negatively affect the mechanical properties of the fabricated components, which can be reduced by varying the angle of the raster infill pattern. This presentation sets forth a method to generate a total 2D raster infill pattern, which alternates by a specified angle of rotation in rectilinear segments. The algorithm presents a flexible solution for users allowing specification of not only the angle of rotation, but also the length and width of the rectilinear segments, and optional translation of the segments per layer. The algorithms features include: 1) using the rectangles to clip the slice into new polygons; 2) a method to generate a rotational raster infill pattern for any polygon. The results show successful generation for rectilinear shapes for a number of models, with proposed future work to test the impact of rectilinear scanning on material properties, and optimising method parameters.

Chris Nyamayaro
Started: October 2017, full-time
Supervisor: Supervisors: Dr Ali Khan (TWI), Dr Andrew Pinkerton (Lancaster University) and Dr David Cheneler (Lancaster University)
Title: Underwater laser cutting
Funder: TWI and Lancaster University
Industrial Partner: TWI

The aim of this project is to develop underwater fibre delivered laser beam cutting technology for primarily decommissioning applications towards oil and gas and nuclear industrial sector. This will involve studying the underwater laser process mechanism using thermodynamics, fluid mechanics and engineering mathematics principles. This will be done to advance the development of an existing underwater laser cutting technology with capability of cutting 50mm thickness stainless steel and C-Mn steel at depths up to 200m; develop scientific understanding of laser material interaction in the cutting process and perform dissemination of the underwater laser cutting project results and capabilities developed towards post project exploitation. The problems, needs, issues of convectional and underwater laser processing in state of the art 1 micron fibre lasers will be studied with the aim of finding the means of achieving underwater laser cutting of C-Mn steels and stainless steel because most offshore structures are made from stainless steel and most non-contaminated offshore facilities are made from C-Mn steels.

The project will aim to improve the cut quality and cutting speed underwater. In cut quality, surface roughness is not important in decommissioning but kerf width and improving dross adherence are vital.

Zewen Gu
Started: December 2017, full-time
Supervisor: Professor Jianqiao Ye; Dr. Xiaonan Hou; Dr. Allahyar Montazeri
Title: Non-linear finite element analysis on the high speed valve spring
Funder: Doctoral Training Scheme: Centre for Global Eco-Innovation
Industrial Partner: Force Technology Ltd

The industrial partner is aiming to improve the engine performances of motorsports and marine applications by developing high precision and high duty valve springs. The high performance engines will optimizing engine operation and improve the fuel economy. These engines are generally running under very high cam speeds. The valve spring as an essential component in valve train controls the valve open and close periodically. Though the static properties of valve springs have been revealed for more than a century, it is still a big challenge to find out the dynamic performance of valve spring during high engine speed operation. The PhD programme contributes to represent valve spring models by using 3D scanning data of existing products. Then non-linear finite element dynamic simulation is conducted on the generated valve spring models to accurately predict their dynamic performances under high engine speed.

A static finite element model was generated to validate the efficiency of the scanning beehive spring data. The varied values of stiffness derived from the model was compared with design specification. A non-linear dynamic finite element model was built to conduct high-speed valve spring simulation. After manipulated into dynamic factor, the dynamic simulation outcomes were compared with existing experimental results. The damping ratio and the variable natural frequency were both considered in the model. Two more types of valve springs, one standard and one with a constant spring diameter, will be research in the following.

Timothy Forber
Started: April 2018, Full-time
Supervisor: Prof Andrew Kennedy
Title: Porous Titanium Scaffolds for Biomedical Implants Using Additive Manufacturing Technology
Funder: Engineering and Physical Sciences Research Council

Human bone is well known to have impressive self-healing abilities; however, large defects can require implant material to assist bone regrowth. Bone implant material can be grafted from another part of the body, such as the iliac crest, or alternatively from a donor. The removal surgery is complex and can cause painful and long-lasting side effects. Therefore, there is a demand for the production of implant scaffolds made from biocompatible materials to be used for this purpose. A number of ceramics have become popular biomaterials; however, most are insufficiently strong to be used for load bearing applications. As a result, titanium and its alloys, in particular Ti-6Al-4V, have become a common choice for biomaterials because of their high strength, corrosion resistance and biocompatibility. It is vital that biomedical implants present similar porosity and mechanical properties to human bone in order to enhance bone ingrowth and prevent shearing at the bone/implant interfaces.
Additive manufacturing allows parts with complex geometries to be produced through layer-upon-layer building methods, and presents the ability to produce highly porous components through a variety of techniques. In particular, Selective Laser Melting combined with the use of a sacrificial space-holder has recently been shown to have significant potential in this area. 3D printing of metal powder suspended in a foamed gel, followed by sintering, also presents a possible novel approach to tackling this issue. However, significant development is still required to optimise these methods before they can be successfully implemented in a medical scenario.

Josh Ingham
Started: January 2018, full-time
Supervisor: Dr David Cheneler
Title: Laser Vaporisation of Thick Films: Altering the heat profile of flame-sprayed nickel oxide heating elements.
Funder: In partnership with 2D Heat LTD, funded through the European Regional Development fund and the Centre for global Eco-Innovation.

Over 68% of electrical energy used by consumers is in the heating of buildings and space, the main causes of inefficiency within heating devices is their heating components not radiating heat directly into their intended use. 2D Heat Ltd produce flat panel heating elements using a novel flame spraying technique from Nickel Oxide matrices. Due to the current flow through the thick film element and the inhomogeneity introduced in the flame spraying process the heating profile of the heating element is not uniform. Through Laser vaporization and infrared thermography, a post-production process is being developed to identify and reduce the thickness of lower heat-output regions of the heating element to produce a uniform heating profile by altering the resistance profile of the film. This presentation discusses the development of the laser vaporization process, electrical properties and infrared thermography of the film.

Kieran Reeves
Started: October 2012, part-time
Supervisors: Dr A Montazeri / Dr C J Taylor
Title: Using Particle Swarm Optimisation techniques to ascertain unknown vehicle dynamic parameters for Hybrid Race Vehicle simulation and validation.
Funder: Self Funded
Industrial Partner: ChassisSim Technologies

Simulation software has for many years been developed to enhance the research and development phase of new vehicle introductions. With the ever evolving power of computer hardware Software in the Loop (SiL), Driver in the Loop (DiL) and Hardware in the loop (HiL) simulations are being utilised more frequently in Motorsport. With limited testing available and tight restriction on test times for Formula 1 the use of DiL simulators has increased massively. The focus of this PhD research and the academic novelty is to *develop a vehicle dynamics simulation model that incorporates optimal control algorithms for stability and energy management within a Hybrid Race Vehicle whilst incorporating trajectory planning*. This model will allow simulation engineers the opportunity to optimize vehicle behavior and hierarchical control for stability during energy management events whilst determining race strategy, lap time and best trajectory routes. To date, a vehicle dynamics simulation has been developed in Matlab/Simulink and validated using measured race vehicle data and particle swarm optimisation techniques to find unknown data.

Oliver Tate
Started: October 16, full time
Supervisors: Prof C. J. Taylor and Dr D. Cheneler
Title: Control and Optimisation of Micro-climates in Buildings
Funding: Department PhD linked to Adaptive Treatment and Robust Control (EPSRC)

Due to the significant energy requirements of heating and air-conditioning systems, there is appreciable interest in creating control systems that provide the optimum balance between energy usage and thermal comfort. Lancaster University is a particularly interesting case study due to the use of a district heating system, combined with a building management system that captures extensive temperature related data from many locations on campus. This presentation discusses the development of models suitable for use by predictive temperature controllers, using both data based and mechanistic approaches, and how these controllers could benefit the University heating system.

Rosie Newton
Started: September 2015, Full-time
Supervisor: Prof Malcolm Joyce
Title: Investigating Artefacts Associated with α Particle Interactions in Charge Coupled Devices

Charge coupled devices (CCDs) have been shown to have potential for detecting charged particles and ionising radiation. In particular, the clusters in the pixel images produced are distinctive for α and β radiation, with α particles causing large, symmetrical clusters or long vertical tracks called blooming, and β particles causing long, curved tracks. The size and shape of these tracks are also related to the energy of the incoming particle, giving the potential for spectroscopy of these types of radiation. This could be used to create a hand-held, portable device for in-situ detection and identification of radioactive contamination.

The response of CCDs to α radiation has been investigated. The CCDs used were Sony ICX825AL interline transfer CCDs, each with an 8.98 × 6.71 mm imaging area consisting of 1392 × 1040 pixels, covered with a thin aluminised Mylar film to stop exposure to light. Images have been taken of exposures to a ^{210}Po α-particle source and both vertical streaks and round clusters have been observed in each of the three CCDs. Increased levels of noise have been seen with continued use, potentially caused by damage from the α radiation. The reduction of this noise via annealing is currently being investigated.

Mike Anderson
Started: September 2014, part-time
Supervisors: Dr David Cheneler and Dr Steve Monk
Title: Dual Mode Seminconductor SpectroScopic/Directional Radiation DetectOr – Neutron/Gamma

Classic ionising radiation detection and identification techniques seek to exploit the best possible detector and focus on a single modality in order to achieve the optimum solution and the detector as an isolated entity. The approach being researched seeks to view the detector as part of a complete holistic system. The detector is fully characterised and the effect of secondary radiation understood. Furthermore, it seeks to extract detector signal features from a processed signal and to extract the maximum data from a signal event. The prevailing scientific thought is that the detector is the most important part of a system and that this must be optimised. The work undertaken to date shows that a sub optimal detector can deliver significant information, if the complete data acquisition system is considered. Experiments have been conducted using CdTe and CZT to show that the signal chain contains useful information. Coated Silicon based detectors have been characterised using neutrons and the core Silicon receptor with alpha particles to allow the data to be used further down the read chain. The ability to use a hybrid detector and an ability to extract features – such as depth of interaction, from the signal further down the read chain would allow the ability to characterise multiple modes of radiation in a single detector. This characterised data could be fed into a deep learning pattern recognition system to allow identification to be made. The ability to use sub optimal detection substrates and pattern recognition approaches could lead to more commercially viable solutions to a plethora of applications.

Anita Crompton
Started: October 2015, full-time
Supervisor: James Taylor and Kelum Gamage
Funder: Nuclear Decommissioning Authority
Industrial Supervisors: Divyesh Trivedi, National Nuclear Laboratory; Alex Jenkins, Sellafield Limited
Title: Long-range scanning based detection of alpha-induced air fluorescence even under daylight conditions

Direct detection of alpha emissions from radioactive contamination is difficult, hazardous and time consuming as it requires close proximity to contaminated surfaces. However, the emission of alpha particles causes radioluminescence. These photon emissions can be detected from a distance far greater than the short travel of an alpha particle, saving time and removing personnel from contaminated areas. This PhD research is to devise detection techniques to locate alpha sources based on this radioluminescence.

Experiments have shown a solar-blind UVC flame sensor is able to detect radioluminescence generated by a 6.95 Mbq ^{210}Po alpha source. Designed to detect the UVC from flames, this sensor has a very low background count in normal lighting conditions which have very low UVC levels even in daylight. The responses of alternative UVTron models have shown a similarly low background count. In further experiments, six different gases were flowed over the source to determine their effect on detection. A flow was used as in many field applications it may not be possible to achieve a fully purged gas atmosphere. For all gases there was an increase in signal count, with xenon increasing sensor response by 52% compared to air. Further work using samples of different isotopes have shown the UVTron is not radiation tolerant and is affected by beta and gamma radiation.

Collectively these experiments have shown the UVTron capable of detecting alpha-induced radioluminescence and it may be suitable, once shielded from other forms of radiation, for inclusion in a stand-off alpha detection system for field operations.

Mauro Licata
Started: October 2015
Supervisor: Prof Malcolm Joyce
Title: Combined fast-neutron γ-ray computed tomography/radiography

Computed Tomography (CT) is a non-destructive testing technique used to investigate the internal characteristics of materials. X/γ rays are used largely as radiation sources in CT but neutron radiation can also be used as a complementary and/or supplementary tool. Exploiting the different interactions of photons and neutrons in matter, and combining them in a sort of cross-check, it would be possible to discriminate between different materials that are otherwise challenging to distinguish using either γ-ray or neutron tomography in isolation. Photon-based scans are unlikely to discriminate between elements of similar density and tend to underperform when imaging materials with low atomic number. On the other hand, neutron-based techniques are more likely to highlight the presence of light elements, in particular organic materials, porous materials and substances with high neutron reaction cross-sections. The union of these different features can yield a better understanding providing both density and compositional information of the object under investigation. The *state-of-the-art* of the project leading to the implementation of a real-time fast-neutron and γ-ray tomography and/or radiography system will be shown as well as the results of an extensive Monte Carlo simulation study. This system is designed in such a way as to be suitable for industrial uses. In addition, the system relies on the use of one single radiation source to produce an acceptable flux of both neutrons and γ rays, with the hypothesis that they can be detected concurrently at the same time. The first tests of the system and results will be presented. This combined γ-ray/fast-neutron technique has potential applications for *in-situ* materials inspection, nuclear safety, homeland security and possibly in safeguards inspection.

Hajir Al Hamrashdi
Started November 2015, full time
Supervisors: Dr Stephen Monk and Dr David Cheneler
Title: Development of a Real Time Neutron-Gamma Imaging System.
Funder: The Government of Oman

Many fields in the nuclear industry utilize imaging systems that only detect a single type of particles, i.e. neutrons or gammas. However, there are many instances where it is recommended or even necessary to detect neutrons and gammas simultaneously. In these instances, a dual particle imaging system can offer a practical solution. However, there is often a trade-off between efficiency and spatial resolution in existing dual particle imaging systems. This trade-off often limits the efficacy of these systems in real applications. This PhD study aims in designing a neutron-gamma imaging system that combines two existing imaging techniques; Compton camera technique and neutron scattering technique. The combining of these two imaging techniques is expected to boost the performance of conventional dual particle imaging.

The main goal of this proof-of-concept study is to design a system that is capable of detecting simultaneously neutron and gamma ray sources in real time and with high efficiency. The main design is based on four layers of scintillation detectors. The plan is to complete this proof-of-concept design through three main stages. In the first stage, each layer is studied individually by testing different scintillation materials and different material thicknesses. In the second stage, an optimum four-layer design is investigated. In the third stage, the design will be experimentally tested. The effect of data reconstruction methods on the image quality will be studied as well. By the end of this PhD project we hope the study will prove the feasibility of constructing a transportable dual particle imaging system that can be used in a wide range of applications.

Ikechukwu Ukaegbu
Started: 1st December 2015, Full-time
Title: Radiological characterisation using radiation imaging and ground penetrating radar.
Supervisors: Dr Michael Aspinall, Prof James Taylor and Dr Kelum Gamage.
Funder: EPSRC and NDA

Traditional methods of characterising wastes buried in opaque materials e.g. soil and concrete, include: logging and micro drilling. These methods are destructive and time consuming with limited spatial extent for sampling. Furthermore, non-destructive techniques such as radiation imaging can only locate these wastes on the surface of the material in which they are buried with no information on how deep the wastes are buried. However, ground penetrating radars (GPR) have proven to be a reliable non-destructive technique for locating and extracting material properties of objects located inside opaque materials. Therefore, this research aims to develop novel techniques for combining radiation imaging and GPR for improved characterisation of wastes entrained in different materials. To achieve this, a novel method for nonintrusive estimation of the depth of buried radioactive wastes have been developed. Experimental results have shown that the method is able to estimate the depth of 329kBq Cs-137 buried up to 18 cm in sand. However, the technique requires foreknowledge of the density of the material in which the radiation source is contained. Therefore, further research is ongoing to remove this density dependency by integrating GPR signals into the novel method.

Nile Quane
Started: December 2016, full-time
Supervisor: D. Cheneler
Title: Maximum yield for reactions with limited resources
Funder: T.E. Laboratories Ltd. & Lancaster University
Industrial Partner: T.E. Laboratories Ltd.

The industrial partner has created a low cost in-situ aqueous pollution sensor. The sensor employs microfluidic technology to allow for chemical testing with minute quantities. This mitigates the need for manually-obtained grab samples to be sent to a laboratory for analysis. The result is more frequent data, with reduced time and labour required. Due to the nature of the sensor, it is prudent to conserve on-board resources where possible. The focus of this research is to limit unnecessary reagent consumption while obtaining an acceptable product yield. This was completed using multi-objective optimisation, with fluid dynamics and species transport both modelled. The optimisation routine adjusted the reagent inflow rate and its concentration for flow in different shaped junctions. The outflow of both reagent and product was calculated. The optimisation returned a Pareto front which identified the most efficient region to operate the reactor given the input parameters. The work is soon to be submitted for publication.

Arran Plant
Started: April 2017, full-time
Supervisor: Dr Vesna Najdanovic and Prof Malcolm Joyce
Title: From waste to wealth: converting abundant waste products into useful compounds by neutron-γ and γ-only radiolysis
Funder: University ECG & EPRSC

Research into the irradiation of glycerol and ethylene glycol by either mixed (neutron-γ) or γ-only (γ) fields will be described. Irradiations have been conducted at the TRIGA reactor of the Jožef Stefan Institute (JSI) in Slovenia. The compounds produced from these irradiations are being evaluated in terms of the possibility of the production of useful platform chemicals from waste feedstocks, specifically focussing on the contributions of neutrons which has received little publication coverage to date which will be relevant to the future applications of fission reactor systems, beyond producing electricity.
In recent work, samples of glycerol and ethylene glycol have been exposed to neutron-γ radiation with fast neutron fluxes ranging from 7.7×10^{10} $cm^{-2}s^{-1}$ to 3×10^{12} and γ-only irradiation. A study of the dependence of product yield versus absorbed dose is being conducted with a total dose ranging of 0.25 kGy to 100 kGy. The chemical products of these exposures are being identified through GC-MS Gas Chromatography–Mass Spectrometry sampling techniques. Preliminary analysis of γ-irradiated ethyl glycol samples indicate quantities of numerous products, including light polar aldehydes, ethyl acetate and ether oligomers, are present. Results are consistent with similar reports that γ-radiation prompts the oxidation of oxygen-containing compounds.

Sebastian Davies
Started: October 2017, full-time
University Supervisors: Dr Richard Dawson and Dr Fabrice Andrieux
NNL Supervisor: Dr Chris Maher
Title: The Electrochemical Treatment of Nuclear Wastes
Funder: NGN Programme

The nuclear industry has generated large amounts of waste materials contaminated with radioactive inorganic species. Some of these species, such as Plutonium (Pu) are particularly hazardous and often require very thorough decontamination techniques to separate the Pu compounds. The use of electrochemistry in processes can be a particularly elegant method of ‘cleanly’ achieving this objective without the need for chemical reagents and the associated, mass, volume and cost these bring. Reaction conditions and electrode potentials will be used to exploit the differences in thermodynamic stability of waste components to produce high degrees of selective separation. This will allow large reductions in the volume / mass of high hazard waste. The project will explore the fundamental electrochemistry of the proposed decontamination schemes, design and simulate the core electrochemical reactors involved and demonstrate their performance on a small scale. This will initially be with chemical analogues but there is an ambitious but achievable goal to use some active materials for direct demonstration of the process and reactor designs by the end of the project. This will be under very carefully controlled conditions at an industrial partner’s site.

Tomas Fried
Started: October 2017, full-time
Academic supervisors: Dr Stephen Monk, Dr David Cheneler, Professor James Taylor
Industrial supervisor: Dr Jonathan Dodds
Industrial partners: National Nuclear Laboratory, Sellafield Ltd
Title: Mechanical analysis of sludge using robotics
Funder: NNL

On the Sellafield site there are a number of legacy storage tanks and silos containing sludge of uncertain properties that need to be ascertained in order to successfully clean out and decommission the vessels. Limited access, the congested nature of the tanks, unknown radioactivity and presence of hazardous substances prevent sampling and usage of sophisticated devices within these tanks. This project concerns the development of a cheap, robust and compact device capable of analysing some of the mechanical properties of the sludge *in situ*. Initially, simulant sludge is being analysed to be used as benchmark material for the developed device using TiO_2 powder suspended in water, before developing and prototyping the intended novel device with the use of resilient electronics, 3D printing and commercial off the shelf electronics.

Alexander Jackson
Date started: October 2017, Full-time
Supervisor: Prof Colin Boxall
Title: The role of kinetics in advanced nuclear fuel reprocessing
Funders: NNL and EPSRC

To reduce the lifetime of nuclear waste, spent nuclear fuel is reprocessed to maximise the efficiency of closed fuel cycles. The i-SANEX process is an organic co-extraction of trivalent actinides and lanthanides from an aqueous PUREX raffinate, followed by a selective stripping of the lanthanides from the actinides. Though the chemical and thermodynamic feasibility of the co-extraction is understood, the mass transfer and chemical kinetic properties are currently understudied. A firm understanding of the mass transfer and chemical kinetics underpins design choices when scaling up (such as determining the residence time and the most suitable contactors) and informs the safety case.
In this research, a rotating diffusion cell (RDC) will be used to study the mass transfer and kinetics of the co-extraction i-SANEX step, which uses the organic ligand tetraoctyldiglycolamide (TODGA). Studies have shown that TODGA migrates from the organic into the aqueous phase, complexes with the trivalent ion, and returns to the organic. Opposite to other reactive systems with this mechanism, extraction rate was found to be inversely proportional to rotation speed. This PhD has so far produced a convection/diffusion film theory model that exhibits this behaviour and it is predicted that, through manipulating the parameters to fit the already published experimental results, the kinetic rate of the process can be procured. The results from this model characterise the reaction zone in the RDC, validating the further experimental kinetic results to come later in the course of this PhD – results which NNL (funders) seek for their industrial flowsheeting.

James Kennedy
Started: October 2017, full-time
Supervisor: Prof Colin Boxall
Title: Brick Decontamination
Funder: EPSRC, NNL, Sellafield Ltd, Lloyds Registry Foundation

As a result of a previous Lancaster-supervised PhD programme conducted at the Idaho National Laboratory (INL), we have developed a physico-chemical understanding of the factors affecting the decontamination efficiency for the removal of tenacious (americium, cobalt) and non- tenacious (caesium, strontium) from commonly used mineral-based urban building materials such as concrete, granite, limestone and marble.
For this CINDe (Centre for Innovative Nuclear Decommissioning) project, we aim to extend this work to the decontamination of radioactively contaminated bricks and especially plutonium contaminated Whitehaven bricks. Specifically we aim to do the following.
To develop an understanding of the materials and mineralogical properties of relevant brick formulations – especially key constituent phases, surface pH, surface charge, permeability and cation exchange capacity.
Based on this and a knowledge of plutonium hydrometallurgical / surface chemistry, we will develop an understanding of the mechanisms by which plutonium and other key contaminants contaminate relevant brick formulations – especially Whitehaven bricks as an exemplar system.
Using this, and the understanding developed with INL of the design requirements for effective contaminant simulants, we will develop a representative non-active simulant system for Pu-contaminated bricks.

Finally, employing this simulant system, we will determine the efficiency of brick decontamination using a range of chemically based decontamination methods including those based on aqueous and non-aqueous solvents, redox reagents, chelants, acid/base treatments, gels and foams.

Sam O'Sullivan
Started: October 2017, full-time
Supervisor: Prof Colin Boxall
Title: The Safe Storage of Reprocessed PuO_2 Powders.
Funder: NGN DTC

Spent nuclear fuel processing in the UK uses a liquid-liquid separation process that exploits the changing solubilities of actinide elements in different oxidation states, to separate uranium and plutonium from fission products and other actinides. Separated plutonium is converted to an oxalate, which thermally decomposes to give plutonium dioxide (PuO_2), suitable for interim storage in stainless steel cans. Over time, some cans have been found to pressurise, and the potential for can rupture poses an additional radiological risk to workers and undermines the safety case for storing plutonium in this form.

Pressurisation is thought to result from helium build-up in the can, contamination with chloride from PVC storage bags or as a consequence of the formation of steam or hydrogen gas from trapped water. There have been extensive studies of water chemistry at plutonium dioxide surfaces and the effects of radiation damage on PVC storage media but limited studies of the release and retention of helium from PuO_2. Helium forms as a consequence of the radioactive decay of plutonium isotopes, and occurs at a constant rate. The isotopic composition of PuO_2 will vary depending on the type of reactor fuel it was produced from, and also due to burn up. The aim of this PhD project is to investigate how helium is retained in and released from the plutonium dioxide powders stored at Sellafield, giving consideration to the different powder properties, such as particle size, purity and morphology. Experiments will initially be run on structural analogues, but may then be extended to PuO_2 in time.

Athanasios Papageorgiou
Started: October 2017, full-time
Supervisor: Dr Fabrice Andrieux and Dr Nicholas Henley Evans
Title: Monitoring of technetium in groundwater: Development of a novel QCN based sensor

^{99}Tc, a pure β-emitter with E_{max} =294 keV, is one of the most significant ($t_{1/2}$ =2.1×10^5 y) nuclear waste isotopes, produced by the fission of U with a yield of 6%. Under normal environmental conditions, it is mostly encountered as the pertechnetate ion, TcO_4^-, which is highly soluble and consequently mobile in water. For this reason, and because it often is the first contaminant to be present in detectable levels, its monitoring into groundwater is a statutory requirement for every nuclear license site. Because of its relatively low concentration in environmental samples, current determination methods of ^{99}Tc involve several steps, such as chemical separation from the matrix, purification and source preparation, prior to radiometric (e.g. liquid scintillation counting) or mass spectroscopic (e.g. inductively coupled plasma mass spectroscopy) determination. The detection of ^{99}Tc may take up to several days, thus making these techniques inappropriate for an emergency situation. Hence, we propose the development of a sensor for real time monitoring of groundwater based on the Quartz Crystal Nanobalance (QCN), a piezoelectric resonator, which oscillates when an electric potential is applied across its body, and which is capable of measuring very small changes in mass at its surface. This will be modified to respond exclusively to the presence of TcO_4^- , using a number of developed (e.g commercial resins like TEVA, inorganic porous compound like NDTB-1) and novel (e.g. TREN derivatives) ligands which will be assessed for their efficacy for TcO_4^- sequestration, including in the presence of commonly encountered interferents.

Amaechi Chiemela Victor
Full Time 3rd year PhD student
Started: June 2015
Title: Numerical design of Novel Composite risers for deep water applications
Supervisor: Prof. Jianqiao Ye
Funder: NDDC Nigeria & Engineering Department

Due to recent challenges in oil exploration, there has been an increase in oil exploration from shallow waters to deep waters. This requires more length of the risers and thus an increase in the weight of the risers on the offshore structure. Risers are conduits which are used to transport fluid from the oil well to the offshore platform of the transport vessel. The application of composites in riser design is to harness the properties of composites. This includes the reduction in the weight of the structure, and to improve the material behavior. Submarine hoses are also a type of risers that are connected to buoys and other offshore structures but have short service periods. The design for some load cases on the composite riser is presented