

# The Rutherford International Fellowship Programme

## Highlights and Summary October 2018



# The Rutherford International Fellowship Programme

The Rutherford International Fellowship Programme (RIFP) is a post-doctoral fellowship programme run by the Science and Technology Facilities Council (STFC) in the UK. It enables high-quality researchers to develop their careers through provision of excellent scientific research opportunities and training.

The Programme has been running for 3 years, since 2015, with 13 researchers having completed 2-year fellowships and a further 12 having been employed for around 1 year; 10 more are just starting their projects. This brochure highlights some of the research achievements of the cohort of fellows to-date, as well as detailing the diverse training they have been able to receive and the work they have done to publicise their achievements.

RIFP Fellows can undertake projects at the world-class facilities and departments available within STFC. This includes the ISIS Neutron & Muon Source,

Diamond Light Source, RAL Space, RAL Particle Physics, the Central Laser Facility, Accelerator Science and Technology Centre, STFC Scientific Computing, STFC Technology Department and the UK Astronomy Technology Centre. The range of science areas encompassed is therefore extremely broad, ranging from astronomy and satellite technology through to advanced materials studies impacting on global challenge issues, developments for next-generation accelerators, and fundamental physics studies at the biggest and smallest scales of the universe.

In addition to an excellent research environment, RIFP researchers have access to a wide range of training opportunities to enable their career development. This includes subject-related training such as conferences, meetings and workshops, as well as on-the-job training in new methods and techniques; but it also includes transferable skills training and public engagement activities.

*The RIFP project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 665593.*

Full details of the Programme, including lists of all the researchers employed to-date and their projects, can be found on the Programme website:

<https://stfc.ukri.org/funding/fellowships/rutherford-international-fellowship-programme/>

The Rutherford International Fellowship Programme is run by STFC, one of the nine research councils within UK Research & Innovation.

*This report reflects only the author's view and the Research Executive Agency of the EC is not responsible for any use that may be made of the information it contains.*

“ This Fellowship has given me the opportunity to be involved in the exciting and challenging world of THz technology with a world-leading group in the field. The MMT Group is leading the European supply of THz devices in several projects. The participation in these projects represents a significant development of my scientific career.

– Diego Pardo ”

# The Rutherford International Fellowship Programme – at a glance

Since the RIFP scheme began in 2015, there have been three calls for fellowship applications. The first cohort of researchers have finished their fellowships and left for new opportunities; the second cohort have been employed for about one year, and the third cohort are just starting their projects.

35



Post-doctoral  
researchers  
employed to-date



17

Countries  
that employed  
researchers have  
come from



15

Different  
nationalities  
of the employed  
researchers



116

Fellowship  
applications  
received over three calls

63



Talks  
given by RIFP researchers at  
conferences, workshops or  
as seminars



61

Published  
journal articles  
produced by RIFP  
researchers so far



over  
150

Training activities  
undertaken

(including conference attendance,  
on-the-job learning, dedicated  
training days, etc)



70

Journal articles  
in preparation by  
RIFP researchers



66

External meetings  
attended by RIFP  
researchers



32

Public engagement  
activities or events

“

I have had the chance to work in a stimulating environment (RAL). I have been involved in the activities of the Molecular Spectroscopy group (MSG) at ISIS and with researchers and engineers at all levels of seniority, carrying out my own research and experiments, and extending collaborations with new people. One of these collaborations has resulted in the writing and submission of a new research project.

– Matia Gaboardi

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# RIFP Research Highlights

RIFP research projects cover a very diverse range of science areas. Researchers choose their own research projects, in consultation with their host department. The projects vary from fundamental physics of the universe to research related to global societal challenge issues. For example, topics of RIFP researchers employed to-date include development of photo-electrocatalysis methods for producing hydrogen from water as a clean energy source; development of medical imaging methods for histological studies; exploration of novel hydrogen

## **Accelerator Science & Technology:**

6 researchers employed, projects focused on development of new technologies for next generation particle accelerators including superconducting acceleration processes and innovative ways of suppressing electron emission instabilities for high intensity particle beams.

## **Central Laser Facility:**

1 researcher employed, looking at laser-plasma instabilities in the context of inertial confinement fusion.

## **Diamond Light Source:**

6 researchers employed, working on a wide range of x-ray-based studies including development of imaging for biomedicine, properties of strongly-correlated materials, clean energy production using photo-electrocatalysis and development of x-ray optics technology.

## **ISIS Neutron & Muon Source:**

8 researchers employed, using neutrons and muons to investigate a wide variety of materials including surfactant behaviour, archaeological specimens,

storage materials; development of THz detectors for Earth observation for climate studies; development of time-resolved x-ray techniques for studying biological systems relevant to disease progression or drug operation; studies of novel surfactants relevant to personal care and pharmaceutical products; and modelling signal transmission for development of high-throughput satellite systems – amongst many others.

The diversity of science represented by the projects of the 35 RIFP researchers employed to-date can be seen by the departments where they have been based:

multiferroics, strongly-corellated systems, hydrogen storage materials and accelerator ion source development.

## **Particle Physics Department:**

5 researchers employed, working on fundamental particle physics arising from work at CERN or development of new detector technologies for particle physics applications.

## **RAL Space:**

5 researchers employed, with projects including satellite communications technology, THz radiation detection and plasma wave propagation.

## **UK Astronomy Technology Centre:**

4 researchers employed, exploring areas such as galactic dust, single and binary massive stars and the use of additive manufacturing for astronomical components.

**A small selection of research highlights from some of the RIFP researchers' projects to-date is presented over the next few pages.**



These fellowships allow the postdocs to work with more freedom than what they have in other postdoctoral positions, allowing the fellows to set their own programme and objectives. In addition to that, Diamond and RAL provide an excellent environment for research.

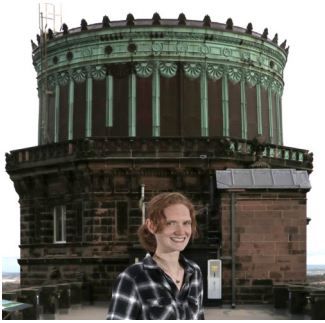
– Javier Fernandez-Rodriguez



# Research Highlights: Carolyn Atkins

## – UK Astronomy Technology Centre (UKATC)

### *Additive Manufacturing for Astronomical Instrumentation*

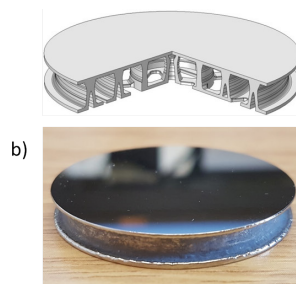
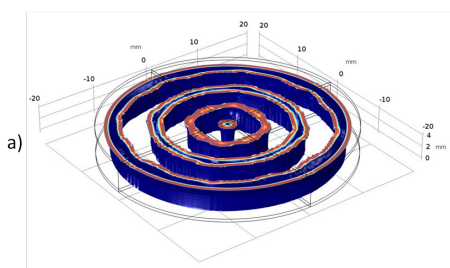


Additive manufacturing (AM, or 3D printing) has revolutionized the fabrication and design of a wide range of components, from bespoke spanners printed on the International Space Station, to replica hearts

to aid doctors prepare for surgery. The majority of these applications can be considered low accuracy, with required dimensional tolerances ranging from  $\pm 0.1\text{mm}$  to  $\pm 0.01\text{mm}$ . The scope of this research was to expand the use of AM to the high dimensional accuracy domain ( $\pm 0.001\text{mm}$  to  $\pm 0.0001\text{mm}$ ) of precision astronomical optics and components, with emphasis on lightweight space-based mirrors. One of the challenges for astronomical or Earth Observation satellites is the need for lightweight optical components to meet launch-weight restrictions, but which also optimise the use of a limited payload volume to ensure the maximum optical surface area to collect light. Additive manufacturing builds an object layer-upon-layer and allows the use of

innovative lightweight structures that are not possible via traditional subtractive manufacture (mill, drill and lathe). The goal of Carolyn's project was to harness the increased 'design-space' of AM and to apply it to astronomical space-based mirrors in order to create a number of lightweight prototype mirrors.

Carolyn led the project from the UKATC in collaboration with a number of academic and STFC departments. The initial phase of the project used a generic lightweight substrate design, which was then printed via AM in a variety of materials and post-processed to achieve a reflective surface. The second phase of the project involved selecting the most promising materials candidates from the initial phase and printing a lightweight substrate design optimised to reduce polishing defects. The experimental side of the project in particular relied heavily on collaborative partners, including RAL Space, Diamond Light Source and Daresbury Laboratory. Carolyn's project demonstrated that lightweight metal mirrors can be produced via AM for optical and infra-red wavelength applications; it is hoped that further research will improve the current mirror quality and extend the wavelength applications to the ultra-violet and X-ray.



This figure highlights the design-to-manufacture chain of an optimised, lightweight, metal, proof-of-concept mirror towards space-based applications. Left: a finite element analysis topology optimisation designed to minimise the effect of polishing print-through (quilting), while reducing the weight by 38% of an equivalent solid. Right-top: a computer aided design of the mirror substrate incorporating an approximation to the topology optimisation. Right-bottom: the finished additively manufactured optically polished mirror.

For further reading: Topological design of lightweight additively manufactured mirrors for space, C. Atkins et al., Proc. SPIE 10706, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation III, 1070601 (2018); doi: 10.1117/12.2313353; Additive manufactured x-ray optics for astronomy, C. Atkins et al., Proceedings Volume 10399, Optics for EUV, X-Ray, and Gamma-Ray Astronomy VIII, doi: 10.1117/12.2274011.

Following her RIFP Fellowship Carolyn has continued within the UKATC on a 3-year post as additive manufacturing technology development lead.

# Research Highlights: Mattia Gaboardi – ISIS Neutron & Muon Source

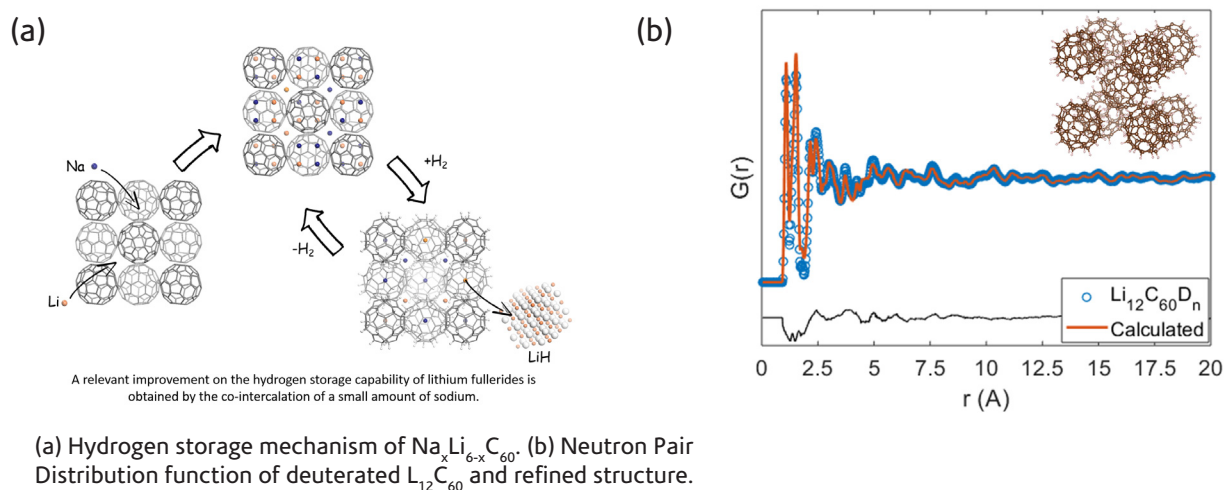
## *Advanced Fullerene-based Materials for Hydrogen Storage*



The use of hydrogen as a renewable, efficient, and clean energy vector to replace fossil fuels could contribute to a global lowering of greenhouse gas production and hence to the issue of climate change. The study of the

mechanisms of hydrogen absorption in new materials is of paramount importance for the design of new, efficient storage systems for hydrogen which meet the requirements necessary for a commercial product. A new class of fullerene ( $C_{60}$ )-based materials offers the prospect of meeting most of the current targets for hydrogen storage, reversibly absorbing large amounts of hydrogen at modest temperatures. Mattia's project aimed to synthesize new fullerene-based materials and to establish their mechanism of hydrogen uptake using the unique techniques available at the ISIS Neutron & Muon Source, including development of gas-sorption equipment for *in-situ* and *in-operando* studies at pressures of industrial and technological relevance.

Mattia undertook a complete investigation of the possible phases of  $C_{60}$  with alkali and alkali-earth metals at RAL with the successful synthesis of  $B_xA_{y-x}C_{60}$  phases (A=Li, B=Na, K, Rb, Ca, and Mg;  $y = 6, 12$ ) and decoration with transition metal catalysts. Hydrogen sorption performance, Raman spectroscopy and X-ray diffraction were carried out. The most promising performance was found for  $Na_xLi_{6-x}C_{60}$  compounds. Studies using neutrons and muons on a variety of instruments at ISIS have allowed an understanding of the sorption processes occurring on these materials, and included development of a new method for the quantitative evaluation of the hydrogenation level in carbon materials. New sample environment equipment has also been developed at ISIS to allow *in-situ* hydrogen sorption experiments on the neutron beamlines, and such equipment could be used in the future on instruments at the European Spallation Source currently being built in Lund, Sweden.



For further reading: Optimal hydrogen storage in sodium substituted lithium fullerenes, M. Gaboardi et al., *Phys. Chem. Chem. Phys.* 19 (2017) 21980; doi: 10.1039/C7CP04353H; Synthesis and characterization of mixed sodium and lithium fullerenes for hydrogen storage, M. Gaboardi et al., *In. J. Hydrogen Energy* 43 (2018) 16766.

Following his RIFP Fellowship Mattia has moved to the Elettra Synchrotron in Italy for a 3-year beamline post-doctoral position.

# Research Highlights: Diego Pardo – RAL Space Terahertz Technology for Space Instrumentation

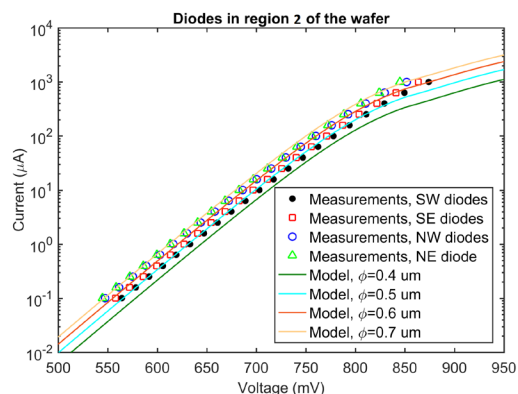
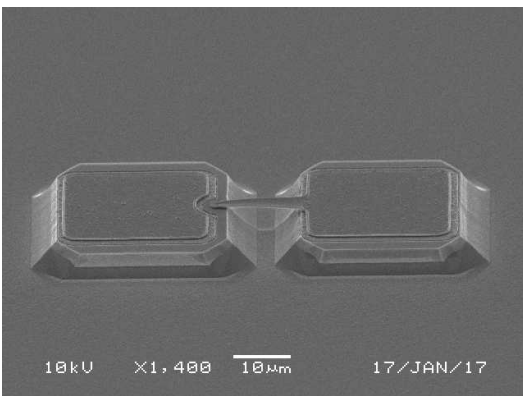


We are familiar with some parts of the electromagnetic spectrum: visible light that we use to see things with our eyes; x-rays that we can use for medical imaging; radio waves used for communications, and so

on. Terahertz (THz) radiation lies between microwaves and infrared waves in the spectrum, and, until recently, has been a relatively unused part of the spectrum as it requires new technology to generate and detect it. But THz radiation opens up a new window for studies in areas such as astronomy and earth observation for climate research, and has applications in medical and security imaging as well. The aim of Diego's project was the development of new THz detection technology, in particular to progress the design and

fabrication techniques of Schottky diode-based circuits operating in the THz band by both simulation of their working and optimisation of production methods.

As part of the project, Diego designed new microelectronic components which have state-of-the-art predicted performance, and these are about to be fabricated to demonstrate their potential. In addition, fabrication techniques based on electron beam lithography (EBL) have also been developed. EBL has enabled diode components to be produced with sub-1mm size, essential for operation of diodes at frequencies above 1THz. The development of design tools and fabrication methods has enabled Diego to participate in earth science and astronomy missions in partnership with other UK groups, and has also led to collaboration with Diamond Light Source for component testing.



Scanning electron microscope image of a diode with EBL anodes (left) and measurements of the fabricated diodes (right).

Further reading: Optimization of noise performance of fundamental Schottky mixers, D. Pardo et al., 2017 42nd International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), doi: 10.1109/IRMMW-THz.2017.8067103.

Following his RIFP Fellowship Diego has achieved a permanent position within RAL Space as a design engineer.

# Research Highlights: Anna Fedrigo – ISIS Neutron & Muon Source

## *Viking Swords Studied by Neutrons*

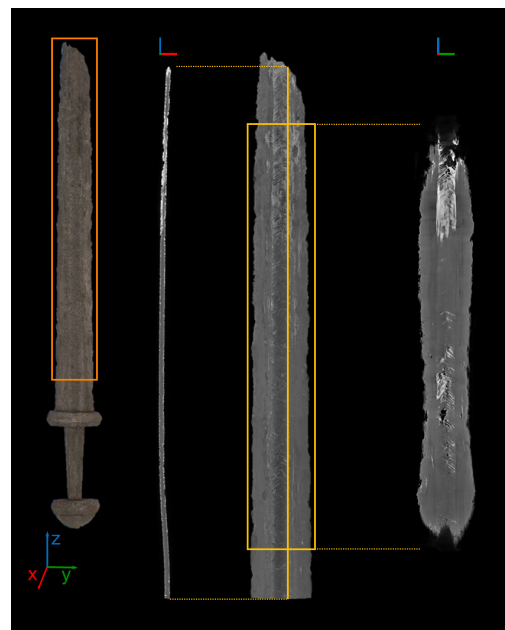


The use of non-invasive, non-destructive techniques for the scientific investigation of archaeological objects is highly desirable, to avoid damaging or devaluing important historical artefacts. Neutron

scattering is an important method in this context, as neutrons are both penetrating, allowing the sub-surface or interior of objects to be studied, and don't harm the object under investigation. Neutron methods can give a wide variety of information on artefacts, including helping with authenticity and construction methods. This in turn can improve our knowledge of the technological evolution of ancient civilisations, as well as helping with the conservation of museum objects. Anna's project aims to further develop the technique of neutron scattering particularly for the study of metal artefacts in order to expand the range of methods available to institutions and museums to understand, investigate and preserve cultural heritage objects.

Archaeometallurgy represents a crucial tool for understanding all the processes used to convert raw materials, like iron ore, into 'cutting edge' artefacts of iron and steel technology, such as arms and armours, where the best materials available and expertise were often applied. Scientific investigations can not only shed light on the manufacturing processes involved (e.g. smelting, refining, and smithing) and on their use and degradation over time; they can also, on a

broader scale, help in understanding the economy of an archaeological site and its technological evolution over time. Specifically, Anna has recently been using neutron scattering to study 'pattern-welded' swords from the Viking Age belonging to the National Museum of Denmark. Pattern-welding produces a decorative pattern on the sword surface by the twisting and joining of things trips of iron and steel. This study, which involved producing 3-D images of the swords, revealed new details of their assembly methods and corrosion, helping our understanding of the sword construction.



Picture of a pattern-welded sword from the Viking Age with tomography reconstruction and selected virtual slices through the volume.

Further reading: Neutron imaging study of 'pattern-welded' swords from the Viking Age, *Archaeological & Anthropological Sciences* 10 (2018) 1249, doi: 10.1007/s12520-016-0454-5.

Anna is currently at the end of the first year of her RIFP fellowship, with a further year to go.



# Research Highlights: Kevin Glize – Central Laser Facility

## *Understanding Laser Plasma Instabilities*



Understanding laser passage within a plasma medium is of primary importance for the areas of high energy density physics (HEDP) and ignition schemes of inertial fusion confinement (ICF), in which laser beams are

used to initiate nuclear fusion within a deuterium and tritium fuel target. Indeed, when a laser beam is propagating into a plasma, non-linear coupling occurs between the beam and the modes present in the plasma. Some of these couplings are unstable and lead to harmful effects such as the scattering of incoming laser light, generation of hot electron populations and energy redistribution of the laser beam. Kevin's particular project has involved the study of laser-plasma instabilities (LPI) in the context of ICF, in both direct (laser beams aimed directly at the fuel target) and indirect (laser beams aimed at the enclosure around the target) drive schemes.

Of particular problem are stimulated Raman scattering (SRS) and two-plasmon decay (TPD) instabilities and crossed beam energy transfer (CBET). Kevin's project aimed to explore the LPI processes and how they are driven, by both numerical and experimental methods, and to consider mitigation methods to reduce the impact of this effect. His work has involved proposing and performing experiments at national laser facilities, and has led to two possible ideas to help mitigate SRS instability. He is continuing to explore both of these, in collaboration with colleagues in the UK and overseas, with future laser experimental time accepted in both the UK and France.

Further reading: Stimulated backward Raman scattering driven collectively by two picosecond laser pulses in a bi- or multi-speckle configuration, K. Glize et al., *Physics of Plasmas* 24 (2017) 032708, doi: 10.1063/1.4978879; Polarization modification of a spatially randomized picosecond-pulse beam during its amplification by a nanosecond pump, C. Neuville, K. Glize & al., *Physics of Plasmas* 24 (2017) 112110 doi: 10.1063/1.4998657

Following his RIFP Fellowship Kevin has continued to pursue his project as a post-doctoral researcher in the Central Laser Facility at the Rutherford Appleton Laboratory.

# Training and Other Activities

## *Some of the RIFP researchers at work*

The RIFP scheme aims to give early-career researchers a wide variety of training and development experiences – not just within their technical areas, but also in a range of wider, transferable skills.

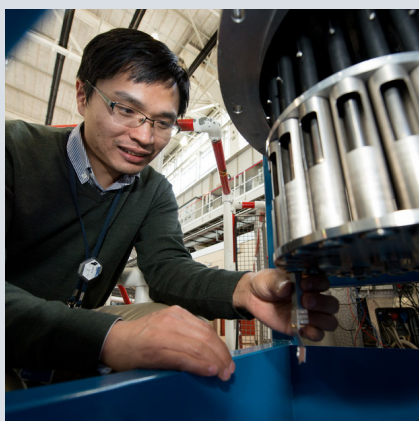
RIFP researchers to-date have undertaken training in public engagement activities, scientific communication with a senior journalist from Nature, grant proposal writing, ‘unconscious bias’ awareness, coaching, facilitation skills, financial management, project management and a variety of other areas.

RIFP researchers have also been involved in a wide variety of public engagement activities, helping the general public to learn about their research as well as developing their own communications skills. For example, researchers have been involved in a public open day at the ISIS Neutron & Muon Source; Royal Observatory Edinburgh public open days; star gazing evenings at a local primary school; hosting a work

experience student; giving tours of their facility; helping at a local museum open day; and giving talks and tours for the EU Researchers Night held by Oxford University.

Researchers have also benefited from opportunities to form new collaborations with university partners or other facilities, and involvement in grant proposals to further support their research areas. They have also been able to gain experience through PhD or graduate student supervision.

Some of the first cohort of RIFP Fellows have now left the programme and gone to new positions. Their destinations have included: a permanent position in their STFC host department; a permanent position in a German Aerospace Centre; a permanent position in a national institute; fixed term positions within STFC departments, universities in other countries or in large science infrastructures.

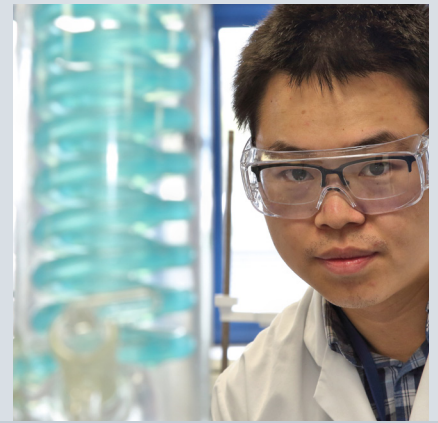


**Lei Ding** Lei Ding mounting a sample for neutron studies at the ISIS Neutron & Muon Source. Lei is using neutron scattering to investigate multiferroic materials – substances whose atoms can order both magnetically and electrically, and which may have applications in computer memory and storage devices.

**Shyamal Mondal** is working in the Accelerator Science and Technology Centre exploring new technology for future accelerator sources based on Terahertz radiation manipulation of the particles.



**Yao Chen**, an RIFP researcher studying surfactant (soap) molecules which are widely used in detergent and pharmaceutical industries. Here he is working in the laboratory where he prepares samples.



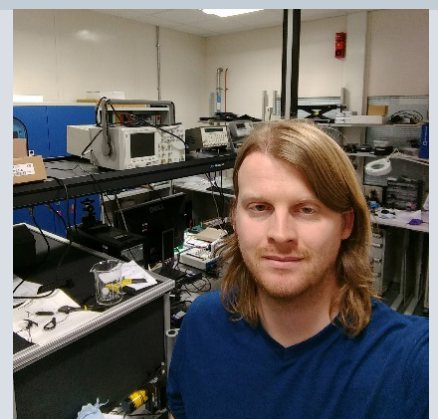
**Nilanjil Misra** is working in the Accelerator Science and Technology Centre exploring novel alloy-based superconducting thin films for use in particle accelerator radio frequency cavities.

**Jhuma Sannigrahi** is an RIFP researcher working at the ISIS Neutron & Muon Source studying materials with novel magnetic structures and interactions between the atoms. Here she is helping out at a public engagement day, welcoming visitors to the facility.



**Jacob Linacre** was an RIFP researcher before gaining a Marie Skłodowska-Curie Individual Fellowship. His project involved using data from the CMS detector on the Large Hadron Collider at CERN to look for new physics involving top quarks.

**Ashley Hughes** Ashley Hughes is working at the Diamond Light Source developing time-resolved pump-probe far-UV polarised light techniques for studies in areas such as pharmaceutical action or protein behaviour.





Rutherford Appleton Laboratory, Daresbury Laboratory, UK Astronomy Technology Centre