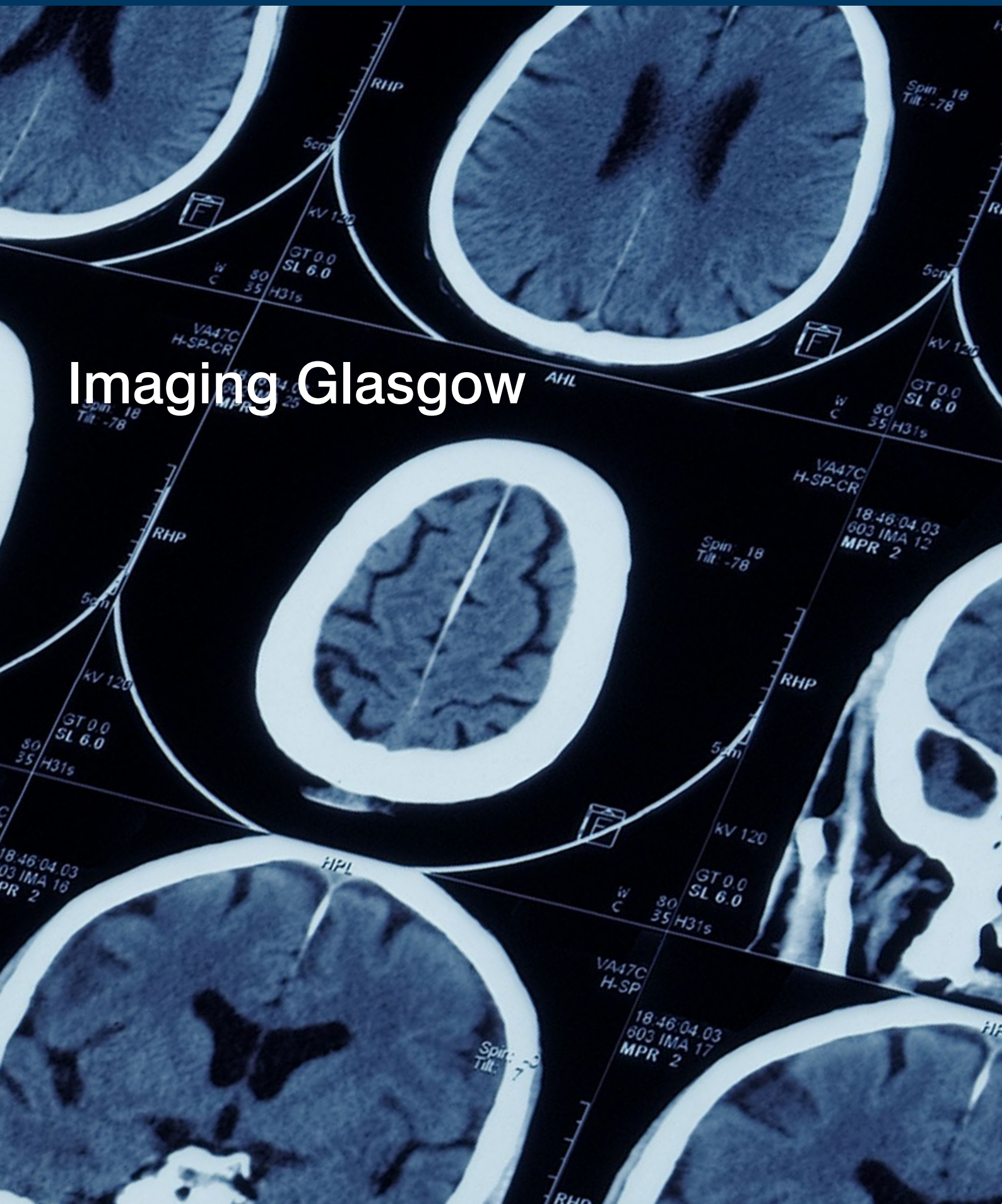
University of Glasgow

Imaging Glasgow



Foreword

The University of Glasgow ranks in the top 1% of the world's higher education institutions and has an ongoing focus on research excellence. Within the Universisty, the College of Science and Engineering and the College of Medical, Veterinary and Life Sciences are home to wide-ranging and high quality imaging research. Imaging Glasgow has been established both to increase cooperation within the University and to promote our expertise to potential external partners.

Imaging is an inherently interdisciplinary activity. The acquisition, reconstruction and interpretation of images require expertise from a wide range of disciplines, all of which are present at the University of Glasgow.

Among the researchers participating in the imaging network are representatives from such diverse fields as archaeology and bioengineering, biochemistry and geology, electrical engineering and dentistry, computing science and veterinary medicine.

The imaging network at the University of Glasgow offers access to our world-class research and infrastructure, tackling the complete range of challenges faced in modern imaging applications.

Working together, we believe we can do more. Interdisciplinary activities fostered by Imaging Glasgow thus provide us with a mechanism to propose new ideas, increase the impact of our research, and improve the capabilities of the projects on which we work.

We trust that this brochure will provide a clear view of our activities and the synergies between them. Going forward we are looking outward to new partnerships and hope that you will be able to engage with us in the future.

Prof John Chapman

Head of College of Science and Engineering

University of Glasgow

Working with the University of Glasgow

The University of Glasgow has a strong track record of collaborating with industry and other research institutions.

We have successfully helped many organisations to strengthen their capabilities and competitiveness through a range of engagement methods. The University's Knowledge Exchange team are highly experienced in working with collaborators; linking industry to academics who can provide the necessary technical programme and deliver the most appropriate solution. The options outlined below demonstrate our commitment to engaging with external partners.

Vouchers

Awards of up to £5k are available to Scottish based companies to work with academics on activities such as: problem solving, proof of concept and technology demonstration. This support helps to create long-term collaborations between SMEs and the University of Glasgow. Priority is given to projects that assess both the feasibility and potential of a new product, process or market and can lead to opportunities to attract follow-on funding.

Student Projects and Industrial Studentships

Student projects are an excellent way for companies to engage with the University to gain access to new ideas, expertise, and capability via the student and their academic supervisor. This approach has the added benefit of allowing the student and the company to consider if there may be future employment opportunities. By sponsoring a studentship the industry partner can specify a PhD topic and work with the student and academic supervisor to access basic research outcomes relevant to their business.

Knowledge Transfer Partnerships (KTP)

KTPs enable businesses to work with the University, bringing knowledge and expertise into your organisation to help solve important technical or business problems.

A KTP Associate, usually a recently qualified graduate, will work within your business to manage the project, apply their own knowledge, and ensure that University expertise is available to your company.

Collaborative research

By collaborating with us your company can benefit from extensive and ongoing input to the research process. You can also gain from access to world-class research expertise and facilities. Jointly we can seek external research funding from organisations such as: Technology Strategy Board, European Commission, Ministry of Defence and Research Councils.

Strategic partnerships

Strategic partnerships deliver research and commercial synergy that neither partner could achieve alone. In many instances, dedicated research laboratories have been established, which significantly extend the capabilities of the industrial partner.

If you would like to engage with the University via any of these routes, please contact us for advice and support to forge new relationships, develop projects and access leading edge research capabilities.

Consultancy

As one of the UK's leading research universities, the University of Glasgow has an outstanding record of achievement in a wide range of subject areas. Our research experts can be relied on to provide substantive opinion and consultancy.

Contract research

The University's expertise and facilities cover a wide range of disciplines allowing us to offer you unique, inter-disciplinary solutions to satisfy your research requirements. Contract research services are tailored to meet the specific needs of individual organisations; projects are well managed and results delivered on time and on budget.

Our wide ranging experience includes working with international blue chip companies from many sectors.

Business Development Team

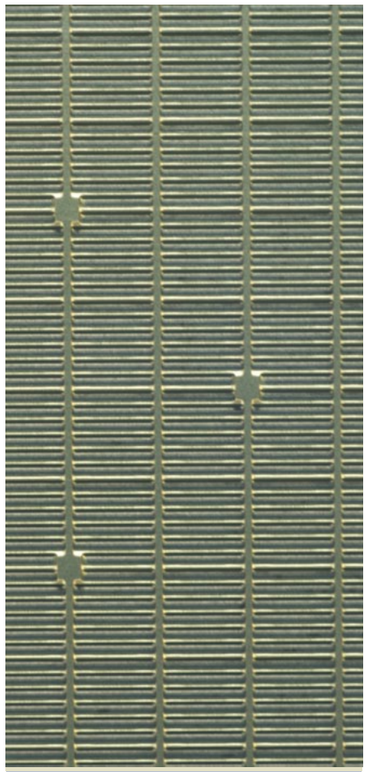
scieng-bdm@glasgow.ac.uk

0141 330 2338/2731

Table of Contents

Position sensitive photon detection devices for high rates and high time resolution

Dr B. Seitz



Contact:
Dr Bjoern Seitz

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

bjoern.seitz@glasgow.ac.uk
Tel: +44 (0)141 330 5118

The challenge

Modern detector systems in nuclear physics require photon detection systems for tracking systems, timing measurements, calorimetry and particle identification detectors. These applications require the detection of single photons at very high detection rates, position resolution and with time resolutions better than 100ps. Similar requirements and applications can be found in many medical imaging modalities. Our work aims at providing the next generation of photon detection devices for applications in fundamental research and elsewhere.

How it is solved

We are specialising in the application of position sensitive photon detection devices for highly granular readout of scintillation detectors for fundamental science, industrial and medical applications, with high rate Cherenkov imaging devices as the most challenging. We are working with leading manufacturers and leading laboratories worldwide, performing in-depth tests on gain, efficiency, time resolution and other response parameters, driving new developments in close collaboration with industrial partners. We also perform very detailed simulation of the devices under test. In addition to bench tests, we test the devices in benchmark detector systems at a variety of test facilities.

Why it is important

The use of position sensitive photon detection devices will find widespread application in a large variety of imaging applications. They are needed everywhere where a highly granular detection of medium to high energetic radiation is required. Medical applications include Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) systems or fluorescence imaging, industrial applications could include for example large area tracking and monitoring devices. They are also mandatory for future detectors for large scale fundamental physics research.

"We are working with leading manufacturers and leading laboratories worldwide to drive new developments in close collaboration with industrial partners."

Microscopy analysis of living cells

Dr I. Watson

The challenge

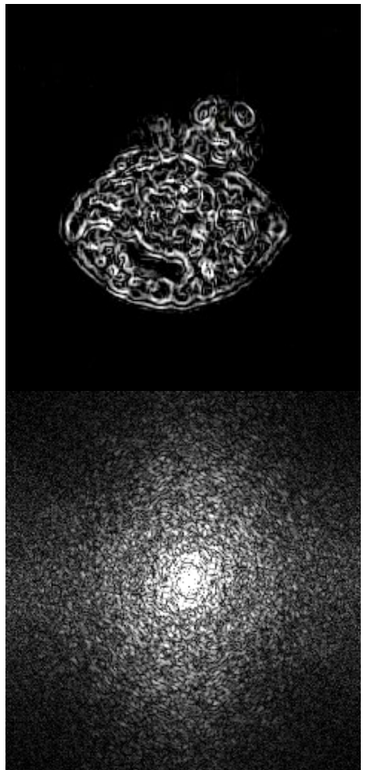
Real time analysis of microorganisms or living cells leads to greater understanding of their behaviour, morphological changes and population dynamics. The cell response during stressed conditions or the life cycle can be identified, leading to novel ways of identifying vitality, death and efficiency of sterilisation processes.

How it is solved

Image processing algorithms were developed and validated to quantify the morphological structure and temporal characteristics of microorganisms. *Euglena gracilis* was chosen as it provided an ideal, well known model to investigate transient analysis imaging methods of live cells. *Euglena gracilis* moves at velocities of the order of micro-meters per second and the cell's morphology varies between cylindrical to elongate and ovate. Real time videos of the microorganism from various microscopy systems (such as bright, dark field and an in-house laser microscopy systems) were captured. The images were processed and analysed to quantify the morphology, structure and temporal characteristics and cell death.

Why it is important

This work allows the development of systems for assessing how microorganisms respond to a change in stimuli. Current work is identifying patterns of behavior with growth and death cycles. Other work is investigating microalgae growth to produce biodiesel, correlating morphology and population dynamics with optimal component production.



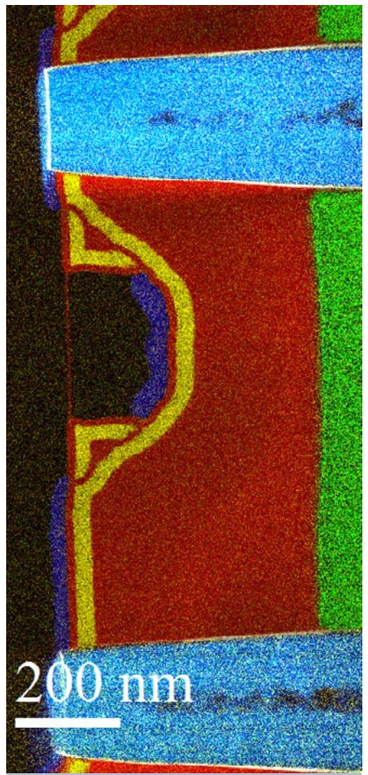
Contact:
Dr Ian Watson

School of Engineering
University of Glasgow
Glasgow
G12 8QQ

ian.watson@glasgow.ac.uk
Tel: +44 (0)141 330 5258

Materials studies down to the atomic scale

The Kelvin Nanocharacterisation Centre



Contact:
Dr Donald MacLaren

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

donald.maclaren@glasgow.ac.uk
Tel: +44 (0)141 330 5886

The challenge

Understanding how materials are structured from micrometres down to the atomic scale is essential to the design of technologies ranging from microelectronics to thin-film coatings and medical implants. Structural features on atomic length scales often enhance or impair the function of high-performance materials.

How it is solved

Recent advances in electron microscopy now allow the physical and chemical characteristics of materials to be mapped on an atom-by-atom basis. The Kelvin Nanocharacterisation Centre houses world-leading electron microscopes, spectrometers and sample preparation facilities; these have enabled the study of materials ranging from diamond coatings for the liners of fusion reactors to polymeric electronic devices. The recent installation of a JEOL ARM scanning transmission electron microscope brings substantially improved time, energy and spatial resolution and allows the chemical composition of materials to be mapped with nanometric precision across micrometre length-scales within minutes (see image).

Why it is important

Our expertise is relevant wherever material properties are important and wherever the link between material structure and function needs to be understood. For example, the constant down-scaling of microelectronic device dimensions will be compromised by nanometre-scale defects that are readily assessed by electron microscopy, providing essential data for device optimisation.

Current studies include:

- nanomagnetics and spintronics;
- interfacial chemistry of functional ceramics;
- strengthening of automobile body steels;
- contacts and gate oxides in III-V semiconductors;
- artificial multiferroic oxides for data storage devices;
- functional studies of materials for energy generation;
- polymeric thin film electronics;
- catalytic nanoparticles and coatings.

Imaging Spectroscopy And Analysis Centre (ISAAC)

Mr P. Chung and Prof M. Lee

The challenge

To generate high resolution images and detailed analyses of natural and synthetic materials with minimal preparation. The sample range is extensive and includes biomaterials, cells, minerals, metals, polymers, electronic components as well as artworks and textiles. The challenge is to determine what these materials are made of and how they function and this requires analysis in the native state.

How it is solved

ISAAC is fully equipped with state-of-the-art analytical and imaging capabilities in scanning electron microscopy and Raman spectroscopy. Materials can be analysed without coating and even when wet. The chemical composition of materials can be measured in the context of the structural details providing exquisite spatial resolution. High and low vacuum chemical analyses are also available along with crystallographic analyses. Construction of 3D images allows accurate measurements of micro- and nano-scale features.

Why it is important

ISAAC enables companies to have access to state-of-the-art instrumentation and expertise in order to receive rapid, accurate solutions to solve problems and optimise processes.

Recent ISAAC cases have: identified defects in LED displays, characterised fuel deposits in engine valves and has also instigated improvements in manufacturing of biomedical implants and authentication of fine artworks.

Contact:
Mr Peter Chung

School of Geographical & Earth Sciences
University of Glasgow
Glasgow
G12 8QQ

peter.chung@glasgow.ac.uk
Tel: +44 (0)141 330 5466/5505

Computer vision for space applications

Dr N. Labrosse, Dr L. Fletcher, Dr I. S. Heng, Dr Z. Li and Dr J. P. Siebert

Image credit: ESA

The challenge

As image resolution from space-based observatories increases, extracting information in a timely manner and providing it to end users is more and more challenging.

It is no longer sufficient to be able to enhance an image or detect and measure a particular visual signal: complex systems are often required to automate the analysis of potentially hundreds of thousands of images in an experiment. Therefore, a complete semantic hierarchy of computation must often be established in order to undertake the analysis of images required to replace human intervention and therefore enable experimentation that would otherwise be rendered intractable. University of Glasgow researchers across a wide spectrum of disciplines face similar challenges.

To be more effective in research based on satellite imaging data and to provide better value products to end-users, University of Glasgow researchers must coordinate their efforts and develop a strategy for image processing. The variety of images to deal with depending on the characteristics of the instrument and the target, however, makes the development of a unique solution challenging to achieve.

How it is solved

Researchers from the College of Science and Engineering have developed a number of state-of-the-art image processing algorithms to solve specific problems and advance in their own fields. New, long-term collaborations involving the computer vision experts and the users who need to solve these challenges to advance their research have been initiated. Developing these new collaborations will lead to step-change improvements in the performance of our own algorithms. Our activities are initially focused around space techniques and applications, but the experience gained and the techniques developed will be transferable to other disciplines.

Why it is important

This research can help us to detect the initial conditions in the solar atmosphere that are likely to lead to an Earth-directed eruption capable of knocking out satellites. This requires analysing and interpreting automatically a large amount of data from different instruments. These different observables then must be 'united' in a meaningful and timely way to inform satellite operators of potential hazards.

Rapid and robust image processing algorithms such as feature extraction, image mosaic and time series analysis are in high demand for rapid response to natural hazards using remote sensing observations.

Contact:
Dr Nicolas Labrosse

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

nicolas.labrosse@glasgow.ac.uk
Tel: +44 (0)141 330 6971

Hyperspectral imaging

Prof A. Harvey

The challenge

Hyperspectral imaging enables the remote mapping of chemical distributions based on subtle variations of spectral signatures. Application areas are wide ranging: from biomedical imaging, through remote sensing for agriculture and mineral exploitation, to surveillance. Application of the technique is restricted by challenges of recording high quality, potentially time-resolved data with instruments that can be employed outside of the controlled environment of the research laboratory and of understanding the phenomenology of recorded data.

How it is solved

We have developed and applied a range of patented hyperspectral imaging techniques that enable real-life applications. These have employed inventive approaches to optical instrumentation, enabling time-resolved or snapshot spectral imaging of transient phenomena; inherently robust Fourier-transform spectrometers for improved sensitivity; and biomimetic foveal or random spatial access spectral imaging to mitigate the data bottleneck constituted by detector.

Why it is important

Time-resolved hyperspectral imaging is essential for applications such as measuring oxygenation in the retina or elsewhere in the body and for time-resolved imaging of transient phenomena such as combustion kinetics or for military surveillance. Random access enables rapid chemical identification and quantification in vivo or at standoff, for example using fluorescence or Raman spectroscopy. Applications range through industrial inspection, endoscopic imaging, microscopy and standoff detection of explosives.

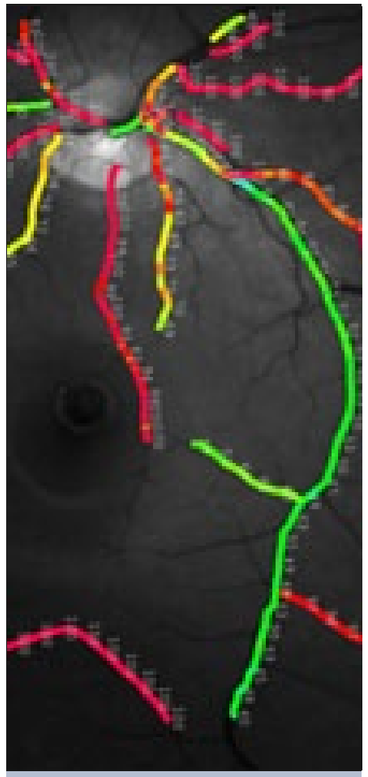
Contact:
Prof Andy Harvey

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

andy.harvey@glasgow.ac.uk
Tel: +44 (0)141 330 8606

Retinal and biomedical imaging

Prof A. Harvey



Contact:
Prof Andy Harvey

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

andy.harvey@glasgow.ac.uk
Tel: +44 (0)141 330 8606

The challenge

Imaging of the retina is the dominant clinical tool for monitoring health and screening for the retinal diseases that afflict the ageing population or as a window on systemic body health. Some well-developed retinal diseases can be detected using conventional colour photography of the retina and newer techniques based on low-coherence interferometry and polarimetric imaging enable retinal structure to be measured. We spectrally map biochemical concentrations in the retina since they provide a direct route to inferring retinal function or the accumulation of chemicals associated with disease. A major challenge is to achieve this with the accuracy and reliability required to satisfy science and clinical needs.

How it is solved

We have developed a range of hyperspectral imaging techniques for researching and exploiting spectral characteristics of the retina for the detection of retinal disease. This involves both flexible hyperspectral imaging for accurately researching retinal spectral characteristics and unique snapshot multispectral imaging for specific and clinical applications. The most important of these is oximetry of the retinal vasculature and choroid. Calculation of retinal chemical maps is achieved using algorithms based on physical optics models for light propagation in the retina supported by holistic Monte-Carlo modelling and *in vitro* and *in vivo* experimental validation.

Why it is important

By 2020, glaucoma, diabetic retinopathy and age-related macular degeneration will afflict two hundred million people worldwide. Spectral imaging offers a non-invasive method with unique capabilities for aiding the detection and treatment of 80% of these diseases. Characterisation of systemic health is possible by exploiting this unique window on the vasculature.

Computational imaging

Prof A. Harvey

The challenge

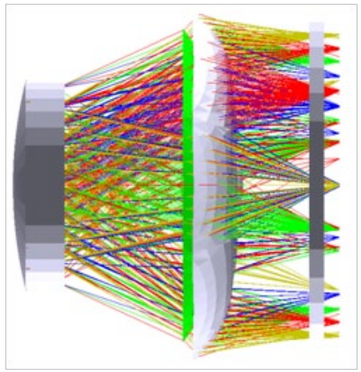
The development of modern optical systems is intricately concerned with the control of optical aberrations: traditionally optical performance can be improved only by increasing optical complexity and cost. The electronic revolution that has enabled doubling of computational power or detector pixel count every eighteen months has had little impact on the optical contribution to optical imaging systems - today's lenses are very similar to those used in the nineteenth century.

How it is solved

Computational imaging is a new approach in which the role of processing is jointly accomplished by optics and digital computation allowing the burden of complexity to be transferred from high-cost, inflexible optics to low-cost agile electronics. The role of the optics is now to enable the recording of information at the detector that can be used to computationally construct an image; this frees the constraints on the optics so imaging can now be achieved where all objects in a scene are in focus and the imaging can be achieved from unconventional shapes – even from flat surfaces - and at a lower cost, weight and volume.

Why it is important

Hybrid optical/digital imaging using wavefront coding can enable imaging with a ten-fold increase in depth-of-field. Multi-scale and multi-aperture imaging paves the way to forming scenes with gigapixel resolution using simple detectors. The use of low-cost digital mirror devices enables the direct and agile recording of images using single detectors at wavelengths from the ultraviolet to the thermal infrared. The use of compressive recording enables these images to be recorded rapidly and with agility. These benefits have applications in cost reduction and miniaturisation of cameras ranging from military thermal imaging to mobile phones and for new capabilities in biomedical imaging.



"Computational imaging can achieve cost reduction and miniaturisation of imaging systems with new or improved capabilities in military, thermal and biomedical imaging applications."

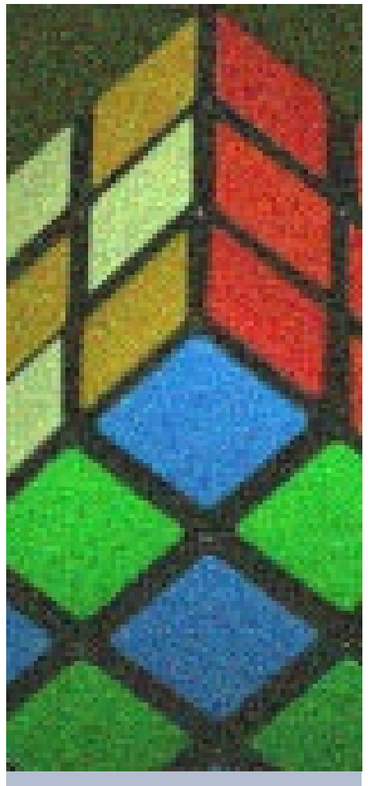
Contact:
Prof Andy Harvey

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

andy.harvey@glasgow.ac.uk
Tel: +44 (0)141 330 8606

Single pixel camera

Prof M. Padgett, Prof A. Bowman and Prof A. Harvey



Contact:
Prof Miles Padgett

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

miles.padgett@glasgow.ac.uk
Tel: +44 (0)141 330 5389

The challenge

Thanks to the development of CMOS technology employed in digital cameras and camera phones it is now very easy to record high quality images in the visible region of the electromagnetic spectrum. The same technology is not however available outside the visible where cameras are expensive or even non-existent. Moreover, issues still exist even in the visible region, for application in which the user might wish to record in a different format compared to RGB.

How it is solved

One way of creating an image of an object is to project a series of known patterns towards it and then use a single element detector to measure the strength of the back scattered signal. After repeating the process multiple times using a series of known patterns and recording the resulting back scatters, the information on the object exists but needs to be reconstructed into an image that can be interpreted by the human eye.

In a similar way to which JPG compression allows users to store an image with a fraction of the file size, the number of patterns required to obtain an image of the object is far fewer than the number of required pixels. Research is currently ongoing to establish how many patterns are required to obtain the desired resolution. This data compression system is called compressive sensing, whereas the imaging approach is similarly known as "computational ghost imaging" or "single pixel camera".

Why it is important

The algorithms we are developing for image reconstruction are suitable for real time implementation using a graphics processor. Optically we are developing full colour, hyper-spectral and 3D configurations image of a Rubik's cube obtained using random pattern projection and single photodiodes to measure the backscattered signal.

One of our short term desires is to image the infrared absorption of a hydrocarbon gas leak.

3D Computational ghost imaging

Prof M. Padgett and Prof A. Bowman

The challenge

tereo imaging is usually achieved by recording two separate images to simulate human binocular vision and capture three-dimensional images. 3D pictures can also be made more inexpensively by taking two pictures with the same camera, but moving the camera a few inches either left or right. If the image is edited so that each eye sees a different image, then the image will appear to be 3D.

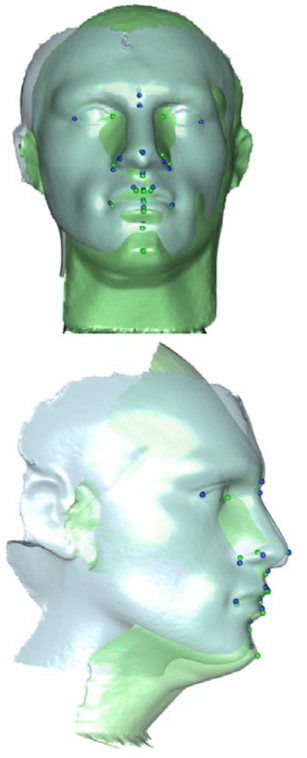
An important difference in our approach is the use of a single projector determines the spatial resolution of the system, removing issues of pixel alignment associated with multiple cameras.

How it is solved

Computational ghost imaging retrieves the spatial information of a scene using a single-pixel detector. By projecting a series of known random patterns and measuring the backreflected intensity for each one, it is possible to reconstruct a 2D image of the scene. We have overcome previous limitations of computational ghost imaging and capture the 3D spatial form of an object by using several single-pixel detectors in different locations. From each detector we derived a 2D image of the object that appears to be illuminated from a different direction, using only a single digital projector as illumination. Comparing the shading of the images allowed the surface gradient and hence the 3D forms of the object to be reconstructed. We compared our result to that obtained from a stereo-photogrammetric system utilising multiple high-resolution cameras. Our low–cost approach is compatible with consumer applications and can readily be extended to non-visible wavebands.

Why it is important

Developments of 3D ghost imaging, for example with the use of broadband white light, could enable ghost imaging systems to become a cheaper alternative for application in 3D imaging and multi-spectral imaging.



Contact:
Prof Miles Padgett

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

miles.padgett@glasgow.ac.uk
Tel: +44 (0)141 330 5389

CASE STUDY: Cube - Portable optical trapping system

Dr G. Gibson, Dr R. Bowman and Prof M. Padgett

Colorado-based Boulder Nonlinear Systems has recently launched a Portable Optical Trapping System known as the "Cube". The Cube provides researchers with a portable, stand-alone, optical tweezers system just one cubic foot in size. The Cube is designed around a custom inverted microscope and the control software was specifically conceived to be easily accessible to non-specialist users, with the added benefit of a multi-touch iPad interface. This compact instrument allows optical trapping and thus physical manipulation of hundreds of microscopic objects in three dimensions using the iPad control to set and move each optical trap independently.

Optical tweezers are an established tool for trapping, manipulation and force measurement of a variety of objects ranging in size from 10's of nanometers to 10's of microns. Holographic optical tweezers employ spatial light modulators (SLMs) and have a number of applications. Trapping examples include cellular organisms, dielectric and metallic spheres, metallic nanoshells, carbon nanotubes, air bubbles, and even water droplets in air. One application of the Cube includes biological research, where it enables measurements of cell properties and controlled studies of how cells interact with foreign objects. Another example of current application is trapping metallic objects and carbon nanotubes for the study of materials with unique thermal and electrical properties.

The concept behind the Cube was developed by the Optics group in the School of Physics and Astronomy at Glasgow in collaboration with Bristol University. The design rights and the software underpinning the optical trap were transferred from the University to Boulder Nonlinear Systems via a royalty free exclusive licence under the Easy Access IP scheme.

The University of Glasgow prides itself on having pioneered this flexible approach to the management of IP, which has now been adopted by a number of leading higher education institutions in the UK and is known as Easy Access IP (http://www.easyaccessip.org.uk/). This scheme reflects the University's commitment to make it easy for industry to engage with us, build mutually rewarding and long lasting partnerships and maximise the uptake of our research by industry so that the impact to society and the economy can be fully realised.

Professor Miles Padgett, Dean of Research in the College of Science and Engineering at the University leads the Optics research group. He said, 'The University recognises the benefits of the Easy Access IP initiative as a means of building long term partnerships with industry. I have long realised the importance of getting research out of the lab and into public use and I look forward to continuing to work with Boulder Nonlinear Systems and making the product a success.'

One of the main advantages of Easy Access IP is the simple one page agreement which makes it possible to accelerate the translation of University technology into marketable products. The deal between Glasgow and Boulder Nonlinear Systems was completed within 8 weeks of the initial discussion and the company's product was successfully launched in September 2012.

Mark Tanner, Vice- President of Boulder Nonlinear Systems, is full of praise of Easy Access IP. He said, "The Easy Access IP Program that the University of Glasgow utilises is a simple and straight-forward approach that focuses on establishing and supporting a relationship to commercialise University developed technology. Boulder Nonlinear Systems appreciates and is honoured to be a part of this programme as it truly establishes a cornerstone for us to build on and be successful."

> "The Easy Access IP deal between Glasgow and Boulder Nonlinear Systems was completed in just 8 weeks from the first discussion."

Technical Specifications

Trapping

- Hundreds (up to 400) of traps achievable, up to 16 supported by iPad interface.
- Traps can be moved interactively at >100 Hz.
- High-speed Spatial Light Modulator operation increases closed-loop trapping and tracking stability.
- System can be set up to trap and image metallic nanoparticles down to 80 nm.

Imaging

- Bright-field, phase-contrast, or dark-field imaging (with appropriate filter).
- Custom re-imaging arm and interchangeable condenser enables different imaging modes to be selected by flipping in/out components without affecting the trapping optics.
- Field of view (FOV) is 12 x 90 µm, pixel size 200 nm (depends on microscope objective/camera).
- Magnification and image size optimised to camera chip size with interchangeable relay optics.
- 640 x 480 camera images at 300 frame per second (fps) full-field, up to 3000 fps for one or two beads.

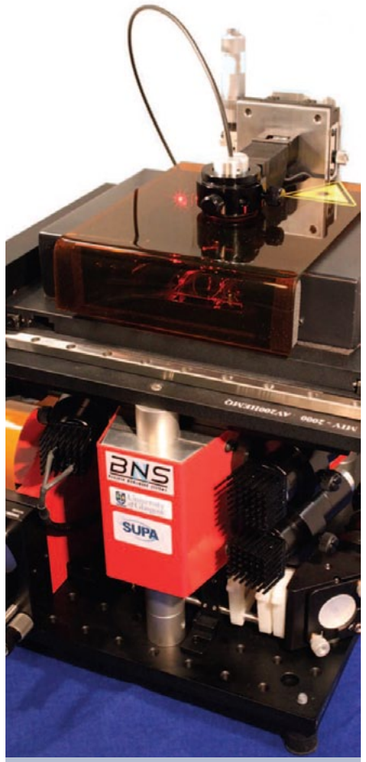
Software Features

- Open Source GUI with dynamic control of trap number, size, position, rotation and pattern.
- Software control of illumination intensity.
- Software control of high speed camera and region of interest.
- Aberration analysis and correction included.
- Comes complete with particle tracking and trap strength measurement software.

Optical Design

- 512 x 512 high-speed, high-efficiency spatial light modulator.
- Fibre laser, 5 W at 1070 nm.
- High NA (1.35) 40x oil immersion microscope objective.
- Dichroic beamsplitter directs >90% of 400-870 nm light to camera port.
- 640 x 480, 300 frames per second camera capable of providing sub-frame windows at faster rates (up to 3000 fps).
- Compact size reduces the impact of thermal drift and mechanical vibrations.
- Minimal moving parts to maximise stability (no floating table required).

For more information please visit http://bnonlinear.com/



Contact:
Prof Miles Padgett

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

miles.padgett@glasgow.ac.uk
Tel: +44 (0)141 330 5389

Improving the performances of CZT detectors for X-ray imaging

Prof V. O'Shea

Contact:
Prof Val O'Shea

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

val.o'shea@glasgow.ac.uk
Tel: +44 (0)141 330 5882

The challenge

Cadmium Zinc Telluride (CZT) has hitherto been impossible to grow in single crystal boules leading to very expensive, artisanal, production techniques. The Particle Physics Group at the University of Glasgow is working with a supplier of CZT that has developed a proprietary technique for growing single crystal wafers with sufficient crystal quality to produce spectroscopic grade material in large quantities.

Using CZT as a detector material presents a different set of challenges when single photon detection needs to be achieved. The relatively energetic fluorescence X-ray production from the constituent atoms of the material requires a particular readout when high spatial resolution using small pixels is required. The range of the fluorescence X-rays in the detector material is large enough to significantly smear the image resolution when using single photon counting.

How it is solved

The challenge presented by using CZT as a detector material for single photon counting with high spatial resolution can be practically eliminated by the use of charge summing across adjacent pixels.

This is a technology that has been developed and implemented in the Medipix3 pixel readout chip. Building on this expertise, the group is implementing charge summing technology across pixels to substantially improve the imaging performance of detectors made from CZT as detector resolution is increased.

Why it is important

CZT is the semiconductor of choice for X-ray imaging at the energies required for most applications in security and medicine.

Wafers of up to 100 mm and 1 mm thick supplied by Kromek are suitable for producing detectors which provide reasonably efficient detection of X-rays up to energies of about 100 keV. This energy sensitivity covers most of the interesting range for security scanning and medical X-ray diagnosis.

Radiation imaging systems

Prof V. O'Shea

The challenge

Radiation imaging systems have a broad range of applications from highly performant scientific instrumentation to specialised imaging techniques with applications in security and medicine. Advanced energy sensitive imaging detectors offer a range of powerful tools for the detection of threats/disease that are not possible with current detector performance. Elemental analysis and tracing through K edge discrimination enables a number of novel diagnostic techniques for materials analysis and medicine.

How it is solved

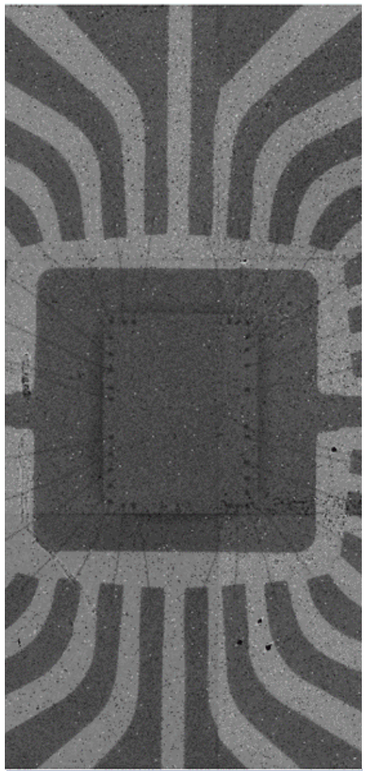
Energy sensitive detection of X-ray quanta in highly pixellated systems can be achieved through the use of custom designed low noise ASIC systems that can be integrated to a suitable detector material. The resulting system can be designed to measure the energy of each individual quantum as it is detected and the image processed with a set of weighted rules depending on the energies detected. Techniques based on imaging gold nanoparticles coated with various biomarkers are just being developed for novel diagnostic techniques. Fluorescence suppression in high Z material improves its performance for imaging higher energy X-rays yielding better system performance for security screening and medicine.

Why it is important

New diagnostic techniques will improve the quality of life of society over the coming decades. A small animal imaging system based on our technology has just been supplied to the Mayo Clinic where clinicians are working on new diagnostic toolsets.

Improved imaging techniques for higher energy X-rays are yielding more powerful systems for the detection of special nuclear materials, which is a topic of major concern in the security arena.

"Improved imaging techniques for higher energy X-rays are yielding more powerful systems crucial in security applications."



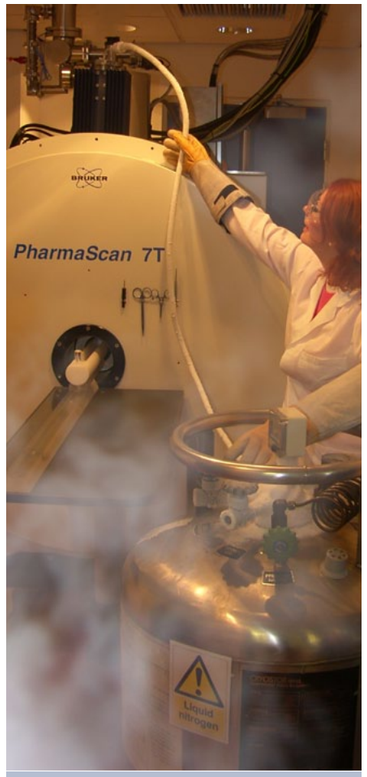
Contact:
Prof Val O'Shea

School of Physics and Astronomy
University of Glasgow
Glasgow
G12 8QQ

val.o'shea@glasgow.ac.uk
Tel: +44 (0)141 330 5882

Glasgow experimental MRI centre

Dr W. Holmes



Contact:
Dr William Holmes

Institute of Neuroscience and Psychology
University of Glasgow
Glasgow
G12 8QQ

william.holmes@glasgow.ac.uk
Tel: + 44 (0)141 330 6984

The challenge

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique widely used in medical imaging. Challenge areas MRI can address are a) Stroke Research; b) Cancer Research; c) Cardiovascular Research; d) Geosciences and Engineering.

How it is solved

MRI provides a method to image the sub-surface non-invasively and without the use of ionising radiations. MRI is particularly suited for imaging soft tissues and organs in the body, with resolution down to 30 microns or less.

The Glasgow Experimental MRI Centre (GEMRIC) has two high-field MRI systems (7Tesla, bore size 15cm) and is fully equipped for pre-clinical *in-vivo* MRI studies.

- Stroke. We use a range of rodent focal cerebral ischaemia models. Most models involve permanent or transient occlusion of the middle cerebral artery. Research goals are to identify those mechanisms responsible for inducing brain damage during ischaemia and reperfusion, and subsequent mechanisms promoting repair and recovery.
- Cancer. The aim is to visualise tumour regression after systemic administration of novel gene medicines, ultimately establishing the morphological characteristics of the tumour along with any functional parameters important in the delivery of the drug. Dynamic contrast enhanced magnetic resonance imaging is a powerful technique for in-vivo imaging of tumours. The time course of the distribution of a contrast agent is an elegant way of characterising barriers to the delivery of drugs within a tumour.
- Geoscience. The emergence of manufactured nanoparticles presents a new threat to groundwater resources. To protect groundwater we must be able to predict nanoparticle pollutant movement within aquifers. MRI can be used to image the transport of nanoparticles inside porous media and real rock, collecting spatially resolved data from which more robust transport models can be developed.
- Civil Engineering. The characterisation of the surface and sub-surface sedimentology has long been of interest to gravel-bed river researchers. MRI provides unique methods to image in 3-D both sedimentary processes and sub-surface flows. Current focus is fluid, sediment and ecological interaction within salmon-spawning gravels in Scotland's rivers.

Why it is important

MRI has revolutionised diagnostic medicine, allowing unprecedented visualisation of anatomy, morphology, blood flow, metabolism and bio-chemistry in vivo. In addition it is now finding application in both Geosciences and Engineering.

The Beatson Advanced Imaging Resource (BAIR) facility

Prof K. I. Anderson

The challenge

The aim of the Beatson Advanced Imaging Resource (BAIR) is to develop a cutting edge imaging facility which will support sophisticated world-class studies of protein localisation and interaction, in living cells, tissues, and animals.

How it is solved

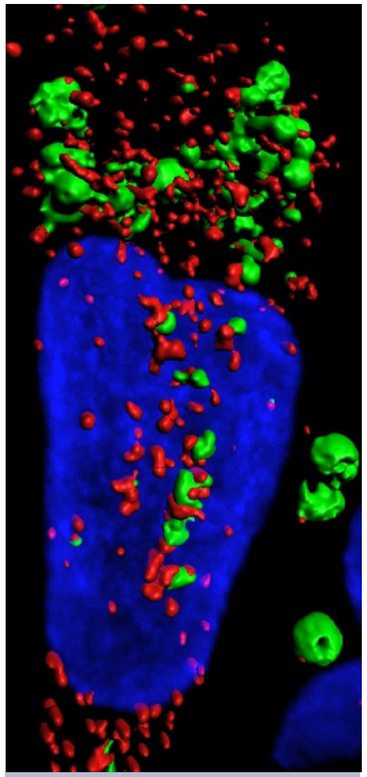
Work in the BAIR is focused on supporting the use of basic and advanced imaging techniques, and assisting in the introduction of new imaging and analysis strategies. This spans the range from simple training through to adaptation of advanced methods for specific research projects. We have identified 5 imaging approaches with the greatest potential to advance the research of the Beatson Institute: two-color live cell FP imaging, photo-activation and photo-bleaching of FPs, TIRF, FLIM-FRET, and in vivo imaging. Through careful selection of new equipment purchases these techniques have been implemented on a wide range of microscope platforms. This provides users with the flexibility to approach the same technique in slightly different ways, which we have found to be critical to success. For example two color FP imaging can be done in wide field, TIRF, and confocal; FLIM-FRET in wide field, TIRF, Spinning Disk, or MPLSM. Furthermore, we have now established a pipeline in which experiments developed in vitro can be translated in vivo.

Why it is important

Modern biological research depends on a wide variety of specialised techniques, which collectively are beyond the grasp of a single research group. Research infrastructure, in the form of services and facilities, is therefore an increasingly important foundation for a competitive research institute.

The BAIR is a vital imaging facility used by many researchers within the institute and beyond both nationally and internationally. We are also a member of Euro Bioimaging and are the site of several proof of concept studies.

"Shared research infrastructres are key to modern biological research as the host of specialised techniques required are beyond the grasp of a single group."



Contact:
Professor Kurt. I. Anderson

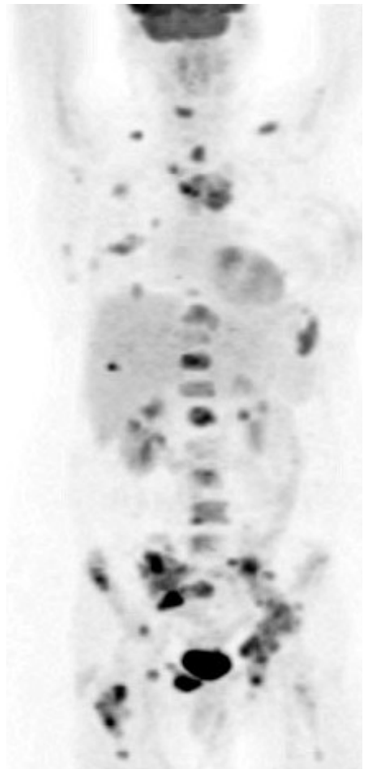
The Beatson Institute for Cancer Research
University of Glasgow,
Glasgow
G661BD

k.anderson@beatson.gla.ac.uk
www.beatson.gla.ac.uk

Image courtesy of Prof Kevin Ryan

Molecular imaging and tracer development

Dr S. Pimlott and Dr F.-W. Poon
[1] West of Scotland PET Centre & Glasgow Royal Infirmary



Contact:
Dr Sally Pimlott

School of Medicine
University of Glasgow
Glasgow
G12 8QQ

sally.pimlott@glasgow.ac.uk
Tel: +44 (0)141 330 6971

The challenge

Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) are molecular imaging techniques that use radioactive molecules or tracers to visualise, quantify and characterise various biological processes at a cellular or molecular level. However, there is currently a limited tool box of tracers available for clinical use.

How it is solved

Highly skilled radiochemists can design specific molecules to target and interact with particular biological processes. These molecules can be labelled with a variety of radioactive isotopes allowing their distribution in the body to be detected by SPECT or PET scanners. Complex reconstruction algorithms are used to produce three dimensional images. The availability of micro SPECT/PET/CT imaging allows us to investigate tracers in the pre-clinical setting before translation in to human studies.

In addition, current research includes the development of novel technology for isotope production and detection of radiotracers in order to improve our ability to supply tracers for clinical use.

Why it is important

Molecular imaging can detect changes in physiological processes at a cellular level. This allows much earlier detection of abnormalities than traditional morphological/structural imaging (e.g. CT/MRI scanning). Early detection leads to better patient management. The availability of biological information from molecular imaging can also aid the development of drugs for the treatment of disease. For example PET and SPECT imaging can be used to rapidly assess the response to therapeutic interventions and can aid dose setting. In addition imaging studies investigating the therapeutic rationale for drug use can be performed.

Design and synthesis of molecular imaging agents

Dr A. Sutherland

The challenge

Many diseases are poorly diagnosed and treated due to a lack of understanding at the molecular level. One approach in gaining a better insight into disease mechanisms, is the design of non-toxic, molecular imaging agents that can bind with high affinity and high selectivity to a targeted biological receptor. The challenge is to generate functionalised molecular tracers that can produce insightful images of a specific disease.

How it is solved

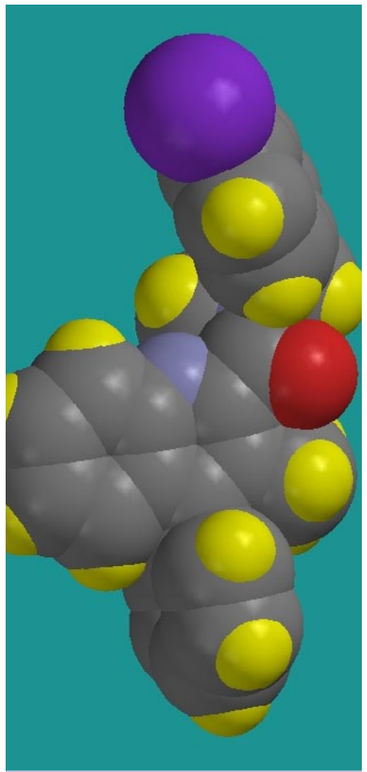
Effective imaging agents can be designed using state of the art molecular modelling and novel synthetic methodology leading to the rapid generation of libraries of small molecules. Testing of these with the biological target can identify a lead compound that can then be labelled and used as an imaging agent in combination with positron emission tomography (PET), single photon emission computed tomography (SPECT) or fluorescent spectroscopy.

Work in the Sutherland group has led to the development of one-pot, multi-bond forming tandem reaction processes that allow the rapid assembly of functionalised drug-like molecules. Used in combination with novel transition metal catalysed labelling techniques has allowed the generation of new, non-toxic molecular imaging agents for a range of neurological disorders and diseases such as cancer.

Why it is important

The development of effective imaging agents will lead to a better understanding of a range of diseases resulting in more accurate diagnosis for patients. There is also the potential to use these in the drug discovery process to establish drug action and create dosage regimens and treatment strategies. Overall, a more general toolkit of imaging agents will lead to more effective healthcare across a wide range of diseases.

> “The development of effective tracers will result in more accurate diagnosis for patients.”



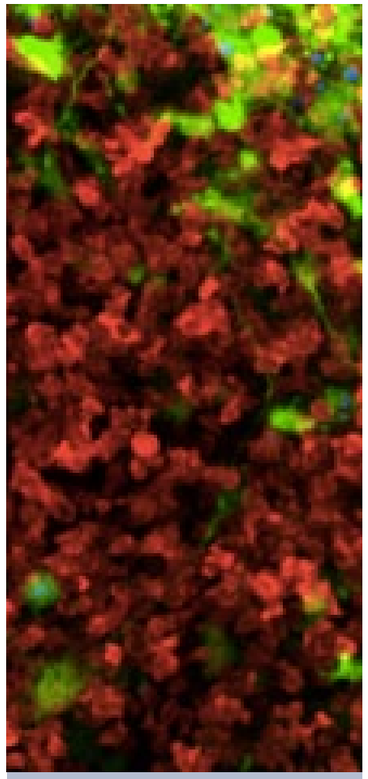
Contact:
Dr Andrew Sutherland

School of Chemistry
University of Glasgow
Glasgow
G12 8QQ

andrew.sutherland@glasgow.ac.uk
Tel: + 44 (0)141 330 5936

Real time in vivo imaging techniques in drug discovery and screening

Prof J. Brewer



The challenge

The immune system is the body's key defence against infectious organisms, however inappropriate immune responses can lead to allergy and autoimmune diseases (e.g. rheumatoid arthritis).

Immune responses are highly dynamic and are spatially organised by the complex anatomy of the immune system. Understanding how the immune system is controlled and investigating how drugs can alter these responses requires an approach to reveal the orchestration of cells and molecules in space and time.

How it is solved

Intravital microscopy is the only approach with the temporal and spatial resolution to fully characterise cellular and molecular processes involved in immune responses in vivo.

Our group has established a 5 channel Multiphoton Laser Scanning Microscope to image at depths and speeds exceeding any currently available system in the UK. It combines a Titanium:Sapphire laser with an Optical Parametric Oscillator to generate a fully tunable, two beam laser source, routed into a laser scanning microscope.

Our state of the art imaging capabilities, together with in vivo models and molecular reporters can identify cell phenotype, specificity, function and fate in a spatiotemporal context *in vivo*.

Image analysis is performed using Imaris and/or Volocity software. The group has also developed novel, automated approaches to determining dynamic colocalisation between cells in vivo over time and continue to drive development of cell tracking software and *in silico* model development in collaboration with colleagues in Mathematics and Statistics.

We have investigated cellular interactions in different tissues in appropriate disease models such as malaria, arthritis and tissue/lymph node interactions.

Why it is important

Cellular and molecular interactions are the key determinants of the decision to induce immunological response. By understanding the basis of this decision making process by the body we can determine protection against infectious and metastatic disease, efficacy of vaccines, or drug intervention in autoimmune, allergic and inflammatory disease.

Contact:
Prof James Brewer

Institute of Infection, Immunity and Inflammation
University of Glasgow
Glasgow
G12 8QQ

james.brewer@glasgow.ac.uk
Tel: +44 (0)141 330 8417

SINAPSE activities within the University of Glasgow

Prof D. Wyper, Prof K. Muir, Dr S. Pimlott, Prof D. Hadley and Prof B. Condon

The challenge

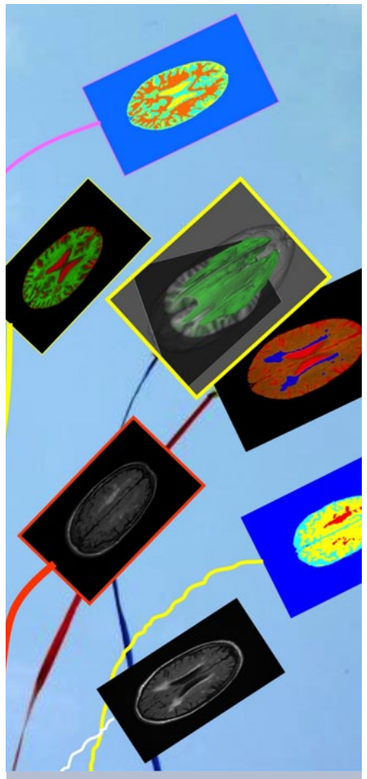
Scotland is a small country. To be competitive internationally and to ensure that innovative developments have access to the required expertise and facilities, partnerships with other institutions are often required. This is particularly the case in medical imaging, where many developments have to be shown to be compatible with the operating platforms established by all the main equipment manufacturers.

How it is solved

SINAPSE was established by the Scottish Funding Council in 2007 to address this challenge. It is one of 14 such 'pooling groups'. The University of Glasgow is one of the founding members. It has many SINAPSE researchers and SINAPSE funding has helped to develop facilities and expertise in medical imaging. Projects led by University of Glasgow researchers can access support from other such pools and other Scottish Universities as concordat agreements are in place. SINAPSE has well-established innovative projects involving other pools such as SUPA [physics] and SCOTCHEM [chemistry] where Glasgow provides the lead researchers.

Why it is important

In the dragons' den of innovation, it is vital that projects progress as rapidly as possible. Many of the developments outlined in this brochure have a SINAPSE connection and have used the SINAPSE network to accelerate progress. The main fields are PET scanning, the production of tracers used in PET, and magnetic resonance imaging where SINAPSE can access all manufacturers' platforms and medical specialists.



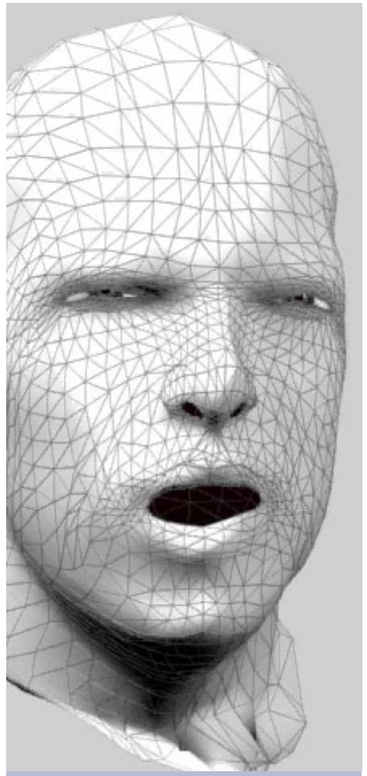
Contact:
Prof David Wyper

School of Medicine
University of Glasgow
Glasgow
G12 8QQ

dave.wyper@glasgow.ac.uk
Tel: + 44 (0)141 638 4199

Computer vision for active 3D imaging

Dr J. P. Siebert and Dr W. P. Cockshott



Contact:
Dr J. Paul Siebert

School of Computing Science
University of Glasgow
Glasgow
G12 8QQ

paul.siebert@glasgow.ac.uk
Tel: +44 (0)141 330 3124

The challenge

Computer-based analysis of images to extract information and classify their contents is becoming increasingly important.

How it is solved

By combining the science of 'photogrammetry' (measurement using cameras) with digital camera technology it becomes possible to capture 3D models of people, animals and objects that are metrically accurate and photo-realistic in appearance.

Furthermore, it is possible to analyse and animate these models by computer for applications such as virtual actors or sports science.

The Computer Vision and Graphics group, CVG investigates fundamental issues of how to analyse images and also how to apply this knowledge within practical applications.

Why it is important

Our projects cover all aspects of human body modelling in 3D, including animation and surface skin modelling. This approach opens a wide array of application areas such as: creative media, engineering, medicine, textiles and clothing, military and security, internet and communications, forensic and fine art.

A key objective of the work of the group is to combine 3D measurement and modelling techniques with image understanding approaches to construct cognitive vision systems that actively search their operating environments using passive digital cameras.

Current research includes:

- Medical and veterinary analysis of 3D surface anatomy to assess change following surgical intervention and surgical outcome prediction.
- Object recognition from 2D and 3D information extracted from static images and moving image sequences.
- Whole body scanning and human/animal form modelling, for production of virtual actors and virtual set-props and real-time "immersive" 3D TV.
- Biologically motivated computer vision, including computational models of the mammalian retina and the early visual pathway for efficient and robust image analysis and interpretation.
- Active binocular robot vision systems, able to operate in unstructured and cluttered real-world environments searching and locating visual cues and objects required in autonomous applications such as unmanned vehicle navigation, flexible manufacture, telemedicine and suspicious object inspection.

Computer vision for autonomous systems

Dr J. Paul Siebert, Dr W. P. Cockshott, Dr G. Aragon-Camarasa and S. Oehler

The challenge

Real-time visual interpretation and visually guided control is a key to enabling applications for autonomous systems such as self-driven vehicles and intelligent robots that interact directly with a dynamic environment. This requires a different approach to traditional machine vision interpretation methods based on the analysis of single images, as employed for image database retrieval or classical visual inspection and quality control systems.

How it is solved

The Computer Vision and Graphics Group, CVG, is developing a real-time binocular vision system intended for robotics applications. Based on the idea of active sensing, pan-tilt units are used to control the gaze of a stereo-pair of cameras to allow them to change their view point, in a manner similar to human eye movements. This sensor configuration enables a scene to be explored visually from different perspectives and thereby additional visual information can be gathered in order to produce a robust and reliable scene interpretation.

A biologically motivated visual processing architecture deconstructs the input image stream into a series of differing spatial scales and analyses this information for tasks such as 3D depth recovery, local visual feature extraction, colour interpretation, motion field extraction and edge contour labelling. A number of intermediate and high-level visual behaviours have been coded to implement functions such as such as camera gaze control, object appearance learning by interaction, visual search and object detection and recognition.

To achieve real-time operation of this complex vision system, expertise in parallel processing that exploits both in multiple CPU cores and special instruction sets implemented in Intel's new generation of multi-core processors is being applied to accelerate system performance.

Why it is important

The primary focus of this research is to develop an active vision system for Glasgow's two-handed clothing manipulation robot, Arcteryx, which is part of a €2.8M EC funded project Clopema: Clothes Perception and Manipulation. When complete, Arcteryx will be housed in a custom laboratory dedicated to investigating visually guided interactive robotics and intelligent control for two-handed dexterous manipulation applications.

The wider goal of this research is to understand how to develop active robot vision systems which are able to operate in unstructured and cluttered real-world environments, searching and locating visual cues and objects required in autonomous applications such as unmanned vehicle navigation, flexible manufacture, telemedicine and suspicious object detection and inspection.

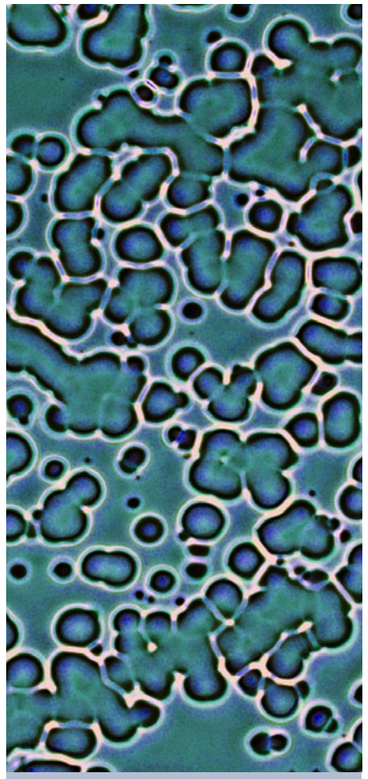
Contact:
Dr J. Paul Siebert

School of Computing Science
University of Glasgow
Glasgow
G12 8QQ

paul.siebert@glasgow.ac.uk
Tel: +44 (0)141 330 3124

Liquid–liquid phase separation

Prof K. Wynne



Contact:
Prof Klaas Wynne

School of Chemistry
University of Glasgow
Glasgow
G12 8QQ

klaas.wynne@glasgow.ac.uk
Tel: +44 (0)141 330 8522

The challenge

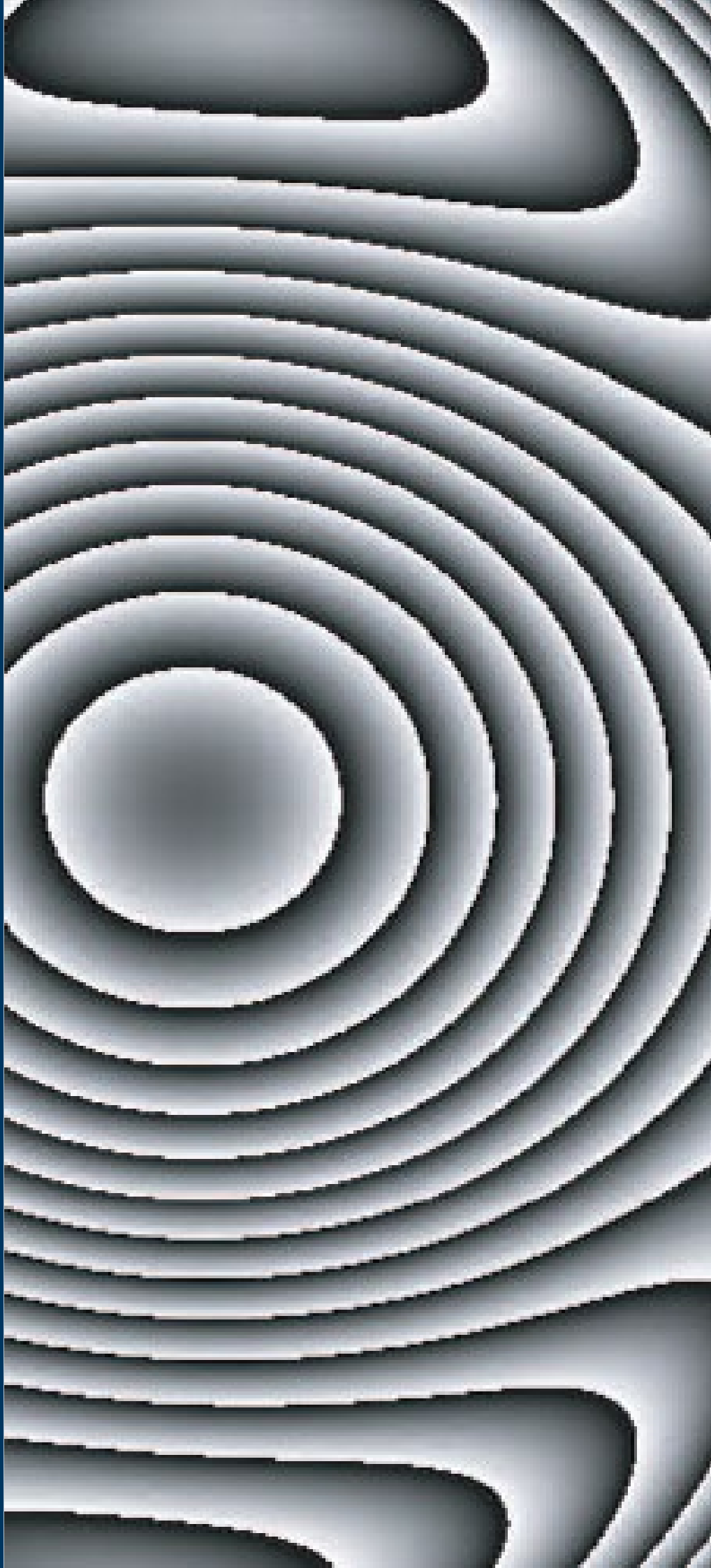
There is increasing evidence that even relatively simple liquids, particularly those that form hydrogen bonds, are not truly amorphous but rather are to some degree structured. It is therefore likely that phase transitions from structured to unstructured or between polymorphs are common. Such amorphous-to-amorphous phase transitions wholly in the liquid phase are crucial to understanding the behaviour of water and biomolecules, and to the technological applications of liquids and solutions in industry. Although such transitions have been observed before using phase contrast microscopy, it is presently unclear what molecular physical changes are responsible for these phase transformations.

How it is solved

We use a range of techniques to elucidate both dynamics from femtoseconds to kiloseconds and structure on length scales from ångströms to millimetres. This will give unprecedented insight into the physical origin of the liquid-liquid phase separation phenomena and allow manipulation and control in future applications. Meso to macroscopic phenomena are studied using optical, confocal Raman microscopy, confocal fluorescence microscopy, and fluorescence lifetime imaging (FLIM). The fluorescence spectrum of solvatochromic dyes, such as Coumarin 153 and Nile Red, is strongly dependent on solvent polarity and a measurement of the emission spectrum is converted to an effective polarity. Thus, these techniques allow us to map molecular environments during the phase separation process.

Why it is important

Understanding the structure of liquids, liquid-mixtures, and solutions is of enormous relevance to chemistry and chemical engineering. The work proposed here is quite fundamental, however, such studies have wide scientific impact due to the enormous range of applications of chemistry in the liquid phase. These include industrial crystallisation of drugs from solution and the role of polymorphs, preparation of nanometre scale materials, electrochemistry, separation technology, and heterogeneous catalysis.



Contact:

Business Development Team

Boyd Orr Building
University Avenue
University of Glasgow
Glasgow G12 8QQ
Scotland, UK

scieng-bdm@glasgow.ac.uk

Tel +44(0)141 330 2338