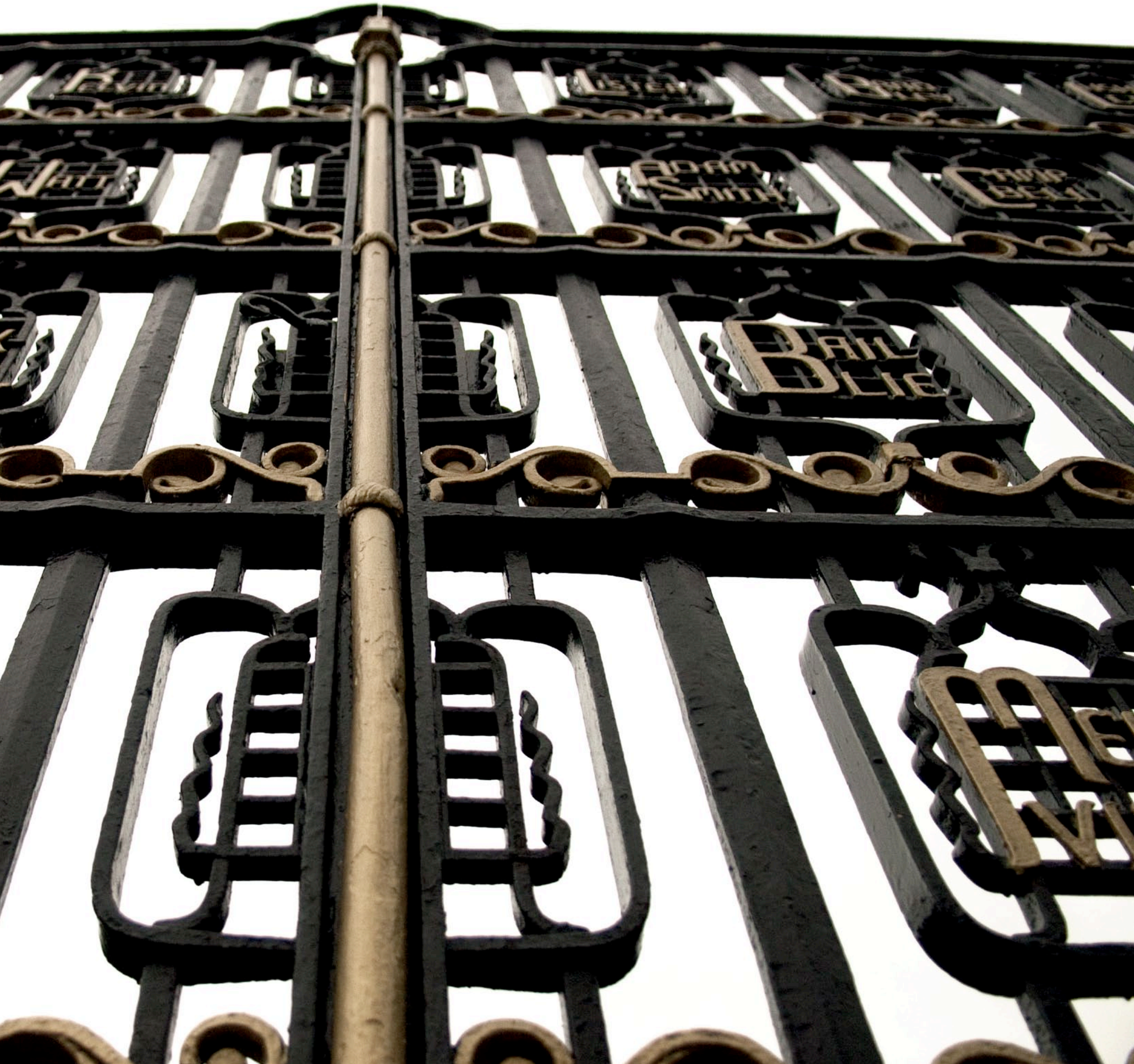
University of Glasgow | College of Science & Engineering

Sensor Systems Research



Sensor systems research at the University of Glasgow

Preface

The University of Glasgow is one of the UK's leading Universities delivering research and knowledge exchange in sensors and sensor systems. Much of the activity is based in the College of Science & Engineering where it is broadly distributed among all our Schools. Our research is supported by Research Councils UK, the European Union, agencies such as SEPA and DEFRA, and a large number of industrial partners. The University has made a commitment to grow our activities further and we are keen to develop new relationships and take existing collaborations in new directions. This brochure provides summaries illustrating the depth and breadth of our expertise.

The University has a distinguished history in science and engineering. Throughout his time at Glasgow, William Thompson (Lord Kelvin) promoted 'practical utilisation of science' and we continue this approach by seeking to develop close connections with industries and agencies both locally and internationally. Increasingly, sensor systems and their internal functions are much more tightly integrated within products, and as technology advances the complexity of a sensor system requires a more formal development methodology. Researchers within the University have recognised this and developed a sensor system representation that identifies functional activities, thus more easily enabling interdisciplinary research. This sensors systems 'stack' approach (see page 5) is rapidly gaining traction within the community and industry as an effective tool for considering complex sensor systems.

This brochure provides a clear snapshot of our activities and I hope it will stimulate you to engage with us. We are very proud of our sensor systems research and trust that it demonstrates the University of Glasgow's commitment to follow Lord Kelvin's ambition to deliver research which is 'practical utilisation of science' into the 21st century.

Professor John Chapman
College of Science & Engineering
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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 Technology Transfer 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 the engagement experience.

First Step Awards and Innovation 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
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, e.g. 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.

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.

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.
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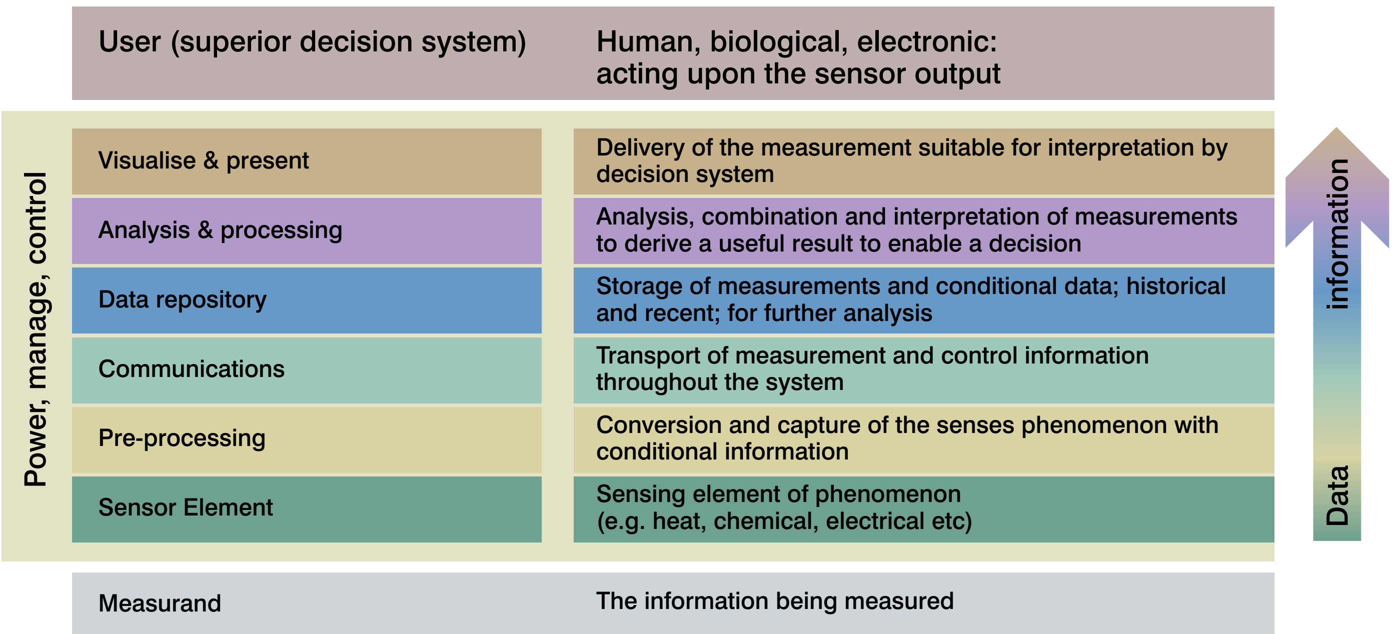
Sensor systems: a hierarchical approach

Sensor systems have grown in complexity so that they now contain many sensors that are integrated to yield sophisticated data. These data need to be combined, processed and communicated to the user where there is an increasing need for automated evaluation and inference to realise high quality information and enable decision making.

Research into sensors and sensor systems is very dynamic and calls for many different skills and areas of expertise to be brought to bear on user defined problems. At the University of Glasgow we have developed a 6 layer 'stack' model to describe the generic functional elements contained within sensor systems, as shown below. The system model mirrors the tried and trusted stack that has been successfully adopted for communication system design. It is comprehensive in its coverage of the technical challenges that we face in sensors research and knowledge transfer, whilst also showing clearly the borders between areas of expertise that are required. The stack seamlessly illustrates the data flow from raw measurand through to tailored information, enabling the end user to make decisions. The model takes into account the broad range of expertise that we can offer collaborators at the University of Glasgow, from basic science, through engineering and computing science, to mathematical and statistical modelling of data to meet specific client requirements.

In this brochure we present some of the ongoing research in the University that covers the layers of the sensor stack. The examples demonstrate just a small sample of the wide-ranging expertise we have on offer here, and that, through collaboration, may be brought to bear of your project needs.

Sensor Systems: data into information

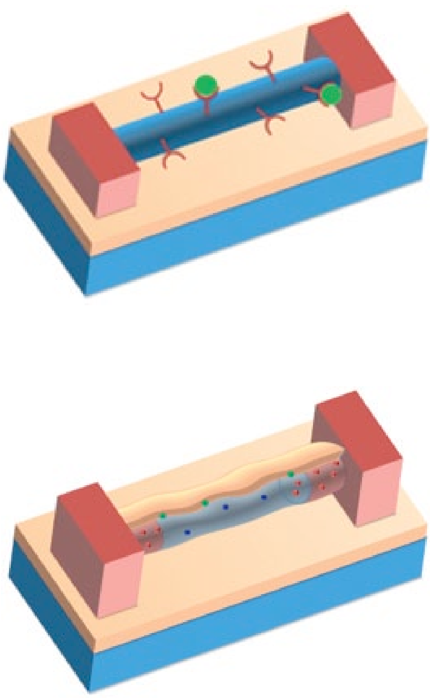


University of Glasgow: Examples of expertise in sensors

			Users and Applications	System Integration	Power, Manage, Control	Visualisation and Presentation	Analysis and Post Processing	Data Repository	Communications and Networking	Transductance and Pre-processing	Sensor Element	Capabilities
Asen	Asenov	Tools for simulating the statistical variability in nanowire biosensors										
Adrian	Bowman	Spatial and temporal trends in river networks and other environmental settings										
Muffy	Calder	Autonomous sensor-driven systems										
Jonathan	Cooper	Advanced diagnostic systems - low cost, miniaturised sensor systems for medical, environmental & industrial applications										
David	Cumming	Ion sensing, integrated plasmonics, terahertz imaging and spectroscopy										
Lyndsay	Fletcher	Detect and characterise energetic solar events										
Charles	Ironside	Tunable quantum cascade lasers and photonic integration										
Nigel	Johnson	Polymer photonics multiparametric biochemical sensor for point of care diagnostics										
John	Marsh	Semiconductor lasers for sensing applications										
Rod	Murray-Smith	Mobile devices with sensors and kinect systems and brain computer interfaces										
Steven	Neale	Optoelectronic tweezers (OET) for medical diagnosis										
Val	O'Shea	Radiation imaging systems										
Miles	Padgett	Environmental gas monitoring, covert imaging, remote sensing										
Douglas	Paul	Silicon nanowires sensors and autonomous sensing power source										
Mathias	Riehle	Nanoparticle translocation across lung epithelia										
Marian	Scott	Environmental informatics - visualisation and statistical modelling										
Bjoern	Seitz	Position sensitive photon detectors										
Joe	Sventek	Wireless network sensor systems										
Iain	Thayne	Technologies and solutions for physically small, low power radio communication										
Susan	Waldron	Using sensor technology to better understand the terrestrial-aquatic C cycle										
Jonathan	Weaver	Functional AFM probes and Compostella										

Tools for simulating the statistical variability in nanowire biosensors

Prof Asen Asenov



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Research opportunity

Nanowire biosensors are currently being developed in industry and academia to enable low cost, portable point of care devices that can perform DNA sequencing and, amongst other applications, detect nucleic acid biomarkers associated with disease. The problem that designers and manufacturers of these devices will be facing is, the spatial and temporal variability that increases with the sensors miniaturisation in a drive to increase the sensitivity. Creative design solutions are needed to ensure the reliability of the systems and the corresponding product in the presence of acute sensors variability. Calibration strategies and signal processing requirements will also be affected by this variability.

How is it solved/purpose of research?

Prof Asenov is developing tools and methodologies that will enable the simulation of the spatial and temporary variability in functionalised NW bio-sensors at the design stage. The tools will demonstrate the impact of the variability on the sensitivity, reliability and yield of these devices. Variability related to the structure and operation of the sensing semiconductor device and variability related to the stochastic nature of the functionalising receptors arrangement and the stochastic nature of the binding process will be taken into account. The primary focus of development is on nanowire sensors offering high sensitivity which are also highly robust in the presence of variability.

Why is it important/what difference will it make (impact)?

This technology will make a marked contribution to two of the important societal challenges in the UK, highlighted also as EPSRC priorities: "Towards next generation healthcare" and "Global Uncertainty". It addresses the challenges of an ageing population and in improving the health of UK citizens at all stages of their lives, through early diagnosis and better treatment. The nanowire sensors targeted in this proposal will power rapid, low cost and high throughput biological tests. Point-of-care diagnostic systems are currently one of the fastest growing areas of health care, with market expected to be worth more than $22.5B in 2013. It is also believed that the development of these low cost, point of care diagnostics will make enormous differences to healthcare in the developing world.

Spatial and temporal trends in river networks and other environmental settings

Prof Adrian Bowman

Research opportunity

Many environmental problems involve the collection of data over time from a collection of sensors which are located across a spatial region. A key aim is to identify trends over time and/or space, in the presence of spatially and temporally correlated noise. A special version of this arises when the sensors lie on a river system, where the flow of water constrains the spatial component into a network structure.

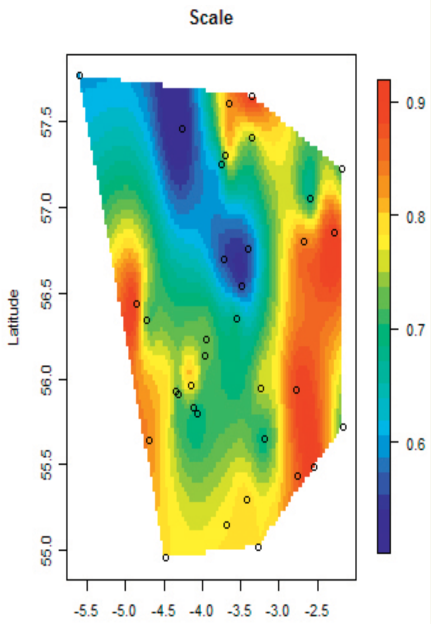
How is it solved/purpose of research?

Methods for spatial modelling and prediction have been developed at a very great pace over the last twenty years and this provides an excellent set of tools for spatial and temporal data. Our interests have focused in particular on models which seek to identify trends and these have been built on flexible regression methods, which is another hot topic in statistical modelling. In addition, we have adapted these methods to the special characteristics of a river network, where distance has to be measured differently, some points are not `flow connected' and dilution effects at network confluences have to be allowed for. We are applying these models successfully to real environmental datasets.

Why is it important/what difference will it make (impact)?

It is important to build statistical models which suitably match the characteristics of the observed data. Ignoring spatial and temporal correlation, or the constraints imposed by flow networks, can lead to models which are inaccurate and potentially misleading. Good models form the basis of good decisions, on management and on policy.

‘...models which seek to identify trends.’



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Autonomous sensor-driven systems

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Research opportunity

Enhanced monitoring and decision-making in autonomous sensor-based systems requires infrastructure that can operate in a changing, uncertain context. For example, changes in environmental conditions and location impact upon the physical context; incorporating new sensors, modifying data formats, and reconfiguring infrastructures, services and requirements impact upon the virtual context. These changes all occur within noisy, lossy and multiple-scale contexts, meaning that the management and decision-making in a sensor network must be driven by uncertain information, modelling, and reasoning.

How is it solved/purpose of research?

We develop and apply techniques from mathematics (logics and dynamic systems), computer science (algebraic specification and model checking), and artificial intelligence (agent logics), to produce new techniques, tools and principles that support smarter, more predictable sensor-based infrastructure. Techniques are applicable to both new software and legacy systems, and can be applied at either/both design-time and run-time verification.

Why is it important/what difference will it make (impact)?

Our techniques are applicable to a wide range of systems, from energy distribution and management, to security and environmental monitoring, waste management, logistics and transportation. We can help the end user answer questions they could not previously answer, for example, quantifying the extent and effect of sensor failures, reasoning about operation within a safe envelope, or criticality of sensors for certain services.

Advanced diagnostic systems - low cost, miniaturised sensor systems for medical, environmental & industrial applications

Prof Jonathan Cooper

Research opportunity

Medical diagnostics are still largely performed in a centralised facility, requiring samples to be taken in a clinic or GP surgery and for the patient to return, often several days later. In both the developed and the developing world there is therefore a need for low cost, disposable point of care devices, which are able to sense analytes from real samples (blood, saliva, urine or faeces).

Similar applications for low cost sensing exist in industry for drug testing (pharmaceuticals), the environment (for monitoring the atmosphere or water systems) and industry (for process development and QA).

How is it solved/purpose of research?

Working with industry, NGOs and local enterprise agencies, we are developing a series of low cost, miniaturised sensors. In some applications, such as environmental sensing, these might be integrated into systems to be able to not only sense analytes, but also interpret the data to provide the user with a clear answer.

In other applications, e.g. the developing world, the sensor may be a very low cost device. Such methods do not exclude high technology methods, although in such cases the innovative step may be in its implementation in a very low cost system.

In many cases, one significant technological bottleneck is in the processing of the sample prior to sensing. This is often not only complex and heterogeneous in nature, but also has a composition which is highly variable (e.g. blood, saliva, faeces will all change in their mechanical properties and composition during the day, with age, with health/nutritional status and with activity/exercise).

Why is it important/what difference will it make (impact)?

In healthcare, in the developed world, sensor technologies that inform the patient at the "point of care" will reduce costs, providing convenient and easy to use tools for diagnostics or for screening. In the developing world, such technologies developed as standalone devices could have a dramatic impact on patient morbidity and mortality in diseases such as malaria, TB and pneumonia which account for 10s of millions of deaths per year.

'...low cost, disposable point of care resources.'

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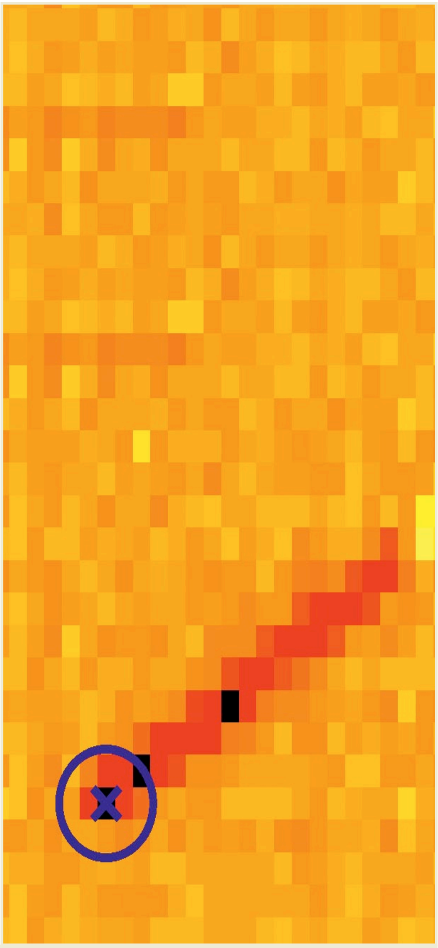
Ion sensing

Prof David Cumming



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Research opportunity

Genomic technology opens up the opportunity for rapid screening of genetic material. The technology can be used not only for whole genomes of humans, but relative genomics and identifying the genome of bacteria and other infectious agents. By doing so, treatment can be more targeted and effective. For such technology to become truly widespread it must become cheap.

How is it solved/purpose of research?

A long and winding path of experimentation with various different devices and systems, and even sensor types, before we decided to focus on the ion sensitive field effect transistor, which can now be made in huge numbers. We investigated single sensors, sensor system on chip with only a few sensors (but complex electronics), and thoroughly demonstrated that standard microelectronics industry technology (CMOS) could be used to make reliable sensors and electronics on the same chip. We then progressed to sensor arrays. The work was identified as being a potential gene sequencing technology and this has since come to pass. The resulting Ion Torrent system is now sold by Life Technologies.

Why is it important/what difference will it make (impact)?

Genomic sequencing technologies are expected to penetrate healthcare markets as diagnostic tools. Sequencing provides scientists with an exact picture of the building blocks which make up any individual, and the microorganisms that affect us. This knowledge can then be used to devise more rapid and targeted interventions. The all electronic system has the potential for miniaturisation and speed up of the next few generations of sequencing technology. Sequencing also has the ability to provide new understanding that will impact upon agriculture, industrial processes, cancer research and public health, amongst others.

Integrated plasmonics: one step to multicolour images

Prof David Cumming

Research opportunity

Colour rendering for packaging and imaging chips requires printing, patterning or processing of coloured dyes and inks, sometimes down to micron levels. In the context of a semiconductor chip this requires several costly manufacturing steps to access a simple, and not necessarily ideal, colour palette.

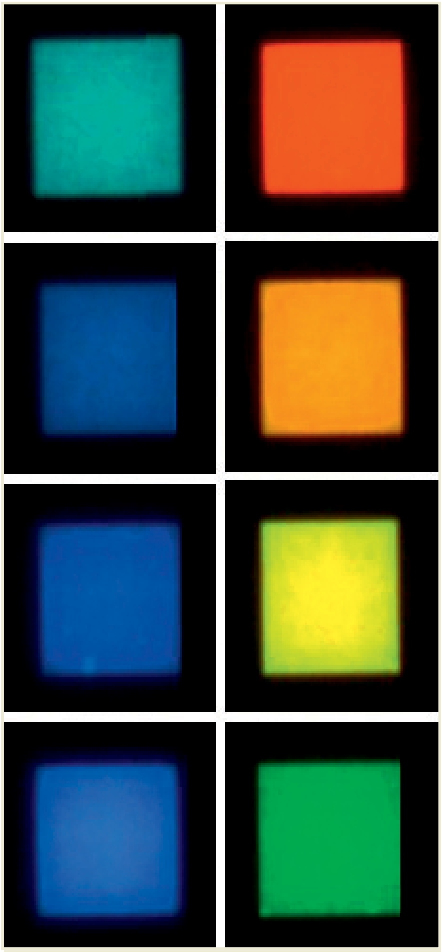
How is it solved/purpose of research?

In our research we have devised the means by which colour filters and other forms of light control can readily be fabricated on to microelectronic camera chips. By carefully patterning a single metal film (we use aluminium) the complete visible spectrum can be accessed and controlled so that multicoloured patternation can be achieved in a one step process.

Why is it important/what difference will it make (impact)

The technique has the potential to reduce manufacturing costs and create potential for hyperspectral imaging.

'...one step process.'



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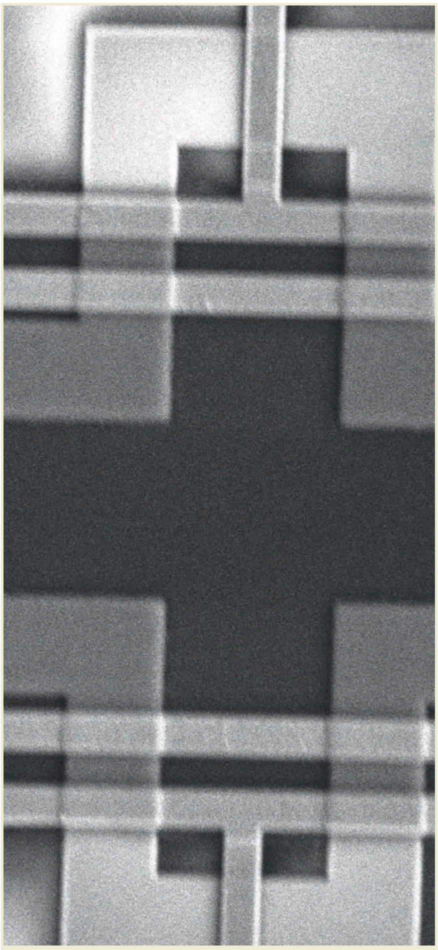
Terahertz imaging

Prof David Cumming



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Research opportunity

A problem in many public spaces and at travel portals is that of security. It is difficult to identify whether or not individuals are carrying items that may be hazardous. Present security arrangements are onerous and expensive to implement. Terahertz has the potential to penetrate clothing and assess the presence of a threat, but unfortunately the instruments work over only short distances, limiting their practical use.

How is it solved/purpose of research?

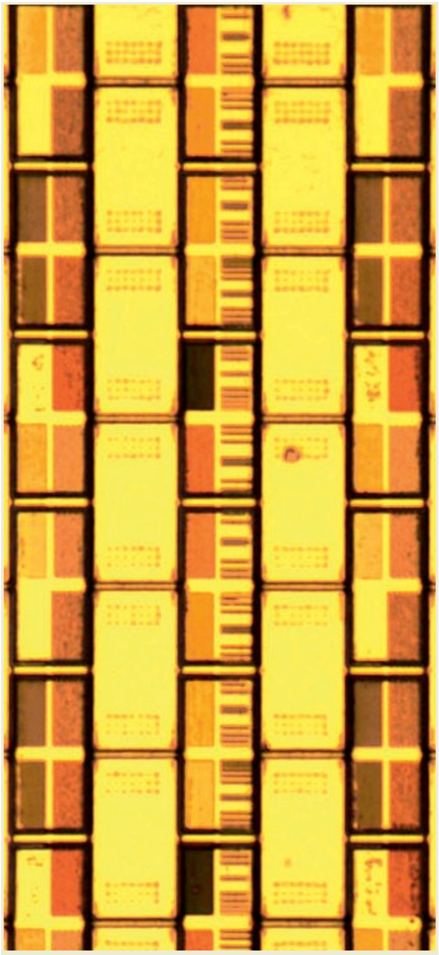
We have developed an imaging system that is capable of long range image acquisition. Furthermore it has the potential for 3D image formation that will aid accurate pinpointing of threatening objects.

Why is it important/what difference will it make (impact)?

The device, if suitably developed, has the potential to improve security, minimise disturbance, and reduce costs where security screening is required.

Terahertz spectroscopy

Prof David Cumming



Research opportunity

Terahertz spectroscopy is widely applicable to security, chemical and biological problems. Unfortunately terahertz signals are strongly absorbed by water and other polar liquids, making measurements very difficult. Work to date to overcome these difficulties has led to the development of sophisticated apparatus that is not easy to use, and has limited bandwidth. As a consequence, uptake of terahertz technology is not presently widespread.

How is it solved/purpose of research?

We have developed a novel liquid sampling device that exploits the behaviour of artificial dielectric optical materials. The device is simple and can be used with a traditional, and widely used, FTIR spectrometer. The device provides an improvement in signal strength of 2 to 3 times that of a conventional measurement, and allows vector measurements of the sample under test to be made over a wide spectrum.

Why is it important/what difference will it make (impact)?

The device will allow more widespread adoption of terahertz spectroscopy and enable a wide range of experimental conditions to be explored more easily than ever before.

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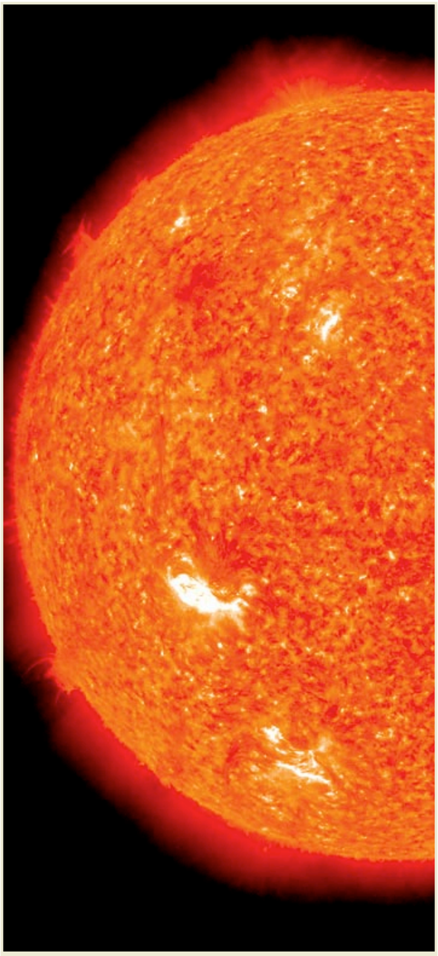
Detect and characterise energetic solar events

Dr Lyndsay Fletcher



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Research opportunity

Solar missions deliver 15TB/day of imaging data - too much data to be sifted through by people. How can computers be made to automatically detect, measure and characterise the properties of the sun and solar activity, such as solar flares or coronal mass ejection, in this flood of data? How do we combine the information thus extracted to improve our ability to predict solar activity?

How is it solved/purpose of research?

We have applied various image-processing techniques including morphology and classifier analysis to quickly extract features of interest. The result of this is the production of catalogues of particular classes of objects on the sun, which can be used by other scientists. The next steps in our approach will include synthesis of multi-spectral data, and machine learning (or other techniques), to extract the 'hidden rules' governing the very complex physics of solar activity, with the ultimate goal being activity prediction.

Why is it important/what difference will it make (impact)?

The techniques developed have broad applicability in general imaging processing problems. From a scientific standpoint, the catalogues developed allow users to make statistical studies of solar behaviour. The rapid detection and prediction of solar activity is core to 'Space Weather', the study of disturbances in the heliospheric and near-Earth environment, and its attendant impact on space-based and some ground-based assets.

Photonic integration for atomic clocks, magnetometers and frequency standards

Prof Charles Ironside

Research opportunity

Chip-scale atomic clocks are now a commercial product and are finding application in global positioning systems (GPS). The premise of the work carried out in this group is that the atomic clocks and other closely related systems could benefit enormously from further photonic integration to make them even more compact, power efficient and robust systems for a range of applications that include clocks, magnetometers and optical communication frequency standards.

How is it solved/purpose of research?

For our work on magnetometers we are proposing to use the coherent population trapping effect in atomic vapours such as Rb and Cs atomic vapour loaded into hollow core optical fibres.

For recent work on a monolithically mode locked semiconductor laser designed for coherent population trapping in Rb see :
http://theses.gla.ac.uk/2721/

Why is it important/what difference will it make (impact)?

A key advantage of atomic magnetometers is that they can operate at room temperature. If the magnetometers can be made sensitive enough they could replace the cryogenic Superconducting Quantum Interference Devices (SQUIDs) currently employed in medical imaging applications such as Magnetocardiography(MCG) and Magnetoencephalography (MEG).

‘...more compact, power efficient and robust.’

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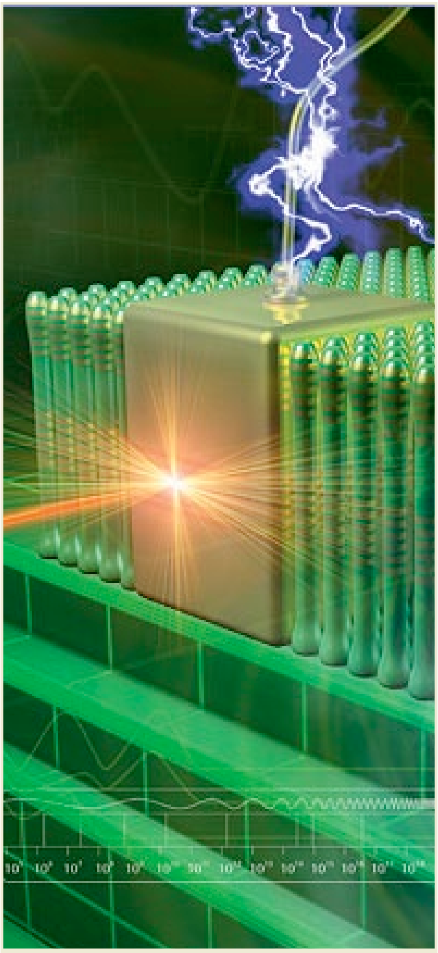
Tunable quantum cascade lasers

Prof Charles Ironside



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Research opportunity

Quantum cascade lasers are mid-infrared semiconductor lasers that employ intersubband transitions in quantum wells. Quantum cascade lasers have several applications including tunable semiconductor laser spectroscopy. As part of the QCSense project we have been developing tunable single mode quantum cascade lasers for molecular vibrational spectroscopy - for the region of the mid-infrared (3000-4000nm) which is absorbed by molecules that have a carbon-hydrogen (C-H) bond; for example, hydrocarbon gases such as ethane and methane. The sensing of trace amounts of ethane has been developed by a major oil company to be used in oil exploration.

How is it solved/purpose of research?

We have developed a technology for producing single mode quantum cascade lasers using both a discrete mode technology and a lateral grating technology.

With the discrete mode technology a stable single mode emission near 3300nm with a sidemode suppression ratio of nearly 25 dB was observed and a tuning coefficient of 0.22 nm/K was obtained in the temperature range of 253 K<T<303 K.

The lateral grating technology allowed the development of room-temperature distributed-feedback quantum-cascade lasers operating in a single mode in the 3340 to 3350 nm wavelength range. First-order lateral gratings with high aspect ratio (the ratio between the grating etch depth and its period) were formed using inductively coupled plasma etching. The as-cleaved lasers emit in pulsed regime with a sidemode suppression ratio of up to 24 dB and a peak single-mode output power of 130 mW from a single facet.

We have also developed ring quantum cascade lasers. Unidirectional ring lasers do not suffer from spatial hole burning, a noise mechanism that broadens the line width of the output. Unidirectional ring lasers can deliver up to twice the output power and quantum efficiency. Coupled ring lasers can be configured to give easily tunable, single mode output emitted in the favored (clockwise) direction.

- the details of the ring laser work can be found in:-http://theses.gla.ac.uk/2603/

Why is it important/what difference will it make (impact)?

It will improve the systems used for oil exploration by providing a laser that does not require cryogenic cooling.

Polymer photonics multiparametric biochemical sensor for point of care diagnostics

Dr Nigel Johnson

Research opportunity

Neurological conditions are notoriously difficult to diagnose, relying on the interpretation of physical symptoms and subsequent brain imaging before positive identification of a condition is possible. The ability to rapidly detect the biochemical markers present within a patient's blood as an aid to diagnosis is an attractive proposition, expected to significantly improve a patients chances of survival and subsequent quality of life.

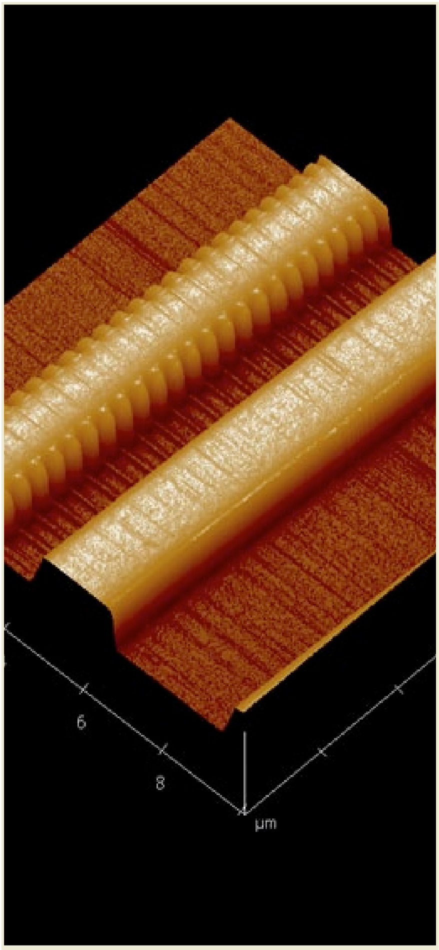
How is it solved/purpose of research?

The consortium has been formed to develop a biochemical detection device suitable for use in emergency-medicine, whether diagnosis is required in an ambulance, emergency room or as part of a rapid laboratory test in a hospital environment – it is anticipated that the combination of highly sensitive Photonic Sensor, a panel of clinically proven Bio-Recognition Elements will result in a novel biosensor system which can make a real difference to stroke patients worldwide.

At the core of the biosensor is a photonic chip employing bus-bar waveguides and several optical cavities. The photonic optical circuitry used to route light around on the chip, and interact it with the medium being sensed, is defined via arrays of features with size of the order 100 nm. These features are formed in polymer by nano-imprint-lithography (NIL). The combined use of polymer material and NIL give a low-cost production technology.

Why is it important/what difference will it make (impact)?

In 2007, the World Health Organisation estimated that 15 million people suffer strokes worldwide each year, with 5 million dying from the condition and another 5 million being left with a permanent disability. Cerebrovascular disease is currently the most common life threatening neurological event, and the leading cause of serious, long term disability. The early diagnosis and treatment of stroke is desirable in order to prevent subsequent vascular events which increase the likelihood of permanent disability or death. The devices are intended to be portable in order that they can be used at the point of care by paramedics.



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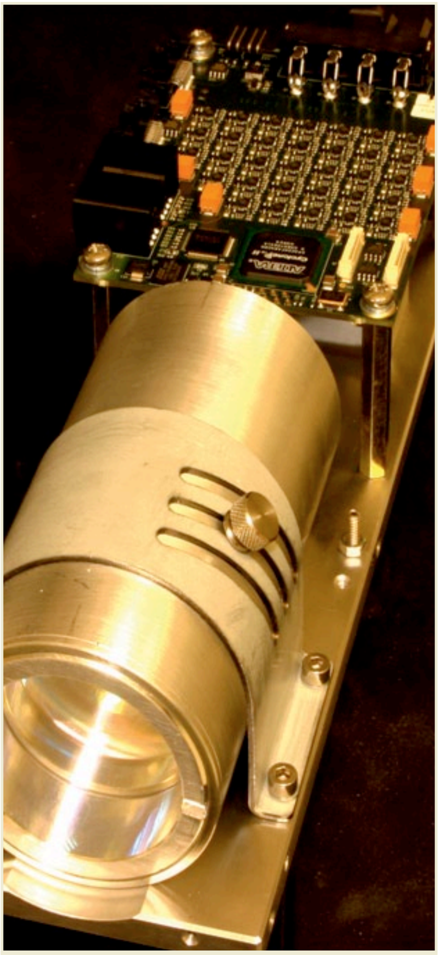
Semiconductor lasers for sensing applications

Prof John Marsh



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Research opportunity

Compact sources of light with well controlled properties are required for advanced imaging applications. In many cases, the source of light is located alongside a camera. The light source is then used to illuminate a scene and the camera (or detector array) records the backscattered image. Properties of the illuminating radiation that is important to control vary with application, but include precise control of power, pulse length, beam quality and polarisation.

We are developing novel semiconductor lasers that can be used to generate radiation with these properties.

How is it solved/purpose of research?

The generic approach is to develop solutions based on semiconductor lasers, monolithically integrated with other components to give the desired functionality. Such sources are compact, efficient and rugged – key attributes for deployable systems.

How is it solved/purpose of research?

There is a wide variety of applications in military systems, biosensors and robotics.

We are addressing

- Short pulse sources for dynamic 3D imaging in real time, illuminating entire scenes and giving depth information that can be used by, for example, autonomous vehicles.
- Polarisation variable sources for polarimetric imaging, giving information such as location of potential IEDs; road surface quality for autonomous vehicles; analysis of biological processes; discrimination between materials in robotics; identification of high stress points in plastics.
- Semiconductor laser arrays where the phase front can be adjusted on a nanosecond timescale. These can be used to scan and manipulate beams rapidly and compensate for atmospheric aberrations. Applications include sightline control systems on fast moving platforms such as aircraft.

Mobile devices with sensors and kinect systems and brain computer interfaces

Prof Roderick Murray-Smith

Research opportunity

1. Mobile computers are becoming the dominant experience of information technology. These devices have increasingly sophisticated sensing systems, and can access virtual sensing data from Wireless Internet connections. Virtual sensors can be inferential processes aggregating information from sensors on the device or elsewhere.

Can we design interactive systems for potentially large dimensional sensing spaces, with a wide range of accuracy?

2. Fixed sensing equipment like the Microsoft Kinect which senses people's behaviour in indoor settings.

Can we design such systems, and fuse a range of mobile and fixed sensors together?

3. Severely disabled ("locked-in") users sometimes depend on Brain-Computer Interfaces (BCI) using EEG signals.

Can we improve interfaces to feedback information about the user's brain state, without overloading them?

'...large dimensional sensing spaces.'

How is it solved/purpose of research?

1. We have developed a series of novel concepts and tested them in experiments. including developing and using custom wireless sensor packs. We have created touch screens which not only sense position but also the pose of the finger.

2. We are performing sensor fusion between mobile devices and Kinects, in work partially sponsored by Nokia and Google. We are exploring virtual bookcases and music collections, as well as fitness and rehabilitation work.

3. We are working on developments such as 'fluid cursors' which cope with the uncertainty inherent in BCI systems to allow easier control of music applications for disabled users.

Why is it important/what difference will it make (impact)?

We have the potential to change how people use mobile phones.

Sensors are of little use if we cannot build them into systems that humans can interact with. If BCI can be made more useable, this is obviously of use for severely disabled people. Also, with the development of dry electrode technology, there is scope for these systems to go mainstream for use in, for example, the computer games community.

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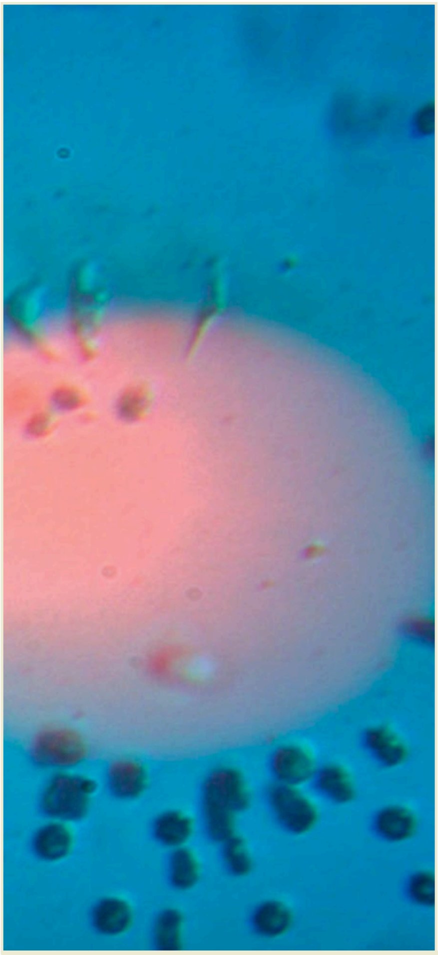
Optoelectronic tweezers (OET) for medical diagnosis

Dr Steven Neale



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Research opportunity

There is a current push towards new medical diagnostic devices that can offer more data on a patient's condition with goals of:

- providing continuous information streams where before only snap shots of data were available
- producing the data faster or at the point of care
- producing data that was not previously available

Optoelectronic Tweezers can be used as a tool to help gather this data.

How is it solved/purpose of research?

Optoelectronic Tweezers (OET) is a method of optically patterning electrical fields that then place forces onto cells. These forces can be used for medical diagnostics in various ways, for example, in one project we use the fact that different species of cell experience different forces to concentrate a rare cell type (here a blood born parasite called a trypanosome) into a specific area of the device to allow us to detect them. These forces can also be used to produce information on the health of single cells for example allowing us to distinguish healthy from unhealthy sperm cells for IVF.

Why is it important/what difference will it make (impact)?

OET allows us to quickly and easily apply different electrical patterns to samples and measure their response. These fields can then be reproduced by miniature electrodes which can be engineered into small inexpensive devices. By creating devices with high sensitivity and high specificity available at the point of care we can revolutionise what data is available to health care professionals and speed up their access to it.

Radiation imaging systems

Prof Val O'Shea

Research opportunity

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.

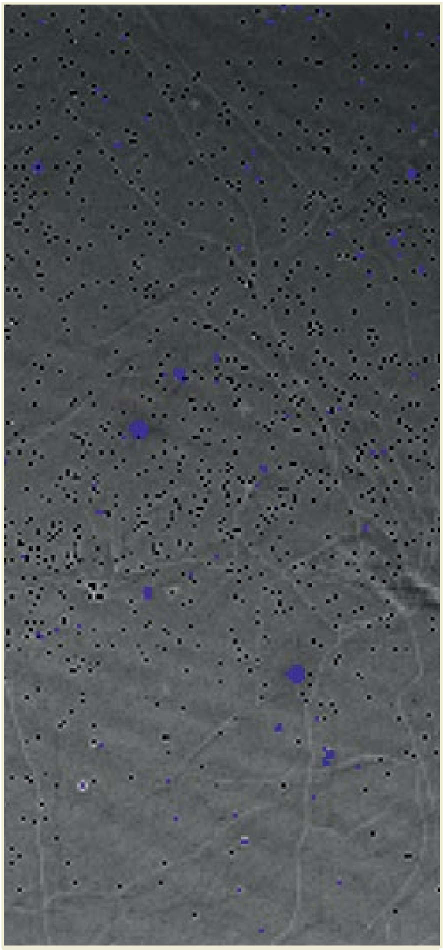
How is it solved/purpose of research?

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 Au nano-particles 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 is it important/what difference will it make (impact)?

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 (SNM) which is a topic of major concern in the security arena.

'...small animal imaging system'.



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Environmental gas monitoring, covert imaging, remote sensing

Prof Miles Padgett

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Research opportunity

What new tool can be applied to help find new oil and gas reserves. Seismic works well to find geological structures but does NOT tell you what's in them. This new method can perhaps fill in that missing piece of information.

How is it solved/purpose of research?

Optical spectroscopy using 3.4 micron diode lasers and a multipass absorption cell to measure atmospheric ethane at concentrations of 1 part per billion.

Move the sensor around the survey area and measure concentration at different positions and under different wind directions.

Use inverse techniques to identify where the ethane is seeping to the surface.

Why is it important/what difference will it make (impact)?

Help in identifying new oil/gas reserves. This technique has been incorporated into a number of different survey campaigns at various locations in the middle east and further afield.

Silicon nanowire sensors

Prof Douglas Paul

Research opportunity

A number of publications have demonstrated the use of breath analysis in the detection and / or monitoring of a range of diseases including diabetes, asthma, lung cancer and liver disease). While a number of sensing technologies have been used with the detection analytes, none of these technologies can be scaled up for mass-market applications such as portable or mobile phone detection.

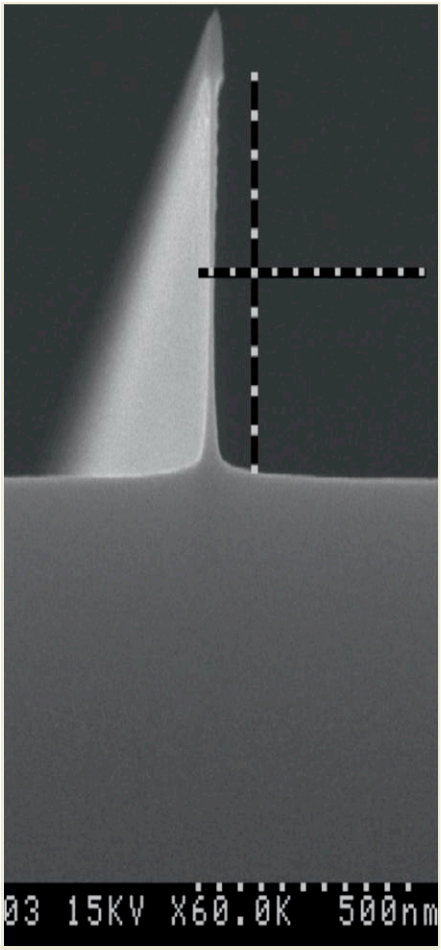
How is it solved/purpose of research?

We have been working on Si nanowire sensors as electrometers (charge detectors) for over 20 years. The detection mechanism is dependent on the change of surface charge when analytes capture disease markers. Silicon technology offers unique solutions mainly due to the low surface charge when surfaces are correctly passivated. The sensors use commercial SOI wafers and lithography i.e. modern silicon technology that is directly transferable to silicon foundries for manufacture in volume. More importantly the technology is robust and offers high sensitivity and high specificity when combined with the detection analytes.

Why is it important/what difference will it make (impact)?

Current healthcare is focused on disease treatment rather than prevention. Laboratory test can take days or sometimes weeks before any diagnosis and in some cases diagnosis is only achieved well after the early stages of a disease for example many cancers, therefore preventing effective medical treatment. The present nanowire technology potentially allows real time testing of a number of diseases allowing a shift to preventative medicine and point-of-care treatment.

‘...high sensitivity and high specification.’



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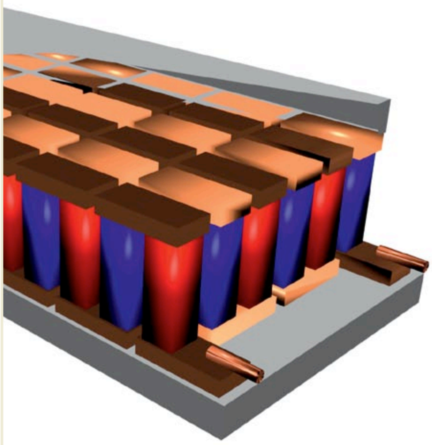
Power source for autonomous sensing

Prof Douglas Paul



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Research opportunity

At present batteries are used for body or remote sensing applications. Such batteries require recharging or replacing at regular intervals and can be the limit to cost or lifetime for autonomous sensing applications. For remote monitoring aged or ill humans, a fit-and-forget power source and sensor with wireless communications for warning would enable many new autonomous sensing applications.

How is it solved/purpose of research?

We are working as part of an EC programme to develop thermoelectric power sources for autonomous sensing that can be fabricated on silicon chips as back-end-of-line processes. The technology is predicted to be able to produce 0.1 mW/mm^2 from a temperature differential of 5˚C and 9 mW/mm^2 for a 50˚C temperature differential.

Why is it important/what difference will it make (impact)?

This technology will allow fit-and-forget solutions with sensor lifetimes of many decades without the requirement of recharging or changing batteries. This can potentially open up a whole host of new applications for autonomous and remote sensing for healthcare, transport, industrial and environmental applications.

Statistical modelling of data from sensor networks

Prof Marian Scott

Research opportunity

The ability to visualise and model complex data, such as those generated from an array of environmental sensors is an important skill, enhancing understanding of the system being studied and facilitating communication of the results to both technical and non-technical audiences. For example, within the legislative requirement that EU governments must report on the state of the environment, until recently this has taken the form of a published report, but it is intended that future reports should be immediate and interactive so that citizens and other users might interrogate the reports. This requires statistical models and visualisation techniques, allowing the evolution of the system over space and time to be followed. In addition uncertainty and variability needs to be captured and portrayed in an understandable way.

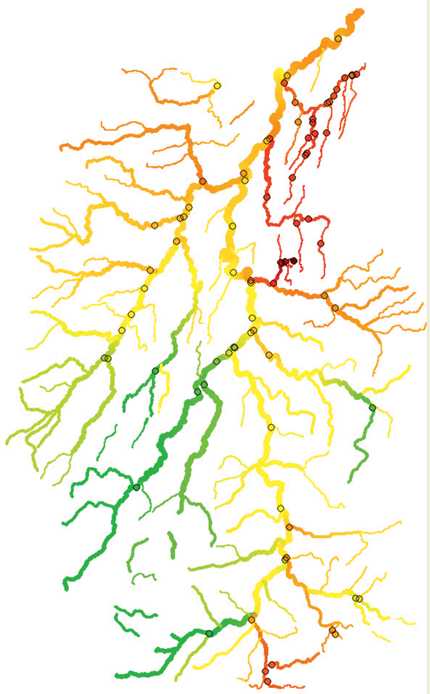
How is it solved/purpose of research?

A common data structure from such a network is one in which there are multiple determinants (e.g. flow, pH, conductivity, DOC, alkalinity, nitrate and phosphate) measured at high temporal frequency at a single sensor, then the sensors are replicated at multiple locations. Natural visualisation techniques include time series and spatial surfaces plots, and multivariate representations of the patterns of relationships between the different determinants. However these displays typically do not show the dynamic nature of the system being studied, nor the landscape on which the system operates so that more recent developments have seen the development of statistical models, incorporating the connectedness of the different sensors, and introducing animation to demonstrate the spatio-temporal development of the system under study and the changing relationships with covariate information.

Some key ecological questions concern the nature of common patterns (coherence) over time and space and what drives these patterns. We have been developing statistical spatio-temporal models suitable for such data structures and questions.

Why is it important/what difference will it make (impact)?

We need to be able to capture the nature of common patterns, trends and relationships which may be complex and themselves changing over time and space. Modelling their nature contributes to improving our understanding of how the systems under investigation work, to providing a better understanding of the wider impacts of environmental change and to presenting, explaining and engaging the wider community in environmental issues.



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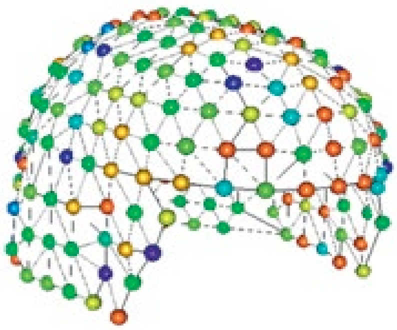
Environmental informatics - visualisation and modelling

Prof Marian Scott



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Research opportunity

A real problem faced by many organisations is that they utilise many different sensors for various purposes, however they often do not have the capabilities to properly design the network to ensure the optimal data are extracted from the system, nor do they fully understand how to use that data. There is a real need for statistical capabilities in the areas of design (where, and how many) of sensor systems and modelling and visualisation of the resulting data.

Environmental statistics and informatics provides the framework for the processing of environmental information. Typically based on a network of sensors deployed in the field (rivers, lochs, cities…), the formal framework builds on the spatial and temporal dynamics of the environment, to integrate the information, identify and quantify impacts across the range of ecological function and service, identify trends and to visualise and summarise the knowledge generated (making use also of expert knowledge) for different audiences including policy makers, environmental regulators and the public. Of particular importance is the quantification and communication of uncertainty and how different forms of evidence can be combined in environmental decision making.

How is it solved/purpose of research?

The statistical capabilities within the University of Glasgow means that we can work with organisations such as regulators or government agencies who gather large volumes of data from large sensors networks and use those data, model and present them to the end user in the most appropriate way to facilitate their decision making. However, at the front end of sensor systems it is necessary to design a network to determine what type of sensors should be used, how many sensors are required and where should they be located to ensure the appropriate data are being collected – we can offer expertise from statistical design, modelling through to visualisation.

Our most recent work (in the environmental arena) with Scottish Environment Protection Agency and the Environment Agency has been the modelling and visualisation of the environment based on several different networks of sensors (some less high tech than others).

Why is it important/what difference will it make (impact)?

The benefits that statistics expertise can bring to the area of environmental and other types of sensors is providing the translation from data to modelling to information and presenting that information in a way that enables companies/policy makers and regulators to make evidence based decisions, fully incorporating the uncertainties.

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

Dr Bjoern Seitz

Research opportunity

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 and with time resolutions better than 100ps. Similar requirements and applications can be found in medical imaging modalities. Our work aims at providing the next generation of these devices for fundamental research and medical applications.

How is it solved/purpose of research?

We are specialising in the application of position sensitive photon detection devices for highly granular read-out of scintillation detectors for fundamental science, industrial and medical applications as well as for Cherenkov Imaging devices. We are working with leading manufacturers and leading laboratories worldwide performing in-depth tests on gain, efficiency, time resolution and other response parameters and drive industrial development. We also perform very detailed simulation of the devices under test. In addition to bench tests, we test the devices in real detector systems at a variety of test facilities, including SCAPA. Our work is embedded into the Framework 7 programme.

Why is it important/what difference will it make (impact)?

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 SPECT and PET systems or fluorescence imaging, industrial applications could include e.g. large area tracking and monitoring devices as they are mandatory for a large scale fundamental physics research as well.

‘...detection of single photons.’

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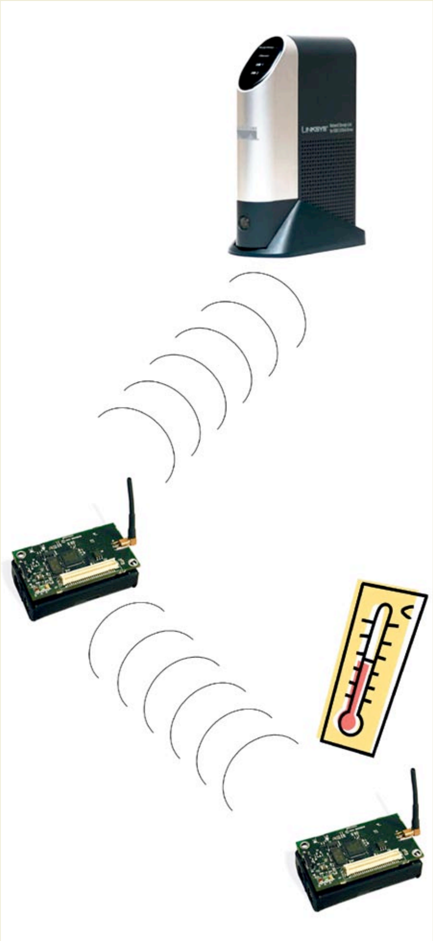
Wireless network sensor systems

Prof Joseph Sventek



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Research opportunity

Programming for unattended embedded environments is difficult and error prone; this is due to the event-based nature of the programming languages/environments used; few software engineers have the skills needed to use these languages/ environments. The promise of environmental monitoring using wireless sensors is unmet due to this shortage of engineers with these skills.

How is it solved/purpose of research?

We have developed a programming language (Insense) for programming constrained wireless sensors; this language provides a stack-based procedure-call paradigm more similar to the typical programming skills found in industry and emerging from universities. We have written a custom operating system that implements this language on typical wireless platforms efficiently. We have tightly intergrated the OS with high-performance networking stacks appropriate to constrained wireless sensor systems. We have provided the ability to prove correctness of applications written in Insense. Finally, we are developing an entire software development environment to support design, implementation, verification, testing, deployment, and maintenance of sensor-networks programmed in Insense. Finally, we have also developed ad hoc routing protocols with different performance characteristics for use in such systems.

Why is it important/what difference will it make (impact)?

This work will enable a programmer knowledgeable in C or Java to program embedded sensor applications for deployment in environments in which such constrained sensor nodes are required.

Technologies and solutions for physically small, low power radio communication

Prof Iain Thayne

Research opportunity

This work was motivated by the SpeckNet project where the University of Glasgow had responsibility for the development of a sub-mW radio for a physically small sensor node (5mm^3), powered from an on-board battery which was itself re-charged from an on-board photovoltaic. The small physical size motivated RF carrier frequencies beyond 6 GHz (antenna size) and low power consumption resulted in simple radio architectures (direct oscillator modulation, and super-regenerative receiver with diode detection).

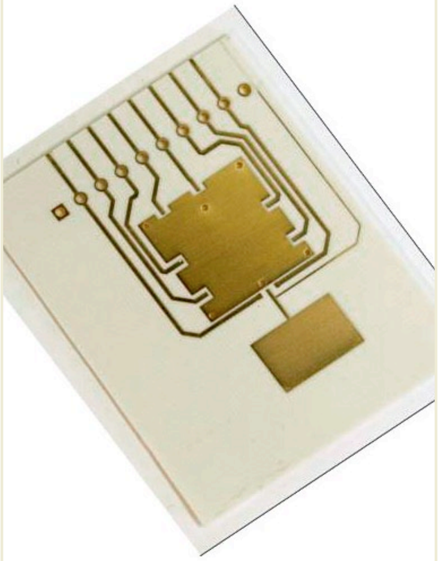
How is it solved/purpose of research?

The Glasgow III-V MMIC technology required performance at sub-mW power consumption (albeit by turning down the supply voltage). Ultimately, getting any reasonable distance requires an antenna is driven with few mA of current, which is a significant issue for a physically small battery. We have demonstrated sub-mW operation of a number of building blocks (switch, amplifier etc), but the fully monolithic solution was elusive. We explored operation at both 10 GHz and 24 GHz, using significantly simplified radio architectures (no heterodyning). Antenna design included all aspects of the full sensor node. A radio link was built and validated using a hybrid solution (passive components were built in the James Watt Nano Fabrication Centre, with bonded in commercial transistors, all bonded onto a PCB with on-board antenna). A 10 GHz radio with 2kbs-1 data rate was demonstrated over 2m, with transmit and receive power consumptions of 750uW(0.75V/1mA) and 900uW (0.75V/1.2mA) respectively.

Why is it important/what difference will it make (impact)?

Ultimately, the key to plug and forget sensor nodes will be radio transmission power consumption - actually, current consumption in driving the antenna. Significant learning has been obtained in this regard. Also, that ultra-small geometry transistor technologies are likely not required, which would significantly ease the yield constraints of MMIC realisation.

‘...plug and forget sensor nodes.’



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Using sensor technology to better understand the terrestrial-aquatic C cycle

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Research opportunity

Currently it is difficult to find the optimum combination of sensors on a single instrument that can determine under what conditions rivers could be a sink or source of atmospheric CO_2. Prof Waldron is also interested in quantifying terrestrial and lacustrine gas efflux. The challenges here are i) generating an understanding that accommodates changing seasonal and hydrological conditions; ii) finding an approach to this that does not require intensive fieldwork: time is limited; some field areas can be remote.

How is it solved/purpose of research?

It is not possible to conduct continuous manual sampling of a river under the full range of flow conditions, and in remote areas, therefore sensors were deployed to collect high resolution environmental data (every 15 minutes).

This research has used sensors already available on the market, and they have been used in a novel manner to estimate determinants not previously quantified by sensor technology. Through this work it has been discovered that simple water chemistry sensors can be used effectively as proxy measurement for many components of the C cycle. However, the longer term aim is to develop a single system that will measure dissolved organic and particulate organic carbon concentrations, as well as dissolved inorganic carbon concentrations. The target is to create a system that will provide data on the measures above and in addition, indicate the quality of the organic matter, and a measure of river discharge. We hope to develop a system no bigger than a shoebox as it needs to be portable to enable deployment in remote environments.

Why is it important/what difference will it make (impact)?

Assumptions are often made about natural system responses that are unsubstantiated. However, detailed semi-continuous time series constructed from in-situ sensor deployment allow generic and site-specific controls to be identified with considerably reduced manpower, providing detail to test assumptions, subsequently redefine understanding and then accurately model the C cycle. Reliable and long-life sensors allow data to be gathered from inhospitable areas, often critical in the global C cycle e.g. Russian tundra.

Functionalised AFM probes/bespoke microscopy - measurement at the nanoscale

Prof Jonathan Weaver

Research opportunity

Atomic Force Microscopy is one of the key tools used to carry out physical measurement at the nanoscale. The information is gathered by "feeling" the surface with a mechanical probe. At the nanoscale it is crucial to understand the properties and structures of materials in order to be able to control device performance.

How is it solved/purpose of research?

The AFM group at the University of Glasgow has invented a complete technology platform for the integration of lithographically defined sensors with AFM as a sensor / sample manipulation system. The group has developed a range of probes (electrochemical, magnetic, optical and thermal) which provide researchers and industry with tools to analyse the properties of materials and devices at the nanoscale.

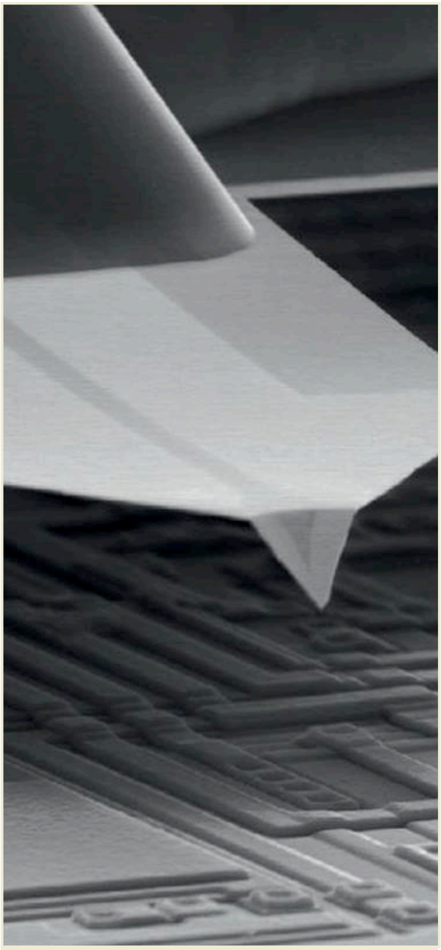
A full set of transferable, wafer scale fabrication processes has been developed and products are available commercially via Kelvin Nanotechnology Ltd.

www.kelvinnanotechnology.com

Why is it important/what difference will it make (impact)?

If you can't measure it you can't control it. Measurement at the nanoscale is hugely important. Most of the probes are used in science for research or in industry for quality assurance purposes. The electrochemical probes are used to carry out measurements on catalysts, fuel cells and provide data on corrosion. Magnetic probes enable physicists working on data storage to better understand the characteristics of their materials. Biologists utilise optical AFM to image proteins and cells. The thermal probes are commercially available and used by those interested in fundamental material science, thermoelectric power generation and computer chips to determine changes in temperature which, at the nanoscale can have major implications in terms of device performance.

'...complete technology platform.'



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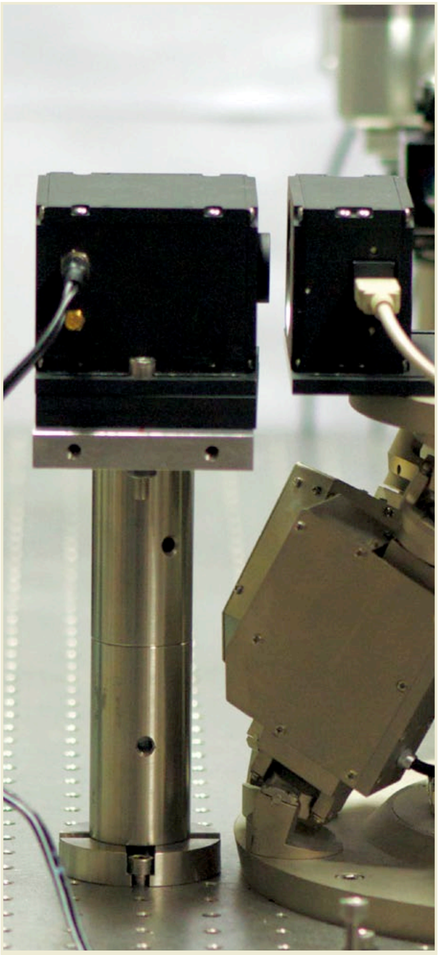
Compostella

Prof Jonathan Weaver



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Research opportunity

Position measurement is a key task in all areas of modern technology with a market valued at billions of dollars. Interferometry is the current 'gold standard' used, but is expensive and requires high levels of technical ability to set up and operate. Another issue with interferometry is amnesia – if the system is switched off or the laser beam is interrupted, it is necessary to re-calibrate and start from scratch.

How is it solved/purpose of research?

Compostella is a novel technology that measures position extremely precisely at low cost. The principle is that of a projector and a screen. By examining the distortion in a known image projected onto a camera the position of one end of the device (camera) in relation to the other (projector) can be calculated. The system generates all six coordinates of position in a single measurement. Compostella's accuracy is comparable to many interferometers, however unlike interferometers, Compostella can be switched off and restarted without losing its position; it is simple to setup and operate, physically small with few limitations on mounting.

Why is it important/what difference will it make (impact)?

This system will be of interest to users of robotics, microscopes and micropositioning stages. These are all used in scientific research as well as by industry, particularly the automotive, astronomical, semiconductor, life and health sciences, defence and aerospace sectors. The system will allow companies often unable to use interferometry, to access high precision position measurement, using it to develop new products or improve the accuracy of existing ones.

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