Queen's University Belfast

THE DNA OF INNOVATION

The Impact of Pioneering Research

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THE CONTENT OF INNOVATION

> “Queen’s inspires its researchers to be the pioneers of progress who change society for the better.”

FOREWORD FROM OUR **VICE-CHANCELLOR**

The global impact of research is a defining feature of Queen's University. From groundbreaking work on gas liquefaction in the late 19th century, which led to inventions like the domestic refrigerator, to playing a world-leading role in cybersecurity, Queen's researchers make an enormous impact on the world in which we live.

As a member of the Russell Group of the UK's 20 leading research-intensive universities, Queen's inspires its researchers to be the pioneers of progress who change society for the better. This pioneering spirit is at the core of the University's ethos, and it is the fuel which drives our outstanding academics to build upon our world-class research reputation.

As the Times Higher Education (THE) Entrepreneurial University of the Year in 2009, and winner of the THE Outstanding Engineering Research Team of the Year in 2010, Queen's is uniquely recognised for the spirit of innovation and enterprise that underpins its exceptional research.

We are delighted to showcase the impact of research funded by the Engineering and Physical Sciences Research Council. However, given the multidisciplinary nature of our work, its impact extends far beyond the engineering and physical sciences.

The research projects which have been highlighted show the breadth and depth of the contribution that Queen's makes to society and the economy: from drug delivery mechanisms to world-leading work in green chemistry, and from the concrete technology used in the iconic Beijing Olympic Stadium to 'micro'-needles that could reduce pain in premature babies.

These examples demonstrate the value that Queen's research offers national economies, international businesses and, ultimately, society itself, and how closely our academics work with external partner organisations to create life-changing solutions. They also demonstrate the University's commitment to continue to advance, develop and, most importantly, apply, knowledge for the greater good.

Professor Peter J Gregson
President and Vice-Chancellor

INTRODUCTION
SCOTT RUTHERFORD

Director of Research and Enterprise

The story that unfolds from the case studies set out in this publication is a truly exciting one. It shows the huge global impact being made by Queen's and how it continues to grow. The case studies emphasise that innovation is in our DNA. It is embedded in our people and our organisation. It is at the heart of our mission.

The University research base is full of inspiring academics with an amazing number of ideas. It is my task and that of the Research and Enterprise Directorate to support them and to help them translate those ideas for the benefit of the economy and society around us.

It is crucial that those who fund this work are aware of what we do. It is key that we demonstrate the value we provide and the difference we make. But making a breakthrough in a field of research is not something that happens overnight. It involves a lifetime of hard work and support from a variety of sources.

On this occasion we turn the spotlight on the engineering and physical sciences. But as we do, we recognise the excellence of the work being carried out in other areas, in arts and humanities and social sciences, where our academics are also held in high esteem and where the research they undertake makes a huge impact on society. This university is, at every level, a vibrant institution.

It would have been easy to have assumed that, as this is a publication based on EPSRC-funded research, it would concern only engineers and physicists. These case studies show something different. They demonstrate a tremendous breadth of activity and they illustrate how collaborative our research is, with industry, both locally and internationally, and across a range of disciplines at the University. We read about how engineers, physicists, chemists and pharmacists are combining their skills and their knowledge for the greater good. This is an approach which is hugely important. The enormous challenges our world faces will not be addressed by researchers working in isolation.

In these case studies, you can feel the dedication and passion of the individuals involved as they talk about their work. Our role as an institution is to advance knowledge, to provide an environment where these great minds can flourish and develop their ideas. These researchers are driven by a desire to make an impact on the world around them, not for personal advancement but for the wider benefit of society. This is what makes the work of the Research and Enterprise Directorate so rewarding. We're supporting and enabling that ambition.

Our links to industry and investment from major companies are also crucial to our success. This also shows how applied our research is and how business can benefit from the ideas we create. It is a further indication, too, of the regard in which Queen's is held around the world, of the strength and reputation of our research base and the outward-looking nature of our academics. We work globally, addressing vital issues, many of them in the developing world, to improve the lives of significant numbers of people.

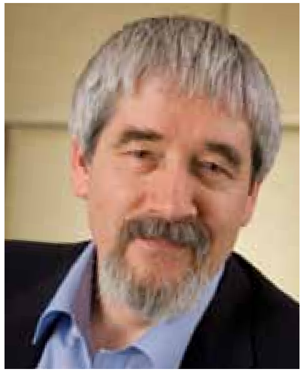
Spin-out companies, created and managed at Queen's, are a unique way of harvesting academic ingenuity and research outcomes. The scope of the activity is immense: nanotechnology, construction, aeronautics, drug delivery systems, as well as cyber security, wireless communication, the digital age so important to us now and in the future.

This is where our enterprise skills come into play. The ability to uncover and bring new technology to market is key to the University's 'Third Stream' activities. In this process we work closely with our academic staff, building their management expertise, and we make careful early-stage investment to help our spin-out companies grow.

Our people are another part of the international success story. We have PhD students from all over the world working on important projects. A world-class institution like Queen's needs the best talent available, whether it's from abroad or just around the corner. That mix is incredibly important in maintaining the high quality of the work and providing new perspectives.

Our research is about new ideas and new talent, brilliant minds making an important contribution to society and the economy. As one of the leading research-intensive universities in the UK, Queen's has long enjoyed an international reputation for scientific investigation at the cutting edge. This publication builds on that reputation and illustrates the significant and ever-increasing impact that Queen's research has on the world around us.

Scott Rutherford
Director of Research and Enterprise



FOREWORD FROM PROFESSOR DAVID DELPY

Chief Executive, EPSRC

EPSRC is the major national funder of long-term fundamental engineering and physical sciences research and training in the UK a nd we are absolutely committed to the RCUK's "excellence with impact" agenda. We are working to keep the UK at the heart of global research and innovation and to deliver greater impact than ever before.

Impact occurs in different ways: it leads to a supply of skills and capabilities for research, industry and the public sector; it achieves specific results from strategic investments aligned to areas of national need; and it provides essential and informed advice to policy makers. In order to maximise the impact and exploitation of the fruits of our investments, we are committed to providing resource to the best people in the right areas through embedding knowledge transfer and impact activities into our research grants.

To facilitate and catalyse this change in approach we introduced a one-off pump priming funding stream "the Pathways to Impact Awards" to encourage researchers and universities to seek appropriate resources to undertake impact-related work arising from their EPSRC research grants. Activities that could be undertaken through these awards included people exchange, proof of concept studies, networking and engagement events, training and employment on specialist knowledge transfer staff. We want to see evidence that the awards have made a real and significant difference within universities so that they think about, and appropriately resource, impact at the outset of a research project, rather than at the end of it. We have been delighted with the feedback we have received on how the awards are being used and this publication showcases many exciting examples of how impact can be achieved.

Professor David Delpy
Chief Executive, EPSRC

BRINGING ORDER TO A UNIVERSE OF FLUID POSSIBILITIES

Professor Chris Hardacre
School of Chemistry and Chemical Engineering

While ionic liquids have been in production for several decades, it is only since the opening of the Queen's University Ionic Liquid Laboratories (QUILL) in 1999 that they have become one of the hottest areas of chemistry research.

Essentially liquid salts, the liquids can now be modelled initially on laboratory computers. Because the characteristics of each one can be selected from a huge menu of physical properties, the possible permutations are almost beyond imagination. In fact it is estimated there are one million simple ionic liquids.

Many though will never make it beyond the computer screen. Those that show potential however may well end up in the real world, purpose-made to perform specific tasks ranging from storing energy and gene therapies to food flavouring and nuclear waste processing.

Bringing order to that universe of possibilities is vital in order to focus research on those liquids that show most promise and can be produced economically. That was one of the main goals of a recently completed five-year EPSRC project involving Head of School, Chris Hardacre.

"The knowledge gained through the project has already paid off handsomely for us. One ionic liquid process we developed for use in the development of gene therapies is now being commercialised through Merck GmBH. We have also won multi-million pound contracts from a leading oil and gas producer," says Chris.

Other significant commercial rewards gained as a result of the project include work for a fragrance house aimed at maximising the production yield of one of its key perfume ingredients.

"After holding a postdoctoral position at Cambridge University, I came to Queen's as a lecturer in 1995. That was before interest in ionic liquids really took off.

"I didn't know much about the University back then but from my earliest days at Queen's, I have always been struck by how willing people were to do interdisciplinary work.

"Chemists were always eager to work with physicists and perhaps, more unusually for the time, with chemical engineers. Interdisciplinary collaboration is essential in the field of ionic liquids so that may help to explain why the University has become such a significant player since the opening of QUILL in the late 1990s.

"Chemistry and chemical engineering is all about being able to control what is happening at the molecular level. Applying those disciplines to ionic liquids is fascinating work. It is still a very young research area but it is one in which Queen's now leads the world."

"The knowledge gained through the project has already paid off handsomely for us.... We have also won multimillion-pound contracts from a leading oil and gas producer."

STRIVING TOWARDS THE HEAVYWEIGHT PRODUCTION OF A LIGHTWEIGHT SOLUTION

Professor Eileen Harkin-Jones
School of Mechanical and Aerospace Engineering

Eileen Harkin-Jones has a deep appreciation of the value of EPSRC funding and support.

"It's difficult to get. It's the most highly-prized and sought-after funding that we in the UK aspire to. In order to win it, you have to show that you have an excellent plan of research. It has to be novel and it has to be adventurous. But once a project is funded they really let you get on with it with a minimum amount of interference and bureaucracy."

One of her major EPSRC projects involves the processing of nanocomposite materials. "I work along with packaging companies to lightweight packaging which reduces raw material consumption, processing and transportation costs. Current improvements in material properties would allow a reduction of between 20 to 50 per cent in packaging thickness with proportional reductions in pack weight and the energy required to manufacture it. The challenge is to achieve this lightweighting and still maintain the mechanical and barrier properties of the pack.

"To achieve our goal we incorporate nanoparticles into the polymer. If we can disperse these particles and align them in a controlled manner in the polymer then we can achieve exceptional improvements in mechanical and gas barrier properties with only a few per cent weight of particles. The challenge lies in attaining this good dispersion and control of particle spatial arrangement in the final product."

Eileen relishes challenges like this. "I've always loved problem-solving and that's what drew me to engineering in the first place." Brought up in Donegal, she studied mechanical engineering at University College Dublin. "I was expected to study medicine but I never really wanted to go in that direction at all."

When she graduated in 1983 there was a recession and a shortage of engineering jobs. She came to Northern Ireland and got a summer position in the sales office of a plastics company in Portadown which is where her interest in polymers grew.

"I gradually moved into the technical end and became research and development manager. But I really wanted to get back to a more academic life.' She completed a PhD at Queen's, graduating in 1992. Soon a lectureship came up in Chemical Engineering in the area of polymer processing and in 1999 she was appointed to the Boxmore Chair in Polymer Engineering in the School of Mechanical and Aerospace Engineering.

She is a firm believer in the collaborative approach to research. She is currently looking at another nanoparticle, graphene, which confers conductive properties to plastic. This material will be used in a joint project with David Jones in Pharmacy and David Linton in Electrical Engineering to make polymer-based medical devices which will resist the build-up of biofilms and help reduce device-related infection in patients.

There are other applications, computers, for example. "Instead of having metal components to provide electro-magnetic shielding in your computer you could use these polymer-graphene materials so that you still get shielding but also a lighter product that can be manufactured more efficiently."

And adding to the range of her research, there is a joint EPSRC-funded project with Mark Price, looking at energy management in the polymer processing industry.

Eileen says: "EPSRC like to see multi-institution, multi-disciplinary research, for good reason. One person working alone is never ideal. You really need the expertise of a number of people. That way you get an outcome that really is greater than the sum of its parts."

"I've always loved problem-solving and that's what drew me to engineering in the first place."

STREAMING HIGH RES BLU-RAY, CRUISE CONTROL SYSTEMS AND BEYOND

Vince Fusco straddles the worlds of business and academia. An international expert in high frequency electronic engineering he is also a co-founder of a successful university spin-out company.

As suppliers of sophisticated types of high performance devices to the UK space industry and the European Space Agency, Vince's research teams are also working hard to have their pioneering work adopted in emerging new technologies back on earth.

EPSRC is playing a vital role in this effort by providing funding through a platform grant aimed at exploiting the considerable know how of the School's high frequency electronic circuits cluster.

One of the largest groups of its kind in Europe, it is based at the School's Institute of Electronics, Communications and Information Technology (ECIT). The institute is housed in a specially-designed 4,000m^2 building, located off-campus, in the Northern Ireland Science Park.

Here, research staff are concentrating their efforts on developing component and systems designs for specific frequency ranges in the electromagnetic spectrum.

Leading that effort is Vince, an international expert in the field, who says the frequencies chosen for research make best use of the resources at his disposal. Another important reason is that they are ideally suited for wirelessly transferring very large amounts of data in very short times. This is an area, he believes, that is ripe for commercial exploitation.

"We picked the area of millimetre wave systems because in this frequency range the enabling technology becomes increasingly complex and the infrastructure you need to model, make and measure anything you design become very sophisticated. Those challenges seemed a good match for the expertise we have developed in recent years working on space and other programmes," says Vince.

"Millimetre wave systems are now being used to stream very high definition pictures from Blu-ray video recorders to large screen televisions, wirelessly. Other applications, though at slightly higher frequencies, include radar cruise control systems for cars and network management systems for future mobile phone networks.

"As our research programmes evolve, the technology evolves with them. The complexity and cost of producing chips is phenomenal so to keep costs down, and to keep fully abreast of the latest technical advances, it is vital to partner with the companies that actually fabricate the integrated circuits you're designing."

To date, the group has built very successful relationships with Infineon Technologies in Austria and OMMIC, a Paris-based semiconductor foundry. Those links were further strengthened recently when Vince co-founded a university spin-out company, Lamhroe, to which the French company has now subcontracted the design of high frequency circuits used in a range of millimeter wave wireless applications.

Lamhroe is also developing its own products, in a number of cases based on research conducted initially under EPSRC programmes. These include microwave-based security perimeter fencing soon to be tested at Singapore's Changi airport.

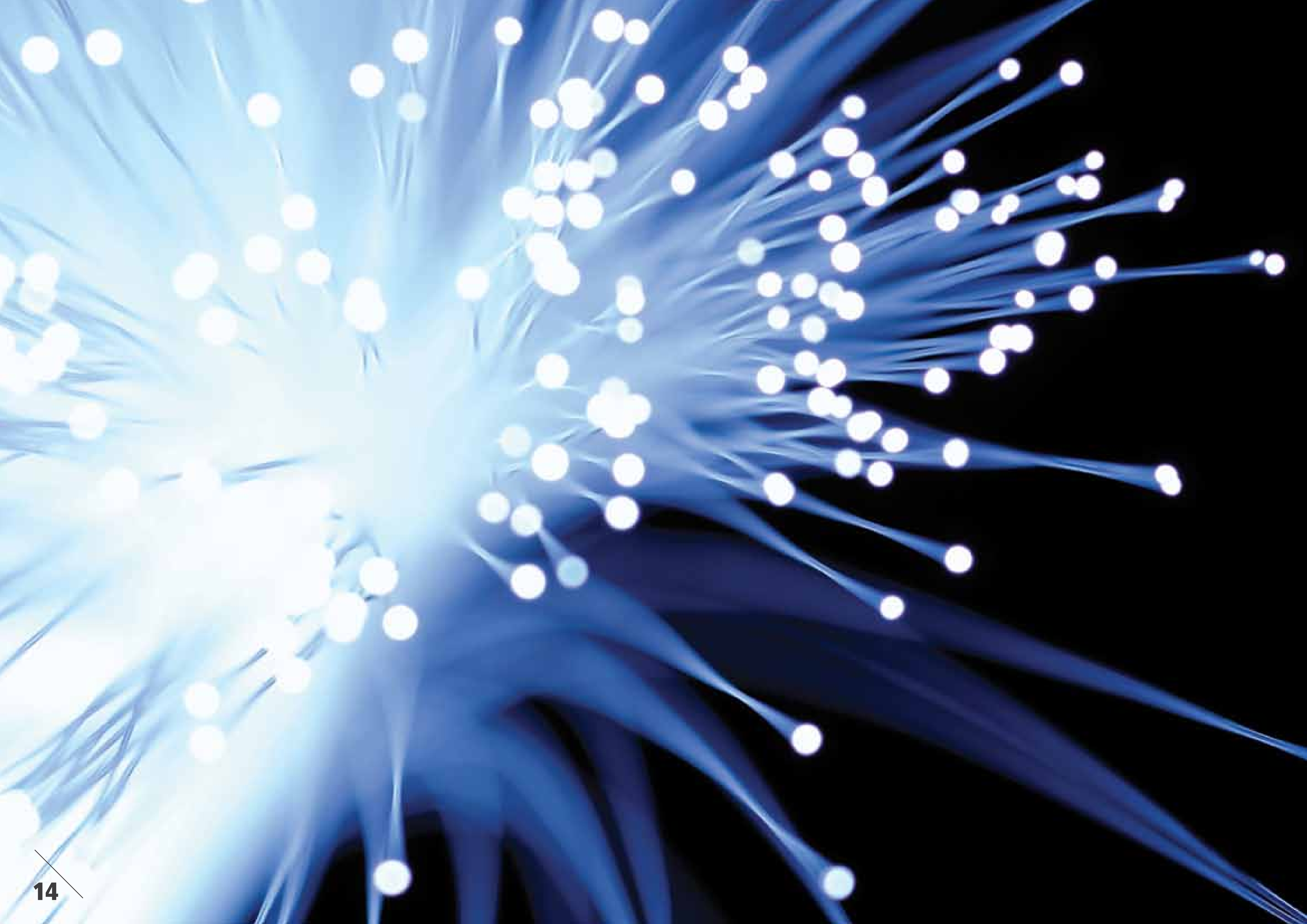
"In other work funded initially by EPSRC, our team is developing a new type of flat, self-aligning antenna that could replace bulky present-generation satellite dishes. Potential uses include the delivery of satellite broadband and television to anyone, anywhere on the planet.

"Research is also underway on a new form of secure wireless system that will focus data transmission so precisely on a targeted recipient it that will allow unencrypted data to be sent securely.

"Our work is not just about designing system architectures or components. It's also about creating systems and how they fit together.

"We are always trying to maximise what we can squeeze out of the technology we're working with. That can mean creating ways of packing chips more densely or synthesising new, highly efficient materials for which we have developed practical and theoretical applications."

Professor Vince Fusco
School of Electronics, Electrical Engineering and Computer Science



PUTTING BACTERIAL INFECTION IN THE SPOTLIGHT FOR THE LAST TIME

Colin McCoy is fascinated by light and how it can be applied in the medical world. "Light is easy to control. You switch a light on or off. What's less easy to control is how drugs move about, what doses we're actually getting. Even with something as simple as taking a paracetamol, it's very difficult to control the level of drug in the blood."

So Colin, Reader in Pharmaceutics, and his research colleagues at the School of Pharmacy began working on a light-triggered drug delivery system. With this, a drug is released only when light is present at a predetermined wavelength and intensity. "We want to control exactly the amount of drug and exactly where to place it. It's a case of what you want, where you want it and how much you want."

This work has now led to another research project with funding from EPSRC. "With patients in intensive care there's a high death rate from pneumonia due to infection. Often they have several devices connecting the body to specialised equipment. One is the endotracheal tube, usually made of PVC, which channels air into the lungs from a ventilator. But bacteria can grow and stick to the surface of the tube."

As Colin explains, "There was no technology out there which could control this effectively. The answer came from what we'd already learned about applying light to the delivery of drugs. That became the driver.

"We'll still use specific and selective antibiotics but instead of giving them by injection or tablet our new approach is to chemically bind them to the surface where the bacteria are going to attach. Then, when we need to, we can break the bond by shining light from a fibre optic. This will release antibiotic in a very high concentration right at the bacteria."

So far everything is going according to plan but Colin says that, unexpectedly, they are finding possible applications in other areas of medicine.

The research will last for three years. "Although we're not proceeding to a full clinical trial yet, we know that the impact is potentially very large. Quite simply, we're showing a general way of delivering drugs with something that's very easy to control, namely light. As a result, being able to stop these infections will save huge amounts of money for the NHS but, more importantly, it will save lives."

Dr Colin McCoy
School of Pharmacy

INTRODUCING THE MOST ADVANCED PIECE OF EQUIPMENT OF ITS KIND

When postdoctoral research chemist Alexandre Goguet moved to Queen's University from Lyon in France, he intended to stay for just a year. Captivated by his work at the leading edge of catalysis, he's still there, more than 10 years later.

Not many researchers have the distinction of helping to develop a product whose technological significance has been ranked alongside such artefacts of modern living as the halogen lamp, liquid crystal displays and high definition television.

One who has is senior lecturer Alexandre Goguet who for the past three years has been working on an EPSRC project alongside the US Department of Energy's Oak Ridge National Laboratory (ORNL) in Tennessee.

"Our research team first became involved with the American laboratory when they produced a prototype of an instrument that could measure the progression of gasses through a vehicle's catalytic converter.

"This allowed scientists for the first time to look under the bonnet and study the physical and chemical processes taking place within the converter. Previously the only way they could investigate what was happening inside was to sample the emissions before and after the catalytic process and compare the results.

"Our job was to use our expertise to make a number of fundamental improvements to the instrument's performance and then help to transform it from a proof of concept prototype into a marketable product.

"The collaboration proved really successful. The instrument is known as a 'spatially resolved capillary inlet mass spectrometer' and it is now being manufactured by a specialist UK company. A truck manufacturer has used it to help meet recently introduced US emission control standards three years ahead of schedule. It has also won a prestigious R&D 100 Product of the Year award for its technological significance.

"We have also developed a complete set of software tools for collecting, scanning and analysing the large volumes of data it produces and this too is being sold commercially.

"The end result of our collective efforts is that we have developed the most advanced piece of equipment of its kind. It can produce highly accurate, three-dimensional, moving pictures of catalytic processes in vehicle systems. Before we became involved it was only capable of producing two-dimensional information.

"We are at the point where we are collaborating with a number of potential customers who are currently evaluating the instrument. They include leading Japanese and American car manufacturers as well as a major UK catalysts producer.

"Catalytic converters for petrol engines are now pretty advanced. With the fuels of the future, however, it's a different story. They are completely unexplored territory for this kind of research.

"Our equipment provides an ideal test bed for this type of work. I believe it has a vital role to play in developing the highly efficient, environmentally friendly fuel handling systems of tomorrow."

Dr Alexandre Goguet
School of Chemistry and Chemical Engineering

Professor Muhammed Basheer School of Planning, Architecture and Civil Engineering

ABSORBING ALL THERE IS TO KNOW ABOUT CONCRETE STRUCTURES

Muhammed Basheer's work has taken him on a journey from India to Belfast and back again many times. He and his team are now world leaders in the technology of concrete structures, how to test them and how to monitor changes, and there has been a particular impact in China.

Muhammed Basheer had more than a passing interest as he watched the Beijing Olympics on television three years ago. He was aware that technology and instruments developed by him and his colleagues at Queen's had contributed to the successful building of the concrete structure that has become one of the 21st century's most iconic images, the Bird's Nest Stadium.

He says, "I became interested in the durability of concrete back in India when I was a student doing masters research. The monsoon weather causing concrete roofs to leak was the starting point. I wanted to know if it was possible to manufacture concrete that was leak-proof. At first I thought high-strength concrete might be the answer but it wasn't. Then I began to ask why it was permeable."

He contacted Queen's, which is known for its structures research, about the possibility of carrying on his work there. He came to Belfast in 1987 and is now Chair of Structural Materials.

At first Muhammed Basheer worked on a project commissioned by the NI Roads Service. The aim was to find out which technology is the most appropriate for manufacturing concrete that is less porous, to see how it can be protected by applying surface treatment and to develop a device to measure the permeability of concrete on site. It was this measuring device, developed successfully, that was eventually to be used to test the concrete of the Olympic stadium.

He says, "Currently I have two EPSRC projects related to testing concrete structures. One focuses on durability, to develop performance specification which will help us make structures last longer. The second is to see how these technologies can become widely known in China and elsewhere."

That latter project is being achieved in part through the UK-China Science Bridge, transferring technology between the two countries. "We have conducted seminars and workshops for engineers and researchers in China and we have had similar conferences in Belfast. What we want to do next is come up with an arrangement with India and

the Middle East, two regions where there is a huge problem with durability."

Queen's is now a world leader, a recognised Centre of Excellence. "The University has always been recognised for its work in structures but now it is also recognised for materials research. For the past 10 years we have been one amongst the top in the area of concrete durability."

As well as the Olympic stadium, other Chinese projects where the test instruments and sensors have been used include nuclear power stations and bridges in the country's highways programme. The commercial spread of the equipment and sensors, made in Belfast, is in the hands of two "spin-out' Queen's companies which have established a worldwide distribution network.

And the work goes on. "In 2005 I suggested that we start an MSc programme on the durability of structures. That now exists, however, I am now also suggesting an MSc in sustainable concrete engineering. The industry is crying out for this, to help reduce the environmental impact of structures. Working with the industry, you continually see the issues which are faced and we must be able to modify the direction of our research in order to help."

Professor Muhammed Basheer
School of Planning, Architecture and Civil Engineering

REDUCING DEVICE-RELATED INFECTION THROUGH INNOVATIVE MEDICAL MATERIALS

Gavin Andrews has a diverse scientific background. He graduated from the School of Chemistry and Chemical Engineering at Queen's, then took a masters in polymer engineering and later a PhD at the School of Pharmacy. He's now a Senior Lecturer in Pharmaceutics.

Along with colleagues David Jones and Sean Gorman, He has invented a new multi-layer biomaterial that provides a controlled release of drug and possesses self-cleansing properties.

It was while carrying out research at the College of Pharmacy, University of Texas, that Gavin first considered whether polymers that are commonly used to coat tablets and protect patients from the harsh environment of the stomach could be translated for use with in-dwelling medical devices.

"My idea was to engineer new materials that would significantly improve the performance of urinary catheters and reduce the complications often associated with their use."

That idea led to a major Queen's research project, assisted by EPSRC funding, which could have a lasting impact on health care.

Gavin explains, "The use of implanted medical devices is routine within hospitals and nursing homes. Although there are substantial benefits associated with their use, there is, very worryingly, a number of potentially dangerous complications that may lead to an increase in the time a patient may remain in hospital and, more importantly, to an increase in the number of patient deaths.

"These complications arise principally because of the way a patient's body reacts to insertion of a medical device and what it perceives to be a foreign object. Patients are often plagued by infection and this is seen to be one of the most critical disadvantages of an otherwise highly effective and beneficial medical treatment. There is an urgent need to improve what we call device-related infection through the development of innovative medical materials.

"The EPSRC grant was to address that issue. We wanted a material that would deliver drugs in a controlled way and additionally cleanse itself if required."

With the support of EPSRC, he and his colleagues David Jones and Sean Gorman developed multi-layer systems that functioned in this way. The technology has been patented and the University is in negotiation with an industrial partner with the aim of bringing this technology to the market.

As Gavin says, "According to recent market research, the medical device industry is valued at over $300bn. So you can see why there's huge commercial interest. It would be wonderful if this were to progress to a marketed product. Not only would we be improving patients' lives, but we would also be providing a wonderful example of how investment in scientific endeavour is an essential strategy to ensure our future economic prosperity."

"The support we're getting shows there's a true belief in what we've been able to do through this EPSRC programme. It's absolutely fantastic for the University."

Dr Gavin Andrews
School of Pharmacy

Professor Bernard Smith School of Geography, Archaeology and Palaeoecology

THE DOWNSIDE TO A CLEANER ENVIRONMENT

Professor Bernard Smith
School of Geography, Archaeology and Palaeoecology

As a UNESCO world heritage evaluator, Bernard Smith has worked in cities such as Venice, Prague and Rio de Janeiro. He has also been involved in the conservation of some of Belfast's best-known buildings including the Albert Clock and St George's Market.

Reducing atmospheric pollution has helped create purer air in our towns and cities.

What isn't so well known is that a cleaner environment, combined with changing weather patterns, is still driving significant damage to some of our most historic buildings. Sadly, a growing number of these buildings, whose stonework had deteriorated only gradually over centuries, are now undergoing unpredictable, rapid and sometimes catastrophic decay. Bernard has won funding under four separate EPSRC projects designed to establish why this should be and what can be done about it. Much of this research has been carried out in collaboration with fellow academics at the University's School of Planning, Architecture and Civil Engineering, Oxford University and City University London as well as a number of commercial partners.

"In the past, pollutants reacted with the surface of many types of commonly used building stone to create a protective surface crust. When that's removed through natural attrition or restoration work, the layer beneath is exposed and the crust won't reform because the air is cleaner than it used to be," says Bernard.

"This can result in rapid decay which can be further exacerbated by changing climatic conditions. To study the impact of these a research facility has been built a in a clean environment in the west of Northern Ireland where a diverse range of environmental sensors have been installed to measure the effects of weather conditions on different types of building stone.

"This is giving us valuable data on how the localized impacts of global climatic change could affect stone. Because the centre is located in an area with particularly high rainfall, we can use that information to predict what could happen to buildings in other locations, especially those where winter wetness is projected to increase.

"Working with our project partners, we have also used our research findings to develop sophisticated fibre optic sensors that can be assembled into networks for embedding in endangered buildings. These will give an accurate picture of the condition of the stonework and indicate if and when any remedial action is required. The most recent EPSRC funding is to bring these sensors closer to commercial development through a university spin-off company.

"Through our research we can now see that some current conservation and restoration practices not only don't work, they can actually make the situation much worse, in a world where environmental conditions are constantly evolving.

"The expertise we have developed should now help ensure that the hundreds of millions of pounds spent annually on preserving the built heritage in the UK and Ireland will be used in the most effective way possible."

Professor Stuart Elborn and Dr Michael Tunney
School of Medicine, Dentistry and Biomedical Sciences and the School of Pharmacy

Professor Stuart Elborn and Dr Michael Tunney School of Medicine, Dentistry and Biomedical Sciences and the School of Pharmacy

AMBITIOUS STUDIES INTO THE TREATMENT OF CYSTIC FIBROSIS

Stuart Elborn and Michael Tunney are at the forefront of one of the most ambitious studies ever undertaken into the causes and treatment of Cystic Fibrosis lung disease. An international research project being carried out at Queen's, the Royal College of Surgeons in Dublin and the University of North Carolina will involve more than 450 patients across the three sites.

Stuart is Director of the new Centre for Infection and Immunity in the School of Medicine, Dentistry and Biomedical Sciences, responsible for 21 senior investigators and their teams. He sees the work now being undertaken as vital progress in a field that has dominated his life since his days as a medical student at Queen's.

He says, "When I started my training in respiratory medicine I realised there was a huge challenge in taking care of people with Cystic Fibrosis who were living longer, moving from childhood to adulthood, and that adult physicians were not sufficiently trained to meet the challenge."

He left Northern Ireland to pursue his ideas, gaining experience in Nottingham and Cardiff, then he came back to set up an NHS clinical service and research programme, later taking on an academic post at Queen's. He now has both clinical and research responsibilities, "but the patients come first."

Michael studied for both his undergraduate and postgraduate degrees in the School of Pharmacy at Queen's. His PhD had involved investigating infection of urinary catheters "and that got me into microbiology in a big way."

In his first work with Stuart, they studied drug levels in sputum from Cystic Fibrosis patients, asking if they matched what was needed to have an effect against bacteria. Using a combination of specialist microbiology techniques and DNA fingerprinting methods, their work has now led to identifying a much wider range of bacteria causing infection. They have discovered bacteria previously unidentified and which do not require oxygen to live. The current programme is designed to establish the role of these organisms in causing infection and damage in the Cystic Fibrosis lung and to determine more effective antibiotic therapies. There is funding support from Northern Ireland R&D and the Medical Research Council.

Stuart says, "We work very closely with Cliff Taggart here at the Centre. Our activity links in very strongly with his EPSRC-funded programme and his work on effective drug levels to kill bacteria."

Michael explains, "We want to look at patients in two conditions, when they're stable and coming in for routine check-ups, and when they get a flare-up of their lung infection. Our focus is on the 18+ age group. The three centres are recruiting individually, but we have developed the standard protocols which all the centres are using."

Stuart says, "We have a very well-educated group of young people who are enthusiastic to help, but we're trying to do this research in a way that doesn't interfere with their lives. These are busy, active individuals, with families, in full-time education. We're very much building the research around what they can do for us in terms of extra time."

As Michael sees it, "The great thing would be that at the end of this study we can make a difference to people."

Stuart adds, "I'm very confident about the robustness of the science we're researching. And we're seeing patients, hospitals and universities working together on real issues that are important for people with this disease. The success of this will be that we understand better how to use antibiotics in treating people with Cystic Fibrosis. By treating their infection better they'll have better quality of life and will live longer."

BRINGING THE AIRCRAFT OF TOMORROW ALIVE TODAY... LITERALLY

Having worked with multinationals such as Ford, Du Pont and Seagate, George Irwin is applying his expertise to help develop novel technologies that could greatly benefit airlines, passengers and the environment.

How will next generation passenger aircraft differ from the planes we fly in today?

George, who is Professor of Control Engineering and Research Director of the University's Intelligent Systems and Control group, believes that one big difference could be that they have their own 'nervous systems' to greatly increase their performance, profitability and safety.

And to prove that concept is feasible, he and colleagues at the School's Institute for Electronics, Communications and Information Technology (ECIT) and the universities of Sheffield, Leicester and Warwick, have recently completed work on two EPSRC projects awarded on behalf of a leading aircraft manufacturer.

That work showed that using 'active skin' technology devised at Queen's could result in savings of up to $3m per aircraft each year and an average reduction in carbon dioxide emissions of more than 12 per cent.

George won funding for the project in competition against consortia involving 50 other universities for what he describes as a "completely off-the-wall" response to the initial brief.

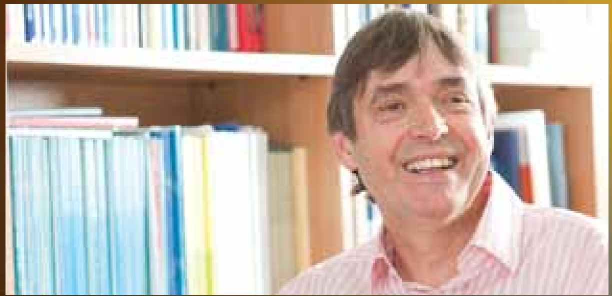
"The original problem we were asked to address was how to make aircraft more fuel efficient. We tackled the challenge by building on one common way of doing this, by reducing the amount of turbulence affecting an aircraft's wings. This decreases friction and drag and therefore the aircraft's fuel consumption," says George.

"What made our approach unique is that we proposed to reduce turbulence by using hundreds of one square millimetre wing-mounted patches, each of them containing sensors and actuators connected wirelessly to a controller in the aircraft cockpit. This would effectively give the aircraft a 'smart skin' with the sensors detecting turbulence and the actuators responding to help counter it in real time through closed loop control.

"But then we took the concept one stage further by suggesting that as well as being used to regulate airflow, the patches could be fitted throughout the aircraft to provide a complete onboard health map and fault diagnostic system. The same technology could also be used to enable commercial aircraft to be controlled wirelessly by the pilot for the first time."

Throughout his research career, George has worked with a number of major multinationals. He was also technical director of Anex6, a University spinout company specialising in process monitoring systems for large chemical plants.

"Whether or not our technology will be adopted by aircraft manufacturers remains to be seen, however, the School's expertise in intelligent systems control and wireless technologies, coupled with our external partners' aeronautical engineering capabilities, certainly showed it is not only feasible, but that it is also of potentially enormous benefit to airlines, passengers and, ultimately, the environment."



Dr George Irwin
School of Electronics, Electrical Engineering and Computer Science

"Active skin technology devised at Queen's could result in savings of up to $3m per aircraft each year and an average reduction in carbon dioxide emissions of more than 12 per cent."

ATTEMPTING TO MAKE HARMFUL SOLVENTS A THING OF THE PAST

Stuart James had originally planned to become a professional musician. While his career path has taken him down a very different route into inorganic chemistry, he's still using his creative abilities to the full.

Solvents are considered essential in a huge variety of today's industrial processes. Unfortunately, many are extremely toxic and huge volumes of waste can be generated making them. Given the scale of their use, combined with the energy required to produce, transport and store them, it is therefore hardly surprising they have long been a major target for environmental campaigners.

Stuart is among a small but growing group of scientists who believe that one day it might just be possible to do away with many of them. And now, with the help of EPSRC funding, he and his team have succeeded in making a special type of polymer without the use of solvents for the first time.

"We've done this by inducing reactions mechanically, rather than by heating, to produce a particular kind of crystalline compound known as a metal-organic framework or MOF for short," says Stuart.

"We believe the type we have developed could be particularly suited for future applications in gas storage and purification systems.

"Usually, MOFs are formed at high temperatures using solvents; we've succeeded in producing them with neither, by placing the reactants directly together along with small metal balls inside what look like miniature cocktail shakers. The containers are then placed on a machine that moves them quickly from side to side to produce a slightly chaotic rotation.

"The reaction happens within minutes. Water and other by-products are then removed, leaving the new polymer behind.

"It is highly unlikely that we will ever be able to do without solvents entirely, but we know there is an enormous amount of chemistry in this area that is simply not being attempted. The same method could be used to make many other similar types of material. It's possible it could even one day help improve pharmaceutical manufacturing processes."

Stuart explains that in some of those processes, solvents account for more than 80 percent of all materials used.

"Our objective now is to move this technique out of the laboratory to prove that it works cost effectively on a large scale in the real world.

"We are very close to obtaining a patent for this new process. We are also currently negotiating exclusive rights with a leading international company specialising in advanced materials technology. That is a very exciting prospect indeed."

Dr Stuart James
School of Chemistry and Chemical Engineering

"Our work is aimed at developing the systems that will be needed to monitor and control these new types of energy stores."

INTELLIGENT CONTROL SYSTEMS OF THE FUTURE

Professor Haifeng Wang
School of Electronics,
Electrical Engineering
and Computer Science

Electricity networks of the future will incorporate intelligent monitoring and control systems enabling them to access and distribute a growing proportion of clean, renewable energy from sources such as wind farms and marine generating stations.

"Smart Grids", as they are known, will also provide significant benefits for consumers. With access to real time information about their energy consumption, they will be able to control and plan their usage effectively and even have the option of switching automatically to the best value energy suppliers.

Helping to turn that vision into reality is Haifeng Wang of the School of Electronics, Electrical Engineering and Computer Science who is working to develop some of the critical technology that will be required.

One of the key challenges faced by his team is the need to increase the reliability of electricity supply to reduce the effects of power cuts on consumers. This will become an ever more complex task in years to come as the amount of energy supplied to the grid from decentralised renewable sources increases substantially to keep pace with government targets.

Part of that solution is to introduce new types of energy storage systems around the network. These will be used to ensure supply in the event of network faults or sudden loss of generating capacity caused, for example, by unfavourable weather conditions reducing the amount of wind or marine energy available to the grid.

"Our work is aimed at developing the systems that will be needed to monitor and control these new types of energy stores. We believe it has big commercial potential because we are the only team in the UK working in this important area of applying energy storage in power transmission," says Haifeng.

"We are fortunate because our close working relationship with the local power industry means we have direct online access to monitoring equipment installed at various location around the grid. This has enabled us to collect vital data, which we have used to develop our initial models.

"Our next step will be to validate those models through field tests in China where a major power company will give us access to their system data."

Originally from Nanjing in southeast China, Haifeng completed his PhD in Electrical Engineering at Southeast University in 1988. Aware of Queen's University's expertise in his chosen field, he applied successfully for one of only two available visiting fellowships and subsequently worked at the University as a research fellow until 1993.

He then moved to England where he held research positions at Manchester and Bath universities before returning to Belfast to take up his current post in 2007. He has worked on a number of projects sponsored by UK power companies, including the National Grid Transco (NGT), the Schneider Group and Toshiba International plc.

"International co-operation is a vital aspect of the EPSRC projects we are working on. It is providing an opportunity to establish international collaboration with leading institutions in China, where previous research links have already resulted in a number of important technology advances."

"In contrast to other regions, the island of Ireland has a relatively small, self-contained power system with a disproportionately high reliance on renewable generation. These factors put our research team in a strong position to develop solutions that will be readily exportable to other power systems around the globe."

Dr Jennifer McKinley School of Geography, Archaeology and Palaeoecology

LEADING THE EFFECTIVE RESTORATION AND CONSERVATION OF OUR BEST-LOVED BUILDINGS

Ensuring the effective restoration and conservation of some of our best-loved buildings involves understanding the long-term changes that occur inside the individual blocks of stone used in their construction.

Until recently, the absence of the technology needed to do this limited knowledge of those processes. Now, thanks to EPSRC funding, Jennifer McKinley is delving deeper, using equipment and techniques normally associated with oil and gas exploration.

Having identified the need for a thorough three-dimensional study, her team is working to model the characteristics of fresh and weathered blocks of stone.

"The blocks were artificially weathered under controlled laboratory conditions to simulate the changing seasons and weather patterns. In addition, salt solutions were added to replicate the salt deposits contained in rainwater," says Jennifer.

"EPSRC funding enabled us to purchase a portable probe permeameter, specialist equipment normally used in oil and gas exploration to evaluate the flow dynamics of porous materials. This allowed us to take high-resolution permeability measurements of stone slices through fresh and weathered blocks.

"We also used laser scanning to provide a picture of surface texture. The results were collated on a three-dimensional grid before each block slice was cut into small cubes. Each cube was then ground to fine powder for chemical analysis.

"This work enabled us to model the extent to which different types of salts had permeated the complete block, how they migrated through it under simulated weathering conditions and how these factors were related to the composition of the stone and the structural variations within it."

The next stage of the project was to repeat the tests, this time on a weathered block of the same type recovered from a 100-year old building undergoing conservation. This work was done in partnership with a specialist firm, Stone Conservation Services, Consarc Design Group.

"We are now working to correlate the two sets of results to enable us to develop a model that will ultimately allow us to predict with a high degree of accuracy how a particular type of building stone is likely to stand the test of time in any given location in light of changing weather patterns."

Dr Jennifer McKinley
School of Geography, Archaeology and Palaeoecology

“We believe that ultimately this will greatly increase the long-term effectiveness of conservation projects and produce significant savings for the parties involved.”

A POWERFUL NEW WEAPON IN THE FIGHT AGAINST TERRORISM AND DRUG ABUSE

Dr Steven Bell
School of Chemistry and Chemical Engineering

As a first year student, Steven Bell switched from Medicine to Chemistry. That change in direction didn't mean retreating into a laboratory. His first spin-out company was acquired by PerkinElmer and he could soon be involved in forming a second one.

Centuries ago, artisans mixed molten glass with nanoparticles of gold to create the distinctive rich ruby tones of medieval stained glass.

Today, Steven and his collaborators in the School of Pharmacy have discovered a novel way of chemically modifying the surface of the tiny particles, potentially creating the platform for a powerful new weapon in the fight against terrorism, drug abuse and pollution.

The approach has recently been proven to work in real life situations to detect tiny traces of ecstasy within seconds of testing. The quantities involved are so small that previously they could only have been discovered through time-consuming laboratory analysis.

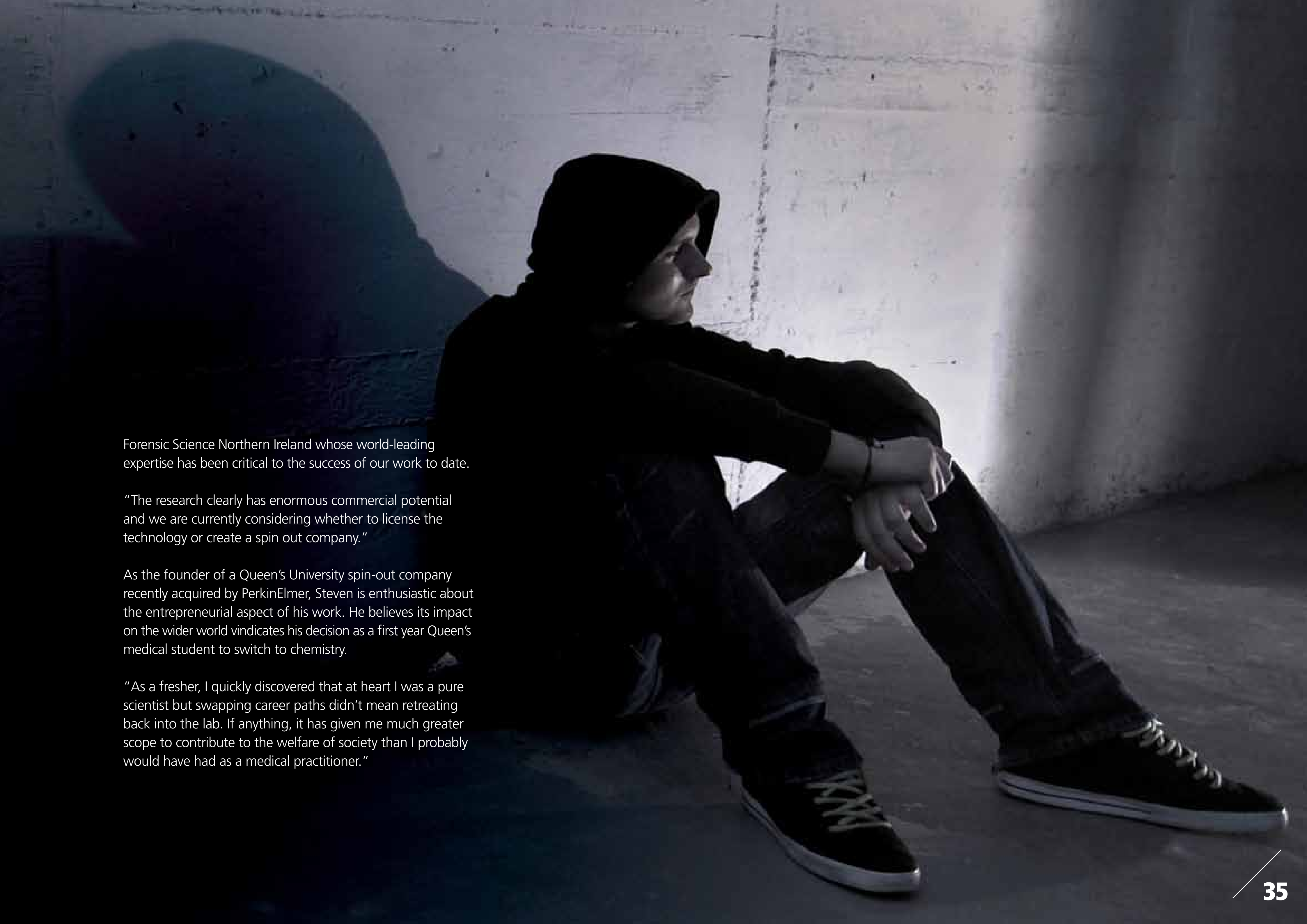
Steven says, "The new method involves the use of a handheld Raman spectrometer to shine a laser beam onto a small quantity of a suspect sample. The instrument then measures the energy of the scattered light to determine the presence of specific chemical compounds.

"Up to now, this type of device has not been sensitive enough to detect low concentrations of chemicals in small samples.

"Through the EPSRC project, however, we have discovered that by chemically modifying nanoparticles of gold and silver, we can make them attach themselves to the specific molecules we wish to target. When this happens, the metal acts as an antenna and amplifies the laser scattering signals by a factor of at least one million. This allows even the smallest traces of specific chemical compounds to be detected and means that better, faster decisions can be made in response to the results produced."

Steven's team is now working to develop special gel pads to swipe an individual or crime scene for instant analysis. These pads will contain the nanoparticles held in a gel-like polymer with a protective cover which can be peeled back to expose them before use.

"We are also continuing our research into extending the range of chemicals the technique can be used to detect. This is being done in co-operation with the project partner,



Forensic Science Northern Ireland whose world-leading expertise has been critical to the success of our work to date.

"The research clearly has enormous commercial potential and we are currently considering whether to license the technology or create a spin out company."

As the founder of a Queen's University spin-out company recently acquired by PerkinElmer, Steven is enthusiastic about the entrepreneurial aspect of his work. He believes its impact on the wider world vindicates his decision as a first year Queen's medical student to switch to chemistry.

"As a fresher, I quickly discovered that at heart I was a pure scientist but swapping career paths didn't mean retreating back into the lab. If anything, it has given me much greater scope to contribute to the welfare of society than I probably would have had as a medical practitioner."

Professor Kenneth R Seddon School of Chemistry and Chemical Engineering

GREEN CHEMISTRY: HARDER, FASTER, BETTER, STRONGER

Ken Seddon, the UK's top research chemist, retains a boyish enthusiasm for the subject he first came to love conducting foul smelling experiments in the family kitchen, using chemicals purchased with his pocket money.

In 1980, BP set up a special unit to seek out and fund the most innovative science on the planet. The project succeeded in identifying and nurturing several brilliantly innovative scientists.

Among them was Ken who, in 1987, was awarded a £250,000 grant to kick start research he believed could change the world. Its goal was to develop ionic liquids that would lead to novel environmentally-friendly processes and non-polluting alternatives to conventional solvents.

Now Professor of Inorganic Chemistry and a Director of QUILL, an industry/university cooperative research centre, he was recently ranked as the UK's leading research chemist of the past decade in Times Higher Education.

His contribution to "green" chemistry has been recognised in the wider world too. In 2005, he was presented with a personal George Bush Green Climate Challenge award. The following year he received the Queen's Anniversary Prize for Higher and Further Education on behalf of QUILL.

"The whole of life is based on chemistry. It's the science of everything around us. It's all about manipulating your starting materials and giving them the properties you want. It's about making things in a better way or making things that have never been made before anywhere in time or space. That is fun," says Ken.

"Green chemistry is all about doing those things in better, cleaner, less polluting, cheaper, more efficient ways, and that is fascinating."

"One of the biggest challenges facing the world today is the problem of industrially produced volatile organic compounds, or VOCs, that are known as greenhouse gasses. If you can stop these compounds being emitted, that would have a massively beneficial effect on the earth's atmosphere.

"Ionic liquids under normal conditions don't produce vapour. That means if we could use them to replace every VOC in industry, we would instantly stop about 90 per cent of industrial vapour pollution.

"To do this you need to look at the entire sweep of the liquids' properties and learn how to choose them, tune them and make them so that they will do exactly what you want.

"There are only 300 or so conventional solvents in use today while there are over one million ionic liquids. If you mix two ionic liquids together, you get a billion solvents and if you mix three, a trillion. That gives you a huge array to work with so you can choose solvents with the absolutely perfect properties for the process you are trying to develop.

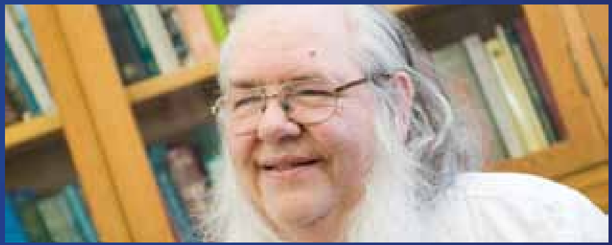
"That is what we do at QUILL, which was set up in 1999. We have 16 industrial members including Shell, Procter and Gamble, Chevron and Petronas. They effectively set our research agenda. The work we do is aimed exclusively at tackling the problems they give us to solve. That makes our research extremely relevant. It's also one of the reasons why we lead the world in this field.

"We have an integrated team of close to 100 amazingly gifted postdocotorals, PhD students, technicians and support staff. Their work has been instrumental in taking a research area that was an academic backwater and turning it into one of huge industrial significance.

"When we published our first paper on this subject in 1996, there were around 20 papers being published each year. Now there are over 3,500. There has never been growth like this in any area of chemistry.

"Increasingly, research is showing up in real world applications. Eight years ago there were only two publicly accessible industrial processes making use of ionic liquids. Now there are 17 and we know of at least another 12 that are likely to come on line in the very near future. That is staggering growth in less than a decade."

Since 1993, Ken has witnessed significant investment and growth in expertise in chemistry at Queen's thanks, in no small part, to his dedication and QUILL's accompanying success.



Professor Kenneth R Seddon
School of Chemistry and Chemical Engineering

FEEDING THE LOOP OF INNOVATION IN A WORLD OF CAUTION...

Mark Price likes new ideas. But he is working in a world where they are treated with caution.

Mark says, "Aircraft manufacturing is a conservative industry. That's understandable because if anything goes wrong it has very serious consequences. So when someone comes along with either a new material or a new process, the certification authorities insist that you demonstrate that they will perform, not just in a laboratory test, but right through in a vehicle that's flying. That's why air travel is so safe."

Mark, Professor of Aeronautics and Director of Research in the School of Mechanical and Aerospace Engineering, is one of the UK's leading aerospace academics with an international reputation for research into integrated design methods. And it's research for which there is a hunger in the industry.

"We work very closely with Bombardier because they're one of the most innovative companies in the world. Right now they're building one of the most advanced passenger jets and in a new purpose-built factory."

Mark once worked for Bombardier himself. That was in 1988 when he left Queen's with a degree in Aeronautical Engineering and a masters in Computing, "which was kind of rare at that time.' He worked in the firm's stress office, carrying out structural calculations, "but there was an element of innovation in the job as well which attracted me to the world of research." He returned to Queen's to do a PhD in making models for analysis. There followed a spell in industry in England then he joined the Aeronautical Department at Queen's in 1998.

"Several of us were 'new starts'. Structural design work was really only beginning. There were questions like, could you weld things instead of using rivets and bolts? A lot of the calculation methods needed changing to cope with these new processes."

He says, "When you're dealing with new technology, new material, you don't just observe it and say, that's ok... it doesn't break... it must work. You carry out a whole series of analyses so that you understand exactly what's going on and then when you take it out, the designer can make the right decisions."

Innovation takes time and money. Mark is appreciative of the research finance that has come from EPSRC. "EPSRC funding is really aimed at longer-term research. Some of the things we're testing now at higher levels, we were doing initial analysis just over ten years ago. So we're looking at a lengthy timescale that allows us to explore things, unencumbered by the immediate demands of industry. That way we can be more speculative and that in turn leads to higher reward in terms of results and feeds tomorrow's industry needs."

A current EPSRC project is looking at thermal management in polymer processing. It stems from an interest in composite materials now being used in aircraft and involves collaboration with colleagues from other fields. The project is aiming to help companies use energy more efficiently without affecting their product quality.

"One of the nice things about EPSRC is that it allows you to cross over. We're building systems models that are as relevant for polymer factories as they are for an aerospace factory. This is an unexpected area for our research, polymers, but I've got a bug for developing new things so we'll develop the technology there and then bring it back into aerospace, once again feeding the innovation loop."

Professor Mark Price
School of Mechanical and Aerospace Engineering

"One of the nice things about EPSRC is that it allows you to cross over. We're building systems models that are as relevant for polymer factories as they are for an aerospace factory."

THE CHALLENGE: NEW SOLUTIONS EVERY DAY...

Professor Robert Bowman
School of Mathematics and Physics

Robert Bowman gazes round the Centre for Nanostructured Media, in the heart of the Department of Physics and Astronomy at Queen's. "Inside these four walls are four academic staff running an activity that has a total of 30-plus people and a multimillion-pound research portfolio. In effect, we're running a small company inside the University."

He continues, "We're trying to be innovative all the time. The pressure is getting the new opportunity, the new contract, opening up a new business area, closing down something that has run its course. The outside world doesn't realise some of the business-process thinking that academics are doing on a daily basis. A massive portfolio of skills is required."

Robert is Director of the Centre and also Professor of Material Physics. He came to Queen's as a lecturer in 1994 with a PhD from Strathclyde and an expertise in the area of high temperature superconductors. Since then he has moved towards research into ferroic materials systems such as ferroelectrics.

He says, "We have benefited over the last number of years from a range of both project and infrastructure grants." He points to two pieces of equipment. "EPSRC funding provided one of these focused ion beam microscopes and our high resolution transmission electron microscope, which are central to the work of Marty Gregg who carries out world-leading research in the properties of nanoscale ferroelectrics."

And he emphasises the innovative brilliance of his other academic colleagues. "We have the work of Bob Pollard who has received a number of awards in new nanostructuring approaches and we've applied these applications from nanoscale capacitors through to a very active programme in nanoscale plasmonics. Paul Dawson has been very active in the area of scanning probe-based nanoscale light sources. And that portfolio has an interest for a company like Seagate Technology."

He says, "We've worked on a range of short projects, one to three years, through EPSRC grants and that has allowed us to develop a strong reputation and performance in nanostructured materials. The most exciting development and a validation of that work has been the launch of our new ANSIN Centre which is the result of a £9.5m investment by Seagate. A large part of that was a capital donation. They've given us state-of-the-art equipment that complements but extends our infrastructure base so that we can engage at a level that's appropriate to dealing with the technology leaders which the multinational global companies are, but at the same time enhances the platform to continue to do interesting science."

And there is now a second major partner. FEI, the global leader in electron and ion microscopy, has recently made a six-figure investment in the work of the Centre.

With all this activity it is appropriate that among Robert's qualifications is an MBA, gained while being active in research at Queen's. "As well as being an academic, I've ended up in a position where a key function is managing people, resources and internal and external relationships."

Of the students working towards a PhD at the Centre, he says, "They all have different reasons for wanting to be here. You see a trajectory of their skills and their capability as they mature and change. In research they have to come up with new solutions every day and that's a big challenge. There are no signposts for them. They have to chart a path and make their own decisions. But that's a training they're getting for life."

He adds, "We see ourselves as a team with core strengths in particular areas but we're always trying to move forward and we have ambitious plans to expand the vision of the ANSIN hub. You have to be entrepreneurial. You have to be continually scanning the environment for opportunities. But if we deliver as an integrated team we'll advance together."

A TREATMENT FOR CANCER WORTH ITS WEIGHT IN GOLD...

Fred Currell came to the Centre for Plasma Physics at Queen's via Manchester and The University of Electro-Communications in Tokyo where he was the first non-Japanese member of staff to be appointed.

Fred's professional journey has taken him not just from Tokyo to Belfast but into new and exciting areas of physics. An interest in radiation generation and what happens to electrons which are tightly bound to atoms has led to a research project with enormous medical relevance, new ways to treat cancer.

At the heart of the research, which has received EPSRC funding, is the discovery that the use of minute particles of gold might be the key to quicker, more effective and more cost-effective treatment.

As Fred outlines, "Any heavy element absorbs x-rays much better than something which is lighter. Our bodies are mostly made of light things and that's why with x-rays we can see through them. But when people don't want x-rays to go through they use something like lead shielding. Lead's a very heavy element but it's not good for our bodies. Gold is much safer. It's another heavy element but it's not bad for us.

"With cancer, there's a lot of discussion about fancy chemotherapy treatment. The reality is, if you go into the hospitals you find that most cancer is treated by surgery and radiotherapy, using radiation to try to kill the part that has the tumour. But you don't want to damage the healthy parts of the patient.

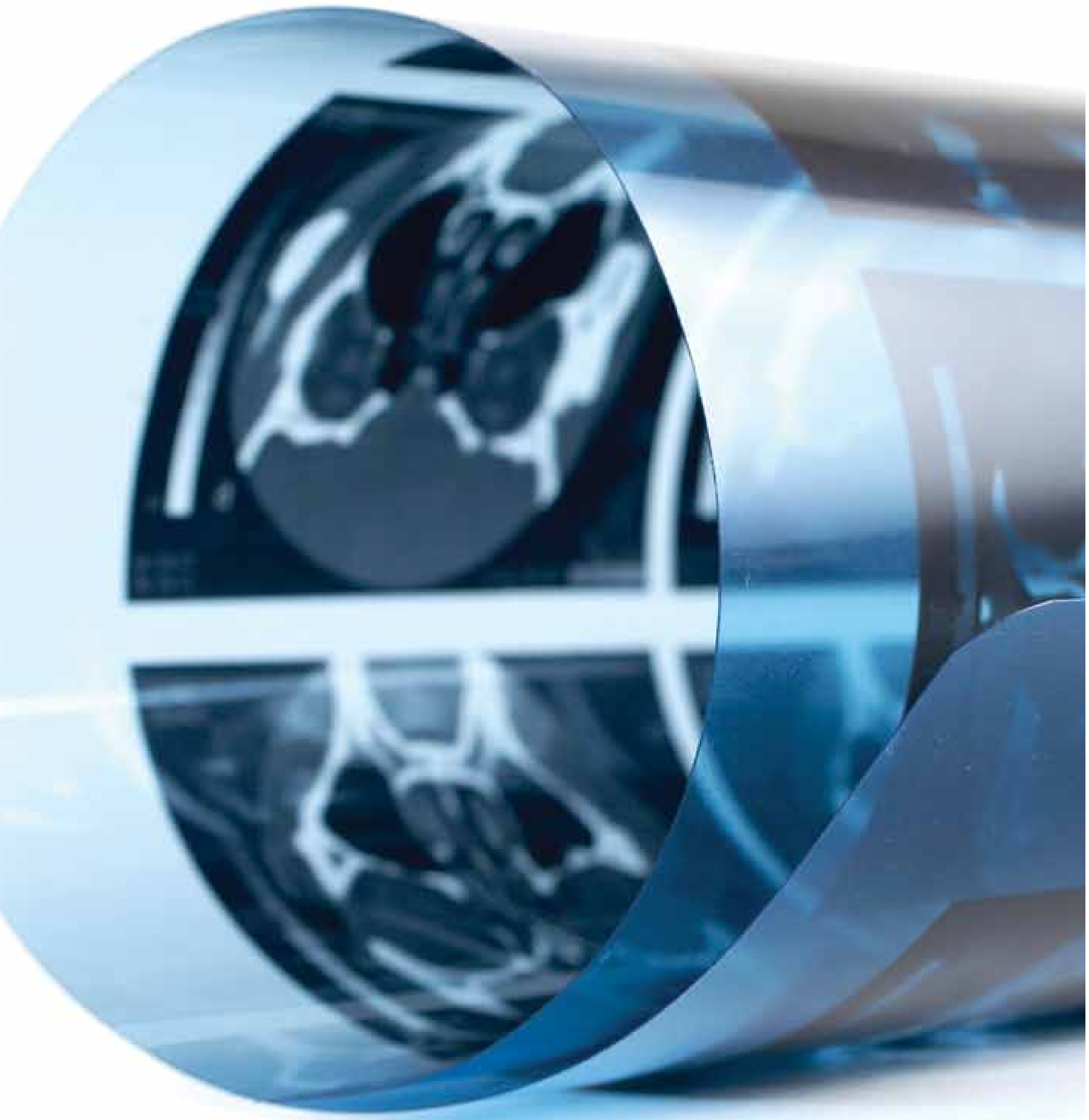
"Nanoparticles of gold are taken up by a tumour much more than by the rest of the body. We've discovered that around each of these nanoparticles there's a massive amount of dose. So if we can put a nanoparticle exactly where we want it there's also a massive effect. It kills but it leaves the healthy parts of the patient unaffected."

Not surprisingly, Fred describes the work as exciting. "We work with the local hospital, with the Clinical Cancer Centre, with people in biology, pharmacy, chemistry. It spans all these disciplines. You have to pull together to make progress in a field like treating cancer.

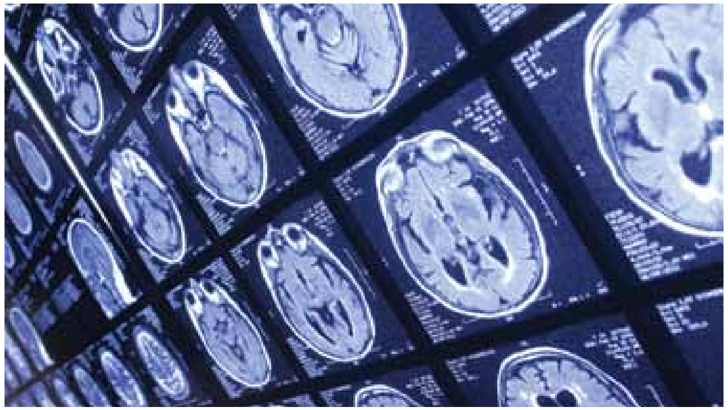
"The approach," he explains, "is also similar to heavy ion cancer therapy used in certain facilities available in only a few places in the world.

"The smallest facility of that kind would cost about $20m before you even open the door. But it looks as if gold nanoparticles, used in conjunction with equipment in present-day hospitals, will give the same level of benefit. So the machines in our own cancer centre would suddenly give much better patient outcome and be much more economical."

Fred concedes that there are many steps to be taken between the current research and delivery to a patient. But he says, "I'm a big evangelist for this."



Dr Fred Currell
School of Mathematics and Physics



FIGHTING AGAINST THE RESISTANCE OF MICROBIAL INFECTION

David Jones can give you a startling view of the future. "The Royal Academy of Engineering has stated that at some stage everybody will have a medical device of some kind, be it something as simple as a contact lens at one level to a dialysis catheter for someone whose kidneys have failed."

Such a vision is of enormous professional relevance to him. "My interest is primarily in the design of medical devices that are resistant to microbial infection. This is the big problem in all medical devices. No matter where you put it or what it is, there is that possibility."

David is Professor of Biomaterial Science and Director of Education at the School of Pharmacy. He graduated from Queen's in 1985 with a degree in Pharmacy, then took a PhD, part of the theme of which was looking at how to prevent bacteria sticking to surfaces. After three years as a lecturer at a university in New Zealand, he came back to Northern Ireland accepting a job at Norbrook, the veterinary pharmaceuticals company, in Newry. Then he joined Queen's as a lecturer. "The first thing I realised was that there was a very different level of collaboration here, compared to New Zealand. There is great collegiality among the academic staff at Queen's. By working in collaboration with other staff members you gain an insight into how problems may be solved, thereby resulting in a better end product."

David's research focuses on the design of advanced medical devices and implantable drug delivery systems. The work has benefited from EPSRC funding.

"With the problems of infection, the cost to the NHS is immense. The actual materials themselves aren't expensive. A urinary catheter doesn't cost very much, but to have it changed requires a hospital procedure and people generally recognise the need to have it changed only when they've got an infection."

A recent project funded by EPSRC looked at surface gels as next generation chemical sensors. "This was an excellent collaboration with the School of Chemistry and Chemical Engineering. We worked previously on particular materials, then we discovered that those materials can be used as sensors. By chemical modification and reformulation of the materials it was discovered that these could be engineered to give a better analytical response when you want it."

The research takes a long time, so does he ever get impatient? "When I was in industry, my job was to formulate new products. The lag time was generally about two years. It still gives me a thrill to see one of my products for sale somewhere and to think that I developed it.

"I have learned that very different timelines are needed with this work. There is no other way. Having said that, when a device of ours that has been developed at Queen's in conjunction with a company hits the market, I'll be a very proud person."

Professor David Jones
School of Pharmacy

THERE WILL COME A POINT WHERE YOU CAN'T GO ANY FURTHER...

Dr Gary Menary
School of Mechanical and Aerospace Engineering

Gary Menary studied Mechanical Engineering at Queen's where he completed a Masters and a PhD. He holds an academic post at the University and is a leading figure in research into the complex field of stretch blow moulding which is used to make plastic bottles for the soft drink and water industries.

He is never away from work, even when he's in the supermarket. "I'm always picking up bottles and looking at them. While other people look at the content, I'm studying the design and wondering how the manufacturers went about it."

Gary's research at Queen's focuses on the development of mathematical tools to try to optimise the design of packaging, to make bottles made from PET (polyethylene terephthalate) lighter and more efficient. The work has brought funding from the soft drinks industry and from EPSRC.

"The process used to make these bottles is very complex and there's very little real understanding of it. I've been researching in this area for 11 years. It's still very much trial and error within the industry. When engineers come up with a new bottle, it's a case of bringing it down to the shop floor where they then make loads of different bottles, to guess the proper design and process conditions.

"We're developing a more scientific approach, building mathematical models, simulations of the process, which will allow an engineer to design in a virtual environment without wasting material or energy."

Gary and his colleagues collaborate with a number of big corporate players who are providing financial backing, including Danone, Evian and Proctor and Gamble. "We talk to Proctor and Gamble in the US every two weeks. It's a teleconference and we make webcast presentations about our latest research.

"This is a very competitive field. The National Research Council in Canada is doing similar work. It's also being explored at research institutes in France and Germany. There's a huge drive in the industry to try to make things lighter. That's why my research is so valuable. Evian make six million bottles a day. If they can save even one gramme of material it will mean a financial saving of £2m a year, plus the saving in energy. There are huge volumes involved and that's what's driving this."

The work has led to the creation of a new company, Blow Moulding Technologies, with Gary as Technical Director, which will sell new technology to the industry. And an international conference has been held at Queen's to facilitate communication between specialists in various fields of material-forming sciences. With world experts attending, the conference presented a unique opportunity to see the latest technology.

And the next step? "Process control is the next challenge, making things run more efficiently. We want to develop instruments which will control the process automatically so that it regulates itself and doesn't need any human intervention.

"There'll come a point where you can't go any further, where there's an optimum amount of material for a specific bottle, but there'll always be a demand for new material and new designs."

UNMATCHABLE PEARLS OF WISDOM INTO THE WORLD OF CRYPTOGRAPHY

Máire O'Neill was still a PhD student when her research was first exploited commercially. Now, the one-time UK Female Inventor of the Year is regarded as one of Europe's leading cryptography experts.

Real pearls, unlike real diamonds, are often difficult to distinguish from fake ones. For pearl farmers in a Chinese region that produces some 95 per cent of the world's freshwater varieties, that is having serious economic consequences.

Máire and her cryptography research team at the Centre for Secure Information Technologies (CSIT) believe they may have come up with a novel answer to that problem. Their proposed solution is to use lightweight uncloneable technology with radio frequency identification (RFID) tags that could be embedded into each pearl to guarantee their authenticity.

This could be done by using a simple scanner to identify, without revealing, specific physical properties unique to each embedded tag, effectively giving each pearl its own unclonable fingerprint.

"That is just one example of the research work we're involved in that addresses the security requirements of applications that can use RFID tags," says Máire.

"There is a rapidly growing need for this kind of technology because of the recent uptake of RFID in applications ranging from "smart' passports to stock control in high street stores. RFID is also increasingly being used in new "purseless" payment systems such as Transport for London's Oyster travel card and the latest generation of mobile phones.

"We have scored a number of notable firsts in this emerging field. These include the development of tiny circuits, half the size of anything else currently available. They are cheaper to produce, require much less power and provide significantly higher levels of data security. They also have the potential to offer much greater resistance to spoofing and skimming attacks.

The team is now exploring the possibility of setting up a spin-out company to exploit some of this work.

Máire knows all about the commercialisation of university research. She was a PhD student working with a Queen's University spin-out company, Amphion Semiconductor, when some of her first electronic designs were sold to a leading US semiconductor manufacturer.

A current holder of a prestigious five-year EPSRC Leadership Fellowship, she has received a number of major accolades for her work. These include the 2007 British Female Inventor of the Year title, awarded by the British Female Inventors & Innovators Network.

"Here at CSIT, we work closely with experienced engineers who help in the commercialisation of our research through the development of proof-of-concept designs and product prototypes that meet industry requirements.

"We are one of the only UK university groups specialising in cryptographic algorithms and architectures for system-on-chip and we are now regarded as European leaders in this field."

Professor Máire O'Neill
School of Electronics, Electrical Engineering and Computer Science

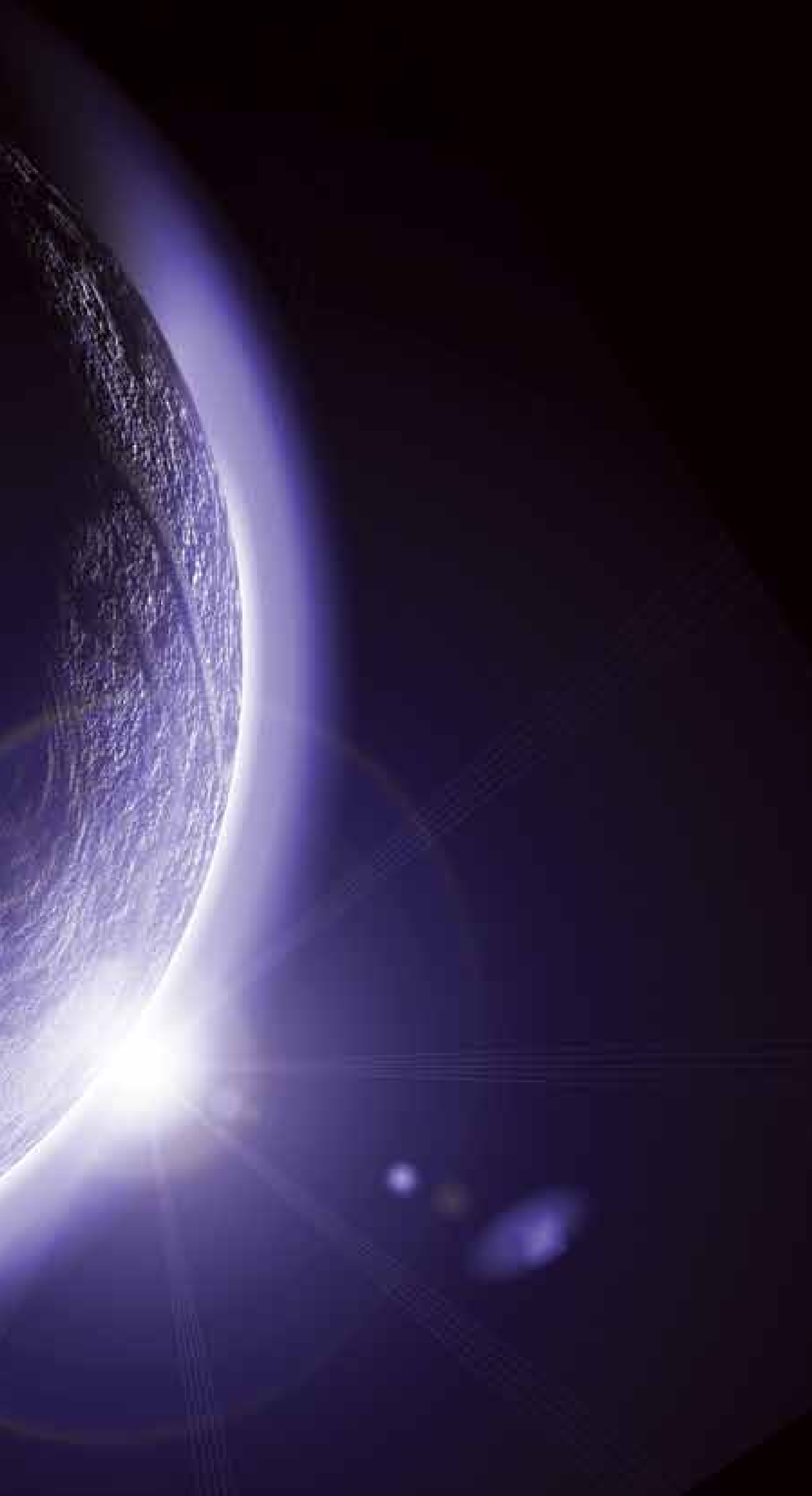
Dr Robert Cahill School of Electronics, Electrical Engineering and Computer Science

THE TECHNOLOGY TO OBSERVE EARTH'S ATMOSPHERE IN A WHOLE NEW LIGHT

Scientists will soon be able to produce more accurate global weather forecasts and gain new insights into climate change thanks to the School of Electrics, Electrical Engineering and Computer Science's success in positively exploiting the commercial potential of work funded by EPSRC.

That initial project has enabled a team lead by ECIT's Robert Cahill to develop high performance electronic devices that are to be fitted to European Space Agency (ESA) satellites due to be launched later this decade to study the earth's upper atmosphere.

Known as dual polarized Frequency Selective Surface filters, they will give scientists access to completely new data on a range of phenomena including ozone depletion. Robert's team is now further exploiting the potential of the EPSRC project by developing much higher frequency versions for retrieving data from clouds. That work is being supported



by the UK Centre for Earth Observation Instrumentation, Rutherford Appleton Laboratories, the European Space Agency and EADS Astrium, the largest spacecraft manufacturer outside the United States.

Robert says, "Up to now space borne remote sensing instruments have only been capable of separating either the vertically or horizontally polarized components of naturally occurring thermal emissions from gasses in the earth's atmosphere, but not both together at the same time. The new filters we have developed resolve this problem and enable complex imaging of clouds to be undertaken for the first time at very short wavelengths.

"The initial EPSRC project allowed us to acquire the highly specialised laboratory equipment we needed. It also enabled us to undertake the fundamental research, training, design and prototype fabrication required for this type of product. This helped to put us in an unrivalled position to bid for commercial contracts which we are now doing with great success.

"We are currently involved in most of the major European climate monitoring space programmes and we are the main supplier of this technology both to the UK space industry and to the ESA which is now our main research funder.

"In addition to these projects we are aiming to further develop the technology for application in other areas, including intelligent control of communication signals into and out of buildings."

Having previously worked for British Aerospace and Matra Marconi Space, Robert has extensive industrial experience of developing antenna and passive microwave device technology for space and defence applications. Aside from his professional interest in the technology he now specialises in, he also has a personal reason to remain deeply involved in its future application.

"The work I'm involved in at ECIT is particularly exciting for me as it was my PhD supervisor at the University of Kent who first worked on the technology back in the early 1970s."

Dr Robert Cahill
School of Electronics, Electrical Engineering and Computer Science

Professor Marco Borghesi School of Mathematics and Physics

A RAY OF HOPE FOR LASER THERAPY CANCER TREATMENT

It was while he was in his last year as a student at Pisa University that Marco Borghesi became interested in plasma physics, the subject that has dominated his life ever since.

He says, "For my final year I had to pick a research project. Some friends of mine were doing a project in a laser plasma lab. I liked what I heard, I liked the people, I liked the laboratory. I know it might sound a bit random but that's the way it began and I've stayed in this field."

After Pisa, he moved to the UK where he obtained a PhD at Imperial College London and then a vacancy came up as a lecturer at Queen's. "That was in 1999 and I was lucky enough to get it."

In the years since then, his work and influence have developed. On behalf of Queen's he is leading a research team involving several other UK universities, including Imperial College, Strathclyde, Surrey, Birmingham and Southampton. The four-year project has been funded by EPSRC and it explores how to develop the technique of laser acceleration for a wide range of applications. But the project team is interested in particular in how ions accelerated by lasers can be used in medicine, especially in cancer therapy.

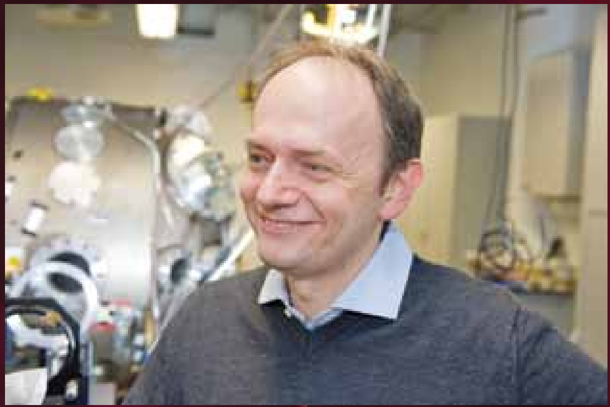
"It's quite an ambitious project but it's very important," Marco says. "Proton therapy is an approach which is emerging. Protons have a different way of interacting with matter. They stop in the cancer area and don't deposit any energy beyond that.

"But to apply this technique requires huge installations, which are very costly and there are only a few of them around the world. Using lasers for accelerating ions is an alternative which may lead in the future to a reduction of costs and would be of benefit to the next generation of treatment centres.

"The advantage of using laser accelerators is that everything is much more compact. If in 20 years' time laser sources can be used for treating patients that would be fantastic. But it is a long journey. The immediate future, the next step, is to increase acceleration and the quality of the ion beams."

Marco praises the facilities which are being used in the project, "including the laser facility here at Queen's which, for a university, is one of the largest around."

He adds: "There is competition. It is a very active field. Our research is quite applied. We enjoy doing fundamental science, publishing papers, but in the end it would be wonderful if we could produce something that is going to be of great benefit to society."



Professor Marco Borghesi
School of Mathematics and Physics

Dr Stuart James
School of Chemistry and Chemical Engineering

Dr Stuart James School of Chemistry and Chemical Engineering

POROSITY: A CONCEPT TRADITIONALLY ASSOCIATED WITH SOLID MATERIALS...

... Until now that is, thanks partly to an EPSRC-funded project 'Developing the Culture of Adventure', through which Stuart James first focused on the possibility of creating porous liquids.

Now, with funding from the Leverhulme Trust, it appears his five-year quest is nearing a successful conclusion. He and his team believe they have succeeded in producing the first liquid with permanent microscopic holes.

"Solids with holes between the molecules act like molecular sieves. They are commonly used for a wide variety of purposes such as removing pollutants from the environment and drug delivery," says Stuart.

"But a liquid that selectively absorbs molecules according to their size and shape the way porous solids do, but much more quickly, is unheard of. It is such a novel concept it is difficult at this stage to predict the potentially huge range of uses it could be put to.

"It is likely, however, that a liquid molecular sieve could be applied in a similar way to dialysis treatments. It might also act as a highly effective medium for storing "difficult' gasses such as hydrogen which may fuel the vehicles of the future."

Work is still underway to verify the unique properties of the liquid which is composed of complex, specially engineered carbon, hydrogen and nitrogen structures. It is expected this will be completed successfully in the near future. At that point the research emphasis will switch to studying its unique properties. When these are better understood, the next phase will be to identify potential applications followed by commercialisation.

Attracted by Queen's University's strong reputation in inorganic chemistry, Stuart joined the School of Chemistry and Chemical Engineering in 1999. Previously he held a variety of posts at Imperial College, Cambridge University and in France and Holland.

The Developing the Culture of Adventure project reflects his passion for encouraging new ways of thinking about science. He believes this creative trait stems, at least in part, from his teenage years when he studied classical guitar at the Royal Academy of Music. His ambition then was to become a professional musician.

"Notes are the basic building blocks of music in the same way, as I later discovered, that molecules are the building blocks of nature. You can play with them and put them together in ways they haven't been arranged before."

Dr Chris Calvert, Professor Ian Williams School of Mathematics and Physics

THE EVOLUTION OF THE CONTROLLED MOLECULE

Ian Williams is in no doubt about the calibre of the PhD students he sees at the Centre for Plasma Physics. "I've been lecturing here for 25 years and the top people we get are as good as students anywhere in the world. They're very high quality, with sharp minds and fresh enthusiasm."

One of the people he's certainly referring to is Chris Calvert who did his own PhD under Ian's guidance, "looking at the dynamics that occur when you interact lasers with fundamental atoms and molecules." They're now working colleagues, along with Jason Greenwood, exploring ultrafast dynamics in intense laser fields.

Chris is in the first year of a three-year Fellowship awarded by EPSRC. "The aim is for me to identify experiments where I can look to apply my knowledge to the life science interface."

He says, "I'm seeking to bring the tools of the physicist's trade to life sciences. We're stepping beyond the traditional remit of fundamental physics, and looking to study ultrafast processes in molecules of biological interest, such as peptides and DNA bases. This avenue of research has really benefited from collaboration with biochemists here at Queen's."

Ian obtained his own PhD at Queen's, in experimental atomic physics, before going to the University of Sussex and then Caltech. He moved back to Belfast in 1985 as a lecturer, becoming a reader in 1996 and Chair in 1999 "with work almost exclusively funded by EPSRC."

He says, "About 10 years ago I began to look at how ions behave when you expose them to very intense, very short pulse lasers. We discovered a lot about the dynamics of very small molecules, for example, and over the years the work has evolved to a point where we can actually start controlling molecules as opposed to just observing them.

And now Jason Greenwood has developed systems that enable us to extend that to much bigger molecules and that's where Chris's work comes in."

Chris adds, "One of the things I've found in applying for funding is that it is important to identify potential applications that may be of industrial significance. We certainly think the work we're doing will have applications for mass spectrometry, a huge industry. You only have to think of airport security and forensic labs where it's important. But we must also constantly strive to understand the underlying dynamics from a physicist's point of view."

Chris is now working with custom-built, ion-trap apparatus for studying the outcomes of ultrafast laser-molecule interactions, "If there's a concept you want to study and a particular outcome that you want then you have to design something specific to your purpose."

Ian adds, "For the PhD students, the development of skills here is tremendous. They get the opportunity to work with unique equipment, they learn how to interface with computers and how to tailor experimental techniques to deal with specific problems. It's fantastic experience. Many of them will end up in the local economy with the high-skill experience that high-tech companies are looking for and that definitely helps to attract some big employers to Northern Ireland."

Dr Chris Calvert, Professor Ian Williams
School of Mathematics and Physics

SOMETIMES THE SMALLEST ADVANCES **ARE THE MOST PRECIOUS...**

Premature babies are often on lots of drugs to keep them alive, so how do we know what concentration to give without causing side effects?

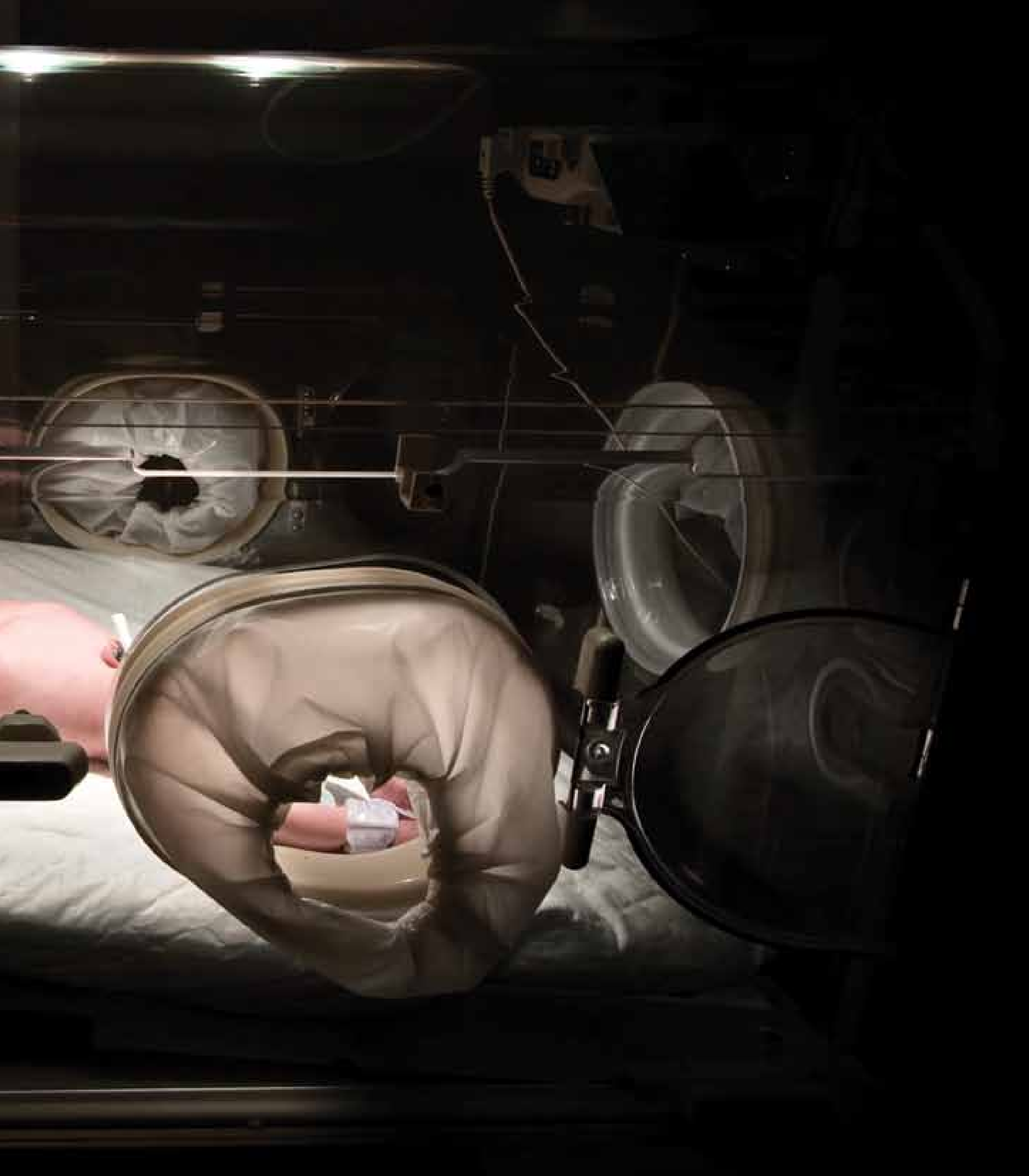
Dr Ryan Donnelly,
School of Pharmacy

Ryan Donnelly joined the School of Pharmacy in January 2004. "I am keenly interested in enhancing the quality of life of patients through designing enhanced drug delivery systems."

The microneedles being developed by him and his team are about the size of a postage stamp, the surface covered with almost invisible pin-points. They're tiny but their potential is huge.

Ryan explains, "These micro-structures painlessly penetrate the skin. They're so small that they don't cause any bleeding and they don't stimulate any nerves. Most drug substances don't cross the skin easily. With our microneedles we can bypass the barrier that the skin provides and deliver a drug of any size, as long as it's soluble in water."

The project has received much support as a means of drug delivery. But the research for EPSRC has a different objective, not delivery, but extraction.



"We realised that there could be another application. The concentration of drug substances in the blood is in equilibrium with that of the fluid in the skin. So our idea is to place a microneedle which swells and provides a conduit. Then we can insert a special type of probe which will detect drug substances. It's a way of blood-free monitoring."

He has examples of how this can be applied. "Premature babies are often on lots of drugs to keep them alive. But we don't know how fully developed their organs are. So how do we know what concentration to give without causing side effects? Heel prick samples are the usual method of taking blood. But these are very limited volumes and you can't do it too often without causing trauma, bruising or scarring. Using a microneedle patch, you can take samples continuously over a day to work out what's going on and in a minimally-invasive, blood-free fashion."

Another example is how to detect whether a driver who has been stopped by the police and has passed a breathalyser test has been taking drugs. "And there is the developing world where a patient may have HIV/Aids and so taking blood samples may be difficult. Microneedles could eliminate a lot of the risk."

Ryan praises the collaboration of colleagues Colin McCoy, David Jones and Stephen Bell.

The project began in July 2010 and will run until 2013. "It's at an early stage but the amount of industrial interest already just shows the possibilities it has."

Professor Ciaran Lewis School of Mathematics and Physics

IF YOU'VE GOT A BIG ENOUGH SLEDGEHAMMER YOU CAN CRACK A LOT OF NUTS

Since 1968, when he came to Queen's as a student, Ciaran Lewis has been at the forefront of research in laser physics. "The laser wasn't invented until 1960 so, by the time I arrived here, it was still a hot topic," he says.

Ciaran gained his PhD at Queen's and later carried out post-doctoral work in England and California. He was appointed to a lectureship in 1980. He is now Head of the Plasma and Laser Interaction Research Group.

By 1968 the Department of Physics had set up a strong group under the pioneering Dan Bradley, who died in 2010. "He left in 1973," Ciaran explains, "and took most of his group with him. I stayed here. We kept things going in the area of laser-plasma physics and the result is that we have a very strong group again with an international reputation."

Since 2000, Ciaran and his colleagues have attracted more than £10m worth of funding, mainly from EPSRC. "The sort of funding provided by EPSRC is the lifeblood of a university group trying to do research, whether it's blue sky thinking or it's applied to particular aims and objectives. The best thing is to keep a mix of the two and we've managed to do that over the years."

He adds, "I've spent the last 10 years trying to get to the stage where we have a laser facility that we can claim is one of the biggest university lasers anywhere. You have to go to nationally-funded government facilities to get anything comparable. It's a very powerful laser and it's like a lot of things in science, if you've got a big enough sledgehammer you can crack a lot of nuts. It gives you an edge, being able to achieve things that other groups can't. We named the laser TARANIS, the European-wide Celtic god of thunder and lightning."

He highlights one area of work. "The energy crisis that's been talked about for so long, and which will eventually come (one solution is through nuclear fusion, in effect making nuclear bombs in a controlled way) and using lasers is one approach. To build up to that, it has to be understood how to do it efficiently and safely and a lot of the interactions that we do with lasers now are very much related to that type of study."

But the work being done by Ciaran and his fellow physicists has other benefits which are sometimes overlooked. "Over the years I've supervised more than 30 PhD students and if I were to plot where they've all ended up it would be quite a scatter diagram. Some are in government laboratories, some are in academia, some have entered into the financial world, some are in big research laboratories in the US and some are in industry, in many cases here, in the local economy.

"We've had quite a few project students funded by EPSRC. All of this means we're training skilled manpower that permeates out into the system."

Professor Ciaran Lewis
School of Mathematics and Physics

> "The end result of our collective efforts is that we have developed the most advanced piece of equipment of its kind."

TEST BED FOR FUEL HANDLING SYSTEMS OF TOMORROW

Alexandre Goguet is widely regarded as one of the foremost young researchers involved in developing new spectroscopic techniques for studying catalytic processes.

Every year, catalysts are used in the manufacture of hundreds of billions of pounds worth of products ranging from ammonia and catalytic converters to margarine and pharmaceuticals.

But as Alexandre explains, while catalysts are big business we're only a little way down the road in our understanding of their properties and potential.

"Catalysts are reagents that accelerate chemical reactions but are not consumed by them. That sounds simple but it is an extremely complex field. Unravelling those complexities will help us tackle more effectively than ever before some really big issues such as how to generate cheap renewable energy, protect the environment, minimise waste and develop benign processes for the chemical and pharmaceutical industries," says Alexandre.

"This is what we are attempting to do through a major EPSRC-funded project called CASTech, Catalytic Advances through Sustainable Technologies. It involves chemists, chemical engineers and physicists here and at the universities of Cambridge, Birmingham and Virginia (USA) working closely with a range of industrial partners to apply fundamental knowledge to specific industrial applications.

"Through this research we are gaining new knowledge about how catalysts are composed, how and why they work the way they do, and how they can be specially tailored to produce the most beneficial results.

"One example of CASTech's synergistic approach is a collaborative project with industry to design and develop next generation gold-based catalysts for the production of clean hydrogen for use in fuel cells.

"The fundamental knowledge we are creating has applications in many other areas. One major challenge, for example, is how we can make best use of the huge quantities of naturally occurring methane gas that exist around the planet.

"We can't do this at the moment because gas is very difficult and very expensive to transport, however, we are hoping that our work may one day lead to the development of new catalysts for use in new, highly efficient processes to convert methane in situ directly into a useable liquid fuel.

"This would make transportation a lot more cost effective but it has not yet been achieved. That's because the process involved is an extremely complex one in which the catalytic reaction has to be controlled very precisely otherwise the end product is water and carbon dioxide instead of methanol.

"Developing the types of innovative catalysts we need to do this will only be possible once we have new tools to enable us to explore them at the most fundamental levels.

"As part of our work we have developed some of the most advanced spectroscopic instruments available in this field of research. We are also making use of synchrotron radiations light source facilities across Europe. In this way we are pioneering new methods of finding out what happens at the molecular level on the surfaces of catalysts for gas and liquid reagents in specific types of very fast catalytic reactions.

"This work is giving us important new insights which we are confident will bring us closer to harnessing the full potential of these vitally important substances."

Dr Alexandre Goguet
School of Chemistry and Chemical Engineering

A NEW FORCE IN THE WORLD OF CYBER DEFENCE SYSTEMS

After completing his primary degree at RWTH Aachen University in Germany, Turkish-born Sakir Sezer first discovered his passion for designing hardware-based network processing following a student exchange programme with Queen's University and subsequent employment at a local high-tech start-up.

Internet and network security threats have evolved from harmless pranks into widespread cybercrime involving viruses, worms and intrusions that cause disruptions and collateral damage worth hundreds of billions of pounds every year. According to the latest Cabinet Office report, the annual cost to the UK economy alone is £27bn.

Within the next five years however, groundbreaking computer hardware now in development at the Centre for Secure Information Technologies (CSIT) could be used to put an end to many of those threats before they can cause any harm.

The innovative technology is being developed with funding from EPSRC by a team led by Sakir who was recently appointed to the newly-created chair of Secure Information Technologies at Queen's University. Their work will allow Internet traffic to be inspected and analysed in real time for malicious content, protocols and anomalies. This will enable risky or threatening online behaviour to be pinpointed and stopped in its tracks.

"Conventional processor technology is unable to meet the real time and throughput constrains of Internet security processing. Content, in particular, is only processed character-by-character at the present time," says Sakir.

"That means it is currently impossible to police, control and manage the phenomenal volume of online traffic. Even advanced firewalls and similar measures offer only limited protection. If a personal/home-PC is not well protected by security software, for example, the Internet can be a dangerous environment, especially for children and anyone who isn't computer literate.

"Research like ours is therefore vital in the development of new technologies that will make the Internet a safer place and in the long term, eliminate the need for users to defend themselves with a set of complex security tools."

Central to CSIT's breakthrough is a new type of highly powerful content processor capable of handling data between 100 and 10,000 times faster than existing solutions. Each one can pre-screen huge volumes of information, equivalent to the Internet traffic produced by over 100,000 households, for malicious content, protocols, and behaviour.

Sakir believes that the rapid take-off of cloud services and the wider use of cloud storage for public and personal data will see a dramatic increase in the demand for this type of complex content processing for security, html/xml parsing, data mining and indexing.

"Our technology significantly outperforms existing solutions both in terms of power consumption and speed throughout. We believe it has the potential to do for cloud computing what Cambridge-based ARM Holdings' processors have done for mobile wireless communications.

"We're developing parallel processors that can be scaled to process up to 32 characters at once, making complex content processing of huge data volumes possible in real time.

"Network providers will soon be able to install and use this technology to provide much better protection for Internet users, improved quality of service and more efficient utilisation and management of network resources."

To maximise the impact of the hardware, Sakir's team is working on new intrusion and malicious code detection algorithms and on optimising proven rules for custom processing. These may be used to govern which website requests to block as well as to identify traffic potentially generated by malicious software or unsolicited emails that may carry damaging content.

“This new generation of hardware optimised security algorithms and detection rule sets combined with custom-purpose parallel processing capability will improve Internet security beyond recognition. Together, they will enable the prevention of Denial of Service (DOS) attacks in real time without constraining the bandwidth and speed of the Internet. They will also provide real time intrusion detection and prevention capabilities to mitigate against emerging targeted attacks.”

Sakir’s team brings together experts in Internet traffic/threat mining, policy/rule set definition, System-on-Chip design and programming and system-level security. Throughout the project, they have been working in close consultation with UK and US equipment manufacturers, security vendors and network operators to ensure their technology meets market needs and delivers real-world benefits as quickly as possible.

“Our research has led to the development of a high performance system we are confident will become a vital component of Internet and cloud security and cyber defence systems.

“It has attracted a large amount of international interest and a spinout company, Titan IC systems, has been set up to commercialise some of the technology that has been developed through the project.”

Professor Sakir Sezer
School of Electronics, Electrical Engineering and Computer Science

Professor Cliff Taggart School of Medicine, Dentistry and Biomedical Sciences

THE PURSUIT OF ACHIEVING THE OPTIMAL DELIVERY OF ANTIBIOTICS

Cystic Fibrosis is one of the UK's most common life-threatening inherited diseases.

Cliff Taggart says, "The inflammatory response goes into hyperdrive in diseases like Cystic Fibrosis. One of the big problems is getting drugs delivered in such a way that they are effective. Infection takes hold at a very early stage in life and constant treatment with antibiotics through the years will inevitably lead to antibiotic resistance. Combined with the very hostile inflammatory environment of the Cystic Fibrosis lung, which includes a build-up of mucus and other secretions, achieving optimal delivery of antibiotics or any other drugs is very difficult."

To try to find a strategy to deal with this, Cliff and several colleagues, Stuart Elborn, Marie Migaud and Chris Scott, came up with the idea of devising compounds that combine antibiotic and anti-inflammatory entities.

"I am working with Chris on the development of small delivery vehicles (nanoparticles) that may be used to penetrate the very hostile environment of the Cystic Fibrosis lung."

A drug discovery grant from EPSRC is allowing this work to progress. "The chemistry involved is quite tricky. We will test to make sure that the compounds, once we make them, are effective. We're joining them up and then we have to take them apart in such a way that we know they still work and that putting them together hasn't abolished the activity of the drugs."

The three-year project itself is a compound, "an interface between chemistry and biology, something that was a very important element of securing this grant. And it's important for the whole aspect of drug development. Increasingly we realise that there must be collaboration, chemists, biologists, pharmacists, clinicians. That may not always have been the case. We've been in our silos but now we're being encouraged to come out of them and collaborate.

"The life expectancy of someone born with Cystic Fibrosis used to be six months. Now people are living until their thirties, although they need huge numbers of drugs to keep them alive. Our aim is to develop a drug that will dampen the bacterial load and inflammation much more dramatically and allow individuals to have a lifespan that goes beyond what it currently is."

Professor Cliff Taggart
School of Medicine, Dentistry and Biomedical Sciences

THE SPOKEN WORD HAS MORE POWER THAN CS LEWIS EVER IMAGINED

Mobile phone key pads could soon become as antiquated as the typewriter thanks to an EPSRC-funded project designed to allow people to interact with their devices using natural continuous speech.

The technology is so sophisticated it is believed that no other currently available applications are able to compete directly with it.

Comprising computer scientists and electronic hardware designers, the research team from the School of Electronics, Electrical Engineering and Computer Science has developed a basic demonstrator to prove their innovative concept works. They have plans to set up a spin-out company to exploit its significant potential, possibly by partnering with a speech recognition vendor.

Project leader Roger Woods is an internationally recognised expert in the fields of programmable system-on-chip and high-level digital signal processing design techniques. Working in collaboration with companies such as DTS, Selex and Xilinx, he has been responsible for a number of technology firsts in these areas. He is also CEO of CapnaDSP, a university spin-out company he co-founded in 2008 to develop complex chip design tools.

Roger explains that while current generation phones can respond to basic voice commands, they are simply not sophisticated enough to cope with normal everyday speech.

"The conventional approach to natural language speech processing is to try to predict what someone is saying by creating a "network' of probable words. This is an extremely large computational task that is normally done through servers.

"To do that on mobile devices requires a connection to WiFi or 3G networks and this consumes a lot of power. Together with problems with transmission delays and connection reliability issues, this drastically limits interactivity with users.

"Our approach represents a significant departure from accepted wisdom because we carry out a considerable amount of pre-processing, thereby avoiding the hassle of creating the 'network' online. All of the computation is carried out in a novel, completely self-contained processor meaning that no network connectivity is required.

"To our knowledge, this is the first time this approach has been used for low-power, large complexity speech recognition.

"We believe it is possible this technology could be embedded in millions of smartphones by 2013. Beyond that, its use could grow exponentially as it is introduced into other types of mobile devices such as tablet computers, satellite navigation systems and health care monitoring products.

"The original project idea came from two engineers working at ECIT, a £40m institute set up within the School to stimulate commercially-viable research ideas and then nurture them through to commercial development.

"EPSRC funding was vital to the project becoming a reality as it enabled us to put 16 people years' worth of effort into the programme. That represents a substantial resource commitment by any standards," says Roger.

Professor Roger Woods
School of Electronics, Electrical Engineering and Computer Science

Dr Paul Miller School of Electronics, Electrical Engineering and Computer Science

MAKING CCTV A MORE POTENT WEAPON IN THE ENDLESS FIGHT AGAINST CRIME

After completing his PhD at Queen's University, Paul Miller took a job at Australia's Defence, Science and Technology Organisation. Now he's back in Belfast working to change the way CCTV technology is used to combat crime.

> We're hopeful our research could soon be incorporated in systems that could significantly reduce crime levels on our streets and public transport systems.

Every year, millions of CCTV cameras capture images of the numerous crimes committed in towns and cities across the UK. While the data they generate may eventually be used to help prosecute some offenders, it is of little value in detecting offences while they're being committed, or stopping them from happening in the first place.

That's mainly because most CCTV control rooms are flooded with information from multiple cameras, making it difficult for their operators to identify situations likely to escalate into criminal incidents.

Making CCTV a more potent weapon in crime detection and prevention is the objective of a group of researchers at the Centre for Secure Information Technologies (CSIT). Under Paul, they are developing technology capable of analysing live camera images and immediately alerting security personnel to suspicious behaviour.

Their work builds on a recently completed EPSRC-funded project known as ISIS (Intelligent Sensor Information Systems).

"Following on from that initial research, we're now working on a second multimillion-pound programme that has attracted further funding from EPSRC and a number of other partners," says Paul.

"In recent years, there has been a trend towards the convergence of physical security systems with IT security. We're taking that approach to a higher level through the use of a new computing paradigm we've developed, sensor event computing.

"This involves enhancing CCTV cameras and other types of sensors with data analysis and artificial intelligence capabilities. This makes them much more than "dumb devices" that simply spit out raw multimedia data as current systems do. Instead, they have the ability to connect small-scale events they observe, draw conclusions about their significance and prioritise the level of threat they represent. Where this is deemed sufficiently high, an alert can be relayed to a central control room for possible human intervention.

"The level of any potential threat is assessed by each camera through a software-based scoring system that takes into account factors such as the time of day, crime statistics for the location in question and a threat assessment of the people shown.

"All of this requires a sophisticated hardware and software system architecture which we've been developing with other specialist teams at CSIT. Our work incorporates a number of firsts. These include complex gender-profiling tools for use in video analysis and the way in which we process multimedia "events".

"Our software will soon be made available to our membership board which includes representative from Thales and BAE Systems. They and others will then evaluate its potential for commercial development.

"We're hopeful our research could soon be incorporated in systems that could significantly reduce crime levels on our streets and public transport systems.

"Ultimately it could be adapted to protect many other kinds of critical infrastructure as well."

Dr Paul Miller
School of Electronics, Electrical Engineering and Computer Science