The University of Manchester
Photon Science Institute

MANCHESTER 1824

NEWSLETTER

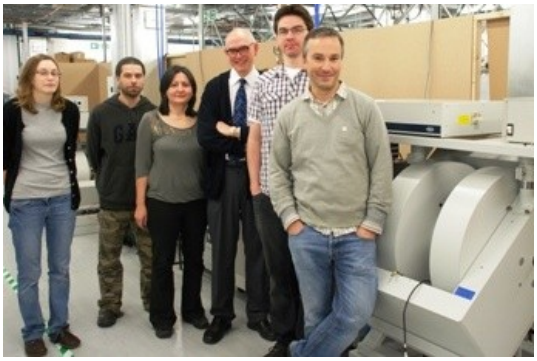
THE PHOTON SCIENCE INSTITUTE

ELECTRON PARAMAGNETIC RESONANCE SPECTROSCOPY

Now located in the PSI, the EPSRC National EPR Research Facility and Service is run by **Profs David Collison and Eric McInnes** from the School of Chemistry and has been established with £4.1M funding from EPSRC, and £355K from the University of Manchester.

The Facility accommodates several Bruker EPR instruments, allowing c.w. and pulsed EPR measurements at frequencies between 1 (L-band) and 95 GHz (W-band), a Quantum Design magnetometer and an ODESSA instrument (built by **Dr Nigel Poolton**) that combines optically detected magnetic resonance (ODMR) with photo-EPR (both 34 GHz; 0-4 T magnet). Together these make a unique research base for studying various types of paramagnetic species and materials.

Researchers across the country are using the Facility on a regular basis. PhD students and academics are encouraged to visit the Centre and to gain "hands on" experience.



The EPR Team from right to left: Prof Eric McInnes, Dr Stephen Sproules, Prof David Collison, Dr Floriana Tuna, Dr Brian Tolson, Miss Chloe Stott, Dr Nigel Poolton (absent)

- Facilities: Frequency (GHz): 1, 4, 9.5, 24, 34, 94
- Frequency Band: L-, S-, X-, K-, Q-, W-
- Modes: Parallel and perpendicular at X-band
- Temperature Range: 4.2 to 300 K all bands, to 500 K at X-band only

For further details see the Facility website: http://www.epr.chemistry.manchester.ac.uk/

NEWSLETTER WINTER 2011/12

This newsletter consists of a combination of articles, highlighting both recent grant successes and those of a personal nature. Until further notice, items for future newsletters and/or the PSI website should be sent to PSIPA@manchester.ac.uk.

THE NAKED SCIENTISTS

http://www.thenakedscientists.com/HTML/podcasts/show/2011.10.09

Dr Mark Redwood

Dr Mark Redwood was interviewed on live radio for the Naked Scientists radio show episode entitled, 'Outpacing petrol—biofuels and hydrogen', about obtaining energy from waste. He spoke about his recent work at the PSI, which achieved a 75% increase in biological photosynthesis using dichroism. See above link to listen to programme podcast.

Mark, who works with Prof Lynne Macaskie at The University of Birmingham, has been seconded to the PSI for the last year. Their work focuses on using photosynthetic bacteria to turn organic waste into hydrogen, the clean fuel of the future.

In the UK, we produce over 110 million tonnes of suitable wastes each year. If we fed it all to photosynthetic bacteria they would produce enough hydrogen gas to make about 22 terawatthours of clean electricity per year, which is worth about £2.3 billion at today's prices and is about half of the renewable electricity the UK is committed to making by 2020. However, as the efficiency of photosynthesis is very low, it would take an area of 3300km^2, which is about the size of Lancashire, or 1.36% of total land in the UK.

To focus on the problem of increasing the efficiency of photosynthesis, Lynne and Mark teamed up with **Drs David Binks and Mark Dickinson**, both of the School of Physics and Astronomy, to work on photonic solutions for bioenergy. The team knew that different photosynthetic organisms prefer different parts of the solar spectrum and had the idea of exploiting dichroism to share one sunbeam between two different cultures and create two different biofuels, resulting in an overall gain of 75%. In application, this would mean a mere 1890km^2, or 0.78% of total land in the UK, to turn all of the nation's organic waste into clean energy and valuable co-products.

The study benefited from the help of MSc Photon Science student, Raveen Dhillon and a research paper is in preparation for Biotechnology Letters.

SINGLE MOLECULE FLUORESCENCE SPECTROSCOPY AS AN ULTRASENSITIVE ANALYTIC TOOL

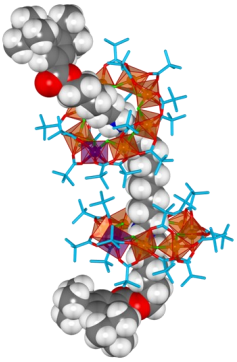
Dr Steven Magennis

£29K EPSRC grant has been awarded to **Dr Steven Magennis** for a 6-month feasibility study to investigate the use of single-molecule fluorescence spectroscopy as an ultrasensitive analytical tool.

HYBRID ROTAXANES AS SCALEABLE TWO QUBIT-GATES FOR QUANTUM INFO PROCESSING

EPSRC has awarded £350K to **Profs Richard Winpenny**, **David Collison** and **Eric McInnes** and a further £339K to his collaborator Prof David Leigh FRS to study the use of interlocked molecules – "rotaxanes" – as two qubit gates as possible components of quantum information processors.

The challenging project is mainly based on synthetic supramolecular chemistry to make compounds such as that shown right, however the molecules once made will be studied using the EPR spectrometers within PSI, and the ability to combine simultaneous irradiation of molecules with EPR spectroscopy to study on/off states of qubit gates will be very important.



MAGNETIC ANGLE-CHANGING TECHNIQUE

Professor George King has just published a review chapter describing the Magnetic Angle-Changing (MAC) technique[1]. This technique uses a shaped magnetic field to deflect an electron beam in a controlled way, and has important applications in electron spectroscopy. For example, when a beam of electrons is scattered by an atomic or molecular target, the electrons may be scattered through an angle between 0° and 180°. Conventional electron spectrometers cannot observe electrons scattered through angles greater than about 135° because of mechanical constraints. The use of the MAC technique, however, allows the full range of scattering angle to be observed. In turn this enables comparison with theory in regions that were previously accessible to experiment. It also allows integral cross sections to be measured over the full range of scattering angle: such data are important in a range of practical applications of these cross sections.

The MAC technique was invented at Manchester and continues to be a powerful tool in studies of electron-photon excitation of atoms and molecules by Prof Andrew Murray and his collaborators and by George and his collaborators. It has also been adopted by a number of research groups around the world. The review describes the physical principles of the MAC, practical realizations and applications of it to a wide range of studies in atomic and molecular physics. A copy of the review can be obtained upon request from: George.King@manchester.ac.uk.

[1] "The use of the magnetic angle changer in atomic and molecular physics". G C King, in Advances in Atomic, Molecular and Optical Physics, Elsevier Inc., Academic Press, vol. 60, pp. 1-64, (2011).

GEORGE KING

Prof George King recently collaborated with an international team lead by Prof Peter Weightman (University of Liverpool) on a research project at Daresbury Laboratory. This project involves imaging of human biological cells using a Scanning Near-field Optical Microscope (SNOM). The cells are irradiated by infra-red (IR) radiation (l ~ 8 mm) from the free electron laser on the Accelerators and Lasers in Combined Experiments (ALICE) accelerator at the Cockcroft Institute.

The aim of the project is to identify early signs of cancer in these cells, with the hope that it could eventually lead to a routine medical procedure for detection and prevention of oesophageal cancer in patients.

Prof George King

George worked with Dr Michele Siggel-King (University of Liverpool and Cockcroft Institute) to optimise the focussing of the IR radiation from the Free Electron Laser (FEL) and its overlap with the cells. They used the infra-red detection equipment of Dr Mark Dickinson's, which includes a high spatial-resolution infra-red camera and associated software. The radiation from the FEL is focussed onto the cells by a lens that can be moved both along the optical axis of the radiation and perpendicular to this axis. The infra-red camera allowed Michele and George to "see" the focussed IR radiation, which in turn enabled them to optimise the focussing action and align the focussed spot with the cell position. Optimisation of the overlap of the radiation with the cells led to improved imaging of the cells and efficient use of the ALICE beamtime allotted to the experiment. The use of the infra-red camera in similar ways has now been extended to other studies using the IR FEL.

FIRST USERS ON I13: PUSHING THE BOUNDARIES AND EXTENDING THE SYNCHROTRON'S REACH

Alongside their equipment and others in the team are PSI members: Dr Tom Waigh (back row, far right); Mr James Sanders (back row, far left); Dr Shaden Jaradat (absent).

Diamond's X-ray Imaging and Coherence beamline has welcomed its first users. As first users of the beamline, **Dr Thomas Waigh, Dr Shaden Jaradat and Mr James Sanders, all of the Photon Science Institute**, are working with the beamline team, led by Dr Christoph Rau and a team from the University of Sheffield to carry out proof of principle experiments on the coherence branch of I13.

The first user group have used l13 to study nanostructured colloids as a means to test the beam line's capabilities, and are now working on a pioneering technique called ptychography (closely related to holography), which involves exploiting the coherent light in such a way that they are able to combine diffraction and image data to create a high resolution computer-generated image of the sample, at the nanometre scale. It has been found to be a particularly useful technique for weakly diffracting and transparent samples. Since I13 is just starting out, they are working on the micron scale but have managed to collect some useful data and are really pleased and looking forward to making use of the beamline in the future to help develop their technique.

Coherence is a property of light, when it is considered in its wave-form as opposed to as particles. In order to produce fully coherent light to enable a wide variety of experiments, beamline I13 sits 250m away from its X-ray source. The X-ray photons are made in a very small light source at 15×200 microns, which was achieved with the mini-beta set up within the storage ring, and then let that light travel a long distance so that it fanned out into a large, lateral coherent light beam. Thanks to the smaller electron beam at the source, emittance is low and means they receive very brilliant light inside the experimental hutch, which can be described as having laser-like qualities. Ultimately, it is hoped to get the spot size of the X-ray beam down to 15 nanometres or less, which will enable top quality results of very high spatial resolution to be achieved.

Dr Thomas Waigh said, "It's really exciting to achieve results from the coherence branch of I13. It has been ten years in the planning so to see it take shape and record some good data has been great. It is a unique instrument that promises to deliver a lot of important results, helping to solve real world problems in a wide range of fields. I am very pleased to be a part of its history."

ENABLING CROSS- AND INTRA-FACULTY RAMAN SHARING

A team led by Prof Robert Young (Materials), and involving **Dr Cinzia Casiraghi** (PSI and Chemistry), **Prof Helen Gleeson** (Physics & Astronomy, PSI), Dr Ewan Blanch (MIB and FLS), Prof Roy Goodacre (MIB and Chemistry), **Prof Matthew Halsall** (PSI and EEE), Dr Ian Kinloch (Materials) and **Dr Phil Martin** (CEAS and PSI) was awarded £81,874 from the EPSRC Strategic Fund to bring together users of Raman spectroscopy to promote cross-fertilization of approaches in materials, physics, chemistry, biology and engineering as well as to enhance efficiency of use through sharing of resources. This is hopefully a first step in bringing together the Raman community in Manchester, and is already an excellent example of how the interdisciplinary institutions can work to break down barriers between traditional disciplines.

LOW TEMPERATURE CRYOSTAT FOR EPR SPECTROSCOPY

A team lead by **Prof David Collison** (Chemistry and PSI) and **Prof Lucio Piccirillo** (Physics and Astronomy and PSI), and involving **Prof Eric McInnes, Dr Nigel Poolton and Prof Richard Winpenny**, were awarded £56,000 by the EPSRC Strategic Fund to design a cryostat to allow EPR spectroscopy to be performed at temperatures as low as 300 mK. The unique design by Lucio and his colleagues fits into a commercial Bruker EPR spectrometer, and we already have interest from Bruker in possibly commercialising the technology once developed. This application of technology developed within astronomy to a technique used in chemistry shows what can be achieved by discussions across discipline boundaries.

SILICON PHOTONIC BIOSENSORS TO MONITOR KIDNEY DYSFUNCTION


Prof Matthew Halsall

£48,548 has been awarded to **Prof Matthew Halsall** (School of Electrical Engineering and Electronics), **Dr Mark Dickinson** (School of Physics and Astronomy) and **Prof Paul Brenchley** (School of Medicine) for the development of silicon photonic biosensors to monitor kidney dysfunction. Dr Sandip Mitra, a consultant Nephrologist, is also collaborating on this project.

Silicon photonics is a rapidly growing industry worldwide, aimed at the convergence of optics and electronics in a way that is amenable to cheap mass production. Prof Halsall's group in the PSI has received substantial funding from EPSRC over the last two years to develop on-chip light sources for


Dr Mark Dickinson

these devices, he has also received some pump priming to investigate the use of such devices for biosensing. The aim of this project is to apply the biosensing devices being made to monitor kidney dysfunction.

Kidney dysfunction is a potentially serious problem for the individual with significant healthcare costs for society. Currently in the UK, nearly 50,000 patients require renal replacement therapy. Studies suggest up to 10% of the population may have an undiagnosed problem. Current NICE guidelines require frequent blood creatinine assays that can only be performed by visits to hospital or clinics with blood samples drawn by venepuncture by a skilled operator. Complex laboratory processing is expensive and introduces time delay affecting clinical management. We have shown that renal analytes such as creatinine/urea are present in the interstitial fluid (IS) in similar concentrations as in blood, and we have developed a hollow microneedle array to sample and capture microlitres of IS in a hydrogel, which can be interrogated by optical techniques.


Prof Paul Brenchley

This project will develop a creatinine biosensor using a waveguide chip, which interrogates the interaction between a modified chip surface and creatinine in the sample. The aim is to produce a device that would be useful for routine GP and outpatient screening that would be minimally invasive, painless, reproducible and reliable, reflect blood levels and changes, is cost-effective and user friendly.

STRONG PRESENCE AT IEEE SENSORS 2011

IEEE SENSORS 2011 CONFERENCE
IEEE SENSORS 2011
LIMERICK, IRELAND 28-31 OCTOBER

The 2011 flagship International Electrical Engineering and Electronics conference on Sensors was held in the last days of October in Limerick, Ireland. In addition to the usual conference contributions, this year **Prof Krikor Ozanyan** of the School of Electrical Engineering and Electronics, organised and chaired a Topical Session entitled, 'Terahertz (THz) sensing: materials, devices and systems', with 10 invited and contributed talks from America, Europe and the Far East.

Recent achievements at Manchester in materials for narrowband THz emitters were presented in the invited talk by **Prof Mo Missous** entitled, 'Advanced MBE low temperature grown materials for CW THz generation and detection'. Such novel emitters allow high-resolution THz spectroscopy to be achieved with THz antenna structures, grown in Prof Missous' Molecular Beam Epitaxy facility in the School of Electrical Engineering and Electronics, when pumped by communications laser diodes, or more powerful laser sources available in the PSI.

OPTICAL FIBRE SENSOR MAT TO DEFINE PATIENT MOBILITY PATTERNS


Dr Patricia Scully

£48K EPSRC grant has been awarded to **Dr Patricia Scully** (School of Chemical Engineering and Analytical Science - CEAS), **Prof Krikor Ozanyan** (School of Electrical Engineering and Electronics), **Dr Phyllis Fiadzomor** (CEAS) all of the PSI, and Dr Christine Brown Wilson (School of Nursing, Midwifery and Social Work), to develop an optical fibre sensormat to define patient mobility patterns that precede a fall.


Prof Krikor Ozanyan

The sensormat will be used as a clinical tool to monitor gait and movement, enabling identification of deterioration with timely implementation of strategies to prevent falls. The technology will be subjected to clinical tests and evaluations in order to define the market and major cost savings achievable in reduced care costs for elderly people, whose independence would be maintained by appropriate intervention.


Dr Phyllis Fiadzomor

NON-INVASIVE MONITORING OF FIBRE OPTICAL CABLES WITH CABLE-SENSE LTD

Prof Tony Peyton

£43K has been awarded by EPSRC from the Knowledge Transfer Account for the non-invasive monitoring of fibre optical cables with Cable-Sense Ltd. Cable-Sense is a spin-out company, established to develop and manufacture new technology for non-invasive interrogation of the physical layer of networked infrastructure such as local area networks (LANs) data centres, campus networks etc. The technology enables the network cable status and connectivity information to be determined without disruption to the cable connection or information integrity.

This proposal involves a collaboration between **Prof Tony Peyton** (School of Electrical Engineering and Electronics) and **Dr Patricia Scully** (School of Chemical Engineering and Analytical Science), both of whom have interests in sensors, with Peyton's background being in electromagnetics and Scully's in optical sensors.

Dr Patricia Scully

Professor Peyton has received several major funding awards from the EPSRC investigating electromagnetic inspection techniques, including twelve as principle investigator. Dr Scully will bring expertise in fibre optic inspection that the company need to complete their ambitions to offer a complete end to end network monitoring solution encompassing all key types of cable, especially optical.

DEAN'S FUND AWARD

Drs Patricia Scully, **Med Benyezzar** and **Nick Goddard** have been awarded £20K from the EPS Faculty Strategic Fund for the purchase of a second nanoscale resolution translation stage. Demand for access has created the need for a second beam-line, which will enable short term feasibility studies to be scaled up into full collaborations, in the form of EU and EPSRC proposals that apply generic techniques and nanostructuring optics to a wide range of materials. This second femtosecond laser beam-line will enable projects to be performed in parallel and not disrupt long term projects with short ones. Overseas visitors and collaborating groups, will be able to access a range of fs laser irradiation, which has not been previously available in the UK and Europe. It will be possible to perform optical material structuring over a unique and wide range of pulselengths (down to 30fs) and wavelengths (down to 200nm).

NEW READ-WRITE-ERASE MATERIALS BASED ON OPTICAL SWITCHES FOR 3D DATA STORAGE

Dr Louise Natrajan

Following on from a research collaboration with **Dr Steven Magennis** of the School of Chemistry, **Dr Louise Natrajan**, also of the School of Chemistry, has been awarded £20K of EPSRC windfall funding to support a research student for nine months to develop read-write-erase materials based on optical switches for 3D data storage.

3D technology has become extremely lucrative in the digital age. Three dimensional optical data storage based on two photon processes is a new, pioneering method with which data can be written and read on disc type storage media providing an immense capacity for information storage (up to 10^{12} bits cm^{-1}).

Currently, there is only one company in the world that has developed 3D optical data storage, and their devices suffer from the inherent drawback that the systems are not re-writable and experience a destructive read-out process. The approach of Drs Natrajan and Magennis addresses both of these issues and once a prototype device has been fabricated and tested, the aim is to patent the design and seek out suitable manufacturing companies.

CHEMISTRY GLOWS

http://www.manchestersciencespectacular.co.uk

On 29th October, 2011, **Dr Louise Natrajan** and her research group took part in the science spectacular, Manchester Science Festival, with their exhibition, 'Chemistry Glows', which attracted substantial interest. See above link for further details of the event.

Uranium glass

EMISSION SPECTROSCOPY OF THE TRANSURANICS

Dr Louise Natrajan has been awarded £12.5K of EPSRC windfall funding, which will support both her and a PhD student to visit the Karlsrhue Institute of Technology (KIT), Germany, for two months. During the research visit, they will perform fundamental studies to ascertain the spectroscopic fingerprints of the transuranic elements (Np, Pu, Am, Cm) with environmentally abundant ligands. In addition, a portable, miniaturised fluorescence spectrometer will be purchased to study the emission profiles of the more radioactive and redox sensitive actinides (Np, Pu).

The experiments carried out at KIT will be crucial in applying for a large programme grant before the end of the 9 months funding period, for the purpose of study and development of 3D non-invasive fluorescence lifetime imaging of actinide migration in the nuclear fuel cycle and the environment.

PHOTONEX 2011

On 18-19 October 2011, the PSI exhibited at Photonex 2011, the UK's largest event for optics and imaging technologies.

The PSI stand was part of 'Innovation Live', comprising a grant funding seminar programme from the Electronics, Sensors and Photonics Knowledge Transfer Network (ESP KTN) and exhibitions from top UK universities. **Dr Patricia Scully** gave a presentation on the facilities available at the PSI, as well as work on the development and application of polymer photonic sensors and devices.

The PSI stand was manned by **Drs Patricia Scully**, **Phyllis Fiadzomor**, **Med Ben-Yezzar** and **Mr Stephen Casabella**.

The exhibition included:

- A conference programme with multiple parallel sessions focussed on applications and technology advances, innovations and emerging technologies;
- Tutorials and educational forums presented by industry specialists;
- An exhibition of leading international vacuum technology suppliers with displays and demonstrations of 10s of products, services and applications.

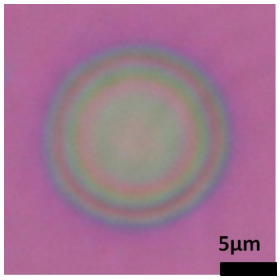
TUNNELLING THROUGH BARRIERS: NEW INSIGHTS INTO BIOLOGICAL CATALYSIS FROM PHOTON SCIENCE

£32K has been awarded to **Prof Wendy Flavell, Dr Darren Graham** (School of Physics and Astronomy) and Prof Nigel Scrutton (Manchester Interdisciplinary Biocentre) to develop technology capable of providing the first experimental observations of the influence of low-frequency vibrations in enzyme catalysis.

In 2006, Prof Scrutton and collaborators proposed that specific low-frequency vibrations of enzymes are key to understanding the reaction rates of biological catalysis. This hypothesis is agenda-setting, but so far direct experimental confirmation has proved elusive as it requires ultrafast laser spectroscopies with a better signal-to-noise level than is commercially available. This project will seek to revolutionise studies of enzymes in solution by developing advanced transient absorption spectroscopic techniques.

GRAPHENE BUBBLES WITH CONTROLLABLE CURVATURE

http://www.apl.aip.org/resource/1/applab/v99/i9?&page=3



graphene bubble

Dr Cinzia Casiraghi et al. have received acclaim for their publication in Applied Physics Letters, which is amongst the most read online articles during September. Entitled, 'Graphene bubbles with controllable curvature,' the research paper was written by T Georgiou, L Britnell, P Blake, R V Gorbachev, A Gholinia, A K Geim, C Casiraghi and K S Novoselov.

Graphene is famous for its exotic electrical properties, but the mechanical properties of these atom-thick sheets of carbon have now been exploited to form tiny bubbles that could one day be useful as lenses. Graphene bubbles are regularly found in large graphene flakes placed on silicon and may arise from the trapping of contaminants or air between the two materials. By applying a voltage, researchers have been able to control the shape of the transparent bubble, which could make a simple, auto-focusing lens for use in small electronic cameras, such as those in mobile telephones and computers.

Dr Cinzia Casiraghi

Published by the American Institute of Physics in Applied Physics Letters, 99, 093103 (2011). See above link for publication text.

MORE MAGIC THAN HARRY POTTER

Dr Andrew Thomas

On 6th December 2011, **Dr Andrew Thomas** gave an invited talk at the IOP Midlands Branch Christmas lecture at Birmingham University with his entertaining, 'More Magic than Harry Potter' demonstration.

Attended by 350 people, the talk covered a range of topics in physics and chemistry including electromagnetism, cryogenics, pressure, energy from sunlight, lasers and energy production from combustion.

NEW ARRIVAL

Congratulations to **Dr Tom Waigh** and his wife, Christina, on becoming parents. Emily Louisa was born on 17th November, 2011. Mother and baby are both doing well.

Emily Louisa Waigh

EFFECT OF WATER ON RESONANT RAMAN SPECTROSCOPY OF CLOSED SINGLE-WALLED CARBON NANOTUBES

http://onlinelibrary.wiley.com/doi/10.1002/pssb.201100074/pdf

Working in collaboration with colleagues at Queen Mary University of London, **Prof Matthew Halsall** and **Dr Iain Crowe**, of the School of Electrical and Electronic Engieering, conducted research in the PSI by optically coupling two facilities (the triple grating Raman spectrometer and the tuneable Ti: Sapphire laser). This enabled them to probe and detect changes under different environmental conditions in specific electronic transitions in semiconducting carbon nanotubes.

As well as improving our understanding of the behaviour of electrons in 1D material systems, this work could find application in future environmental sensing. More studies involving different liquids are in progress in order to further understand this effect and the involved microscopic mechanisms.

The work by A J Ghandour, D J Dunstan, A Sapelkin, I Hernandez, M P Halsall and I F Crowe was published in Physica Status Solidi B, 248, 11, pp. 2548-2551 (2011), see above link to view research paper.

Hot Off the Press! - In addition, exciting preliminary results have been published entitled, 'Raman excitation spectroscopy of carbon nanotubes: effects of pressure medium and pressure'. This latest work by A J Ghandour, A Sapelkin, I Hernandez, D J Dunstan, I F Crowe and M P Halsall, has been published in High Pressure Research, iFirst, pp. 1-5 (2012), and can be viewed at the link below. As a result of this initial work a more detailed publication (in a higher impact journal) is anticipated.

http://dx.doi.org/10.1080/08957959.2011.649280

MESSAGE FROM THE DIRECTOR

Prof Richard Winpenny

Happy New Year. According to the Mayan calendar, the world will end in December 2012 so we should enjoy 2012 while we can!

The PSI had a very good 2011. We were involved in two large awards: Prof Phil Dawson's programme grant, joint with Cambridge, started at the beginning of 2011 and the National EPR Facility led by Profs Collison and McInnes arrived in the summer. Dr Darren Graham obtained an EPSRC Career Advancement Fellowship, valued at £755K. Taken together these three awards are worth around £12M.

Recently, we had great success from the EPSRC Strategic Fund – at least five awards involving PSI – and we continue to attract funds from the EPSRC Knowledge Transfer Account. These awards are mentioned elsewhere in this newsletter.

The targets for 2012 include increasing our interactions with the rest of the university. Discussions with Prof Nigel Scrutton (Director of MIB) have already led to a joint proposal in magnetic resonance; there are huge opportunities for further links with MIB. A second target is to continue to bring in large grants – we need to be leading or partners in two or more programme level grants every year to achieve the funding needed to make PSI a major research institution. If you have ideas for a major initiative, please bring them to my attention and we will try and support such initiatives. The future direction of the PSI will be decided by these initiatives.

Until further notice, please send any items you have either for The Photon Science Institute website or the next newsletter to PSIPA@manchester.ac.uk