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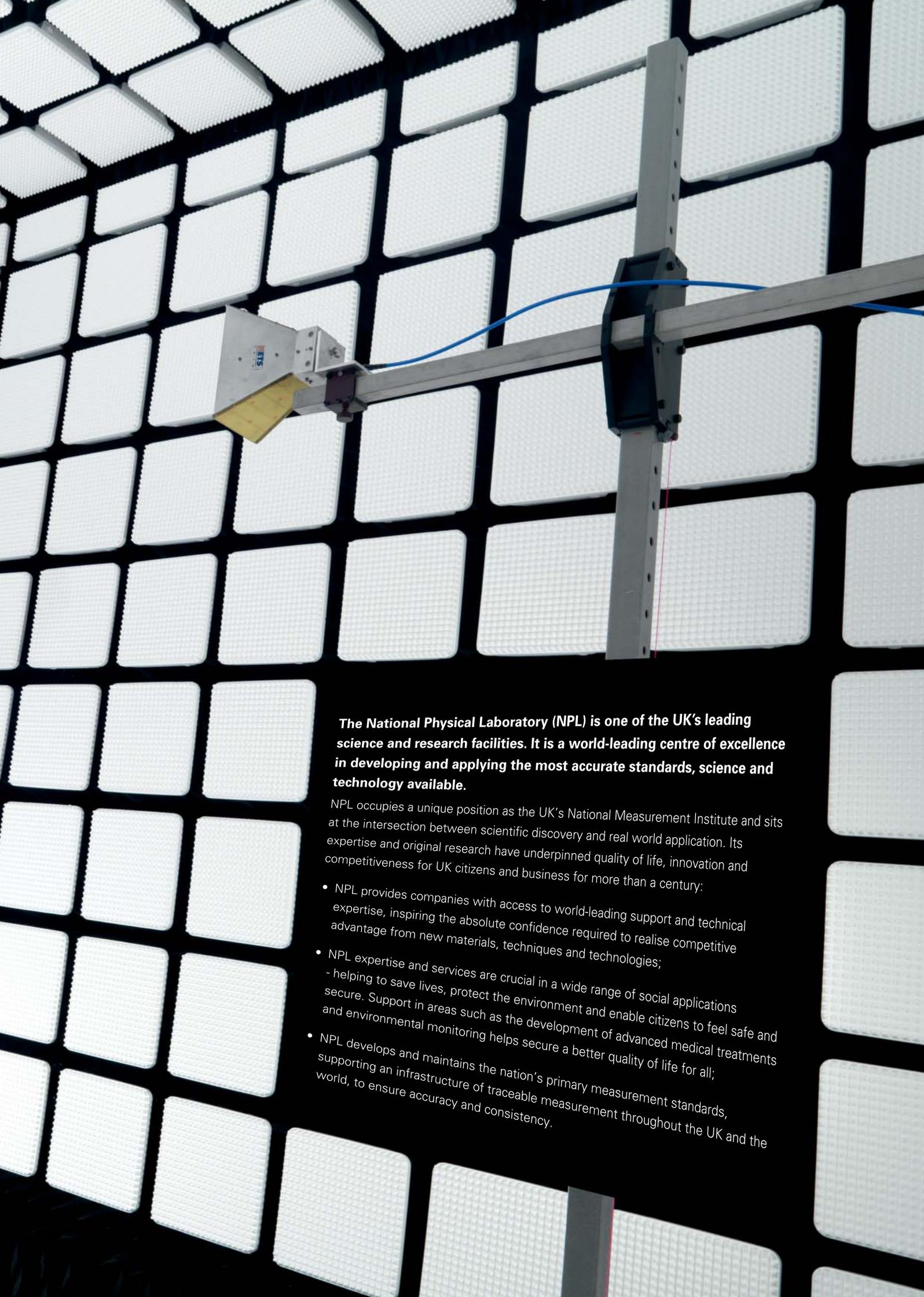
**Science** review

**The following pages give a brief overview  
and highlight some of NPL's recent  
achievements split into thirteen areas:**

- Acoustics
- Advanced materials
- Analytical science
- Biotechnology
- Electromagnetics
- Engineering measurement
  - Mass & dimensional
  - Temperature & humidity
- Environmental measurement
- Ionising radiation
- Mathematics & scientific computing
- Nanoscience
- Optical radiation & photonics
- Quantum phenomena
- Time & frequency



The NPL SMART Chamber  
for measurement of wireless  
communication antennas.



**The National Physical Laboratory (NPL) is one of the UK's leading science and research facilities. It is a world-leading centre of excellence in developing and applying the most accurate standards, science and technology available.**

NPL occupies a unique position as the UK's National Measurement Institute and sits at the intersection between scientific discovery and real world application. Its expertise and original research have underpinned quality of life, innovation and competitiveness for UK citizens and business for more than a century:

- NPL provides companies with access to world-leading support and technical expertise, inspiring the absolute confidence required to realise competitive advantage from new materials, techniques and technologies;
- NPL expertise and services are crucial in a wide range of social applications - helping to save lives, protect the environment and enable citizens to feel safe and secure. Support in areas such as the development of advanced medical treatments and environmental monitoring helps secure a better quality of life for all;
- NPL develops and maintains the nation's primary measurement standards, supporting an infrastructure of traceable measurement throughout the UK and the world, to ensure accuracy and consistency.

# Managing Director

**I am delighted to be able to report on another successful year in the life of NPL; a year in which, once again, we have delivered excellent science, and in particular world-class metrology, with real and demonstrable economic and social impact.**

I believe that NPL's impact will be all the more important as we navigate uncertain economic times. Continuous innovation and improvement are well established as vital ingredients of business survival and success in a shrinking economy. By generating and transferring unique knowledge to UK businesses, NPL plays a crucial enabling role in the innovation cycle. In the months ahead we will redouble our efforts in this area, to ensure that UK businesses can remain competitive through innovation and excellent science.

In May 2008, the official opening of our state-of-the-art laboratory in Teddington – currently one of the most sophisticated of its kind in the world - re-affirmed our commitment to providing talented people with the facilities they need to deliver world-class science. As expected, they have more than risen to the challenge. The selection of science highlights set out later in this report provides a clear demonstration of the breadth of research activity we are involved in and illustrates the real and positive impact our science is having on everything from alternative energy and security to Earth observation, emerging technologies and healthcare.

I am also pleased to report that revenue from our commercial activities rose by 12% in 2008, reflecting our ability to meet the needs of government and business; developing novel solutions to complex challenges. Over the course of the year, we provided technical consultancy and services to organisations tackling a huge range of issues – from photovoltaic performance to anti-counterfeiting measures. On a personal level, our technical contribution to the Bloodhound SSC land speed record project, of which Serco is a founding sponsor, was a real highlight.

Our commercial activity strengthens our ability to invest in people and facilities such as our new clinical linac. This state-of-the-art facility, jointly funded by NPL and two UK Government departments will provide a vital resource for those developing and delivering radiotherapy cancer treatment. Our commercial activities also play a vital role in maintaining the relevance of our core research, with feedback from industry, along with a range of



Martyn Sené

stakeholders, ensuring that we continue to identify and tackle emerging measurement challenges.

This year has also seen NPL formalise a series of important partnerships and co-operation agreements. On the international stage, we took a lead role in brokering the European Metrology Research Programme, which marks a step-change in research collaboration between National Measurement Institutes (NMIs) across Europe. Closer to home, we have agreed strategic partnerships with a number of universities, which will see us share specialist facilities, work together on joint research, and collaborate on post-doctoral programmes.

Finally, we are all extremely proud of the role that NPL continues to play in the community. Our education outreach activities are helping to nurture and inspire the next generation of science talent. In particular, our national 'Investor in WISE' award for 2008, presented by Women in Science Engineering and Construction is a source of great satisfaction. The award recognises our commitment to encouraging women into science, engineering and construction, via our educational outreach and diversity programmes. Meanwhile, our commitment to good corporate citizenship earned us a Big Tick Award from Business in the Community.

I would like to finish with a word of thanks for our outgoing Managing Director, Steve McQuillan, whose vision, energy and commitment were so important in shaping and embedding the strategic direction that drives our success today. Our new MD, Dr Brian Bowsher, joins us from AWE in March 2009 and will find an organisation in good shape to continue to deliver excellent science with real economic and social impact.

A stylized, handwritten signature in blue ink, consisting of several overlapping loops and lines, positioned above the name and title.

**Martyn Sené**  
Managing Director (Interim)

# Chief Scientist

**This report provides a snapshot of the breadth and quality of scientific research carried out at NPL this year, and demonstrates our ability to innovate in bringing research excellence to bear on the world around us. In each of our key science areas we are engaged in research and collaborations that have significant impact both on long-term economic prosperity and on quality of life.**

For example, we are involved in research that will help to shape the future of renewable energy exploitation – responding to both the climate change and energy security agendas. As a vital public science resource, it is entirely appropriate that we should play a leading role in addressing these issues, since they are priorities for government and will increasingly impact on the wider society.

Similarly, our work in quantum information sits right at the frontier of what is possible to measure, and will prove a vital enabler in the emergence of a range of new technologies when the science is applied in a commercial context. Along with our work on nanotechnology standards – vital to the UK’s leadership in this emerging technology market – this kind of activity is at the heart of our national competitiveness.

NPL, as a national measurement institute and as a science and technical partner to business and government, delivers an immense economic and social impact. This is underpinned by providing talented people with the facilities, freedom and support required to do their best work.

But we can do more. The sheer diversity of our impact and the rapid evolution of new areas of science and technology mean that NPL is not an organisation that can stand still. I want to continue to accelerate our science, and effect a qualitative change in the type of science we pursue. We are looking for opportunities to both expand our investment in longer-term research and nurture our business and social impact.

I believe there is significant scope to expand well beyond our core measurement science remit. NPL has the people, facilities and capability to be the national laboratory for the physical sciences. That would enable us to make a real contribution in many key areas, such as data security, where our ability to drive development of international



John Pethica

standards would be as important as our technical and research input. Crucially, an issue like data security also highlights the role that NPL could play as a trusted independent technical advisor to government and industry. That would mirror the situation in other countries. In the US, for example, NIST is tasked with advising on technical policy issues such as the use of smart cards and security protocols. This is a remit well within our technical ability, and important and topical for the UK.

In my role as Chief Scientist and working with our incoming Managing Director, these are some of the issues that will be occupying my time in the year ahead. Continuing to evolve our science, ensuring its impact and working to expand our remit as a critical public science resource are at the heart of our ambitions.

A handwritten signature in blue ink that reads "John Pethica". The signature is fluid and cursive, written in a professional style.

John Pethica  
Chief Scientist



*A polyurethane tile developed as an acoustic absorber for sonar frequency water tanks has properties which make it very absorbing and minimally reflective to water-borne sound above a frequency of 20 kHz.*

# Acoustics

**Advances in our understanding and application of acoustic metrology have implications for everything from occupational and environmental health to the safe use of medical ultrasound and offshore engineering, where the effect of noise on marine life is as yet only partially understood.**

The Acoustics Team at NPL works closely with industry and academia to undertake leading edge research into improved measurement methods, and formulates novel solutions to real measurement challenges. This research, which includes development of novel acoustic sensors and optical measurement techniques, is enabled by specialist facilities including reverberation and free-field rooms, environmental test facilities, open-laboratory tanks and water sites for underwater measurement.

For more information visit: [www.npl.co.uk/acoustics](http://www.npl.co.uk/acoustics)



# Acoustics

## Case studies

### *Silent running*

NPL is helping to develop the acoustic treatment panels that will clad the interior of submarines. The NPL reverberation chamber was the site for sound absorption tests designed to assess the efficiency of cladding materials, building on work undertaken to assess the performance of stealth materials.

### *Noise annoys*

NPL played a key enabling role in construction of a wind farm off Skegness. Responding to the need to minimise disruption to marine life, NPL carried out sophisticated underwater noise monitoring during piling operations. The wind farm's first turbine is now operational – the first of 54, which will make it the world's largest offshore wind farm.

### *Safer ultrasound*

The novel use of a material derived from submarine cloaking technology is set to make physiotherapy ultrasound machines safer. A new measurement device, developed at NPL, absorbs and measures ultrasound more accurately than ever before, helping manufacturers and users to better calibrate ultrasound devices. This will ensure that patients are not exposed to potentially damaging levels of ultrasound.

### *Pumped up*

A collaborative NPL project to examine hydrodynamic cavitation (bubble formation) occurring in pumps and flow systems is underway, building on acoustic cavitation characterisation techniques already developed. The research could eventually result in the development of more reliable and energy efficient pumps, based on a clearer understanding of the causes and implications of cavitation and the development of novel detection methods.

### *Bajram Zeqiri*

Bajram Zeqiri has this year been appointed an NPL Fellow, in recognition of his leadership of NPL science. An internationally renowned leader in the field of ultrasonic metrology, Bajram has been responsible for a range of novel developments in measurement techniques, including pioneering work on detection methods for acoustic cavitation and the development of a wide range of acoustical absorbers.





*NPL's nano probe system being used to measure electrical properties of materials at the nano scale.*

# Advanced materials

**Materials technology is vital to industrial competitiveness and innovation across all sectors - UK businesses which produce and process materials have an annual turnover of around £200 billion.**

Adoption of new materials - or their use in new applications - depends on an ability to understand, characterise and measure these materials throughout their working life. This includes their processing properties, performance and durability. NPL plays a leading role in the measurement of materials and development of new international standards.

The Materials Team at NPL covers these areas of expertise; structural materials, surface engineering and materials chemistry, and multifunctional materials.

For more information visit: [www.npl.co.uk/materials](http://www.npl.co.uk/materials)



# Advanced materials

## Case studies

### *Eco-design*

A consortium including NPL, Rolls-Royce, Eurocopter, Emerson, NASA, Astrium and Granta Design has established the Environmental Materials Information Technology (EMIT) project. EMIT will develop information sources and software to aid consortium members' response to environmental regulations (such as RACH in the EU) and to enable design for minimum environmental impact – with a focus on materials and process decisions that control the impact of engineered products on the environment.

### *Solar superpower*

NPL is supporting the development of existing and emerging photovoltaic (PV) technologies to harness solar energy more effectively – focused on the development of new materials and devices capable of dramatically cutting the cost per watt of solar power. The development of a measurement and testing platform to support UK development, competitiveness and exploitation of PV technologies is at the heart of NPL's work in this area. As a result, NPL has developed links with key PV academic and industrial players in the UK and is supporting an EPSRC CASE award for a PhD on dye sensitised nanocrystalline solar cells with the University of Bath.

### *Bloodhound SSC*

NPL provided expert consultancy on the vehicle that will spearhead Andy Green's attempt to smash his own land speed record by travelling at speeds of over 1000 mph. NPL advised on optimum wheel materials, based on analysis of a choice of metals and composites, and collaborated on the development of an engine modelling tool that will greatly improve internal motor ballistics.

### *Ground-breaking fuel cell measurements*

NPL has carried out the world's first in situ measurements of temperature and humidity along both gas channels of an operational polymer electrolyte membrane (PEM) fuel cell. Miniaturised probes were incorporated into specially designed recesses in the graphite flowplates to carry out the measurements, which have shed new light on the distribution of water in the fuel cell during operation. This improved understanding of water transport in PEM fuel cells could lead to vast improvements in performance and durability. The benefits of fuel cells over conventional power sources are higher efficiency, lower carbon emissions and reduced environmental and noise pollution. NPL's long-term aim is to reduce costs and optimise performance to facilitate widespread commercialisation of PEM technology.

### *Materials metrology expands*

NPL currently chairs the VAMAS (Versailles Project on Advanced Materials and Standards) G7 pre-normative organization, which has expanded considerably its steering committee by inviting Australia, Brazil, India, Korea, Mexico, South Africa and Taiwan to join. This represents better the growing economies and world order as shown by the recent G20 economic summits. VAMAS has also signed a MoU with BIPM (Bureau International des Poids et Mesures) following a 2-year study led by NPL on the importance of the metrology applied to the measurement of material properties.





*Measuring the ionic composition of ambient particulate matter using ion chromatography.*

# Analytical science

**The Analytical Science Team at NPL is a multi-disciplinary team focused on government priority areas including environmental protection, energy and sustainability, healthcare, and nanotechnologies.**

Its world-class research, consultancy, calibrations and specialised measurement services in Gas Standards, and Trace Analysis & Electrochemistry supports quality of life, innovation and competitiveness. In particular, the Team is a world-leader in instrumentation for atmospheric science, including remote sensing for pollution mapping, air quality modelling and stratospheric measurements (see also Environmental Measurement). The Team also performs research at the frontier of science in the analysis of nanoscale chemistry at surfaces, interfaces and nanostructures (see also Nanoscience).

For more information visit: [www.npl.co.uk/analytical](http://www.npl.co.uk/analytical)



# Analytical science

## Case studies

### *Strong pipeline*

New measurements from NPL have persuaded oil and gas producers to introduce new guidelines for the installation of duplex stainless steel in marine environment pipelines. The research used a modified drop evaporation test with improved control specimen temperature and stress, and found that in some cases the threshold temperature for cracking was as low as 70 °C or 80 °C, rather than 100 °C to 110 °C as previously thought.

The results have prompted producers to revise guidelines on the operation temperature thresholds above which pipe work should be protected with anti-corrosive coatings.

### *Richard Brown*

NPL's Richard Brown has been awarded the 34th SAC Silver Medal by the Royal Society of Chemistry – the first time the award has gone to a non-university academic for more than a decade. The award was in recognition of Richard's excellence in the application of measurement science to a variety of analytical chemistry problems.

### *Nobel Prize*

Two NPL scientists have been recognised for their contribution to the award of a Nobel Peace Prize to the Intergovernmental Panel on Climate Change (IPCC). Martin Milton and Garry Hayman were given personal copies of the award certificate for their work.

### *Mercury standards*

NPL, together with specialist instrumentation company PS Analytical, have developed a method to ensure that measurements of mercury vapour in the air can be linked to the SI system of units. Until now, measurements were traceable to the vapour pressure of mercury, based on a range of different empirical equations – the data from which can vary by as much as 5%. NPL's breakthrough means that mercury vapour measurements undertaken by different laboratories at different times and using different equipment can be compared with confidence. The research may lead to an automated method for analysis of mercury vapour in ambient air, and gives the UK a distinct advantage ahead of expected European ambient air legislation.





*Analysis of a gel after protein gel electrophoresis to determine the purity of protein solutions prior to downstream analysis.*

# Biotechnology

**The Biotechnology Team at NPL is a rapidly growing multi-disciplinary team working at the interface between biology, chemistry and physics to pioneer metrology for biotechnology, especially in healthcare where its impact is greatest.**

It has built strong collaborations with industry and academia, in order to respond to a developing need for accurate measurements in biotechnology - fuelled by the increasing awareness of the need for comparability and traceability in product conformance, quality control and regulatory compliance. Accordingly, research activities are closely aligned to the priority areas of protein, cell and bio-nanotechnology exploitation and safety.

For more information visit: [www.npl.co.uk/biotech](http://www.npl.co.uk/biotech)



# Biotechnology

## Case studies

### *Testing, testing*

NPL has developed a means of characterising single molecules of DNA, based on the single molecule detection capability developed under the Strategic Research programme. The technique can be used to analyse complex or mixed DNA samples, with applications in genomics research and tracking mutation frequencies in viruses.

### *Regenerative medicine*

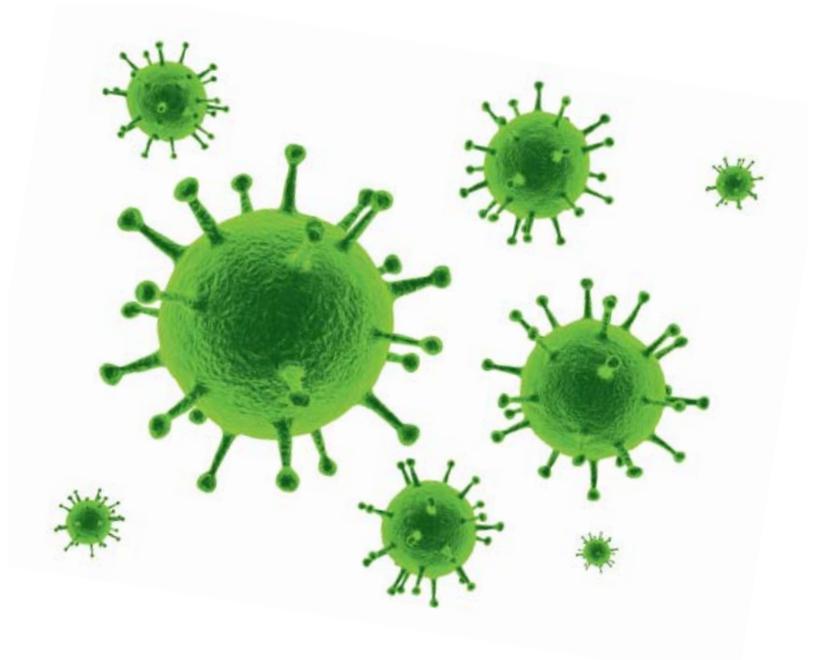
NPL is playing a leading role in the European Metrology EMRP (JRP4) project, which represents a major international co-operation on measurement techniques as applied to regenerative medicine. Through research on a combination of imaging, biomarker detection and studies of protein and cell behaviour on surfaces, the project will establish measurement methods for generating and interpreting 3D functional maps of surfaces and cell cultures. This will establish much needed quantitative measurements for biocompatibility and analytical methods. It will also provide a quantifiable chemical assay of cell behaviour by spatially probing key biomarkers and cell health. The technologies developed will be important for a wide range of health related sectors, including diagnostics, cell based sensing and toxicology testing.

### *Pharmacopeia*

A representative from NPL recently visited the US Pharmacopeia (USP), taking up an invitation to attend an advisory meeting on four key chapters in the area of characterising protein glycosylation, which is linked to biological activity. NPL also took part in an additional meeting between USP and the UK's National Institute for Biological Standards and Control, to discuss data analysis on the current international inter-laboratory study on protein glycosylation.

### *Bio Nano Consulting*

In a significant step forward for the delivery of nanotech for biomedical applications, the newly-launched Bio Nano Consulting brings together NPL, the London Centre for Nanotechnology at UCL, and Imperial College London's Institute of Biomedical Engineering. The initiative provides clients from industry with access to state-of-the-art visualisation, prototyping and characterisation equipment - offering a seamless concept to market route for the first time.





*Electromagnetic anechoic chamber.*

# Electromagnetics

**The manipulation of electromagnetic signals lies at the core of all modern technology - so electromagnetic measurements play a key role in ensuring the effectiveness of technological solutions and innovations.**

The Electromagnetics Team at NPL is home to one of the world's most comprehensive national capabilities for measuring electromagnetic quantities across the spectrum from DC, via RF and microwave, up to terahertz frequencies and beyond. Based on this core capability, and drawing on world-leading facilities and expertise, the Team provides leading edge consultancy on electromagnetic measurement to support R&D in areas where innovation are important for the UK economy.

For more information visit: [www.npl.co.uk/electromagnetics](http://www.npl.co.uk/electromagnetics)



# Electromagnetics

## Case studies

### *Current thinking*

Experts from NPL, University of Cambridge and Germany's National Measurement Institute are collaborating on research that will lead to a re-definition of electric current. Research approaches currently being explored include an electron pump, which transports single electrons via electrostatic barriers oscillating at high frequency, and exposure of an extremely thin superconducting wire to microwave energy. Both have the potential to generate electric current with extraordinary accuracy, which is the key to developing a standard capable of supporting the needs of industry, society and science for the 21st century and beyond.

### *Winds of change*

NPL is working to improve the accuracy with which wind turbine power output is measured. By 2020, the government aims to put in place wind turbines capable of generating enough power to meet the domestic energy needs of the UK. To help ensure this target is met, NPL is working to reduce by a factor of ten uncertainties in the way power output is measured – in the context of government plans, current uncertainties create an error margin of about 0.3 gigawatts, enough to power all the homes in Sheffield.

### *Antenna survey*

Ordnance Survey needed a range of commercially available GNSS antennas evaluated for geodetic surveying. The accuracy with which positions can be determined is limited by the accuracy with which the phase centre of the antenna is known and how it varies with the satellite signals' angle of incidence. NPL developed novel techniques to measure the position and stability of the true phase centre of the antennas as part of a project to assess antenna performance.

### *Martin Alexander*

The BSI has presented Martin Alexander of NPL with the IEC 1906 Award, stating: "This is a very prestigious award to recognise your exceptional contribution to the work of the International Electrotechnical Commission (IEC), having been nominated by your peers in the technical committee CISPR/A."

### *Smart facilities*

The development of smaller, smarter and even wearable antennas has moved a step closer thanks to the opening of a new facility at NPL. The facility will allow minimally invasive measurements of electrically small antennas, and smart antennas, for wireless communications – so that their performance can be accurately measured and compared during development and testing.

### *Cauliflower eyes*

Working with KMS Projects and Vehicle Harvesting Systems, NPL has embarked on a project to research the use of imaging technology as a non-invasive means of determining the optimum harvesting time for cauliflower crops. A prototype autonomous imaging vehicle will be deployed over the next 12 months, with the project expected to significantly cut waste and losses for farmers.





'Silicon Kilogram' - silicon Avogadro sphere.

# Engineering measurement

## *Mass & dimensional*

**Innovative engineering measurement methods, based on the application of physical sciences techniques in areas such as length, mass, force, temperature and humidity, are vital to the competitiveness of UK industry.**

The Engineering Measurement Team at NPL provides support for industry through the development of new measurement methods, tailored measurement solutions, and a wide range of collaborations, including consultancy, measurement research, and instrumentation.

For more information visit: [www.npl.co.uk/engineering](http://www.npl.co.uk/engineering)



# Engineering measurement

## *Mass & dimensional case studies*

The Team's work on mass and dimensional measurement is based on its research to realise and disseminate the base SI units of mass (the kilogram) and length (the metre), and derived SI units, including those for density and force. This enables the Team to offer highly accurate measurement services to customers using equipment of the highest calibre, as well as measurement advice, expertise and training to solve measurement problems for industry that may result in process efficiencies, improved quality control and scrap reductions.

### ***Strengthened collaboration***

NPL has worked with engineers and designers at Hexagon Metrology, to develop a commercial version of the NPL Primary Length Bar Interferometer. Hexagon has sold its first copy of this world-class instrument to the Indonesian NMI, along with several NPL-designed stabilised lasers and a Phase-Stepping Gauge Block Interferometer. NPL and Hexagon have been collaborating in this field for over twenty years, resulting in sales of over thirty NMI-level instruments and nearly a hundred lasers.

### ***Richard Leach***

NPL's Richard Leach has been appointed a visiting professor to the Wolfson School of Mechanical & Manufacturing Engineering at Loughborough University. NPL and Loughborough have for some time been collaborating on limitations and innovations in the use of white light interferometry to measure surface topography. NPL is also at the forefront of the move to 3D or areal surface topography standards and has recently developed traceable instrumentation. The ability to measure areal surface topography accurately will facilitate a step change in manufacturing allowing designers to alter significantly the functionality of components.

### ***Micro thrust***

There is a growing need for highly controllable thrust at the micro-Newton level and below for drag compensation, formation flying and attitude control of spacecraft. Several technologies are being developed around the world to provide efficient and controllable thrust, but before they can be deployed, they must be evaluated on the ground. NPL is working closely with ESA to develop the next generation of micro-thrust balance to provide a traceable, direct thrust measurement capability with an unprecedented combination of accuracy, resolution and measurement bandwidth. When up-and-running in the Electric Propulsion Laboratory at ESA's Space Research and Technology Centre in the Netherlands, this instrument will be the first accredited micro-thrust measurement facility in the world.

### ***Knowledge dimension***

NPL has drawn on its extensive expertise in dimensional measurement along with its track record of developing good practice guides, used by 80% of the UK's leading aerospace companies, to create a dimensional training programme for industry. Since its publication over 3 000 copies of the Fundamental Good Practice in Dimensional Metrology booklet have been downloaded. The training responds to the need for a greater understanding of the basics of measurement in industry, where lack of knowledge can lead to poor decision-making and expensive mistakes.



*High temperature blackbody for radiance temperature calibration.*

# Engineering measurement

## *Temperature & humidity*

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# Engineering measurement

## *Temperature & humidity case studies*

The accurate measurement of temperature and humidity is vital across a broad spectrum of activities, including industrial processes, manufacturing and healthcare. NPL's temperature and humidity experts maintain and disseminate the SI unit of temperature (kelvin) and the derived unit of humidity. They are currently involved in ground-breaking research to develop new thermometry and high-temperature measurement techniques, as well as new ways to measure humidity under a range of conditions.

### ***Hot stuff***

Temperature experts at NPL have developed a new platinum/palladium thermocouple that has the potential to make step-change improvements in high-temperature measurement to 1500 °C. Platinum/palladium thermocouples are extremely stable high temperature sensors but are currently only used by a handful of national measurement institutes. NPL has licensed its new thermocouple design to leading UK thermocouple manufacturer CCPI Europe Ltd, enabling CCPI to manufacture and distribute these thermocouples. This is a significant step towards the dissemination of these devices to industry throughout the UK.

### ***Breathe easy***

NPL's humidity experts have helped design a new testing facility for the evaluation of an innovative tautology breath-monitoring instrument, developed by respiratory measurement specialist Anaxsys Technology. The testing facility will help Anaxsys evaluate their product for several potential applications, including asthma monitoring.

### ***Taking your temperature***

NPL has developed a training course for users of clinical ear thermometers in the medical environment. Developed for the South East of England Development Agency the course has been successfully piloted with Oxford Radcliffe Hospitals NHS Trust and is enabling users to ensure they are following best practice in the use of these thermometers so that accurate readings are taken, which are vital for patient care and treatment.

### ***Bomb-proof thermometer***

To understand the physical and chemical processes that occur during explosions, NPL was asked to develop a high-speed thermometer that would not only survive the harsh conditions inside an explosion fireball, but also measure its temperature. Following laboratory experiments, a rugged fibre-optic based radiation thermometer probe was developed, which detects thermal radiation at four different wavelengths, collecting more information about the thermal physics of the fireball than could be obtained from any one wavelength alone. In the vicinity of the explosion, the optical fibre probe (contained in a rigid steel conduit for protection) collects thermal radiation. This is transmitted over a safe distance via a secondary fibre to the main instrumentation, where the measured thermal radiation signals are converted into temperatures.

### ***Constant improvement***

NPL is leading a major international research project that will help improve the definition of the kelvin, the SI unit for temperature. The project, which also involves experts from France and Italy, aims to measure the Boltzmann constant with uncertainty of less than 1 ppm. This measurement is key to making improvements in the definition of the kelvin. NPL's Zeiss UPMC550 co-ordinate measuring machine was used to measure the dimensions of quasi-spherical resonators direct from CAD models – addressing a key limiting uncertainty in Boltzmann research.



*Airborne Nanoparticle Metrology Laboratory;  
airborne nanoparticle concentration calibration.*

# Environmental measurement

**Critical environmental issues such as climate change, pollution and air quality have a very high public and government profile. Accurate measurements from the Environmental Measurement Team at NPL play a vital role in gauging the scale of anthropogenic and naturally driven effects, pollutant concentrations and the development of strategies to mitigate short and long-term impacts.**

Accordingly, NPL has a strong international reputation and track record in this area, playing leading roles in the World Meteorological Organisation (WMO), the Committee on Earth Observation Satellites (CEOS) and the European Air Quality Reference Laboratories (AQUILA) and with agencies such as ESA and NASA. We are entrusted by Defra, the Environment Agency, and NERC to lead UK monitoring networks and to provide traceable measurements for climate change models.

For more information visit: [www.npl.co.uk/environmental\\_measurement](http://www.npl.co.uk/environmental_measurement)



# Environmental measurement

## *Case studies*

### ***Good prospect***

Along with BASF, Naneum, Exeter University, Imperial College London and other partners, NPL is taking part in the PROSPeCT Link project, led by the Nanotechnology Industries Association. The project will develop essential and seminal test methods and data on two agreed nanomaterials (CeO<sub>2</sub> and ZnO) that are of particular commercial relevance to the UK. NPL will characterise the nanoparticles in four liquid media, and as aerosol, for properties such as agglomeration, zeta potential and surface area, and do developmental work in how to detect airborne manufactured nanoparticles. The resulting scientific advancement will help to advance the commercialisation of nanotechnologies in and by the UK, and provide crucial UK leadership and information to the OECD's global programme on nanomaterials safety assessment.

### ***CAVIAR***

NPL is leading a Cross-Research Council (NERC, EPSRC) project, called 'CAVIAR', involving the University of Reading, Imperial College London, the Met Office, Rutherford Appleton Laboratory, University College London, University of Cambridge, and University of Leicester. The combined research effort - from laboratory and theoretical spectroscopists, field measurement and atmospheric modelling groups - hopes to resolve a major uncertainty in climate change and atmospheric science – the water vapour continuum absorption across the infrared region.

### ***DIAL NPL for measurement***

NPL is carrying out the overall design, development and integration of an advanced Differential Absorption Lidar (DIAL) instrument for operation on board the NERC Facility for Airborne Atmospheric Measurements. The DIAL instrument will make range-resolved concentration measurements of water vapour and ozone, in addition to aerosol backscatter and polarisation measurements.

### ***Teddington energy summit***

In June 2008, NPL held an open day on the theme of energy generation and conservation. The day included laboratory visits, talks, demos, exhibition stands and a school poster exhibition. Visitors on the day included Vincent Cable MP, Councillor Martin Ellengorn and local residents.





*Clinical electron linear accelerator (linac).*

# **Ionising radiation**

**Radioactivity and radiation measurements are fundamental in a large group of activities – from nuclear power generation to healthcare - and their use is expanding.**

The Ionising Radiation Team at NPL plays a leading role in measuring and monitoring discharge from nuclear power plants. It develops techniques, designs instruments, performs real measurements, provides reference materials and acts as a national focus for knowledge transfer, bringing together operators, contactors and regulators.

In healthcare applications, the impact on patients of radioactivity and radiation used in diagnosis and therapy has to be predicted and a clear balance established between clinical result and the potential for harm. NPL is at the forefront of developing measurement techniques for new applications and ensuring the quality of current approaches.

For more information visit: [www.npl.co.uk/radiation](http://www.npl.co.uk/radiation)



# **Ionising radiation**

## *Case studies*

### ***Clinical linac***

NPL and two UK Government departments have invested in a state-of-the-art clinical electron linear accelerator (linac) which will help improve the success rates of radiotherapy cancer treatments. Every hospital needs to ensure that its radiotherapy equipment is stable and accurate - if too low a dose is delivered the cancer may continue to grow, if it is too high healthy tissue could be damaged. The clinical linac provides highly stable beams to enable more accurate calibration of treatment devices and ensure cancer patients receive effective therapy.

### ***Always faithful***

A new instrument developed by NPL will ensure the safety of patients having nuclear medicine treatments. Fidelis, comprising an NPL-designed ionisation chamber and a brand new electrometer module from Southern Scientific Ltd, allows medical physicists to check in-house instruments against the UK standard for radioactivity, held at NPL. This ability to calibrate treatment devices accurately will ensure that the right dose of radioactive compounds is always delivered.

### ***Best in class***

The NPL manganese bath facility, used to make primary measurements of the neutron emission rate from radionuclide sources, was this year identified as the best in the world during a recent audit carried out by an international expert in the field. The acclaim comes after the facility was moved into a new state-of-the-art laboratory, delivering major improvements in radiation protection, security, working environment and general ease-of-use.

### ***Reactor instrument testing***

NPL used the closure of the last UK research reactor, Imperial College London's CONSORT reactor, as an opportunity to provide thermal neutron irradiation facilities based on the Neutron Group 3.5 MV Van de Graaff accelerator. Although intensities are much lower than achievable with a reactor, the NPL facility has already been used to perform acceptance testing for control instruments which are urgently needed at a UK power station.





*Evaluation of Biometrics systems performance.*

# Mathematics & scientific computing

**All measurements are subject to uncertainty and a measured value is meaningless without a quantitative statement of its quality in the form of an uncertainty.**

NPL's Mathematics and Scientific Computing Team is working to support the evaluation of measurements within the National Measurement System (NMS) and industry through the development of uncertainty evaluation techniques, based on the application of Bayesian statistics and Monte Carlo methods. It is also working on a range of projects to assess the reliability of mathematical modelling software used to predict the performance and behaviour of components, systems and experiments – to improve users' confidence in modelling results. NPL is also a recognised source of advice on the evaluation of biometrics technologies.

For more information visit: [www.npl.co.uk/math](http://www.npl.co.uk/math)



# Mathematics & scientific computing

## *Case studies*

### ***The real thing***

NPL has assembled a multi-disciplinary team of scientists with skills in optics, terahertz radiation, materials and surface science, mathematics and software, to determine how best to help UK business fight the counterfeiting threat.

The project will establish how best to support both business and regulatory authorities in resisting the growing threat of counterfeit products and documents. It combines experimental research into a range of potentially-useful measurement techniques with a study into the needs of both manufacturers of materials and products that are at risk of counterfeiting and those whose job it is to detect or prevent counterfeiting.

### ***Timing is everything***

In collaboration with the Royal Marsden Hospital Medical School and the Royal Free and University College Medical School, NPL has carried out research into the analysis of clinical data with low numbers of data points and large uncertainties. An approach to the analysis of such data has now been successfully trialled with 30 sets of patients. The research could mark a breakthrough in understanding and monitoring of patient responses to cancer treatments, enabling better prediction of the optimal time for further drug administration.

### ***Rising to the Challenge***

Congratulations to Roger Scowen, James Miall, Louise Wright and Kevin Marshall, who flew the flag for NPL in the BBC's University Challenge, 'The Professionals' quiz series. The team put in an outstanding performance, eventually finishing second to an impressive Ministry of Justice team, and beating the Authors' Guild, and Consultant Surgeons along the way.

### ***Birth of the Internet***

The technology which underpins everything from the Internet to telephone networks and mobile phones was developed at NPL 40 years ago. Packet Switching was the brainchild of Dr Donald Davies and his team, with the idea first published in a paper prepared for the International Federation for Information Processing conference in 1968. Soon after, Davies and his team put the idea into practice, developing the world's first local area network at NPL.





*Micro-Scanning Laser Doppler Vibrometer used for imaging the dynamic properties of MEMS.*

# Nanoscience

**Nanoscience and nanotechnologies are widely predicted to become a central focus for economic growth in the 21st century. The Nanoscience Team at NPL aims to make a significant impact on the UK economy and quality of life through the development of key and novel measurement techniques and standards that will enable industries to innovate and adopt new technologies.**

NPL's Nanoscience Team supports a wide range of industries, from plastic electronics and personal care to high-density magnetic storage and spintronics. These developments rely on frontier research in areas such as nanoparticle characterisation and nanoprobe microfabrication techniques, and leadership in the development of international standards based on innovative and robust measurement science.

For more information visit: [www.npl.co.uk/nano](http://www.npl.co.uk/nano)



# Nanoscience

## *Case studies*

### *Nano standard*

NPL has successfully led an international collaborative project to develop the first standards document to be published within ISO TC 229 Nanotechnologies. The technical specification covers terminology and definitions for nano-objects, including nanoparticles.

### *Down to the wire*

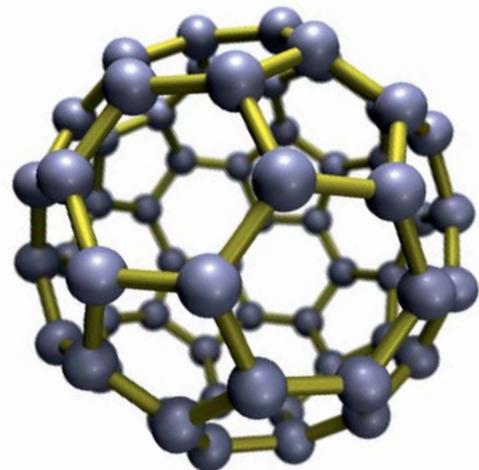
The electronics industry is hungry for innovations that will enable it to sustain the pace of innovation - with the use of electron spin in semiconductors, to make electronic devices more efficient, a leading contender. Breakthrough research from NPL's Nanoscience Team has highlighted the importance of dimensionality as well as the type and distribution of magnetic effects in spin-dependent scattering and the dynamic magnetic properties of diluted magnetic semiconductors.

### *Joanna Lee*

Joanna Lee of NPL has been recognised as the Young Surface Analyst of the Year by the UK Surface Analysis Forum. The award was given for Joanna's outstanding work on understanding, characterising and reducing topographical effects in SIMS (Secondary Ion Mass Spectrometry) – critical to almost all industrial applications.

### *Nanomaterials in space*

The European Space Agency (ESA) has appointed NPL to survey nanotechnology capabilities in Europe, to identify nanomaterials companies with the potential to contribute to the future of satellite navigation and Earth observation. The 'encyclopaedia for space nanomaterials' will also define how these materials can add value to real space applications. It will be developed in consultation with a specialist space consultancy and the Institute of Nanotechnology.





*UV Dosimeters for effective and safer UV treatment of skin disorders.*

# Optical radiation & photonics

**The Optical Radiation and Photonics Team at NPL is engaged in research that is central to developments in communications and healthcare, and our understanding of climate change.**

Optical radiation standards are based on radiometric techniques which equate optical to electrical power and NPL has led the world for many years in the application of cryogenic techniques in this field. Research areas include accurate measurement of optical radiation in space to underpin the metrology of climate change, and developing low-photon generation systems and associated analysis tools – critical to the development of new communication systems using quantum cryptography.

The Team is also working with healthcare specialists to develop non-invasive diagnostic techniques based on Optical Coherence Tomography, which promises to give more quantitative information on the properties of biomaterials.

For more information visit: [www.npl.co.uk/photonics](http://www.npl.co.uk/photonics)



# Optical radiation & photonics

## *Case studies*

### ***The TRUTH***

NPL has played a key role in establishing new reference standards for Earth observation and driving the acceptance of a Quality Assurance strategy for Earth observation, working with the European Space Agency and NASA. The development also brought international recognition of the importance of the NPL-led calibration benchmark, TRUTHS, which promises to underpin greater accuracy in Earth observation.

### ***Better by nature***

An international team of researchers led by NPL is working on a project to understand what determines whether something is perceived as being 'natural'. The project is seeking to understand how the physical properties of materials affect sensory systems, for instance looking at how light interacts with a surface to produce perceptions of depth, colour and gloss – using a new instrument called IRIS (Image Replicating Imaging Spectrometer). The findings may be used by manufacturers to develop ever more realistic synthetic materials, reducing the need to exploit the Earth's natural resources.

### ***Blinded by the light***

The proliferation of small new light sources to provide environmentally-friendly light introduces new problems for accreditation bodies trying to ensure the optical safety of new products. NPL contributes to the development of international standards, which allow the safety of optical sources to be measured in a way that defuses debate. To this end, NPL is building an artificial eye with some of the attributes of a real eye - a variable focus lens and a motorised iris. It is hoped that this will prove the basis for a simpler and more robust method for assessing any optical hazard in the workplace, public spaces, hospitals and the home.

### ***3D models***

NPL is working with the BBC, IBM and the Centre for Advanced Software Technology on the Technology Strategy Board funded VSAR (Viewers' Situational and Spatial Awareness for Applied Risk and Reasoning) project. The research is designed to fuse together various input data formats to develop a tool kit for live interactive 3D models that enhance visualisation and spatial awareness. Applications include security, training and entertainment.

### ***Delivering data***

NPL is working on measurement techniques and simulations to help deliver the rapidly growing volume of data demanded via the internet, fuelled by applications such as the BBC's time-shifting TV service iPlayer. One approach to squeezing these data through the existing infrastructure is the use of advanced data modulation techniques. NPL expertise in optical communications is being used to assess the ultimate data capacity of existing and future communications networks. On a smaller physical scale NPL is working with industrial and academic partners to develop optical techniques to overcome the data bottlenecks found in high capacity storage arrays. Optical waveguides bring benefits of higher capacity and lower energy consumption compared to the copper tracks normally used to connect arrays of hard drives.

### ***The GRASS is greener***

NPL has developed an instrument that helps validate Earth observation data used in climate models, increasing our understanding of the planet. The Gonio Radiometric Spectrometer System, or GRASS, is a ground-based instrument that collects data on how the optical radiation from a surface changes depending on the angle it is viewed from. GRASS collects data for ground reference sites, which is then used to validate satellite data and should lead to the creation of more accurate Earth systems models.



*NPL scientists working on dilution refrigerator used for ultra-low temperature experiments which are aimed at studying the properties of individual electrons in nano-electric systems.*

# Quantum phenomena

**As an essential element of every scientific experiment, metrology typically represents the first application of new scientific discoveries.**

The Quantum Phenomena Team at NPL undertakes fundamental research into new areas of measurement science, particularly those exploiting quantum mechanical phenomena. This includes the development of new devices and techniques for generating, detecting and characterising quanta and quantum mechanical states, which will then allow scientists to exploit quantum coherence and entanglement to enhance the precision of measurements.

The goal of research in this area is to develop an entire set of SI unit standards that are based on fundamental constants and the measurement of quanta rather than relying on artefacts to define our system of units.

For more information visit: [www.npl.co.uk/quantum](http://www.npl.co.uk/quantum)



# Quantum phenomena

## Case studies

### *When dots meet points*

Working with Royal Holloway, Chalmers and Tokyo Universities, the Quantum Phenomena Team at NPL has published a paper describing a quantum dot-point contact detector, which promises to mark a significant breakthrough in terahertz detection. The new sensor operates at higher temperatures, making cryogen-free operation possible. The quantum dot-point contact detector has potential applications in homeland security, materials analysis and healthcare.

### *Single electrons on the move*

NPL has published a paper in Physics Review describing an extremely simple quantised charge pumping mechanism. The work involved a large international collaboration involving PTB, Ben Gurion University, Sichuan University and the Integrated Research Institute, and builds upon the GHz pumping mechanism first reported by NPL in 2007.

### *Alexander Tzalenchuk*

NPL's Alexander Tzalenchuk has been appointed a visiting professor in the Department of Physics at University of London's Royal Holloway College. This appointment is in recognition of NPL's work in superconducting quantum devices, single-photon detectors, nanotechnology and quantum information processing.

### *Spin doctors*

An NPL collaboration with scientists in Russia and Japan has demonstrated that by manipulating the chemical composition of molecular magnets it is possible to modify their mirror symmetry or 'chirality'. The work proves for the first time that spin chirality can influence spin excitation processes such as generation, annihilation and propagation of spin waves and spin solitons. Practical interest in these transparent compounds is motivated by their tuneable magneto-optical properties.

### *European header*

As part of the European Metrology EMRP funding NPL is taking a lead role in defining the experimental set up that it is hoped will lead to the first demonstration of a quantised current standard. At present there are three competing technologies, competing to be the one used in this international collaboration, two of which are being developed at NPL. The aim of the experiment will be to establish the quantum Hall resistance standard and the Josephson standard for voltage simultaneously and use these measurements as a comparison to the measured current. This should lead finally to being able to prove  $V$  really does equal  $IR$ .



*Strontium end cap ion trap.*

## Time & frequency

**Home of the nation's atomic time scale and a caesium fountain primary frequency standard to provide top-level realisation of the SI unit of time, the Time and Frequency Team at NPL is the focus for time and frequency measurements in the UK.**

The Team is at the forefront of international research, for instance developing unique clock steering algorithms, together with methods to evaluate clock and time transfer noise processes. This work is making a crucial contribution to the development of the reference time scale for the Galileo satellite navigation system. Another major area of research is the development of a new generation of highly accurate optical frequency standards - with potential applications ranging from improved satellite navigation systems to sensitive tests of fundamental physical theories.

For more information visit: [www.npl.co.uk/time\\_frequency](http://www.npl.co.uk/time_frequency)



# Time & frequency

## Case studies

### *Frequency comb transfer*

NPL has demonstrated the fibre transfer of a microwave reference using an optical frequency comb, with the highest stability ever reported. Transfer via optical fibre links has been identified as the most promising replacement for current satellite link transfer, which will soon not be capable of the necessary transfer stability required by state-of-the-art optical clocks. The results achieved by NPL are a factor of two better than the best previously reported.

### *Stephen Webster*

NPL's Stephen Webster was awarded the 2008 European Young Scientist at the 22nd European Frequency and Time Forum in Toulouse. The award is for the development of vibration insensitive thermal-noise-limited optical cavities and the development of the ytterbium ion octopole frequency standard.

### *Patrick Gill*

The highly prestigious Institute of Physics Young Medal and Prize was awarded to NPL's Patrick Gill in 2008. The award is for distinguished research in optics and recognised Patrick's contribution to optical frequency metrology.

### *Leap second*

A leap second – the first for three years – was added to the international timescale Coordinated Universal Time (UTC) on New Year's Eve 2008, thereby delaying the start of 1st January by one second.

NPL scientists made sure that UK time remained synchronised with international time – and the Earth's time – by adding a second to the UK atomic timescale, which is held at NPL in Teddington.

The insertion of the leap second at the end of 2008 was picked up by a large number of national media organisations, including The Guardian; The Independent and BBC online.





*Exterior view of front of NPL building.*

## Contact us

**We help all UK industry, research organisations, institutions and government departments to use our knowledge to support their business. Working with NPL opens the door to 500 passionate scientists and world-class facilities through research programmes supported by the Department for Innovation, Universities and Skills.**

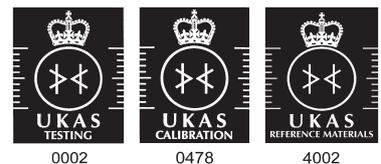
NPL provides a range of services to solve your problems by applying measurement advice to enhance and complement your skill base. NPL experts give up to two hours of free advice and have many guides and dissemination events available.

Contact the NPL Helpline staff, who will be happy to advise you and find the correct person with the right expertise for your enquiry.

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Cover image: UV Dosimeter for effective and safer UV treatment of skin disorders.

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