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Inside the world of measurement science & technology

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Revolutionising the science of sound

Biological glue for micromanufacturing

Commercialising nanotechnology

A new security dimension

Free guide

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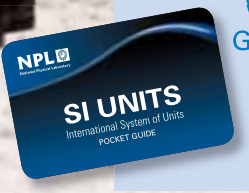

NPL / Andrew Brookes

Out of the darkness

Teresa Goodman's work on lighting standards may make twilight streets safer

NPL is helping to make it safer to drive at twilight when light conditions are most dangerous for motorists and pedestrians.

Research into how the eye performs in low-light conditions may lead to new street lighting standards which help drivers to recognise obstacles and react better to dangerous situations.

It could also improve emergency lighting on aircraft and boats, which use batteries and require maximum lighting efficiency from minimum energy.

"Scientists have been working on this for more than fifty years," says Teresa Goodman, who represented NPL in an international research consortium.

"We think we may be nearing the end of a very long quest."

There are no international standards or policies for the most effective illumination under twilight lighting levels.

Experimentation is difficult because of the way the eye changes in response to light.

NPL was part a consortium of European research institutions which examined how the human visual system performs tasks at twilight levels. Among tests was a simulated drive along a deserted and bending road, with participants responding to the emergence of virtual targets under a variety of light levels.

Experts in vision science, metrology, human behaviour and data processing have now developed a simple measurement system for human sight at twilight light levels.

The results have been well received and are being considered by the International Commission on Illumination (CIE).

Light, dark and twilight

Twilight is commonly defined as a natural phase between light and dark. But it can also be considered in terms of light level, typically measured in candelas per metre squared (cd m^{-2}) and covering the range from about 0.001 cd m^{-2} to about 3 cd m^{-2}. It includes natural darkness which is illuminated by artificial light.

Comparative light levels (approximate values)	
Complete darkness (absence of light)	Zero
White paper in bright moonlight	0.003 cd m^{-2}
Illuminated road surface at night	**0.3 cd m^{-2} to 2 cd m^{-2}**
White paper in bright sunlight	30,000 cd m^{-2}
Clear blue sky	5,000 cd m^{-2}
Surface of sun seen from Earth	1,600,000,000 cd m^{-2}

Biological glue for micromanufacturing

NPL is developing ways for biological recognition to bond hundreds of tiny components into a mechanical device the size of a full stop.

Instead of the painstaking manual assembly of a MEMS device, an emerging biomimetic technique gives each silicon component a set of DNA strands with a particular code. Each set has a matching partner on another component. The components are mixed together till they find each other and bond.

"It's like a jigsaw puzzle with hundreds of pieces that fit together in a particular way," says NPL's Alex Cuenat. "We make the pieces and nature puts them together."

Thousands of sets of components – each with their DNA 'glue' – can be used to simultaneously manufacture thousands of MEMS devices.

Microelectromechanical systems (MEMS) refer to mechanical components and machines measured in micrometres, or thousandths of a millimetre.

Biomimetics is the application of methods found in nature to the study and design of engineering systems and technology.

"It's like a jigsaw puzzle with hundreds of pieces that fit together in a particular way."

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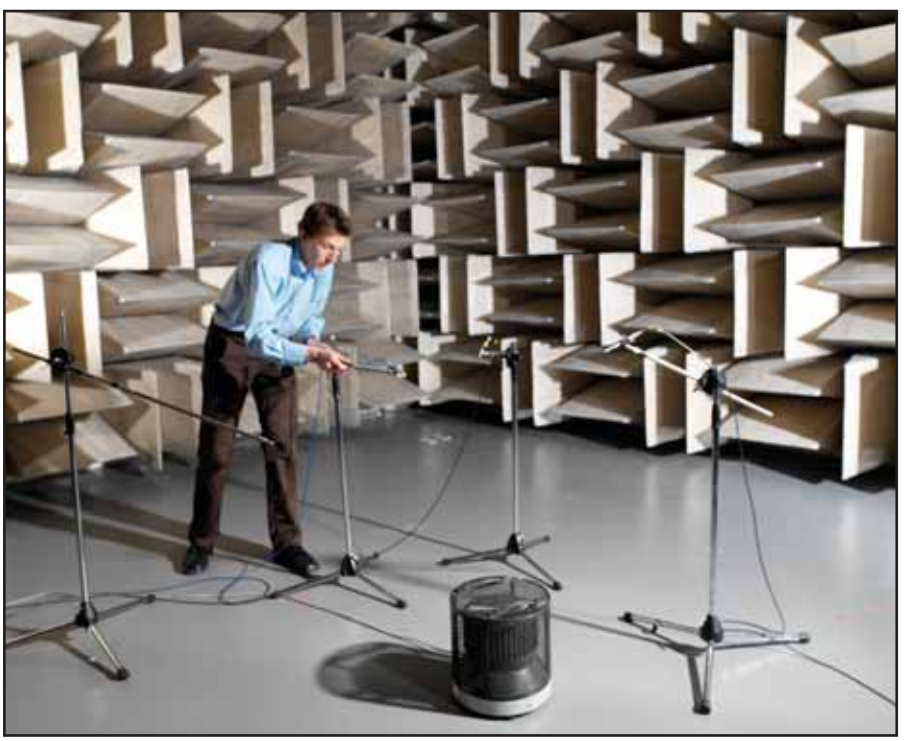
Scanning electron microscope image of nanoscale gears on a MEMS device

NPL

Acoustical measurement has come a long way since this 1929 experiment at NPL

Revolutionising the science of sound



NPL / Andrew Brookes

Richard Lord in NPL's anechoic chamber

Sound affects everything from survival of whales to safety of workplaces and success of medical treatments.

The re-emergence of acoustic measurement as a discipline is partly due to stringent health regulations and a European directive requiring a 20% reduction on 2000 noise levels by 2020.

The effect has also been felt of environmentalists campaigning about the impacts of underwater noise on marine life, and residents expressing concern over increasing urban noise pollution.

"We are revolutionising the science of sound," says Mike Goldsmith at NPL, which leads UK research into the measurement and manipulation of sound in workplaces, hospitals and the environment.

Treating cancer at the speed of ultrasound

NPL is improving the application of a new non-invasive therapy which uses ultrasound beams to kill cancer cells without the need for surgery.

More than 5,000 people are diagnosed with cancer every week in the UK. Most patients require surgery, drugs or radiotherapy which can have severe side-effects and damage healthy tissue as well as the tumour.

HIFU - or high-intensity focused ultrasound - exposes cancer cells to a focused short pulse of ultrasound energy. This heats the cells to more than 70 °C and kills them within seconds while leaving the surrounding healthy tissue unharmed.

By reducing the need for treatments like chemotherapy which affect the entire body, patient recovery time and discomfort is reduced. NPL is working with the Institute of Cancer Research (ICR) to improve the measurements for HIFU.

Acoustic shock research

Millions of call centre workers are at risk of acoustic shock from unexpected sound in their headsets.

The sounds can cause tinnitus, hearing difficulties and depression, and lead to absenteeism and claims against employers. Out-of-court settlements to date have reached more than £2m in the UK and £10m internationally.

NPL is investigating the cause and effect of acoustic shock in an alliance with the Acoustic Safety Programme supported by the Communication Workers Union (CWU). The CWU receives hundreds of complaints about acoustic shock each year from call centre workers. "It is the industrial injury of the 21st century," says CWU spokesperson Steve Mann.

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Explaining the supernatural

Spooky sound

NPL has helped to show that low-frequency sound waves may be behind ghostly sightings and haunted buildings. The suggestion that infrasonic waves are present in 'haunted houses' prompted an investigation into the effect of the waves on human emotions.

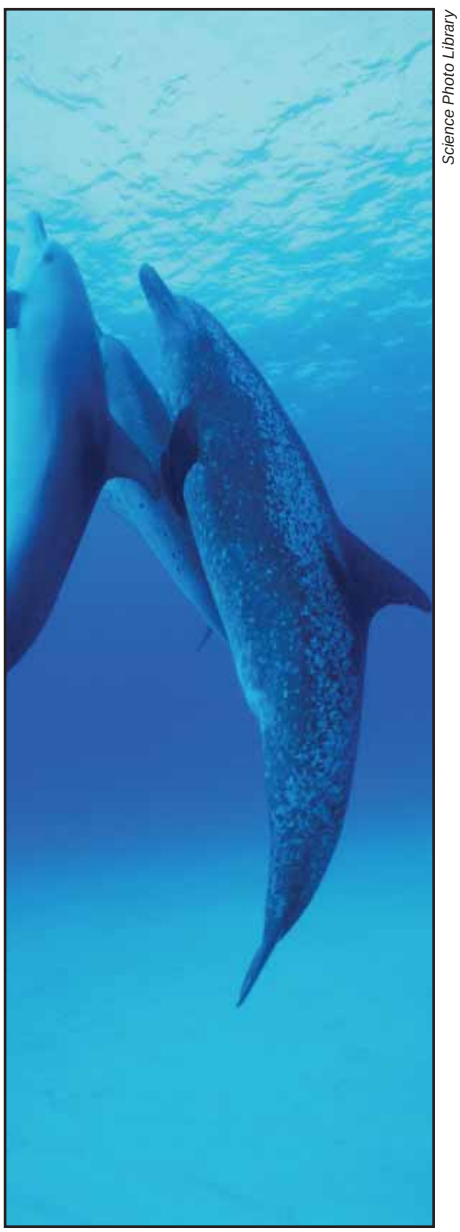
Members of an audience at an experimental piano recital, where music was laced with bursts of infrasound, were asked to record their moods at particular times during the concert. Some reactions included an extreme sense of sorrow, coldness, anxiety and even shivers down the spine when the infrasonic pipes were switched on.

These emotional responses may help to explain some haunting phenomena, where naturally occurring infrasound may be present.

Submarine safety

NPL is helping to understand the impact of noise generated by human activity on marine life. Whales and dolphins use sound to hunt and communicate, so even subtle acoustic signals may disrupt them. Powerful underwater sound waves can be generated by offshore oil and gas activities, naval sonar and surface vessels.

There is growing concern about the impact of this noise, but there is often confusion about the best way to measure and express its levels. NPL has brought together leading researchers, environmentalists, biologists, naval staff and the offshore industry to share acoustics measurement expertise and best practice.



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Dolphins use sound to hunt and communicate

Commercialising nanotechnology

NPL is helping industry and consumers to benefit from nanotechnology

Nanomaterials can have outstanding properties of fire resistance, conductivity, impact resistance and strength which make them valuable for domestic, medical and industrial use. They are found in products as diverse as crisp packets, clothes, tennis balls and self-cleaning windows.

Thin films between 10 nm and 100 nm thick may be used to sense temperature, pressure, strain and sound. They can respond to a local chemical environment in tiny devices designed to work as drug delivery systems inside the body.

Research presents unique measurement challenges in this promising science, which can be usefully applied only with a proper understanding of the characteristics and behaviour of materials at the nanoscale.

"Everybody agrees the nanotechnology market will be worth trillions of Euros over the next ten years," says Del Stark, chief executive of the Euro Nano Trade Association. "What we really need now are standards that can be validated by measurement."

It's the surface that counts

Many nano-applications depend on the properties and behaviour of a surface, prompting NPL to develop a unique device to measure and test surface coatings as thin as five nanometres. It is helping industry to monitor the rapid changes in a nano-coating under stress, providing valuable information to designers about the degradation of materials.

NPL nanometrologists are measuring the friction between nano-coatings, testing for imperfections in diamond coatings and inspecting the scratch resistance of metallic films just a few nanometres thick. Modern glasses are coated with hundreds of nano layers of titanium or chromium to provide insulation or self-cleaning properties. NPL is able to separate each film to test its adhesive properties.

Scientists are also supporting the pharmaceutical industry with new techniques to measure the dimensions of millions of nanoparticles – such as biomolecules or quantum dots – in a suspension.

Atomic force revolution

Were it not for the atomic force microscope (AFM), nanotechnology would not have enjoyed such publicity over the past few years. An AFM relies on a tiny cantilever with a tip that moves over the surface of a sample. The cantilever bends up and down as the tip is repelled by or attracted to the surface. The AFM traces the profile of the surface by 'feeling' its forces. These forces are so tiny they can't be related to a standard weight, and are therefore difficult to quantify. NPL has developed a MEMS device that can relate the force on the AFM tip to the electrical units – the volt and ampere. This will allow AFM users to quote the forces they measure in SI units for the first time.

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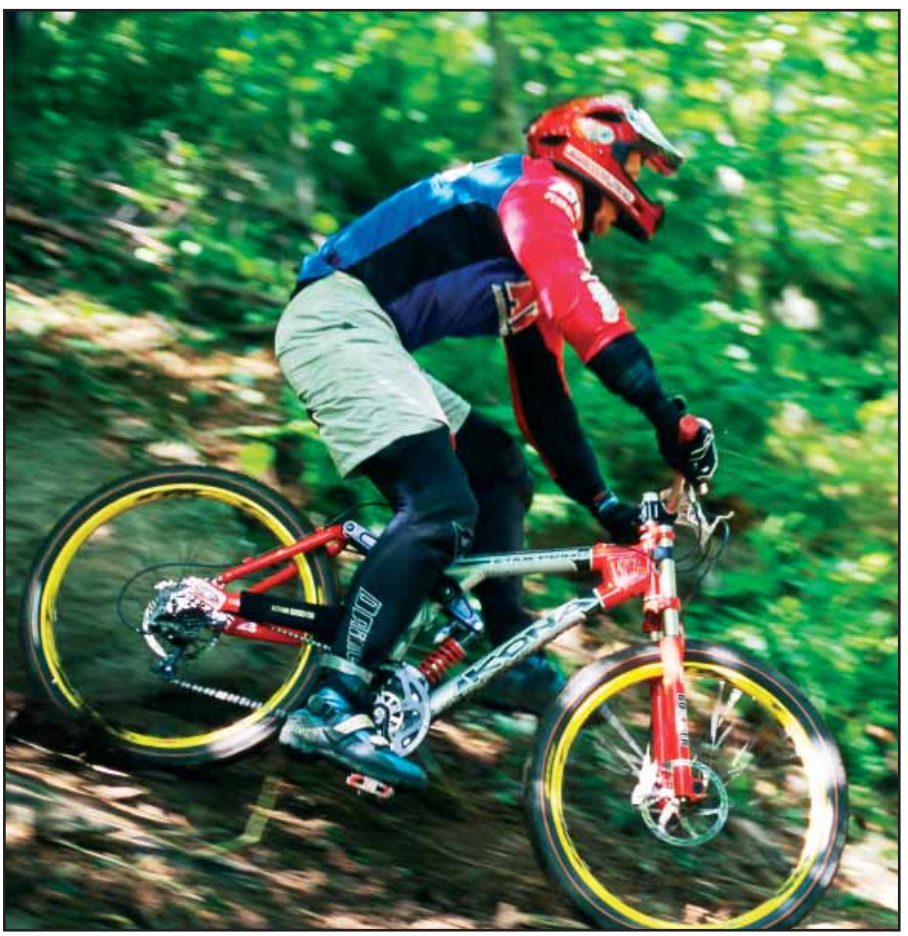

Nanotechnology is finding its way into sports equipment

Nanometre (10^{-9})

A nanometre is a billionth of a metre.

Nanotechnologies include the design, characterisation, production and application of devices and systems by controlling shape and size at the molecular and nanometre scale, where properties of materials differ significantly from those at a larger scale.

Exploiting the potential of nano and micro IP

NPL research frequently leads to intellectual property which it develops and exploits with commercial partners. Current innovations include a novel nanosecurity device and a new type of hearing aid.

A new security dimension

NPL's nanomaterials team has patented a three-dimensional barcode with so many permutations a computer crunching a million options a second would take ten times the life of the universe to crack it.

The tiny device can be concealed behind a human hair. It is an irregularly-shaped silicon cube measuring 30 by 30 microns. Its surface is coated with 100 nm of hard polymer and divided into 90,000 squares, each drilled to one of five depths from zero to 80 nm. A code based on the relationship between the squares would allow for about nine billion billion permutations.

It is impossible for all but a handful of specialist laboratories to detect so could form the next generation of security on identity cards, passports and works of art.

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Nanotechnology may increase security measures on passports and identity cards

Music for their ears

A novel cochlear implant is being developed by scientists at NPL in collaboration with the Institute of Nanotechnology.

A major cause of deafness is degradation of hair cells in the inner ear. Current implant technologies overcome this by sending electrical signals directly to the brain via cochlear nerves.

But it is difficult to implant more than about 20 electrodes per device, so the acoustic resolution of today's implants is inferior to that of a normal ear. NPL is working on microsensors that can be tuned to resonate at different frequencies by adjusting their length and width. This may allow hundreds of tiny sensors to be contained in a single implanted hearing device. It may increase the capacity for deaf people to hear a range of sounds, including music.

The new implant mimics how the cochlea selects sound frequencies entering the ear. It vibrates in response to sound, which causes the piezoelectric material to produce a small voltage. The electrical signal travels down the auditory nerve to the brain. NPL's research has been welcomed by the medical device community, and discussions are underway with potential partners for development of commercial prototypes.

Nanobriefs

Supporting nanoproducts

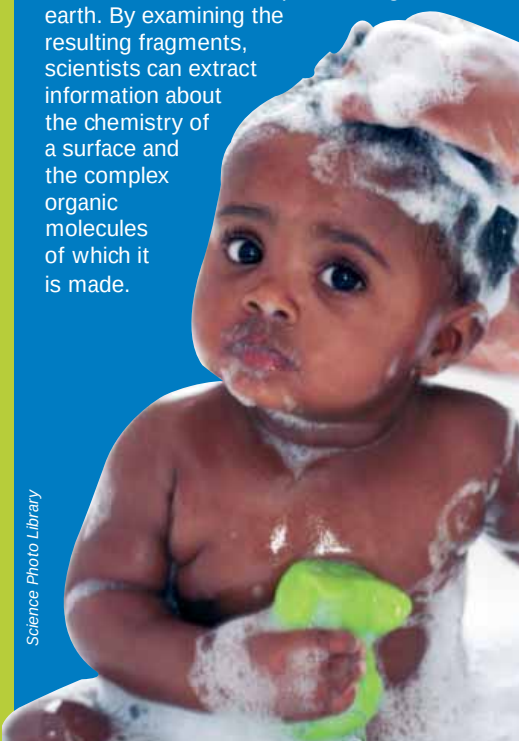
NPL has helped to establish the Centre of Excellence for Metrology in Micro and Nanotechnology to support the commercialisation and manufacture of nanoproducts.

Crispy snacks

Snacks are kept fresh through NPL research. Potato crisps today are packaged in a highly-engineered material made of multiple layers less than 100 nm thick, each with a particular function. One layer makes the chip packet easy to seal, while another makes it easy to open. A thin layer of aluminium prevents oxygen from penetrating the packet. "Miles and miles of this packaging is made at a time – all of it a miracle of nanoengineering," notes NPL knowledge leader Mark Gee. "But this and many other applications of nanotechnology are only possible with the traceable measurements pioneered by NPL."

Shampoo chemistry

NPL is examining how natural and synthetic fibres respond to new formulations of washing powder, and how the chemistry of the human hair responds to shampoo. One of its tests, using a technique called secondary ion mass spectroscopy, involves slamming heavy ions into a surface – like a stream of meteorites pummelling the earth. By examining the resulting fragments, scientists can extract information about the chemistry of a surface and the complex organic molecules of which it is made.



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How does hair respond to shampoo?

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National Physical Laboratory | Hampton Road | Teddington | Middlesex | United Kingdom | TW11 0LW

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Measurement news in brief

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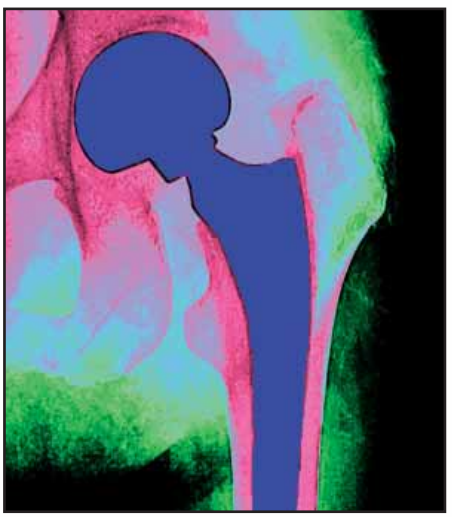

Customised hip implants could save the NHS millions of pounds

Hip hip hooray

The orthopaedic industry has welcomed research which could help customise medical implants to individual patients. By 2010 more than 100,000 people in the UK will require hip replacements, at an annual cost to the NHS of £250 million. Up to 20% of hip replacement patients currently require corrective surgery due to fractures from poor implant design or materials failure. Researchers are investigating whether 3D computer simulations can accurately predict the suitability of an implant for a patient.

Tough enough

Composites stronger than naturally occurring elements are used by the mining and construction industries. NPL is helping researchers at the UK Hardmetal Trade Association to test the hardness and behaviour of new materials at temperatures up to 800 °C.

Metrology training

The UK's first independent accredited metrology training course is being launched by NPL to address the decline of measurement skills in UK manufacturing. It is supported by Rolls-Royce, Hexagon Metrology and Mitutoyo.

You can still count on it

The time signal used to keep Britain's clocks accurate is on the move from the Midlands to the west coast of Cumbria. Transmitted from Rugby since 1927, its new home is in Anthorn from where its reassuring beeps will be known as "The Time from NPL". NPL maintains the UK's atomic clocks which underpin the national time standard. The time signal, which moves from Rugby in April 2007, is accurate to within one thousandth of a second.

Precision time ensures the operation of global navigation systems, the internet, email, television, the power industry, transport, and financial systems. It also supports the emergency services, train companies, cash machines and mobile phone billing systems.

NPL / Andrew Brookes

The man behind the time, Steve McQuillan, MD of NPL

Crash test materials

A team at NPL is working with Land Rover to predict the effect of accidents on car interiors. The entire structure of a vehicle can be affected in a crash. Knowing how the interior behaves will influence the materials chosen by manufacturers when designing a new car. "We support the use of measurement science in the automotive industry if it enables manufacturers to make more accurate predictions which improve vehicle safety," says Adrian Hobbs, secretary general for Europe's New Car Assessment Programme (EuroNCAP).

When you hear the signal

NPL is among leading players in Europe's timing community who will synchronise the precision time signals underpinning the ambitious Galileo constellation of navigation satellites.

Free guide

NPL offers a free wallet-sized guide to SI measurement units.

Need to tell your **teslas** from your **katals** and your **pascals** from your **newtons**? **Zetta** or **zepto**? **Yotta** or **Yocto**? Scientists, students and pub quiz fans all need the International System of Units (SI), the internationally agreed basis for expressing measurement.

Get your wallet-sized SI guide from NPL by e-mailing SI@npl.co.uk with your name and postal address.

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