Physical Sciences and Engineering

UNIVERSITY OF Southampton

NB

Physical Sciences and Engineering New Boundaries

2013

Fulfilling future energy demands

Sustainable power for the world

Past, present and future of the internet
Revolutionising information technology

Developing the strongest, lightest material
Strongest silica nanofibres in the world

Pushing the boundaries of astrophysics
Answering fundamental questions about the Universe

In this issue

Welcome to *Physical Sciences and Engineering New Boundaries*, the University of Southampton's research magazine for Electronics and Computer Science (ECS), Physics and Astronomy, and the Optoelectronics Research Centre (ORC). In this issue, you will learn about some of the outstanding research that is being carried out by our internationally recognised academics and students.

From exploring the wonders of our universe to helping create and shape the World Wide Web, the breadth of our work is enormous.

We combine strengths in world-leading research that is conducted in superb facilities and research centres and we are proud of our distinguished reputation for enterprise and industrial engagement.

We are also one of only a handful of universities to receive the prestigious title Regius Professor, an honour bestowed by HM The Queen. The rare professorship marks our excellence in the field of Computer Science and reflects our exceptionally high quality of teaching and research.

Our academics are committed to improving the quality of life on our planet, seeking more efficient solutions to the demands of modern life, such as energy consumption and the accessibility of data as a public resource.

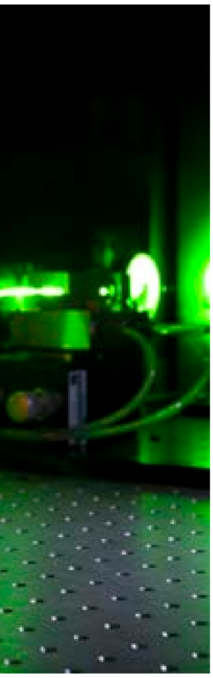
On page 12, find out more about our Optoelectronics Research Centre's development of the strongest, lightest glass nanofibres. Discover how our Physics and Astronomy team are inspiring the next generation of scientists on page 16. Read about how we are developing micro devices being used in health and medicine on page 22.

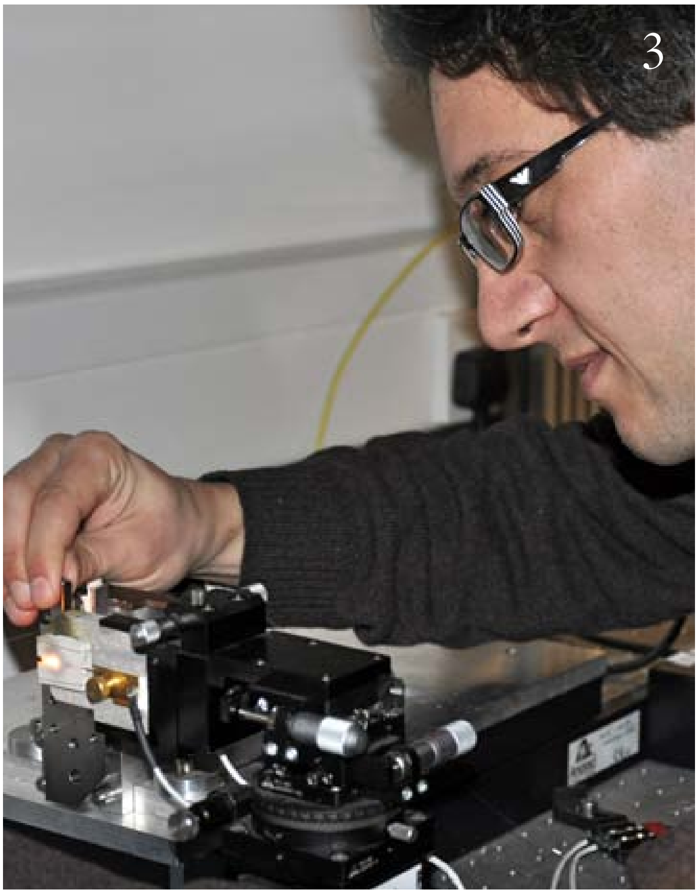
These are just a few of the stories about how our research is impacting communities and the world. To find out more, visit **www.fpse.soton.ac.uk**

Professor Bashir Al-Hashimi
Associate Dean Research, Physical Sciences and Engineering

Please send us your feedback

We appreciate your feedback about *Physical Science and Engineering New Boundaries*. If you have any comments or suggestions, please send them to fpse-marketing@southampton.ac.uk





More highlights

Fulfilling future energy demands

Our researchers are partnering with industry to find savings in the monitoring and transmission of energy. From thumbnail-sized generators powered by ambient vibration to massive, undersea electrical cables, discoveries at Southampton are helping provide power to the UK and the world in a more economical and environmentally sustainable manner.

Delivering greener energy

In 2011, total electricity generation in the UK increased by 33 per cent, to 34,410 GWh, with certain renewable sources of energy, such as wind power increasing by as much as 45 per cent. Investment in offshore wind power, alone, from 2011 has increased more than 60 per cent to £1.5bn, while planning approvals for onshore wind farms are at a record level.

Despite these changes, key aspects of the technology relating to power transmission and distribution systems – underground coaxial cables and overhead lines – have not significantly changed since the national electrical grid was created in the 1960s. Professors Paul Lewin and Alun Vaughan in Electronics and Computer Science (ECS) have been working with major industrial organisations and the UK transmission system operator National Grid to address important problems related to the design of high-voltage cables and their operation to reduce operational costs, minimise risk of network failure and cut carbon emissions.

Current electricity transmission systems include alternating current (AC) cables, a technology that is proven for short lengths of cable and where power flows are predictable. However, the key insulating material currently used in AC cables has a maximum operating temperature of approximately 95°C. Overheating of a cable and subsequent breakdown of a network is a serious threat when these links have to be worked hard because of difficulties elsewhere in the network. Under such emergency conditions, peak current flows (at approximately 2,500 amps) cannot exceed six hours without risking overheating the cable and causing permanent damage which could, in the most extreme circumstances, lead to blackouts.

Alun explains: "When the National Grid was installed, many of the design principles were based on the premise that things should not go wrong, so a degree of over-engineering was the rule and this has served us well since the middle of the last century. In principle this is fine, so long as you are prepared to pay for it but, as we go forward, the key things we need are efficiency, resilience and adaptability in our infrastructure.

"In the future, we are going to be less reliant on conventional forms of energy generation and more reliant on renewable forms, which are by definition intermittent. If you install cables to transmit the maximum of power, you will inevitably build in redundancies and higher capital costs, due to having more copper in the cables than you need.

> "When you look at wind energy and the interconnectors in the North Sea, places like Ireland and Scotland have vast amounts of resource, but they haven't got the local demand to match that resource."
>
> Professor Paul Lewin,
> Electronics and Computer Science (ECS)

Most of the time, the wind farm will be generating useful amounts of power and very occasionally it will be generating its maximum possible output. The ideal cable would be something that allows you to run at peak capacity for short periods of time and operates under normal conditions the rest of the time."

With significant funding from the Engineering and Physical Sciences Research Council (EPSRC) and collaborating with a range of industrial partners, including National Grid and GnoSys Global, Paul and Alun began working with a multidisciplinary team five years ago to realise the manufacture of sophisticated materials that would adequately insulate new, high-voltage cables, be less energy intensive in their production, be fully recyclable at the end of their life, and have been shown to offer network businesses enhanced operational flexibility. Additional funding from EPSRC is being used to explore the development of related high voltage direct current (HVDC) cables for use at extremely high voltages (up to 1 MV), which will greatly increase the efficiency of energy transmission over long distances, such as from an offshore wind farm to shore.

In addition to the new cable technology, Paul and Alun have proposed more accurate rating methods for existing cables that could save the energy operator National Grid more than £1.2m annually. They have also recommended new techniques – such as improved modelling of ventilated tunnels for existing cables – that deliver an estimated cost savings of 85 per cent. A recently announced contract between Southampton's world-class Tony Davies High-Voltage Lab (TDHVL) and wind farm company Centrica plc to test HVAC offshore wind farm export cable highlights how these savings can be implemented in the burgeoning renewables sector.

"This is extremely important work for the UK offshore wind farm industry as a whole," Paul says. "The outcomes from this testing programme could ultimately lead to improved international standards for the rating of offshore wind farm export cable circuits. When you look at wind energy and the interconnectors in the North Sea, places like Ireland and Scotland have vast amounts of resource, but they haven't got the local demand to match that resource. In the future, these places will export wind energy to Europe, and that will be done by cable. That is why what we are doing at Southampton is so important."

Micro-generator: no batteries required

Another area where Southampton researchers are creating more efficient and greener delivery of electricity is energy harvesting, or the process by which energy is derived from external sources, captured and stored for small, wireless device sensory networks. Monitoring the conditions of industrial equipment is costly to the transportation, aeronautical, energy and military sectors. Whether done remotely with wireless devices or via manual inspection by service personnel, condition monitoring is also time-consuming and uses large numbers of batteries which must be replaced at irregular intervals. Each year, we throw away 300 million batteries, or 22,000 tonnes, often sending them to landfills where they leak poisonous cadmium, lead, mercury, copper, zinc, manganese, lithium, or potassium into the soil, groundwater and surface water.

To help solve this problem, researchers at Southampton have invented a micro-sized energy harvester powered by ambient vibration. The energy harvester – models range from the size of a thumbnail to one the size of a coffee mug – uses four magnets and a coil to create an electromagnetic field for power generation when it shakes, converting linear (up and down) motion into energy. Using the vibration from machinery upon which it is mounted, the energy harvester can last up to 25 years without replacement, a characteristic that allows it to be placed in inaccessible or hazardous locations.

The harvester was created by Professor Steve Beeby, EPSRC Leadership Fellow, and Dr Geoff Merrett, Lecturer, Electronics and Computer Science (ECS), with underpinning research led by Professor Neil White and Dr John Tudor and funded by the EPRSC and European Union. Steve was working in a clean room with piezoelectric materials – which convert mechanical energy to electricity – in 1998 when he realised how an energy harvester could be built based on these principles, and then switched to one based on electromagnetics in 2001. Since 2004, Steve and John have been working with the Dutch electronics manufacturer Philips to develop MicroElectroMechanical Systems (MEMS) to the energy harvester. A spin-out company, Perpetuum, has been formed that has attracted almost £10m in venture capital and has placed Southampton at the global forefront of energy harvesting research and a market worth an estimated $700m in 2011.

The energy harvester is being developed for use by at least one industry partner, Scotia Gas. The devices will facilitate wireless condition monitoring at Scotia's power plants, replacing expensive (£120 each) sodium-lithium (NaLi) batteries. Shell UK is also using Perpetuum's generator. Previously, if the company wanted to monitor machines around a several hectare petrochemical plant, a worker must go around with a probe to check each machine sensor's batteries once a month or observe its infrared spectrum for hotspots, using a wireless human monitoring solution.

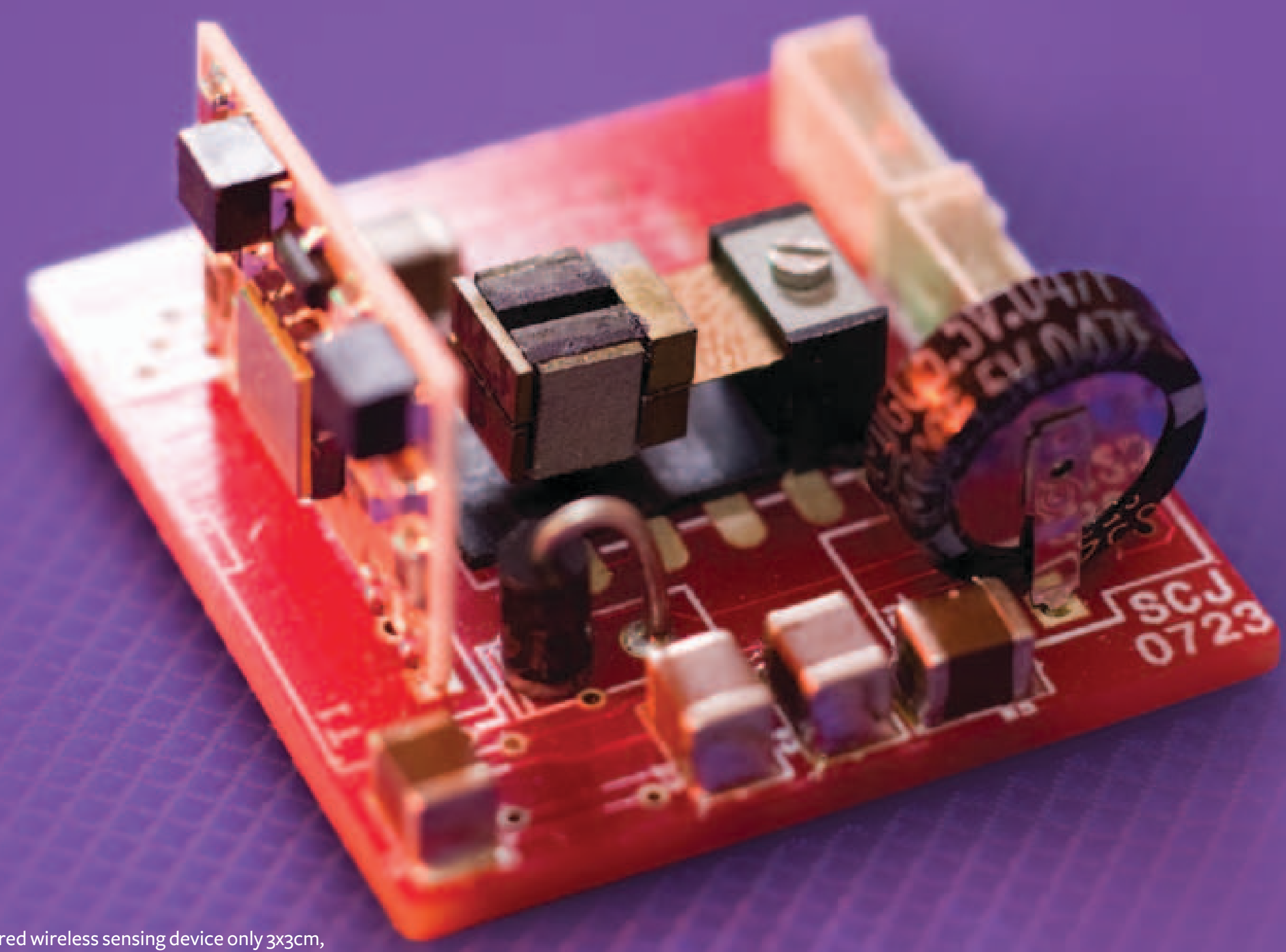
Steve notes that the energy harvester is not a replacement for all batteries, but he is optimistic about its application: "It is quite an elegant role for the device when you consider that you are monitoring the health of a machine by looking at its vibrations, while collecting energy from those vibrations."

Tuning is the next challenge for device development, Steve explains. At present, the micro-device is designed to operate at a constant frequency; Steve and Geoff are exploring how the device can be modified to adapt to variable frequencies, such as those produced by car engines at different speeds.

In the future, Steve imagines that distributed sensors in a smart building could power themselves with energy produced by our own footfalls on carpet designed to capture kinetic energy.

The University's research in developing next generation electronics systems powered by energy harvesting is continuing as part of the UK Microelectronics Grand Challenge, "Batteries not included," which is led by Professor Bashir Al-Hashimi. Southampton is leading a consortium of four UK Universities and four industrial partners to develop holistic energy harvesting systems that are more complex and more compact but also intelligent, adaptive and able to perform more computation with less energy.

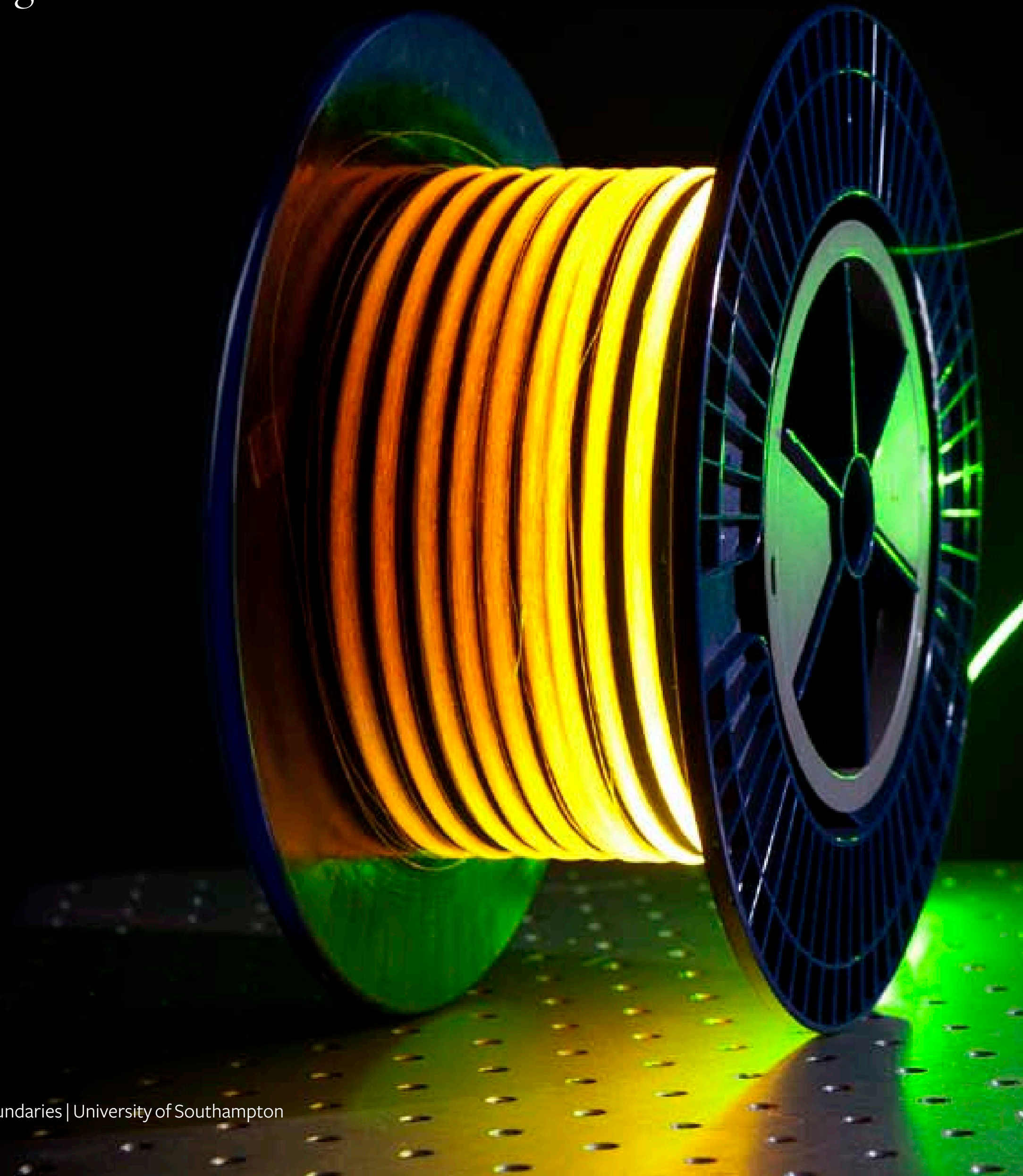
For more information, visit:
www.highvoltage.ecs.soton.ac.uk/
www.holistic.ecs.soton.ac.uk/



A self-powered wireless sensing device only 3x3cm, which harvests energy from ambient vibrations

Past, present and future of the internet and the World Wide Web

It is 60 years since the internet was first introduced and dramatically altered the social and political realities of our world. Our engineers and scientists have been inextricably linked to the emergence of the internet and the World Wide Web and are still working today to shape the future of these technologies.



Southampton made the breakthrough in developing the low-loss optical fibres which now drive the internet. The University continues to lead applied research into the power of the information that the Web holds and the ways it continues to transform our lives.

Laying the foundation

Research that forms the foundations of the internet's infrastructure began at Southampton in the 1960s. One of the most important breakthroughs in the history of the internet happened here, with the development of low-loss optical fibre. During the mid-1980s, Professor of Photonics, Sir David Payne, at the University, integrated laser amplifiers into optical fibres to dramatically boost the speed with which the internet transmits data.

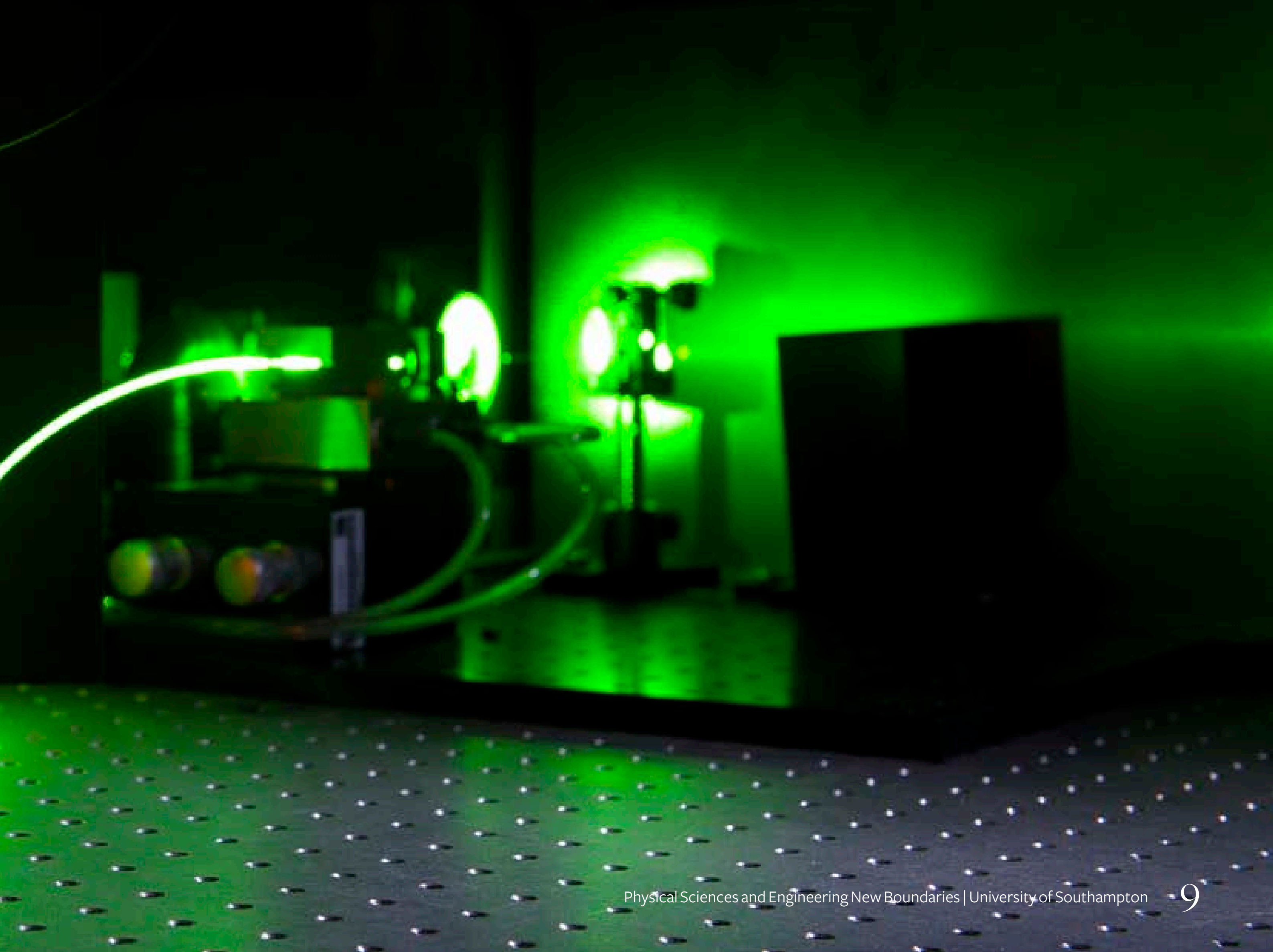
In 1989, Professor Alec Gambling, Sir David and Professor of Physics David Hanna founded the Optoelectronics Research Centre (ORC) at the University. The ORC has revolutionised the telecommunications industry by developing optical fibres that have formed the basis of the global internet. The Centre continues to lead today's generation of optical and optoelectronic system development, with a long and well established track record in the fields of optical fibre, lasers, waveguides, devices and optoelectronic materials that has fostered innovation, enterprise, cross-boundary and multidisciplinary research.

The results of research at the ORC have touched everyone's lives one way or another, according to Sir David, current ORC Director.

"The whole global internet relies on our invention of erbium-doped fibre amplifiers that amplify optical signals, which allow fast telecommunications. Whenever you use a mobile phone you are probably using our amplifiers, because the phone signal goes to a mast that is then optically connected through fibres to other masts," he explains.

The ORC has a worldwide reputation using fibre optics to assist industry. Researchers recently developed sensitive optical fibres that help detect strain and temperature variations in buildings, oil pipelines, dams, bridges and aircraft. With the global energy company BP, the ORC has developed sensitive optical fibres and Fibre Bragg Grating (FBG) to monitor distributed, dynamic disturbances along oil pipelines that could result in a rupture.

Scientists from the ORC are also part of an international project that is investigating the use of fibre lasers in groundbreaking particle accelerator technologies, such as the Large Hadron Collider (LHC). Looking to the future, Sir David is now leading a £7.2m project to pioneer new technologies capable of creating a photonics hyper-highway that will make broadband internet 100 times faster than it is at present. ▸



The importance of the ORC work has led to a 'photonics valley' of manufacturing companies in the Southampton area that export across the world, creating jobs and wealth in the local community.

Creating the World Wide Web

The World Wide Web provides a perfect platform with which to support a host of applications that enable global communication. It is now the world's document management system; a global interlinked information system with the capacity to store all of our knowledge and, potentially, answer all of our questions. It is changing the shape of nations and giving a voice to the silent majority.

The origins of the World Wide Web lead back to its inventor, Professor Sir Tim Berners-Lee, who is Chair of Computer Science at Southampton. Sir Tim first proposed the Web as an information management system in March 1989, implementing the first successful communication between a Hypertext Transfer Protocol (HTTP) client and a server via the internet in November, the following year.

Professor Dame Wendy Hall, Dean of Physical Sciences and Engineering at the University, is another of the University's Web trailblazers. Dame Wendy, whose own career has paralleled the history of the Web, is focused on understanding what the Web is and how we might engineer its future to ensure maximum social benefit. Dame Wendy is working with social scientists and others to study how the Web evolves while considering issues of Web security, privacy, policy and regulation. Her work with Sir Tim, and Professor Nigel Shadbolt, who heads the University's Web and Internet Science Group, led to the recent creation of Web Science as an academic discipline at Southampton.

Dame Wendy predicts the rise of what Sir Tim calls the Semantic Web, a more intelligent way of linking us to the data we seek via the internet.

"We've evolved to a society where everyone looks for information first on the World Wide Web following links to a number of documents that match your search terms. You then do the intelligent bit by working out which documents provide you with the information you need," says Dame Wendy.

"That system works, but a machine can't read a document. What we're looking to do in the future is to help machines understand what's there on the Web then have processes to answer questions for you," she adds.

"The development of the Semantic Web technology began with research into the exchange of knowledge and logic. Later, the data layer (Linked Data), which forms the backbone of a global interconnection bus for open and industry data, blossomed across the Web. More recently, data orientation is becoming widespread, with search companies that traditionally used only links and human language words now building huge assets of semantic information which computers understand," says Sir Tim.

Using open data for the public good

In today's Web-connected world, data drives transactions and decisions of every kind, from planning a journey and anticipating the weather to choosing a house or university. Thanks to the pioneering work of Nigel and Sir Tim, an unprecedented amount of UK government data is now freely available to the public. They have worked with the previous and current government to establish a single point of access for this data, **www.data.gov.uk**

A range of open government data is creating new and innovative services from applications that avoid accident black spots to ones that find the nearest empty car parking space. Releasing this data has created new opportunities and made the UK a world leader in this area. In October 2012, Southampton helped establish the world's first Open Data Institute (ODI), marking the latest chapter in the University's continuing Web success story.

Co-founded by Nigel and Sir Tim, the ODI's mission is to incubate new companies and support entrepreneurial developers that seek to exploit open data.

Sir Tim, President of the ODI says: "One of the reasons the Web worked was because people reused each other's content in ways never imagined by those who created it. The same will be true of Open Data. The Institute will allow us to provide the tools, skills and methods to support the creation of new value using Open Government Data." Working with Southampton the ODI will also offer a range of open data training.

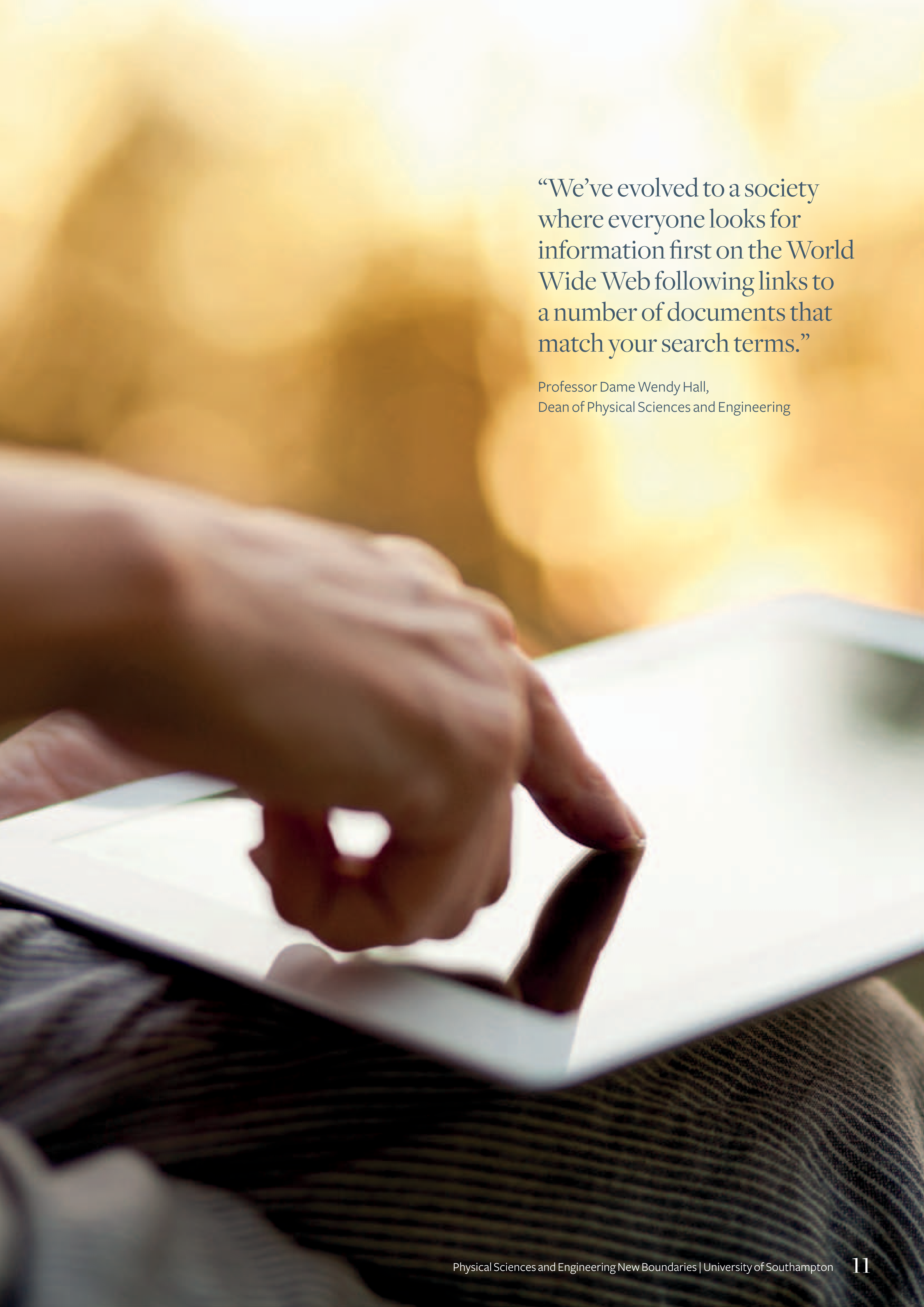
Nigel, who is also the ODI's Chairman, explains: "At the ODI we are committed to training the next generation of open data technologists and policy makers. We will work with the public sector to make the data it publishes as good as possible. We will train data entrepreneurs who want to build new companies and new services using this data. We will work with existing corporates to realise the value in open data. We want to ensure our work has the widest national and international impact."

Around the world, governments and citizens are already seeing the benefits of open data. In the UK, analysis of government data by the ODI start-up, Mastodon C and its partners, suggests that the National Health Service (NHS) could reduce its spending on drugs.

In 2011-12 the NHS in England spent more than £400m on statins –cholesterol-lowering drugs prescribed to help reduce the risk of heart attacks – out of a total drug budget of £12.7bn. Mastodon C researchers examined a huge amount of medical data on regional prescription patterns and determined that – despite guidelines advising prudence in the prescription of more costly, branded statins – there was a great deal of inconsistency. They estimate that, had every doctor prescribed more affordable generic statins, the NHS would have saved £200m.

At Southampton we are proud of the pioneering work our academics have been involved in creating the Internet, the World Wide Web, and Open Data. We look forward to addressing the many global challenges that will arise from the development of these technologies to ensure they are robust enough to meet future use.

For more information, visit:
www.orc.soton.ac.uk/
http://webscience.ecs.soton.ac.uk/
www.theodi.org/



"We've evolved to a society where everyone looks for information first on the World Wide Web following links to a number of documents that match your search terms."

Professor Dame Wendy Hall,
Dean of Physical Sciences and Engineering

Developing the strongest, lightest material

Southampton researchers are on a global quest to find light, ultrahigh strength composites that are not compromised by defects.

"Our discovery could change the future of composites and high strength materials and have a huge impact on the marine, aviation and security industries worldwide."

Gilberto Brambilla,
ORC Principal Research Fellow

Scientists at the University of Southampton's Optoelectronics Research Centre (ORC) are pioneering research into developing the strongest silica nanofibres in the world.

Historically, carbon nanotubes were the strongest material available, but high strengths could only be measured in very short samples, just a few microns long, providing little practical value.

Now research by ORC Principal Research Fellow Gilberto Brambilla and ORC Director Professor Sir David Payne has resulted in the creation of the strongest, lightest weight silica nanowires that are 15 times stronger than steel and can be manufactured in lengths potentially of thousands of kilometres.

Industry interest

Their findings are already generating extensive interest from many companies around the world and could transform the aviation, marine and safety industries. Tests are currently being carried out globally into possible, future applications for the nanowires.

"With synthetic fibres it is important to have high strength, achieved by production of fibre with extremely low defect rates, and low weight," says Gilberto.

"Usually, if you increase the force that a fibre can withstand, you have to increase its diameter and, thus, its weight, but our research has shown that as you decrease the size of silica nanofibres their strength increases, yet they still remain very lightweight. At lighter weights, they can withstand stronger forces than other, comparable materials. To date, we are the only researchers who have optimised the strength of these fibres.

"Our discovery could change the future of composites and high strength materials and have a huge impact on the marine, aviation and security industries worldwide. We want to investigate their potential use in composites and we envisage that this material could be used extensively in the manufacture of products such as aircraft, speedboats and helicopters."

Environmental and economic impact

Future use of silica nanowires may have huge economic and environmental benefits.

David explains: "Silica and oxygen, required to produce nanowires, are the two most common elements in the earth's crust, making their production sustainable and affordable. Furthermore, we can produce silica nanofibres by the tonne, just as we currently do for the optical fibres that power the internet.

"Weight for weight, silica nanowires are 15 times stronger than high strength steel and 10 times stronger than conventional Glass Reinforced Plastic (GRP). We can decrease the amount of material used thereby reducing the weight of the object."

Gilberto adds: "In a few years the amount of composite materials used in machines such as aeroplanes, boats and high specification cars is likely to increase. Using silica nanowires as the composite material reinforcement means

ORC Principal Research Fellow Gilberto Brambilla mounting a fibre on the nanowire fabrication rig

the vehicles will be lighter, thereby reducing their energy consumption and fuel costs.

"If silica nanowires are used for windmill blades, the blades will be stronger and lighter, thereby increasing the amount of energy that the windmills can produce.

"Overall, the development of silica nanowires could have a very positive impact on the future of our environment as well as on our economy," adds Gilberto.

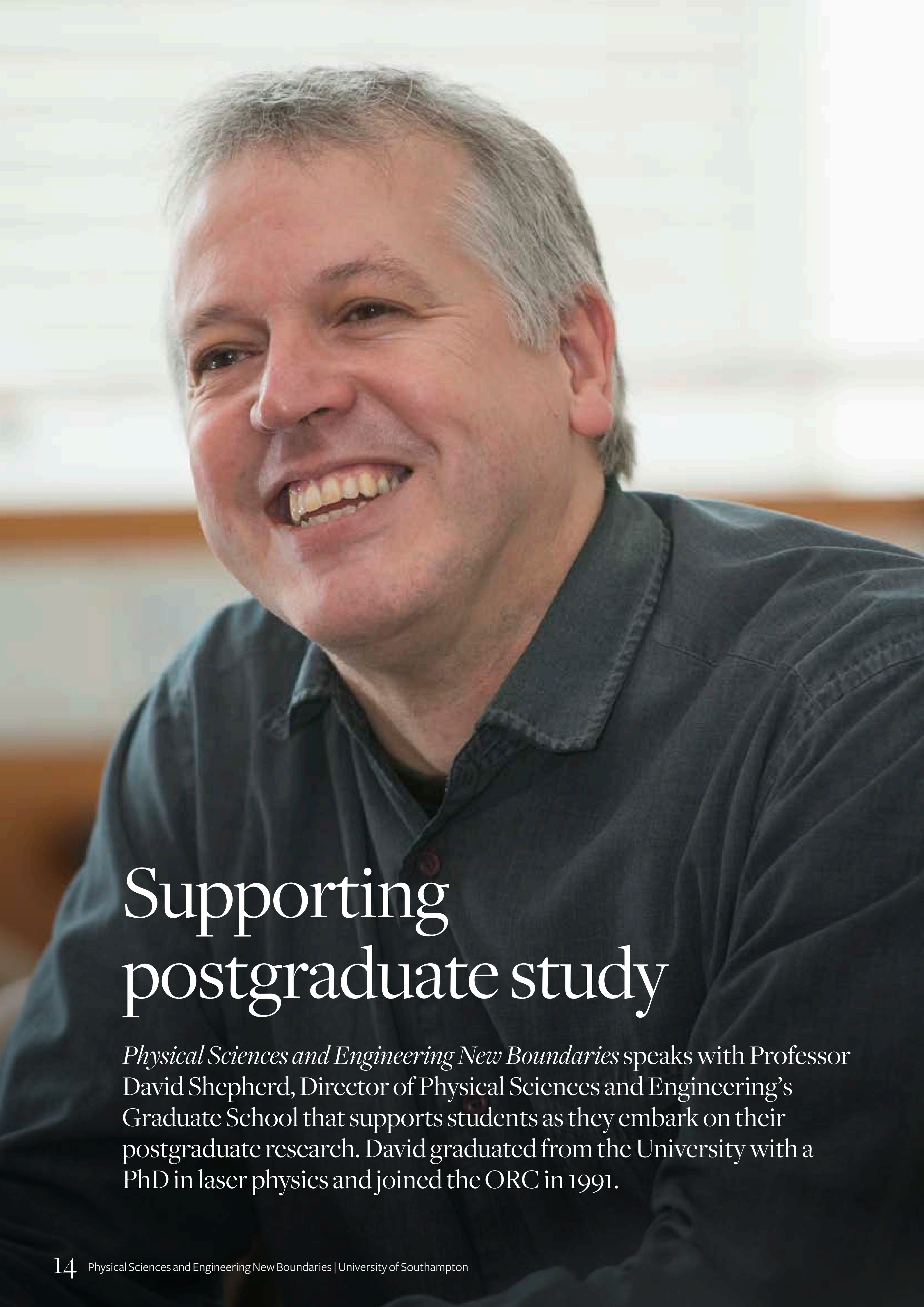
Hands-on research

In five years of research by Gilberto and David, funded by the Royal Society, the pair encountered challenges working with the materials. "It was particularly challenging dealing with fibres that were so small. They are nearly 1,000 times smaller than a human hair and I was handling them with my bare hands," explains Gilberto.

"It took me some time to get used to it, but using the state-of-the-art facilities at the ORC I was able to discover that silica nanowires become stronger the smaller they get. In fact, recent research shows that when they become very, very small they behave in a completely different way. They stop being fragile and do not break like glass but instead become ductile and break like plastic. This means they can be strained a lot.

"Up until now most of our research has been into the science of nanowires but in the future we are particularly interested in investigating the technology and applications of these fibres."

To learn more about nanofibre and metamaterials research visit:
www.orc.soton.ac.uk/omfds.html



Supporting postgraduate study

Physical Sciences and Engineering New Boundaries speaks with Professor David Shepherd, Director of Physical Sciences and Engineering's Graduate School that supports students as they embark on their postgraduate research. David graduated from the University with a PhD in laser physics and joined the ORC in 1991.

Q What is the role of the Physical Sciences and Engineering Graduate School?

Our Graduate School helps postgraduate research students from the day they arrive until the day they graduate. We support them through their initial induction, make sure that a suitable supervision team is in place, monitor their progress throughout their studies and ensure that they receive training in essential transferable skills as well as in their own particular area of study. We also make sure that the quality of our PhD awards remains high by monitoring the appointment and reports of our external examiners.

Q What support do you provide to students to ensure they gain the most from their studies?

In Physical Sciences and Engineering we are proud of our outstanding facilities and our academics, who are world-leading experts in their fields of research and provide first-class supervision of students and their projects. These academics are very successful at obtaining research funding from many sources, giving our students the opportunity to take part in world-class research, travel to conferences and summer schools, and present their work to international audiences.

Q How do you help researchers in their career development?

Encouraging employment is vitally important to us in Physical Sciences and Engineering and we work in many ways to help our students be ahead of the game in today's global competitive jobs market.

Many of our students are working on topics that are very relevant to industry and often collaborate with partners in industry. They attend conferences that are usually attached to large industrial shows and industry-based researchers are regularly invited to give seminars to postgraduate students. This helps our students become aware of possible career development paths into industry. We also encourage our students to take part in education activities such as laboratory demonstrations to undergraduates and we offer a limited number of Mayflower PhD Scholarships where students can spend 25 per cent of their time on education activities.

Students looking for an academic career often move into post-doctoral research positions within Physical Sciences and Engineering and we ensure any students interested in applying for prestigious academic fellowships are well prepared for their interviews.

We are also part of the University's Researcher Development and Graduate Centre which provides students with a broad range of transferable skills training mapped to the national Researcher Development Framework. Through this partnership we aim to enhance our capacity to build the UK workforce, develop world-class researchers and build the UK higher education research base.

Our students can also access the University's Career Destination service that gives careers advice, holds careers fairs and events, and provides training on curriculum vitaes, applications and interviews. It can also help with work placements and bringing in advice from relevant alumni.

Q What training and supervision can postgraduate research students expect from the Graduate School?

At the start of their studies all students have a training needs analysis with their supervisory team, when they discuss their project, their existing skills, as well as those they need to develop. This leads to training recommendations including directed reading, taking high-level undergraduate or masters courses, training on specific pieces of equipment or techniques, attending subject-specific training run by research groups, attending transferable skills courses and further English language support.

Experts in Physical Sciences and Engineering can provide first-class supervision of the students and their projects. We ensure that a supervisory team is in place so that all aspects of their research are covered and that there is always a second opinion on hand. Supervisory teams are increasingly valuable as many of our research projects are becoming interdisciplinary.

At the Graduate School we also provide mentoring and pastoral support for our students that can be very useful in times of stress.

Q How do you collaborate with the University's Doctoral Training Centres?

We play a key role in two of the University's current Doctoral Training Centres (DTCs), Complex Systems Simulation and Web Science. These centres are multidisciplinary and provide their own strong training programmes. Students spend their first year mainly devoted to training within the DTCs; after this they carry out research projects within the faculties but maintain a strong connection to their DTC for further training and cohort building activities. At the Graduate School we work with the DTCs to ensure that supervision, training, and progression monitoring for these students are of the highest standards.

Q What is special about the research environment and facilities you offer?

We have some truly unique research facilities including the £110m Mountbatten Building's clean-room facilities for photonics and nanofabrication – one of Europe's leading multidisciplinary and state-of-the-art clean room complexes. It provides our students with the opportunity to work hands-on with equipment at the cutting edge of modern technology.

In Physical Sciences and Engineering we cover a broad spectrum of science and engineering topics including astronomy, computer science, electrical power engineering, electronics, nanotechnology, optoelectronics and physics. In the last Research Assessment Exercise (2008), 95 per cent of our research was ranked at world-class or international standard.

Encouraging the next generation of scientists

Inspiring local schoolchildren and encouraging the next generation of scientists is at the heart of extensive work by the University's Physics and Astronomy Outreach and Public Engagement Team.

Every year, this enthusiastic team of researchers organises and participates in hundreds of activities, such as BBC 2 programme *Stargazing LIVE* and the Solent Big Bang fair, to try and break down the barriers to higher education and inspire children to get interested in physics and astronomy. The team actively promote their leading-edge research to schoolchildren and the local community, encouraging them to become researchers and to take an interest in science.

The Outreach team translate their research into activities and demonstrations, including the Soton Astrodome mobile planetarium and the Light Express Roadshow, that excite and engage people of all ages. The activities instil in the audience a fascination with the wonders of the Universe or a desire to untangle the theories of particle physics.

Professor Malcolm Coe, Outreach and Public Engagement Team Leader explains: "In Physics and Astronomy we are continually pushing the boundaries of our knowledge and research, so we want to ensure that there is a new generation of scientists ready and willing to further this research and make new discoveries in future years.

"Research scientists have an obligation to explain to the public what they are doing and why it is so exciting, and to do this in a language everyone can comprehend. By running our programme of public engagement and outreach activities we hope to make what we do understandable and accessible to people of all ages and explain to everyone what goes on at their local university."

The team takes part in local and national events, visits local schools and opens the doors of the University to the public to demonstrate some of the pioneering research that it undertakes.

Outreach Leader in Astronomy Dr Sadie Jones and Public Engagement Leader Pearl John organise numerous activities.

Taking science to schools

Working with young people, from four to 18-years-old, plays a major part in the programme of events run by the team. Many of the researchers go out into schools and colleges to talk about subjects such as astronomy, particle physics, nanotechnology and photonics.

As well as these external visits, the team runs workshops and summer schools at the University for local students. These include holography demonstrations and a talk about Aliens in the Universe that challenges students to decide where life is most likely to exist in our solar system. University students are encouraged to help in the workshops and school visits. A dedicated team of physics undergraduate students goes into schools to provide physics workshops for Year 10 pupils in order to support teachers with curriculum relevant activities. These workshops are designed by the South East Physics Network, which helps to fund the Public Engagement and Outreach Programme.

An interactive display

The University's Soton Astrodome and Laser Light Express Roadshow maintain a busy schedule visiting local primary and secondary schools.

The Astrodome is a state of the art mobile planetarium, supported by SEPnet and the Ogden Trust, which provides interactive shows that let visitors marvel at the starry skies, planets and galaxies. The dome also goes out into community arenas such as the City Art Gallery, the Racecourse Newbury and local scout venues.

The Laser Light Express Roadshow dazzles scores of schoolchildren with its visual and interactive performances. Aimed at four to 18-year-olds, it contains demonstrations featuring the physics of light and the science behind the internet. Students also get the unique opportunity to see powerful lasers in action that are not generally seen outside research laboratories.

A national arena

It is not just local events that are on the agenda; the outreach team is also heavily involved in work to coincide with national events, including *Stargazing LIVE*, National Science and Engineering Week and the Solent Big Bang fairs.

Earlier this year more than 150 people took part in a special event at the University organised by Physics and Astronomy to celebrate BBC programme *Stargazing LIVE*. Visitors were able to explore the mobile planetarium, listen to lectures on black holes and the extinction of the dinosaurs, investigate spacecraft test models and witness the extent of damage that space debris can do to household objects.

In March the University hosted the Solent Big Bang fair. 500 local secondary school students and teachers took part in hands-on science and engineering activities run by local industries and University departments. The students also took part in *Accelerate* an exciting, interactive lecture about particle physics.

Partnership working

A new partnership between the University, the INTECH Science Centre and Planetarium and Southampton City Council is funding admission charges to give children and teachers from Southampton primary and secondary schools unlimited free entry to INTECH for organised school trips over the next five years. INTECH, which is near Winchester, has more than 100 hands-on, interactive exhibits and has worked with the University on an ad hoc basis since it opened in 1985.

To learn more about the many activities organised by the Physics and Astronomy Outreach and Public Engagement Team visit: **www.phys.soton.ac.uk/outreach**

Spin-out success

Professor Peter Smith, Associate Dean for Enterprise in Physical Sciences and Engineering, is the founder of two University spin-out companies, Covesion and Stratophase. He tells *Physical Sciences and Engineering New Boundaries* how he has helped translate research into industry and the economic success both companies are having.

Q *What work was your research group doing that led you to create the spin-out companies Stratophase and Covesion?*

I lead the Planar Optical Materials research group which had been developing optical devices from industrially accepted optical materials, such as lithium niobate or glass, and processing them to give them new properties and functions. We discovered ways of modifying the properties of these materials, by developing new ways of creating optical waveguides and Bragg gratings, or by creating nonlinear grating structure.

This technology allowed us to make robust optical fibre accessed sensors that are ideal for in-situ applications and hostile environments. We soon realised there was a market demand and commercial potential, so we formed the spin-out company Stratophase in 2003. We created the spin-out company Covesion out of Stratophase in 2009 to produce wavelength conversion crystals that can transform the colour of laser light. These crystals are playing a vital role in the rapid growth of energy-efficient laser projectors.

Q *What has been the economic impact of creating the two spin-out companies?*

Both companies are having a major impact not just in the UK but globally. Together they have generated sales of several million pounds and have created more than 20 jobs. Millions of pounds of investment have been generated from external companies in the UK and overseas. Covesion is also enabling a substantial, multi-million pound market as a result of sales of its crystals – a market that would not be possible without their product.

Q *How are the companies gaining commercial success? What commercial success have the companies had?*

Stratophase is providing off-the-shelf solutions for batch monitoring and process control in the pharmaceutical and chemical manufacturing industries. These products allow companies to monitor their processes in-situ and in real-time, reducing their costs and improving their yield and product consistency. The technology is already being deployed in bio-reactor monitoring trials for major companies including GlaxoSmithKline, Greenbiologics and CPI. With the Defence Science and Technology Laboratory (DSTL) they have also successfully implemented a portable bio-detection platform that can identify biological hazards such as ricin and anthrax in air.

Covesion is one of three leading companies in the world having an impact in the use of nonlinear crystals for energy-efficient laser projectors. More than 90 per cent of their sales are exported overseas and they have recently agreed to a major license deal with a company producing wavelength conversion materials for pico-projectors, handheld projectors with miniaturised hardware and software that can project digital images onto any nearby viewing surface. As well as communication technologies, the crystals are also being used in missile countermeasures for aero defence.

Q *Why is it important to translate research into industry applications?*

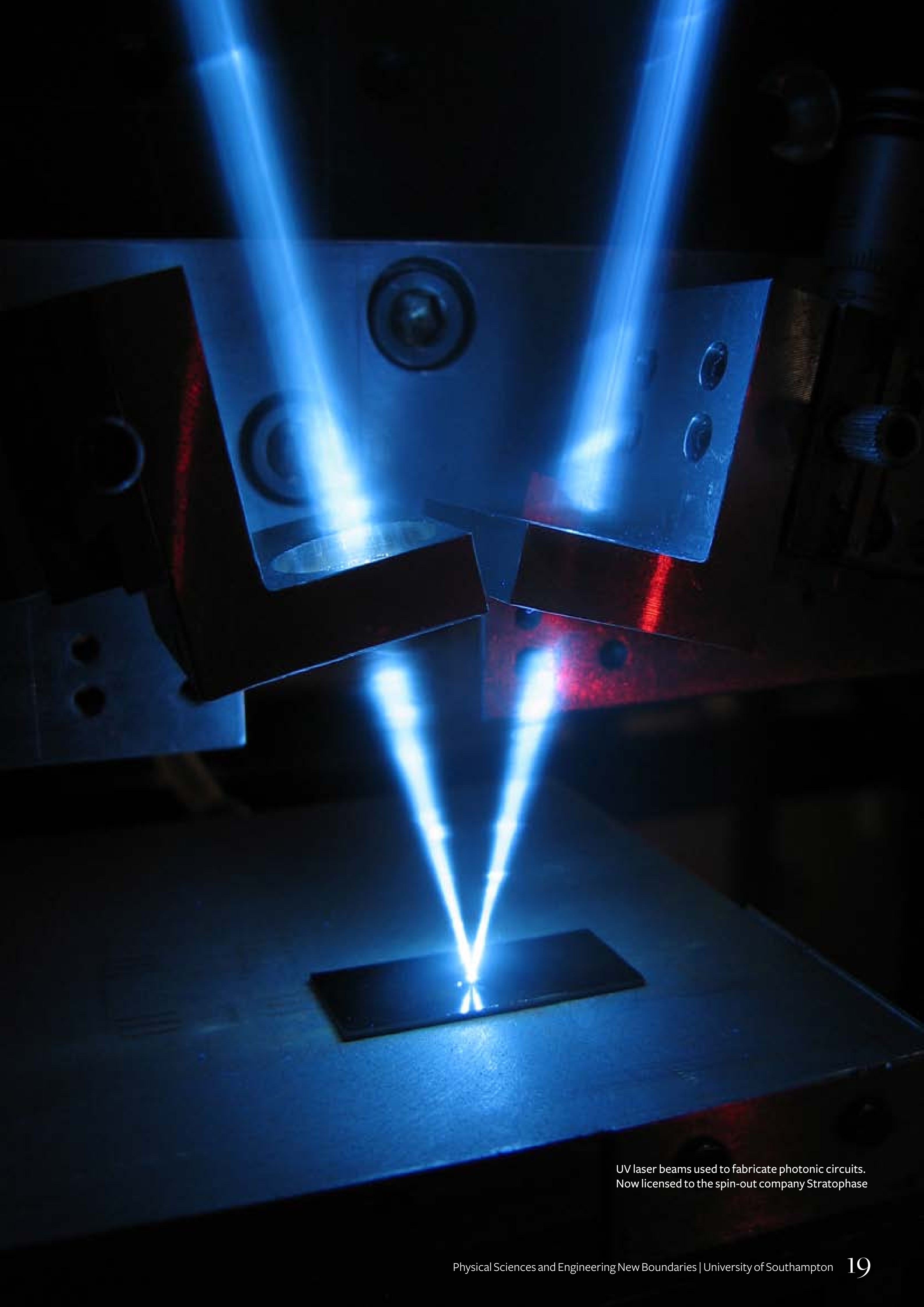
It is very important that universities bridge the gap between research and industry. At the University of Southampton we are successful at translating research so that it can have a significant impact on industry. The research doesn't stop when we publish a paper; we strive to look at where we can take that research and whether we can move science forward or create a working product.

Q *What does the future hold for the companies?*

The future for both companies is very bright. Stratophase is at the forefront of technology to monitor and control processes in-situ and in real time. This technology is set to have huge benefits to the pharmaceutical and chemical industries and Stratophase is ready to be at the centre of this drive.

Consumer demand for laser projection technology is growing rapidly and Covesion is well-placed to maximise on this. Eventually, more and more products, from desktop projectors to mobile phones, will have laser-based displays inside and Covesion's crystal technology is set to be at the heart of this expansion.

To learn more about enterprise in Physical Sciences and Engineering, visit **www.fpse.soton.ac.uk/enterprise**



UV laser beams used to fabricate photonic circuits.
Now licensed to the spin-out company Stratophase

Putting research into practice

At Southampton we place strong emphasis on translating our research into innovative scientific and engineering applications. *Physical Sciences and Engineering New Boundaries* speaks with Jatin Mistry about his experiences of an internship and how it helped him put his research into practice and get the job of his dreams.

Q *How did you become interested in a career as an electronic engineer?*

When I was studying for my A Level exams, I wasn't entirely certain about my career. I knew it would be something involving both physics and maths and I also really enjoyed technology and gadgets. After further research I decided that electronics was the area I wished to pursue.

Q *What made you decide to study at Southampton?*

When I looked at the universities offering electronic engineering, Southampton came out on top. I am not someone to shy away from striving for the best, so I decided to apply. I also liked the fact that Southampton had less of the hustle and bustle feel of London universities and more of a campus feel, but it still had the city of Southampton close by.

I started at the University of Southampton as an undergraduate on the MEng Electronic Engineering degree. After obtaining a BEng Electronic Engineering after three years, I decided to pursue a PhD immediately after, instead of doing a fourth year master.

Q *What did you enjoy the most about your studies in electronic engineering at Southampton?*

My time at the University of Southampton was fantastic. The facilities are second to none. The lecturers are brilliant. They are working on leading-edge research and have got good links with industry which means their teaching is influenced by the latest developments in the field.

Electronics is moving ahead at such a pace that you need to be able to keep up with it and I think Southampton achieves that very well. In addition they are always updating their electronics labs and providing the latest machines in the computer labs. They are always providing the best of the best.

Q *What was the basis for your doctoral research?*

For my PhD, I researched leakage power minimisation techniques for embedded microprocessors and how they could be used in smaller low performance devices such as wireless sensor networks, biomedical sensing applications and even in emerging 'Internet of Things' applications

All of these applications rely on minimal processing performance as they are not doing a lot but all rely on very high energy efficiency to ensure a long device lifetime. For example, wireless sensor networks are deployed out in the field for years to monitor things like the environment. Biomedical sensing on the other hand enables wearable real-time processing of signals such as the heart or brain. The problem is, as they are portable devices, their lifetime is governed by how efficiently you can use the energy provided by a battery.

I considered how we could reduce the power needed to run the micro-processor on these sensors and how you could improve the existing design to make it a low-power device. With the research I have done, you can take any low performance embedded micro-processor and apply my work to it, to improve its energy efficiency.

As part of my PhD I fabricated a silicon chip by taking a standard ARM Cortex-M0™ design and improving the energy efficiency by applying my design techniques to it. This was one of the most rewarding and key moments of my PhD: creating a practical device and testing it for real. Exploring the theory is great, but it is important to prove that it can work in everyday use.

Q *What did you do during your internship with ARM?*

I have benefited greatly from my collaboration with ARM. The main focus of my internship was to test my silicon chip and my PhD advisors at ARM were very helpful in assisting me while I tested it, from September to December 2011. I was able to make use of their equipment and draw on their expertise. I appreciate working with people who have knowledge of best practice when testing things. That was my third internship with them – I did two summer placements as an undergraduate – and I have now ended up working for them full-time.

Q *How have you applied what you have learned at Southampton towards your career?*

One of the biggest benefits of my PhD was that it was a combination of research theory and practical work. In my job at ARM I will be doing just that: putting research and development into practice. The practical side of my research was a whole new learning curve for me. I needed to learn all the necessary skills, such as software tools, that come with actually implementing the research. I am looking forward to building on this knowledge from my PhD and facing new challenges and problems.

Ever since I started as an undergraduate, working at ARM has been my idea of a dream job. I have just started working with them as a Graduate Engineer in their Cores Implementation Team focusing on implementing processors. The team investigates tradeoffs involved in processor implementation but also makes test chips and liaises with partners to cost, design and provide the methodology to make silicon chips.

I feel that internships and experience with industry are very important for a more holistic education. You can learn from lectures but until you actually try it you don't understand it fully. My internship experience at ARM certainly helped me in this way.

For more information about the University's industrial partnership with ARM, visit **http://arm.ecs.soton.ac.uk**

Micro-technologies for medical diagnostics

Electronics and Computer Science (ECS) researchers at Southampton are collaborating with colleagues in Medicine to take advantage of the latest advances in nanotechnology and micro-devices to deliver new therapies to patients.

This new generation of portable electronic monitors offers patients and healthcare providers greater flexibility and accuracy in diagnosing and treating chronic conditions such as diabetes, predicting and preventing heart attacks, and helping children with autism.

More efficient blood testing

Professor Hywel Morgan, ECS, has been working with Professor Donna Davies and Dr Judith Holloway (both in Medicine) and global electronics giant Philips, to develop a point of care micro-cytometer capable of measuring blood cells from a finger prick of blood and automatically relaying that information to clinicians. Such a device would improve the rate of diagnosis of new illness and the monitoring of on-going illness. The device would also make doctor-patient interactions more efficient. It could reduce or even eliminate the number of visits a patient must make to their doctor and to the hospital for diagnosis, to receive a blood test and then discuss its results.

The cytometer relies upon recent advances in the fields of microfluidics (the manipulation of fluids at the micron level) and electrokinetics (the motion of electric currents or charged particles) that Hywel and his colleagues have realised since 2004 with funding from the Engineering and Physical Sciences Research Council (EPSRC). More recently, they have received funding from the Technology Strategy Board (TSB). Translated into technologies for miniaturised diagnostic systems, these advances allow the cytometer to integrate multiple analytical methods onto a single platform, termed Lab-on-a-Chip.

Using the cytometer, a patient on chemotherapy treatment with drug cycles every three weeks could do a home blood test, with the results being uploaded to a 24-hour manned ward. The patient could then be advised appropriately to stay at home, come in to hospital tomorrow or call an ambulance immediately.

"As treatment costs rise, there is a growing need for home monitoring of patients," says Hywel. "The cytometer will help identify medical risks before they arise with patients, thus saving money otherwise spent in hospitals on emergency care."

With Sharp Labs Europe, Hywel is also developing novel fluid-handling technology based on digital microfluidics. This involves manipulation of water-in-oil droplets by application of appropriate voltage on a large array of programmable electrodes. The electrode array technology is the same as the one used for smart phones. Proof-of-concept has been shown for a blood glucose assay, for use in home tests by diabetics.

Mobile heart monitoring

Dr Koushik Maharatna, ECS, also specialises in creating home monitoring medical devices. With Professor John Morgan and Professor Nick Curzen, both in Medicine, he has developed software compatible with a patient's Samsung Galaxy mobile phone or laptop (or any other Android-based platform like Motorola Defy+), that allows their doctor to monitor their heart condition via body-worn sensors, in order to better predict and prevent heart attacks. The software, Fully Automated Low-Complexity tool for ECG characterisation (FALCON), provides real-time analysis and clinical features extraction from an electrocardiogram (ECG) – a test that measures the electrical activity of the heart – and then plots this data in a trend analysis facilitating prediction of future cardiac incidents that may prompt clinical interventions. Previously, a doctor could only take a snapshot of the patient's heart condition each time the patient visited a hospital for an ECG.

Koushik says: "FALCON is the perfect tool for real-time monitoring and diagnosis of patients, where the physician may ask the patient at a remote location to do certain physical activities in order to ascertain their heart condition. The physician can observe changes in the patient's ECG characteristics on their mobile device in real-time while the patient executes the physician's instructions."

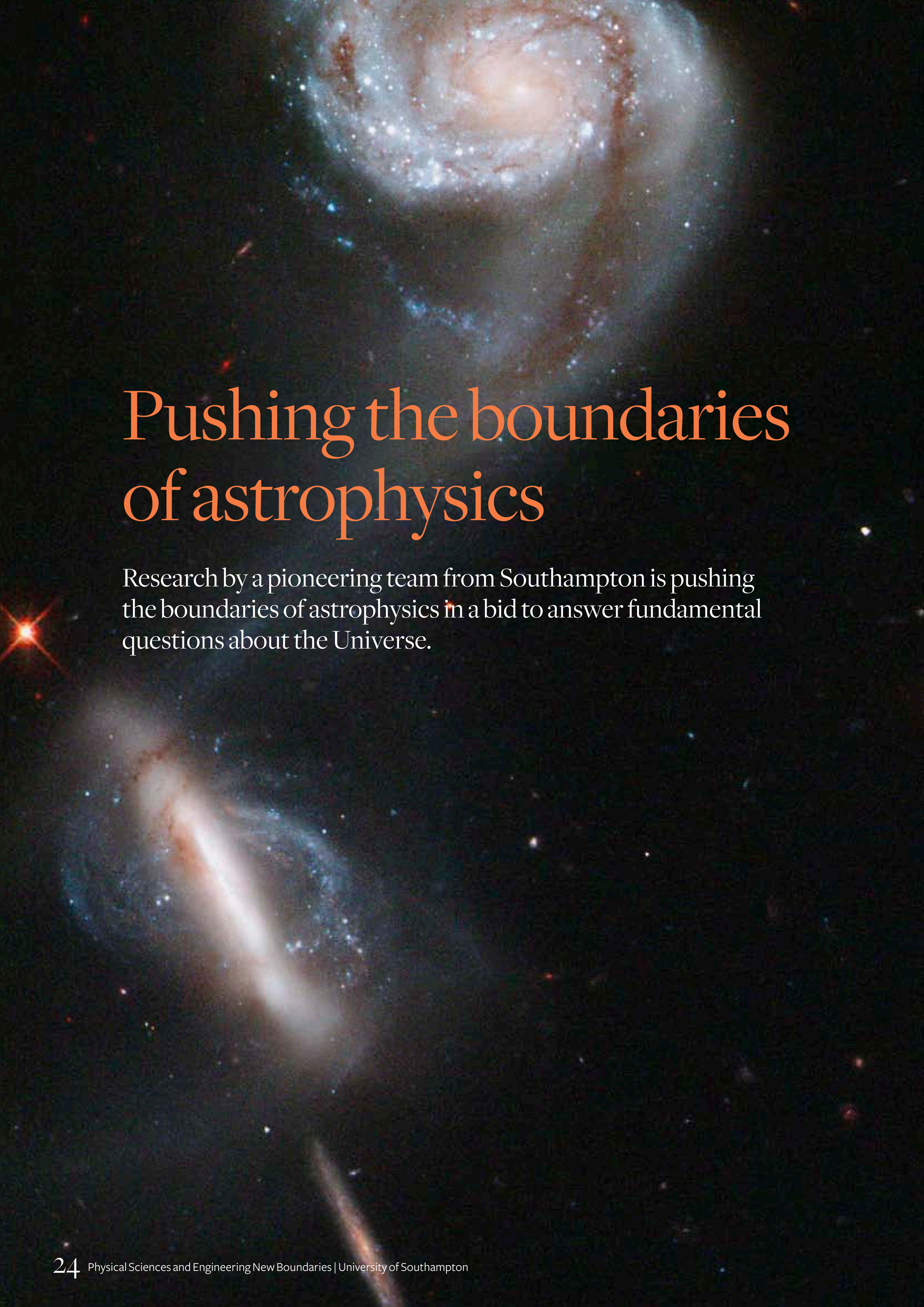
FALCON was funded and developed as part of a larger undertaking, the pan-European CHIRON project (Cyclic and Person-Centric Health Management: Integrated Approach for Home Mobile and Clinical Environment), which aims to combine state-of-the-art technologies and innovative solutions into an integrated framework, designed to enable more effective health management. Clinical trials of the CHIRON platform, with FALCON as the key analysis tool, are taking place at University Hospital Southampton NHS Foundation Trust and Policlinico Umberto 1, in Rome.

Tackling autism

Koushik has also been developing a tool to treat children with autism in their homes. With €3.5m of European Union funding, he and a consortium of researchers in the FP7 MICHELANGELO project, have created an advanced method for deriving connectivity between different regions of the brain using a pervasive Electroencephalography (EEG) device and functional Magnetic Resonance Imaging (fMRI) technique. StarLab, Barcelona has built a pervasive EEG machine which will allow children with autism to be monitored and treated in their natural environment.

Koushik explains: "The traditional approach of using EEG technology requires the patient to sit with an apparatus on his/her head in a constrained position. The patient's awareness of its presence affects their cognitive ability and influences the outcome of the brain connectivity mapping. We plan to use a pervasive EEG machine just like a cap, which can be worn by the child, capable of transmitting EEG data wirelessly to a nearby computer for analysis. This allows us to measure more realistically the connectivity between different regions."

For more information, visit
www.ecs.soton.ac.uk/people/hm
www.ecs.soton.ac.uk/people/km3



Pushing the boundaries of astrophysics

Research by a pioneering team from Southampton is pushing the boundaries of astrophysics in a bid to answer fundamental questions about the Universe.

> "Very little is known about dark energy except that it comprises about 70 per cent of the Universe and it acts in an anti-gravitational way, forcing the Universe to expand at an ever-increasing rate,"

Dr Mark Sullivan,
Royal Society Research Fellow

The Astronomy Research Group is at the forefront of work to open up our understanding and knowledge of the Universe and how it evolved. In recent years it has been involved in a number of high-profile projects and made some significant discoveries.

Astronomers at Southampton recently observed that the temperature of bright X-ray flares in one of the nearest galaxies was so low that it was likely to be produced by a white dwarf – a stellar remnant composed of mostly degenerate electron matter – rather than a black hole. In the past year, researchers in the group were involved in discovering a black hole that is binge-eating – rapidly consuming gas from its stellar companion at a rate very near a theoretical maximum – in neighbouring galaxy Andromeda (also known as M31).

The group is also playing a key role in a number of international collaborations, such as the Low Frequency Array (LOFAR) project that is creating a wave of new technology telescopes across Europe and enabling astronomers to view the Universe in unprecedented detail. Head of the Astronomy Research Group Professor Rob Fender recently led a consortium of more than 20 partner universities that coordinated the UK's station based at Chilbolton, near Winchester. Rob is also leading a prestigious €3m global project called 4 PI SKY that combines the power of three state-of-the-art radio telescopes to help identify sources of explosive and variable radio emission such as black holes and exploding stars.

Exploring the cosmic web

Dr Anna Scaife, Astronomy, is breaking new ground through her explorations of the foundations of the Universe and the formation of large-scale structures.

Anna is leading a team that will use a €2m European Research Council grant to investigate the origins of magnetic fields by examining the cosmic web, a spider web-like structure of hot gas that joins together large-scale objects in the Universe such as galaxies and clusters of galaxies.

Using new, large radio telescopes such as LOFAR and other pathfinder instruments from the Square Kilometre Array (SKA) projects, the team will investigate these vast filaments of hot gas, which are thought to contain two-thirds of the normal matter in the Universe. They will also map the magnetic fields within them, patching the gaps in our understanding of how the modern Universe evolved and formed.

"Magnetic fields are ubiquitous in astrophysics but we still don't know where they came from originally," said Anna. "Until now the possible answers to this question have remained largely untested as we simply haven't had the experimental resources to differentiate them. The new generation of radio telescopes coming online has changed this. They will allow us to make much more sensitive observations at low radio frequencies and, for the first time, measure the strength of the magnetic fields in the cosmic web with high precision.

"These measurements will help us confirm where the magnetic fields came from, how they trace the cosmic web and will fill a real gap in our knowledge," she added.

Branching out

The Astronomy Group has also branched out into a new area of research that is studying cosmology through supernovae and aims to determine the nature of dark energy, a hypothetical form of energy that permeates all of space and tends to accelerate the expansion of the Universe.

Dr Mark Sullivan, who was recently appointed Royal Society Research Fellow at the University, is leading the exploration into the fields of supernovae and dark energy research. Mark's further investigations into dark energy's role in the expansion of the Universe are expected to contribute to Nobel Prize-winning research by others in this area.

"Very little is known about dark energy except that it comprises about 70 per cent of the Universe and it acts in an anti-gravitational way, forcing the Universe to expand at an ever-increasing rate," said Mark.

"By studying supernovae and their luminosity, which are about ten billion times brighter than the Sun and can be seen halfway across the Universe, we can determine how far away they are. By comparing these distances with the parameters set out by general relativity, we can constrain the amount and nature of the dark energy that is pulling the Universe apart," he added.

To learn more about research by the Astronomy Group, visit **www.astro.soton.ac.uk**

Professor Dame Wendy Hall

Helping shape public policy around the globe

Universities have a key role to play in providing a strong evidence base to inform decision-making by governments. Here at Southampton, many of our academics are helping to ensure that policy-makers have access to relevant information and research-based evidence across a wide range of disciplines

"It is crucial that governments and other influential organisations are fully informed about the facts of an issue before they make decisions. Academics at Southampton are at the forefront of research in their fields and many play key roles in policy groups both nationally and internationally. Their research, analysis and expertise are vital in ensuring that policy-makers have access to the facts and can make evidence-based decisions."

Professor Don Nutbeam,
Vice-Chancellor, University of Southampton

Physical Sciences and Engineering New Boundaries talks to three Southampton academics helping to shape future policy around the globe.

1. What is currently the main global challenge in your research area?

2. Can you explain the role you play in advising on public policy?

3. What benefit has your research had on big, global issues and social problems?

***Professor* Dame Wendy Hall,**
Dean of Physical Sciences and Engineering

1. I think one of the biggest challenges we face today is that people don't fully understand the impact that computers have had on the world and that this impact is on-going. We need to understand how people use the internet and what we need to do to develop effective tools, languages and standards to ensure its continuing, creative use. That is why, together with some of my colleagues, I have been involved in setting up the Web Science Trust, a charitable body that aims at supporting the global development of Web Science through its international network of research laboratories; and the Web and Internet Science Research Group led by Professor Nigel Shadbolt, that is carrying out research to better understand the origin, evolution and growth of the Web, how it is transforming society, and how we can make sure it is robust enough for the future.

2. Over the years I have had a number of different roles including being a member of the UK Prime Minister's Council for Science and Technology, President of the Association for Computing Machinery and Vice President of the Royal Academy of Engineering. These have involved me advising and helping governments and other organisations to shape public policy and education. I am also a very strong advocate of the role of women in science, engineering and technology and hope that my leadership roles on national and international bodies show that women can be influential and prominent figures in these fields.

3. I was one of the first people to undertake serious research into multimedia and hypermedia and have been at the forefront of this discipline ever since. I am proud to have played a major role in the creation of the Web and to see the impact it has had on linking the developed world. In the future, more and more people in rural areas of countries such as China, India and Africa will be able to access the internet through the mobile Web and it will be very exciting to see the effect this will have on changing the lives of these people.

Professor Nigel Shadbolt

Professor Nick Jennings

Professor Nigel Shadbolt,

Head of the Web and Internet Science Group

1. For the past three years, one of my main roles has been as an Information Advisor to help transform public access to UK government information. One of the key challenges facing the world today is the amount of information available on the Web and how to bring that together in an easily-useable format. In my role I have been involved in creating the **www.data.gov.uk** site that has collated raw public data from all central government departments, a number of other public sector bodies and local authorities into one searchable website that people can easily access.

2. At the moment the majority of my focus is on the implementation of open data. I am a founding member of the Open Data Institute. The Institute is a world-first that will support the publication and exploitation of high quality open data from across the public sector to help new and existing businesses that want to use this data to create economic growth. I am also a member of the steering group for the new global Web Index that measures the Web's growth, utility and impact on people and nations; and I have also been appointed by the government to the Public Sector Transparency Board that is responsible for setting open data standards across the public sector.

3. It is a huge challenge to create an infrastructure so that open data can be easily accessed and used as a powerful tool to inform decision making. My colleagues and I have already created effective resources that are being drawn on by governments, companies, organisations and individuals to help them shape policy.

Professor Nick Jennings,

Head of the Agents, Interaction and Complexity Group

1. The main research challenge that I'm currently involved with is cyber security. Cyberspace lies at the heart of modern society and impacts on our personal lives, our businesses and our essential services. Cyber security covers national security in the public and the private sectors, such as terrorism, crime or industrial espionage.

Cyber-crime relating to theft, hacking or denial of service to vital systems has become a fact of life and industrial cyber espionage where a company attacks another to acquire high value information through cyberspace, is also very real.

Cyber terrorism is also a challenge. We have to be prepared for terrorists to attack or disable key systems through the internet.

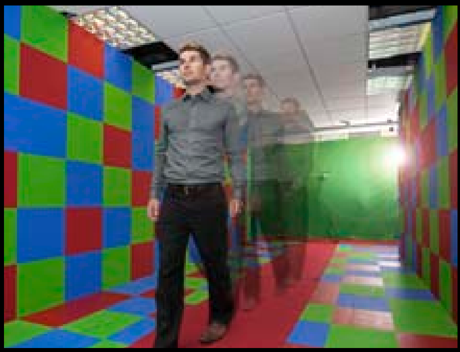
One of my roles is as a Chief Scientific Advisor (CSA) supporting the Centre for the Protection of Critical National Infrastructure (CPNI) that protects national security by providing advice on physical security, personnel security and cyber security/ information assurance. The CPNI works with the Cabinet Office and lead government departments and agencies to counter these threats.

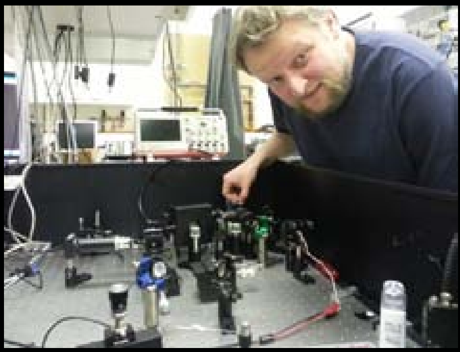
2. I ensure that CPNI makes the best use of science and engineering to pursue its national security imperatives. This involves looking at what we do now and also making sure we are prepared for the future. We commission research with companies and universities that is pulled through into the advice we provide and the tools we exploit.

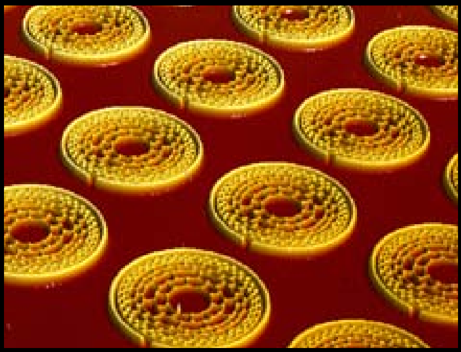
I work closely with Government Chief Scientific Advisor Professor Sir Mark Walport and other departmental CSAs. I also work with a group of CSAs assisting Mark Walport in providing advice and opinions to the government across a broad range of topics, from badgers to nuclear accidents.

3. The results of CPNI's research sees advice being given to the owners of the critical national infrastructure including communications, emergency services, energy, financial services, food, government, health, transport and water. This can change the physical, personnel and cyber security of key parts of the infrastructure that are central to our country's operation.

In brief







Identification using gait

Research at Southampton has led to biometrics such as gait being used as an identification technique.

The notion that people can be recognised by the way they walk has gained increasing popularity as a result of considerable scientific development since 1994, in Southampton. Professor of Computer Vision, Mark Nixon, and Dr John Carter, both from Electronics and Computer Science (ECS) at the University, have developed new techniques in computer vision, such as the world's first 3D biometric tunnel, to enable the automated understanding of walking motion in video sequences.

The biometric tunnel – a constrained environment designed with public places such as airports and shopping centres in mind – is equipped with eight synchronised cameras that collect a variety of non-contact biometrics of the gait from different angles with 99.6 per cent accuracy as the subject walks through the tunnel. John and Mark have created a gait database featuring images of more than 100 subjects; the database has around 300 registered users from over 30 countries.

"Just as fingerprinting transformed policing, gait biometrics has the potential to revolutionise the methods employed by security agencies to identify criminals and terrorists," says Mark. "Research at Southampton has advanced the use of gait as a biometric from concept to reality, and is now recognised internationally as a technique ripe for societal and commercial exploitation."

The research has already impacted the forensics field, leading in 2008 to the first use in the UK of gait biometrics as a form of evidence in a successful criminal prosecution.

Search for quantum limit

Physics research at Southampton is using nanoparticles of increasing size to recreate a classic experiment in physics to test the limits of quantum mechanics.

Dr Hendrik Ulbricht and his team have been awarded a John F Templeton Foundation grant of £500,000 to carry out matter-wave interferometry experiments which could reveal where the quantum realm ends and the classical world begins.

In collaboration with theorists in India and Italy, Hendrik is looking at interference patterns of nanoparticles of 10–100nm diameter and recreating a test which has all the elements of Thomas Young's two-slit experiment, in which a light wave from a single source is shone through a pair of slits and onto a screen, where an interference pattern of light and dark bands appear. However, they aim to perform this experiment with very large nanoparticles – the most massive so far.

Only in quantum physics, even a single particle itself can interfere. Over the years, single particle interference patterns have been created by firing neutrons, electrons, atoms and large molecules at the slits. Hendrik hopes to push the quantum-to-classical boundary a big step further by demonstrating interference using nanoparticles, a thousand times heavier than the largest molecules tested so far.

"These experiments will help us understand the mechanism which links the quantum to the classical world in a consistent picture," says Hendrik. "Our results could have huge implications on the understanding of natural processes and will be relevant for any quantum technology."

Photonic metamaterials

A multidisciplinary team at Southampton is pioneering the development of radically new nanotechnology-enabled materials that will drive the next photonic revolution.

Metamaterials – artificial electromagnetic media structured on the sub-wavelength scale, emerged initially as a paradigm for achieving optical properties beyond those available in nature and for manipulating the propagation of light waves in previously inconceivable ways. Now, researchers in Southampton, led by Professor Nikolay Zheludev, Deputy Director of Southampton's Optoelectronics Research Centre, are turning attention towards tuneable, switchable, and nonlinear metamaterials to provide a functional platform for future nanoscale optical devices.

"We aim to develop a new generation of revolutionary nanostructured photonic media to provide groundbreaking solutions for telecoms, energy and light generation, imaging, lithography, data storage, sensing, and security and defence applications," says Nikolay. "These goals will be achieved by advancing the physics controlling light in nanostructures and by developing new nanofabrication techniques and material hybridisation processes."

The research programme explores and exploits a wide variety of response mechanisms to deliver useful metamaterial functionalities in the optical, infrared, terahertz and microwave electromagnetic domains, from reversible light-induced phase transitions in the chalcogenide glasses behind rewritable CD/DVD technologies and electro-/opto-mechanical forces driving coordinated spatial rearrangement of structures on the nanometre scale to the highly nonlinear and quantum response of superconductors.

Detecting bomb threats

Southampton researchers are helping national security agencies improve their ability to detect dirty bomb threats at ports in the USA and the EU with highly sensitive gamma ray imaging technologies.

Created in Physics and Astronomy by Emeritus Professor Tony Dean and Dr David Ramsden (retired) and refined by Dr Tony Bird, the imaging technology's objective was to solve galactic riddles for the European Space Agency's International Gamma-Ray Astrophysics Laboratory space telescope. In 2002, Symetrica was spun out from the University and provides radiological and nuclear detection devices to the US Department of Homeland Security Customs and Border Protection, US Coast Guard and the European Illicit Trafficking Radiation Assessment Programme.

Symetrica began developing its first gamma ray detector to overcome the shortcomings of existing detection systems, which were unable to discriminate between real threats and natural radiation sources. The company's detector has spectroscopic capabilities that enable it to distinguish different radiation sources and accurately identify threat materials hidden in heavily shielded containers.

Symetrica's successful implementation of its original detector has led to a series of contracts and technologies that improve upon the device. Next-generation, hand-held radiation detectors developed by the company were used to screen ocean-borne debris as it reached Hawaii in the aftermath of the Fukushima nuclear reactor disaster in Japan, and its future technologies may have application in the nuclear power and medical sectors, as well as in the space industry.

Centre of Excellence

The future of cyber security research has been placed in the capable hands of experts at Southampton following the opening of a new Academic Centre of Excellence.

Led by Professor Vladimiro Sassone, from the University's Web and Internet Science Group, the Centre draws on expertise from across the University.

Southampton is one of eight UK universities identified to help make the country's government, businesses and consumers more resilient to cyber-attack. Government Communications Headquarters (GCHQ) conferred the Academic Centre of Excellence status upon the University as part of the government's national cyber security strategy in partnership with the Research Council UK's Global Uncertainties Programme, the Engineering and Physical Sciences Research Council and the Department for Business Innovation and Skills.

Each of the new Centres will benefit from closer collaboration with GCHQ and the UK Cyber Community and industry.

"This places the University in a unique position. Online activities underpin a growing range of day-to-day activities and there is a real need to ensure that users are supported in their online transactions and behaviours. Issues span the robustness of our national security and economic processes, to the security of digital information held by government and public bodies, and recognise the technical, legal, ethical and social responsibilities around our own personal privacy," says Vladimiro.

High-power lasers

Researchers at Southampton pioneered the high-power ytterbium-doped silica fibre lasers and amplifiers that have revolutionised the manufacturing industry.

Doping silica fibres with rare-earth metal ions allows active light sources and amplifiers to be integrated with passive fibre networks. This innovation famously led to the invention at Southampton of the erbium-doped silica fibre amplifier that is the underpinning technology of the internet.

Professor Anne Tropper, now leading the Ultrafast Semiconductor Laser Group in Physics and Astronomy, was among the first to identify the ytterbium ion as the optimum dopant for efficient high-power fibre lasers and amplifiers.

Anne explains that ytterbium-doped fibre is used to convert the raw infrared power from semiconductor diode lasers into bright coherent beams that can be tightly focused for cutting, welding and material processing.

The simple electronic structure of ytterbium is what makes it efficient under the intense light field present in a fibre core. "Ytterbium just doesn't have the extra excited states where wasted energy can accumulate, and leak into the surroundings as parasitic fluorescence or heat," she says.

"Today, the largest market for these high-power lasers is manufacturing, in particular the automotive industry, which is a consumer of large numbers of units. It means that resistant materials can be cut with high speed and precision and there is no edged tool to get blunt."

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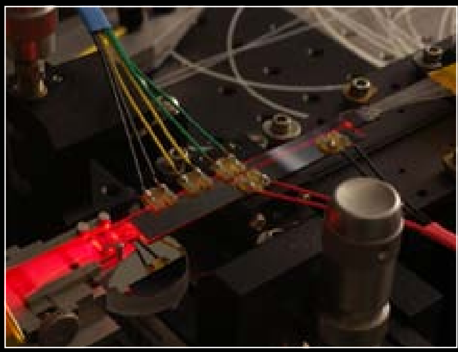

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