UNIVERSITY OF
Southampton

Zepler Institute

The future
starts here

"Fibres designed and drawn by Zepler Institute researchers have been instrumental in bringing hollow-core technology into network operator focus, enabling a demonstration of various record-breaking transmission experiments."

Dr Maxim Kuschnerov
Product Management DWDM, Coriant GmbH

"Researchers from the Silicon Photonics Group at the Zepler Institute are not only leaders in high-speed silicon modulators and devices but they are also early pioneers in the field of silicon photonics."

Dr Mario Paniccia
Director Photonics Technology Lab, Intel Corporation

"The Zepler Institute has provided us with a wealth of know-how and practical experience in microfluidics and bio-electronic interfaces. This has enabled us to focus and accelerate our R&D programme."

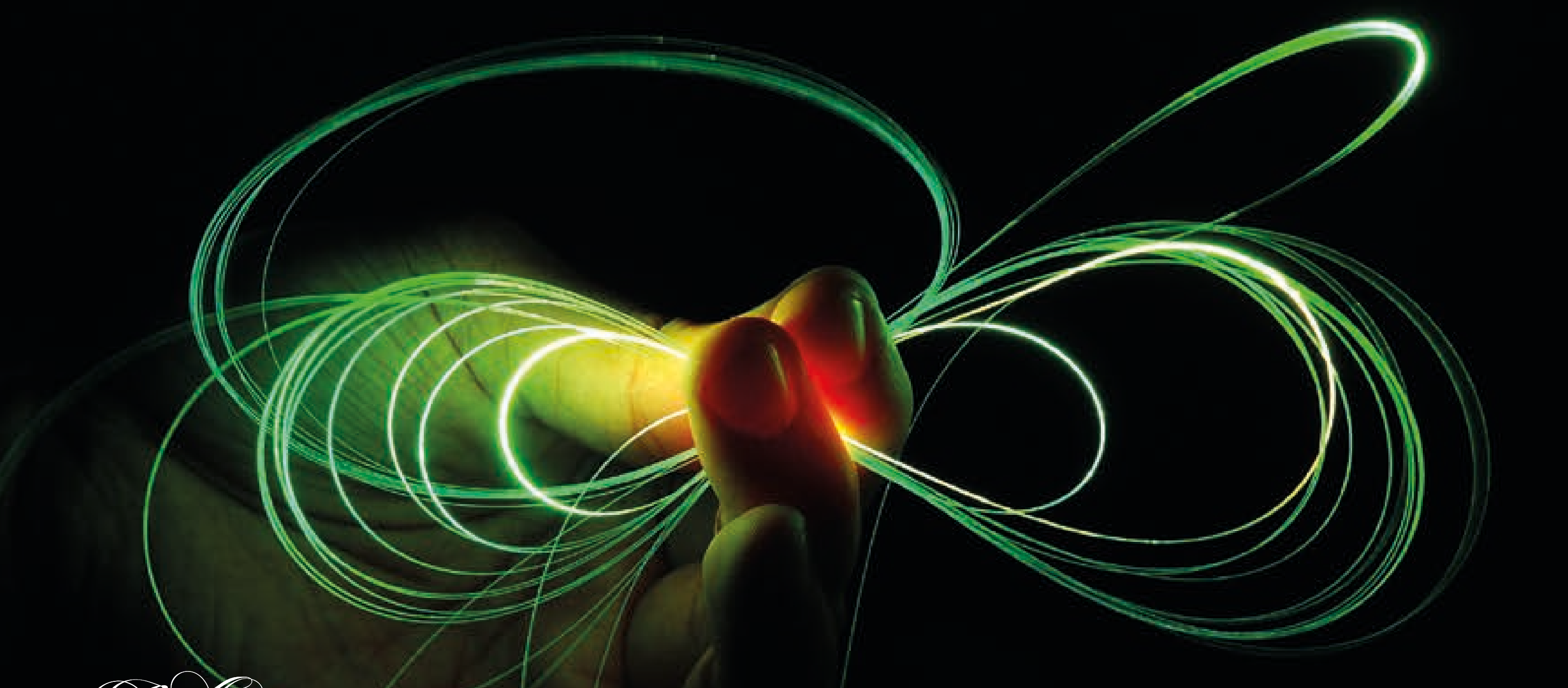
Chris Brown
Research and Development Manager, Sharp Laboratories of Europe

"The metamaterials research at the Zepler Institute is highly original and covers an extraordinary breadth of topics. It will become transformative because it addresses real-world applications."

Professor Federico Capasso
Harvard University

"Researchers at the Zepler Institute's Nano Research Group are among the very few in the world that have successfully fabricated, characterised and employed memristive nano devices in real applications."

Professor Leon Chua
Inventor of the memristor



The **Zepler Institute** is a community of researchers from the University of Southampton's **Optoelectronics Research Centre**, **Electronics and Electrical Engineering Group**, **Nano Research Group** and **Quantum Light and Matter Group**.

"We explore the boundaries of knowledge to discover world-changing inventions that can create wealth and boost the UK economy."

Professor Sir David Payne

Welcome to the Zepler Institute

The Zepler Institute is the largest photonics and electronics institute in the UK. It brings together leading researchers from across the University of Southampton and enables us to innovate by providing access to one of the most comprehensive collections of nanoelectronics and photonics fabrication equipment in Europe.

Our 350 research staff and PhD students use their expertise in optoelectronics, electronics, quantum technologies, physics and nanoscience to tackle key societal challenges and develop technologies and devices that make a real difference to our daily lives. From ultra-high bandwidth communications, through biophotonics for point-of-care diagnostics for combating antibiotic resistance, to ultra-sensitive sensors for explosives detection – we can work with you to design and fabricate devices for diverse applications.

At the Zepler Institute, we explore the boundaries of knowledge to discover world-changing inventions that can create wealth and boost the economy. We achieve this through a combination of decades of experience, industrial awareness and commercial intelligence to match science to real world products, either through our own spin-out companies or industrial partners.

Our interdisciplinary, industry-focused approach to research has resulted in many successful spin-outs and the commercialisation of products. The erbium-doped fibre amplifier, invented and developed in the late 1980s at the University, is now a crucial component of the internet, fibres developed here can be found in the Moon Rover and Mars Explorer and are used in the manufacturing of life-saving medical devices.

The Zepler Institute is working on many exciting projects that will change our future. From electronic circuits that store and process information like a human brain, to materials that can change their properties on demand. We are developing functional inks that can be used to print flexible circuits and solar cells, and we are working with physicists across the globe to develop new types of lasers that will probe the universe. Our researchers are making fibres that can carry more data than anyone ever thought possible, fabricating silicon photonic circuits that will enable faster computer chips and designing sensors for tamper-proof navigational systems.

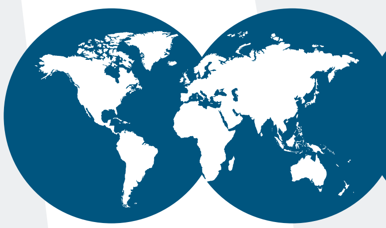
None of these projects would be possible without the state-of-the-art cleanroom complex that is at the core of the Zepler Institute. With all the facilities and equipment of a modern-day foundry at their fingertips and all under one roof, our researchers are free to innovate and experiment. Together with our extensive international links and our new joint laboratory, The Photonics Institute in Singapore, the Zepler Institute is a truly international operation pioneering the concept of research without borders. Our facilities are also available for collaborators and partners to access. So contact us to find out how we can work together at the Zepler Institute. The future starts here.

Professor Sir David Payne
Director

Contents

Facts & Figures

Over 100
laboratories in our
£120M
cleanroom complex

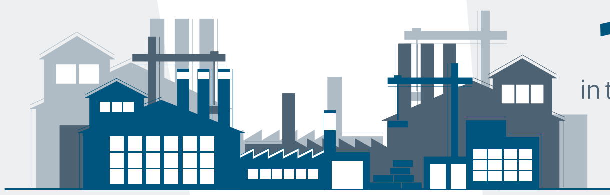


Over 350
researchers

representing **33 nationalities**

372
publications on average per year (2010-2014)

15
patents generated on average per year



10 companies with their roots in the Zepler Institute*, employing over **400** people in the south east region

World firsts

Invented the erbium-doped fibre amplifier (EDFA), the first successful optical amplifier and an essential component of today's optical communications networks

Demonstrated the world's first >1 kW diffraction limited fibre laser, breaking the kilowatt barrier for fibre laser output

Pioneered the first ever 50Gbit/s modulator for silicon photonics technology

Engineered the world's first screen-printed watch display on fabric and all-printed active electrode array on fabric for ECG health monitoring

Realised the first reconfigurable photonic metamaterials for the optical part of the spectrum – devices harnessing elastic, electrostatic, magnetic and even optical forces on the nanoscale to deliver dynamically controllable optical functionalities on demand

Zepler Institute researchers have used **over 50%** of elements in the periodic table in creating new advanced materials and devices

>10,000,000 years, estimated lifetime stability of optical storage technology developed by Zepler Institute researchers

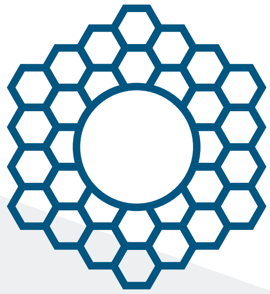
*spin outs or founded by members of staff

10–15

kilometres of special fibre is manufactured every month, with fibre diameters in the

50–1200

micron range



<100m

the potential length of a particle accelerator...

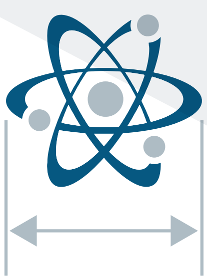
... based on fibre lasers being developed by Zepler Institute researchers, in contrast to today's particle accelerators which are tens of kilometres long, such as the Large Hadron Collider (27km)

>£60M
Secured research funding

Partner in
47
European Union funded projects 2007-2013
4 as the **lead partner**

Home to over
30%
of UK government-funded photonics research

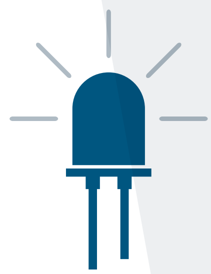
EPSRC
Pioneering research and skills
Holders of
4
EPSRC
programme grants



10 nanometres (nm)

the size of features achieved by Zepler Institute researchers developing memristor-based devices, who are now working to go down to

1nm



Surface structuring of LEDs using techniques developed by Zepler Institute researchers has increased their efficiency by up to

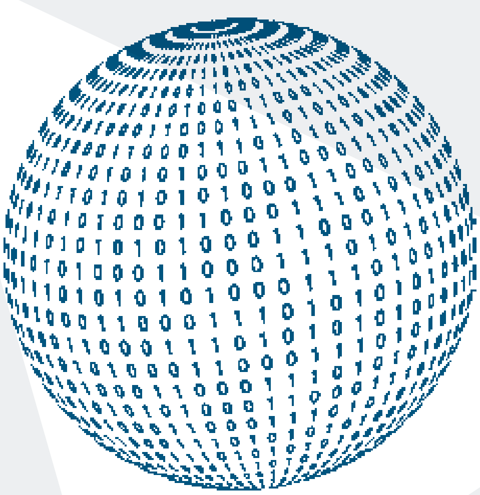
200%

4 times more bandwidth

over longer distances – the potential for increased amplified data transmission in the 2 µm region, as compared to the 1.5 µm used in current optical communications networks; Zepler Institute researchers hold the record for the amount of amplified data transmitted at 2 µm

A record of
0.24nm

– the resolution achieved by the ORION™ Helium Ion Microscope, close to the diameter of a single atom



2.7 Tbit/s (2,700 Gbit/s) and 1.3 Tbit/s (1,300 Gbit/s) – the amount of traffic handled by EDFA-based undersea fibre-optic systems through the Atlantic and Pacific oceans respectively, corresponding to a deployed infrastructure of

240,000

route-kilometres

“Researchers from the Silicon Photonics Group at the Zepler Institute are not only leaders in high-speed silicon modulators and devices but they are also early pioneers in the field of silicon photonics.”

Dr Mario Paniccia
Intel Corporation

Zepler Institute facilities used

Nanofabrication facility

- Etching
- Laser annealing
- Raman spectroscopy
- Electron beam lithography
- Scanning electron microscopy
- Rapid thermal annealing
- PECVD
- Optical lithography
- Hot wire chemical vapour deposition

Other labs used

Electronics and Computer Science Characterisation Suite
Atomic force microscope

Achievements

First ever erasable gratings for wafer-scale testing

High-speed > 50Gbit/s modulators for silicon photonic circuits

Silicon carrier depletion modulator with 10Gbit/s driver realised in **high-performance** photonic BiCMOS

Circuits of light in silicon

Researchers at the Zepler Institute are developing silicon photonic circuits to enable the next generation of computer chips and support the massive increase in internet usage.

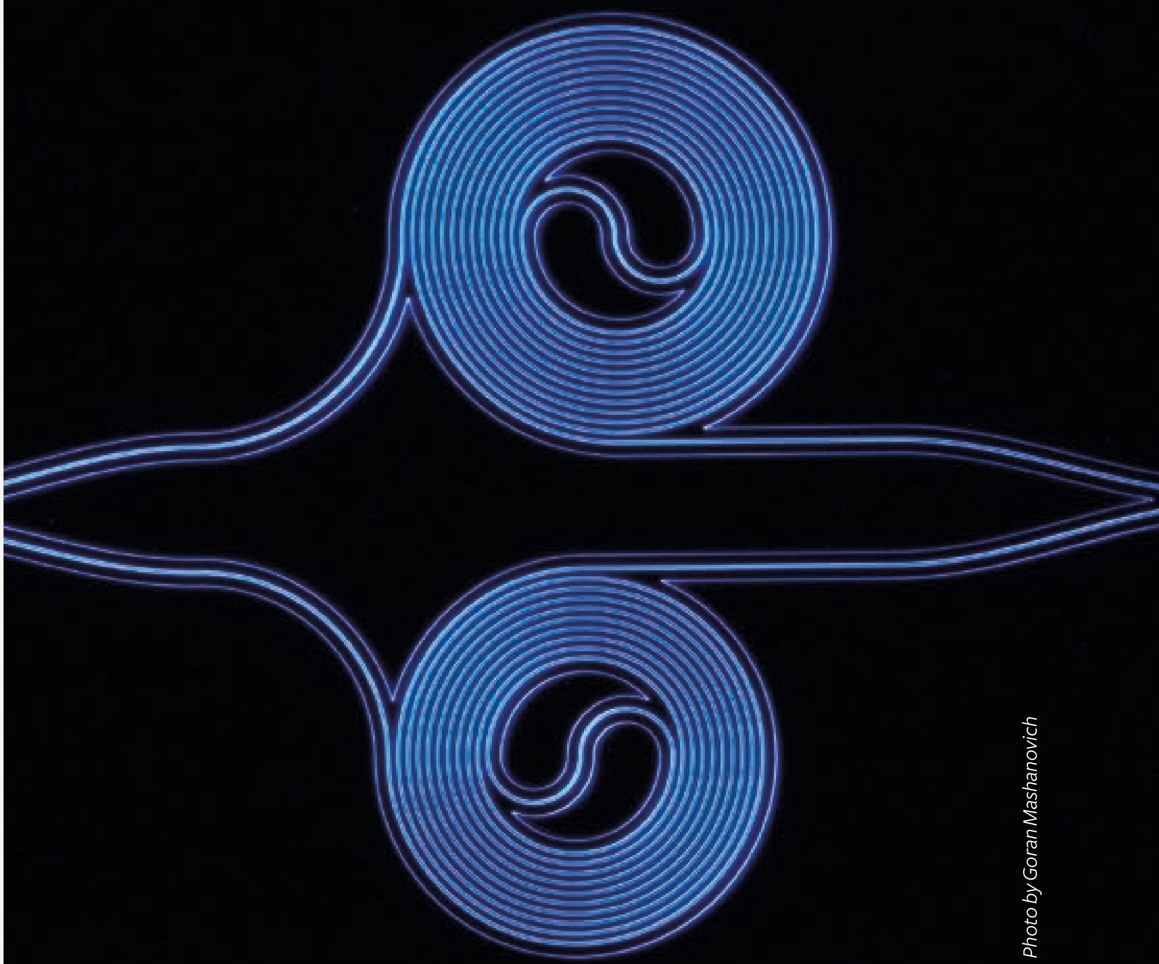


Photo by Goran Mashanovich

Tomorrow’s computers will need to use photons instead of electrons if they are to keep pace with demand for computing speed and low power. Silicon photonics is seen as the most likely candidate for inter-chip and perhaps even intra-chip communications. It also promises applications in data centre interconnect, fibre-to-the-home transceivers, high performance computing interconnect and as a platform for lab-on-a-chip sensors.

Despite its potential, there are several major challenges that need to be tackled before silicon photonics can become a commercial reality, including wafer-scale testing, multi-layer photonics, passive alignment, scaling up to Tbit/s and low-cost lasers on a chip.

Researchers at the Zepler Institute are working to solve these problems and to develop commercial processes that will enable the mass manufacturing of silicon photonic devices. They were the first in the world to develop a 50 Gbit/s silicon modulator and to fabricate the erasable gratings that will facilitate wafer-scale testing of silicon photonic devices, an important step towards commercialising this revolutionary platform.

For more information visit **www.zeplerinstitute.com/research/siliconphotonics**

Optical properties on demand

Zepler Institute researchers are merging nanotechnology with light to study the physics and technology of artificial optical materials with properties on demand.

Zepler Institute researchers at the EPSRC Centre for Photonic Metamaterials are pushing the boundaries of photonics by developing artificial optical materials which can change their properties on demand.

They study and engage the changing balance of forces, structural transformations, light confinement and coherent effects at the nanoscale to create materials with properties not available in natural media and design them such that they can be controlled by external signals. Through better understanding the new physics of advanced materials structured on the nanoscale, the team explores technological applications of reconfigurable photonic metamaterials.

Zepler Institute researchers believe that new nanotech-enabled photonic metadevices and metasystems will be vital for improving competitive performance in all kinds of applications using light and lasers. They will also play a crucial role in solving key societal challenges such as the ever-growing demand for telecommunications bandwidth and the ever-increasing energy consumption of data processing devices.

For more information visit **www.zeplerinstitute.com/research/metamaterials**

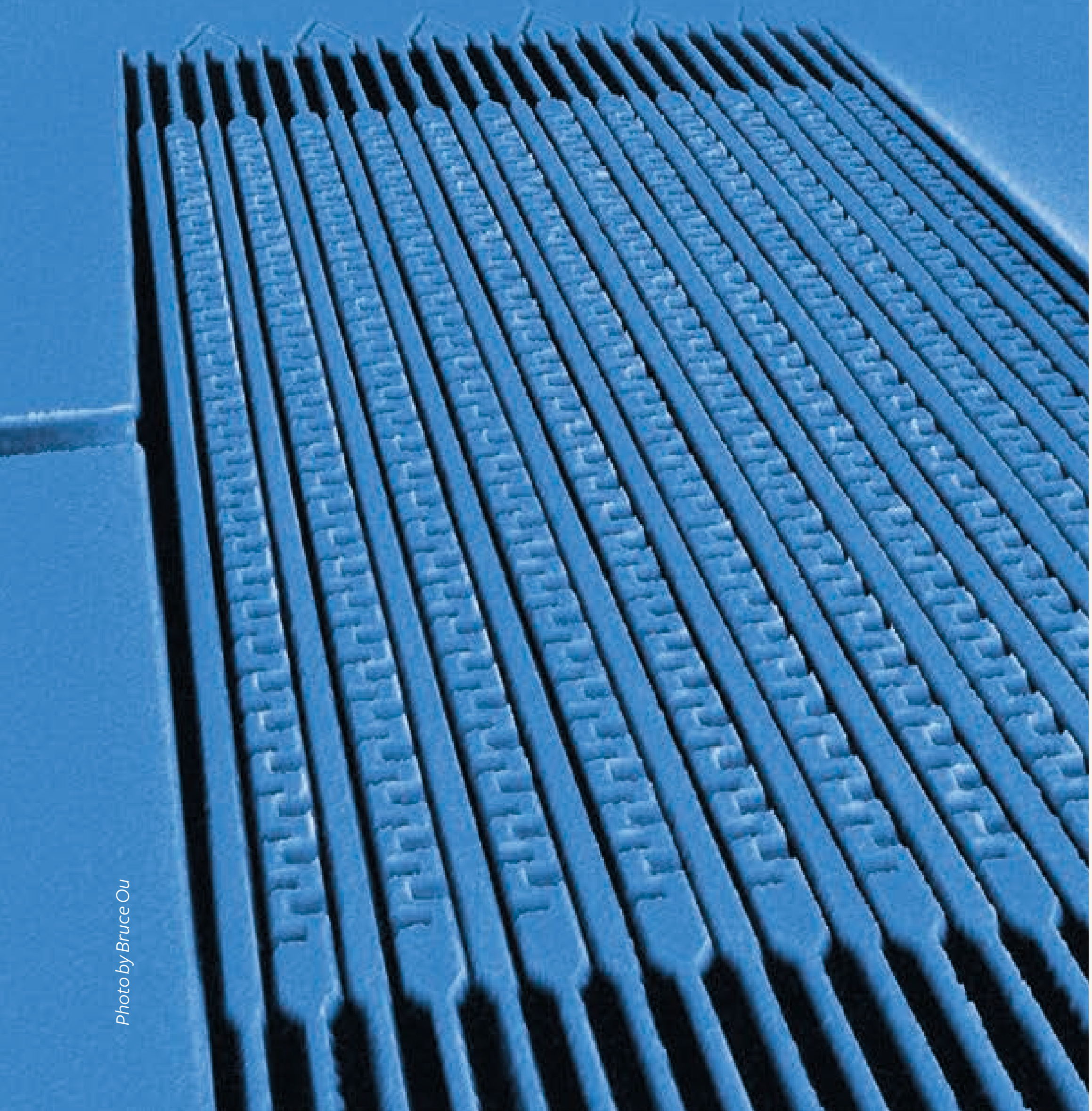


Photo by Bruce Ou

"The metamaterials research at the Zepler Institute is highly original and covers an extraordinary breadth of topics. It will become transformative because it addresses real-world applications."

Professor Federico Capasso
Harvard University

Zepler Institute facilities used

Focused Ion Beam facility

Integrated Photonics facility

Nanofabrication facility

Nanophotonics spectroscopy labs

Other labs used

Centre for Disruptive Photonic Technologies (CDPT) – A close collaboration and coordinated research programme with our CDPT sister centre in Singapore **www.nanophotonics.sg**

Achievements

Nano-mechanically reconfigurable metamaterials with tuneable and switchable parameters

2- and 3-D chiral metamaterials and seminal studies of **polarisation phenomena** in artificial chiral media

New generation of **nonlinear, gain, switchable and memory metamaterials** using carbon nanotubes, graphene, phase-change chalcogenide glass and superconductors

Invention of the ground-breaking **structural transformation nanophotonics** concept

“Fibres designed and drawn by Zepler Institute researchers have been instrumental in bringing hollow core technology into network operator focus, enabling a demonstration of various record-breaking transmission experiments.”

Dr Maxim Kuschnerov
Coriant GmbH

Zepler Institute facilities used

Silica fibre facility
- Glass work
- Preform fabrication
- Fibre drawing
- Modified chemical vapour deposition (MCVD)
- Outside vapour deposition (OVD)

Achievements

- **Invented** new fibre amplifiers
- **First** to make wideband thulium-doped fibre amplifiers suitable for **high capacity data transmission**
- **World records** for the amount of data transmitted down a hollow core fibre and the amount of amplified data transmitted at 2µm

Next-generation optical networking

After playing a key role in the development of today’s telecommunications infrastructure, researchers at the Zepler Institute are now working on next-generation technology for even faster, higher capacity networks.

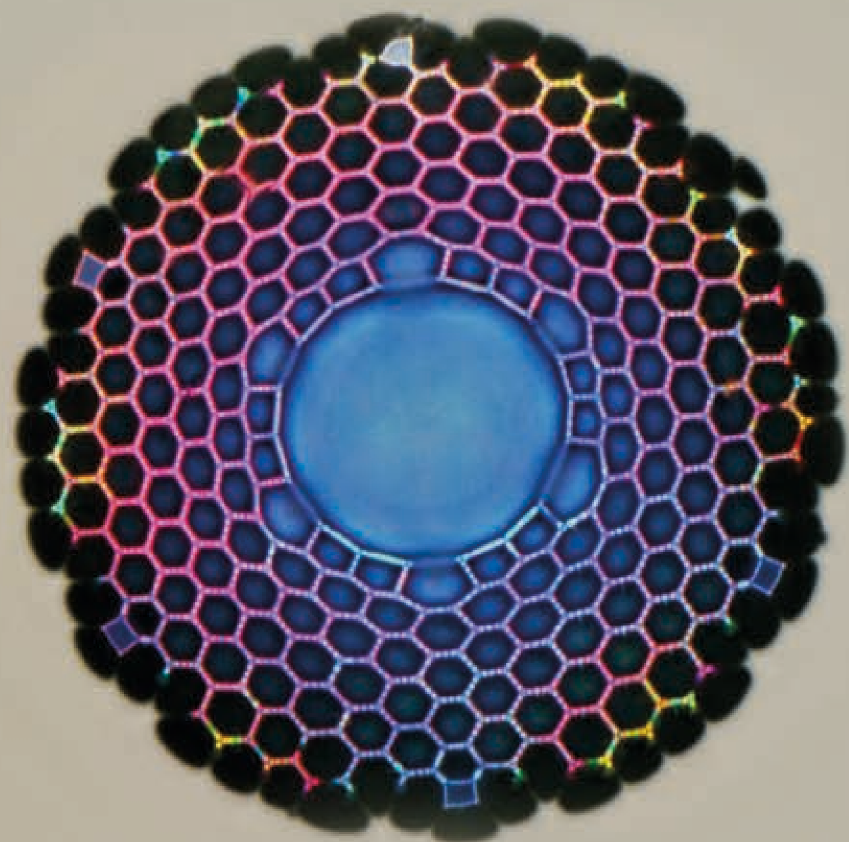


Photo by Reza Sandoghchi

The erbium-doped fibre amplifier (EDFA), an essential component of today’s optical communications networks, was invented by Southampton researchers in the 1980s. Since then, Zepler Institute researchers have been further developing the technology and looking for a suitable next-generation fibre amplifier better able to cope with the ever increasing internet traffic in order to avoid a future capacity crunch. Current optical communications networks use light at a wavelength of around 1.5 µm, which is ideally suited to silica fibres and EDFAs. However, another potential transmission window is emerging at around 2µm which offers the possibility of delivering up to four times as much bandwidth and longer distances before the data traffic needs to be amplified.

Achieving these improvements in performance involves using thulium-doped fibre amplifiers (TDFAs) and special transmission fibre optimised for this new wavelength.

Zepler Institute researchers are pioneers in both these areas and hold records for data transmission at 2µm, as well as the highest data capacity through a hollow core fibre, a completely new form of fibre with the potential for lower loss than existing solid fibres. With the continuing rapid growth of the internet, the technologies being developed at the Zepler Institute aim to radically transform today’s ICT infrastructure to meet long-term data capacity needs.

For more information visit **www.zeplerinstitute.com/research/telecomms**

Probing the universe

Zepler Institute researchers hope to combine thousands of fibre lasers to develop a source that will enable a more powerful, compact particle accelerator.

Fibre lasers were pioneered by researchers at Southampton and today they are used in a plethora of applications from welding cars to cosmetic surgery. These revolutionary lasers, renowned for being stable, efficient sources producing high average powers, are now being investigated for an entirely new application: particle acceleration.

Today's particle accelerators are huge structures, tens of kilometres long. By contrast, a particle accelerator based on fibre lasers could be less than 100m long and use even higher energies to probe the fundamental structure of the universe. Zepler Institute researchers are involved in an international project to develop fibre lasers for precisely this application.

At present, the lasers available consume too much power and can only produce the ultrafast laser pulses required to yield acceleration around once per second. However, a solution may lie in combining the output of thousands of pulsed fibre lasers, a novel laser system that researchers at the Zepler Institute are seeking to develop using their track record in the design and fabrication of new optical fibres. This new laser system could also have other innovative applications such as proton therapy for cancer patients, nuclear transmutation for cleaning up radioactive waste and in a new class of accelerator-driven nuclear reactors, not reliant on chain reactions and therefore more easily switched off.

For more information visit **www.zeplerinstitute.com/research/fibrelasers**

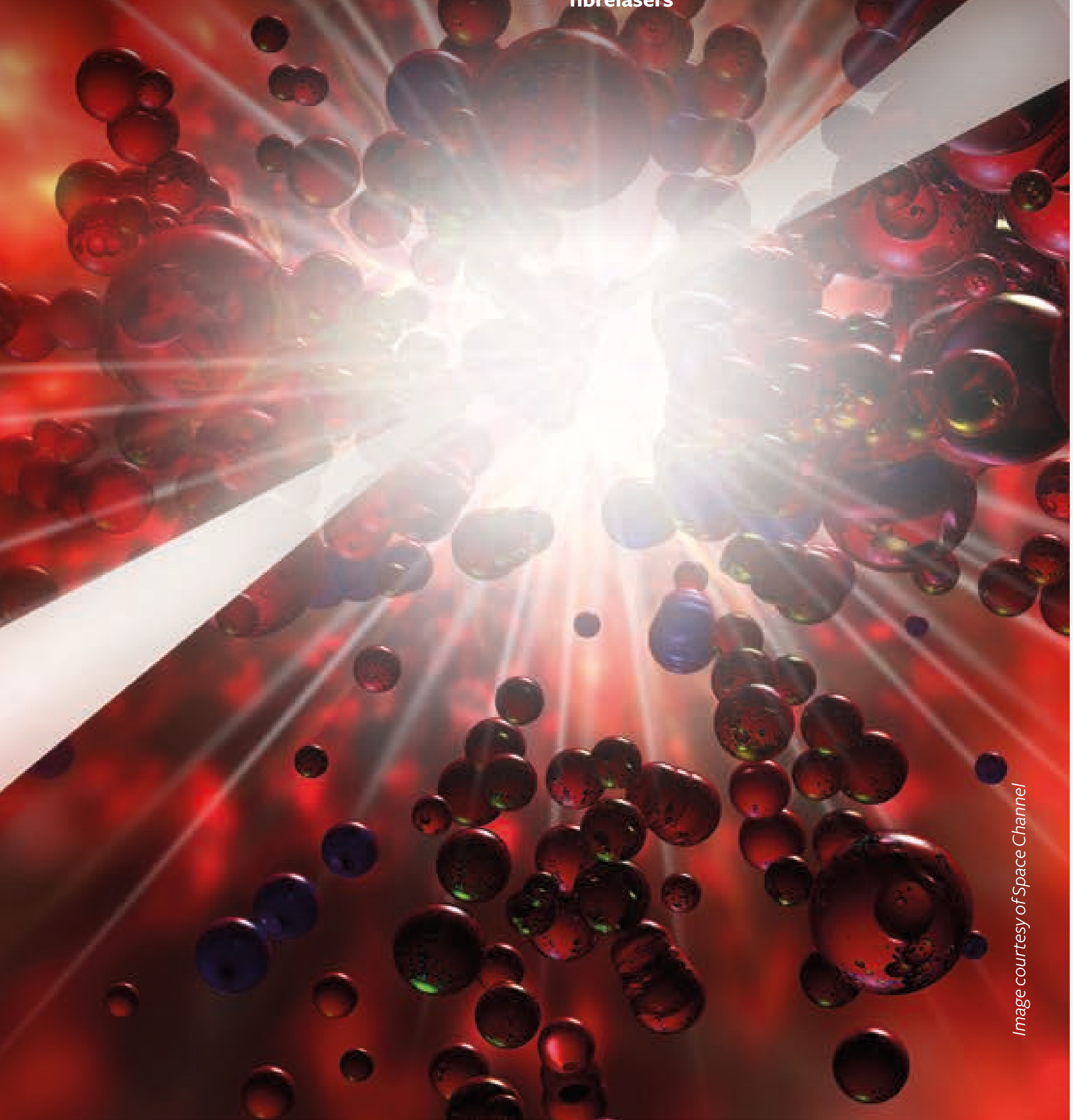


Image courtesy of Space Channel

"We wanted to work with Zepler Institute researchers because of their formidable track record in fibre laser development, the world-class facilities they have at their fingertips and their pioneering attitude to problem solving."

Professor Gérard Mourou
Director, International Centre for Zetta- Exawatt Science and Technology

Zepler Institute facilities used

Silica fibre facility

Preform manufacture

Fibre drawing

Other labs used

Laser labs
Characterisation

Achievements

First in the world to break the kilowatt barrier for the output of a fibre laser

Invention of the **single mode silica fibre laser** and **amplifier**




Nanofabrication

Encompasses a uniquely broad range of technologies, combining traditional and novel top down fabrication with state-of-the-art bottom up fabrication, and extensive characterisation capabilities, including lithography down to 5nm, deposition of 1nm thin films and microscopy down to 0.24nm.

Rapid Prototyping Room

Enables the rapid prototyping of simple systems including microfluidic chips and operates as a training facility for new cleanroom users by providing a more flexible environment.

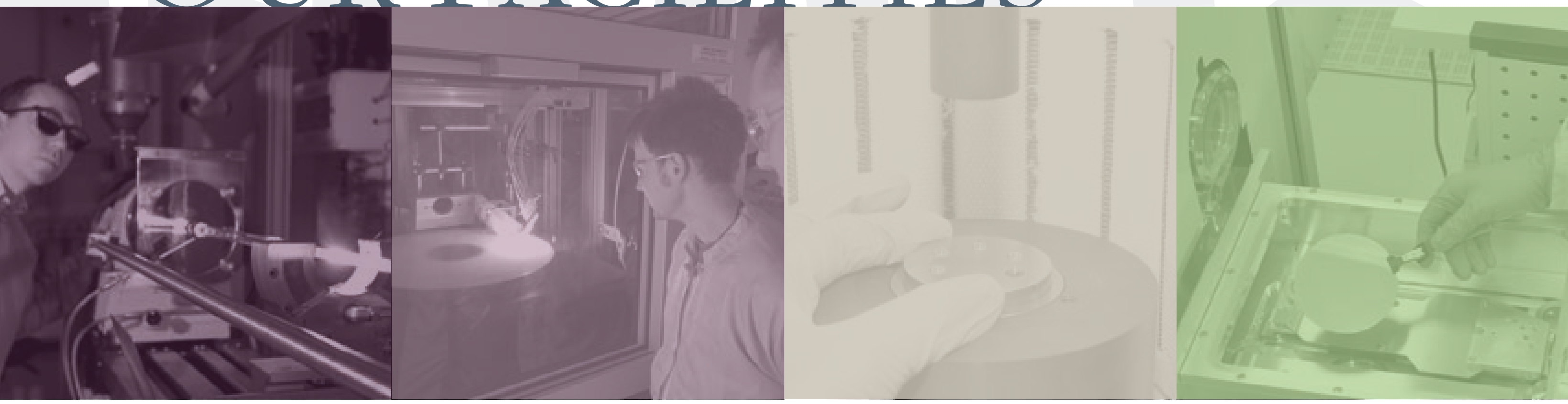
Thick Film

Enables the production of larger scale devices in semiconductor, metallic and piezoelectric materials – allowing us to fabricate novel devices such as the world's first all screen-printed electroluminescent watch display on fabric.

Focused Ion Beam

Allows us to prototype at the nanoscale, resulting in several world firsts, including the first reconfigurable photonic metamaterial for the optical part of the spectrum, making metals 'invisible', and commanding nanoparticles to stop and let light go in optical fibres.

Our Facilities



Silica Fibre

Offers four fibre drawing towers, with a range of technologies (OVD, MCVD) and processes to produce a huge range of fibre types – including rare-earth doped, microstructure, spin, ribbon and bundle in the 50–1500 micron range.

Flame Hydrolysis Deposition

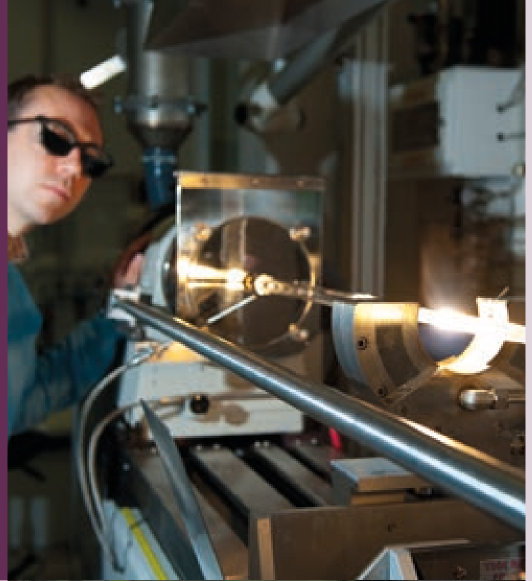
Provided the optical platform for the first demonstration of Boson sampling for quantum information processing, optical circuits for next generation telescopes and biosensors for chemical, biological, radiological and nuclear (CBRN) detection.

Novel and Compound Glass

Enables our researchers to melt and purify some of the highest quality chalcogenide glasses in the world. 2D material systems are of particular interest, where new techniques for fabricating materials such as molybdenum disulphide (MoS2) in large uniform thin films have been developed and numerous applications in aerospace, healthcare, electronics and telecommunications are being explored.

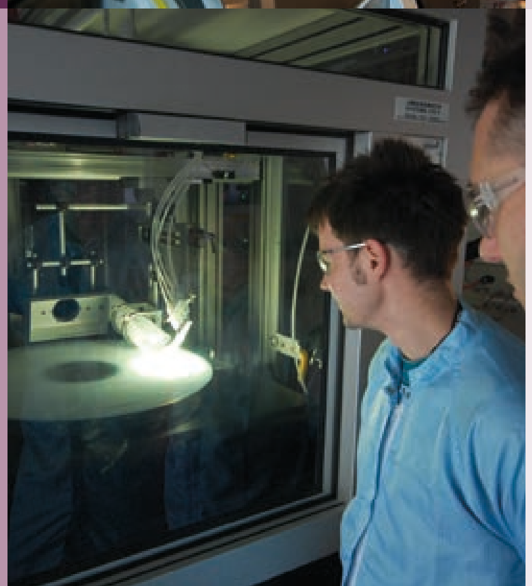
Integrated Photonics

Takes raw, novel and commercial materials and processes them to realise photonic devices for broad applications. Biosensor chips are a core competence and we have demonstrated devices which can detect and identify up to 32 trace organic pollutants simultaneously in river water at ppt levels, such as oestrone at 1ppt and bisphenol-A at 20ppt.



The **silica fibre facility** occupies over $160m^2$ of class 10,000 cleanroom space and comprises state-of-the-art fabrication equipment complemented by cutting-edge process advances. The facility includes a modified-chemical-vapour-deposition (MCVD) lathe, outside-vapour-deposition (OVD) equipment, a six metre high dual-sided fibre drawing tower and dedicated chemical preparation areas for glass etching and machining. The facility is capable of producing industry standard passive and active preforms and fibres, and a wide variety of specialist fibres with complex structures, enabling research into high-power fibre lasers and advanced telecommunications and sensing devices. Complete post-processing and characterisation of silica fibre includes preform and fibre index profilers, fibre proof-testing and high-resolution optical time domain reflectometry (OTDR).

For more information visit **www.zeplerinstitute.com/facilities/silicafibre**

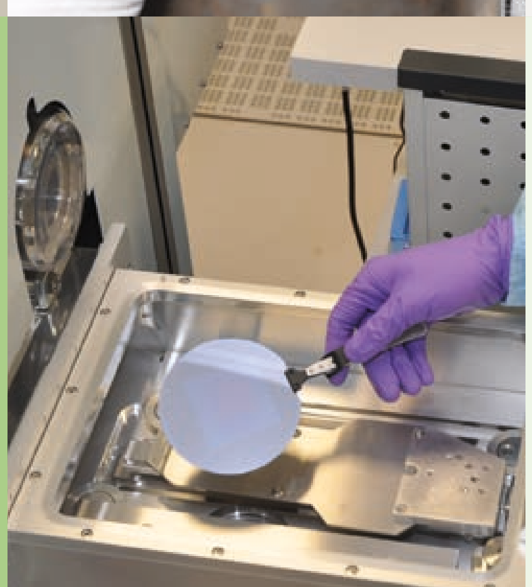


The **flame hydrolysis deposition** tool (FHD) is a state-of-the-art system for the growth of silica to form waveguide structures for integrated photonic circuits. The system allows the precise doping of germanium, phosphorous and boron within the silica films and is particularly optimised for the growth of films with high photosensitivity for direct UV laser writing of advanced photonic circuits. The tool can grow films ranging from 2 to 50 microns in thickness. The system is designed to deposit onto 150mm silicon wafers (other substrates can also be used) and has a high throughput of up to 30 wafers per day.

For more information visit **www.zeplerinstitute.com/facilities/fhd**

The **novel and compound glass facility** offers a wide range of specialised glass making and fibre drawing equipment including a variety of horizontal and vertical tube furnaces, chamber furnaces, ovens, vacuum processing, glove box systems for batching, melting, annealing and casting of glass under dry inert atmosphere, extrusion and hot pressing equipment. A suite of thermal, mechanical, optical and electrical test equipment supports material characterisation. Advanced glasses are realised from raw materials and can be used to form novel optical fibres, integrated optical circuits and micro-optical components, providing almost unlimited materials flexibility for device research. We are continuously improving the quality of our facilities and our upgraded process gas distribution system has seen moisture levels in our glass drop to less than 500 parts per billion.

For more information visit **www.zeplerinstitute.com/facilities/novelglass**



The **integrated photonics facility** is a $200m^2$ cleanroom designed for planar processing of a very wide range of materials not normally found in silicon processing facilities, from PTFE to germanium telluride, $KY_{1-x-y}Gd_xLu_y(WO_4)_2$ to Pyrex, and from ytterbium metal to lutetium biphthalocyanine. The prime purpose of this facility is to take raw and commercial materials, as well as those made by our researchers, and process them to realise photonic devices for use in applications from telecommunications to all-optical data processing and from biochemical sensing to the lab-on-a-chip. Thin film deposition, photolithography, etching and diffusion processes can all be applied to full wafers or unconventionally small or irregular samples.

For more information visit **www.zeplerinstitute.com/facilities/integratedphotonics**

Zepler Institute facilities

The Zepler Institute Cleanroom Complex is our state-of-the-art multidisciplinary centre for materials and device research in electronics, photonics and nanotechnology.

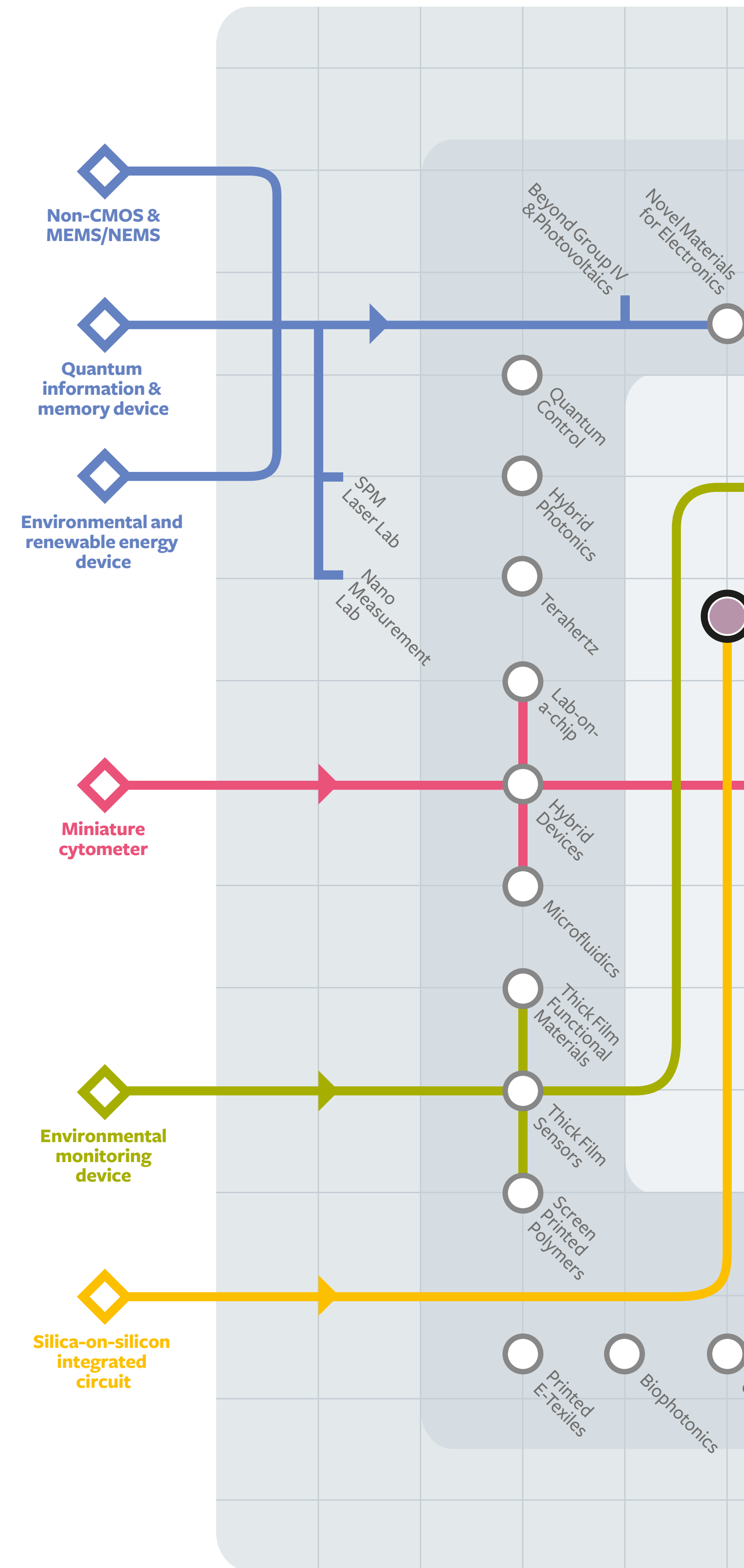
A unique collection of cleanroom facilities under one roof, our extensive capabilities are used by researchers and engineers from across academia and industry. Integrated with specialist application and development laboratories including communications, lasers, sensors and biotechnology, and advanced characterisation capabilities, the Zepler Institute impacts the entire the value chain, from electronics to enterprise, from photons to production.

Scan this QR code to take a **360° virtual tour** of our facilities and learn more about the devices we make or visit **www.zeplerinstitute.com/facilities**

Facilities key

- Silica Fibre
- Flame Hydrolysis Deposition
- Novel and Compound Glass
- Integrated Photonics
- Thick Film
- Rapid Prototyping Room
- Nanofabrication
- Focused Ion Beam
- Other labs

Each colour line below represents the creation of a novel device developed by our researchers. Use the map to follow the journey of each device through our Cleanroom Complex, specialist application laboratories and partner facilities.



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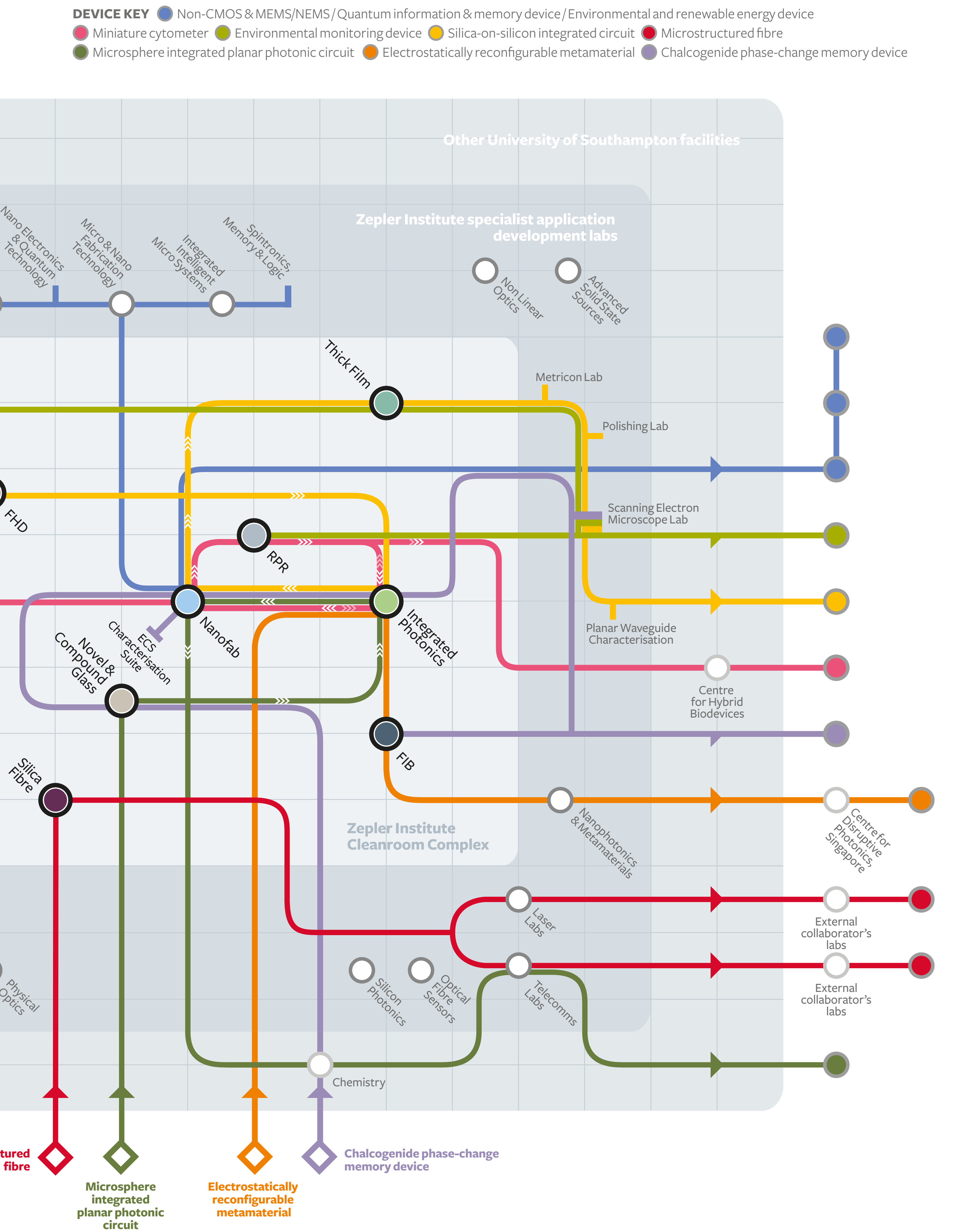
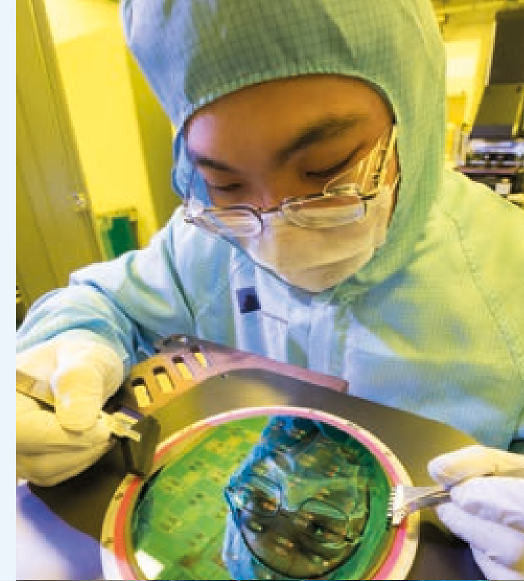


Our **nanofabrication facility** offers industry-compatible nanoelectronics/nanophotonics processing, including 150mm and 200mm wafer capability. Our lithography capability combines photo- and electron beam lithography from 20nm with nano-imprint and hot embossing. Self-assembly of nanostructures is used to grow carbon nanotubes, nanowires and quantum dots. Thin film deposition is performed by ALD or PECVD. We can deposit optical layers using Plasma Assisted Reactive Magnetron Sputtering, and fabricate multi-stack devices using wafer-to-wafer aligning and bonding. We offer device fabrication for silicon electronics, photonics, MEMS, lab-on-a-chip, and spintronics. Fabrication/characterisation capability includes FIB with integrated SEM and SIMS. The range of other measurement tools available include ellipsometry, XPS, Raman spectroscopy, cryogenic prober, RF measurements up to 60GHz, Field-Emission Scanning Electron Microscopy (FESEM), AFMs and a Helium Ion Microscope.

For more information visit **www.zeplerinstitute.com/facilities/nanofab**

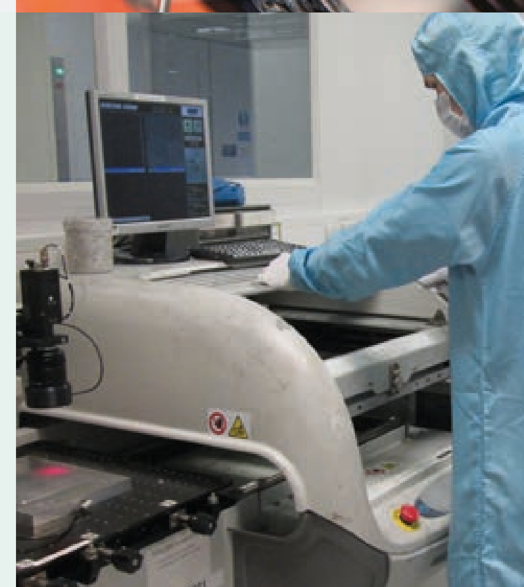


The **rapid prototyping room** (RPR) is a class 10,000 cleanroom designed for rapid prototyping of simple systems and for initial training of new cleanroom users. The RPR houses similar equipment to that in the main Nanofabrication facility, such as plasma tools, wet decks, optical lithography and metrology but allows more flexible working for the production of simple devices, including microfluidic chips. The facility also houses the two-photon lithography tool (Nanoscribe) that is used to produce three dimensional structures from resist materials on the nano-scale and environmental scanning electron microscope (Zeiss EVO SEM), which is able to image a wide variety of non-conducting materials and is specially designed to allow imaging in liquids, lending itself to MEMS and microfluidics research.

For more information visit **www.zeplerinstitute.com/facilities/prototyping**

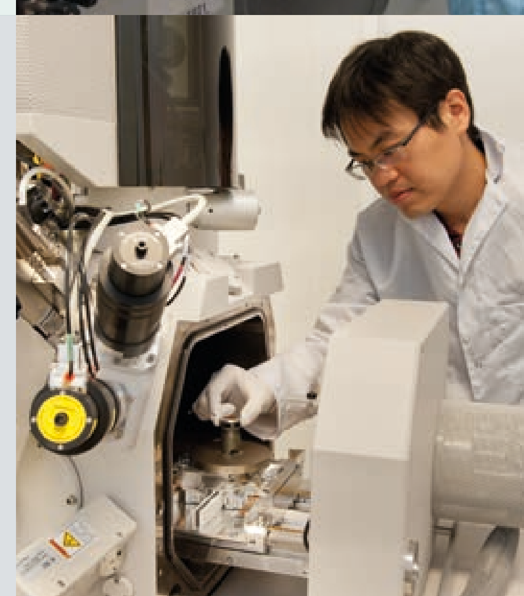
The **thick film facility** realises novel electronic sensors, actuators, circuits and systems printed with a DEK248 screen printer and Dimatix DMP2831 inkjet printer on a variety of substrates using commercial and in-house inks and pastes. The printed devices developed within the facility include micropumps, heaters, multi-layer flexible printed circuit boards, accelerometers, gas and liquid sensors, electroluminescent displays, pressure sensors and energy harvesters. A Netzsch Microcer Bead Mill is used to develop our own printed electrically active materials and materials analysis tools such as the Malvern Mastersizer and Zetasizer are used to study the effects of particle size and distribution upon electrical performance.

For more information visit **www.zeplerinstitute.com/facilities/thickfilm**



The **focused ion beam facility** (FIB) specialises in rapid nanostructuring of metallic, semiconducting and dielectric materials and devices, from free-standing nano-membranes to multilayer structures and optical fibres for nanophotonics/electronics, metamaterials and plasmonics research. Our two gallium FIB systems provide milling resolution down to 30nm, and additional capabilities including high-resolution electron microscopy and electron beam lithography, beam-induced deposition of platinum, tungsten, carbon and silicon dioxide, and chemically accelerated milling of insulators, all on substrates up to 150mm in diameter. The Helium Ion Microscope provides FIB milling at even smaller scales, enabling precise material modification in the sub-10nm range.

For more information visit **www.zeplerinstitute.com/facilities/fib**

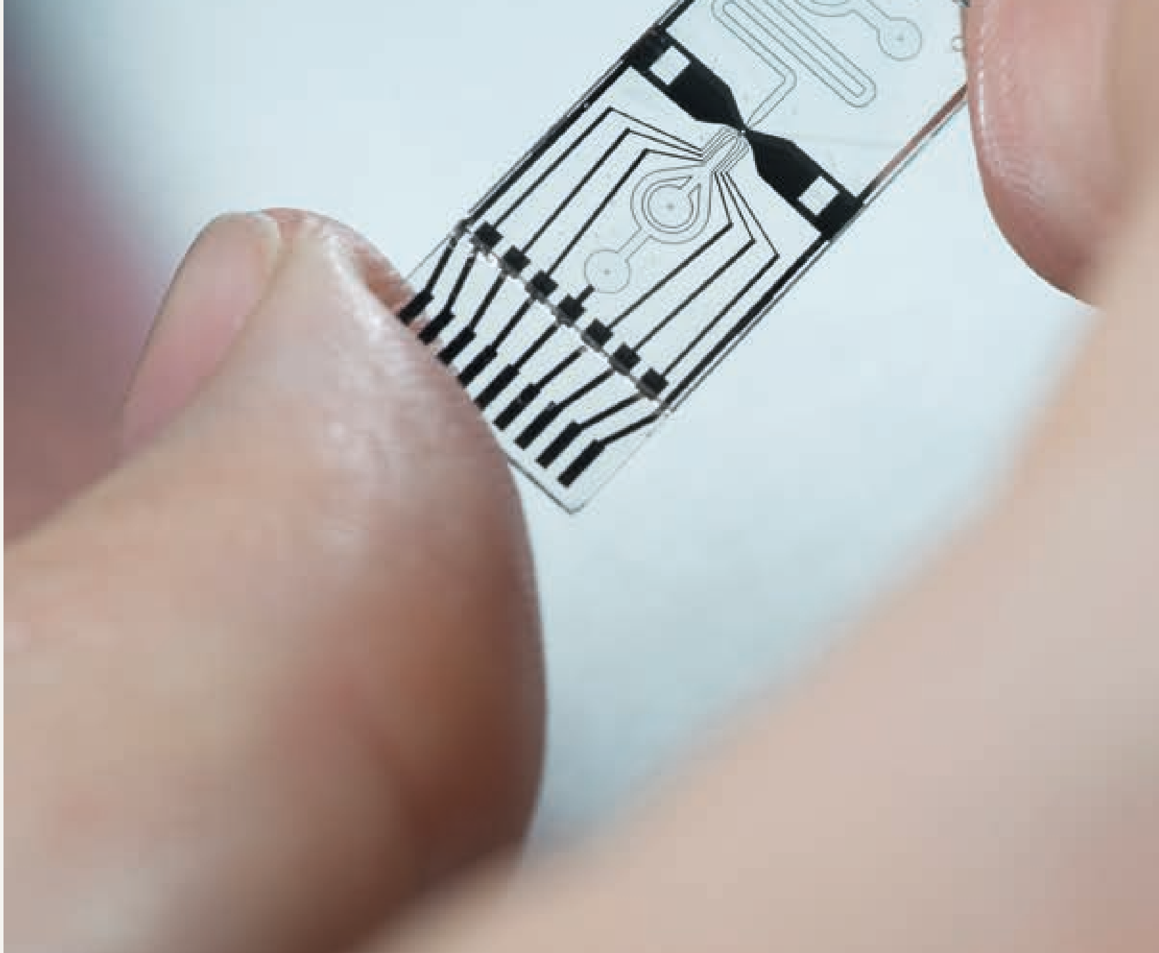


"The Zepler Institute has provided us with a wealth of know-how and practical experience in microfluidics and bio-electronic interfaces. This has enabled us to focus and accelerate our R&D programme."

Chris Brown
R&D Manager,
Sharp Laboratories of Europe

Lab-on-a-chip

Researchers at the Zepler Institute have used consumer electronics technology to make a hand-held diagnostic tool that quickly helps GPs decide which antibiotics to give to their patients.



Treating bacterial infections is becoming increasingly difficult due to the growing threat of antibiotic resistance. Bacterial mutations can mean that the antimicrobial drugs once successfully prescribed to treat an infection may no longer be effective. The result is a trial and error process for patients with sometimes unsatisfactory outcomes.

The Zepler Institute has developed a lab-on-a-chip that can tell doctors whether the bacteria causing the infection are resistant to certain antibiotics. The chip uses the thin-film transistor technology found in most television or computer displays and a procedure that would typically take days to carry out in a specialised laboratory, into a 10 minute test that can be administered by a GP on the spot.

The chip contains many thousands of individually addressable electrodes that are fully reconfigurable and can be programmed to support multiple simultaneous operations. Starting with a single drop of fluid, the chip then splits this into many nanolitre-sized droplets and uses novel nanowire sensors to detect and identify molecules within them. This process takes only a few minutes and requires no additional specialist training to be undertaken by the GP. Using low-cost lithography techniques and standard manufacturing processes such as deposition and etching, Zepler Institute researchers are developing a method of fabricating the device in a way that will enable its mass-production.

For more information visit **www.zeplerinstitute.com/research/biodevices**

Zepler Institute facilities used

Nanofabrication facility
Photolithography
Etching
Deposition of dielectrics

Achievements

Turning a labour intensive process that requires laboratory analysis into a **ten minute diagnostic test** that can be carried out by a GP

A **new technique** for the mass-manufacturing of nanowire sensors

Use of **low-cost** consumer electronics technology for microfluidics

Brain-inspired circuits

Researchers at the Zepler Institute are developing electronic circuits that function more like the human brain and will be smaller and faster than today's devices.

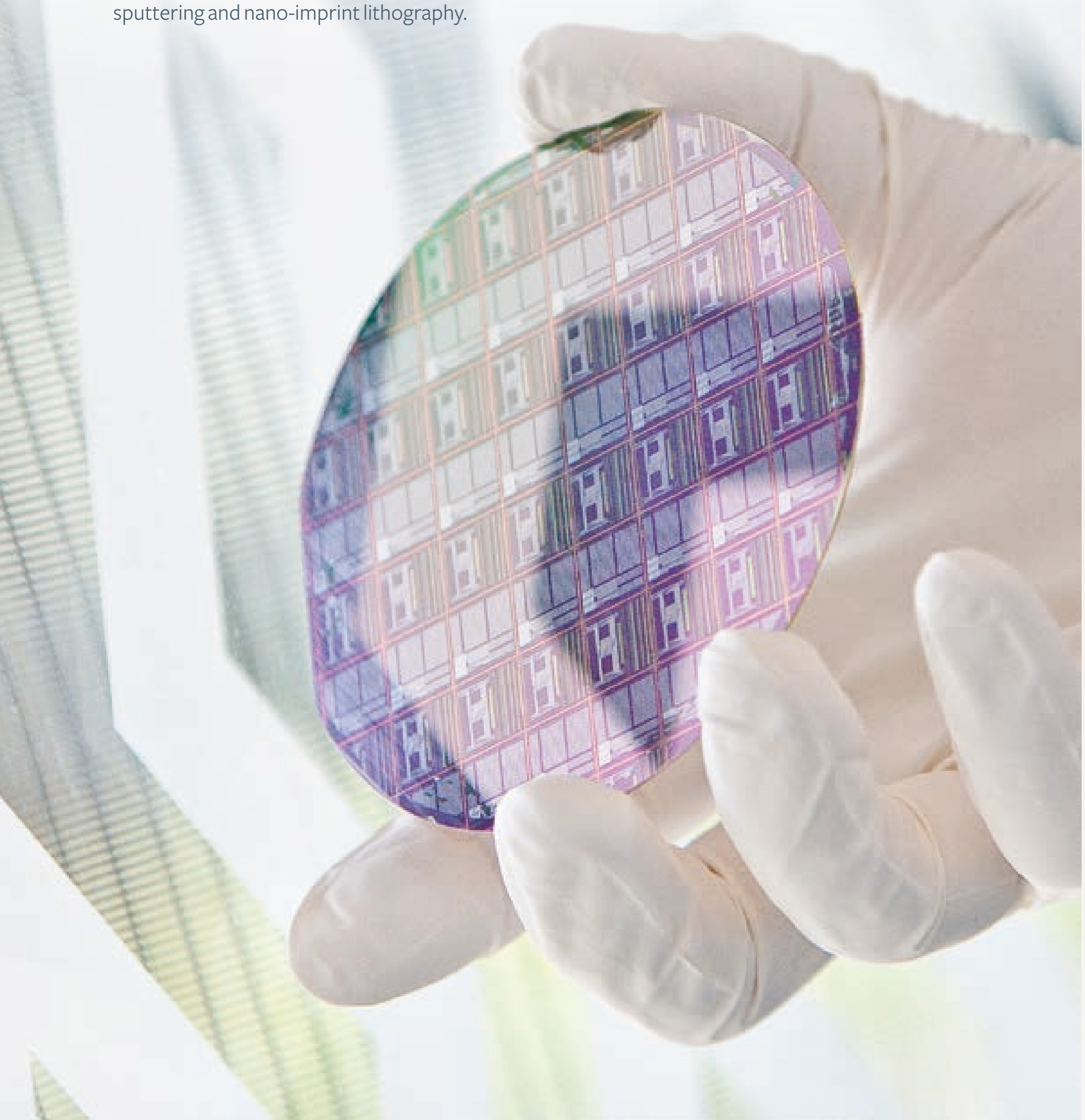
Conventional computers store information in one place and process it in another. A chip being developed at the Zepler Institute is different: this device works more like the brain, processing and storing information using the same hardware, and, like the brain, it has incredible image processing capabilities.

Having demonstrated that such a device is possible, Zepler Institute researchers are now developing the manufacturing techniques to enable it to become a reality. Using the Institute's unique prototyping and characterisation facilities, they are fabricating circuits based on nanoscale memory-resistors (memristors) and creating entirely new types of computer chips. Inspired by neural networks and synapses in the brain, these circuits are manufactured using techniques such as electron beam lithography, atomic layer deposition, sputtering and nano-imprint lithography.

Feature sizes down to 10nm have been achieved and researchers aim to go down to 1nm, using 8-inch wafers and commercially-compatible manufacturing techniques to produce reliable, high-quality, medium-to-large-scale memristor-based devices.

These devices will enable the computers of the future - with more functionality than today's systems but far smaller and requiring less power; computers that are able to perform massive processing tasks in fractions of a second and even to function as autonomous cognitive systems.

For more information visit **www.zeplerinstitute.com/research/memristors**



"Researchers at the Zepler Institute's Nano Research Group are among the very few in the world that have successfully fabricated, characterised and employed memristive nano devices in real applications."

Professor Leon Chua
Inventor of the memristor

Zepler Institute facilities used

Nanofabrication facility

- Electron beam lithography
- Atomic layer deposition
- Sputtering
- Nano-imprint lithography

Achievements

Demonstrated how single TiO_2 memristors are capable of capturing short- and long term- synaptic dynamics using the same experimental protocols used to test real synapses

Use of nano-imprint lithography to achieve small feature sizes, down to 1nm, **quickly**, **reliably** and at a relatively **low cost**

Use of **commercially compatible fabrication processes** aiming for medium-to-large-scale production

> "SPHERE is a £12M EPSRC project which collaborates with the Zepler Institute on smart materials that harvest energy for wearable health devices. Its expertise and fabrication capability is vital to our research."

Professor Ian Craddock
Director, EPSRC IRC 'SPHERE'

Zepler Institute facilities used

Thick film facility

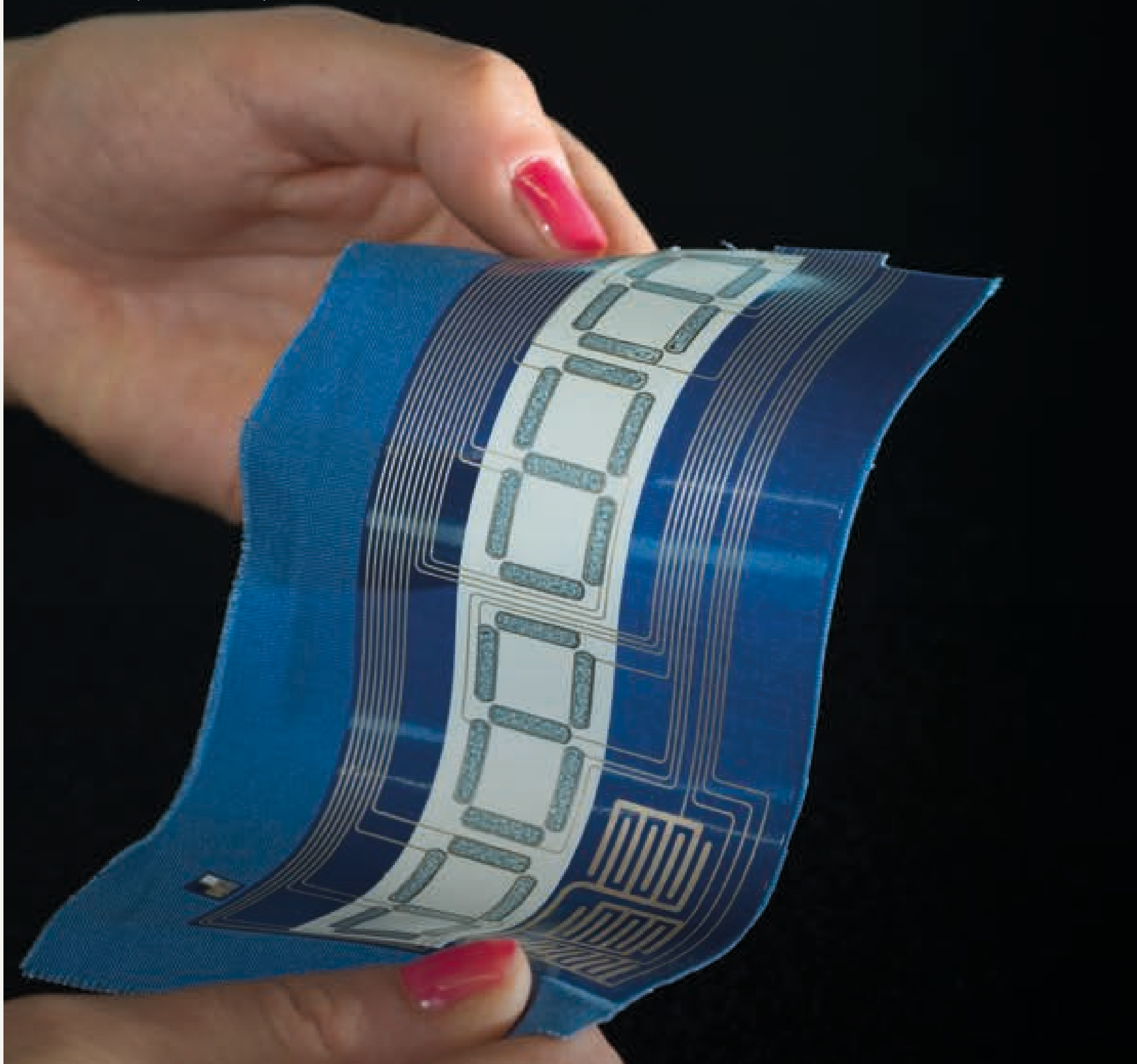
- Screen printing of functional electronic pastes
- Inkjet printing of functional electronic inks
- Dynamic light scattering particle size measurements
- Viscosity and rheology measurements of inks
- Bead milling to create different sized particles and size distributions
- Ultra violet curing
- Controlled atmosphere convection oven vacuum curing
- Paste and ink mixing

Achievements

- Fabricated the **world's first** screen printed watch display on fabric and all-printed active electrode array on fabric for ECG health monitoring
- **New, low-temperature functional inks** for fabrics and flexible substrates
- **High precision** screen printing of six layers
- Chemists and creative designers **working together** with electronics engineers

Smart materials

Zepler Institute researchers have developed functional inks that can be printed onto flexible substrates such as textiles and low temperature plastics.



Printing electronic circuits onto textiles is a huge challenge. Not only do the inks have to be conductive, elastic and flexible, they also have to survive washing. At the Zepler Institute, chemists and electronics engineers are working together to find solutions to these problems.

Building on expertise gained in screen printing devices for energy harvesting applications, Zepler Institute researchers have developed novel printable materials such as piezoelectric, piezoresistive, thermochromic, sacrificial and electroluminescent inks. These new materials have enabled the world's first electroluminescent watch display on fabric to be produced using the Zepler Institute's dedicated thick film processing lab, with its capabilities in screen and inkjet printing of advanced materials and novel ink formulation.

Fabricating the watch, which is flexible and comfortable to wear, involved creating new, low-temperature inks and functional materials and then printing six different layers with high precision. The novel inks developed during the project are now being sold through a spin-out company, Smart Fabric Inks, and researchers are exploring a variety of new applications for printed electronics, such as wearable medical sensors, solar cells on yacht sails and illuminated removable building facades and displays.

For more information visit
www.zeplerinstitute.com/research/printedelectronics

Printing patterns

The idea of etching nano-scale patterns onto surfaces has resulted in many applications from ultra-sensitive sensing techniques to increasing the efficiency of light-emitting diodes and photovoltaic cells.

Surface-enhanced Raman Spectroscopy (SERS) is a powerful sensing technique that relies on patterning nanoscale features onto a surface. It can be used to detect a variety of molecules including drugs, explosives, bacteria and indicators of cancer. The technology was pioneered by Southampton researchers and is now being used around the world in a range of applications. The same researchers have now managed to increase the sensitivity of SERS and have also worked with industrial partners to develop manufacturing techniques to make the sensors on a plastic substrate instead of silicon. Using nanoimprint technology and roll-to-roll printing techniques, large numbers of SERS substrates can now be manufactured simultaneously. This not only makes SERS devices cheaper to produce, it also paves the way for plastic-based integrated optical components such as lasers, light sources and optical interconnects.

Zepler Institute researchers have also used nanoimprint lithography to texture the surface of light-emitting diodes (LEDs), improving their efficiency by up to 200%. This technique, which also makes the devices simpler to manufacture, is today used in millions of LEDs every year. The surface patterning enables light to be emitted that would ordinarily be trapped inside the structure. This same idea can be used in reverse and applied to photovoltaic cells to improve the way in which they capture light and generate electricity.

For more information visit
www.zeplerinstitute.com/research/pvleds

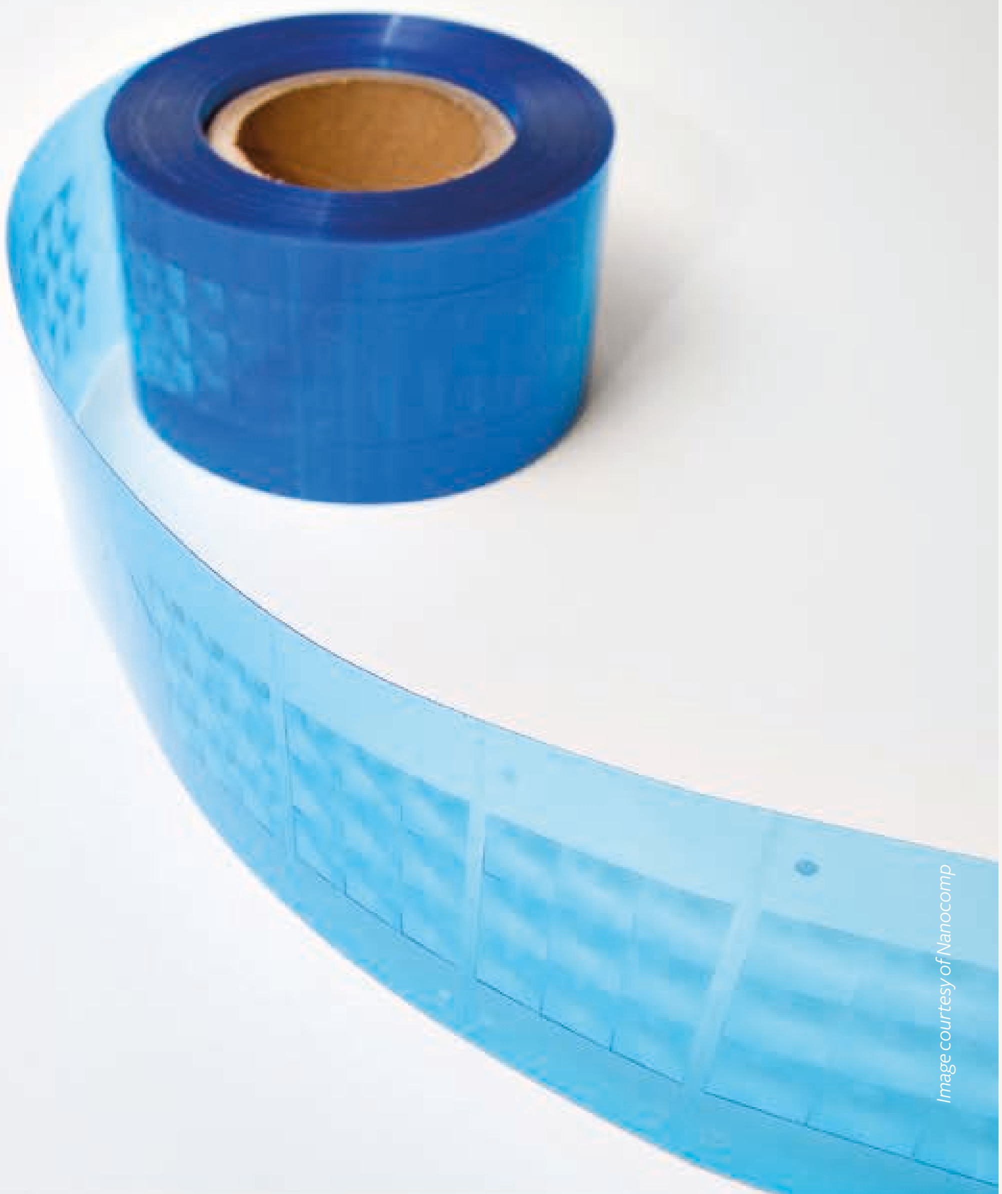


Image courtesy of Nanocomp

> "The world-class facilities at the Zepler Institute can contribute to all stages of real-world product development, from conceptual design by computational methods to prototype production via their advanced suite of instrumentation."
>
> **Dr David Eustace**
> Renishaw Diagnostics

Zepler Institute facilities used

Nanofabrication facility

- Etching by ICP and RIE
- Wet room
- Deposition by e-gun evaporation
- Electron beam lithography

Achievements

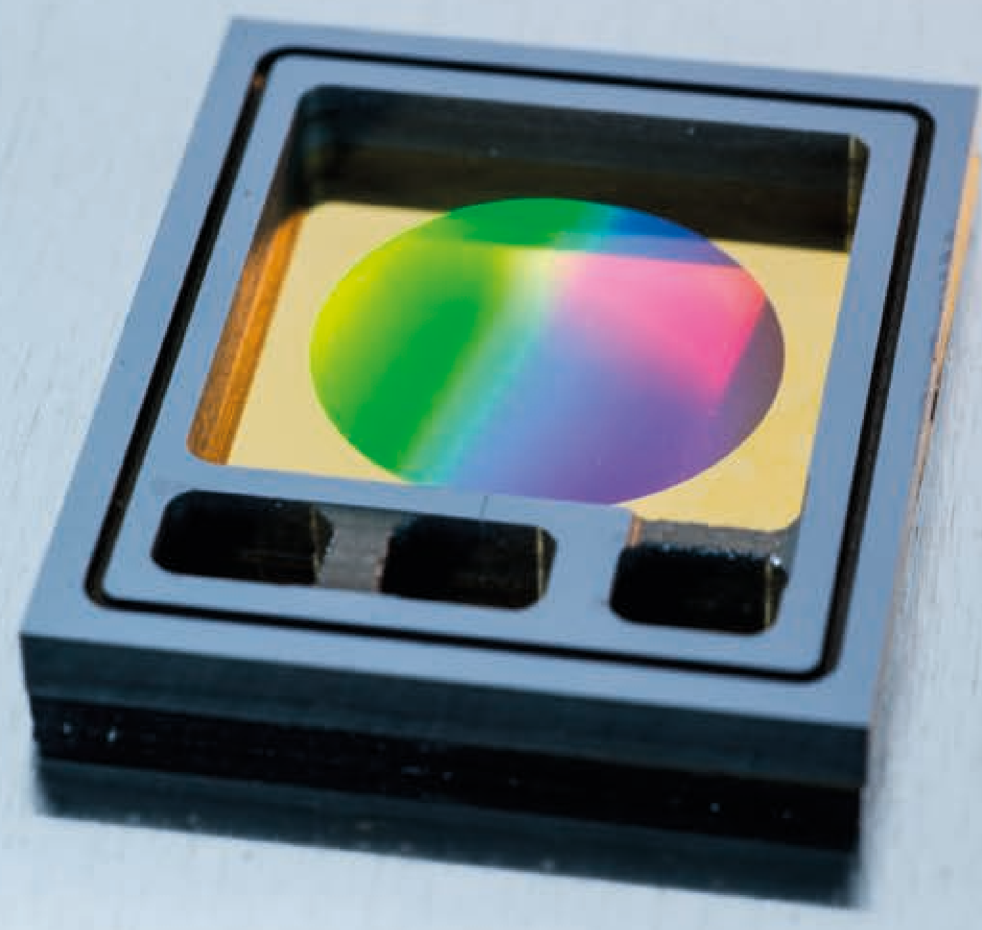
- Up to **200% increase** in the **efficiency** of LEDs by surface structuring
- **Surface-enhanced Raman spectroscopy** on a plastic substrate, making it **cheaper** to manufacture and even **disposable**
- **Mass production** of technology in LCD TV and general lighting applications

> "The work at the Zepler Institute will enable a more widespread adoption of quantum sensing than could be achieved with conventional techniques."

Dr Cliff Weatherup
E2V Technologies

Ultra-cool technology

Chips containing ultra-cold atoms will enable the next generation of navigation and sensing technology.



At close to absolute zero, atoms exhibit certain quantum-mechanical behaviours which can have a host of useful applications from highly accurate, tamperproof navigational systems and clocks to finding oil underground. However, maintaining atoms at a temperature a fraction above zero Kelvin requires large equipment, most which is not portable.

Physicists at the Zepler Institute are working on shrinking the vacuum chamber needed to create these ultra-cold atoms from something the size of a fridge to a chip the size of a postage stamp. In order to achieve this, they have taken a bottom-up approach which has pushed standard silicon manufacturing processes to their limits. Using electron beam lithography, they have successfully etched deep millimetre-sized features with nanometre precision and with an ultra-high vacuum bonding machine, they are fabricating a vacuum chamber measuring just a few millimetres across. The rubidium atoms inside the chamber are cooled using a magneto-optical trap powered by a laser which will eventually also be integrated into the chip.

This vacuum chamber is based on a passive design which requires no pumps and therefore no power. Once other components, such as lasers, optics and detectors, are integrated on to the chip, the whole system can be battery powered, making it ideal for mobile applications.

For more information visit
www.zeplerinstitute.com/research/atomchips

Zepler Institute facilities used

Nanofabrication facility

- Deep reactive ion etching
- Thin film sputtering
- Ultra-high vacuum bonding

Achievements

- **Deep reactive ion etching** through millimetres of silicon
- Ultra-high-vacuum, low-temperature bonding

Capabilities

Novel optical fibre

- Microstructured optical fibre
- Rare earth & novel doped fibre
- Photodarkening free fibre
- Photonic band-gap structured fibre
- Large mode area & double clad fibre
- Birefringent fibre
- Compound glass & infrared fibre

Sensors & sensor networks

- Chemical, biological and molecular sensor and systems
- Wireless sensor networks
- Integrated THz spectroscopy
- Chemical, biological & life science sensors
- MEMS & microfluidic sensors
- Point-of-care diagnostics
- Intelligent, high-reliability & radiation-tolerant systems

Characterisation

- Scanning probe microscopy
- Electron microscopy
- 2D &1D stylus profilometry
- Optical, RF, electrical and cryogenic testing

Metamaterials, plasmonics, & non-linear optics

- Switchable, tuneable, reconfigurable and non-linear metamaterials
- Ultrafast coherent absorption modulation and controlled optical activity
- Phase-change hybrid meta-devices
- Super lenses/ sub-diffraction limit focusing
- Plasmonics of superconductors & topological insulators
- Meta-surface optical elements
- Carbon nanotube & graphene metamaterials
- Free-electron evanescent field amplification
- Tesla-scale magnetic pulse generation
- Toroidal multipoles
- Metamaterials for LEDs and photovoltaics
- Superconducting metamaterials & bolometers for light-harvesting

Quantum devices & technologies

- Cooling, trapping & manipulation of atoms & molecules
- Silicon photonics
- Spintronics
- Information processing
- Quantum dot devices
- Molecular interference
- High density memory & unconventional computing

Lasers

- Supercontinuum generation & highly tuneable laser sources
- High power fibre lasers
- Pulse tuning & shaping
- Laser beam transport, delivery & characterisation
- X-ray, UV, visible & infrared lasers
- Femtosecond & short pulse lasers & amplifiers
- Modelocked Vertical-External-Cavity Surface-Emitting Lasers (VECSELS)

Optical communications

- High-bandwidth multicore & multimodal optical transmission
- Silicon photonics
- High-speed modulation
- Low latency, high-speed communication
- Integrated photonics
- All optical signal processing in new materials
- Data centres, metro & long haul communications

Advanced materials, nanostructures & thin film deposition

- Chalcogenide, phase-change & thermoelectric materials
- Energy harvesting
- Smart fabrics
- Photovoltaics & photosensitive materials
- 3D integrated photonics
- Novel 2D thin films
- Atomic layer & chemical vapour deposition
- Physical vapour deposition
- Displays & LEDs
- Thin-film & nanowire field-effect transistors
- Plastic/flexible electronics
- Magnetic materials
- Inorganic semiconductors

Micro & nanofabrication

- 3D, hybrid, fluid systems & polymer fabrication
- Supercritical fluid deposition
- Graphene
- Extreme & imprint lithography
- Biological self-assembly
- Novel material integration
- Helium Ion & Focused Ion Beam fabrication

Contact us

No matter where you are or whatever your interests, we want to work with you to push the frontiers of photonics and electronics research, and help to bring new innovations to market.

Speak to us about accessing our unique knowledge and facility base through collaboration, joint and sponsored research, commercialisation, consultancy and development projects.

> "From electrons to enterprise, from photons to production."

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