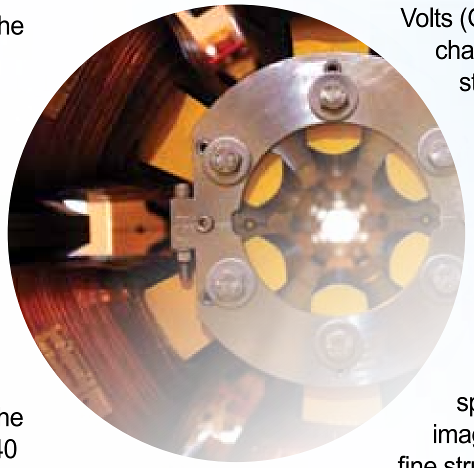
How the synchrotron works

A brief history

X-rays were discovered by Wilhelm Röntgen in 1895, and in 1912 Max von Laue used them in the determination of crystal structure. In the same year, William Henry Bragg and his son William Lawrence worked out the equations that make it possible to calculate the positions of the atoms within a crystal from the way in which an X-ray beam is diffracted by the crystal lattice.

As particle accelerators were developed from the 1930s onward, scientists noticed that these machines also generated as a by-product very bright light, and these were used for various experiments. In 1980, the world's first dedicated Synchrotron Radiation Source (SRS) was built at Daresbury in Cheshire, and now there are around 70 synchrotron light sources around the world.



In 2002, Diamond Light Source Ltd was established as a joint venture funded by the UK Government and the Wellcome Trust with an initial investment of £263 million, making it the largest UK scientific facility to be built for over 40 years. Construction began in early 2003 and Diamond Light Source became operational as planned in January 2007.

www.diamond.ac.uk/Home/About/Synchrotrons

Accelerating electrons

Diamond generates brilliant beams of light across the electromagnetic spectrum from infra-red to powerful X-rays a billion times brighter than the sun. To achieve this, an 'electron gun', essentially a cathode ray tube, releases a stream of charged particles into the linear accelerator and booster ring, where powerful arrays of magnets focus the electrons into bunches and accelerate them to 3 Giga electron Volts (GeV). These high-energy electrons are channelled into the 562m circumference storage ring, where even more powerful magnets keep these bunches travelling at near the speed of light – completing 555,000 circuits every second! Some of the magnets act to excite the electrons, causing them to give off brilliant light, including X-rays that are focused into the various experimental stations known as 'beamlines'. These use advanced spectroscopy, diffraction, scattering and imaging techniques to explore the ultra-fine structures of materials and molecules.

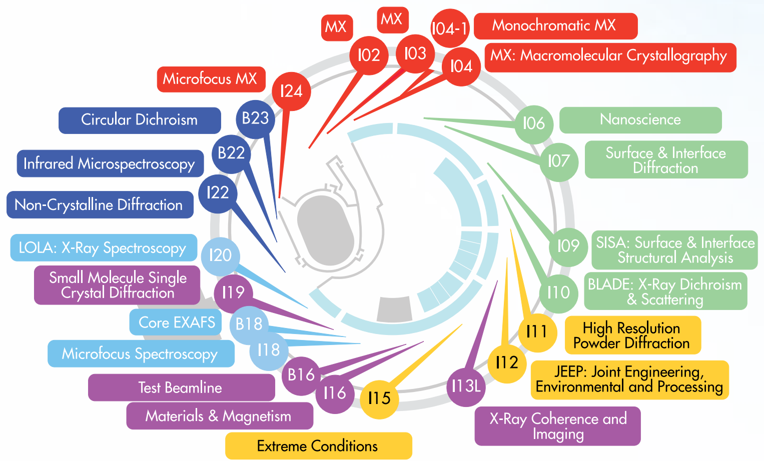
www.diamond.ac.uk/Home/Technology

Brilliant beamlines

Opened in 2007, Diamond is being developed in three phases. Phase I included Diamond's buildings and the first seven beamlines. Phase II enabled the construction of 15 more beamlines between 2007 and 2012. Phase III expansion involves an additional 10 beamlines coming on line between 2012 and 2018, bringing the total to 32.

This diagram shows Diamond's beamlines, each with its own experimental capabilities and technology, and staffed by a team of scientists who are leaders in their respective fields, and technicians expert in the advanced optics, experimental, detector and data acquisition techniques required to operate and develop the beamline.

www.diamond.ac.uk/Home/Beamlines



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A brief guide to Diamond Light Source

Diamond Light Source is the UK's national synchrotron science facility. By accelerating electrons to near light-speed, Diamond generates brilliant beams of light from infra-red to X-rays which are used for academic and industry research. It is located on the Harwell Science and Innovation Campus in Oxfordshire.

Science at Diamond

Over 2,000 scientists use Diamond to conduct experiments in a wide range of disciplines including structural biology, health and medicine, solid-state physics, materials & magnetism, nanoscience, electronics, earth & environmental sciences, chemistry, cultural heritage, energy and engineering. Diamond is free at point of access for academic researchers, provided the results are in the public domain.

This work now generates hundreds of research papers every year, many in leading scientific journals, and the rate of publication continues to increase as the facility expands. Diamond increasingly supports industrial research and development, technology and innovation. We are currently working with a wide range of companies including Rolls Royce on aerospace and energy applications, Pfizer and GlaxoSmithKline on drug discovery and development, and Johnson Matthey on improved emissions control catalysts.

www.diamond.ac.uk/Home/Science

Some current research projects

- Understanding how HIV and other retroviruses infect human or animal cells
- Virus research to assist with a fast global response to new outbreaks
- Studying protein structures to improve chemotherapy drugs for cancer
- Investigating tissue to improve metal hip replacement technology
- Engineering experiments to reduce stress in aero engines
- Developing efficient, cost-effective and flexible thin polymer films for solar cells
- New materials for hydrogen storage fuel cells
- Molecular magnetism to develop new generation semi-conductors
- Investigating the composition of meteorites and comets
- How gases behave under extreme pressure within stars and planets

New frontiers in research

The UK government and Research Councils have identified six priority areas for research. As a key science facility, Diamond is using world-leading synchrotron technology to meet these challenges.

Digital economy

Understanding matter at the nano-scale enables us to create revolutionary new materials and technologies. Magnetic phenomena, such as giant magneto-resistance (GMR) have led to dramatic improvements in data storage. Being able to manipulate nanoparticles has potential for engineering materials from their atomic building blocks with unprecedented precision. A group led by Geoff Thornton at University College London have been using Diamond to develop techniques for growing nanoscale wires particle by particle.

Energy

Secure and sustainable energy supplies are vital to our future. Scientists researching solutions use Diamond to develop and refine new and renewable energy technologies. Solar power has great potential for meeting our energy needs, but existing solar cells are expensive and difficult to produce in large areas. Scientists from the universities of Sheffield, Cambridge and Cardiff are collaborating to develop commercially viable flexible thin polymer films to capture sunlight and turn it into useable energy. They are using Diamond to investigate the nanoscale properties of these films to bring about the efficiency improvements that are needed.

Environmental change

Environmental remediation, the removal of pollution from soil and water, has an important role to play in protecting health and biodiversity, and preparing contaminated land for redevelopment. Environmental scientists are using Diamond to advance understanding of how these processes work in living organisms and complex organic materials. Scientists from the University of Reading have been using Diamond to study earthworms to see what is happening to the heavy metals they ingest along with the soil. This is important because worms, bacteria and other organisms can help clean up sites contaminated by industry and mining.

Food security

Over half the world's population rely on wheat for their basic food. Increasing the nutrient content of white flour could significantly improve its value as a basic food. Scientists from BBSRC Rothamsted Research, the UK's leading agricultural research centre, are using Diamond to pinpoint the location of essential nutrients within wheat grains and gather data about their concentration, composition and digestibility. The technique could revolutionise bread-making and boost the natural iron and zinc content of wheat products.

Global uncertainties

The impact earthquakes have on the earth's surface is well documented. However, much less is known about what happens deep in the planet's interior. An international group of researchers have been using Diamond to study the mineral ferropericlase over 300 miles (670 km) deep in the lower mantle. By simulating the high temperatures and pressures, this can provide clues to how earthquake waves propagate. Another team has been using Diamond to study nuclear waste remediation, an area which requires ongoing attention as more countries develop nuclear programmes.

Health & wellbeing

Our bodies are amazing, but nature isn't perfect. During our lifetime, most of us will suffer from conditions or diseases that require medical attention. 40% of Diamond's work is in the broad area of life sciences. This work ranges from using macromolecular crystallography (MX) to work out the complex 3D structure of thousands of vital proteins to understanding how metal affects the brain. For example, researchers are using Diamond to investigate the mechanisms behind the early rupture of amniotic membranes, which account for nearly half of premature births.