Getting to the heart of the matter

A new 'super X-ray' machine promises improvements in health, industry and technology, says ***Dr Andrew Taylor***

Future aircraft: Airbus has used the Isis facility since 2006

As scientists at Cern in Switzerland endeavour to fix the world's most powerful particle accelerator, researchers from the Science and Technology Facilities Council are this month firing up their own device: the Second Target Station, a "super-microscope" that uses beams of neutrons to examine the molecular structure of materials ranging from aircraft wings to shampoos and fabric conditioners.

The Second Target Station is part of the Isis facility at the Rutherford Appleton Laboratory in Harwell, Oxfordshire. This cutting-edge piece of machinery – built over five years, at a cost of £145 million – was fired up for the first time last month, and takes only seconds to produce digital images of molecules jostling into position.

The way it works is essentially a hybrid of particle accelerator and X-ray device. To start with, groups of protons are fired through a circular particle accelerator that covers an area the size of a small village, making 10,000 circuits (the equivalent of travelling from London to Aberdeen and back) within 10 milliseconds. Once the protons – which are fired in 50 batches every second – have reached 84 per cent of the speed of light, they are fired at a small tungsten target, no bigger than a packet of biscuits.

As with an atomic reaction, the proton bombardment generates a stream of neutrons, which are channelled towards 30 separate instruments. Each uses the stream of neutrons as a kind of "super X-ray", monitoring how they scatter off the atoms inside the target materials and thereby revealing their atomic structure, at scales 10,000 times thinner than a human hair.

The idea of "neutron scattering" is nothing new – the Isis Pulsed Neutron and Muon Source (to give it its full name) has been generating neutrons since 1984, and has established itself as a world leader. But as materials science grows more complicated, and the demand for such services increases, it has become crucial to stay ahead of the pack, especially with the Americans and Japanese spending more than a billion dollars each to construct similar facilities.

> *The research at Isis touches on almost every walk of life*

The reason why there is such interest – and such demand for the Second Target Station's services – is that the research at Isis touches on almost every walk of life.

For example, hydrogen-power cars have been much talked about, as a way to reduce our dependence on fossil fuels and eliminate harmful emissions (as the only by-product of the reaction would be water). However, the car industry has yet to find a safe, low-cost way to store hydrogen: Isis is being used to study materials at the atomic level that could store the hydrogen and allow us to use that power on our roads or in our homes.

Isis also helps engineering firms assess the quality of their components, and make lighter and safer parts at a lower cost: Airbus has used the facility since 2006 to research the integrity of welds in aluminium alloys, and to assess their suitability for future aircraft programmes.

Then there is the medical aspect: scientists are working with medical researchers to develop a glass that could replace bone transplants, of which more than 300,000 are needed in Europe each year. This new type of glass would release calcium into the body as it dissolved, which could one day prevent the need for surgery by enabling patients to regrow their own bones. Using neutron scattering, we can see how the calcium is stored in the glass and how it is released. Last year, the system was also used to analyse the human body's most common antibody, immunoglobin A, and to understand how pollution moves through river systems at the molecular level.

In other words, the Second Target Station will enable scientists to explore and create super-fast computers, more effective drugs, cleaner energy and better materials. By studying the behaviour of materials at the atomic level, we can make breakthroughs in research that will underpin the technologies of tomorrow – and perhaps solve some of humanity's most pressing problems.

Dr Andrew Taylor is director of facilities development and operation at the Science and Technology Facilities Council, which oversees Isis