Synchrotrons, ships and sulphur: Using a particle accelerator to help conserve the Mary Rose

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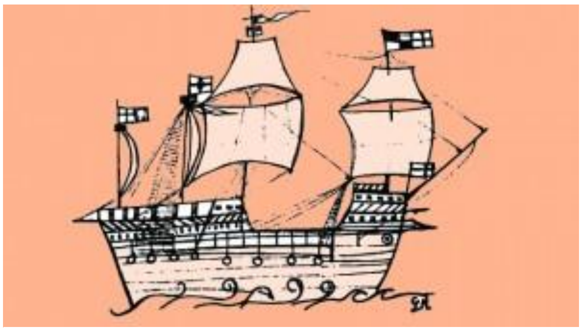

Artwork by Sophia Malandraki-Miller

A few miles outside of Didcot, housed within what seems to be a flying saucer stranded in the Oxfordshire countryside, is one of the UK's biggest and most expensive scientific instruments. This is Diamond Light Source, the country's national synchrotron, which produces intense beams of light used in a variety of research techniques. *Bang!* was recently invited to Diamond to take a look at the facility and find out about some of the cutting-edge research taking place there.

Throwing some light on Diamond

A synchrotron is a kind of particle accelerator, which produces light by accelerating electrons around a curved path. The video below describes the process involved in generating this light at Diamond.

http://www.youtube.com/watch?v=_xv_GwCgpAc [Video embedded on blog]

An electron beam is first produced by an electron gun, and accelerated through two devices: a *linear accelerator* and a *booster synchrotron*. Once the electrons are travelling at close to the speed of light, they enter the 500m-long *storage ring*, made of up 24 straight sections joined together, forming a circuit following the circumference of the facility. Electromagnets are situated at the joints of the sections, which cause the electrons to curve, producing the synchrotron light utilised by the researchers at the facility. Light is also produced by other magnets situated in the straight sections of the ring – these *insertion devices* cause the electrons to oscillate along their path.

Experiments themselves are conducted in individual 'beamlines' situated at points along the storage ring. The synchrotron light passes into the beamline, where it is filtered and focussed before being utilised for whatever experimental technique that particular beamline is set up for.

And there is a huge number of different techniques being used across the 22 beamlines so far constructed at Diamond. Some researchers use the synchrotron to determine a substance's atomic structure, by shining X-ray light on to the material and examining the diffraction pattern this produces. Others use the light to produce high resolution X-ray images of samples. Yet other groups use spectroscopy to elucidate a substance's chemical composition (more on this below!).

The diverse range of experimental methods available at Diamond means that scientists from all disciplines use the facility, as this list of recent publications shows.

Researchers use the synchrotron to study everything from neurological disease to nanotechnology. Unsurprisingly, "beamtime" is highly sought after, with over 3000 researchers using the synchrotron per year – and many more applying to do so.

Save Our Ship

One of those fortunate enough to get some beamtime was Dr Eleanor Schofield, conservation manager at the Mary Rose Trust. Together with Professor Alan Chadwick from the University of Kent, Dr Schofield is utilising the synchrotron to aid in the conservation of the *Mary Rose*.

The *Mary Rose* was Henry VIII's flagship, which served for many years before sinking in 1545 during the Battle of the Solent against France. She remained largely undisturbed until her rediscovery, embedded in the sea floor, in the early 1970s. This was followed by an ambitious recovery mission which culminated in the raising of the wreck in 1982.

Since her recovery, the *Mary Rose* and other artefacts from the wreck have undergone extensive conservation efforts. The problems of trying to preserve a ship that had been underwater for over 400 years were considerable. The ship's timber was so waterlogged that allowing it to dry out would cause shrinkage of up to 50%, warping its structure. Exposure to oxygen was also a problem: the ship had survived underwater for so many centuries because she had been submerged in silt, preventing oxygen from reaching the wood of the ship. This shielded the *Mary Rose* from attack by micro-organisms that rely on oxygen for respiration.


The *Mary Rose* at her current home in the Mary Rose Museum in Portsmouth

To overcome these issues, the *Mary Rose* was sprayed constantly with cold water, to stop the wood from drying out and to prevent attack by micro-organisms. Then from 1994, polyethylene glycol (PEG) was introduced into the water spray. This is absorbed into the wood and gradually replaces the water in the cellulose. The sprays have now been turned off, and the *Mary Rose* is drying. In a few years the ship will have dried off with her structure intact.

But there is another problem that comes from exposing the *Mary Rose* to oxygen again. When the ship was underwater, reduced sulphur compounds had been introduced into the wood from the surrounding environment. Buried in the silt, this was not a problem, but exposure to oxygen causes these to oxidise, creating sulphuric acid which deteriorates the wood. This is particularly an issue in areas of wood where there is a large proportion of iron ions, for example near bolts and nails. These ions act as a catalyst for the oxidation of sulphur compounds, thus increasing the production of sulphuric acid.

Old meets new at the synchrotron

Now that the PEG sprays have been turned off, it is important to determine the extent of ongoing sulphuric acid production in the ship's timber. Dr Schofield is currently making use of Diamond to examine the sulphur content of wood samples taken from the *Mary Rose*, in order to establish whether sulphuric acid is present in the ship and if so, how this is changing over time.

Dr Eleanor Schofield analysing a sample from the *Mary Rose*. *Image courtesy of Diamond Light Source*

The technique that the group is using is called X-ray absorption spectroscopy. Every atom has a specific wavelength of X-ray light to which it is sensitive, termed the atomic absorption edge. If you shine light onto this atom at this wavelength, it will release a core electron (that is, an electron not involved in bonding). Instruments measure the fluorescence associated with the release of the electron. Elements within a sample can therefore be identified by determining the wavelength at which electrons are released.

Dr Schofield's work relies on the fact that different oxidation states of the same element have different atomic absorption edges. Thus X-rays with longer wavelengths are needed to release an electron from reduced sulphur compounds than for those compounds that have been oxidised into sulphuric acid. In this way, different forms of sulphur present in the wood can be identified.

The work on the *Mary Rose* is important because it is the first time X-ray absorption spectroscopy has been used to examine the sulphur content in wood during the drying phase of PEG treatment. PEG is commonly used in maritime archaeology, so conservationists around the world are eager to know what happens to the sulphur content in the wood once the sprays have been turned off.

It was fascinating visiting Diamond and learning how a state-of-the-art particle accelerator can be used to assist in the conservation of a 500 year-old ship. With any luck, the work that Dr Schofield's group is doing at Diamond will help preserve this treasure for generations to come.

Diamond Light Source hosts regular public open days throughout the year. If you would like to sign up to find out when registration opens for the first Inside Diamond open day of 2014, please e-mail diamond.communications@diamond.ac.uk*. Visit Diamond's website for more information on the facility and the science happening at the synchrotron.*

The Mary Rose *is on display in the newly opened Mary Rose Museum at the Historic Dockyards in Portsmouth.*