Seeing with Atoms by **Professor Paul Dastoor** with **Dr David Ward** on 15 -11-19

He began by saying that all science starts with an observation – and how the observation is made. The human eye can resolve about 50µm; with a good microscope this can be reduced to 0.1µm (100nm). X-rays can resolve 30nm. An electron microscope 1-10nm.

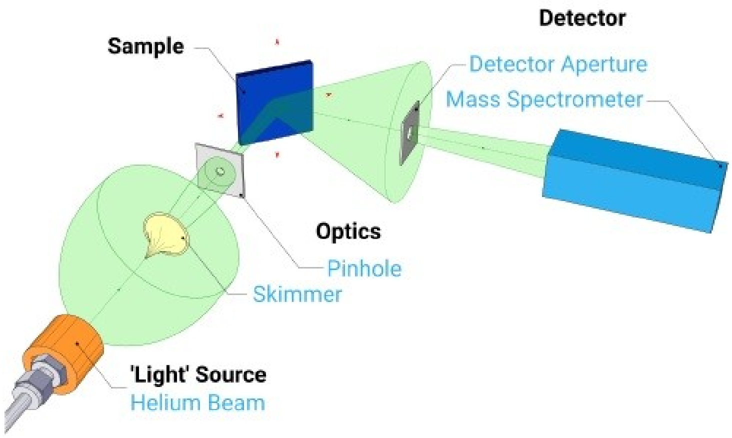
Sunlight conveys energy - clothing often fades if left in the sun, showing that has enough energy to cause a chemical reaction. Electromagnetic radiation is made up of photons whose energy increases at shorter wavelengths. Visible light is a band in the spectrum of electromagnetic radiation to which the eye is sensitive.

Shorter wavelength electromagnetic radiation, such as X-rays, have more energy than visible light, and can damage the material one is studying. An electron microscope, with electrons of higher energy still, can do significant damage to some materials, so that what they show is not is not an accurate picture.

To find the photon energy (E) in electron-volts (eV), using the wavelength (λ) in micrometres (µm), the equation is approximately: $E = 1.24 / \lambda$ For visible light this comes to about 2 eV.

The energy of a chemical bond is about 1eV. hard X-rays, 5-10 keV - with a wavelength of 0.1-0.2 nm, similar in size to an atom – are destructive (for instance used medically to destroy cancer cells); electron microscopes, although giving very high resolution, at 10-100 keV, are potentially even more destructive, and sample preparation is essential.

A Helium microscope uses He atoms with an energy of 0.05 eV – the wavelength is 0.025 nm, much less than a typical bond length of 0.1nm. They are totally non-destructive, indeed they cannot penetrate a surface. A beam of He atoms will be reflected off a surface at an angle determined by its roughness or softness.



Professor Dastoor's team have built two **Scanning Helium Microscopes** (SHeM) – one in Cambridge the other in Newcastle. Helium at 100 bar pressure is released and collimated through a 'skimmer' to remove the outer atoms and then a 10 µm pinhole in a Silicon Nitride membrane, leaving a near constant wavelength beam of 10^{14} atoms/sec. The beam is directed at the target and the scattered atoms are first ionised, enabling them to be accelerated, then detected with a mass spectrometer.

It can take hours to generate a good image, though they are refining their techniques to improve the sensitivity of the apparatus, the proportion of He atoms detected rising from 1 in 10^{-5} to 1% , with 25% in prospect, and correspondingly quicker image times.

Nothing is transparent to a helium beam, only surface reflections can be seen, either from surface detail or impurities. The first three of four pictures of a logo printed on a substrate in Nickel, Gold, Chromium and Platinum showed the logo in in different intensities, but the Platinum, with the same reflectivity as the substrate, did not show up at all. A picture of a bee's wing showed its structure in fine detail. [cf. the dragonfly wing in the write up on Bio-Inspired Technologies, 17 May 2019.]

A piece of shark skin showed that it was covered in fine 'teeth', smooth on one side jagged on the other, which helps the shark to swim faster. These are a type of trichrome, others being hairs on a leaf, scales, etc.

Beams of different atoms are being considered to see what other effects might be observable.

Organic Electronics by **Professor Paul Dastoor** on 15-11-19

Professor Paul Dastoor spoke briefly about developments and applications of semiconductor polymers.

Unlike conventional semiconductors, based on crystalline silicon and similar materials, these are flexible, and can even be made up as a paint. His first example was a water based solar paint, which could be applied to a PET sheet, then be sealed under another PET sheet. An early design managed 2½ % efficiency (compared to 17% for a conventional solar panel) but similar in cost for a given output, provided one had a sufficient area for the installation. Its durability is poor, but improvements are in hand. And it is entirely recyclable.

Another application was a patch that a diabetic could put on their tongue to check their blood glucose level. It has to be quite sensitive as the surface of the tongue only has about 1% of that of a direct blood sample.

Organic PhotoVoltaic materials can be used for imaging, probably not at a high rate, but adequate for many applications. They could be used in engineering and biological systems.