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Double whammy in microscopy

A refinement in electron microscopy promises 10 to 100 times finer views of magnetic properties of materials than possible so far, says S.Ananthanarayanan.

Microscopy has depended on light being bent in lenses and helping create enlarged images, something like the simple magnifying glass. And then, light of shorter ‘wavelength’, like blue light, rather than red, threw sharper images. And, as X-Rays have even shorter ‘wavelengths’, X-Ray microscopy was ‘high resolution’ indeed.

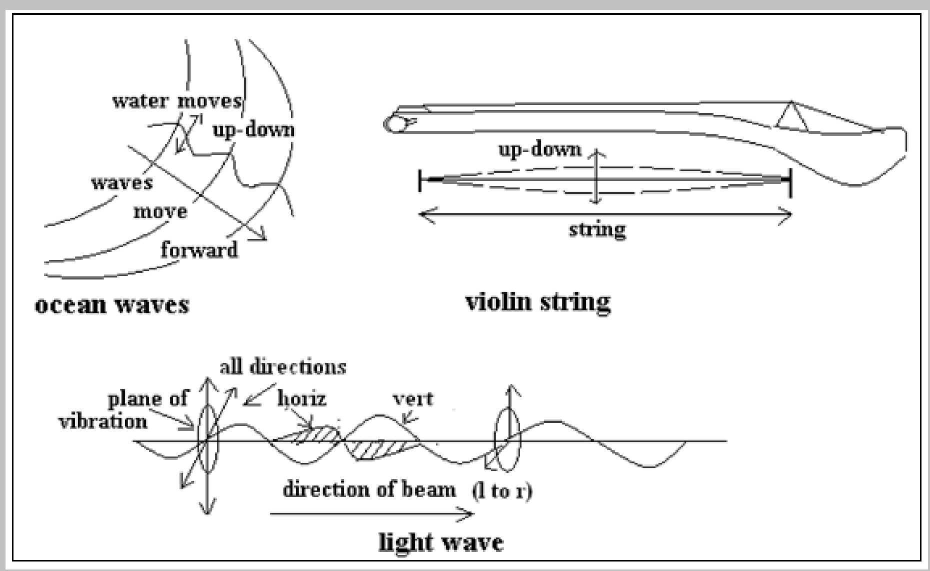
Theory of relativity

Albert Einstein was able to show that the mass of a particle was the same thing as a certain amount of energy. His $E=mc^2$ relation is legendary. As waves also had energy that depended on how short their wavelength was, it was not long before it was shown that beams of material particles, like electrons, could look like light waves too, and of very short wavelengths. This threw up the possibility of ultra high resolution microscopy using a beam of electrons, in place of X-Rays!

Beams of high energy electrons were focused on slivers of metals, bacteria, fossils, and with magnetic fields used to bend the electron beams, rather than glass lenses, electron microscopy has been the standard for the most examining of things at the finest scale, almost the level of individual atoms!

Dichroism

Along with the property of scattering radiation, which enables microscopy, some materials have different effects on different parts of the light falling on them. What are these ‘different parts’? Well, like ocean waves or the vibration of a string, light is a wave that oscillates in the plane at right angles to the direction of motion. A glance at the picture will make this clear.



But the difference with light is that the movement need not be only ‘up-down’ as in ocean waves, or in any one direction, as in a string, but may be in all directions in that right angled plane.

This is where some materials, called optically active materials, differentiate between light waves that are vibrating in different directions. Some parts of the light falling on such a material thus pass through at one speed while other parts of the light pass through at a different speed. The mix of directions of vibration, or the ‘polarisation’ then undergoes a change.

This effect, of splitting light into 2 parts is called dichroism. The name is not quite right, because the word suggests splitting into 2 ‘colours’, rather than polarization states, but the name has stuck.

X-Ray magnetic dichroism

This kind of effect in X-Rays, which, as we know, have very short wavelengths, when used with materials like iron, which have magnetic properties, enabled insight into very fine grained structure of the materials. It was found that the dichroism produced underwent changes when a magnetic field was switched on. With the help of the known wavelength of X-Rays and the known atomic structure of the materials, this change in behaviour with a magnetic field was able to reveal details down to nearly ten millionths of a millimeter.

The question was whether this could also be done with an electron beam? Electron beams are different from light beams in ways other than the wavelength alone. The main difference is that electrons are charged particles with a definite size and mass, unlike the photons, or particles of light and X-Rays. Electrons also have a different value of a property of ‘spin’, which means particles have some energy like what a spinning top has, apart from their energy of motion and the energy because of their mass. All this had suggested that magnetic dichorism with electron beams would need beams that had been specially prepared, at the very least.

But it works!

Researchers at the Vienna University of Technology at in Austria reported last month (in May 2006) that this kind of microscopy did work with a simple electron beam. They detected these ‘dichroism’ effects in a Transmission Electron Microscope and then compared the results with those of an X-Ray magnetic dichroism scan and other electron micrographs, as well as theoretical calculations. The result was that the technique showed consistent results and was hence one more weapon the scientists’ arsenal to probe the very small!

“A useful tool for investigating new materials for miniaturized recording devices, computers that store data using the spins of electrons, or even to probe bacteria that can sense magnetic fields”, scientists say.