James Clerk Maxwell was not only a leading scientist of his time, but his work was to form the basis of much of today’s technology. This lecture by Professor Andrew Walker FRSE, of Heriot-Watt University, provided a background to Maxwell and his connections to Dumfries and Galloway and an accessible explanation of some of his theories of colour and wave properties that are the foundations of photography and holography, illustrating how these techniques have recently been used to create a memorial of Maxwell himself in the form of a hologram of his statue.

James Clerk Maxwell 1831–1879
He was Fellow of Trinity College Cambridge, Fellow of Natural Philosophy at Aberdeen, Professor of Natural Philosophy at Kings College London and first Cavendish Professor of Experimental Physics at Cambridge. His short life was rich in distinguished contributions to every branch of physical science: heat, light, mechanics, above all by unifying the theories of electricity and magnetism. He established a sure foundation for modern physics, electrical engineering and astronomy and prepared the way for radio communication and television.

(Citation from James Clerk Maxwell Memorial, Parton Kirk)

Introducing James Clerk Maxwell to the audience, Professor Walker stated that “many would say he was one of the greatest physical scientists that ever lived; he laid the theoretical foundations of electromagnetism. The whole of modern technology is highly dependent on the theories he developed and the insight he gave us.”

Although born in Edinburgh, James Clerk Maxwell’s strong connection to the Dumfries and Galloway region stems from having been brought up at Glenlair House, near Corsock, Castle Douglas. He was schooled at Edinburgh Academy and his studies at the University of Edinburgh led to academic positions at Aberdeen University, Kings College London and Cambridge University. After his death, aged just 48, his remains were buried in Parton Kirk churchyard, where his memorial is now located.

Building on the earlier theories of colour, Maxwell’s early work developed these further and established the foundations on which colour photography and holography would subsequently be developed. Describing Maxwell’s colour wheel and tri-chromatic theory – which says that you can get any colour out of just three basic ones: red, green and blue – Professor Walker illustrated the principle of the additive mixing of colours, noting that red and green together form yellow. He contrasted this with subtractive colour mixing that results when an artist, beginning with a white sheet of paper, uses different coloured paints to filter out other colours. For example, yellow paint lets through the red, yellow and green light; whereas most blue paints transmit blue and green. When combined they leave only green reflecting from the white paper.

In 1855, aged 24, Maxwell gave a paper to the Royal Society of Edinburgh (RSE) where he proposed a method for using a three-colour technique for producing a coloured photographic image, which he successfully demonstrated in 1861, working in conjunction with photographer
Thomas Sutton. Reflecting his Scottish roots, the subject was a tartan ribbon. The essential details stand good today, in that colour TV operates with an additive colour-mixing process.

Continuing his work, Maxwell was to develop the foundations for understanding electromagnetism. His theories and calculations led him to conclude in 1862 that “we can scarcely avoid the inference that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomenon and that light itself, including radiant heat and any other radiations if any, is an electromagnetic disturbance in the form of waves propagated through the electromagnetic field according to electromagnetic laws”. Professor Walker noted the breadth of this conclusion, likening it to writing a patent that covers every aspect of the ‘invention’, particularly as Maxwell’s theory has subsequently proven applicable to the full gamut of em-radiation – from gamma rays and x-rays to microwaves and radio waves. Maxwell brought his concepts together with some very powerful mathematical techniques, which led to the publication of his two-volume *Treatise on Electricity and Magnetism* in 1873. Within it he developed the four partial differential equations – that would become known as Maxwell’s Equations and which form the basis of classical electromagnetic theory. The significance of these was subsequently summed up by the eminent 20th Century physicist, Max Planck, who stated “this theory must remain for all time one of the greatest triumphs of human intellectual endeavour”.

With this basic background, Professor Walker went on to highlight the work of two other scientists, who built on Maxwell’s contributions to develop colour photography and holography. The first was the Frenchman Gabriel Lippmann, who received a Nobel Prize in 1908 for his method of reproducing colours photographically, based on the phenomenon of interference. He used a pool of mercury as a mirror to reflect the light entering through the camera lens to create a standing wave, which could then be captured in a photographic emulsion. The image is recorded through variations in the intensity and wavelengths of the different colours causing changes in the optical properties of the emulsion which, when subsequently illuminated with white light, recreates the image in full colour. Further developing the Lippmann technique, the Russian physicist Yuri Denisyuk came up with a means of creating holograms. Light from a laser is shone on an object placed closely behind the photographic plate. The light scattered from the object interferes with the incident beam and the pattern is recorded. (Lasers are used because they produce very well defined single colours.) By shining a light onto the plate, after developing the exposed emulsion, the original pattern of light is reconstructed, allowing the viewer to see what appears to be the object still behind the plate.

In recognition of Maxwell’s very significant contributions in his field, which were, until recently, relatively unappreciated by the wider public, the Royal Society of Edinburgh commissioned sculptor Alexander Stoddart to create a statue of him to be erected in Edinburgh. At the same time, former RSE President Sir Michael Atiyah also wanted to “bring Maxwell inside the rooms of the RSE”. In a conversation with Professor Walker, the highly appropriate idea of creating a hologram of the statue was devised and subsequently approved by the sculptor.

Through a series of pictures, the whole process of creating the hologram or, to correctly describe it, a holographic stereogram, of the 2.5-metre statue was illustrated to the audience. A detailed planning process, including consultations with Colour Holographics based at Trinity Wharf, London, led on to a test photographic shoot at the Edinburgh College of Art in October 2008, with the assistance of photographer Zoe Gibson. To create the 3D image, a series of 200 pictures, three degrees apart and spread across an arc of 60 degrees, were taken using a camera mounted on a four-metre long arm pivoted around a vertical axis through the centre of the simulated statue.

The statue itself was fabricated at the Black Isle Bronze Foundry near Nairn. Once completed, to allow enough space for the photographic shoot, it was temporarily taken (on an open trailer) to a nearby hangar. There, the required 200 pictures were taken over a period of about two hours. Subsequently, the four Maxwell equations were added digitally beneath the statue images, such that each appears in turn as the viewing angle is changed. These images were
processed by Holographics North, a specialist holography company in Vermont, USA. This entailed two steps, the first to produce a master hologram, by exposing narrow strips from each 2D image in turn. Secondly, a single large hologram (~1 metre wide x 1.5 metre high) was recorded from this master such that, when reconstructed, all the necessary views of the statue are presented with the correct perspective. Finally, a reflecting layer was added to permit lighting and viewing from the same side. When not illuminated correctly (i.e. with green light from a vertical line of LED lamps, at the required angle) the hologram simply looks like a mirror.

The hologram was completed and delivered from the US in time to be framed and mounted for the occasion of the unveiling of the Maxwell statue itself in George Street on 25 November 2008. It was installed in the RSE's James Clerk Maxwell Room, where it remains on view. A small version was available for viewing at the lecture.

In addition to the recognition of Maxwell in Edinburgh, with the statue in George Street and the associated hologram at the RSE, Professor Walker concluded by highlighting some of the recent and on-going local activities in Dumfries and Galloway. These include the partial restoration by the Maxwell at Glenlair Trust of Maxwell’s family home, which had been seriously damaged, and the gravestone and memorial in the churchyard at Parton Kirk.

Questions

Professor Walker was asked what dictated the original decision to restrict the hologram to a 60-degree angle. He stated that this was on the advice from the consultants at Colour Holographics, based on the fact that it is difficult to get good reconstruction at wider angles.

An audience member noted that the colour of the hologram is an eerie green and, whilst this is very effective, it is also intriguing – why was this colour chosen? Professor Walker explained that it is easier to make the hologram a single colour, and in this case it is appropriate because the sculpture itself is essentially monochromatic. Whilst there was a choice of colours, the one chosen represents the verdigris of the statue.

When asked what is possible today in holography, with regard to colour and to the scope of angles, Professor Walker described that it is indeed possible to create a full colour, cylindrical hologram, but the image does need to be within the cylinder. It is not possible to project an image that sits on a table that you can walk around – this is still science fiction at present. The light has got to come from somewhere, i.e. be scattered off something.

Professor Walker was asked how the holograms used on credit cards relate to Maxwell’s Statue hologram. He noted that they are similar, as those used on credit cards are also not full holograms. They are known as rainbow holograms because they change colour. The Maxwell hologram, if lit with white light, would also be multicoloured.

The audience was interested to know why Professor Walker thought Maxwell’s achievements have not been celebrated until relatively recently, and what more could be done to make him better known. Professor Walker acknowledged that whilst Maxwell has been greatly celebrated by the cognoscenti, he was less well known by the general public. He considers a key challenge to be that Maxwell’s equations are difficult for the non-specialist to understand and therefore it is not so easy to appreciate why they are of such significance. More effort is needed in terms of general press and events such as this one organised by the RSE.

Opinions expressed here do not necessarily represent the views of the RSE, nor of its Fellows

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