http://www.bbc.co.uk/dna/h2g2/A2875430

Camera Obscura

Have you ever been sat in a darkened room, when it has been bright outside due either to the Sun or to a full moon? If so there may have been the tiniest chink in your curtains through which a light beam was able to enter, and this might have projected the inverted image of whatever was outside (eg a tree, a building) onto the opposite wall. If you have ever observed this, then you have experienced the effect of the camera obscura, which is really a room-sized pinhole camera. However, the camera obscura is usually fitted with a lens. The name 'camera obscura' comes from the Latin meaning 'dark chamber'. The camera obscura has been a source of fascination to people for hundreds of years; originally used to observe solar eclipses safely, they were recognised as an aid to drawing in the 15th Century, and by the 19th Century they had become popular sea-side attractions, much as binoculars are today. Some of these sea-side cameras obscura still exist today.

Early Observations and Use in Astronomy

The principle of the camera obscura was known to thinkers as early as Aristotle (300 BC) who, it is said, happened to be sitting under a tree (much in the manner of Sir Isaac Newton of 'falling apple' fame) during a partial eclipse of the sun. Aristotle described in his *Problemata* (350 BC) how, during the eclipse, the sun cast multiple crescent-shaped images of itself on the ground at his feet. This is because the movements of the leaves created transient gaps between them which behaved as pinholes allowing the sun's rays to pass through and cast images on the ground. Following this observation, Aristotle built his own device which consisted of a dark chamber with a single small hole to allow for sunlight to enter. Aristotle noted that no matter what shape the hole was, it would still display the sun correctly as a round object. His description of this device in *Problemata* is the earliest known written evidence of a camera obscura. Although no one is perfectly sure, many attribute the invention of the camera obscura to Aristotle.

The first scientific description of the camera obscura was by the Arabian scientist, astronomer and mathematician, Ibn al-Haytham (Alhazen) (965-1038). The son of a civil servant, Alhazen was born in Basra, Iraq. Yet he spent much of his live living and teaching in Cairo, where he conducting extensive experiments, many of which centred on a darkened room with a hole in one of the walls. On one occasion, five lanterns were suspended outside, adjacent to the wall containing the hole. He noticed that five 'lights' appeared on the opposite inside wall - however, when obstructions were placed between one of the lanterns and the hole, Alhazen observed that one of the 'lights' on the wall was no longer be visible. As the lantern, the obstruction and the hole were all in alignment, this experiment proved that light travelled in a straight line. Furthermore, he realised that although light from each of the lanterns travelled through the same hole at the same time, they did not become mixed up. This gave him pioneering insight into the workings of the human eye. Hitherto, people had believed the teachings of Plato and perhaps Aristotle, who believed that the eye sent out rays to scan objects; but Alhazen now realised the opposite to be the case - that light from the sun or another source was reflected into the eye from a person's observations. These insights, recorded in copious writings, thus refuted a thousand years of scientific thinking; indeed, the experiment provided the first scientific description of the 'camera obscura' (dark room). Alhazen's theoretical and practical approach, as well as the quality of his conclusions, gives him strong claim to the title of 'inventor of the camera obscura'. However, during the translation into Latin of his monumental work, *Perspectiva*, the first three chapters were omitted. These contained his studies on the camera obscura, and subsequent scholars had to rediscover these findings afresh. Alhazen's missing chapters were only discovered during the early 20th Century and were subsequently studied in depth.

Meantime, in 13th-Century England Roger Bacon was one of the scholars particularly drawn to scientific study. He had an eclectic range of interests including alchemy as well as optics, and these interests often found him in conflict with the Church. Despite spending many years in prison (from 1278 to 1292) he managed to write several major works, one of which focussed on the spiritual quality of light as the fundamental unit of all creation. In terms of scientific contributions, he invented the magnifying glass and foretold the possibility of telescopes and microscopes. In his more scientific texts, Bacon described the use of a camera obscura for the safe observation of solar eclipses.

Leonardo da Vinci (1452 - 1519) was also interested in the camera obscura, and proof of his experiments appears in several of his notebooks. He spent a considerable amount of time trying to understand human eyesight, and regarded the camera obscura as an 'artificial eye'. He was particularly perturbed by the fact that the image in the camera obscura was inverted, for this suggested that this occurred also in the human eye.

Correcting the Image in the Camera Obscura

In order to account for the fact that human beings see objects the correct way up, da Vinci put forward several suggestions, including that the eye had several lenses to re-invert the image. These ideas must have seeded the idea of adding a lens to the camera obscura to put the image the correct way up, but it was not until 1550 that Girolama Cardano, a physician, mathematician and professor explicitly suggested doing this. In 1558 the flamboyant thespian Giovanni Battista della Porta suggested the alternative of using a mirror to correct the image, and in 1569 the Venetian nobleman and scholar Daniel Barbaro reiterated the benefits of using a lens and a mirror, and made the further improvement of adding an adjustable diaphragm for the aperture. The camera obscura was now a self-contained instrument.

Use of the Camera Obscura in Art

Artists have long aspired to being able to paint pictures with accurate perspective to create a three-dimensional scene. By the late 15th Century a variety of mechanical aids had been developed, ranging from a simple grid frame to Sir Christopher Wren's pantograph. Successful use of these required considerable skill on the part of the user. It was Daniel Barbaro who first recommended the camera obscura as an aid to drawing. He wrote:

Close all the shutters and doors until no light enters the camera obscura except through the lens, and opposite hold a piece of paper which can move forward and backward until the scene appears in sharpest detail. There on the paper you will see the whole view as it really is, with its distances, its colours and shadows and motion, the clouds, the water twinkling, the birds flying. By holding the paper steady you can trace the whole perspective with a pen, shade it and delicately colour it from nature.

In essence, by hanging a canvas on the opposite wall to the lens of a camera obscura, one can faithfully reproduce the image - a little like painting by numbers! Later on, Giovanni Battista della Porta wrote that the camera obscura made it 'possible for anyone ignorant in the art of painting to draw with a pencil or pen the image of any object whatsoever'.

Meantime, in 1558, the 23-year-old della Porta published a miscellany of spells, potions, magic tricks and scientific experiments under the title of *Magiae Naturalis* (Natural Magic). He was entranced by the magical potential of the camera obscura and this book contains what is believed to be the first account of the possibilities of the camera obscura as a spectacular aid to theatre. It is said that he made a huge 'camera' in which he seated an audience, having arranged for a group of actors replete with horses, and exotic animals such as rhinoceros and elephant to perform outside, so that visitors could see their images on the wall inside. The story goes, however, that the sight of upside-down actors was too much for the visitors - they panicked and fled, and Battista was brought to court on a charge of sorcery! This was not healthy in those days - we all know what happened to Joan of Arc.

Following publication of *Magia Naturalis* the profile of the camera obscura was considerably enhanced, and it became very much more popular as a mechanical aid to drawing. Over the years there has been considerable debate about the possible use of the camera obscura by artists of the calibre of Vermeer (1632-1675) and Canaletto (1697-1768). Another artist known to have possessed a camera obscura was Sir Joshua Reynolds (1723-1792).

Contribution of Johannes Kepler

The German astronomer Johannes Kepler (1571-1630) lived during the time of discovery of the telescope, and was therefore very interested in astronomy. He also was one of the few vocal supporters of Galileo's discoveries and the Copernican system of planets orbiting the sun instead of the Earth.

Kepler was interested in concerns about the different apparent diameters of the moon when observed directly and when observed using a camera obscura. To facilitate his observations he built his own makeshift cameras obscura in the attics of his observation posts, where he allowed light to come in through a small aperture in the roof, and a sheet of paper formed the screen. Similarly he also blacked-out the window and allowed only a narrow ray of light to enter. During observations of the sun in Prague on 28 May, 1607, with Martin Bachácek at his home in Ovocný trh and later on with Heinrich Stolle in the Castle, they observed sunspots. At first Kepler ascribed his observations to a transit of Mercury, and it was not until later that he realised his mistake and made the appropriate corrections to his observations. This was an error which amazed later astronomers.

When Kepler first heard of the idea of incorporating a lens into the camera obscura, in della Porta's *Magiae Naturalis* he was somewhat dismissive as della Porta was clearly not a scientist. However, Galileo's invention of the telescope caused him to change his view, and Kepler subsequently came up with a series of great discoveries using a camera obscura with a lens. Thus, Kepler came up with the first correct mathematical theory of the camera obscura which he dealt with in his work *Astronomiae pars optica* and explained its optical representation.

Kepler's work on cameras obscura enabled him to solve one of the outstanding optical puzzles of the time - how the eye works, with an upside-down image formed on the retina - and thus he became the first person to make significant progress in our understanding of vision since al-Hazen. He correctly compared the camera obscura and the eye, taking the comparison further than da Vinci had in identifying the role of the lens and retina. He noted that if the back layers of the eye were to be peeled back, it would be possible to see the inverted image that would normally be cast on the retina.

This experiment was carried out in 1657 by the Jesuit scholar, Kaspar Schott, using an ox's eye. Kepler did not attempt to clarify how the image was re-inverted, merely stating that:

…whether it is made to appear before the soul or the tribunal of the visual faculty by a spirit within the hollows of the brain..... I leave to be disputed by the physicists.

As we now know, the image on the retina is not intended to be 'seen' but is sent via the optic nerve to the brain, where it is translated. These results were published in *Supplements to Witelo, on the Optical Part of Astronomy,* (Frankfurt, 1604).

In 1601 Kepler succeeded Tycho Brahe as Imperial Mathematician, the most prestigious appointment in mathematics in Europe. In this post, Kepler was required to produce topographical maps and drawings. He created a tent form of the camera obscura which was portable and allowed views to be easily, quickly and accurately traced. Diplomat and traveller Sir Henry Wotto was so enamoured by the images Kepler produced in his tent camera obscura that, in 1620, he wrote a glowing account of it to Sir Francis Bacon, describing it in detail. This tent-form camera obscura became very popular and was widely replicated throughout Europe. It was Johannes Kepler who, in the early 1600s, gave the camera obscura the name by which we now know it.

Astronomy

The major astronomical application of the camera obscura is for safely observing phenomena connected with the sun, for example eclipses and sunspots.

Eclipses

The first Astronomer Royal John Flamsteed (1646-1710) was appointed a member of a committee to study a method for determining longitude at sea. Flamsteed pointed out that this could not be achieved without obtaining accurate positions of the stars and moon. This led to the formation of the Royal Observatory at Greenwich. This was completed in 1676 and at some point between then and 1679 an Eastern Summer House was added which contained a camera obscura for solar observations. An engraving produced at this time has (in Latin) the inscription, ‘darkened room, very convenient for receiving sunspots and solar eclipses'. Flamsteed records its use during the eclipse of 2 July, 1684: ‘I observed the eclipse of the sun.... on a scene (screen) in a darkened room’. An illustration by Johannes Zahn from his *Oculis Artificalis* of 1685 shows a similar arrangement to the engraving of Flamsteed's camera obscura. The essential components are a microscope mounted in a 'scioptric ball', and a moveable viewing screen. The scioptric ball was developed by Daniel Schwenter in 1636, inspired by his studies of the human eye. It provided a firm anchor for the telescope whilst allowing the telescope to be swivelled in all directions in order to follow the course of an eclipse.

Sunspots

Sunspots are a phenomenon that has been known about for several thousands of years. There is evidence that the Greeks knew of them at least by the 4th Century BC and the Chinese had already made systematic observations 2000 years ago. Early observers would have been able to view the sun safely when its brilliance was filtered by the atmosphere near the horizon, and they would have observed these dark patches on the surface which we now call sunspots. A better method was to 'project’ the sun using a pin-hole camera or a camera obscura; and this is something the first Astronomer Royal, John Flamsteed may well have done.

Despite these early observations, it was only after the invention of the telescope, in 1609, that any real study of sunspots was possible. In 1610 (though he was not the first) the astronomer and mathematician Galileo Galilei made one of the first serious studies of sunspots. Discussion of the use of telescopes is outside the scope of this article.

Sunspots are usually seen in groups of two, and their duration can vary greatly. Some last for just a few hours, the longest (in 1943) about six months. The 'orbits' of the longer-lasting spots can be plotted since they can survive several revolutions around the sun; and by plotting their pattern over a period of time it is possible to firstly, gain an appreciation that the sun is indeed rotating and, secondly, to obtain an estimate for the period of rotation of the sun, which is about 31 days.

In 1843 the amateur astronomer Heinrich Schwabe noted that the number of sunspots follows a cyclical period of about 11 years. The year 2000 was a peak of the cycle, a period known as the Solar Maximum. This period of high activity is expected to drop steeply from then and begin building again in around 2005. There are two ways of plotting this cycle. One is to simply count the number of spots and by plotting the numbers against a time scale a periodicity can be determined. Another is by means of the so called 'Butterfly Diagram'. At the beginning of a new sunspot cycle sunspots appear mainly close to the Sun's north and south poles. As the sunspot cycle progresses more sunspots appear closer to the sun's equator. By plotting the latitudes of sunspots throughout the solar cycle we obtain a 'Butterfly Diagram'.

There is also a quantity known as 'sunspot number'. This is calculated by first counting the number of sunspot 'groups' and then the number of individual sunspots. The 'sunspot number' is achieved by adding the sum of the number of individual sunspots and ten times the number of groups. Since most sunspot groups have, on average, about ten spots, this formula for counting sunspots gives a reliable figure, even when the observing conditions are less than ideal and smaller spots are hard to see.

Discussion of the cause and nature of sunspots is beyond the scope of this entry, but in simple terms, they are caused by changes in the sun's magnetic field resulting in the creation of areas of lower temperature which are visible as dark spots. However, they are still in the region of 4,000°C. By comparison, the surface temperature is around 6,000°C.

There has long been interest in whether or not there is a connection between sunspot activity and the day-to-day variation in the weather on Earth. No such connection has been found although some scientists do make a link between climate change on Earth and state of the solar cycle.

FILMOGRAPHY

A camera obscura featured in a highly acclaimed 1946 film, *A Matter of Life and Death*, starring David Niven (GB 1946; 104m Technicolor - US title: *Stairway to Heaven*). This was inspired by a camera obscura installed at Portmeirion, Wales in 1922. In this film a pilot with brain damage after bailing out is torn between this world and the next, but an operation puts things to rights.

Leisure

Whilst the use of the camera obscura by artists required relatively small portable devices, during the early part of the 19th Century the camera obscura room became popular as a combination of education and entertainment. This was partly due to the development of the meniscus lens around 1812 by Dr William Hyde Wollaston. These improved lenses could cast larger and sharper images, all of which was in focus. This meant that the camera obscura itself could be made sufficiently large to accommodate a group of people, and such cameras obscura flourished at the seaside and in areas of scenic beauty. Many of the cameras obscura that were erected during the 19th and early-20th Centuries did not survive (some were only temporary structures which could be erected at holiday locations during peak season), yet a few can still be found today; some of the more notable ones are listed below.

A camera obscura was set up in the Royal Observatory in Edinburgh in 1835, and was opened to the public in 1856 by an optician, Maria Theresa Short. An updated lens arrangement was installed in 1957 and the camera obscura is still open to the public today.

The Clifton Observatory in Bristol was converted from a burned out snuff mill around 1828 by William West, and in 1829 he installed a camera obscura which is still open to the public (more information on these cameras obscura and others can be found by clicking on the hyperlinks at the foot of this article).

As mentioned earlier, a camera obscura was first set up at the Royal Observatory, Greenwich in the 17th Century. Since then, the Royal Observatory has housed several cameras obscura, which are described in more detail in the booklet, *The Camera Obscura and Greenwich* (see Bibliography). Just before World War 2, a combination of fog, light pollution from London and electrification of the Southern Railway affecting magnetic instruments caused the Royal Observatory to move out of Greenwich and in 1951 the Observatory buildings became part of the National Maritime Museum. In 1993 sponsorship by Glaxo Holdings enabled a new camera obscura to be installed for public viewing of the environs. In this camera obscura, the lens and mirror rotate automatically to afford a panoramic view of Greenwich and London.

Military

During the 1860's a room-sized camera obscura was used to conduct a military experiment at Anvers in Belgium. It was set up to present a view of the River Scheldt in which a mine had been placed, and the observers marked its position on the viewing table. An enemy ship passing over the mine could therefore be seen and as it approached the optimal position the mine could be exploded by remote control. The experiment was repeated in Venice in 1866, with more elaborate precautions to pinpoint the location of the mine. In this way both the position of the mine and the extent of the blast could be marked on the viewing table. This ingenious arrangement was never tested in action.

There is brief reference to the use of the camera obscura during World War 1 for observation purposes, but during World War 2 its use to observe and record the accuracy of target bombing by trainee pilots is well documented. The wartime camera obscura was a very simple apparatus, employed in both Britain and Australia, consisting of a canvas tent structure over a tripod with a hole containing a lens at the top.

The camera obscura was used:

- to test a pilot's ability to fly a straight, level and steady course
- to find wind velocity by day or night
- simulation of level bombing (day or night).

An image of the sky and aircraft was made on the viewing table in the tent. From observations and measurements it was possible to calculate whether a simulated bomb was on target.

A set of lecture notes issued by the Royal Australian Air Force in 1949 contained full instructions and formulae, and a metronome was used for timing.

The Royal Aircraft Establishment at Cardington had a camera obscura for the measurement and analysis of wind movements of clouds and the oscillations of tethered balloons. The RAE at Orfordness erected a permanent camera obscura around 1928-30 for the accurate determination of wind velocity at different altitudes.

The camera obscura which was installed at the Museum of Army Flying at Middle Wallop, Hampshire was used only for entertainment purposes and had no military function.

Camera Obscura and the Shroud of Turin

There continues to be controversy over whether the image on the Shroud of Turin is the genuine image of Christ, produced by some supernatural process at the instant of his death, or whether it is a medieval forgery.

Radiocarbon tests completed in 1988 appeared to show that the cloth was medieval, dating from between 1260 and 1390. During the mid-1990s a South African scientist, Professor Nicholas P Allen, conducted experiments to show that, if the image on the Shroud is of medieval origin, it could have been produced in a camera obscura.

He built a room-sized camera obscura containing a lens in one wall. On the opposite wall he suspended a cloth which had been pre-soaked in a solution of a (light-sensitive) silver salt. Outside the camera he suspended a manikin which had been coated in whitewash to reflect the rays of the sun to the maximum extent. After three days he had produced an image on the cloth which he was able to 'fix' by soaking the cloth in urine - a dilute solution of ammonia. The image possessed many of the three-dimensional features of the image on the Shroud of Turin.

All the necessary chemicals would have been available in medieval times.

Glass lenses for the medieval camera obscura would have just about been available. Until recently they were believed to have been produced in Europe from the end of the 13th Century. However, in 1998 archaeologists discovered some clear quartz disks at a Viking settlement in Sweden. These dated from 700-1000 AD. Although originally thought to be jewellery, it has since been found that they were sophisticated lenses.

If the image on the Shroud of Turin was produced in this way, then it would be a genuine photograph which pre-dated the official discovery of the photographic process (by Fox-Talbot) by several hundred years. It has been suggested that the image is that of Leonardo da Vinci, but this would appear to have been rebutted by a Channel 4's *Secrets of the Dead* documentary, because the image appears to be that of a genuinely crucified man.

Follow this link for an idea as to whose image might appear on the Shroud.

Cameras Obscura in Britain

- Visitors’ reports
- The Camera Obscura: A Chronicle. John H Hammond (Bristol, 1981)
- The Camera Obscura and Greenwich. Pip Brennan (National Maritime Museum, 1994)