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THE CINEMA IN FLUX

The Evolution of Motion Picture Technology from the Magic Lantern to the Digital Era

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4. Plateau Invents the Phenakistoscope

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Lanternists strove to project images in motion, but their work was limited to real motion effects, in which each effect required a specific solution. But every kind of motion could not be represented by the translation of slides or two-dimensional puppets on glass. The solution to the problem of creating any kind of motion did not spring from their efforts but rather from those of Brussels-born physicist Joseph Antoine Ferdinand Plateau (1801–1883), who discovered the principle of apparent motion. He was the first to demonstrate that the illusion of motion could be created by the proper presentation of a series of closely related incrementally different still images, an accomplishment that places Plateau in the company of the most significant inventors in the field of cinema technology, like Huygens and Edison, despite the fact that his work was limited to a direct view peepshow-type device rather than projection.

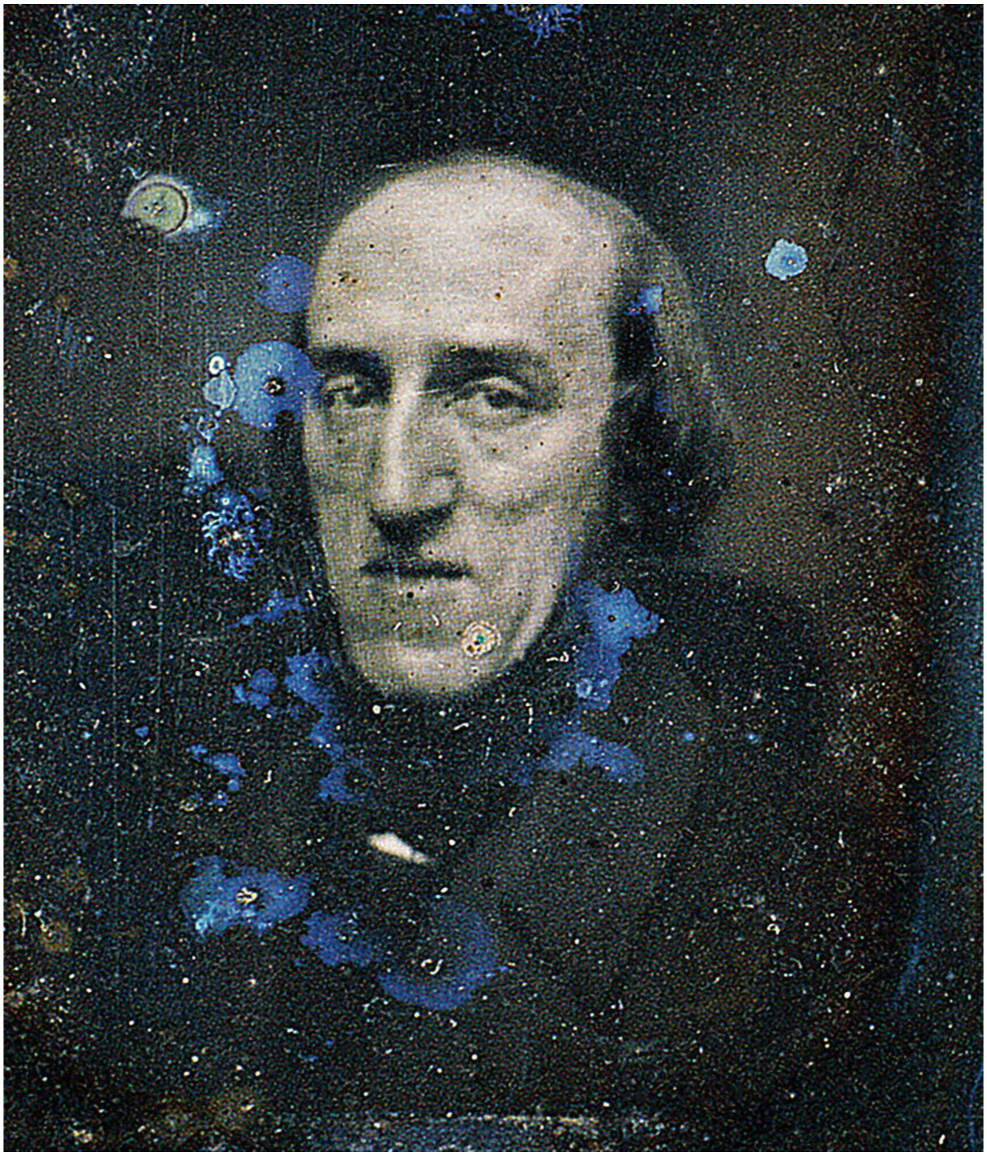

Fig. 4.1 Joseph Antoine Ferdinand Plateau. Photo taken in 1843. (Cinémathèque Française)

Plateau's father was an artist who wanted him to follow in his footsteps, but that was not to be. His father and mother died only a year apart, and from the age of 14, Plateau and his two sisters were raised by his lawyer uncle who wanted him to study law. While he dutifully pursued a law degree he remained driven by a love for mathematics and physics, which he went on to study at the University of Liège. Although he wished to obtain a doctorate, his plans were disrupted because of the need to provide for his sisters; after a delay he completed his dissertation in the field of visual perception and was awarded a degree in 1829. Plateau, in a truly ill-advised experiment, stared at the bright sun for almost half a minute permanently damaging his eyes leading to complete blindness by 1840 or 1841, a catastrophe that did not diminish his scientific output. His first major contributions were in the field of visual psychophysics, a term to describe the subject more often used then than now, in his case the perception of colors and the afterimages created by a moving bright light. However, he is best known for his later work in apparent motion, the illusion of motion, potentially indistinguishable from real motion (Quigley 1948). Physicists also know him for his work clarifying the geometry of minimal surfaces known as the Plateau Problem, which began with observations he made of soapy water and glycerin films.

The reader may be familiar with the streaking seen when Polynesian fire dancers twirl and throw burning torches: the effect on the eye is like that of a photographic time exposure. In 1765 Irish mathematician Count Patrick d'Arcy (1725–1779) sought to quantify the phenomenon, which he did by building a machine that rotated an iron rod with a burning tip at a precise rate. Plateau also attempted to measure the duration of the afterimage but for different colors, white, red, yellow, and blue, and in 1827 arrived at a figure of about a third of second for each (Hecht 1993, entry 134D). These experiments, and the work of Peter Mark Roget and Michael Faraday, would later provide the basis for Plateau's explanation of the phenomenon of apparent motion when he coined the phrase "the persistence of vision." The January 1821 *Quarterly Journal of Science*, published in London, ran a note signed by J. M., probably its chief editor, John Murray, calling attention to an unusual visual phenomenon he had observed: the spokes of carriage wheel, when moving rapidly, and seen through vertical fence posts, appeared to him to be a series of stationary curved lines (Mannoni 2000, p. 205).

Fig. 4.2 A Tahitian fire dancer in French Polynesia. (Photo by the author)

An explanation of Murray's observations was given in an influential paper, *Explanation of an optical deception in the appearance of the spokes of a wheel when seen through vertical apertures*, written by English-Swiss polymath Peter Mark Roget (1779–1869), which he read before the Royal Society in 1825. It was published in their *Philosophical Transactions*, wherein Roget (1825) writes: "The true principal, then, on which this phenomenon depends, is the same as that to which is referable the illusion that occurs when a bright object is wheeled rapidly round in a circle, giving rise to the appearance of a line of light throughout the whole circumference: namely, that an impression made by a pencil of rays on the retina, if sufficiently vivid, will remain for a certain time after the cause has ceased."

The paper was read by both Plateau and Faraday, which prompted each to build an apparatus to demonstrate and study the phenomenon. Writing decades later, Helmholtz (2005, p. 223), following up on the work of Roget, notes: “Here also should be mentioned certain curves that are seen when two sets of straight and curved rods are moved one behind the other. The first case of this kind (referring to Murray) to attract attention consisted of certain figures that appear on a carriage wheel when it goes past a row of paling.”

In 1828 Plateau built a laboratory device using vertical spinning counter-rotating disks to represent the “row of paling” and the carriage wheel in order to replicate Murray’s observation and to test Roget’s explanation, which led to his invention of the anorthoscope (described below) in 1836 (Hecht 1993, entry 137C). In 1830 Michael Faraday pursued the subject without knowing about Plateau’s work, which had been published in 1829. On January 21, 1831, in the lecture room of the Royal Institution, Faraday (1831) gave a demonstration of a similar apparatus that was dubbed the Faraday wheel (not to be confused with the Faraday disk, also sometimes called the Faraday wheel , the experimental device that led to the creation of the dynamo or electric generator) (Hecht 1993, entry 138B). The Faraday wheel worked on the same principle as Plateau’s device, which according to Hopwood (1899, p. 10) involved: “two disks with notched edges (that were) revolved at equal speeds in opposite directions by friction gearing.” When looking through the cogs of the nearest disks, it was perceived that the rear cogged disk appeared to be stationary. Faraday also explained that the effect could be achieved using a single spinning wheel’s reflection viewed through its cogs in a mirror, the arrangement used by the phenakistoscope, as we shall see. After having learnt of Plateau’s work, Faraday graciously acknowledged his priority. Helmholtz (2005, p. 223) describes the Faraday wheel (which applies equally to Plateau’s device) as follows: “The simplest illustration is the one observed by Faraday . He made two equal toothed wheels revolve rapidly in opposite directions one behind the other, their axes being in the same straight line. Owing to the rapidity of the motion, it was not possible to see the separate teeth of either wheel, but when he observed them so that one row of teeth could be seen through the other, he beheld a stationary wheel with double as many teeth.”

Fig. 4.3 A Faraday wheel from the collection of Will Day. Possibly the very one used in Faraday's lab. (Cinémathèque Française)

Faraday continued to work in this area and produced several variations, which may have influenced both Plateau and Austrian mathematician Simon Ritter von Stampfer (1790 or 1792–1864); they announced what became known as Plateau's phenakistoscope (to fool, to see) and von Stampfer's stroboscope (whirling, to see).[1] Plateau originally called it the Fantascope (the name used by Robertson for his projector) but yielded to popular usage based on a product of that name released without his knowledge or authorization. Plateau, unlike von Stampfer, did not patent the device or monetarily profit from it and publically deplored the cheap and inferior imitations of his invention on the market (Hecht 1993, entry 146B). Plateau's work preceded that of von Stampfer by 2 years according to Helmholtz (1962, p. 218). In his monumental *Treatise on Physiological*

Optics (Vol. II), he tells us, in a footnote, that Plateau sent a model of the phenakistoscope to Faraday in November 1830 and that von Stampfer completed his version in December 1832. (The date of the invention is given as 1833 in the literature.) The phenakistoscope is the device by which the natural phenomenon of apparent motion was first demonstrated, one of the technological underpinnings of the celluloid cinema.

The phenakistoscope consists of a vertical disk, 6–10 inches in diameter, which rotates around its central axis (Hecht 1993, entry 139B). This spinning flat wheel's periphery is arrayed with a series of, in some cases, 16 slightly different drawings of the phases of motion, often using figures of people, by Helmholtz's account (who helped to associate the term phenakistoscope with Plateau's invention) (Hecht 1993, entry 146A). This disk format is similar to that described by Zahn in the late seventeenth century. The disk, with the images of the phases of motion facing away from the user, is spun, and the images are viewed in a facing mirror through a series of narrow radial slits (shutters) located between each image. When so viewed the drawings are seen to have lifelike movement. The phenakistoscope was usually held by a handle or set on a stand and rotated. This simple device that provided the first demonstration of apparent motion was superseded by the easier to use zoëtrope, to be described in chapter 6.[2]

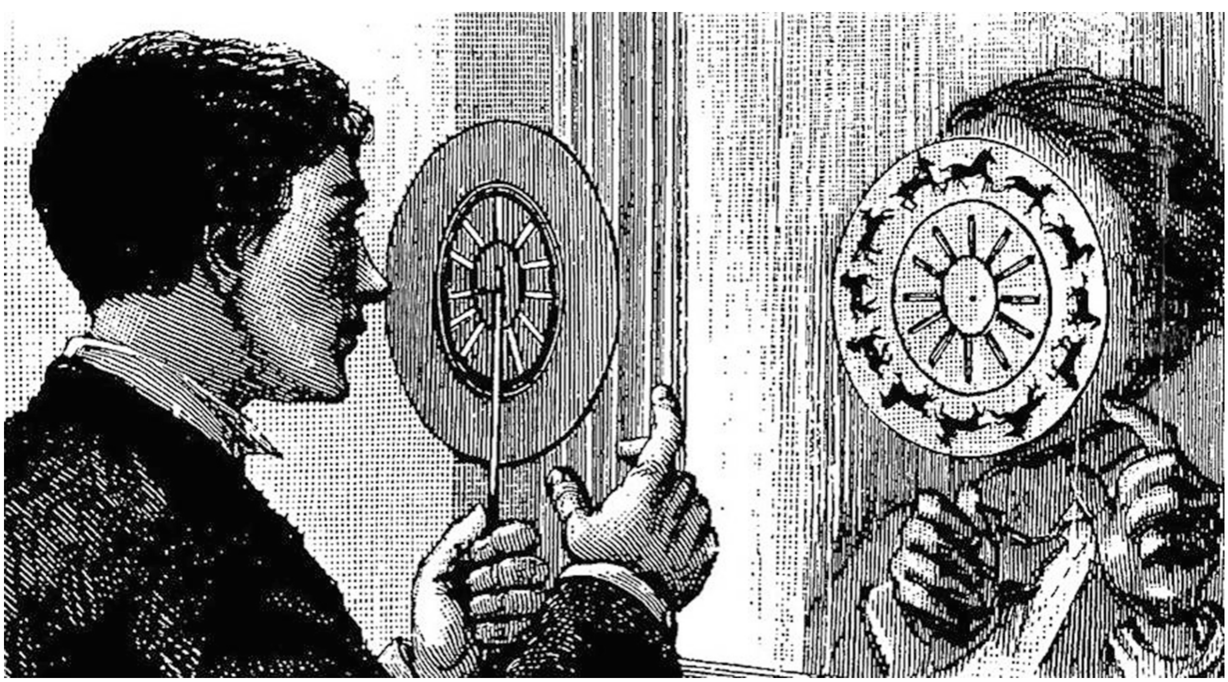

Fig. 4.4 The phenakistoscope. The user spins the disk and looks through the radial shutter slits to see the reflected images of the phases of motion on its inside surface. When doing so the images appear to be animated.

Fig. 4.5 A phenakistoscope disk. (Cinémathèque Française)

Viewing the phases of motion through the radial slit shutters of the phenakistoscope, or the zoëtrope, produces images that are elongated or compressed. When the image and the slit are moving in the same direction, as is the case of the phenakistoscope, the image is elongated; when it is moving in the opposite direction, as is the case with the zoëtrope, the image is compressed. For this reason, to have the drawings appear to have normal proportions, they were often drawn geometrically distorted to compensate. The origin of this anamorphosis is that the sampling rate is different along the length of the slit shutter – if the shutter operated instantaneously to pass light, there would be no distortion. To eliminate the compression of the image and to increase its brightness in 1869 physicist James Clerk Maxwell used concave lenses in place of the zoëtrope's radial slit shutters. With a properly chosen focal length, a virtual image of each drawing appears at the axis of the zoëtrope cylinder's rotation thereby remaining motionless until it is swept away by a successive image (Hopwood 1899, pp. 26, 27). This approach to optical image stabilization may have been the inspiration for Reynaud's Praxinoscope of 1877, which used mirrors rather than lenses.

Plateau also invented the parlor novelty the anorthoscope (I straighten, I see), which was introduced in 1836, which looks like a manually operated motion picture rewind. It consists of two vertically mounted counter-rotating disks set a small distance apart on the same shaft. The rear disk has a greatly distorted image, and the front disk has four narrow radial slot shutters through which the picture is observed. The hand-drawn or printed images look like they have been liquefied and spread across a circular surface, but when rotated and viewed through the counter-rotating radial shutter slits, they are returned to their intended proportions and can be viewed as recognizable images. When the user looks through the rotating radial slit shutters at the counter-rotating distorted image, along the length of a slit, different arc lengths of the image are seen at the same moment. (The technique somewhat resembles Nipkow disk scanning, as described in chapter 71). The result is that the observer's visual system integrates these scanned arc-elements of image into one undistorted image. The anorthoscope is a device that decodes a geometrically encoded image; it is not a moving image device. Roget's (1825) explanation of why Murray saw the spokes of a wheel as curved as the wheel passed behind the openings of fence posts is also a temporal sampling phenomenon involving retinal retention, but it is often misstated as being the basis for the phenomenon of apparent motion. Nonetheless, it inspired the invention of the phenakistoscope and the discovery of apparent motion.

It took a decade or so after Plateau's discovery of apparent motion before inventors adapted his discovery to the magic lantern to project moving images. Some of these magic lanterns used a disk whose periphery contained painted lantern slides that rotated continuously as they passed through the projector's gate. Inventor T. W. Naylor's motion projection device of 1843 is notable because it may be the first magic lantern design to adopt the phenakistoscope principal (Liesegang 1986, p. 35). However, there is no record of Naylor's "Phantasmagoria for the exhibition of moving figures" having been built or demonstrated (Mannoni 2000, p. 224; Hecht 1993, pp. 177). Naylor suggested the use of a disk shutter rotating in the same direction as the image disk, both of which were operated by the same handcrank. Both image disk and shutter rotated continuously with the shutter designed to arrest the projected images, just as it did for the phenakistoscope. In the case of Naylor's device, the image disk passed through the projector's gate, but the radial shutter disk passed between the projector's lens elements. Why place the shutter within the projection lens itself and not at some more convenient place? According to Hecht, the combination of a phenakistoscope and projector had been proposed earlier by both von Stampfer and Jan Purkinje (Purkyně) (1787–1869), the Czech anatomist who discovered that under certain conditions the eye can detect polarized light.

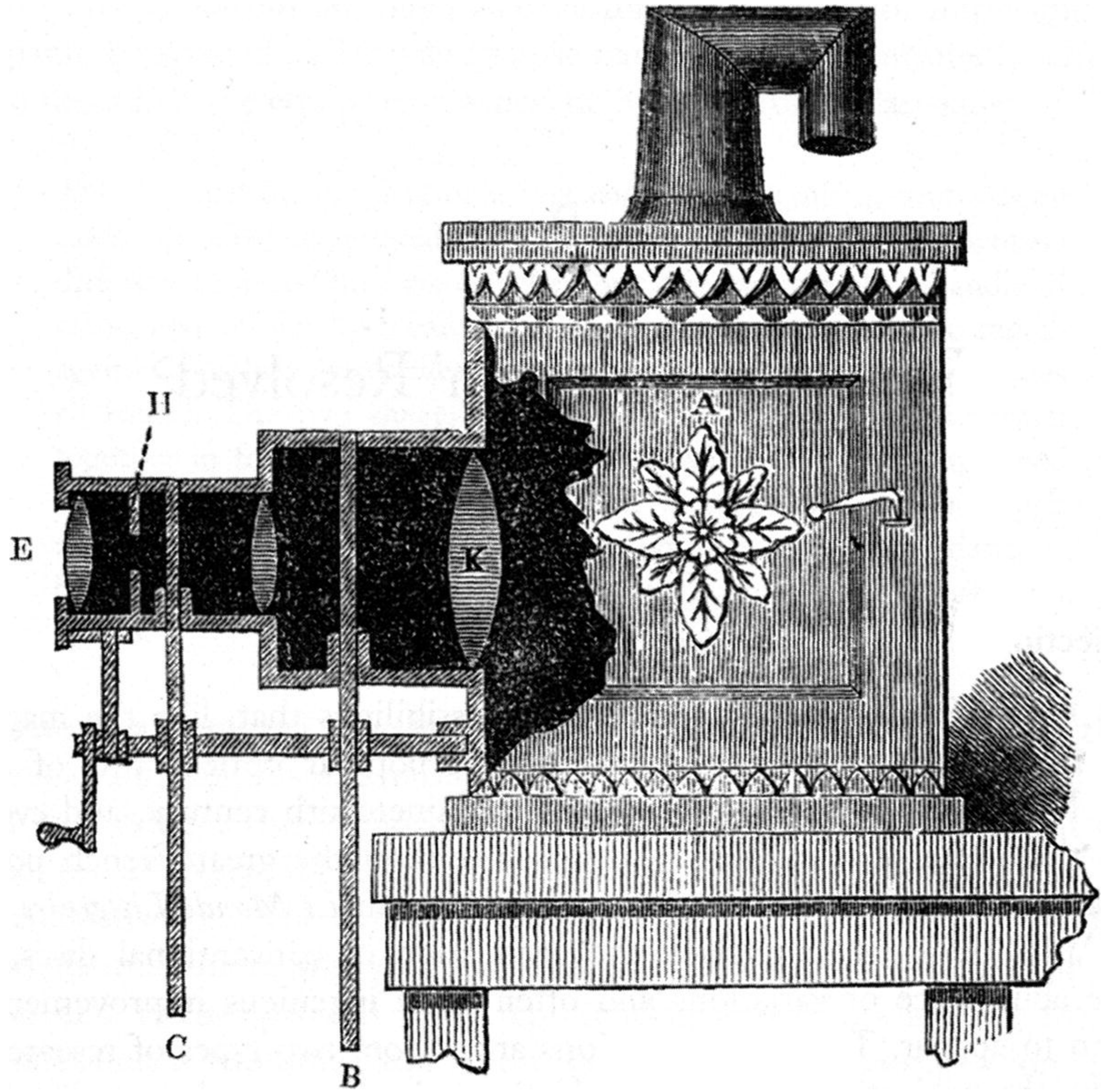

Fig. 4.6 Naylor's Phantasmagoria. The radial shutter disk C passes between the lens elements. B is the Zhan disk. (Mannoni 2000)

In 1845 Imperial Austrian Army Artillery Captain (subsequently General) Franz F. von Uchatius (1811–1881) built a projecting phenakistoscope, but unlike the Naylor suggestion, its shutter was in close proximity to the image disk; both it and the image disk were operated by a handcrank. The slides were about 2.4 inches in diameter illuminated by either limelight or an Argand oil lamp (Hecht 1993, entry 210; Liesegang 1986, p. 35). Because of the radial slit shutter's loss of light, the projected image was restricted to about 6 inches in width (Hopwood 1899, p. 17).

Features of the phenakistoscope were adopted by Uchatius and other inventors in their quest to project apparent motion, efforts that endured until the last years of the nineteenth century. A circular array of images was used, as slides at the outer edge of the disk, which unlike the drawings on the phenakistoscope disk are transparent to permit projection. The phenakistoscope disk is a self-shuttering apparatus, with the shutter slits located between the phases of motion, but projection required a separate shutter. The disk format, with its peripheral array of drawings of the phases of motion painted on glass slides, lent itself to projection, just as Zahn had suggested in 1685, but some interesting projection devices departed from this approach, such as Uchatius' next attempt.

Fig. 4.7 Franz F. von Uchatius

Uchatius constructed a more ambitious and unusual projector designed to improve image brightness. His new design used a motionless disk holding 12 painted slides of the phases of motion each one designed to project using its own lens. (This design has similarities to those later described by Le Prince and Jenkins.) Uchatius' projector used a rotating limelight and condenser ensemble, driven by a handcrank located at the back of the projector, which swiftly moved behind the fixed radial array of slides and lenses. Each lens, as the light source passed behind its slide, projected an image onto a screen, with the lenses adjusted so that the images were superimposed on the screen. The projector was first demonstrated to the Vienna Academy of Sciences in 1853 and the magician Ludwig Döbler successfully toured Europe using one that was built by the Viennese optician Prokesh. Uchatius' machine was capable of projecting an image about 2½ meters in width (Liesegang 1986, p.36).

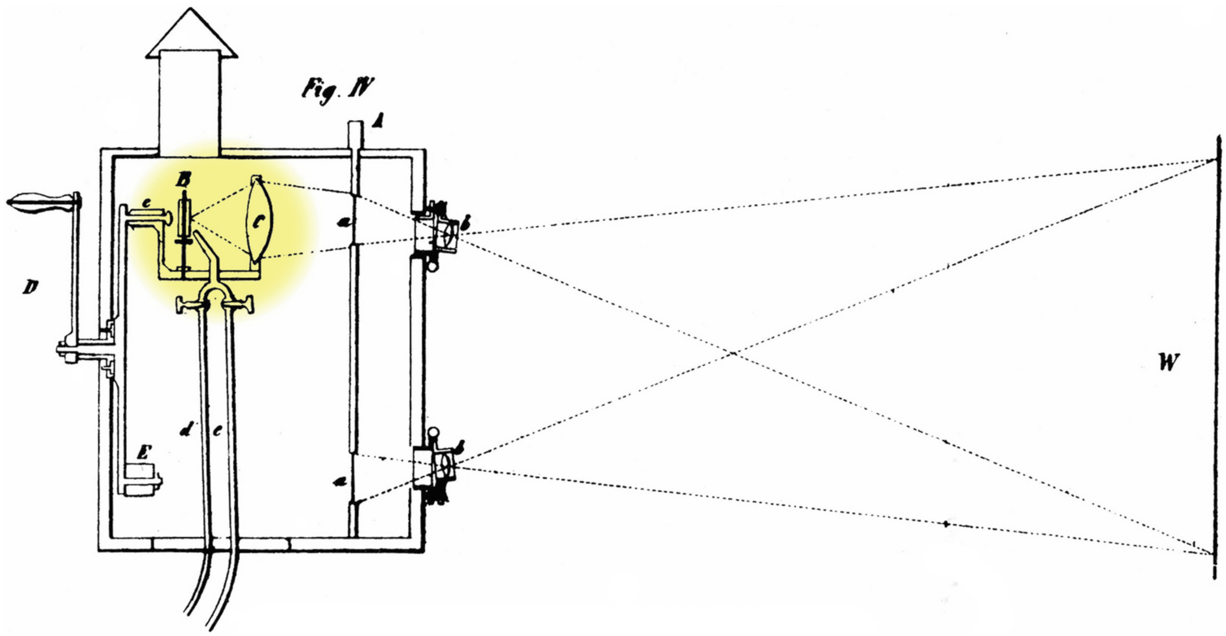

Fig. 4.8 Uchatius' projector used a rotating limelight and condenser (highlighted). This side view shows only two of the fixed slides and lenses.

Lionel Smith Beale (1828–1906), an English physician and professor at King's College London, in 1866 designed a slide carrier for the magic lantern, the Choreutoscope, which he did not patent (Liesegang 1986, pp. 31, 34, 36, 37). The Choreutoscope was popular enough to have become a generic term for similar devices offered for sale in the following years. It was appealingly compatible with existing magic lanterns turning them into apparent motion projectors. It consisted of a wooden frame slide carrier, which was designed to permit the horizontal travel of six hand-painted slides making up an animated sequence. With the continuous turning of a handcrank, the slides moved intermittently, each halting in the projector's gate to be moved along and replaced by the next slide. The Choreutoscope slide carrier fit into the gate of the projector without it having to undergo any modification and used a horizontally laid-out mechanism similar in function to a Maltese-cross movement (also called a Geneva drive after the clockwork mechanism) within the wooden carrier. During the time each slide was transported a vertical traveling or guillotine shutter occluded it to prevent image travel ghost (image smearing). One account has Beale performing a Choreutoscope projection at the Royal Polytechnic Institution, which was known for holding projection events, but Mannoni (2000, p. 233) believes it cannot be established for certain that this event took place.

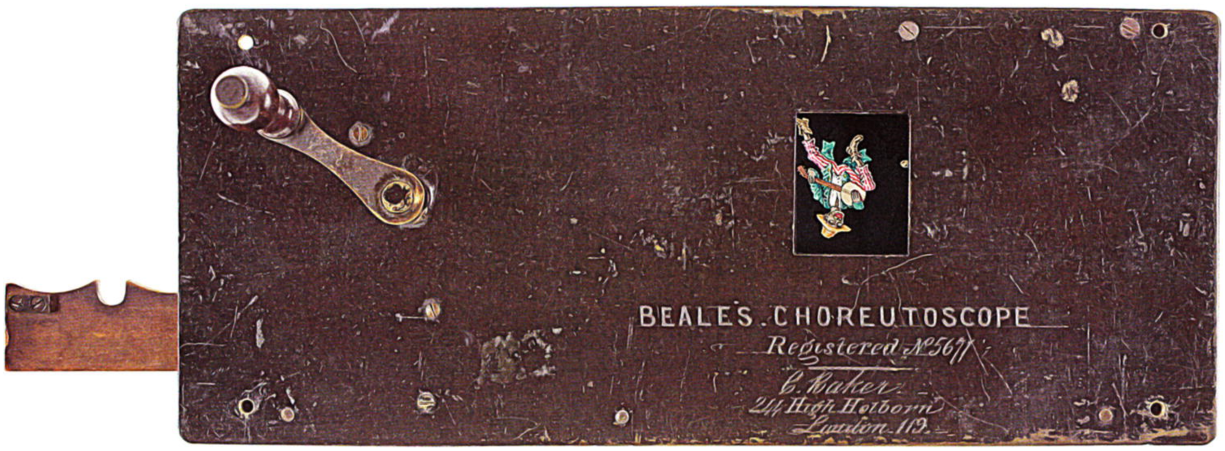

Fig. 4.9 A Choreutoscope slide carrier with an animation of a clown playing a banjo. Made by instrument maker C. Baker of 244 High Holborn, London. (Cinémathèque Française)

In November 2001, Christie's (2001) auction house, only a few miles from Beale's London birthplace, auctioned off a Choreutoscope for $1247. The animation of a crying baby, in various stages of distress, painted on six slides, was attributed to James Henry Stewart who was in the business of making Choreutoscopes. The notes of the sale state that the device lacked a handle, Maltese-cross movement, and metal shutter. There were not enough frames in the Choreutoscope's carrier to provide more than a moment of animation, but integrated into a magic lantern show, it would have added an interesting element and the duration of motion could be extended if the sequence was properly designed for shuttling it forward and backward. In 1884 W. C. Hughes was granted British Patent 13,372 for a magic lantern slide carrier based on Beale's Choreutoscope, an improvement according to Hopwood (1899, p. 20), which is an indication of decades of continued interest. The Choreutoscope continued to be developed until a decade before the invention of the celluloid cinema; its intermittent movement anticipates that used by 35 mm theatrical projectors and also cameras, but it's an open question as to whether or not celluloid cinema inventors were influenced by it. Therefore, however prescient its design may be, this invention's role or influence in the evolution of the technology is unclear.

American Obadiah B. Brown's *Optical Instrument*, USP 93,594, granted August 10, 1869, describes a magic lantern projector using a similar approach. Brown's patent does not give the filing date. (References to US patents are given as USP. The filing date is usually given since it gives a better idea of the date of conception than the date of issuance.) His Phoenocinopticon was based on a miniature Zahn polygonal disk array of paintings of the phases of motion. An intermittent mechanism stopped and started the disk's rotation to momentarily halt the slide in the projector's gate (Liesegang 1986, p. 37). The disk was, in effect, a rotated gear whose circumference was made up of teeth, edge driven by the stop-start mechanism. The disk and mechanism were built into a wooden slide holder, but despite this degree of compatibility, the Phoenocinopticon could not be used in a lantern unless it had a rotating shutter in front of the lens, namely, the two-bladed shutter disclosed in '594. The Beale and Brown approaches anticipate the coordination of image intermittency and shuttering that is the basis for celluloid cinema projection.

No. 93,594. PATENTED AUG. 10, 1869.

O. B. BROWN.

OPTICAL INSTRUMENT.

3 SHEETS—SHEET 1.

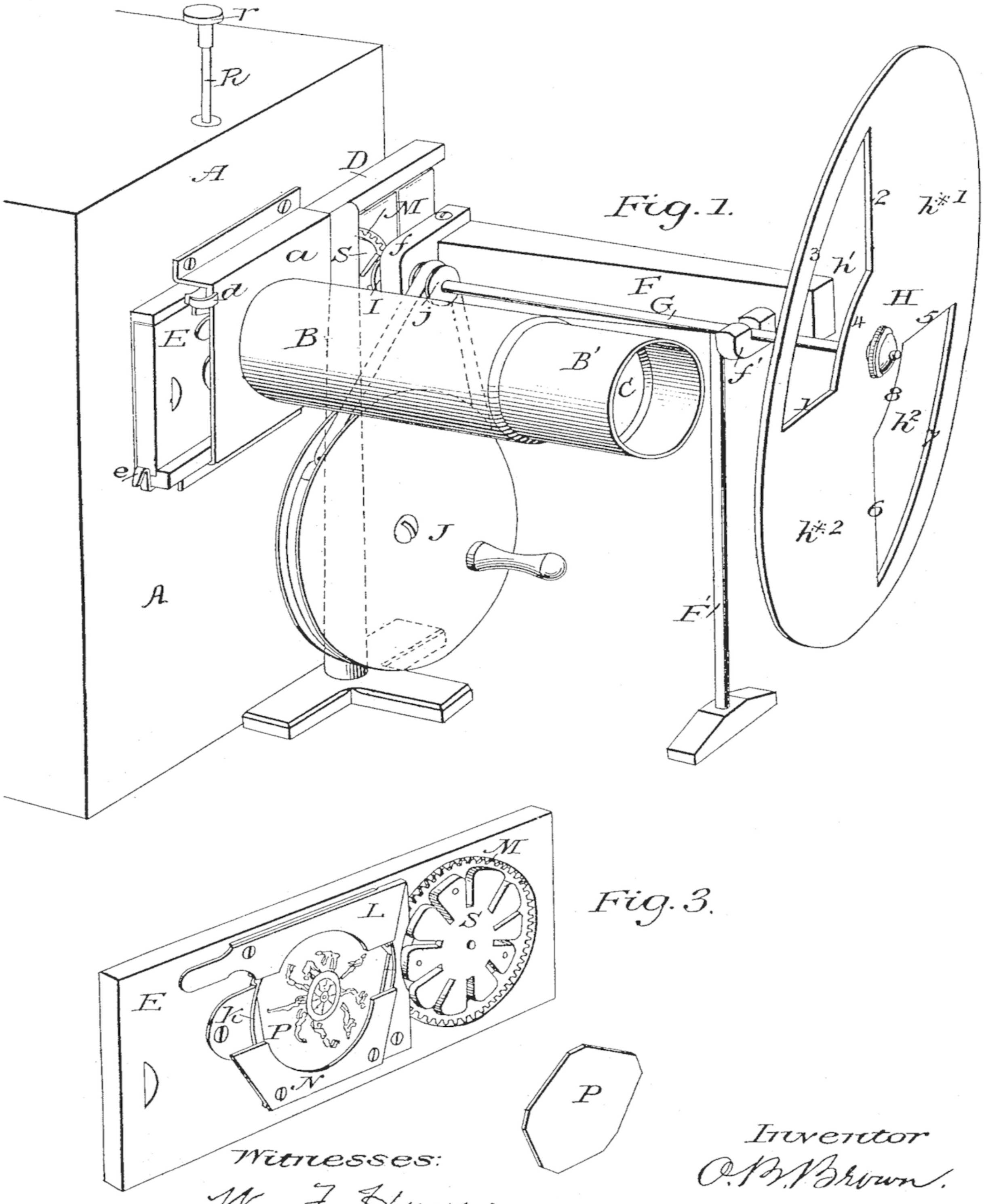

Fig. 1.

Fig. 3.

Witnesses:

W. F. Hunter

F. Henry Chadwick

Inventor

O. B. Brown.

Fig. 4.10 The USP cover sheet describing Brown's intermittent action apparent motion magic lantern and slide carrier.

As such Beale's invention deserves recognition as one of the most significant contributions in the history of cinema. It's instructive to compare this method with that of Uchatius: Uchatius' first machine used a continuously spinning radial slit shutter in conjunction with a continuously spinning image disk. While the moving slit shutter can provide an image of adequate sharpness, the brief duration of the image flash, something like a twentieth of the duration of an intermittently arrested frame, precludes the projection of the bright image required for a big screen. On the other hand, the Beale-Brown designs provide for intermittent motion of the image coordinated with an occluding shutter to allow for far brighter projected images. While Beale's Choreutoscope slide carrier, made by various suppliers such as Stewart, was successful in the marketplace, Brown's projector was not, probably because it required the purchase of a special projector. Similar devices were made by Duboscq, François Binetruy, and others, which were generically known as *the lantern wheel of life* .

Although both Brown and Beale demonstrated apparent motion projection using intermittency with coordinated shutter occlusion, efforts persisted based on the phenakistoscopic principle, notably by Muybridge with his Zoöpraxiscope. A strongly related method used by Anschütz's successful Electrotachyscope (Elektrischer Schnellseher) used the flashes of a Geissler discharge tube to freeze the images, an electrical stand-in for the phenakistoscope's radial shutter, but more elegant and without the anamorphic distortion artifact since the entire image was displayed at one instant. During half a century of experimentation Plateau's discovery was adapted to projection, aided and abetted by the introduction of photography, during a hybrid period as inventors combined the old and the new, to finally achieve the celluloid cinema; the second half of the nineteenth century was an effervescent time of invention that led to the celluloid cinema of apparent motion. The basic principles of the cinema technology that prevailed during the twentieth century were demonstrated by ingenious inventors who used the magic lantern for their projection platform applying what they learned from the phenakistoscope. Fittingly the phenakistoscope's shuttering technique was the basis for Edison and Dickson's peepshow Kinetoscope, the original display device of the celluloid cinema. The experiments and apparatus of the Victorian cinema left a historical record posing a challenge for celluloid cinema inventors who sought to obtain strong patent protection since so much fundamental technology had already been described.

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Footnotes

1 Today the word stroboscope is used for the class of devices for visually arresting and analyzing motion, often by means of a high-speed shutter, flashing electronic strobe, or flashing diode.

2 Just as Plateau invented the phenakistoscope to demonstrate apparent motion, a few years later Wheatstone announced the invention of the stereoscope to demonstrate that binocular stereopsis was a discrete depth cue.