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GABRIEL LIPPMANN (1845–1921) & FREDERICK IVES (1856–1937):
THE FRENCH PHYSICIST VERSUS THE AMERICAN INVENTOR IN THE PURSUIT OF COLOUR AND 3-DIMENSIONALITY

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Abstract

I explore the reception to photographic invention at the end of the nineteenth century and how photographic practice was embraced by the Academy with Lippmann's Nobel Prize-winning process. Whereas Lippmann published a theory in the public domain, a requirement for the Nobel Prize, Ives was dependent on commercial sales. However, Ives was a critic of Lippmann's process which competed with his own efforts for display and publicity. Here, I review the division of theory with mechanical invention that existed between Lippmann's and Ives' 3-Dimensional concepts. And I discuss the assessment by Herbert Ives (1882–1953), the son of Frederick Ives, of both these inventions.

Keywords: *Lippmann; Ives; interference; theory; colour; three-dimensional; photography.*

In 1891, during the *Belle Époque*, an inegalitarian era with the upper 10% of the French population owning 90% of the wealth (Piketty, 2014, p. 264), Gabriel Lippmann, physicist and Professor at the Sorbonne, Paris published his Nobel Prize winning theory of colour photography by interference of light waves (Lippmann, 1891).

What was or could become colour photography in the early 1890s had, in advance of any human endeavour, patent or theory, been built on a long-awaited public anticipation of colour since the publication of the Daguerreotype in 1839. The *Lippmann photograph* appeared to fulfill the criteria; it had an instantaneity through the direct action of rays of sunlight touching the emulsion-coated plate that resulted in a natural colour, without pigment, or chemical intervention; and Lippmann presented this event itself as a natural process, one inherent to light: interference.

It required a photographic emulsion thick enough to record more than half a wavelength of light which could respond to the swelling of exposed silver salts. This eponymous emulsion was to become the enduring legacy. To accompany his theory, Lippmann presented first a Lippmann-solar-spectrum, an entirely credible image, to a scientific audience of Fellow Academicians. However, to appeal to a much wider audience and the press, Lippmann needed to provide pictorial examples. This he achieved through his relationship with France's leading photographic technologists: the Lumière Brothers who, from 1891, supplied Lippmann with pre-coated plates (Lumière, 1995).[1]

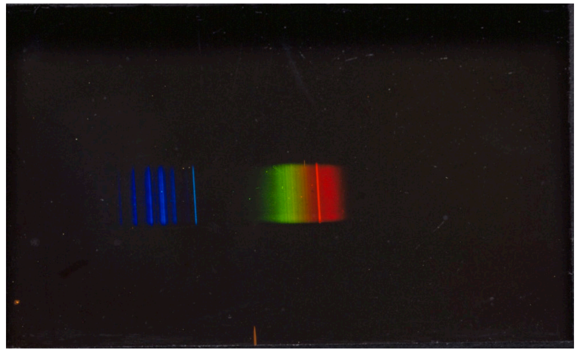

Fig.1 *Lippmann Solar Spectrum*, attributed to G. Lippmann. Reproduced with permission from the Musée de l'Elysée Lausanne, Switzerland

Even with a prepared emulsion, Lippmann's process was already intricate: involving the loading of a cumbersome vacuum plate-holder containing the liquid mercury 'mirror' which permitted the interference of light waves, as well as a final finishing after development. The resources provided by the Lumières in producing the emulsion – possibly one of the most difficult and mysterious aspects of the Lippmann process to the studio photographer – created a false impression to others of Lippmann's ease in producing his own pictorial photographs (Lumière, 1995).

With plates supplied by the Lumières, Lippmann was able to present pictorial colour photographs to the Académie des Sciences, Paris, in April 1892, just less than a year after the publication of his original theory. The *Lippmann* pictorial images could then be presented across the boundaries of two distinct societies: the scientific elite and the artisanal

1) Lippmann to Monsieur Lumière, Paris, 2 August 1891 "In any case, could you perhaps send me a supply of gelatine bromide plates in October..." (Lumière, 1995, p.4). See also: Mitchell, D. J. (2010). Reflecting Nature: Chemistry and Comprehensibility in Gabriel Lippmann's 'Physical' Method of Photographing Colours. *Notes and Records of The Royal Society, 64*, 319–337.

photographers. It was the Lumières who were to target the *Lippmann photograph* at the wider public arena, exhibiting images that were critical to the medium's public reception. For larger public displays, the Lumières also invented a Megascope to enlarge and project the small *Lippmann-photograph* to an audience (Bolas, 1900). This was not a projection through the image, but by light reflected off the front surface of the photograph. The Lumières also produced a metallic-surfaced screen that reflected the projected image more efficiently: these images could then be seen at their most luminescent.

It was the Lumières that photo-historian, Josef Eder, credits as producing the first "satisfactory" images (1945, p. 670). Presented in Geneva, 1893, at the International Photography Congress, they projected images of artful flower arrangements: floristry itself suggested subjective expression. The Lumières recorded soft muted colour that achieved a degree of realism which critics spoke of as: "…the effects of luminous watercolours" (Vidal, 1893, p. 196). The comparison with paintings was frequent; the medium was well above photography in the hierarchy of the Fine Arts. And the Lumières projection displays of 1893–94 sited this colour photography somewhere between painting and the emerging new realism of the Cinematograph in 1895. Both these technological media formed in "light" an immaterial image that seduced the audience with what Rosalind Williams describes as: "elegant and worldly dramas which introduce them to a milieu where they cannot otherwise penetrate." (Williams, 1982, p.79)

Fig.2. *Lippmann-photograph* (attributed to G. Lippmann). Reproduced with permission from the Musée de l'Elysée Lausanne, Switzerland

But by the time they arrived at the Royal Society, Conversazione, London, in 1896, where Frederick Ives also presented his latest product – the stereo *Kromskop* – the press were far more interested in another new form of scientific photography: images taken with the new X-rays ("Royal Society Soiree", 1896).[2] And even when presenting his theory to the Royal Society Fellows, Lippmann was asked if this photographic method could record X-rays ("Professor Lippmann's Presentation at the Royal Society", 1896).[3]

The London Arena and Frederick Ives

Frederick Ives, the American inventor of colour photography and subsequent critic of Lippmann's process took up residence in London, in 1894, with his wife, and son Herbert whom Ives sent to Harrow public school. Ives sought to promote and market his colour photographic process, and was intent on manufacturing a table-top instrument and its subsequent stereo update, the *Kromskop*, in Europe (Ives, 1928, p. 39). Later, Herbert Ives, as a PhD student in the USA, attempted to recreate Lippmann's photographic invention unaware of the assistance of the Lumières.

He also brought a young assistant, Bill Jennings, whose defining remark on the *Kromskop* – "That name killed it" (Jennings, 1930) – summed up their investment of time and struggle with this particular product. For promoters of invention like Ives, as well as potential buyers, London was "the capital of capital; a social summit open to talent, accessible to worldwide ambition". Britain had then the most permissive commercial regulations in Europe, and British sterling was the international currency (Crook, 1999, p. 155). Opportunities existed within this society which supplied Ives with a platform, and a market, that did not exist at home in the United States.

Ives was a man essentially not driven by theory: rather than publishing "papers" he relied on demonstration for putting his inventions across, and for skillful hand-drawn patents for their definition. For Ives, the culture of display for the arts and sciences provided excellent opportunities to exhibit in London. In addition to the Royal Institution, Ives appeared at the Society of the Arts, Royal Photographic Society and the Royal Society. Every year the Royal Society, an all-male scientific fellowship held a *Conversazione*. This was an elite social event, with the possibility of Royal Patrons attending, and here, demonstrations of the latest science and technology intermingled with women in (required) tiaras and full evening dress.

The acme of the *Kromskop's* display was an appearance at St. James Palace in 1896. There, according to his wife Mary, "Fred was introduced to the Duchess of York…" (Ives, 1896) These exhibitions came with the possibilities for publicity, sales of patent licenses and instruments, as well as social opportunities for what Ives's assistant described as "gormandising and inflating" (Jennings, 1930). Ives also exhibited and sold both his instruments and sets of his own accompanying photographs through the London private gallery system (Ives, 1897).

Ives was born into a rural community in Connecticut, in 1856, that had a Puritan culture of self-reliance. Initially, he was a "journey man" printer, someone in the printing industry who could retain his intellectual property: his skills and patents (Sipley, 1951, p. 13). Ives worked independently, with a religious dedication: a commitment to continue in his chosen vocation in the face of any adversity (Roberts-Miller, 1999,

2) Staff reporter (1896, 7 May). Royal Society Soiree. *The Daily News*. "Roentgen rays (the new photography) the most popular exhibit …"

3) Staff reporter (1896). Professor Lippmann's presentation at the Royal Society, April 23. *NATURE*, *154*(1384), 12–13.

Fig. 3 *Kromskop*, stereo viewer, 1894, by F. Ives, sold with images.
Reproduced with permission from the Tokyo Metropolitan Museum of Photography.

p.9). It took the form of projected lantern slides with aphorisms to motivate that mind and body unison as the means to success: MENTAL SUNSHINE CREATES PHYSICAL HEALTH; I AM OPTIMISTIC IN THOUGHT.[4] This heroic, pioneering stance was to define the peculiar creativity of the nineteenth-century American inventor.

With his photography and instruments, Ives relied on superimposing three colour images optically over each other with prisms and filters: a visually transparent theory, rendered with elegant mechanics. But it was this apparently mundane and pragmatic approach to creating an image that was disappointing to the public and press in the late nineteenth century,

4) Frederic E. Ives, *Undated Lantern Slides* (1992.co47.024: Photography Collection of the Smithsonian Museum of American History).

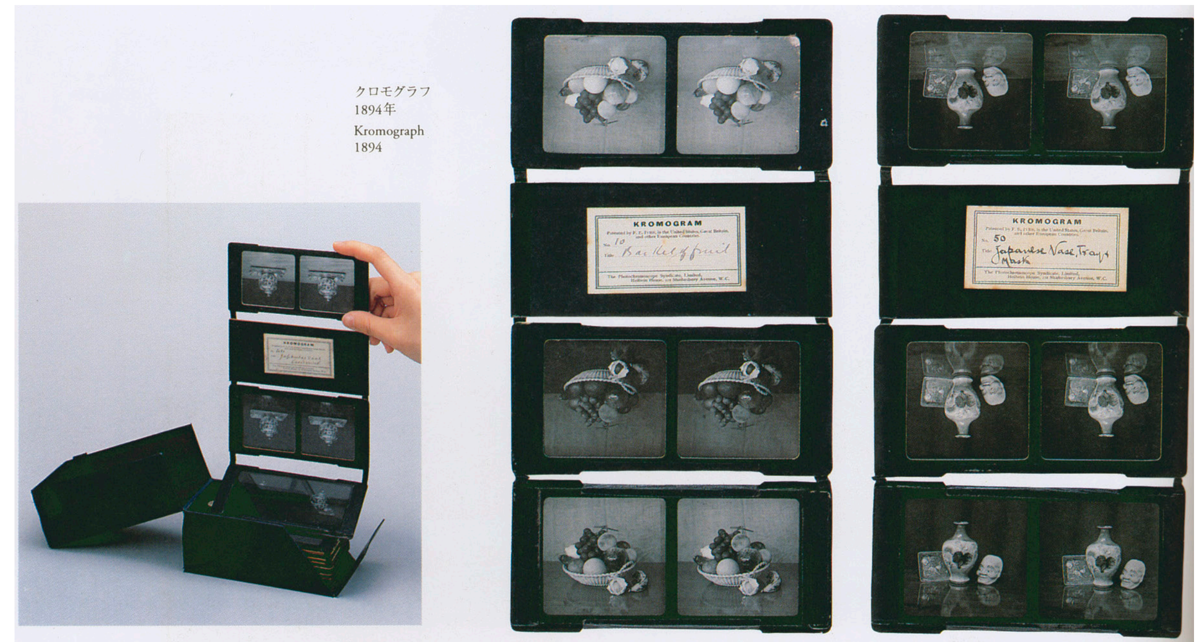

Fig.4 *Kromographs* by F. Ives, three linked sets of stereo pairs, taken through three different colour filters, within the *Kromskop*; a system of prisms combined all three.

as evident in *The Photographic News* report, on Ives winning a gold medal in 1893:

> Mr. Ives process is not the kind of photography for which the world has been looking, and may never find, nor is it "photography in natural colours" … In a technical and scientific sense "natural colours" are those which are produced in any substance by the direct effect of light itself, acting according to the laws of nature. ("A Gold Medal for Mr. Ives", p.13)

The meticulous engineering and optical craftsmanship that Ives applied to photography were not enough.

The general assumption was that anything other than a divinely inspired intervention with nature, that could be compared to Fox Talbot's or Daguerre's "discoveries" with sunlight, was to be considered synthetic. A mechanical invention that creates coloured effects and artifice was not a true "natural" process of colour. This belief dominated the reception of methods of producing colour in photography well into the twentieth century and was perhaps only suspended briefly by the French, in favour of Lippmann's interference photography.

Frederick Ives, the Critic

Ives damned Lippmann's work in print before ever having seen it himself. Ives' own belief in the impossibility of a "colour photography" ever existing convinced him to state plainly with common sense that: "A scientific friend of mine who has …. seen it says the results are pure humbug. The colours got by it are due to interference of light by thin films on plates backed with mercury." ("Mr Ives and Photochromy", 1893, p. 554). Ives refers here to the visual phenomena of popular educational experiments such as those on the surface of blown soap bubbles, or manifest in Newton's Rings, between thin sheets of glass. These were popular exhibits in the London display arena Ives operated in, and images Lippmann himself repeatedly alluded to in describing his colour process.[5]

Ives admits to the existence of such effects, but they cannot be considered a new theory or invention: wave theory was humbug to Ives. For Ives, it seemed that there was hidden deceit to Lippmann's process because Lippmann could never make "visible" by demonstration the event described as interference. If not projected, the sealed glass plates on display seemed suspiciously designed to thwart visual inspection; the lamination prevented the photograph from being viewed in transparency (Ives, 1893). This was so unlike Ives' own products, which were made vulnerable to copying by others by virtue of their technical honesty: a visual inspection of the inside of his instruments would expose his clever geometrical arrangement of optics and mechanics. Without a visual demonstration, a colour process would not be a logical, fair, and honest process to Ives, who relied on patents and thus gained protection only through revelation.

Ives as an inventor had succeeded without theory, basing his inventions on a practical and craft understanding of geometrical optics. To the puritan Ives, obscure reasoning was not logical, and therefore not true. Ives was later to admit unapologetically his ignorance of Maxwell's colour theories on which – to educated Europeans – his own process was seen to have derived (Ives, 1928, p. 57).

Nor could Lippmann rely on his rhetoric outside his peer group, or the terminology of physics or the eloquence of the French language in explanations to the English. English science was not presented and written so poetically. To the French – as the nineteenth-century author, on religion and science, Ernest Renan saw it – English protestant science was inelegant and did not aspire to spiritual heights. Renan wrote that it was "so lacking in loftiness, in philosophy" (Renan, 1891, p. 16) and under a state church it was merely used as an educational tool: "A kind of petty process to knock a little bit of understanding into folk." (Renan, 1891, p. 17) For an English audience, Lippmann himself attempted to provide a visual demonstration of the event of interference. Thomas Bolas (1900), in 1897, reported with some scepticism on such a model presented to a group of photographers at The Royal Photographic Society, in the following way:

5) "The colours reflected by the film are due to interference: they are of the same kind as those reflected by soap bubbles or by Newton's rings." (Lippmann, 1896, 12).

> … a pretty illustration of the formation of so-called standing waves by reflection is obtained if a rope as thick as ordinary clothes-line and some thirty feet long … is fastened by one end to a nail and the other end is held in the hand and set in motion so as to produce waves … (p. 9)

This model failed to provide a convincing demonstration, of what may be occurring within the emulsion, to these empirical British practitioners. There is no evidence in any British museum, for example, that any British photographer pursued Lippmann's process for pictorial photography; although, like many experimenters, Edgar Senior described the technique (1900). These inventions relied heavily on written reports – descriptions of the subjective viewing experience – in popular and professional journals to disseminate the imagery to readers. This required readers to place their trust in the author to judge competently the validity of these new forms of colour photograph.

Lippmann's Proposal for a 3-Dimensional Image

On receiving the Nobel Prize for Physics in 1908, Lippmann was one of the earliest recipients. It signaled a moment when photographic development had succeeded within the Academy. The prize also defined a more popular role and responsibility for the recipient and a movement towards an international standardisation in science publications.

That year, Lippmann published *Épreuves réversibles. Photographies intégrales*, aiming to solve an increasingly consumer-led desire for a new form of three-dimensional photographic product, one that could overcome for the viewer the obvious physical restrictions of the stereoscope. Frederic Ives also continued to apply his patents to three-dimensionality, pursuing a similar goal, with his *Parallax Stereogram*. Unlike the spectrum he exhibited with his 1891 presentation on interference photography, Lippmann had no physical example or image to display; therefore, Lippmann's claims for this proposal appear more literary. He asserted that the ordinary photograph failed the viewer: "La plus parfaite des épreuves photographiques actuelles ne montre que l'un des aspsects de la réalité; elle se réduit à une image unique fixée dans un plan, comme le serait un dessin ou une peinture tracée à la main." (Lippmann, 1908, p. 446)[6]

Lippmann demanded a medium in order to perform, as if a window onto the world. To fabricate this, he suggested a structure formed in a transparent medium – Celluloid, an American product – which when heated could be embossed into a raised pattern producing many small lenses. On this structure would be a coating, of a photographic emulsion, on the back surface of the "lens", facing the incoming light. In this paper, Lippmann provided a minimal graphic drawing, a plan elevation of a series of ridges, that were to form the lenses, and each one would "… constitue une petit chambre noire sphérique, pareille à un œil: la lentille en est la cornée transparente; la couche sensible remplace la rétine." This eye-like optical system was to form a simulacrum of nature's cellular

6) "The most perfect photographic print offers only one aspect of reality: it reduces the image to a fixed plane, as if drawn or painted by hand." (Translated by the author.)

Fig.5 Drawing by G. Lippmann, illustrating a section of the screen. Lippmann, G. (1908). Épreuves réversibles. Photographies intégrales. *Comptes rendus*, *146*

visual systems with a multitude of these lenses, forming in total, "… un œil simple, leur ensemble rappelle l'œil composé des Insectes."[7] (Lippmann, 1908, p. 447)

In theory, this system provided both the camera – with an embossed convex lens at the front – and the recording medium, the photographic emulsion coating the "retina", or the focal plane, to the rear. One need only take the system (shielded at first from the light) into the sun, stand it on a tripod in front of the desired subjects, and finally remove any cover to expose it. Then it was necessary to return the object (covered), to the dark-room following exposure, develop, and fix the entire structure: "Le résultat de ces opérations est une série des petits images microscopiques fixées chacune sur la rétine d'une des cellules." Kim Timby, also suggests the structure might function in this manner (2015, pp. 65–66). However, I speculate that Lippmann intended this to support a *Lippmann emulsion*, the miniscule 'cameras' exposing at speed a microscopic image on the film, that would have been faster than an attempt to obtain one large *Lippmann photograph*.

Lippmann explained that in looking at the photographic structure, after chemical development, it would show no indication of the resulting image, it would be just an uniform grey surface. But when the eye is in the correct location to look through the small images and the structure is illuminated with bright diffuse lighting then, Lippmann concluded that: "…une seule image résultante projetée dans l'espace, en vraie grandeur."[8] (1908, p. 448)

Lippmann theorised that this 'correct' location of the eye was at the focal point of the light rays as they came through the structure, here: "Leur système constitue donc un objet virtuel à trois dimensions …".[9] This visual sense of seeing objects in

7) "…create a spherical camera, like an eye: the lens is the transparent cornea; the sensitive emulsion recalls the retina …a simple eye that resembles the compound eye of insects." (Translated by the author.)
8) "…a single image will be projected into space, in true *grandeur*." (Translated by the author.)
9) "Here the system constructs a virtual object in three dimensions …" (Translated by the author)

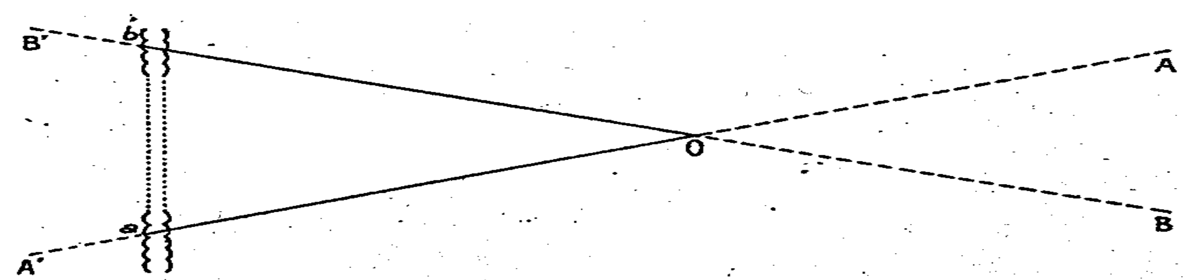

Fig.6 Drawing by G. Lippmann, illustrating the proposed optics. Lippmann, G. (1908). Épreuves réversibles. Photographies intégrales. *Comptes rendus*, *146*

relief was to be engineered by virtue of optical geometry and stereoscopy which Lippmann illustrated. One problem arose here that Lippmann described, and theoretically resolved. It was that this lensed image is inverted so that the viewer's eyes would be in a "virtual image" (if the viewer's eyes are in the zone A B to the right of 0), that is both upside down and inside out, and perhaps also in negative, depending on the type of emulsion used. To the viewer, at this stage, the image might appear as pseudoscopic nonsense. To render the scene geometrically correct, Lippmann suggested turning the structure 180 degrees, or making a "contact" copy, although, with this structure, the object would not be in exact contact (as with a "normal" flat negative to a print) but at some distance corresponding to the eye. Lippmann suggested that this method also offered the more practical modern advantage of replication. (1908, p. 448).

There was no limit to the number of lenses in a structure. The larger the structure, the greater the angle of view the window could provide onto a scene; and the more of the panorama it could take in. The full "virtual" effect of reality could be obtained: "Avec une pellicule bombée comme le serait une portion de sphère ou d'ellipsoïde, on embrasserait le ciel et la terre en même temps…"[10] (Lippmann, 1908, p. 450).

As with his interference photograph, Lippmann appealed to his audience to consider this concept as if it were a natural object. Embossed in Celluloid, it might resemble something more akin to a huge Tiffany lamp, that popular American import to the Parisian department stores which were frequently based on cellular structures. Like Louis C. Tiffany, Lippmann took a structure from nature – here the insect's composite eye – on which to model a man-made product..

10) "With a curved film like a section of a sphere or an ellipsoid, it could embrace the sky and the earth at the same time …" (Translated by the author)

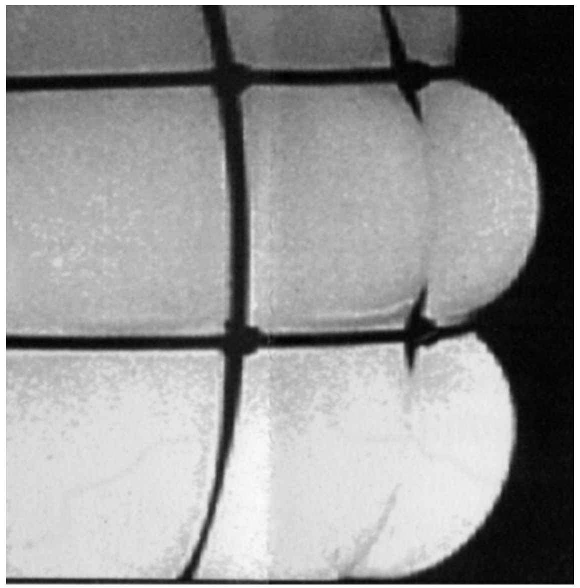

Fig.7 Detail of a Tiffany lamp.

Fig.8 Produced in New York, Tiffany lamps were a bourgeois "mass-produced" item that won awards at the Paris Exhibitions. Figs.7& 8. Reproduced with permission from the Neustadt Collection, Queens Museum, NYC.

Lippmann sought perhaps to raise the aspirations of the medium above commercial demands which served to replicate images for the mass market. Lippmann's proposed lenticular virtual reality was a piece of optical naturalism, an art nouveau-like photographic technology. Of the movement *art nouveau* and its mannerisms, historian Debora Silverman writes that in France, it sought to "aristocratise the crafts" (Silverman, 1989, 12). Lippmann invents the ideal photographic object free from market constraints. Unlike the mass appeal of the Cinematograph, Lippmann's technology would have been limited to one individual's private experience, accommodated in the correct optical position.

Herbert Ives on Lippmann's Structure

The son of Frederick Ives, Herbert, gained a PhD in 1908 from The Johns Hopkins University. Herbert Ives reviewed Lippmann's concept theoretically, through the application of meticulous ray tracing at Bell Laboratories in 1931, and was to concede that Lippmann's scheme would work.

For Herbert Ives and others who endeavoured to realise the elusive three-dimensional world, the problems of geometric correction examined by Lippmann in his 1908 paper were to persist. Ives commented on this problem: "The occurrence of pseudoscopic relief, [a "false" image] where stereoscopic relief [the "true" image] is sought is the bête noir of relief picture schemes ..." (Ives, 1931, pp. 171–172). Here was one persistent reality of the aspiration to three-dimensionality that Lippmann had discovered, this intrusive optical phenomenon. The pseudoscopic image or the reversed image (where far objects can appear as if near ones) was to plague attempts at three-dimensional image-making. To Herbert Ives, with his ray-tracing methodology, it seemed not to matter whether you turned the image through 180 degrees – Lippmann's first suggestion to rescue the image from its nonsensical state – or viewed it in a mirror. It will not correct the geometry and therefore it will not be truly stereoscopic. However, it was well known to practitioners of illusionistic tricks that pseudoscopic images could make visual sense.

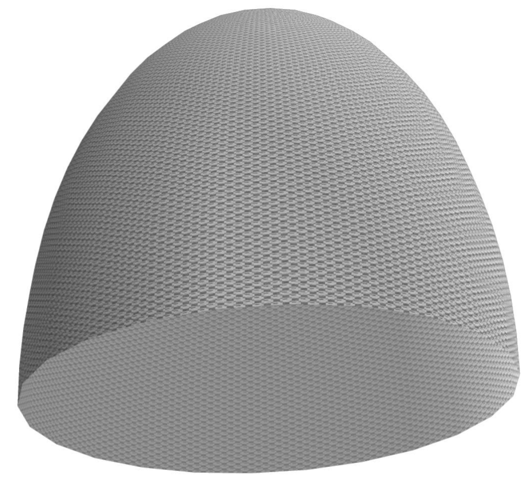

Fig.9 Computer drawing, by the author, of Lippmann's lenticular screen.

Hollowed out (inverted/negative) casts of plaster busts, or face masks, seen from "inside", for example, could, under certain light, be perceived by the viewer as being solid, if only momentarily. But Lippmann's second suggestion, of making a copy, would be credible. Herbert Ives wrote: "a pseudoscopic copy of a pseudoscopic picture, becomes, by virtue of a double reversal, a picture in correct relief." (Ives, 1931, pp. 176) Paradoxically, either way – nonsensically pseudoscopic or correctly, geometrically stereoscopic – a viewer might have perceived that they did indeed witness the depicted illusory object.

Lippmann was aiming for geometrically correct stereoscopic vision. If that could be achieved, then for Lippmann the image would be, in principle, a mathematical synthesis of reality. To achieve this, Lippmann defined a means of combining geometrical optics and interference photography. These two notional devices at work here – geometry and wave theory – are often perceived as opposing paradigms, the latter pertaining (as Jonathan Crary has suggested) to a modernistic visualisation, and the former to a Renaissance perspective. Lippmann's early twentieth-century vision theoretically combined both, as would synthetic radar holography in the 1960s, contradicting the simple "rupture" between the two that Crary has suggested exists (1990, pp. 1-4).

Ideally for Lippmann, the structure should contain as many lenses as necessary to correspond to every predicted movement of the viewer's eyes, to simulate the sensation of seeing. Lippmann was replicating an image by physically engineering a point-to-point analogue translation from the real to the virtual. Herbert Ives informs us that Lippmann's lenticular screen could attain stereoscopic perfection but that the viewer would have to conform to the geometry. (Ives, 1931, pp. 176)

Frederick Ives' *Parallax Stereogram*

Contrasting with Lippmann's naturalism, Frederick Ives, in 1903, invented his *Parallax Stereogram*, referring with this complex but functional name to the images' changing stereo viewpoints. Ives published no physical or perceptual theory, or mathematical calculations regarding this invention, implying that he achieved this result – as with his other inventions – by empirical experiments with lenses and varying line widths printed onto screens. The underlying principle of his method is entirely geometrical, and his patent is on the arrangement of the optics – lenses, lines, and apertures – within the camera. This camera depended on a large wide-angle lens. Behind the lens in the camera, are two apertures, placed to correspond in distance with the separation between the viewer's two eyes. These two "viewpoints" through the apertures are recorded with a "line screen" – or a series of linear pinholes – placed over the sensitive photographic emulsion and behind the lens, during the exposure of the image or negative. In printing the positive print from the negative onto glass, the "line screen" is also employed to maintain the alternate separation of the images. In the final positive transparency, the linear images are back-projected by the illuminating sunlight into the viewer's eyes, the screen directing a different image into each retina.

The *Parallax Stereogram* takes advantage of an inherent artefact, due to the position of the human eyes, and the virtue of

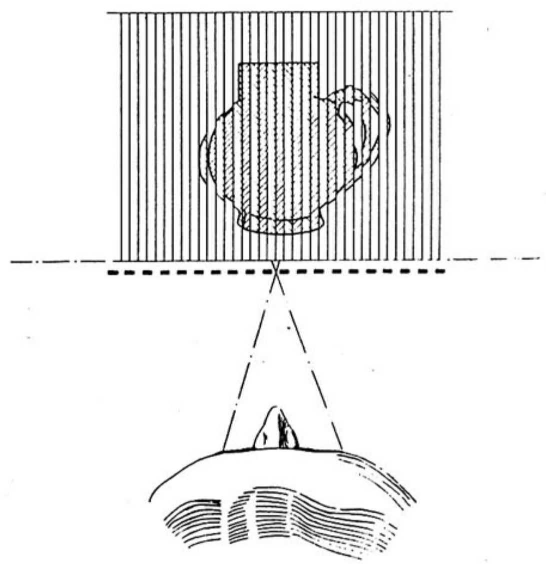

Fig.10 Illustration by Herbert Ives. *Pan-stereoscopic Photography and Cinematography: The Traill-Taylor Memorial lecture before the Royal Photographic Society, October 3, 1933 London*

what information (here in the form of image) may be hidden behind a fine "line" from one eye, but simultaneously exposed to the other.

By employing a wide-angle lens, Frederic Ives exploited the nature of this lens to "take in" as much information – as wide a scene as possible. Also put to use is the inherent distortion by the wide-angle lens of any object close to the camera – to further simulate the effect of three dimensions. In looking at the two separate parts of the parallax stereogram, the pipe, which is the object that appears to be "real" – to project out in front of the final image – is the part of the photograph that

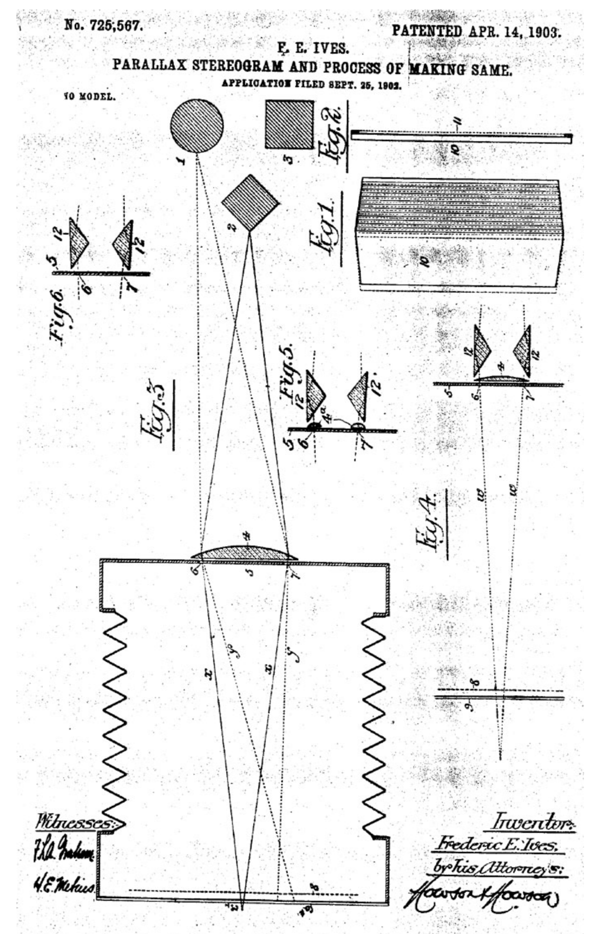

Fig.11 Patent 1903. F. Ives.

is paradoxically the most distorted and unreal in two dimensions. Reality effects are created out of unrealistic raw material. The printed image of the pipe is spread out over several 'linear' images. The invention is a simple geometrical synthesis of human vision with two holes and a line-screen, assembled within an already existing instrument – the camera – to create many left and right halves, which are then "processed" together in the final image by the viewer. This invention is entirely bound within the knowledge of geometrical optics, and like other geometrical illusions, including Renaissance perspective painting or seventeenth-century peepshows, it relies on the subjective "standpoint" of the viewer to assimilate the information into the correct image.

This robust physically kinetic imagery required something more masculine than the floristry of his previous colour *Kromograms*. It was not intended for display to mixed-gender audiences, in the refined salons of Europe, but targeted to Board Rooms and potential all-male American investors. Despite the "in-your-face" visual effects – which were to become a characteristic of this genre – Ives felt that his remarkable invention received little attention. Speaking of his disappointment, Ives stated "it bought some medals from scientific societies [but it] did not sufficiently appeal to the general public to justify continued commercial production." (1924).

Frederick Ives, in a typically puritan manner, blamed public reception for the invention's apparent failure (Roberts-Miller, 1999). Kim Timby states that this invention was a "minor" one to Ives (2015, p. 35). However, Ives may have wished to minimise its lack of success. Writing of early twentieth-century America, economist Piketty has pointed out that failing in a "modern meritocratic society is harder on the losers." (2014, 416)

Fig. 12 *Parrallax Stereogram*, c.1903, attributed to F. Ives. Courtesy of The George Eastman Museum. The *Parallax Stereogram* consisted of two combined photographic plates: a printed screen of vertical fine lines; and a photographic image printed in a series of lines, each alternative image-line consisting of one-half of a stereoscopic pair.

Ives' son Herbert judged that the *Parallax Stereogram* had two limitations: first, "there is just one correct viewing position and distance …" and secondly, the images, "… are in transparency form and must therefore be illuminated from behind." (Ives, 1933, p.3) In 1903, the lack of an artificial light source bright enough to provide back-illumination to the transparency, would have severely restricted the object's possibility for display; exhibition was critical to the object's dissemination.

The *Parallax Stereogram* offered a lesser "window onto nature" than Lippmann's notion of a domed cellular structure. Lippmann's idealism privileged the viewer with many viewpoints, seeking to match the viewer's physical experience. Lippmann's screen, if constructed as a 180-degree domed structure employing interference colour, might – as a three-dimensional image – have been a private immersive "photo grotto". However, neither invention was to endure in their original form.

The Lumières assisted Lippmann again, after WW1, in attempting to manufacture a prototype section. That Lippmann intended this for his colour emulsion is perhaps indicated in his demand for a substrate with a high refractive index … not merely a transparent base (Lippman, 1908, p. 451). A lack of industrial materials and manufacturing design technologies available after the war prevented its realisation. The sole outcome of Lippmann's 1908 invention was to manifest itself within an American corporate product in 1928, the moving-film product: Kodacolor. Historian, Eder, writing in 1932, described how Rodolphe Berthon, Louis Lumière's lens and machine-tool maker, co-opted one of Lippmann's design elements – the cellular lens – to solve the problem of colour motion film. Berthon, in a partnership with Albert Keller-Dorain, created micro-lenses directly in the celluloid with twenty-two lenses to a square millimetre of film (Eder, 1945, p. 672). These lenses focus the image through three filter colours onto a panchromatic emulsion; after development to a positive film, the microscopic colour separations would overlap in the diverging beam of the projection lamp. This resulted in a soft-focus full-colour image. The rights to the process were

bought by the Eastman Kodak Company. Frederick Ives also sold some of his patents to Eastman Kodak in 1914.

Conclusion

Both F. Ives and Lippmann represented an individualism that was to disappear in the twentieth century. Lippmann's poetic language would be replaced, in scientific papers, by a more generic "international" terminology. Whereas F. Ives was heralded for his individualism as the 'Wizard of Color', an American inventor to be compared with Thomas Alva Edison (1847–1931) the 'Wizard of Menlo', his son H. Ives, at Bell Laboratories, was to exemplify the emerging salaried mid-twentieth-century researcher (Cloudy, 1920). Lippmann's own reliance on the Lumières for his material technology revealed the problematic division of theory and mechanical invention that was to be overcome with changes in education and corporate teamwork, both in Europe and America. In 1895, the Lumières rejected their father's offer to present the Cinematograph citing the American showman: "… we do not like the prospect of you playing Barnum showing off his magic lantern." (Lumière, 1995, p. 27). For the educated consumer they sought to create an image of the professional operator with a technology, rather than a mid-nineteenth-century genius with a novel invention. In doing so, they could control any inspection of the equipment, unlike F. Ives and his "society" demonstrations.

The unincorporated enterprises of individuals, or family firms, formed a great pool of research which might become available (by death, bankruptcy or voluntary sale) for purchase by larger corporations. It was considered that much German and American industrial success, in the early twentieth century, was due to the policy of: "Buying in new ideas, whether in the form of patents held by independent inventors or through the absorption of smaller companies …" this saved investment and limited risk (Fox and Guagnini, 1999, p. 267).

Amongst these were some of the major twentieth-century photographic companies: Agfa Gevaert in Germany; Lumière Brothers, France; Ilford, Great Britain; and Eastman Kodak, USA. Once absorbed into the corporation, these inventions would often lose their identity and history; what remains in the public domain may only consist of the literature – a theory or patent.

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