Coherent Light from Projectors to Fibre Optics

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[*accompanying slides are available at http://www.slideshare.net/seancubitt/seanscreen2011projection*

Arguments for the 'Death of Cinema" hold that film's realist destiny has been betrayed by digital technologies. Arguments for the 'Post-medium Condition' hold, against the medium-specificity of Greenberg and after de Duve's art made of 'n'importe quoi', that medium no longer matters. In papers on colour separation and management, the temporalities of film and electronic frames, optical construction of volume and chip design, I argue that the material matters more than ever, but that crude binaries do not help understand the dialectic of standardization and divergence characteristic of contemporary mediation. This is especially true of the glass technologies that are key to the history of projection and of digital networks.

Projectionists

For a considerable period, well into the 1960s and in some cinemas for far longer, tending the lamp was a full time occupation, since the illumination source forcing light through the tiny 35mm aperture onto theatrical screens metres across, was a carbon arc, which burns away in use and has to be adjusted constantly to keep the spark brilliant and steady. The xenon arc lamps which came in from the late 1950s were far easier to manage, but the change-over system of projection, where two projectors alternate, with reels of between ten and twenty minutes following one another, and the use of rectifiers to increase the voltage sufficiently to power the big lamps, meant that projection was a concentrated and technical profession. The introduction of 'cakestands', holding a whole program (features, trailers, ads, music, even cues to open and close curtains and adjust tabs) and of clockwork and later digital towers (allowing one or several films to be programmed across multiple screens from a single control point) changed much of the old craft, but the principle of controlling light carefully and of forcing it through a small area onto the screen with the minimum flicker and shudder remains a constant of cinematic projection.

Piercingly bright for the operator, arc and xenon lamps have to be observed – when checking for flicker or wear – through the kind of dense glass plate used by welders. But even this much light is a drop in the ocean when it is asked to illuminate a whole wall, metres distant. Every photon is precious. The lamps radiate light in all directions. Heat- and light-absorbent linings for the lamp-housing reduce scatter. Condensing mirrors orient the radiating light towards the business end of the projector, cornering as much of the light as possible and ensuring it passes through the two compound lenses. The first of these lies between the lamp and the filmstrip, focusing the light as close to parallel as possible so that as much as possible of the data in the frame can be gathered for display. The second lens diverges the parallel rays, refocusing them to illuminate the screen ahead as evenly as possible. Between the filmstrip and the second lens lies the aperture plate, which cuts off the outer, more distorted edges of the frame. Tabs – black curtains drawn up to the edge of the projected image on screen – and the black surrounds of the screen itself cut off the outer edges, while the cinema screen is perforated to allow sound through and to diminish the effects of air-conditioning on the hanging screen. Even with the silvering used to increase the amount of light reflected, the screen cannot help bouncing light all round the theatre. The amount of light reaching the eyes of the audience is thus far less than that emitted in the lamp-house. The critical sites for minimising the loss are the lenses.

Lenses

A simple lens throws a circular image, one in which, if the centre is in focus, the poorer the focus towards the edges (and vice versa). The simple convex lens – like those you find in a magnifying glass – produces a number of such aberrations: the coma (stretching circles into ovals due to focusing different rays from a single object at different distances), spherical aberration (corona effects produced by light travelling different distances through the lens and so being differently refracted), a variety of colour fringing effects, where different wavelengths travel at different speeds through the optical glass, and many others, some shared with the lenses in human eyes. Correcting these imperfections calls for secondary elements to be added to the lens: coatings, and additional glass elements, for the most part also lenses, including some glued together and some which use the air between elements as an operating part of the system. Lens complexity depends on the aperture in relation to the curvature of the prime lens. A wide-angle lens with a large aperture requires more correction, as more of the distorting outer area of the lens is exposed. Wide-angle lenses can have up to fifteen elements, while a long lens with a small aperture may require as few as two.

As well as air, the differences between types of optical glass are critical. Flint glass has a high lead content and prismatic characteristics which neatly match and cancel out those of crown glass, a mediaeval invention so called for its shape when blown. In the 1880s the Jena-based company Zeiss began manufacturing new kinds of glass for scientific instruments, which they then commercialised for the photographic market. Paul Rudolph, their master designer, pioneered the practice of gluing different elements, and different glass types, together to form compound elements, and later combined converging with diverging lenses to reduce or amend aberrations. These two techniques proved invaluable, especially in conquering chromatic aberrations. This requires combining a biconvex (positive or converging, with two convex surfaces) lens boasting a high refractive index with a biconcave (negative or diverging, with two concave surfaces) element which refracts the incoming light much less. Zeiss maintained their leading position in lens design after WWI by pioneering the use of anti-reflective coatings to improve the quantities of light travelling to the film strip. These were needed because the increasingly complex compound lenses absorbed or reflected an increasing proportion of the available light away from the film surface (Kingslake 1989).

Recent glass and plastic lenses include rare minerals like lanthanides and caesium to control the refractive index and transparency The interior of the barrel housing the glass elements had also to be of the deepest black available. In January 2008 a Rensselaer Polytechnic team announced the blackest material known to science, a forest of carbon nanotubules that absorbed all but 0.045% of visible light (Yang et al 2008). The first use proposed for it was lining light-sensitive scientific instruments, and cameras. Such contemporary moves to improve lens and housing performance continue to build on century-old design principles, even as the language we use changes. Today, from the moment the lens cap comes off to the retinal wall of audiences' eyes, the aim is to retain the greatest density of information possible, even though we know that, analog or electronic, the image degrades from the moment light enters the lens.

The rich history and complexity of lens design is for the most part hidden from users today. This is in part perhaps an effect of the 'black-boxing' that occurs as mechanical devices become digital, passing beyond the skills base of the average tinkerer. Yet lens design, except in the use of exotic minerals in glass making, has not fundamentally changed in the transition from analog to digital photography in the 21st century. While Eastman Kodak's 1900 box Brownie may be said to have started the process of black-boxing for consumer snapshots, professional and pro-am photographers kept their interest in the technological at least as late as the 1950s, when advertising for anastigmatic lenses came to an end (despite the fact that all lenses had been anastigmatic for some decades by this point). The inference of the adverts was that photographers understood the optics of astigmatism (the aberration which makes it impossible to have both horizontal and vertical lines align on the focal plane) and appreciated the engineering required – a minimum of three elements and two types of glass – to correct it. After the 1950s, lens design became even more a matter of branding, the domain of white-coated boffins, removed not only from the snap-shooter but for the most part from the professional photographer as well. The choices for those most intricately involved in the technical aspects of the profession – cinematographers for example – were restricted to the *choice* of lens, or in extreme instances like that of Stan Brakhage, the rejection of lenses altogether. In Brakhage and related practices we confront art premised on revolt against universality and invisibility of the grammar of the lens. We should consider the options for such a revolt today, as we migrate to digital projection. The engineering marvels we encounter should not distract us from increasingly relentless standardization, in direct continuity with the history of analog projection.

DLP

DLP (digital light programming), developed by Texas Instruments for digital projection, is the commonest form of projection today. DLP projectors use metal halide arc lamps, either in mercury vapour or in inert noble gas tubes, with infra-red reflective surfaces to concentrate heat at the tips of the arc itself, where the intense light is produced, advancing on but sharing the same fundamental design as the old carbon and xenon arc lamps. This light, as white as possible, is then beamed towards the DMD or Digital Micromirror Device. This is a chip (expensive models have three) containing up to 1.3 million digitally controlled mirrors (in 1280 x 1024 resolution machines), each of them 16 micrometers square, or about a fifth of the diameter of a human hair. The micromirrors, which fit on a DMD chip the size of a postage stamp, tilt ten degrees, with 16 millisecond response times, to reflect optically programmed light towards or away from the projector lens. 'Black' translates as a turn away from the lens; grey is produced by flickering at a higher rate than the basic 16 milliseconds as appropriate to the shade desired. Single chip DLP projectors use filters to send three versions of an image, red, green and blue, to the screen, a process which clearly makes resolution and registration extremely important if fringing and other artefacts are to be avoided, and reduces the amount of light that actually gets to the screen. Thus the kinds of lens technologies we have mentioned are still vitally important to digital projection, and still control and shape the grammar of the projected image. High-end projectors use one DMD chip each for red, green and blue signals, using additive colour to make white, and absence to make black. The proximity of DMD cells to one another is far greater than in LCD screens, giving a far greater apparent density, needed to make up for the difference in intensity between light sources like the LED backlights on LCD screens and merely reflected light from projection screens, however finely silvered. The same can be said of liquid crystal on silicon (LCOS) projectors, which split the incoming light prismatically, reflecting it from red, green and blue pixels as desired, as in DLP projectors either sequentially (in single-chip projectors, relying on optical mixing n the viewer's eye) or simultaneously (in more expensive three-chip versions), the pixels themselves being formed not as mirrors but from the same liquid crystals used in LCD screens. Only the older and cheaper LCD projectors do not reflect the light but beam it through LCD panels. In all three designs, focusing the light of the arc lamp towards the projection lens is absolutely critical, and in all three the compound projection lens is tuned to produce a standard cinematic grammar.

Much of the old work of the projectionist is automated here, such as the aperture: the hand-cut aperture plates of yore no longer exist – it is impossible to get inside the lens assembly. Levels of illumination and colour are controlled with a remote; and a critical issue in projection, key-stoning (the trapezoidal result of distortion caused when the edge of image closest to the projector is shorter than that furthest away) is automatically reset by the projector without interference – in fact getting a digital projector to give anything but a four-square image is a problem.

The cine projector has a sibling which makes evident a quality of projected light which would make it foundational for 21st century media. In the intangible architecture of the zeppelin field devised by Albert Speer for the Nuremberg rallies, the coherence of projected light attains a certain purity: light without image, light as sheer spatial organisation. The purpose of the condenser lens and the parabolic mirror in both searchlights and cine projectors is to produce coherent light. Lyotard, in his 'Acinéma', painted the apotheosis of cinema in the wasteful, playful figure of a child playing with matches. Its actual apotheosis is the light pillars of the Nuremberg rallies: the symmetry and order of classicism subordinated to total command.

Some decades later, lasers would take over as the medium of choice for dynamic urban architectures and stadium rock. Light Amplification by Stimulated Emission of Radiation, laser, relies on controlling the random production of light typical of the sun, flames and incandescent lamps. A coherent waveform can function as a carrier, modulations decipherable as signals. After experimenting with airborne transmissions (rain and fog dissipated the signal), Cold War experimenters in the US, UK, Russia and Japan converged on getting coherent light from lasers to travel through flexible glass pipes.

Fibre optics work on the principle of total internal reflection, a phenomenon already observed and reproduced as a scientific amusement in 1844 (Hecht 1999: 13-14). Here the light from an arc lamp is guided through the curving fall of a jet of water, the light waves bouncing from the inner walls of the jet, reflecting back from the meniscus. An 1881 patent suggested using the same phenomenon in glass rods to deliver light throughout an apartment building (Hecht 1999: 23). Coherent waveforms were much better guided between surfaces when a glass rod of one refractive index was fused inside a glass tube of another, and the two heated and extruded to a fine filament. Already in use over the short distances of gastroscopy in the 1950s, the nascent technology was wedded to lasers in the 1960s (Hecht 88-91). In a return to cinematic technologies, confocal lenses – deliberate 'imperfections' functioning as series of lenses keeping light away from the walls of the fibre – guide and thus amplify the transmission of light through fibre. These optical amplifiers of the later 1970s completed the innovation period.

The principle of control emerged in the design of both lenses and even more specifically of projectors, where control over the random flight of photons in every direction and at every wavelength from any source had to be tamed if projecting a tiny frame of film-stock onto a huge screen was to need any usefully achievable quantity of energy. Shaping the beam through parabolic mirrors and condenser lenses structured other informational uses of light in searchlights and lighthouses The irony is that the light which is so powerfully constrained in these systems, and which is even more tightly corseted in the internal reflections of fibre optic waveguides, is the medium of 21st century telecommunications and network media. The organization of light in projection has found in the 21st century an even more precise conformation of light to the requisites of an instinct towards order that has become totalitarian.

Glass, the medium of Duchamp's modernist masterpiece, *has never been 'digital', but digital visual media are unthinkable without it. The continuities between older and new media are as important as the discontinuities; and the physical specifications – caesium doping and Corning glass for example – are so important that knowing the spec of a lens or a length of fibre is as critical as knowing the gauge of filmstock. The medium-very-specific approach observes the divergence of materials. But in the case of projected light, we also have to observe the race to standardization, and to a mode of totalitarian control over light. Analysing the agonistic dynamics of normativity and creative invention is more interesting and beneficial than technically ill-informed and philosophically poorly-parsed analog-digital binaries.*