DIGITAL 3D PROJECTION

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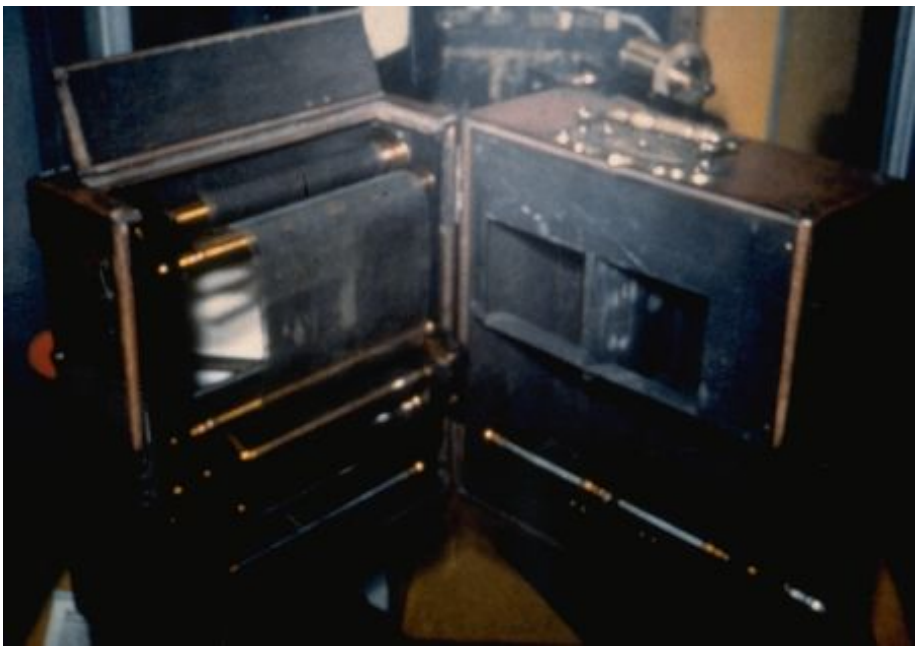
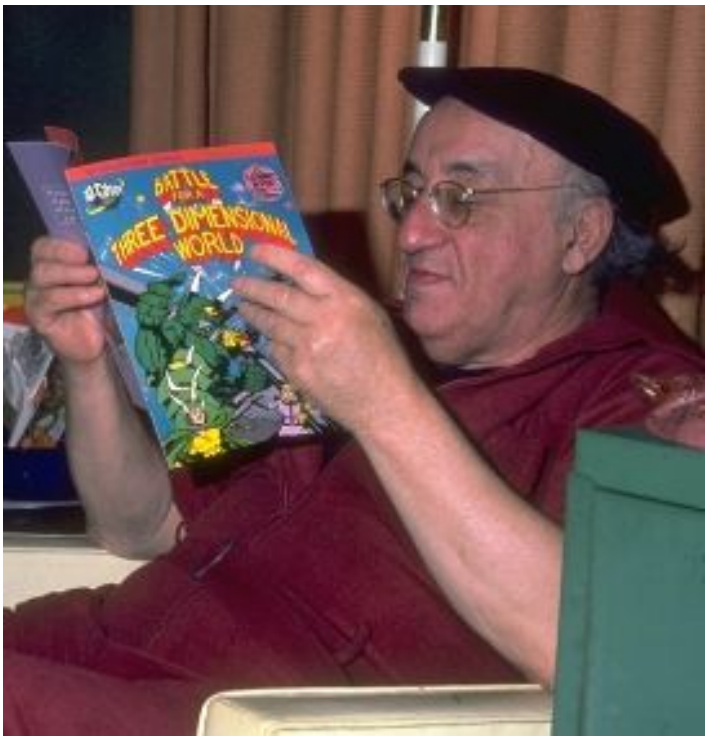
There is no question that the current revolution in 3D imaging is due primarily to the commitment of Hollywood to the making of major 3D films and that this has been due principally to Los Angeles Corporation Real D's spending of huge amounts of money to put digital 3D projections systems in place. From my point of view this happened because I saw Arch Oboler's Bwana Devil in 1952 and began researching 3D in 1973 which led to the founding of StereoGraphics Corp in 1979 which was taken over by Real D in 2004. It is truly gratifying and amazing to see the vision I started to pursue in 1973 come to fruition.



World's first stereoscopic motion picture and camera made by William Friese-Green in 1893. Photographed by the author in the British

Museum in 1986. At this time there were no sharp frame lines, no perforations and no projectors. The original film, sometimes called "A Walk in the Park" is in the French National Library. I copied a pair from it and it is still possible to see the depth.



Pioneering 3D Movie director Arch Oboler (Bwana Devil, The Bubble, Domo Arigoto) reading a 3D Comic ca 1982. Modern 3D film more or less begins with Bwana Devil (1952) and is directly responsible for my 35 year career in 3D which includes the founding of StereoGraphics Corp (1979) and 3DTV Corp (1989). Photo courtesy Susan Pinsky of Reel 3D.

However, as anyone who has reflected on the causal nexus is aware, there are an unlimited number of other takes on reality, all equally valid. One could say that Arch Oboler is responsible or that Ed Land (founder of Polaroid Corp, one major inventor and marketer of polarized sheets) is, or that Larry Hornbeck (principal inventor of DLP projection) or the 50,000 or so engineers and chemists who developed digital and liquid crystal (LC) technology are responsible and so on back to the beginning of time. Likewise, we are beholden to the great grandparents of Walt Disney, without whom there would presumably have been no Walt, no Mickey and Donald, no Shamrock Holdings and

no $50M in the bank for Real D. Or perhaps if Real D had found ColorLink and talked to me first they would have had no reason to buy controlling interest in StereoGraphics.

Even if LC's or DLP projectors or polarizer technology did not exist it would still be feasible to have a 3D cinema now (e.g., using film with polarized glasses or mechanical shutters- as was done 80 years ago- or CRT or light valve projectors such as Eidophor-the king of large screen electronic projection for many years (http://www.dcinematoday.com/dc/ProjectorHistory.aspx?index=31) , or with the Infitec system described below). So, all that was ever required was someone willing to get things started by spending alot of money to establish a 3D projection network and that just happened to be Real D in the last few years.

There are at least 8 distinct types of large screen 3D projection currently available but I will omit standard bicolor anaglyph completely as it just does not make the grade, and only briefly mention several kinds of autostereoscopic projection.

All techniques that use sheets of plastic polarizer in the projection path have the limitation that these absorb much of the light and so high brightness projectors will require cooling and degrade the polarizer. Some have dealt with this and other limitations by specifying wire grid polarizers (e.g., US 6,831,722, WO2007/070245). Conventional TFTs have crucial advantages over current LCOS and so Kodak and others are developing ways to make more complex projectors to enable their use for 3D (WO2007/070245).

The dominant stereoscopic projection system at the moment (marketed by Real D and several others) uses electrooptic switching of circular polarization (CP) with a specially constructed multilayer LC plate (US 2007/258138, WO2007/067493) in front of the projector lens with a silver (i.e., aluminized) screen and passive paper or plastic CP glasses for viewing. This is a very old idea and goes back at least to the 40's when the first sheet polarizers were invented, at which time it was done via a rotating polarized disc (a system resuscitated and being marketed to the 3D movie industry now).

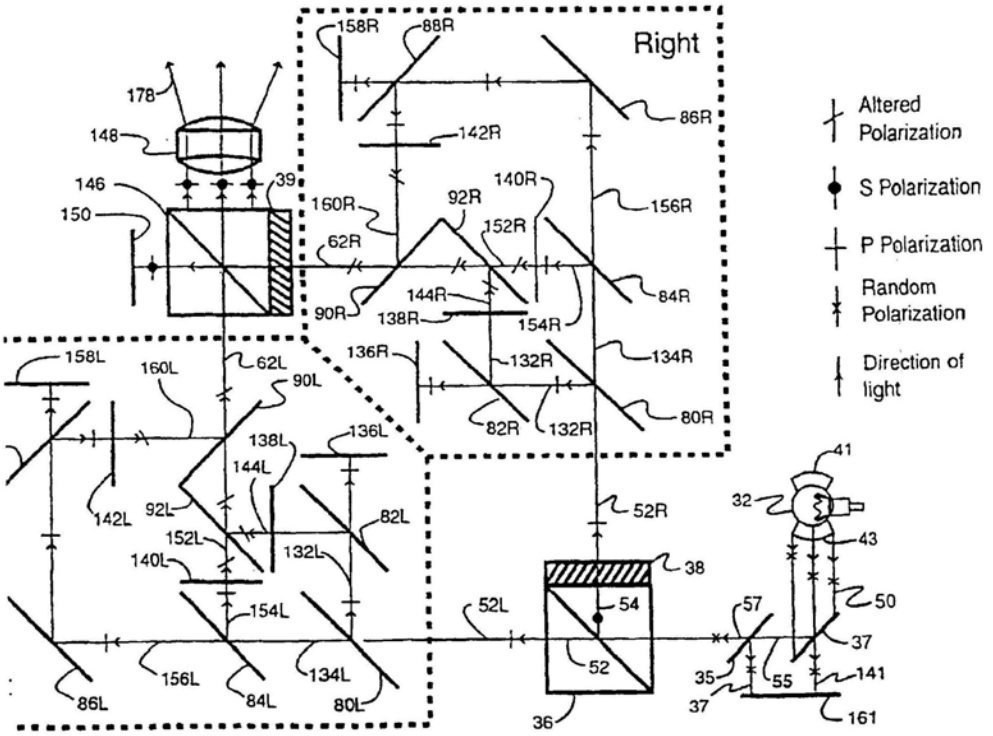
Kerr cells (electrically switchable polarizing liquids, in principle identical to the CP switching of LCD's due to the same electrically controlled birefringence), were invented and patented for this purpose about the same time. The achromatic (color correcting) properties of triple sets of mutually orthogonal half-wave retarders, discovered long ago by Hariharan (Proc. of Indian Academy of Sci. (1952)) and well known in the art, has been researched frequently, and most vigorously recently by ColorLink (now part of Real D), and its components and related or alternative display tech is coming in an avalanche from all the big companies as well as countless smaller ones—e.g., DigiLens (now owned by SBG Labs--- i.e., Switchable Bragg Gratings-- http://www.sbglabs.com/company.htm , LC tech from Rolic, tunable electrowettable diffraction filters from Nokia (WO2007/096687) and many others.

Those interested in details of ColorLink's achromatic polarization switches and related tech may consult their numerous patent applications such as US 2008/0129939, 2008/0129900 , 2007/0188711 , 2006/0291053 and 2006/0285026, WO2007/086952, WO2007/024713 ,WO2006/135867, WO2007/095476 or their many granted patents for an introduction to the extensive prior art.

As in any HiTech arena, many of these patents get quite esoteric, e.g., using Poincaire spheres for calculating achromatism, and of questionable utility as practical methods for digital 3D cinema. US 2008/0129900 e.g., attempts to fix artifacts due to the gap between segments of the color wheel in single chip DLP projectors, which produces time sequential color ghosting (see Andrew Woods work on this issue relevant to frame sequential viewing with DLP), by instantaneously altering the driving voltage and hence the chromatic properties of the multilayered LC pi-cell, to blank gap image frames and smooth out their sequential spectral color.

It has been said (e.g., on the Real D page) that one cannot use single chip projectors for any active (i.e., frame sequential) 3D technique, but various single chip projectors operating at 85 or 120hz have been in successful 3D use with shutter glasses for at least 5 years, though they currently have some limits on image quality. In addition, new tech is being introduced and many new models specifically engineered for 3D will appear soon. There are also numerous patents on new projection

technology for active or passive glasses which look promising. One promising example is a LC light valve method with the unfortunate acronym PEMFVORD (Programmable, ElectroMagnetic wave Field Vector Orientation Rotating Device), patented by Steven Sedlmayer of Arizona for the Taiwanese display company AUO last year, that appears able to produce very high efficiency native dual polarization (US 7,295,371). This could have a major impact on 3D projection due to low cost, brightness, image quality, energy efficiency and compactness. Of course many new technologies are being developed but they are probably years away. Those who want the bleeding edge might talk to Boeing about their quantum dot 3D displays (GB 2,425,673).



Sedlmeyer's 2007 patent for AUO on light valve dual polarized projection.

Regarding patents, we can expect numerous variations of every stereo display modality to appear in the next few years and much overlapping tech in the patents and products since the basics are public domain and, insofar as there are novel claims, patents take about 4 years to issue and meanwhile anyone is free to use them. One can also anticipate some complex patent fights since there is a huge and intricate prior art on all methods. The only part of a patent that matters are the claims and the

granting of a patent merely says that they appear to be valid—an issue that only the patent courts can decide. I have studied the 3D patent and technical literature for 35 years and I suspect that more than 95% of all granted claims could not withstand a serious challenge.

CP and LP switching by multilayer LCD plates was specifically patented for 3D by many companies including StereoGraphics (now Real D), the company I started in 1979, and marketed by them under the name "Z-Screen", sometimes called "Z-Filter". LCD shutter glasses and CP switching screens were originally developed and marketed by Tektronix in the 70's and, after poor management destroyed their LCD division, the USA's finest LCD R&D facility, it was licensed to NuVision of USA and Delta of Taiwan. Independently, various other companies worked on this, including the Japanese petrochemical company Idemitsu, who released an all plastic version (i.e, no glass whatsoever) that I used for some time in the late 1990's. A few years ago ColorLink began marketing one and Real D (the new name of StereoGraphics after some Hollywood hotshots bought controlling interest in 2004) solved the problem of competition from a superior product by buying ColorLink (http://www.reald-corporate.com/story030807.asp). Presumably they now realize that if they bought ColorLinkfirst, there would have been no reason to buy StereoGraphics.

A little known aspect of this history is that Tektronix was sued by LC pioneer James Ferguson over pi-cell patents, and, despite assurances from their patent and tech staff that they would win easily, they paid him off rather than pursuing it, since they had a lucrative business selling high end devices such as time domain reflectometers and they did not want to interrupt the cash flow. Possibly this enabled StereoGraphics Corp. to survive since Tek might have sued them for patent violations.

The CP switching method has the same problem as other active or passive (e.g., dual projector) CP methods—more ghosting or crosstalk than LP (Linear Polarizer) methods. In fact there are so many problems with CP that Real D says it will not work for screens wider than 40 feet and has filed a whole series of patents trying to correct them (e.g., US 2008/0206155 and above). This necessitates the preprocessing of all 3D films by Real D to decrease ghosting (US 2008/0268104, US 2007/188602, EP001883835), though they say they will put the

algorithms in a chip soon and do it realtime on the projector. There is a long history of ghost reduction going back to the days of ghosting in 2D television broadcasting and there have been a number of stereoscopic implementations in the patent and technical literature (e.g, see the patents by Street US 6.075,555 etc and others in my SPIE article) and also in the common educational 3D system from Neotek www.neotek.com.

From the earliest days of LC's in the 60's to the present, there is a massive body of literature (tens of thousands of patents and papers) relevant to polarization switching and there is no possibility that anyone has a fundamental blocking patent on LCD shutter glasses, or CP or LP switching. Countless companies worked on this in the 70's and 80's and you can get a good sampling in the SPIE review paper I published over a decade ago, which is also on my page www.3dtv.jp as the Stereoscopic Imaging Tech article, but this article only relates to certain areas of 3D and barely touches on the much larger literature relevant to polarization switching.

Consequently, it is clear that active CP (or LP) switching for active glasses or projector StereoPlates (the name I have long used for these devices when placed in front of a projector or CRT) is a public domain technique, though possibly some companies have protectable refinements. Real D claims they will release a new XL version of the ColorLink CP switch in late 2008 with double the brightness (which can be achieved e.g., with sufficiently rapid switching, by eliminating the polarizers and using a cholesteric LC layer that can theoretically convert to CP 100% of the unpolarized light). This technology is well understood by thousands of engineers in the LC industry and new products from other companies are already appearing, but it is possible that one of the mechanical LP or CP alternating systems will obsolete them all. The simple rotating CP disk system works, but has problems which will be obvious to any EO engineer, but modern tech provides other options and this is being done.

E.G., one promising improvement prototyped over the last 3 years and patented by IBM (US 2008/555402, 2008/555401, 2008/0055546) uses small pieces of magnetically oscillated polarized filters placed at the internal focal point of the projector with magnetic bearings and magnetic or air core solenoid damping. I estimate a parts cost of about

$20 and it can be modularized for quick install by unskilled personnel. However the same IBM researchers are hedging their bets with a conventional rotating polarized wheel (WO2007/071614).

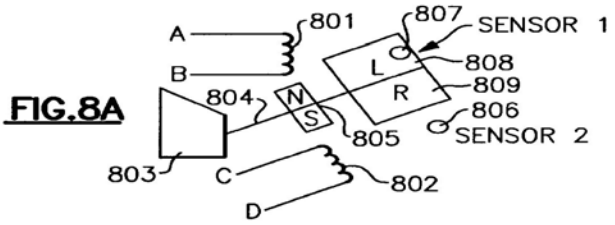


FIG.8A

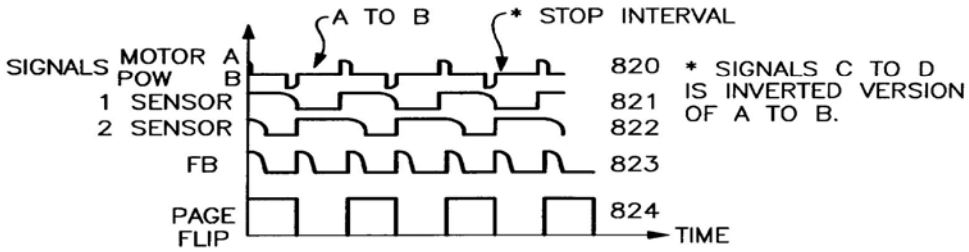


FIG.8B

IBM 2008 patent application on magnetically controlled frame sequential polarized 3D projection with the polarizers, sensors and dampers in Fig 8A and the timing diagram in 8B.

With these devices, internal or external, it should be easy to retrofit theaters currently using a CP switcher or other means, thus eliminating the need for preprocessing, expensive glasses and licensing fees. Like most of the other methods, it should also work with GLV projectors (http://www.siliconlight.com/brochure1.pdf), a laser addressed MEMS technique that has been exclusively licensed to SONY for display applications. Perhaps SONY will finally recover its investment on the PlayStation 3 this year and be able to afford developing GLV, which, blindsided by the 3D revolution, they sorely need as their high end projector is LCOS, incompatible with all frame sequential methods.

All this points to the fact that the real reason for Real D's current dominance in 3D digital projection is not technology but the $100M or so invested. They would almost certainly have the same dominance if they had promoted any of the other 4 common 3D projection

technologies instead. However the apparently proprietary nature of the CP switcher was undoubtedly appealing. It appears that in addition to the approx. $75 to $150K cost of the hardware and screen (most for the 3 chip projectors), Real D requires theaters to pay a $30K/year licensing fee and to buy the expensive (ca $3/pair-but see below) plastic CP glasses, the cost of which, in the fastidious and rich USA at least, is passed onto the customers.

These glasses can be made for about 30 cents each, or even less in paper, and of course reused so that customers do not need to pay a premium. It is true that if one tips the head about 10 degrees to the side, the ghosting advantage of LP over CP disappears, but few find it necessary to watch 3D movies with head tilted and even with 2D virtually everyone keeps their head vertical. With shutter glasses there are no extra charges and no problems with head tipping but of course the theater must clean the glasses and replace dead batteries. Batteries in new glasses from 3DTV Corp should last for over 500 hours, based on the actual in theater performance so far.

Regarding wireless shutter glasses, the new model from 3DTV Corp, incorporates a microprocessor, which enables many desireable functions including power management, which extends battery life, and easy check on battery level.

Fig 2 3D Cinema System from 3DTV Corp with microprocessor controlled LCD shutter glasses.

Image brightness is always a major consideration with 3D and the active CP technique (e.g., StereoPlate, Z-Screen) passes about 25-27% in the case of double LC layer (for pi-cells or surface mode LC with LC layer thickness about 5 mcm). Of course in multilayered (super high contrast—i.e., low ghosting) LC pi-structures the optical efficiency will drop further. The LCD shutter glasses (with a single LC layer as a rule) pass about 32-35% in case of pi-cells and about 20-25% in case of pi-cells doped with cholesteric LC. These will have an overall contrast about 100:1 (uncompensated) with a driving voltage no more than 12V in comparison with a contrast between 10 and 30:1 in uncompensated undoped pi-cells with driving voltage about 20V. Dual polarized DLP or LCD can pass up to a max of 38% (but probably typically below 30%) and up to ca 60% with dual LCD polarized internally (eg by Barco) or with use of special external filters (e.g., http://www.advisol.co.il/StereoBright%20home.html or http://www.silverfabric.de/html/sf_polarizers.htm). Standard LCD projectors have significant chromatic aberration and existing polarization but this can be eliminated simply by a layer or two of common clear acrylic in front of the lens.

Uncompensated CP and LP methods (i.e., normal theatrical paper or plastic 3D viewing glasses with just one layer of the plastic polarizer) used with CP or LP on projector give a typical stereo separation ratio of up to 100:1 while the compensated (pi-cell or surface mode LC) active glasses currently used can give up to 500:1 on axis. ColorLink has reported up to 5000:1 contrast in compensated systems which is better than the best Nitto Denko LP plastic sheets. In practice however, such complicated compensation is not used for active glasses. For example, the StereoGraphics CrystalEyes active shutter glasses use one rotated half-wave retarder to transform the elliptical polarization caused by residual birefringence of the liquid crystal into quasi LP for increased on-axis contrast (i.e., with the eyes looking straight ahead perpendicular to the LCD shutter), but with little increased contrast off axis, so the eyes see the periphery with poorer contrast and the result averaged over the whole image should be about the same 100:1 contrast as with uncompensated passive glasses.

However, the bottom line is whether any of this makes a difference in the image quality and enjoyment by the average viewer, and it is my view that they will be equally satisfied with the cheapest method. For example, my own observations on a variety of monitors with the various types of wireless IR shutter glasses driven by our Universal Emitter shows essentially identical image quality (ghosting, color, contrast) of the cheapest and most expensive models (i.e., $30 vs $800).

Fig 3 Universal Transmitter introduced by 3DTV Corp in 2008 with 3 of the many kinds of wireless LCD shutter glasses compatible with it.

The biggest problem with all techniques (ignored by virtually everyone) is fingerprints on the glasses. Based on my own observations over 35 years, I expect that, regardless of the method used, more than 50% of all viewers put a serious fingerprint in the viewing area of at least one lens by the time the film starts (assuming, contrary to common practice, that they are clean to begin with!). This detracts greatly from the experience as anyone can demonstrate. All viewers should be told to avoid touching the lenses and to check them carefully for prints just before the movie starts. $100 million for the film and $20M for the theater and $200K for the projection system can be defeated by a single fingerprint!

In addition, for all polarized methods, it is essential to QC every batch of glasses, as well as the projector polarizers and silver screens. Silver

screens, even from major manufacturers, can have very uneven polarization properties, to the point of being useless, and projector polarizers can burn out quickly. Uneven glasses quality is always a problem as well. I recently received (from a very well known 3D company) a shipment of LP glasses of which 30% were totally useless, along with a silver screen that depolarized the image almost completely and when they sent me the remetallized screen it still depolarized irregularly and was full of hot spots. The same QC problems exist for the polarizers used in StereoPlates or in active shutter glasses.

All frame sequential techniques (i.e., CP rotating discs, CP or LP switchers, active Infitec or LCD shutter glasses) suffer from motion artifacts due to the fact that the right and left images are not presented to the two eyes simultaneously (as they are in the real world) and this is worse if the two images are not captured by two cameras in perfect sync. The problem worsens with faster object motion but should not be present with frame simultaneous presentation with any dual projector technique (unless demultiplexed from a low frame rate sequential format) and likewise should not appear if demuxed from a high frame rate file (e.g., dual 60hz shot with twin video cameras with progressive scan preferably) or played from HD DVDROM in TriD format in dual out mode (see 3DTV page), or demuxed by using 3DTV Corp's new high frame rate HD Demux which will also be the first device to convert standard field sequential DVD's (SD or HD) for viewing on 3D ready tv sets.

Though Real D's huge bankroll and inside position in Hollywood has given them an early lead, the Infitec system now marketed by many projector companies, and most aggressively for the big screen at the moment by DOLBY and BARCO, is quite superior in terms of image quality (10,000 to 1 stereo separation with essentially ZERO ghosting) and, like active shutter glasses, permits the use of any kind of screen (i.e, no need for a silver one). Created by a German team at Daimler-Chrysler a few years ago and then spun off, it is a triple anaglyph notch filter method and Barco offers both dual projector and single projector (ie, active Infitec, a frame sequential anaglyph with rotating or switching internal filter EP 1 830 585) versions, while Dolby and others have the dual projector version. With the many advances in light generating displays (e.g., MEMS systems from Kodak etc) it is not out of the question that a native Infitec flat panel and projector will be

produced in the next decade. Bose Corp has several patents on an active 3D color wheel method with special filter glasses similar in principle to the Infitec system (WO2007/118114, WO2007/118075).

Major downsides of Infitec are that it loses even more light than polarizers, passing only about 7% with one or 17 % with dual projectors (though Barco says 27% in one brochure), the fact that the glasses cost $60 or more and the fact that active Infitec will show the same motion artifacts as CP or LP switching or LCD shutters. Also, as with any anaglyph technique, there is a different tint to the two images and this causes a small but noticeable color aberration which could produce a bit of eyestrain during a 90 minute film. However, all the techniques produce some demands on the visual system and there has never been a careful controlled study of relative comfort of the various 3D projection systems, nor I believe even one comparing 2D and 3D. There is, however, a vast psychological literature on stereo perception, but most is difficult to relate to the 3D cinema parameters, and in any event it is totally ignored by Hollywood and the rest of the 3D industry.

Unlike all the other methods, the basics of which clearly lie in the public domain, the triple interference filters used by Infitec seems to me a good basic patent (though I would not be surprised that a careful search found prior art). However, the basic idea is well known and I have on my desk the two-color orange/blue interference filter glasses I used with my SpaceSpex anaglyphs in 1993.

The home 3D-ready DLP rear projection TV's introduced by Samsung and Mitsubishi in 2007 and several 3D ready plasma panels from Samsung also produce 120hz frame sequential projection with active LCD shutter glasses. However these do NOT take in the normal field sequential 3D signal but rather the 60hz Texas Instruments checkerboard stereo format (US 2008/0036854, WO2008/021856) that facilitates conversion of 60hz to 120hz, so files must currently be reformatted by software on a pc. 3DTV Corp. will soon release the world's first Universal wireless glasses transmitter with the standard VESA stereo plug for use with these sets (and also for any of the high end video cards from Nvidia, 3D Labs etc, or with the ubiquitous 3D gaming hardware including wired shutter glasses sold by the hundreds of thousands by X3D, I/O, 3DTV, E-Dimensional etc.).

The Universal Transmitter can be used with virtually any kind of wireless shutter glasses (though only one of the 4 standards works at a time). With suitable interfaces it will also work with the common low cost dlp projectors running at 60, or 85hz or higher-- such theaters have been in use for at least 5 years. Australian engineer Andrew Woods has researched this extensively and there are lists of frame sequential compatible models from others on the net as well. As expected, all the projector companies are now introducing lower cost 120Hz (or frame and timing rate variable--like the high end 3 Chip ones) DLP projectors which will further stimulate the market.

In this context one should note a simple technique for reducing flicker with active glasses and 85hz projectors. Removing the front layer of polarizer from the glasses and putting it in front of the projector greatly reduces or eliminates flicker due to ambient light and may increase contrast, but necessitates the silver screen and special glasses. This occurred to me many years ago and I have seen it patented several times so it is somewhat surprising to see this idea recently presented as a novelty in one of SG/Real D's many vanity patents as "partial shutters" (US 2008/0062259), and as a display modality for monitors with no mention of projectors. As with most patent applications, this one fails both the tests of no prior art and of nonobviousness. Likewise with Real D's application for making cheap CP glasses by combining LP and retarder in one frame, rather than buying laminated CP (US 2008/0018851). This is possibly feasible in large quantity as it might reduce the cost to near that of LP and make more uniform quality.

There have been many innovations in shutter glasses techniques yet to be implemented, including such whimsies as universal glasses able to sync to any of the various transmitters (3DTV prototype) and a nifty design intended for ophthalmic use that displays personal messages (a natural for advertising or in-theater paging)-- US 2008/0062338.

Most of the world cannot afford $100K projection systems and is not able to pay huge licensing fees nor $3/pair for glasses, so naturally they are going for shutter glasses systems (perhaps 200 theaters so far), mechanical rotating CP discs, or dual polarized projection. Presumably, all the cinema servers are compatible with two projectors, which has the great advantage of lower cost and easier backup as well as the ready availability of cheap LP glasses, which also have lower

crosstalk than CP, and with dual projectors you should be able to avoid the annoying motion artifacts with fast movement and the binocular color asymmetry of Infitec. It is clearly easier and cheaper to find two projectors (LCD or DLP) which combine to make a suitably bright image than to be forced to buy one top of the line high brightness unit. It is also feasible to maintain a backup unit and to source and change projectors quickly.

Several companies have developed 3D Cinema shutter glasses systems, and I have been instrumental in the creation of such products in Russia and China in 2007. The 3DTV Corp 3D Theater Transmitter costs about $5000 and comes with sophisticated microprocessor controlled wireless glasses. It is compatible with 1 chip or 3 chip projectors up to 144hz and should work well with large or medium venue projectors from NEC, Panasonic, Digital Projection, Barco, Christie, Projection Design and others (but not the well known Sony high end unit which is not DLP but LCOS).

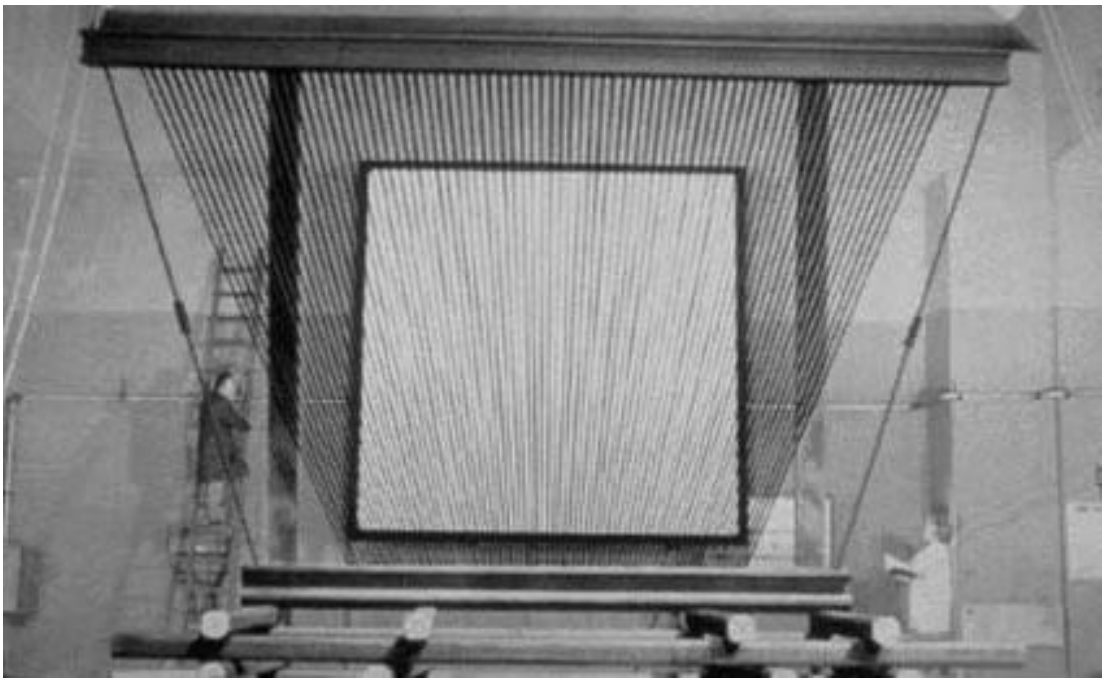
There are a variety of options for live 3D projection, but perhaps the cheapest and easiest is the TriD software sold by 3DTV Corp. which lets you display/record/edit/compress/playback all the pixels of two cameras in frame sequential or dual projector mode with a small executable program running on a standard pc or even a good laptop. It is highly intuitive and can be learned in an hour.

IMAX 3D theaters, which use very large screens with high brightness projection, afford a unique experience which, due to screen size and brightness, emphasizes problems with filming, editing and projection, and everyone interested in the field should see as many of the films as possible, removing the glasses frequently to observe the mistakes. I have written several articles on IMAX 3D in which I discuss the films and the technology (www.3dtv.jp or in my booklet Stereoscopic Imaging Technology). They have used bicolor anaglyph occasionally, but mostly active and passive one and two projector methods.

Laser projection has seen sporadic use for both polarized and frame sequential methods for over 30 years, and with native polarization, zero optical distortion, highly saturated colors, highly flexible distances and screen sizes due to almost limitless depth of focus and resolution, extremely rapid decay and electrooptic switching, it should be the

sharpest, brightest, highest contrast, truest colored of all, but perhaps because of safety issues, need for water cooling, and the need to eliminate the speckle interference by screen vibration or other means, no large entity has consistently championed it, so it remains a rarity. However work has been done by Mitsubishi and others which attempts to combine the advantages of laser addressing with those of DLP and so polarized lasers may yet appear in theatrical projectors (US 2008/0049197).

Autostereoscopic (no glasses) 3D projection has a long history but only the Soviet Union had any large screen commercial theaters, with headrests for the no glasses seats (they projected simultaneously with LP for people in the bad viewing zones). They used screens made of slanted piano wire and later some made of glass, but these are long gone.



Russian autostereoscopic movie screen developed at NIKFI in Moscow in 1960's and used in a few theaters until the early 80's. Slanting was necessary to match viewing zones on the slanted theater floor.

There have been countless varieties of autostereo projection displays since the 1930's, most using special screens made with more conventional materials and methods, to direct the images and this work

continues (e.g., US 6,533,420, US 2006/0066810, W0 98/43441 WIPO 2005/122595, WO 2007/062644, US 7,230,759).

There were also some noncommercial holographic screens created by Komar at NIKFI in Moscow, but these were never commercialized. Many others have described autostereo projection using holographic screens (beginning of course with Gabor) and work continues from many quarters (e.g., US 2008/0007809). Recently NewSight Corp has created POLO, a large venue holographic projection system WO 2004/008779, US 2006/0103932 (www.newsight.com). NewSight (formerly X3D-to whom 3DTV Corp has provided consulting and technology-including my own patent for realtime 2D to 3D video conversion US 6,108,005—incorporated in the well known Virtual FX box) has begun work on POLO-2 –an improved version, and also a different technology for large screen autostereo (even outdoors in daylight), which they hope to have ready in mid 2008. Both these technologies can be tiled to any size.

In addition NewSight has recently introduced a digital signage mode for autostereo which eliminates the "dead zones", at the cost of reducing the depth, and realtime synthesis of multiview autostereo, on a standard pc, from right and left live cameras or image files. This may be of special interest to the movie industry since it provides a means of showing 3D trailers in theater lobbies and malls and of course they can be updated over the net. NewSight has also made very high quality autostereoscopic trailers from 2D films. A network like this is being planned in Asia this year.

A major problem with common autostereo displays is the reduction in resolution, but Vasily Ezhov has just patented (PCT/RU2008/000233) and is prototyping what I think is the world's first planar auto 3D display using exclusively standard LCD technology (i.e., COTS) with full display resolution in each eye and this should greatly stimulate applications. It is also fully 2D compatible. In addition, he has another application pending on a more general universal auto 3D method that can be realized on practically any type of LC matrix (IPS, FFS, VA, MVA, PVA, ASV and so on, including bistable ones – FLC etc). I recommend his recent articles (http://3dstereo.ru/ezhovpublications_e) as the best extant short overview of 3D display methods, in which he defines several that have never been built or even named.

Readers of my articles over the last 15 years are aware of the work on autostereo projection by Robert Collender, whom I have called the Einstein of 3D for solving the problem of glasses free stereo for large audiences. He gave up trying to make the world listen long ago but, after a 20 year hiatus, recently did another patent with his son, extending his stereoptiplexer ideas, and anyone with lots of money and good R&D capabilities should take a look (US 7,180,663, US 2003/0234909A1).

Robert Collender of California in 1978 with a model of his autostereoscopic StereoMultiplexer theater.

Finally, I must note that any technique is only as good as the available software and that minimization of binocular asymmetries (e.g., image skew on any axis, zoom discrepancies or color or luminosity imbalance), avoidance of violations of the stereo window, minimal horizontal parallax, minimal divergence of in focus objects, and no vertical parallax, should be strictly observed. Even those regarded as experts are given to oracular pronouncements that are often quite confused or blatantly mistaken (rarely citing studies, but relying on their own prejudices and anecdotal reports). It is for example wrong, wrong, wrong, wrong to permit frequent and prolonged breakdown of the accommodation/convergence relationship (the IMAX "standard") if it can be avoided. This happens when objects are given large negative parallax and pushed into audience space, forcing the eyes to converge

well in front of the screen while maintaining focus on the screen. It was shown by Russian researchers many years ago that this tends to make the eyes focus on the convergence plane, leading to blurry images and eyestrain as the visual system tracks in the attempt to focus.

Stereo errors of every kind are unavoidable in live action with even the best system and these add to those from projection and viewing, which sum and cumulate over time. That is, orthostereoscopy is unobtainable (even orthoscopy in 2D eludes us as well---like a perfectly frictionless surface) but one must try. With even the best technique it is near universal to have some mild discomfort from prolonged stereoscopic viewing and this is likely to increase with age. It does not serve anyone's interests to encourage bad technique.