BRIGHTEST 3D PROJECTION

By Lenny Lipton

I have been working on a new stereoscopic projection method, the Oculus3D™ system, using 35mm projectors and specially formatted film. From a business perspective there is a strong demand for a product like this since there are not enough digital projectors, the usual platform for 3D projection, in the United States, North America, or the rest of the world, for that matter. There are theatrical features, mostly adventure fantasy films, shot in 2D, that are being converted so that they can be shown in 3D. And there are 3D movies in the pipeline that were planned to be in 3D -- something like two features a month for this year. A studio executive is probably making a good decision to convert assets to maximize attendance and profits after the robust success of *Avatar* and *Alice*, which are financial successes that have given a boost to the stereoscopic medium. We are seeing steps toward the ubiquity of the stereoscopic cinema on a genre by genre basis – first kids' animation, then horror date movies, and now action, science fiction, and adventure films. The 3D films that are getting made are, with the passage of time, for older and older audiences. Now it would seem that all tent-pole movies are likely candidates for 3D.

Even before *Avatar* one could make a good case for the eventual ubiquity of the theatrical stereoscopic medium since about 15% of the box office for the year 2009 came from about a score of 3D movies – even before *Avatar*. Part of this is because good attendance and part is because 3-D movies are priced as a special event. (They're not priced at two or three bucks more because of the eyewear as is commonly asserted; people pay more because they are getting something special.) Also, given the history of the motion picture medium and commonly observed pricing trends, prices don't go down; so we are likely to see a continuation of this pricing trend, which is good news for the exhibitors and the studios.

There is a shortage of digital projectors. They're costly -- averaging $70K to install, according to the February 6th LA Times, and that doesn't include a similar sum over a few years for the 3D hardware sale or license. We are hopefully passing through the great recession and that makes it hard to finance digital projectors. The just announced closing of a financing deal by a major investment bank is a year late and at half of its original goal. There is some question in my mind about the rate of deployment of digital projectors. Some of the problem has to do with the financing model, the so-called virtual print fee, and some of it has to do with digital projectors remaining viable in the long run. I think digital projection is just great. I stood up at an ASC technology committee meeting and said so, and was booed by those in attendance. They are film guys, and so am I. I love film, but my eyes told me that digital projection looks as good. There are good things about digital projectors, and good things about 35mm projectors and you can say bad things about both. The troubles with digital projectors are that there are not enough of them and they're costly to purchase and maintain.

There are about 135,000 theatrical screens in the world. I am not completely certain of the numbers (nobody is) but I think there are about 7,000 3D screens in the world, the great majority of which are based on DLP projectors. In the U.S.A, according TO the referenced LA Times article, there are 37,000 screens, or which I think there are between 3,500 and 4,000 3D screens. This means that there are not enough screens for the shows that are being released. Everybody in the business knows it and has reached crisis proportions with one show bumping into another.

My work for 37 years has been to create advanced stereoscopic displays, and in particular to invent a viable stereoscopic cinema -- and I've done my share. The major technology components of stereoscopic DLP projection were developed by my colleagues and me at StereoGraphics many years ago, and are today being deployed in thousands of cinemas.

On a worldwide basis what's blocking the growth of the stereoscopic cinema is the lack of 3D theaters. My obsession of late has been how to overcome this problem. So I began to think about the projection of 3D movies using 35mm projectors and I'm not the only one who had this idea. In the early 1990s I was the chairman of the SMPTE working group that recommended standards for the projection of motion pictures using the above-and-below system. It's a deeply flawed system, and I regret seeing its return by no less than three entities. It has three major technical shortcomings: it's dim, it's easy to project a pseudostereoscopic image, and it has asymmetrical vignetting for the left and right fields. The last is the only problem that can be solved but by means of adding vignetting to the prints' subframes in order to symmetrize the illumination -- a grim prospect for a system that is too dark to start with.

Aware of these issues I began to think about what I could design that would be better. I hit upon a different idea; and I have been working on it for many months with my colleagues at Oculus3D, and together we have gone beyond my original conception.

Here is the thinking that went into this system: One of the important considerations in designing optical systems is brightness. We had to figure out how to make the system bright. That is because the great majority of stereoscopic digital projection systems just aren't bright enough. The SMPTE recommendation for projecting 35mm in theatrical cinemas is 16 fL. Why shouldn't stereoscopic movies also be projected at 16 fL? Is there something special about stereoscopic projection that makes a dark image better? The answer is no. 3D movies are usually a lot darker than 2D movies because of two factors: Duty cycle and the selection device. The field sequential system used by all DLP single projector solutions has to divert half the light to each eye. Hence the duty cycle looses 50% of the available light. Of that remaining 50% per eye maybe another 70 to 80% must be lost to the specific selection technology, be it polarization or super anaglyph.

Most 3D movies are being projected at light levels that are from 3.5 to maybe 5 fL. (I saw *Alice* in a theater that was, to my estimation, running at 2 fL or less. The image was so dark I needed a flashlight to find the screen.) 3D movies generally, for digital projection, have to be specially timed to boost color saturation because at such low light levels the eye starts to lose its color perception. When 3D movies are projected properly, that is brightly, the colors are rich and deep and the image has better contrast and looks sharper.

So my thinking went like this: The split-lens approach can't have the brightness I desired. The maximum size barrel that a 35mm projection lens can fit into is a little less than three inches. That means that if you use the split-lens approach – in other words, trying to stuff two lenses into a single barrel, which is an idea that goes back at least half a century – you have two limits: Either you have two lenses that have diameters of approximately three inches, and you slice them in half and put them together; or you have two lenses that have inch-and-a-half diameters, and you stack them on top of each other. What you must do is try to find a diameter that optimizes transmission. A system that tries to stuff two lenses in a small barrel just can't pass enough light. So I had to think of something different, something better.

I felt the new approach needed to have one projection lens to get all the light down its barrel and onto the screen. I also knew that the 1:85 format was inefficient and yet produces a great image on theater screens, even those that are 60 feet wide. Let me explain. In the early 1950s Fox introduced CinemaScope, which used virtually all of the available 35mm frame area. Over the years the size of the 35mm frame has shrunk. First when soundtrack was added because in order to put the optical track on the film it had to intrude into what had been image area. In order to maintain the aspect the approximately 1.3:1 aspect ratio the image got less wide and less high. When Scope was introduced much more of the available area could be used in conjunction with anamorphic lens that could fill the screen with what is today a 2.4:1 aspect ratio. When this happened in the early 1950s Universal introduced a counter-format which, instead of being 1.3:1, was 1.85:1. They achieved the wider aspect ratio through cropping the top and bottom of the image. The newly cropped image an image throws away a lot of frame area. But advances in film stock and the digital intermediate process have allowed for a good image within the 1.85 area.

I thought to myself that if the new 3D format is based on1.85, with two sideframes occupying as much area as possible, I'd have a shot at great brightness. With the right optical system it could be like having two 35mm projectors side by side projecting on the screen. As we designed the format (and this is work that was done with my colleague Al Mayer, Jr. in conjunction with both EFilm and FotoKem) we came up with a way to maximize the size of the format without intruding into the optical soundtrack area or perforations. The concept is to have two side frames, left and right, but rotated by 90 degrees That works out nicely to two 1.85 images with room for a septum between them (or you might call it a sideframe frameline).

After many experiments we decided that the images would be rotated facing in the same direction. With this orientation the images have identical steadiness. In fact, with a good projector the images are rock steady. It is also important that the left and right illumination fields have point for point brightness that is as close as possible and we found an optical solution to make this juxtaposition of sideframes work just fine in terms of the illumination symmetry.

Because the side frame height isn't quite as wide as the normal1.85 frame it's going to require some optical expansion (plus rotation) to fill the same size screen. Since the sideframe 17% less wide, that means that to fill the same size screen the image has be blown up about 17%. But back to my dual 35mm projector idea -- conceptually you can think of this as two projectors side by side, projecting a slightly smaller image than 1.85 that has to get blown up a little bit. Brightness is a function of area, so there has to be some light loss. Another light loss that occurs involves the optics required for image rotation. And the final loss comes from the requirement to polarize the images.

There are several optical functions required to get a 3D image on the screen: First there has to be an image-forming lens. Then, for various reasons, we needed to extend the length of the optical path so that the final device in the optical chain has room to do its job. Projector lenses are typically buried in the projector or off to one side, so the optics responsible for rotation, converging the images, and polarizing them must be out in front of the projector so there is no mechanical interference.

Reflecting surfaces used for the rotation and converging functions can be extremely efficient. But they aren't perfect, so some light is lost. And polarizing systems have to lose light (they can lose anywhere between 65% and 70% of the light). Can the design wind up with a lot of light on the screen? According

to the theoretical calculations these optics could produce an image having 8.4 fL per eye, as measured through the eyewear polarizing. That's rather remarkable. It's not as good as having two 35mm projectors side by side with the same size format, which would be more like 11 fL, but it's pretty darn good. Remember, almost all 3D digital projection systems are down at about 3 to 5 fL. Al and I had the help of John Rupkalvis, who joined the effort early on, and is a well-known stereographer and an expert on reflection optics for stereoscopic systems. John built our first proofs of concept and added greatly to the design.

This is what I wrote when the first version of this article appeared early in February: *The completed prototype, for which Al did the mechanical design, was measured operating in two theaters in the LA area, both of which ran at SMPTE spec. The resultant projected light has an astonishing 7.8 fL per eye. What we've got on the screen is probably the brightest single-projector 35 mm 3D image. It's much brighter than ordinary single projector 3D.*

But we didn't stop there. We decided the best way to make this system work to use refractive optics made for us, to our specification, to optimize the system. The first three prime focal lengths were tested and the result is that we are getting over 10 fL per eye. There are some people I have talked to, industry experts, who doubt this. But it is true. That makes this the brightest 3D projection system from a single projector. Or at the very least none is brighter. The system is capable of projection on the largest cinema screens.

I should mention that the Oculus3D system takes advantage of the entire digital infrastructure. Infrastructure – which is a fancy word but one that everybody's familiar with, whether it's the electric grid or roads – has been the key to my life as an inventor. When I was a boy I read about Thomas Edison, and one of my books said that Edison's big invention wasn't the light bulb, it was the electrical distribution system infrastructure. In order for the Oculus3D system (the lens is called the OculR™), we had to fit into the existing infrastructure. We had to have everything drive down the existing road. So, as far as the way 3-D movies are made today – no change. It's the same pipeline. Instead of a hard drive being distributed to the digital cinemas, it's a 35mm print – the result of a film out and the usual way prints are made. The 35mm print runs the same length, but in the place where it had one picture it now has two in the frame. The soundtrack is in the same place. Although at this moment I've had limited experience, I'm expecting the timing is going to be pretty much the same as it would be for any 35mm print. That's because our system is very bright. It is bright and it's on film.

In a screening at a major studio the executives and my team watched a reel of one of their features projected in both digital 3D and in Oculus3D. It was hard to tell the difference. At another studio an executive told us the system was too bright and that he was concerned about timing the show for release in our format because it would be different from that which would be used for the dimmer digital releases.

We are using linear polarizers rather than circular. Circular is good but SuperLinear™ is pretty close in terms of head tipping attributes and has an order of magnitude better dynamic range. And our eyewear, because linear polarizers are less expensive than circular, cost about 25% less. **That would have saved Fox some $15M on the release of Avatar.**

Technology follows patterns. First stage there's a system or product that people are using, but that product is available only to well-heeled users because of its price. Next somebody comes along with a product that has equal or superior performance, and it's appealing to a broad range of customers who don't have the deep pockets that the first guys had. While the early adopters get to use whatever it is first, the guys who waited may be at an advantage. I think that's where we're at with the Oculus3D system. Although it may be thought of as an interim system think again about a system that costs a fifth to a tenth of a digital 3D setup, is two to three times brighter, and uses far less expensive eyewear, all in the cause of projecting a superb image (incidentally free of triple flash artifacts.)

When I got started at StereoGraphics in the 1980s, the applications for stereoscopic imaging were limited. It was mostly molecular modeling, aerial mapping, and a little bit of CAD. Now we've got a whole world wanting stereoscopic movies and other consumer applications. That's a different situation from my early years. I'm looking forward to helping the industry have what it needs, and so far it's been a lot of fun. Our first industry screens are taking place a few days after I write this.

I want to mention Marty and Robert Shindler who, until they became seduced by the good side of the force, had been running a think tank consulting group called The Shindler Perspective. I also want to thank the people who have believed in -- at FotoKem and EFILM and thanks to Deluxe for letting us have a bit of work space in Burbank – and also Pacific Theatres for allowing us to use one of their theaters for development and testing.