SPACESPEX™ ANAGLYPH—THE ONLY WAY TO BRING 3DTV TO THE MASSES

By Michael Starks

SpaceSpex™ is the name I applied to my versions of the orange/blue anaglyph technique in 1993. In fact the Gang Li/ColorCode and some models of SpaceSpex use amber or orange/brown rather than yellow, but they are on a continuum. Like all the bicolor anaglyph methods it is compatible with all video equipment and displays and I think it's the best of the methods using inexpensive paper glasses with colored lenses. Until someone comes up with a way to put hundreds of millions of new 3D TV's in homes which can use polarized glasses or LCD shutter glasses, anaglyph is going to be the only way for mass distribution of full color high quality 3D over cable, satellite, the web or on DVD. However the solution I have proposed for Set Top Boxes, PC's, TV sets and DVD players for the last 20 years is to have user controls, so those with display hardware that permits polarized or shutter glasses or even autostereo viewing or who want 2D can make that choice from the single 3D video file. This is the method of the TDVision codec, Next3D, and of Peter Wimmer's famous StereoScopic Player (a new version due end of 2009), (all of which should appear in hardware soon) and probably the best stereoplayer of all in Masuji Suto's StereoMovie Maker, and is being incorporated in most well known software DVD and media players. This is a photo of SpaceSpex™ Model E glasses for a webzine project I did in 1995 (made by APO).

Although there are many hundreds of patents on anaglyphs in a dozen languages going back 150 years (and most not indexed in any of the recent patent literature nor even searchable electronically) and doubtless many experimented with varying colors/densities of orange/blue (Lipton and I did so in the late 70's and I recall the Marks brothers showing some at the CES show in the 80's and their 1981 patent 4,247,177 is cited in the recent US ColorCode™ patent 6,687,003, which has an international filing priority for 1999), one might say that the ColorCode™ type of Orange or Amber/Blue anaglyph method of making and viewing stereo was invented by my friend Gang Li and his colleagues of Ningbo, China in the late 80's and described in his articles and patents (e.g. Chinese Patent 16492 granted in 1992 as shown in the following image). It was used at that time for TV broadcasts (both live and taped) in Xian and other cities for several years.

发　　明

第　16492　号　　共　2　页

发明名称：立体摄像系统及图像观看眼镜

发明人：李刚

专利号（申请号）：89 1 04038.2

专利申请日：1989年 6月15日

专利权人：李刚

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中华人民共和国专利局局长　高卢麟

1992年10月21日

I showed personnel associated with Xian TV how to genlock a pair of cameras and described how to make realtime anaglyph video with standard equipment. They made expensive plastic frame glasses with glass color filters. I still have a few pairs which I got when I went there for China's first ever 3D Imaging conference in 1993. The method is a direct outgrowth of the work of Ed Land (the scientific genius who founded Polaroid Corp) in the 50's. In the course of his work on color vision, which was motivated by his desire to create instant color photos, Land discovered that he could produce nearly perfect color images using only two primaries and that the orange and blue portions of the spectrum worked best. This led to his Retinex Theory of color vision. It is well known that the retina has R, G and B sensitive cones, so the production of essentially full color from Y and B is a mystery.

In 1999 Danish inventors also patented the Orange/Blue method and unlike Li or myself have promoted it heavily. Their patent is impressive as they have worked hard to give this old and simple method a modern digital twist and, as always in patents, the claims, which are really the only part of a patent that matter, are rather opaque and very difficult to interpret. However the bottom line is very simple--Gang Li, working a decade earlier with just a swatch of color filters and without benefit of digital computers, digital cameras or displays, or sophisticated equations, came up with essentially identical filters. It is, after all, our eyes (and brains) that determine optimal color, depth and ghosting and then we can make equations and not the reverse. One can indeed use a spectrophotometer to

determine optimal cancellation, but brightness, depth and natural color (especially skin tone) must be simultaneously determined and these are subjective matters the spectrophotometer cannot judge.

The major thrust of the ColorCode™ patent is the addition of varying amounts of black (i.e., neutral density) to control the transmittance of each filter. This is e.g., equivalent to adding a neutral density filter to a suitable orange filter for the left eye and/or a blue filter for the right. This is what the filter companies have always done to get varying colors and transmittances, as can be seen in their catalogs, where they often list a series of color filters made by adding increasing neutral densities. One finds e.g., in Lee Filters swatch booklet "207 C.T.Orange +.3 Neutral Density reduces light one stop" which gives an amber, and so the ColorCode patent merely practices the art of making color filters which has been known for centuries. It is no surprise that Lee makes the custom filters for ColorCode, which are only a hair different from the ones long available in their catalog. Thus, for the Orange/Blue, as for all other anaglyph and Pulfrich 3D viewing glasses, it has always been possible to make any kind of glasses just by selecting existing filters from the catalogs (with addition of an extra layer of ND gel if desired), and so it cannot be the case that any such glasses can be the subject of a valid patent claim, since they fail the test of obviousness "to one skilled in the art" and lack any inventive step. In addition I noted 15 years ago that simply turning down the brightness of the TV/monitor gives almost identical results to adding neutral density to the glasses. Putting more ND in the glasses takes most of the control of color/brightness away from the user and since their displays and visual systems are so variable this is not a good move.

The Danes have gone so far as to insist that people who prepare images for use with their glasses pay them (a Euro/frame!!) to convert stereo images to "their" format and even tell potential clients that they are infringing the ColorCode™ patent by using Final Cut Pro and other programs to make images compatible with their glasses. This is a gross abuse of patent law and illegal. If it were true, then Apple could tell everyone they are violating the iPod patents when they convert their music to MP3 or other iPod compatible formats. Clearly preposterous! They even contacted me in the mid 90's asking if I wanted to license "their" technique and I referred them to the SpaceSpex info and images on my page and never heard from them again. It is a requirement of patent procedure that all relevant work be cited but there is no reference to SpaceSpex in their work.

The Danes use the name ColorCode™ and the glasses are produced by APO Corp in the USA (the same company that produced Model E and Model U SpaceSpex for me in 1995). The biggest 3D glasses order ever was filled by APO in Jan 2009 with the production of 130 million pairs for the SuperBowl ads. You can download these ads on YouTube and many other sites, but get the hiRes versions as there are many very poor lowRes ones. The consensus is that it was not highly successful as 3D but much of the material was unsuitable due to its color (i.e., all white background with people in white suits), or to that fact that it was animated (i.e., the Monsters vs

Aliens trailer). Animations work less well with any stereo method due to their lack of all the rich stereo cues in real world video. On the other hand, since they are entirely computer generated, changing the colors and brightness of every object to optimize the anaglyph will be much easier than for live action where the objects will have to be first identified by hand and/or an image segmentation program.

If you want see good anaglyph 3D and to verify the clear superiority (in my view) of SpaceSpex, look at live action 3D such as the Chuck 3D ad or series 2 episode 12 on www.youtube.com (http://www.youtube.com/watch?v=vNyqwgI5jic)--also available on many other sites as well as p2p-- or at the 3D stills available on ColorCode's page (www.colorcode.com) with the ColorCode glasses vs SpaceSpex Model U and you will see better color and more than double the brightness. It's like day and night with ColorCode producing a dim image with muted colors that looks like its been shot in the evening or on a rainy day, which turns to a sunny day when you put SpaceSpex on. No contest. To convert any 3D video for realtime viewing with SpaceSpex you can download Peter Wimmer's popular StereoScopic Player from www.3dtv.at. The free version times out after 5 minutes and the full version is about $50. You can play field sequential, right/left, top/bottom or separate R and L files in any stereo format including Yellow/Blue anaglyph (i.e., ColorCode/SpaceSpex) and you can download 3D video sample files. I recommend the Heidelberg demo. You can freeze frame for careful comparison and alter H and V parallax with the arrow keys on your keyboard. SpaceSpex support is also being included in the Next3D and TDVision HD DVD players.

However, Masuji Suto's StereoMovie Maker has what seems to be the most sophisticated stereoplayer and it's free! http://stereo.jpn.org/eng/stvmkr/index.html. Use the stereoplayer in Movie Maker and not the standalone stereoplayer as it is older and lacks many of the advanced features. Not only do you have a large number of choices of input and output formats but you can even control the gamma of each eye independently and the stereowindow. It also has a hotkey for parallax control.

Anyone technically adept will surmise that it should be straightforward to use edge detection and other well known functions to create a program that automatically registers the two images for minimal ghosting by reducing H and V parallax, size (i.e., zoom correction), skew, brightness, and color. Athough I mention in my other articles that such things have been done in research work many times, recently Suto and ColorCode have begun doing this with the readily available SIFT software created by David Lowe. It is often called "autopano-SIFT" due to its use by Sebastian Nowozin for stitching together panoramas from several photos. See e.g., http://user.cs.tu-berlin.de/~nowozin/autopano-sift/. The program seems to currently work only with still images, but they can be batch processed with multithreading and it should be simple to register a 3D video using the easy align or other choices in Suto's menu. Clearly this program can be improved and put in

firmware for realtime alignment by cameras, pc's, DVD players, broadcasters, set top boxes and TV sets and this would be another great advance in the stereo art, and of especially great value for anaglyph viewing.

Keep in mind that the all the Orange/blue images and players noted above were created using the ColorCode software for the ColorCode filters and the improvement of SpaceSpex is even more striking when the images are tweaked to exactly match the SpaceSpex filters (such as those below). However all four models of SpaceSpex are 100% compatible with any images created with the excellent ColorCode Player or the 3D Suite ($200 from their page for PC and MAC) or with Wimmer's Stereoscopic Player or with Suto's StereoMovie Maker. The elegant ColorCode software (a new version just became available in mid 2009) or the other players can easily convert video realtime for SpaceSpex.

For optimal effects with and 3D glasses but especially with anaglyph, people must be told to make sure there are no fingerprints on the glasses just before they watch the film, to reduce room lights and keep glare off the screen and the glasses, to adjust screen brightness, contrast and color and to use the dvi or HDMI input. Each of these makes a difference and together they will on average make a huge difference in the enjoyment for the viewers.

Of course one does not get the brighter image and better colors of SpaceSpex without giving up something and the downside is that there is a greater brightness imbalance with Model U, which may take some time to get used to. For this reason I created the SpaceSpex Model E, Model C and Model A. Model E gives an even brighter image that is more comfortable for longer viewing, but it requires tweaking the colors of the images and reducing the horizontal parallax and adjusting your TV or monitor/projector for best results. Model C gives a less bright image but is more tolerant of ghosting. Model A is quite similar to ColorCode but is a bit brighter and so has less of the "screen door effect" (i.e., the feeling of looking at the image through a screen door).

SpaceSpex Models Image Quality 4= Maximum

Model	Depth	Brightness	Color	Comfort
A	4	1	3	4
C	4	2	3	3

U	**4**	**4**	**4**	**1**
E	**3**	**4**	**4**	**4**

SpaceSpex Models E, U, C, A

Since I did my original work 16 years ago, I recently did extensive testing of the newest stereo players, 3D DVD's and LCD displays with all SpaceSpex Models. My conclusion that no other method gives as bright and beautiful image with good color was confirmed. Here are a few of the tests I did. In each case I tried not only the glasses that came with the DVD but several variants on them (i.e., slightly different colored filters) all viewed with HDMI connection from a pc to a new 23 inch HP LCD monitor with the brightness at about ¾ maximum.

"Fly Me to the Moon" is an animated feature with Red/Cyan glasses. Dim, dull image with very poor color and noticeable ghosting.

"The Stewardesses" is a live action film digitally remastered by a team led by veteran stereoscopist and anaglyph expert Daniel Symmes with its own unique Red/Blue glasses is probably the best registered stereo film ever to be released on video. Reasonably good but color and brightness still modest and some ghosting.

"Shrek 3D" is an animated film with Red/Cyan glasses. Dim, dull image with poor color and ghosting.
"Shark Boy and Lava Girl" –live action embedded in graphics with Red/Cyan glasses. Dim with poor color. I found that some other Red/Cyan glasses gave a brighter image with better color and no more ghosting.

"Barbie and the Magic of Pegasus" is an animation with Red/Cyan glasses. Dim, poor color, ghosting—almost unwatchable.

"Friday the 13th Part 3" is live action in a new (2009) release with Red/Cyan glasses. Dim, poor color and horrible image misregistration with severe ghosting. Pretty much unwatchable. And this is from Paramount, owned by Viacom, one of the worlds largest media conglomerates.

"Journey to the Center of the Earth" is live action with a new (for DVD releases) Magenta/Green glasses (TrioScopics). Dim, poor color, ghosting.

"The Polar Express" is an animated feature with Red/Cyan glasses. Dim, poor color, ghosting.

"Amityville 3D" is a live action film in frame sequential format. Using one of its few daylight sequences ColorCode gave its usual dim image with modest color but good depth (provided of course that the monitor brightness is near max) while SpaceSpex U gave an excellent image in all respects. Surprisingly, SpaceSpex E also gave an excellent image very similar to that of SpaceSpex U, using the same yellow/blue setting in those sequences where the parallax was minimal. This shows that subtleties of encoding/decoding the color gamut and parallax can be manipulated to make all the yellow/blue glasses types compatible and to give a 3D image which is excellent in all respects.

"Ape" is an old live action 3D film in the frame sequential format which gave essentially the same results as "Amityville 3D".

"Taza-Son of Cochise" is a live action Technicolor film from 1953 released in 2008 in side by side squeezed format by Sensio Corp for full color viewing with projection using their custom hardware, but playable on a pc with various stereoplayers such as Wimmer's Stereoscopic Player. I chose either red/blue anaglyph, high quality red/blue anaglyph, yellow blue anaglyph (i.e, ColorCode or SpaceSpex U or C). In spite of the bizarre choice of the H squeezed format (also done by StereoGraphics Corp for many years), which eliminates half of the H pixels needed for depth, the sharpness of the original dual filmstrips and the spectacular color of the 3 strip/eye Technicolor save the day when projected or viewed in frame sequential mode on a CRT or probably on one of the 3D Ready DLP TV's from Mitsubishi or Samsung (Wimmer and many other consumer and Professional programs now have settings for these). On my LCD monitor with red/blue glasses it was dim, with very poor color and ghosting but good depth. ColorCode gave OK depth with little ghosting but, as always, a dim image with modest color. SpaceSpex U gave a bright image with essentially full color and little ghosting and OK depth. SpaceSpex Model E was not useful as there is no setting for it and the gamut different than for the above two films.

"Bugs 3D" is a live action IMAX film released by Sensio in their side by side format. Results were similar to those of "Taza".

The bottom line is that only the SpaceSpex give a bright, colorful 3D image. The fact that this happened even though neither the files nor the players were optimized for SpaceSpex indicates that with such optimization they are suitable for any use including the cinema. ColorCode may be feasible in situations where the brightness of the display can be very high without washing out the color and contrast.

I assume everyone knows that you have to view anaglyph DIGITALLY- i.e., with a good LCD or plasma or DLP monitor or TV or projector with DVI or HDMI connection to the DVD player, PC/Mac or server and NOT a CRT and NOT with a VGA connection (i.e., not with the analog DB9 or HD15 cables)! Most consumers will not know this but it is a testament to the sloppiness of nearly all anaglyph DVD releases that they give little or no instructions. A few mention reducing room lights and avoiding glare on the monitor (absolutely critical!), but only one I looked at (Shrek 3D) mentions that you get the best 3D from DVI (or HDMI) connection, next best from component etc. and not one that I have ever seen for any method mentions that keeping the glasses free of fingerprints is mandatory.

Ideally, you will adjust the brightness, contrast, sharpness, gamma, hue, saturation or color temperature on your display/video card/server/broadcast equipment optimally.

Many anaglyph DVD's have appeared, one in ColorCode™ (the Japanese release of Cameron's "Ghosts of the Abyss", about a dozen in red/blue or cyan/blue (SpyKids 3D, Treasure of the Four Crowns etc) and recently at least one (Journey to the Center of the Earth) in a magenta/green method called TrioScopics™, but it seems to me that all these other methods are lacking in either color,brightness, depth or comfort and SpaceSpex™ appears to be easily the best choice.

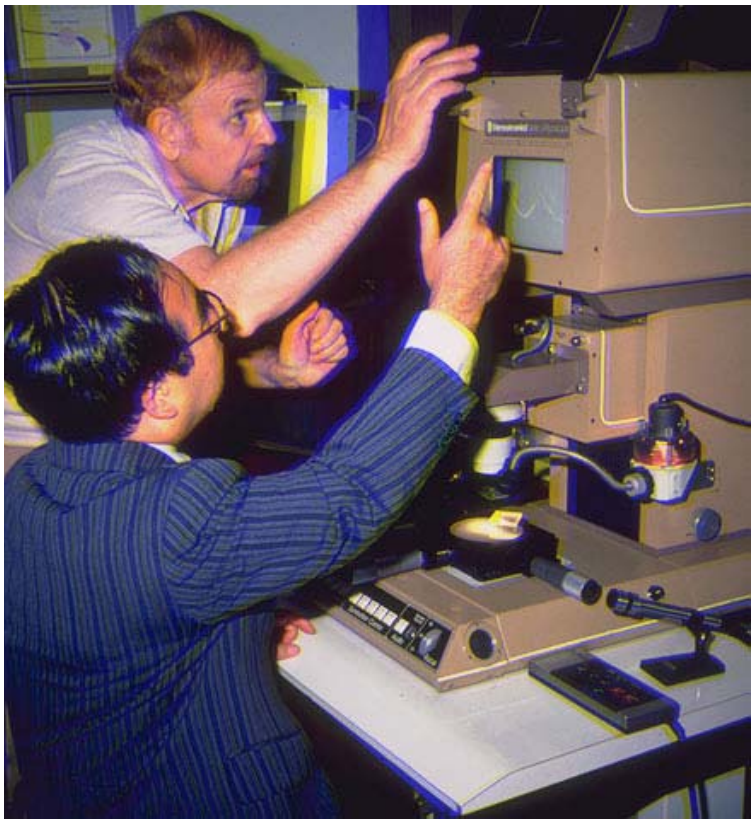
As noted above, I cannot see any possibility that any bicolor anaglyph (i.e., one color lens for each eye) is patentable. Anaglyphs have been common for well over 100 years and there are hundreds of patents. All claims relating to bicolor glasses fail the mandatory requirement that the inventions must not be "obvious to one skilled in the art." The Daimler-Chrylser/Infitec/Dolby Digital 3D triple notch filter system now common in cinemas (see my other articles) is also obvious after the fact, but sufficiently inventive that it seems protectable. I used single orange and blue notch filter (i.e., multilayer interference type) glasses for SpaceSpex in 1993 but did not regard it as patentable. I got these old glasses out of storage recently and they do give a better image than the plastic filters, but of course they are far more expensive. So far as I know a double notch filter in each eye has not been used.

It should be understood that in order for ColorCode to get their patent they had to narrowly define the filter spectra to avoid the patents by Marks and Beiser and my work with SpaceSpex (and to be unaware of Li's papers and patents). Consequently even if one ignores the clear priority of Li, ColorCode cannot claim any orange/blue filters except those narrowly defined in its patent and even then

only if they are custom made and quite different from those that have are commercially available from the various filter companies. It is abundantly clear that SpaceSpex are different just by looking at them and dramatically demonstrated by looking at the same images with the two types of glasses. The 3DTV Corp page is one of the best known 3D sites and has been at the top of Google and other searches since the beginning of the net. It is remarkable that neither these inventors nor the patent examiners nor the general public were aware of this.

Also remarkable is that fact that ColorCode says that their glasses are NOT anaglyph! By definition all colored lens 3D viewing glasses (and originally all 3D viewing glasses of ANY kind) are anaglyph--look up the Greek root words.

You can find sample SpaceSpex™ images and info on how to make them on our page on our page (where they have been for 16 years) at http://www.3dmagic.com/spacespex/spacespex.html or its mirror at http://www.3dtv.jp/spacespex/spacespex.html. I reproduce them here for convenience. As noted you can also use the ColorCode software on their page for making SpaceSpex images.



3D Video pioneer James Butterfield showing his 3D video microscope to Takanori Okoshi, author of the classic text "3D Imaging Techniques". Photo by Susan Pinsky ca 1985.

Photo by famous British stereographer David Burder ca 1985

Balinese Dancer
Photo by Michael Starks 1985

Lucia-Queen of Bahia photo by Michael Starks 1988

If you look at these images successively with the Gang Li/ColorCode glasses, then the SpaceSpex Model U and then the SpaceSpex Model E you will see that for the converged objects (i.e., those having little or no horizontal parallax) all three glasses types show good depth and color (any differences can be largely eliminated by tweaking the images when made or the display parameters (tint, brightness etc). The Li/ColorCode method gives lowest ghosting but at the cost of diminished brightness and color and with some eyestrain for most people with prolonged viewing, while the SpaceSpex U (i.e., for 3D video not specifically edited for them) gives a bright image and good color at the cost of brightness asymmetry which may be bothersome to some people. SpaceSpex Model E (i.e., for properly edited video) give the best 3D image, but at the cost of ghosting on objects with significant horizontal parallax and some binocular brightness asymmetry. Model C is in between and Model A very close to ColorCode. If it is impossible to H shift and color adjust or ghostbust the image to reduce ghosting then Model U (Unedited) is best, but it is tricky to adjust the images so Model A is generally used. Model E or C would be a good choice for SuperBowl ads where a quick fusion with bright images and good depth for short viewing times is desired. Fusion of the images into a stereo image with depth takes some seconds with any anaglyph and maybe 5 seconds on average. As with any stereoviewing modality, ghost reduction is desireable but the general algorithms created by Graham Street, RealD, JVC and others will probably need to be modified for anaglyph ghostbusting. Now that RealD has released their realtime ghostbusting server software RealD 3D EQ, this can be easily tested. Of course all methods need to be given a serious trial and this means at least 20 minutes and preferably repeated viewings of various films on different displays over a period of time.

All anaglyphs force one eye to focus at a different plane than the other (the basis of chromostereopsis and the recent ChromaDepth method --first noted by famous scientist Hermann von Helmholtz) and also the different light levels tend to make one pupil dilate more than the other. Stereographer Allan Silliphant has tried to ameliorate this situation with glasses that contain a low diopter in one eye www.anachrome.com. He has produced the best red/blue anaglyph video I have seen, but I still think SpaceSpex has an edge, so we agreed to try to combine his diopter method with the SpaceSpex colors.

Here are some instructions we made 16 years ago on how to make SpaceSpex images from a stereo pair. They are of course largely obsoleted by the growing availability of programs to convert stereo formats in realtime but I present them so that one can get some idea as to what is done to make anaglyphs. As noted, you just take the blue of the left image and replace with the blue of the right and then if feasible tweak it in any way possible with your particular program to optimize color and depth and to reduce ghosting. It should not be difficult to find the optimal settings in Premiere, Final Cut Pro etc to do this or to set hardware such as Pirhana's, Pablos, DaVinci's etc or even the cameras themselves to create SpaceSpex™ video in realtime for live broadcasts via cable, satellite or the net. Of course for optimal viewing at home the broadcaster/DVD maker should test the final result on samples of actual consumer equipment at the end of the broadcast or playback chain and there should be some instructions and a test image so the end user can tweak their own PC or TV. The single commonest adjustment needed is brightness.

Using Adobe Photoshop to Create SpaceSpex™ Blue/Orange Anaglyphic Stereo Images

These instructions are based on version 3 of Photoshop for Windows (this was done 16 years ago). The details will be different for other versions, and of course there are other ways to do this, but the principle is the same: remove the blue component of the left image and replace it with the blue component of the right image.
Start with a stereo pair of images of the same size and scale, preferably in 24 or 32 bit color. To minimize ghosting, avoid images with lots of horizontal parallax and high contrast (e.g., a person with a white shirt on a black background) in the extreme foreground and background (i.e., in the typical shot with convergence in the midground). The color depth of your display should be at least 15 bits.

Open the left image in Photoshop.
From the Mode menu choose RGB color.
Open the Layers window (right click in window, click "Show Layers").
Click the Channels tab and drag the Blue thumbnail to the trashcan.
Open the right image, repositioning it if needed to uncover part of the left image.
Choose RGB Color from the Mode menu.
Drag the Blue thumbnail from the Layers window and drop it on the left image.
Close the right image without saving changes.
The left image is now selected and in Multichannel mode.
Choose RGB Color from the Mode menu.

Choose Save As... from the file menu to save the altered left image with a new file name in a 24 bit color format.

Click the Blue thumbnail from the Layers window to select the Blue channel.

Click to the left of the RGB thumbnail in the Layers window to display all three channels.

Click the reposition tool from the standard toolbar.

Put on your SpaceSpex™ and drag the blue channel to align the right and left images. Use the zoom control if needed. Try to get the main subject of the image lined up properly, so that ghosting is minimized and confined to the background and extreme foreground.

These images do not respond well to color reduction techniques. As you might expect, reducing them to 256 colors with any dither at all mixes the color channels enough to destroy the stereoscopic effect.

Here is the way we did orange/blue from a right and left 3D file in Adobe Premiere ten years ago.

1. video 1A - right image / video 2 - left image

2. In video 1A - reduce red, green to 0% from video filter - color Balance

3. In video 2 - reduce blue to 0% from video filter - color Balance

4. In video 2 - click on your right mouse button and then video option - Transparency - screen

This will give the approximate ColorCode hues so to change for SpaceSpex you can adjust the % color for one or both eyes and/or the transparency. To make a red/blue anaglyph you reduce blue green for 1A to 0% (or near) and reduce blue for the other (but why bother if you can make the superior orange/blue?).