3D Display Technology

Presentation
Outline

- 3D Display Overview
  - Focus on 3D displays aimed at consumers
- Color Filtered Time Parallel Displays
  - Overview of procedure
  - Discussion of common problems
- Polarized Time Parallel Displays
  - Overview of linear polarization
  - Overview of circular polarization
  - Discussion of implementations
- Time Multiplexed Displays
  - Overview of implementation
- Current Developments
  - Overview of problems and what is being done to combat them in current displays

3D Display
Overview

Classification		Depth Cues	Key Component
Stereoscopic	Time Parallel	Binocular Disparity	Polarizing Glasses
			Wavelength Selective Glasses
	Time Multiplexed		Liquid Crystal Shutter Glasses
Autostereoscopic	Dual or Multi-view Displays	Binocular Disparity, Convergence, Motion Parallax in the horizontal direction with limited and discrete range	Parallax Barrier
			Lenticular Lens
			Holographic Optical Element
			Directional BLU
	Super Multi-view	Binocular Disparity, Motion Parallax in the horizontal direction with continuous range, Accommodation	Lenticular Lens
	High Density Directional Display		Multiple Projection
			Laser Scanning
	Integral Imaging	Binocular Disparity, Motion Parallax in the horizontal and vertical direction with continuous range, Accommodation	2D Lens Array
	Volumetric Display	Binocular Disparity, Convergence, Motion Parallax, Accommodation	Stacked Screens
			Swept Volume
			Cross-Beam
	Holographic Display	Binocular Disparity, Convergence, Motion Parallax, Accommodation	Electro-holography/Coherent Optics

Color Filtered

Time Parallel Displays

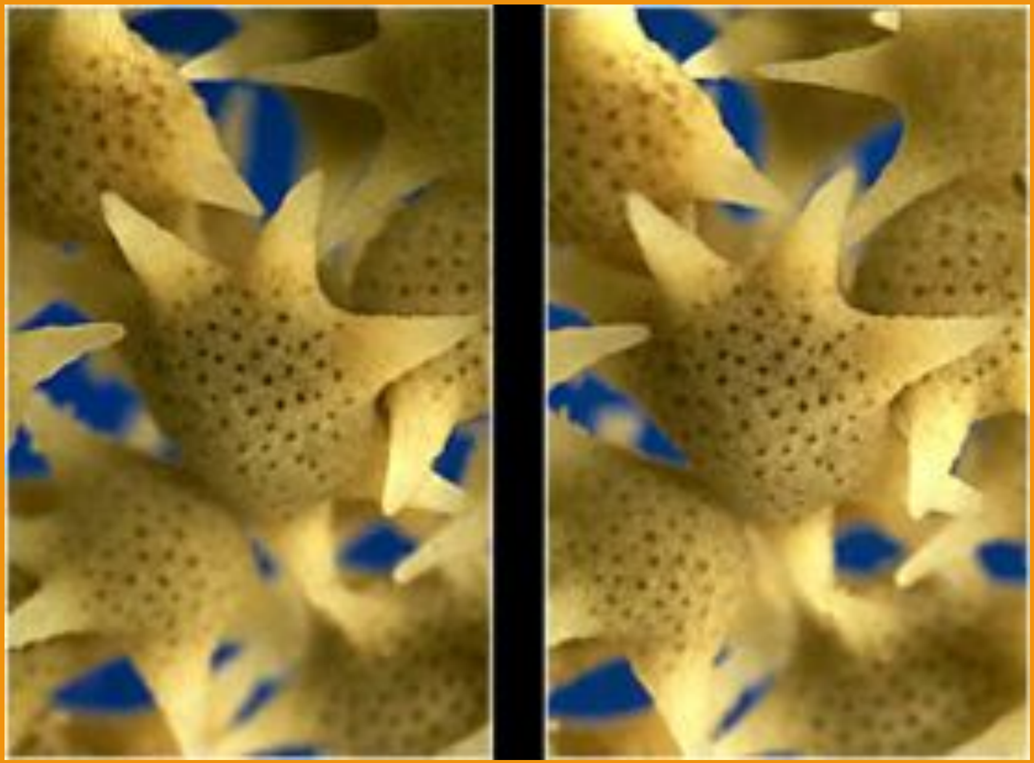
- Known as anaglyphs, one of the first popular and widely used 3D technologies
  - Still used today as they do not require special hardware other than easily and cheaply made color filter glasses

- Based on wavelength specific encoding
  - Cyan and Red wavelength filters or Blue and Yellow wavelength filters
  - The two wavelengths must be easily separated from each other to prevent cross talk, so “opposite” colors of the spectrum are preferred
  - The wavelengths of light opposite the particular color filter in front of the eye are allowed to pass through and reach the eye where as wavelengths matching the color filter’s range are blocked

Color Filtered

Time Parallel Displays

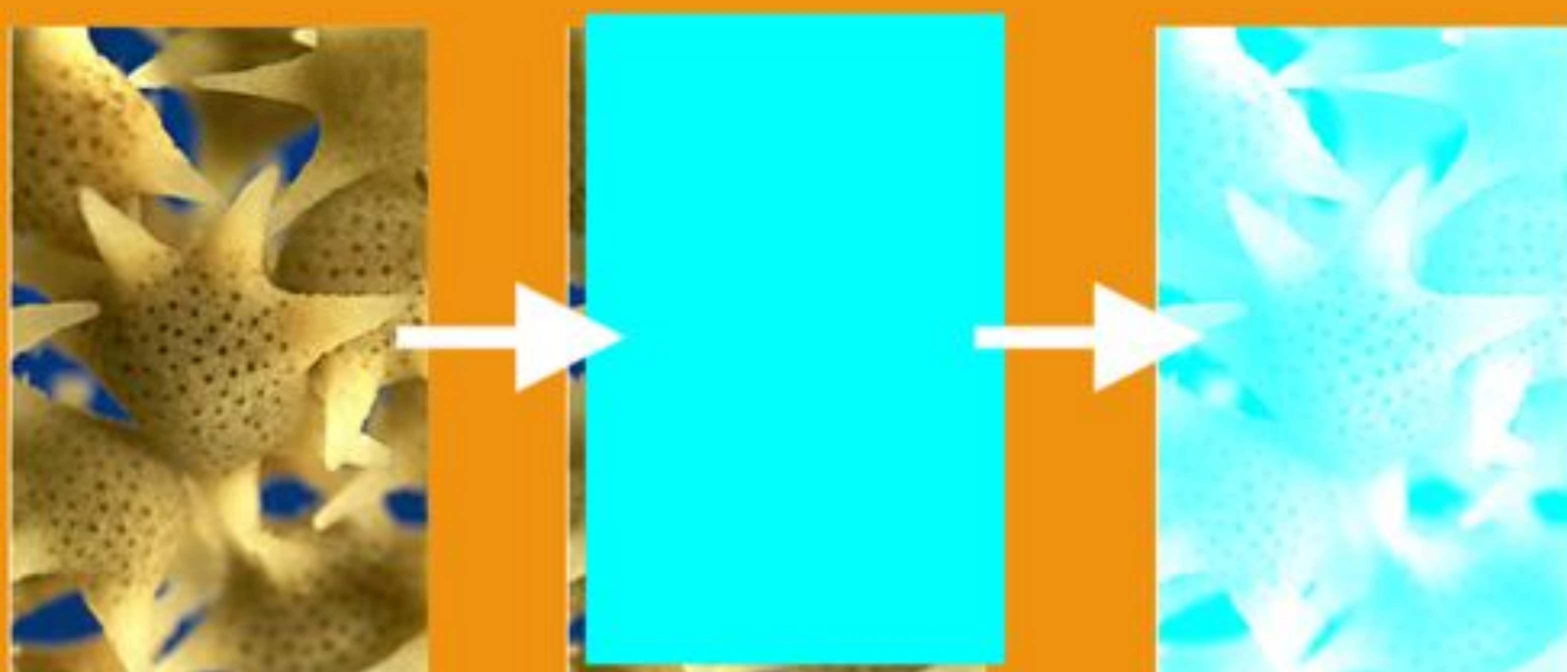
- How an anaglyph is created:
  - A stereo image pair is used, one for the left eye and one for the right eye



Color Filtered

Time Parallel Displays

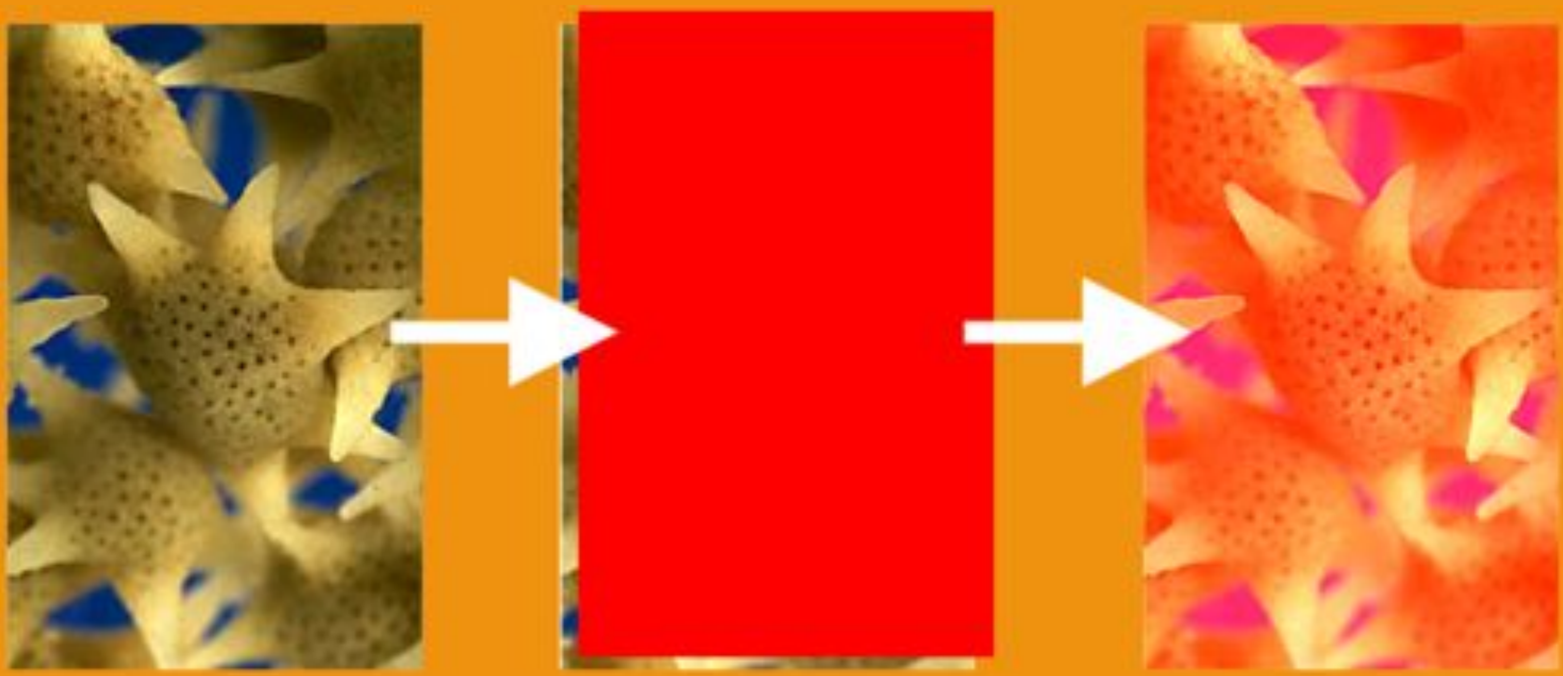
- How an anaglyph is created:
  - For the left eye image a cyan mask (R-000, G-255, B-255, in hex: #00FFFF) is applied to the image in a screen blending mode which allows the cyan mask to preserve some of the intensity differences in the original image



Color Filtered

Time Parallel Displays

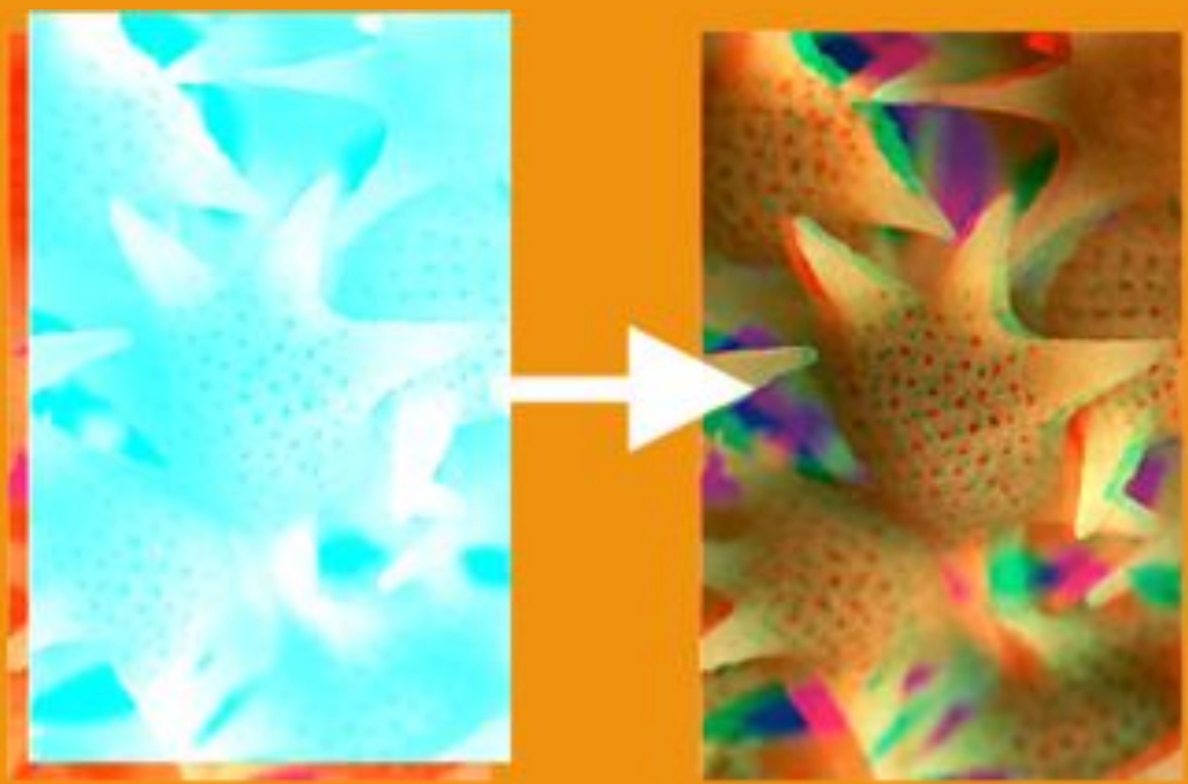
- How an anaglyph is created:
  - For the right eye image a red mask (R-255, G-00, B-00, in hex: #FF0000) is applied to the image in the same screen blending manner



Color Filtered

Time Parallel Displays

- How an anaglyph is created:
  - Once the left and right images are properly masked they are positioned one top of the other and added together using a multiply blending mode



Color Filtered

Time Parallel Displays

- How an anaglyph is created:
  - It is interesting to note that the ColorCode anaglyphs switch the G channel to be coupled with the R instead of the B which results in the Yellow (R-255, G-255, B-000, in hex #FFFF00) and Blue (R-000, G-000, B-255, in hex: #0000FF) masks

Color Filtered

Time Parallel Displays

- Problems with anaglyphs:
  - High cross talk, especially if the color filters aren't perfectly matched to the colors being shown on the display
  - After effect of a shift in chromatic adaptation from prolonged viewing
  - Reduced perception of color, but can be aided by deliberately allowing a "leaky" filter to allow warmer and cooler tones to each eye which in turn allows for cross talk

Polarized

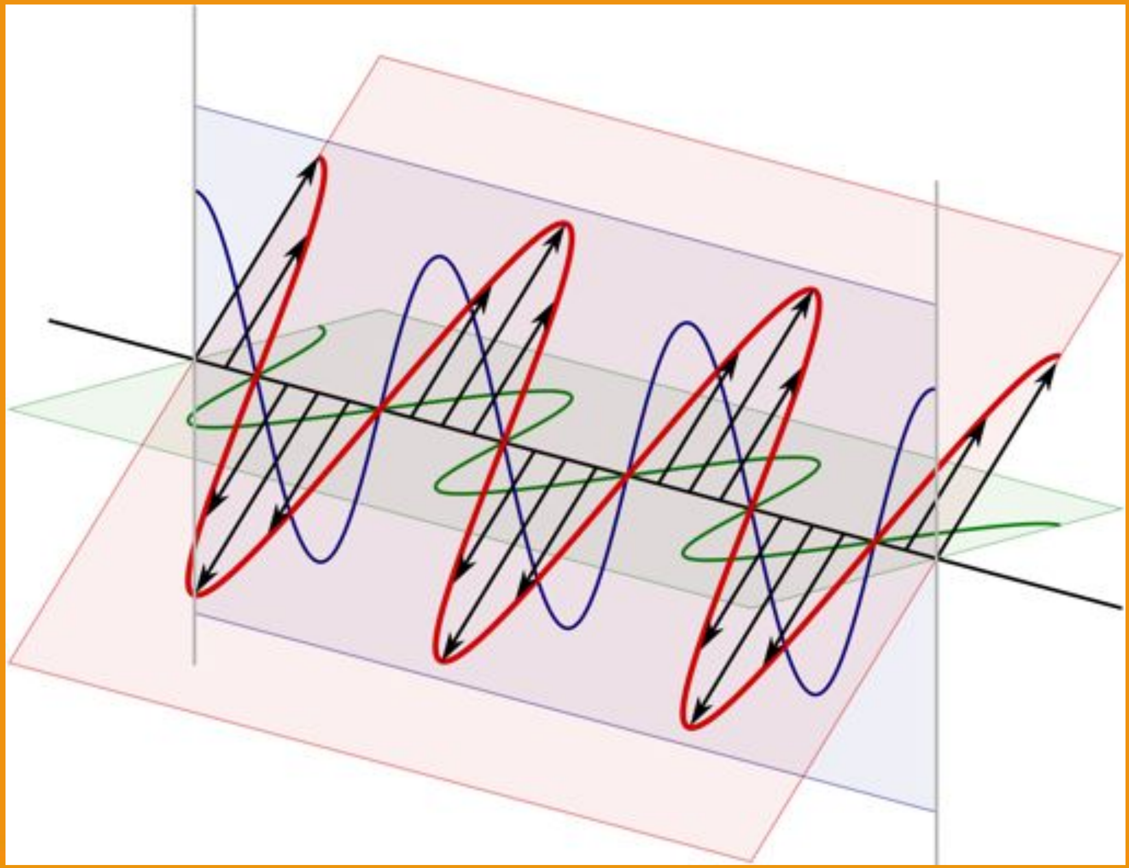
Time Parallel Displays

- Currently the most widely used methodology mostly due to it's uses in theatres and amusement park attractions
  - When used in a large theatre-like setting where the image is projected on to a screen the use of a polarization preserving screen is required in order to keep the left and right eye encoding when the light is bounced of the screen
  - For theatre settings dual projectors are used to display a left and right image simultaneously
  - For smaller consumer displays the display itself uses a polarization filter but image resolution is affected

Polarized
Time Parallel Displays

- How linear polarization works:
  - Light waves propagate along a plane, this means that the light wave will have a horizontal and vertical component projected on each respective plane
  - Linear polarization works by tilting the plane of the light that comes out through a polarized filter by modifying the horizontal and vertical components of the light wave
  - The tilts that are done for the left eye are opposite to the tilt that is created for the right eye there by enabling the separation of light into each eye

- How linear polarization works:



Polarized

Time Parallel Displays

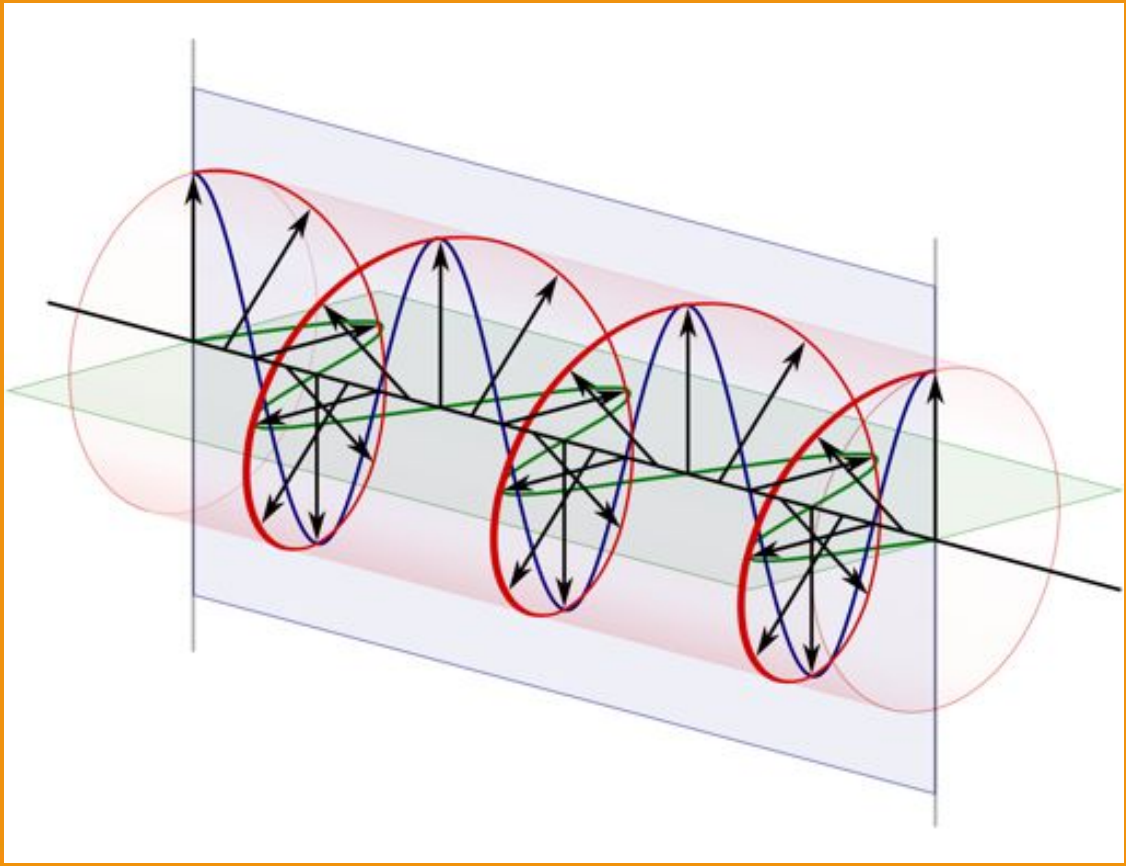
- How linear polarization works:
  - The receiving eye glasses have lenses that allow only a specific orientation of light in while blocking all other orientations
  - The big problem with linear polarization is that the decoding ability of the glasses can easily be thrown off by tilt
  - In order to combat the problem of head motion dependency the polarization filter is modified to generate a wave in a volume instead of a single plane, moving the projection from being a 2D based encoding to a 3D based encoding

Polarized

Time Parallel Displays

- How circular polarization works:
  - Circular polarization works much the same way as linear polarization only now the light waves travel through a tube shape instead of a plane
  - When the light passes through the circular filter, instead of keeping both the horizontal and vertical components synchronized in phase, one of the components passes unchanged while the other is delayed a quarter wavelength
  - The delay causes the sine wave of light to travel in a circular helix-like shape

- How circular polarization works:



Polarized

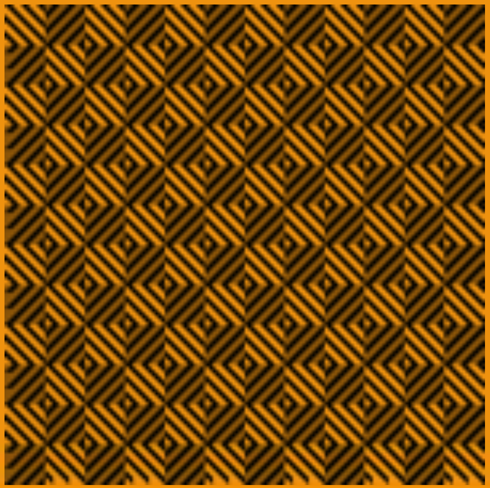
Time Parallel Displays

- Polarized Display Implementations:
  - The first simplest implementation of a polarized display uses a filter in front of the display (today commonly LCD) that polarizes the light from successive rows of pixels (scanlines) to contain image data for each eye (one dimensional polarizer)
  - Creates obvious problem in the reduction of resolution of the image, each image is only half the resolution of the of the full screen and is missing information for alternating scanlines

Polarized

Time Parallel Displays

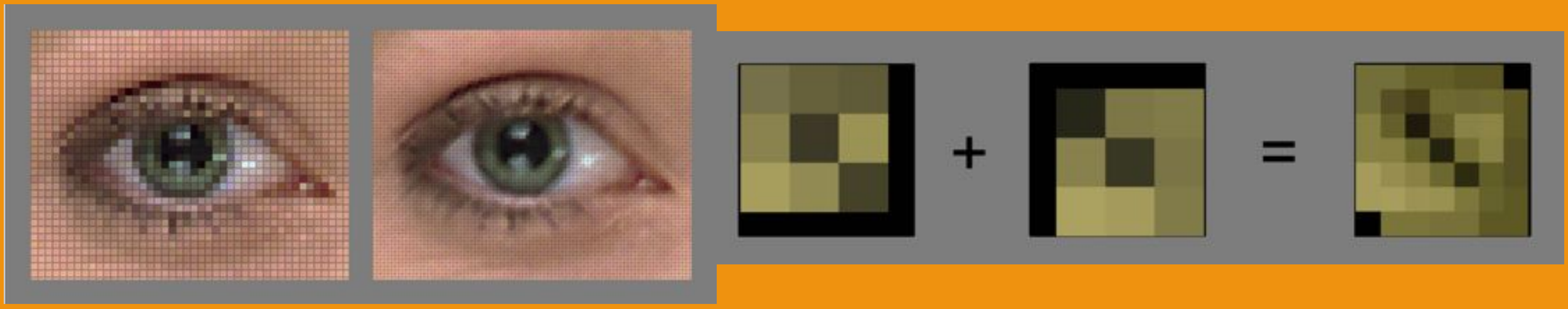
- Polarized Display Implementations:
  - In order to alleviate the resolution problem of missing entire scanlines a two dimensional polarizer is used, known as spatial multiplexing
  - Each image is modulated using an operator to create a checker board pattern in the image's pixels and the left checker board is the inverse of the right
  - Note that each image is still missing half of the original data but because it is evenly interspersed the quality of the image is better due to more uniform pixel sampling



Polarized

Time Parallel Displays

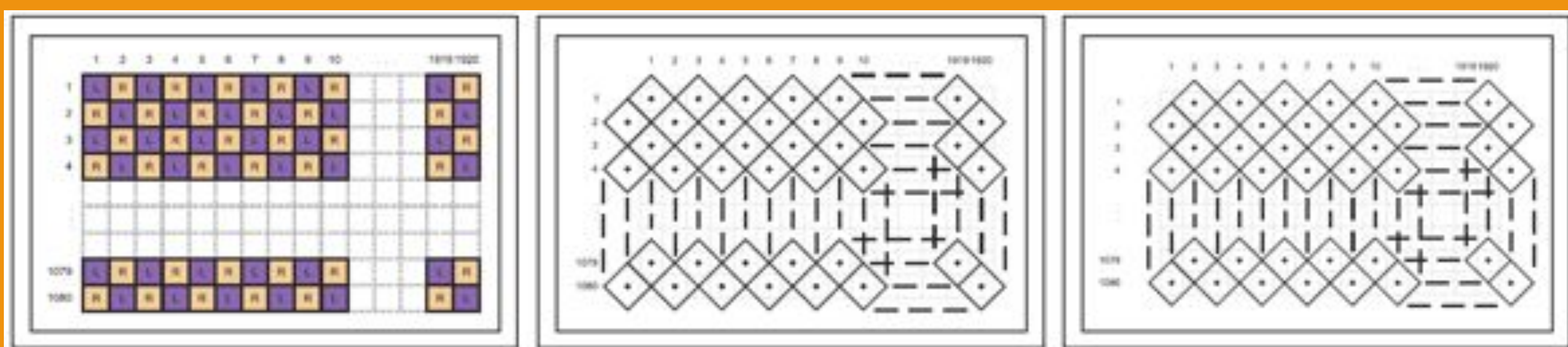
- Polarized Display Implementations:
  - One way to combat the loss of resolution is through wobulation
  - Wobulation works by averaging 2 subframes together to increase the accuracy of an image
  - A left and right subimage is diagonally shifted half a pixel and then averaged together to provide a higher resolution image



Polarized

Time Parallel Displays

- Polarized Display Implementations:
  - For the 3D case you have the left and right images presented in the standard checkerboard pattern and you then take sub image samples using a diagonal pixel paradigm: the center of the pixel is sampled in the square pixel's center but you end up sampling areas outside the square pixel as well
  - For this case you can shift the checkerboard pattern in a direction to have the diagonal pixels sample within only the left or right eye pixels



Polarized
Time Parallel Displays

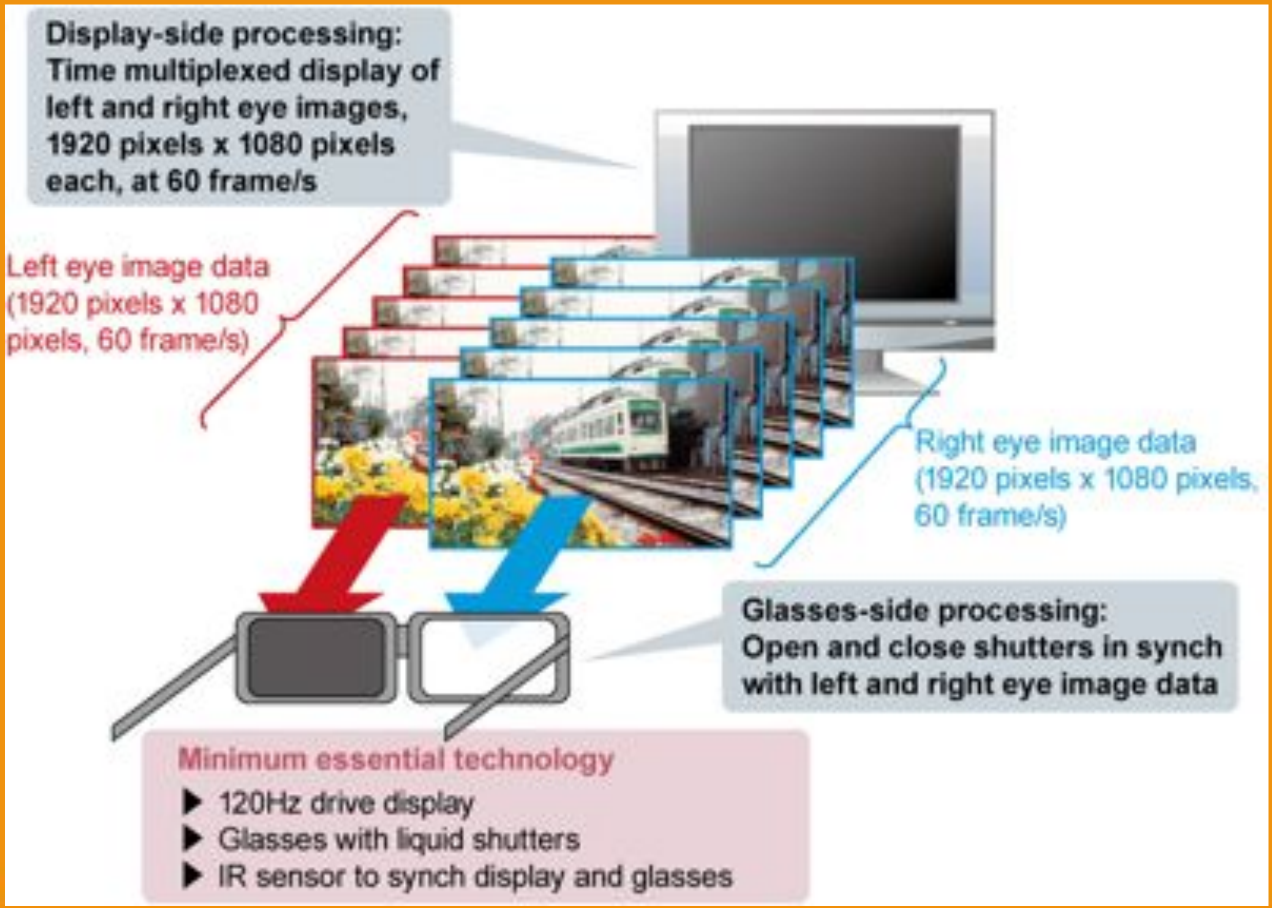
- Polarized Display Implementations:
  - Another way to present polarized information is through the PolarScreen's system of using a modulo and angular LCDs to control the light coming from each pixel (keeping the full resolution of the display)
  - The system works by fusing the left and right image using the modulo panel and then controlling how the light is polarized for each pixel by the angular panel. The angular panel is given information about which direction each pixel's light needs to travel and polarizes the pixel based on whether it needs to go to the left, right or both eyes.

Time
Multiplexed Displays

- Time multiplexed displays are more commonly used in smaller more personal settings
  - These displays are usually presented at around 3 feet away from the user so disparities need to be adjusted for presentation of 3D content
  - Originally only used with CRT displays as LCDs did not have the high frame rate required for implementation
  - These displays are prone to cross talk due to decay properties of the display technology itself

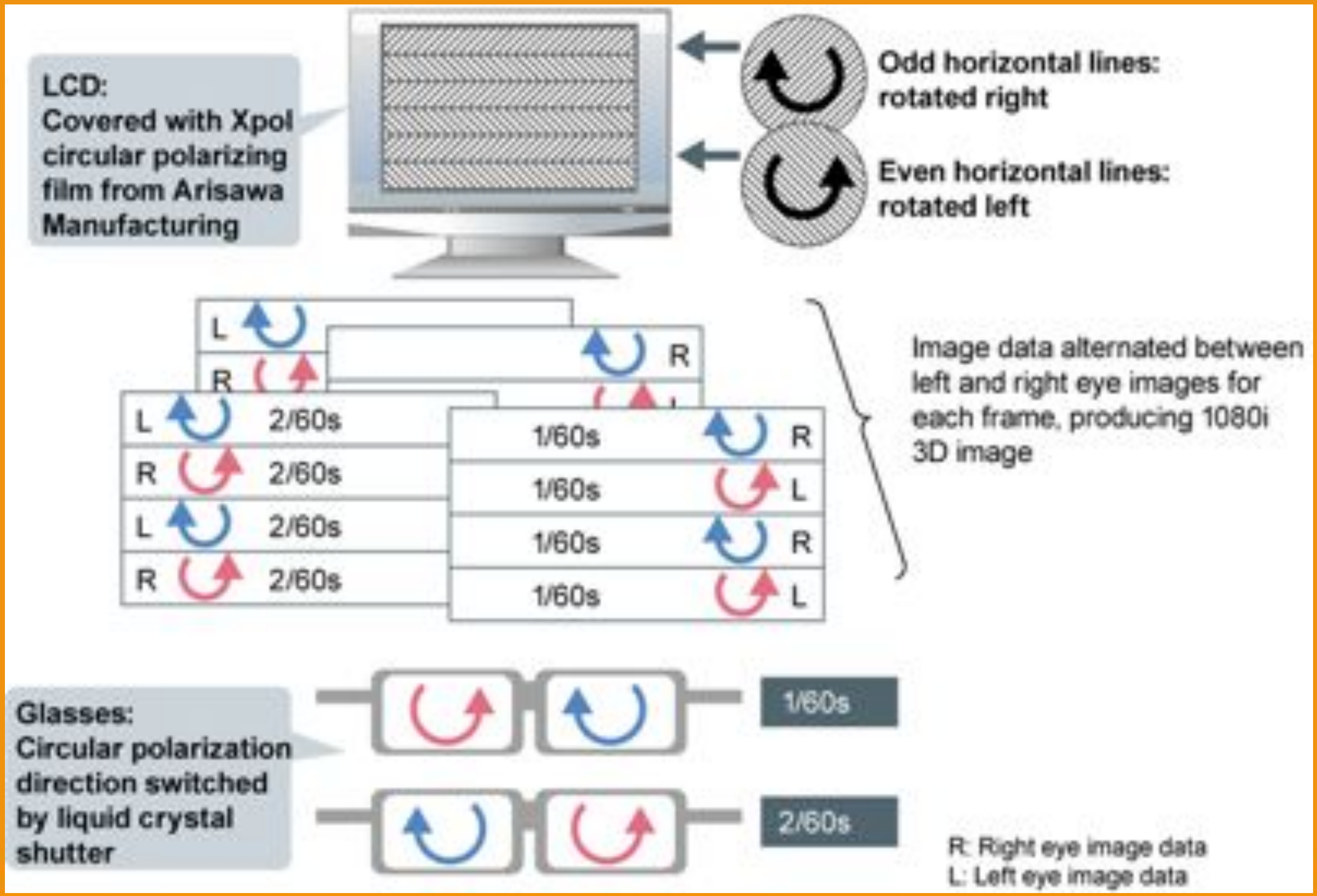
Time
Multiplexed Displays

❖ How time multiplexing works:



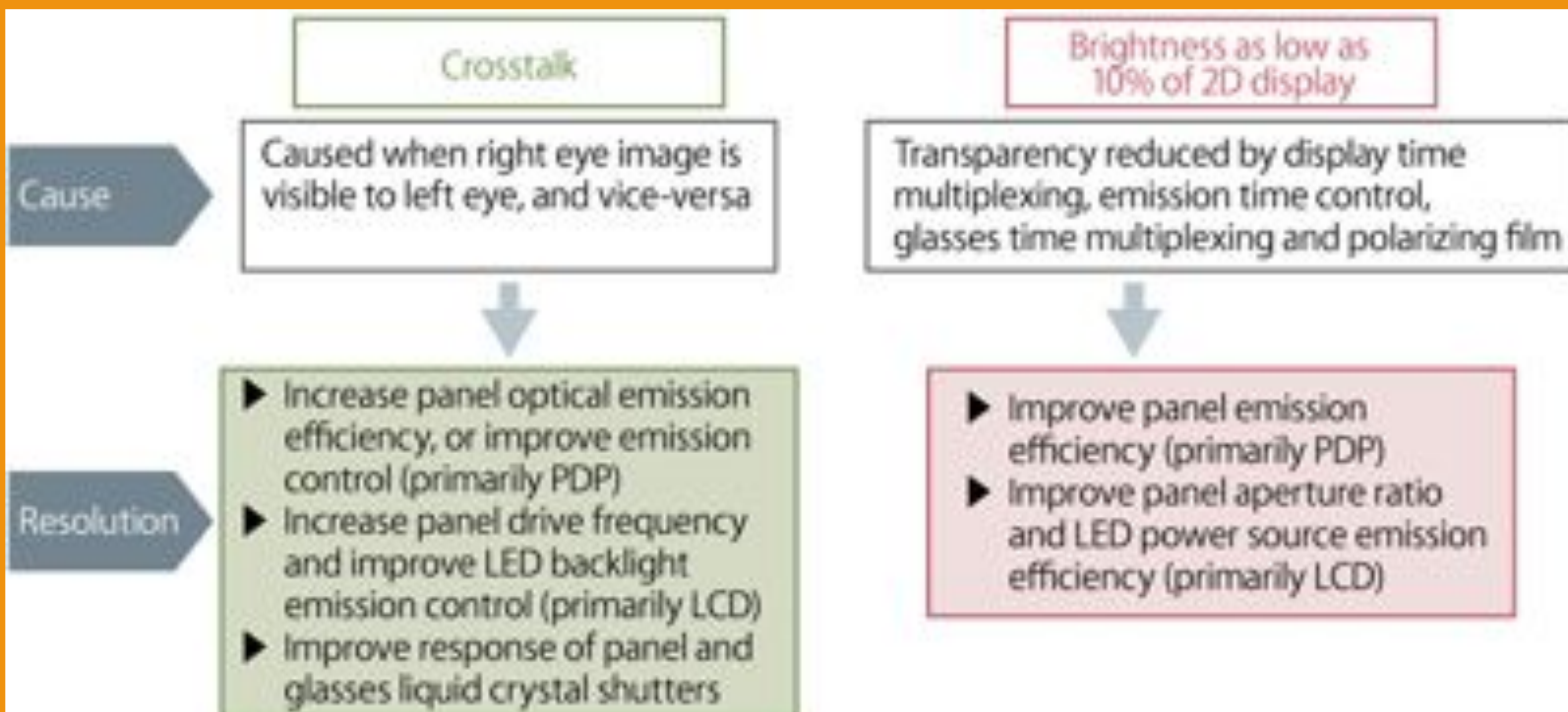
Time
Multiplexed Displays

❖ How time multiplexing works:



Current Developments

- Most of the 3D capable display technology that is being marketed today particularly for consumers revolves around time multiplexed displays

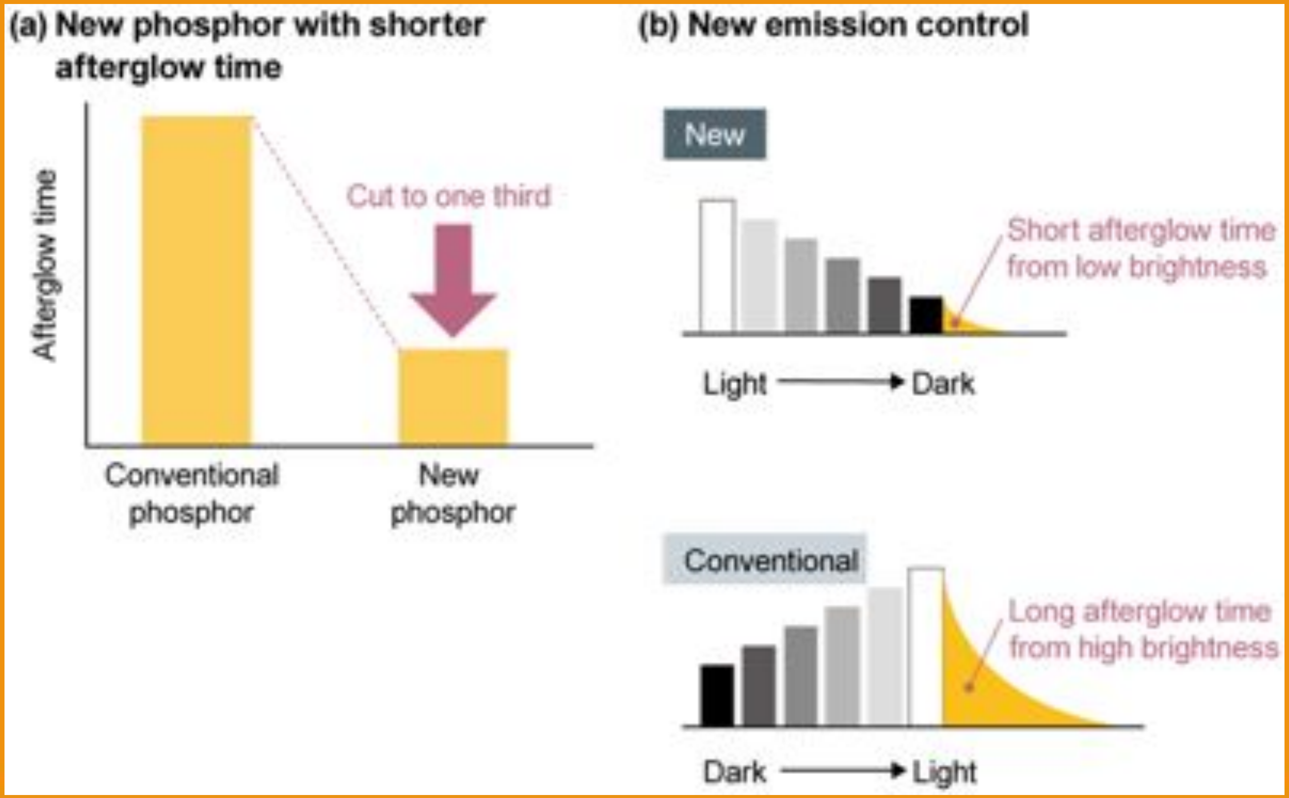


Current Developments

- Crosstalk:
  - Refers to the visibility of the left image in the right eye and vice versa.
  - Apart from degrading 3D quality it also causes fatigue and motion sickness
  - Resolving the crosstalk issue with regards to time multiplexed displays requires creating a faster response in the device
  - Plasma panel displays have an upper hand in solving this problem because of the short emission times and short afterglow times that they can produce

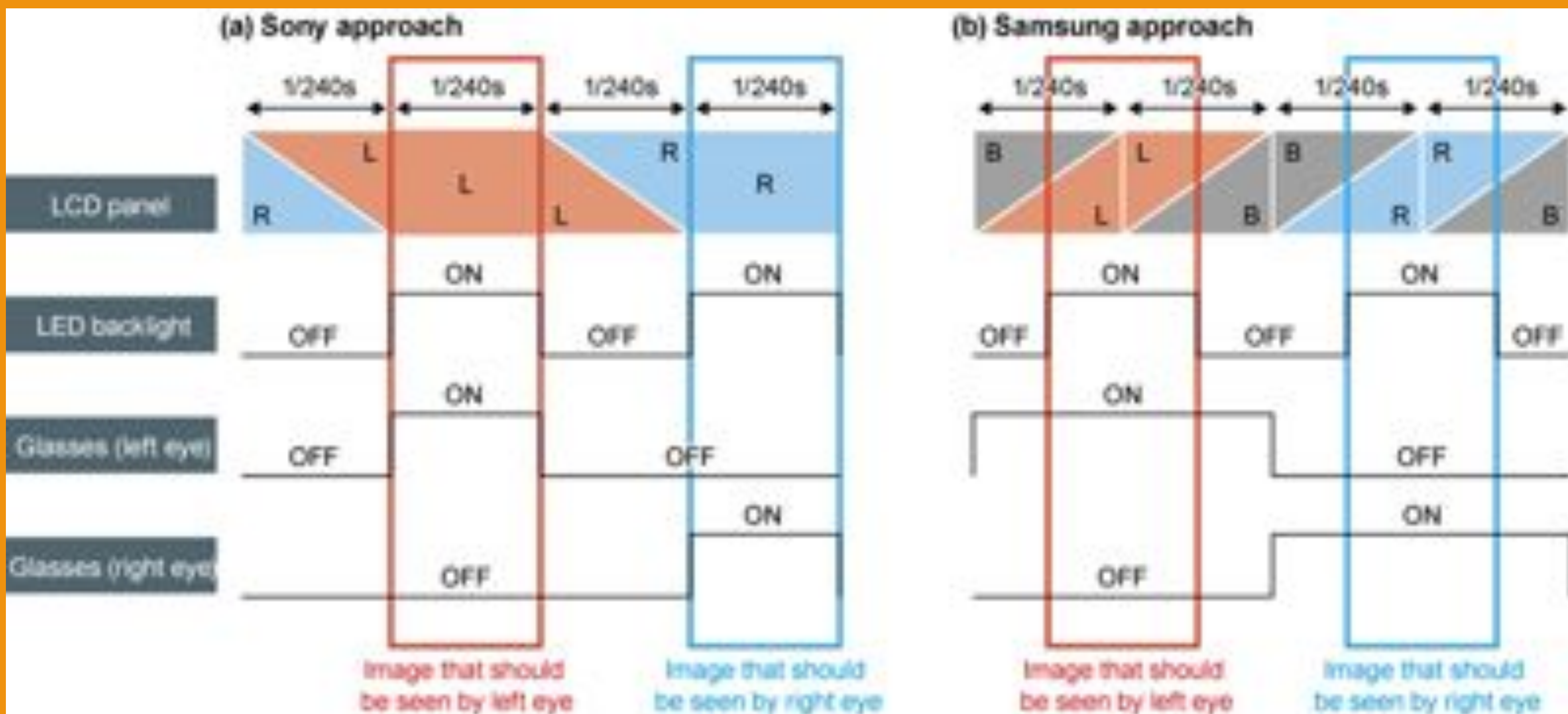
Current Developments

- Crosstalk:
  - For plasma, enhancements in the phosphor afterglow times and ordering of emitted pulses greatly reduce crosstalk



Current Developments

- Crosstalk:
  - For LCD, increase in drive frequency to 240Hz as well as enhancements to the backlight system reduce crosstalk



Current Developments

- Brightness:
  - Reduced image brightness due to the layers of other surfaces need to modulate the light in the appropriate eye
  - Solutions for increasing the brightness include:
    - Boosting emission efficiency of LED lighting in the backlight
    - Reducing the number of polarizers used
    - Using UV light to orient liquid crystals instead of slits and ribs
    - Adding yellow to create a 4 base color system (RGBY)