1 Laboratory #3: Color CRT and LCD Displays

1.1 Objective:

To understand the principle of additive mixing of colors and its role in color video displays

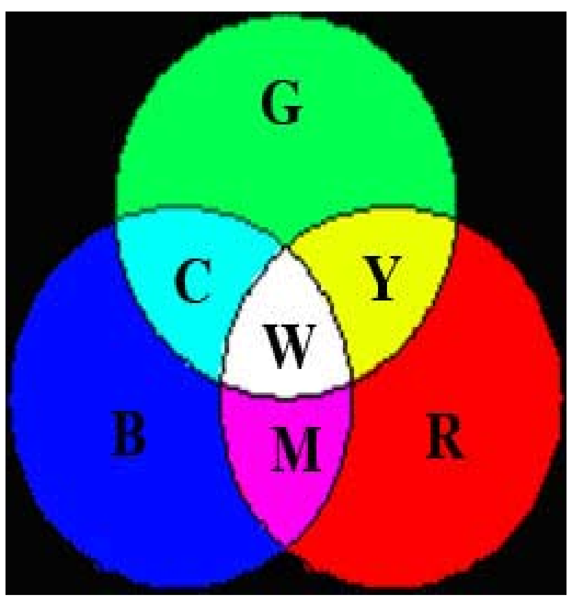
1.2 Materials:

Magnifying glass (Any convex lens with focal length of 2 inches or less. Lens "B" of the *OSA Optics Discovery Kit* works well.)

1. Observations will be made of the behavior of the following types of displays:
2. Color television with reasonably large CRT screen
3. CRT display of a desktop computer (the big heavy kind)
4. Liquid Crystal Display (LCD) of a laptop or a flat panel desktop display
5. Black-and-white television set (if available)

1.3 Background:

Different colors of light are generated by adding two or more lights of different color at the same spot on a diffuse white screen. The resulting light that reaches your eyes is an additive mixture of the two sources. In other words, the intensities of light add at each wavelength to generate a "new" perceived color from this combined wavelength distribution. The additive primary colors are red, green, and blue. A mixture of green and red creates yellow, mixing blue with green creates a "bluish-green" (surprise!) called cyan, and mixing blue with red makes magenta. The sum of all three primary colors creates white. These combinations are shown below:



Additive color Mixing: the three primaries are Green, Blue, and Red. The sums of equal amounts of two primaries create yellow, cyan, and magenta, and the sum of equal amounts of all three primaries creates white

If the system can display $2^8 = 256$ colors for each of the primary colors, then the theoretical number of colors that the monitor can display is $\left(2^8\right) \times \left(2^8\right) \times \left(2^8\right) = 2^{24} = 16,777,216$.

Spatial partitive mixing is a form of additive mixing that is achieved by placing small light sources sufficiently close enough that your eyes cannot see them separately but "blends" them together; in other words, your eye cannot "resolve" the individual lights. The concept of spatial partitive mixing was used by the French artist Georges-Pierre Seurat (1859-1891), who created colors paintings in the late 19^{th} century.by dabbing small bits of paint onto canvas; the method is called "pointillism." A person standing very close to the painting sees a seemingly random pattern of colored dots that appear to merge as as the person moves farther away. The merging of the dots is due to the limited spatial resolution of the eye, which makes the colors "appear." This is not a perfect analogy, since the primary colors for pigments are not red, green, and blue, but rather cyan, magenta, and yellow (!).

Television sets create colors through spatial partitive mixing. In the familiar cathode-ray tube (CRT) display, electrons are accelerated and directed by electromagnets towards a screen coated with a pattern of three different types of phosphors arrayed as small "dots." Phosphors are materials that phosphoresce, or "glow," when stimulated by electrons. Different types of phosphors emit different colors, and the phosphors are selected to emit the additive primary colors: red, green, and blue. The typical CRT contains three electron "guns" and the electrons from each can "hit" only the phosphors of a specific color. By varying the intensity of the electron beam from each gun, the phosphors in a local region can be stimulated to different levels of brightness determined by the scene to be imaged. The phosphors concentrated in a small area appear to blend together to the viewer's eye to form a large range of color when viewed at a sufficiently large distance from the screen.

Another form of color addition is *temporal partitive mixing*, where the individual color channels (RGB) are presented to the eye at different closely spaced times. This method depends on the same limited time resolution of the human visual system that is responsible for the blending of individual images into the appearance of continuous motion in a movie. The temporal mixing method is used by modern Digital Light Processor (DLP^{TM}) projectors and modern digital cinema projectors.

1.4 Experimental Procedure:

1. With the CRT turned off, use the convex lens to magnify the image of the face of the screen. Make sure the magnified image is in good focus. Record what you see.

2. Turn on the display to a color broadcast; again examine the CRT screen with the convex lens, making sure the magnified image is in good focus. Record your observations, making note of the relative intensities of the individual phosphors in regions of specific object color as the broadcast proceeds. You should try to do this for areas that are bright white, black, and different mixtures of color.

3. Examine black-and-white televised images on the color CRT (and on a B&W TV, if available). There are two ways to accomplish this. (A) Find a program that was originally recorded in black and white (e.g., "I Love Lucy" or "The Dick Van Dyke Show on "Nick at Night"). Alternatively you may have a recorded program on VHS tape or DVD . (B) turn down the "color" control on the television set until the screen shows only black-and-white images. Again use the convex lens to examine the television screen, and record your observations, making note of the relative intensities of colors as the broadcast proceeds.

4. Repeat steps 1-3 for both computer monitors (CRT and LCD). The sample color image shown below may be a good image to examine. Look at the different colors; note the appearance of the magnified screen within a bright white region and compare it to a black region. Observe regions of the screen that are white, red, green, blue, yellow, magenta, cyan and black.

Sample color image

5. Record your observations for each display and include them in your report.

1.5 Questions to be addressed in report:

1. Discuss your observations of the differences between the CRT computer screen and the LCD screen. What do you think is going on that makes the magnified screens look different?
2. Describe the way the TV uses the concept of spatial partitive color mixing to display B&W and color images.