

# Introduction to Computer Graphics (CS602)

## Lecture 02

### Graphics Systems

#### 2.1. Introduction of Graphics Systems

With the massive development in the field of computer graphics a broad range of graphics hardware and software systems is available. Graphics capabilities for both two-dimensional and three-dimensional applications are now common on general-purpose computers, including many hand-held calculators. On personal computers there is usage of a variety of interactive input devices and graphics software packages; whereas, for higher-quality applications some special-purpose graphics hardware systems and technologies are employed.

#### 2.2. VIDEO DISPLAY DEVICES

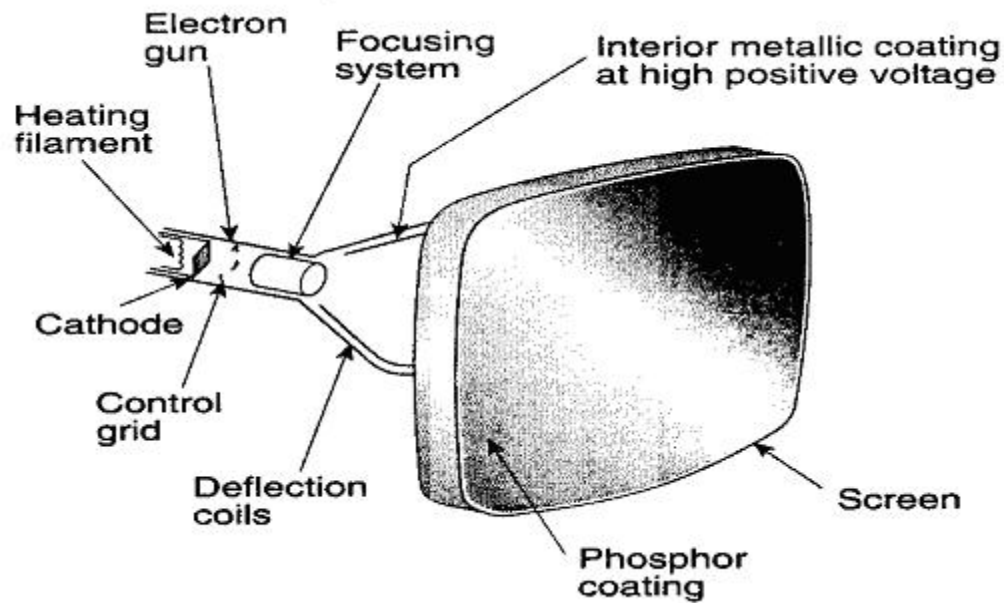
The primary output device in a graphics system is a video monitor. The operation of most video monitors is based on the standard cathode-ray-tube (CRT) design, but several other technologies exist and solid-state monitors may eventually predominate.

#### 2.3. Refresh Cathode-Ray Tubes

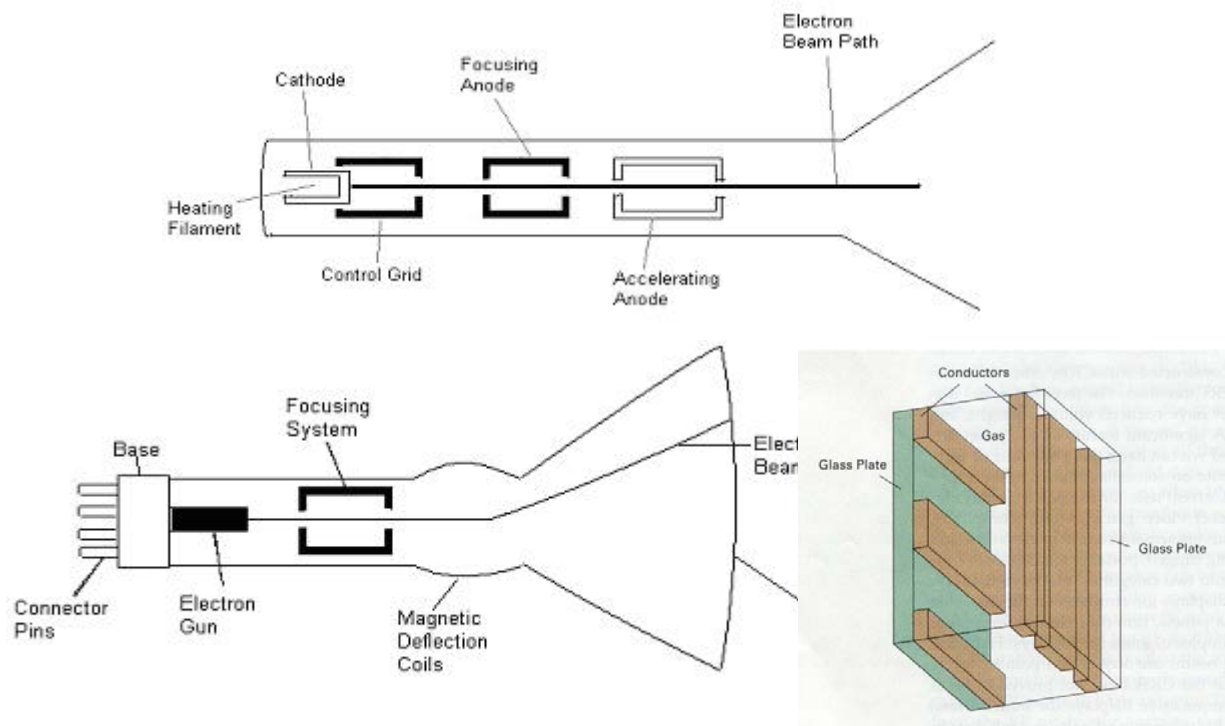
Following figures illustrate the basic operation of a CRT. A **beam** of electrons (cathode rays), emitted by an **electron gun**, passes through **focusing and deflection systems** that direct the beam toward specified positions on the **phosphor-coated screen**. The phosphor then emits a small spot of light at each position contacted by the electron beam.

The light emitted by the phosphor **fades** very rapidly therefore to keep the picture it is necessary to keep the phosphor glowing. This is achieved through **redrawing** the picture repeatedly by quickly directing the electron beam back over the same points and the display using this technique is called **refresh CRT**.

The primary components of an electron gun in a CRT are the **heated metal cathode** and a **control grid**. **Heat** is supplied to the cathode by directing a current through **filament** (a coil of wire), inside the cylindrical cathode structure. Heating causes electrons to be boiled off the hot cathode surface. In the vacuum inside the CRT envelope, the free, negatively charged electrons are then **accelerated** toward the phosphor coating by a high positive voltage.



The **accelerating voltage** can be generated with a **positively charged metal** coating on the inside of the **CRT envelope** near the phosphor screen an **accelerating anode** can be used.



**Intensity of the electron beam is controlled** by setting voltage levels on the control grid, a metal cylinder that fits over the cathode. A high negative voltage applied to the control grid will shut off the beam by repelling electrons and

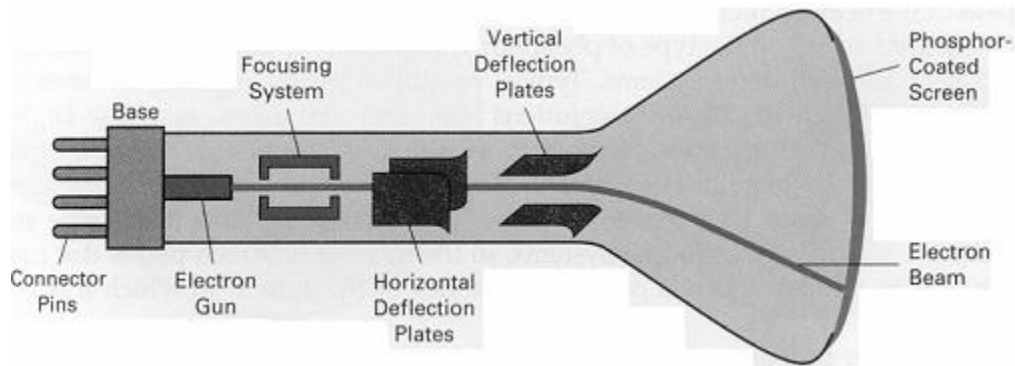
stopping them from passing through the small hole at the end of the control grid structure. A smaller negative voltage on the control grid simply decrease the number of electrons striking the phosphor coating on the screen.

It is the responsibility of **focusing system** to converge electron beam to a small spot where it strikes the phosphor. Otherwise the electrons will repel each other and the beam would disperse. This focusing is achieved through **electric or magnetic fields**.

In **electrostatic focusing** the electron beam passes through a positively charged metal cylinder that forms an electrostatic lens. Then electrostatic lens focuses the electron beam at the center of the screen. Similar task can be achieved with a **magnetic field** setup by a coil mounted around the outside of the CRT envelope. Magnetic lens focusing produces the smallest spot size on the screen and is used in special purpose devices.

The distance that the electron beam must travel from gun to the exact location of the screen that is small spot is different from the distance to the center of the screen in most CRTs because of the curvature therefore some **additional focusing hardware** is required in high precision systems to take beam to all positions of the screen. This procedure is achieved in two steps in first step beam is conveyed through the exact center of the screen and then additional focusing system adjust the focusing according to the screen position of the beam.

**Cathode-ray tubes** are now commonly **constructed** with magnetic deflection coils mounted on the outside of the CRT envelope. Two pairs of coils are used, with the coils in each pair mounted on opposite sides of the neck of the CRT envelope. One pair is mounted on the top and bottom of the neck, and the other pair is mounted on opposite sides of the neck. The magnetic field produced by each pair of coils results in a traverse deflection force that is perpendicular both to the direction of the magnetic field and to the direction of travel of the electron beam. **Horizontal deflection** is achieved with one pair of coils, and **vertical deflection** by the other pair. The proper deflection amounts are attained by adjusting the current through the coils. When electrostatic deflection is used, two pairs of parallel plates are mounted inside the CRT envelope. One pair of plates is mounted horizontally to control the vertical deflection, and the other pair is mounted vertical to control horizontal deflection.



**Phosphor** is available in different kinds. One variety is available in color but a major issue is their **persistence**. Persistence is defined as the time it takes the emitted light from the phosphor to decay to one-tenth of its original intensity. Lower persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker. A phosphor with low persistence is useful for displaying highly complex, static pictures. Monitors normally come with persistence in the range from 10 to 60 microseconds.

The maximum number of points (that can be uniquely identified) on a CRT is referred to as the **resolution**. A more precise definition of resolution is the number of points per centimeter that can be plotted horizontally and vertically, although it is often simply stated as the total number of points in each direction. Finally **aspect ratio**; is the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen. An aspect ratio of  $3/4$  means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points.

## 2.4. RASTER-SCAN SYSTEMS

Raster scan is the most common type of monitors using CRT. In raster scan picture is stored in the area called **refresh buffer or frame buffer**. First of all why information is stored; because picture have to be refreshed again and again for this very reason it is stored. Second is how it is stored; so picture is stored in a two dimensional matrix where each element corresponds to each **pixel** on the screen. If there arise a question what is a pixel? The very simple answer is a pixel (short for picture element) represents the shortest possible unique position/element that can be displayed on the monitor without overlapping.

The frame buffer stores information in a two dimensional matrix; the question is that how many bits are required for each pixel or element. If there is black and white picture then there is only one bit required to store '0' for black or 1 for white and in this case buffer will be referred as **bitmap**. In colour pictures obviously multiple bits are required for each pixel position depending on the possible number of colours for example to show 256 colours 8 bits will be required for each pixel and in case if multiple bits are used for one pixel frame buffer will be referred as **pixmap**.

Now with the information in frame buffer, let us see how an image is drawn. The drawing is done in a line-by-line fashion. After drawing each line from left to right it reaches at the left end of the next line to draw next line; which is called **horizontal retrace**. Similarly after completing all lines in horizontal fashion it again reaches the top left corner to start redrawing the image (that is for refreshing) and this is called **vertical retrace**. Normally each vertical retrace takes  $1/60^{\text{th}}$  of a second to avoid flickering.

There are two further methods to scan the image: **interlaced** and **non-interlaced**. In interlaced display beam completes scanning in two passes. In one pass only odd lines are drawn and in the second pass even lines are drawn. Interlacing provides effect of double refresh rate by completing half of the lines in half of the time. Therefore, in systems with low refresh rates interlacing helps avoid flickering.

## 2.5. RANDOM-SCAN Displays

In random-scan displays a portion of the screen can be displayed. Random-scan displays draw a picture one line at a time and are also called vector displays (or stroke-writing or calligraphic displays). In these systems image consists of a set of line drawing commands referred to as **Refresh Display File**. Random-scan can refresh the screen in any fashion by repeating line drawing mechanism.

Random-scan displays are designed to draw all the component lines of a picture 30 to 60 times each second. High-quality vector systems are capable of handling approximately 100,000 short lines at this refresh rate. When a small set of lines is to be displayed, each refresh cycle is delayed to avoid refresh rates greater than 60 frames per second. Otherwise, faster refreshing of the set of lines could burn out the phosphor.

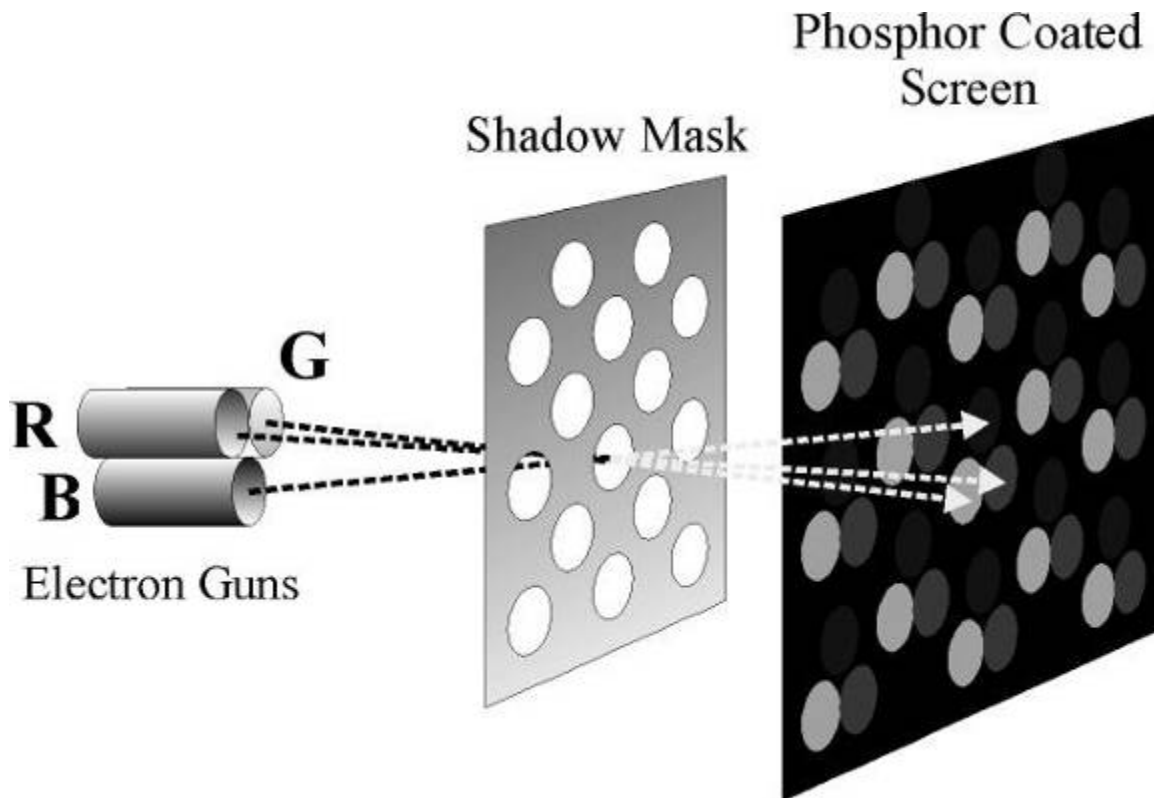
Random-scan displays are designed for line-drawing applications and cannot display complex pictures. The lines drawn in vector displays are smoother whereas in raster-scan lines often become jagged.

## 2.6. Color CRT Monitors

A CRT monitor displays colour pictures by using a combination of phosphors that emit different coloured light. With the combination of phosphor a range of colours can be displayed. There are two techniques used in colour CRT monitors:

- Beam Penetration Method
- Shadow Mask Method

In **beam penetration** method two layers of phosphor, usually coated onto the inside of the CRT screen, and the displayed colour depend on how far the electron beam penetrates into the phosphor layers. At intermediate beam speeds, combinations of red and green light are emitted to show two additional colours, orange and yellow. Beam penetration is an inexpensive way to produce colours as only a few colours are possible and the quality of picture is also not impressive.



**Shadow mask** methods can display a wide range of colours. In this technique each pixel position is made up of three phosphor dots called triads as shown in the following figure. Three phosphor dots have different colors i.e. red, green and blue and the display colour is made by the combination of all three dots. Three guns are used to throw beam at the three dots of the same pixel. By varying intensity at each dot a wide range of colours can be generated.

A **shadow-mask** is used which has holes aligned with the dots so that each gun can fire beam to corresponding dot only.

## CRT Displays

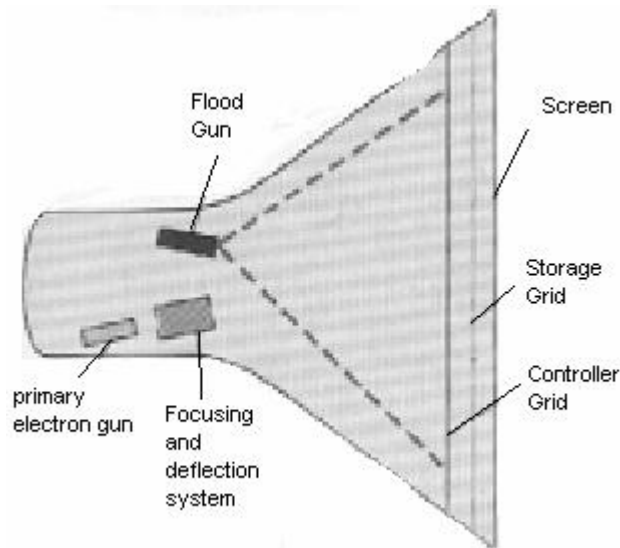
### Advantages

- Fast response (high resolution possible)
- Full colour (large modulation depth of E-beam)
- Saturated and natural colours
- Inexpensive, matured technology
- Wide angle, high contrast and brightness

### Disadvantages

- Large and heavy (typ. 70x70 cm, 15 kg)
- High power consumption (typ. 140W)
- Harmful DC and AC electric and magnetic fields
- Flickering at 50-80 Hz (no memory effect)
- Geometrical errors at edges

## 2.7. Direct View Storage Devices



A direct view storage tube stores the picture information as a charge distribution just behind the phosphor-coated screen. Two electron guns are used in this system as shown in the following figure. They are:

- Primary Gun
- Flood Gun

**Primary gun** is used to store the picture pattern whereas **flood gun** maintains the picture display.

DVST has advantage that no refresh is required so very complex pictures can be displayed at very high resolutions without flicker. Whereas, it has disadvantage that ordinarily no colors can be displayed and that selected parts of a picture cannot be erased. To eliminate a picture section, the entire screen must be erased and the modified picture redrawn. The erasing and redrawing process can take several seconds for a complex picture.



### Flat-Panel Displays

This is emerging technology slowly replacing CRT monitors. The flat-panel displays have following properties:

- Little Volume
- Light Weight
- Lesser Power consumption

Flat panels are used in calculators, pocket video games and laptop computers.

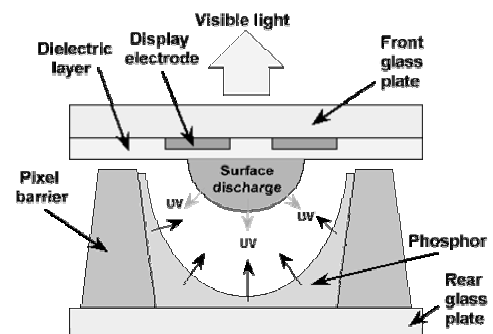
There are two categories of flat panel displays:

- Emissive Display (Plasma Panels)
- Non-Emissive Display (Liquid Crystal Display)

The **emissive displays** (emitters) are devices that convert electrical energy into light. Plasma panels, thin-film electro-luminescent displays, and light-emitting diodes are examples of emissive displays. **Non-emissive** displays (non-emitters) use optical effects to convert sunlight or light from some other source into graphics patterns. The most important example of a non-emissive flat-panel display is a liquid-crystal device.

## 2.8. Plasma-panel Displays

Plasma panels also called gas-discharge displays are constructed by filling the region between two glass plates with a mixture of gases that usually includes neon. A series of vertical conducting ribbons is placed on one glass panel, and a set of horizontal ribbons is built into the other glass panel. Firing voltages applied to a pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into a glowing plasma of electrons and ions. Picture definition is stored in a refresh buffer, and the firing voltages are applied to refresh the pixel positions 60 times per second.



### Advantages

- Large viewing angle
- Good for large-format displays
- Fairly bright

### Disadvantages

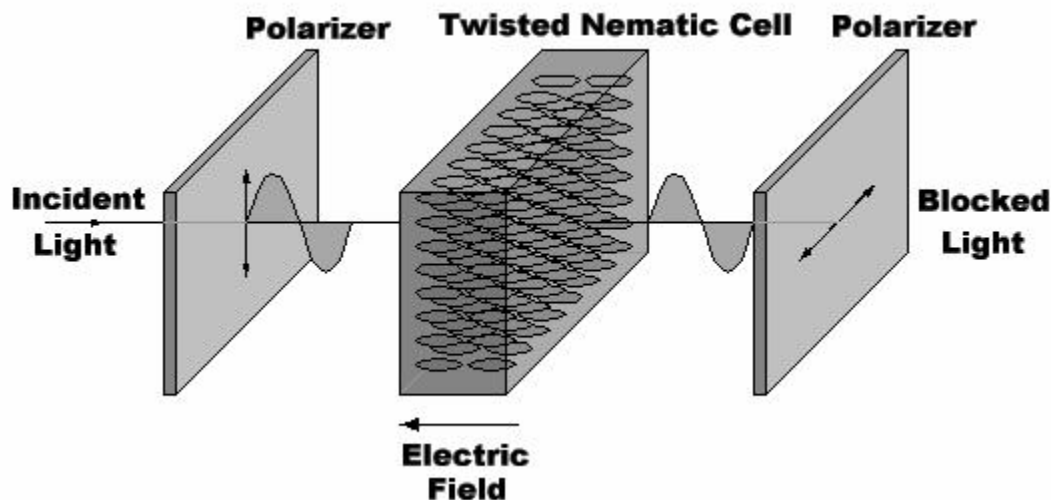
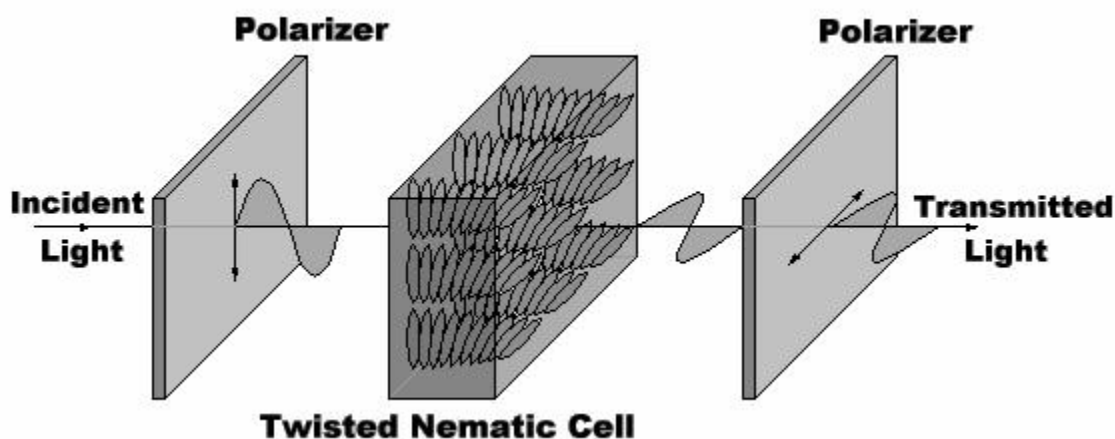
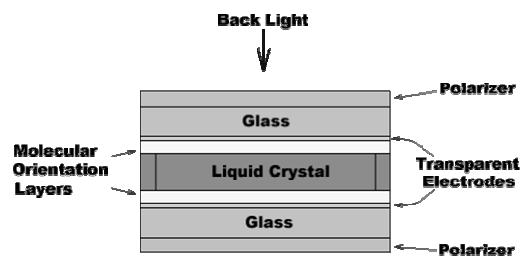
- Expensive
- Large pixels (~1 mm versus ~0.2 mm)
- Phosphors gradually deplete



–Less bright as compared to CRTs, using more power

## 2.9. Liquid Crystal Displays

Liquid crystal refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid. Flat panel displays use nematic liquid crystal, as demonstrated in the following figures.



Two glass plates, each containing a light polarizer at right angles to the other plate, sandwich the liquid-crystal material. Rows of horizontal transparent conductors are built into one glass plate, and columns of vertical conductors are put into the other plate. The intersection of two conductors defines a pixel position. Polarized light passing through the material is twisted so that it will pass through the opposite polarizer. The light is then reflected back to the viewer. To

turn off the pixel, we apply a voltage to the two intersecting conductors to align the molecules so that the light is not twisted.

## LCD Displays

### Advantages

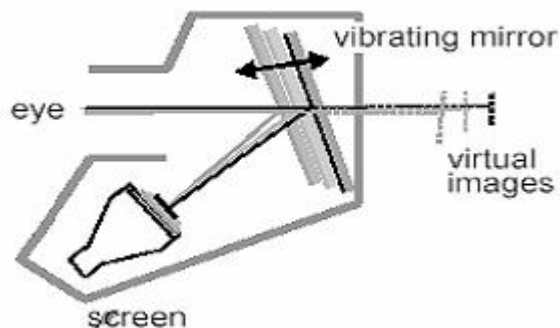
- Small footprint (approx 1/6 of CRT)
- Light weight (typ. 1/5 of CRT)
- Low power consumption (typ. 1/4 of CRT)
- Completely flat screen - no geometrical errors
- Crisp pictures - digital and uniform colours
- No electromagnetic emission
- Fully digital signal processing possible
- Large screens (>20 inch) on desktops

### Disadvantages

- High price (presently 3x CRT)
- Poor viewing angle (typ. +/- 50 degrees)
- Low contrast and luminance (typ. 1:100)
- Low luminance (Natural light) (typ. 200 cd/m<sup>2</sup>)

### Three-Dimensional Viewing Devices

Graphics monitors for the display of three-dimensional scenes have been devised using a technique that reflects a CRT image from a vibrating, flexible mirror. In this system when varifocal mirror vibrates it changes focal length. These vibrations are synchronized with the display of an object on a CRT so that each point on the object is reflected from the mirror into spatial position corresponding to the distance of that point from a specified viewing position. This allows user to walk around an object or scene and view it from different sides.



## 2.10. Virtual Reality Devices

**Virtual reality** system enables users to move and react in a computer-simulated environment. Various types of devices allow users to sense and manipulate virtual objects much as they would real objects. This natural style of interaction gives participants the feeling of being immersed in the simulated world. Virtual

reality simulations differ from other computer simulations in that they require special interface devices that transmit the sights, sounds, and sensations of the simulated world to the user. These devices also record and send the speech and movements of the participants to the simulation program.



To see in the virtual world, the user wears a head-mounted display (HMD) with screens directed at each eye. The HMD contains a position tracker to monitor the location of the user's head and the direction in which the user is looking. Using this information, a computer recalculates images of the virtual world to match the direction in which the user is looking and displays these images on the HMD.



Users hear sounds in the virtual world through earphones in the HMD. The haptic interface, which relays the sense of touch and other physical sensations in the virtual world, is the least developed feature. Currently, with the use of a glove and position tracker, the user can reach into the virtual world and handle objects but cannot actually feel them.



Another interesting simulation is **interactive walk through**. A sensing system in the headset keeps track of the viewer's opposition, so that the front and back of objects can be seen as the viewer walks and interacts with the displays. Similarly given below is a figure using a headset and a **data glove** worn on the right hand?



data glove as  
interaction  
device

HMD in combination  
with data glove