

### 3.15

#### Displays

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References: Braithwaite and Weaver chapter 6.4

#### Displays can work by

##### -emitting light, eg.

Incandescence (light from heating a filament)

Cathodoluminescence (light from electron bombardment)

ZnS +Ag (blue), (Zn,Cd)S +Cu (green),  $Y_2O_3S +Eu,Tb$  (red) –excited by three 20kV electron guns in a TV screen

Photoluminescence (light from UV irradiation), eg anti-theft printing on banknotes, black lights, etc. Use phosphors,  $TiO_2$

Electroluminescence (light from electrical excitation)

LED or semiconductor laser

Plasma emission (light from electrically excited plasma). Sodium light, Hg lamp, neon tube. In a plasma screen, a small UV plasma excites a phosphor, similar to a fluorescent light.

-or modulating light, e.g. liquid crystal display, electrooptic modulator, micromirror array, etc.

#### Liquid crystal displays

Stiff, rod-shaped organic molecules such as cyanobiphenyls which can order in different ways:

Nematic (lined up parallel)

Cholesteric (helical, also called a chiral nematic) –pitch of helix is a fraction of a micron

Smectic (layered arrangements, 8 different types)

Optical properties are different parallel vs perpendicular to the molecule. Polarizability is higher parallel to the molecule. The complex refractive index, dominated by electronic polarizability, is higher parallel to the molecule, so light with electric field parallel to the molecule is transmitted better.

Twisted nematic display consists of

Polarizer/ front plate with electrode pattern /grooved polymer /  $\sim 10 \mu\text{m}$  nematic + cholesteric / grooved polymer / back plate /polarizer / mirror

The grooved polymer sheets are oriented perpendicular to each other and guide the nematic into a slow  $90^\circ$  twist; light is transmitted. Applying a vertical electric field (eg 3V) between the front and back plates aligns the nematic and light can no longer pass, so the display is dark. Colors come from dyes or filters. Response time limited by viscosity.

Electrode patterns are made from thin film transistors (TFTs) made on glass – these use a-Si to make the channel region, with p-type source and drain doped with Al, and a Cr gate. The drain is connected to a pixel made from ITO (indium tin oxide, a transparent conductor).