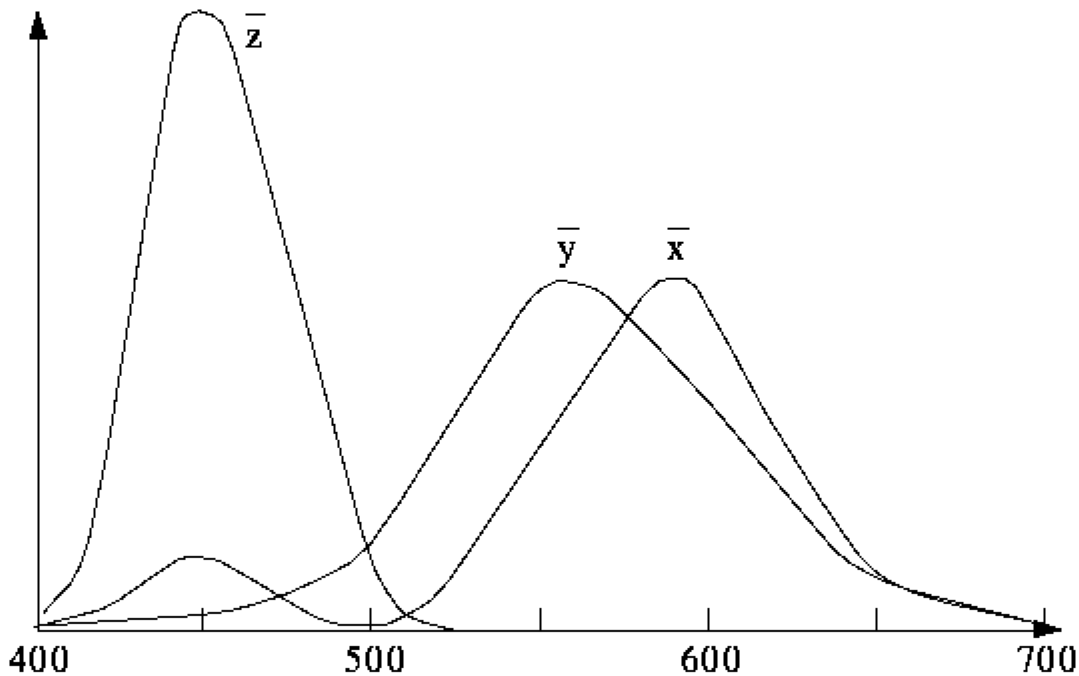
Does a set of primaries exist that span the space with only positive coefficients?

- Yes, but no pure colours.
- In 1931, the CIE defined three standard primaries **(X, Y, Z)** . The **Y** primary was intentionally chosen to be identical to the luminous-efficiency function of human eyes.



Reproducing Visible Colour

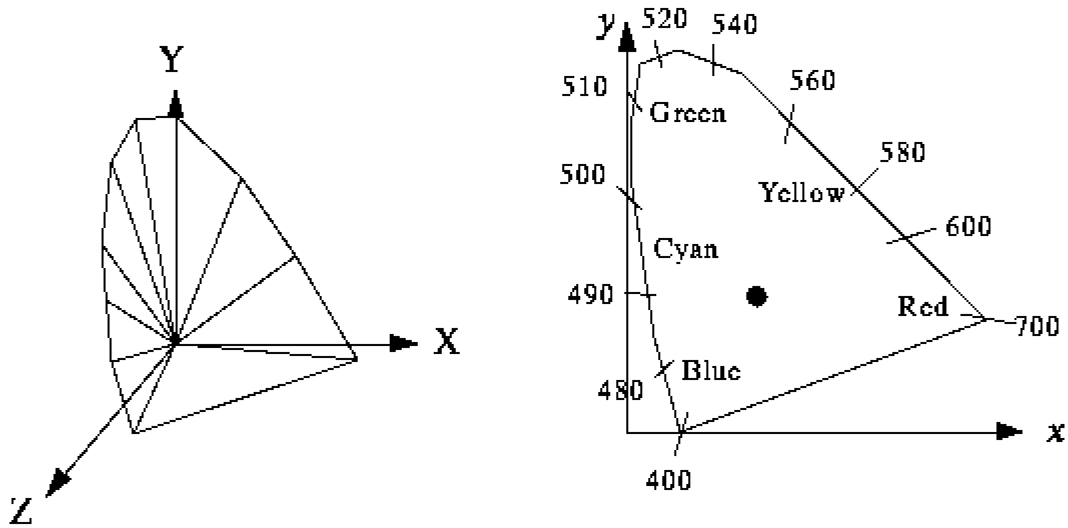
- Figure 6.19 shows the amounts of X, Y, Z needed to exactly reproduce any visible colour via the formulae:

$$X = \int E(\lambda)\,\bar{x}(\lambda)\,d\lambda$$

$$Y = \int E(\lambda)\,\bar{y}(\lambda)\,d\lambda$$

$$Z = \int E(\lambda)\,\bar{z}(\lambda)\,d\lambda$$

- All visible colours are in a ***horseshoe*** shaped cone in the X-Y-Z space. Consider the plane *X+Y+Z=1* and project it onto the X-Y plane, we get the *CIE chromaticity diagram* as shown in Fig. 6.20.

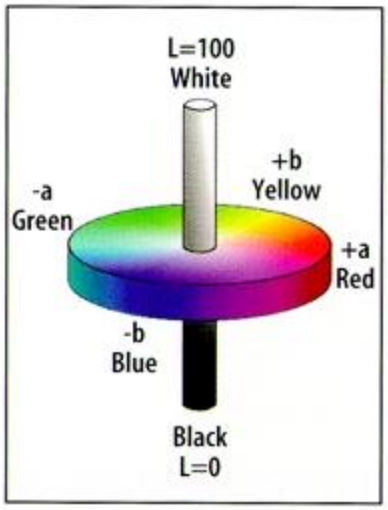


CIE Chromaticity Diagram

- The edges represent the ***pure*** colours (sine waves at the appropriate frequency).
- White (a blackbody radiating at 6447 kelvin) is at the ***dot.***
- When added, any two colours (points on the CIE diagram) produce a point on the line between them.

L*a*b (Lab) Colour Model

- A refined CIE model, named CIE L*a*b in 1976
- Luminance: L Chrominance:
- a - ranges from green to red, b - ranges from blue to yellow (Fig, 6.21)



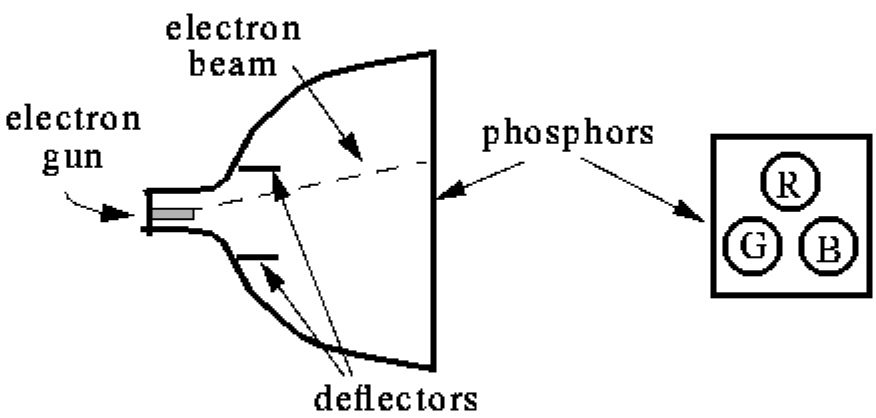
Lab model

LAB Colour Model

- Used by *Photoshop*

CRT Displays

- CRT displays have three phosphors (RGB) which produce a combination of wavelengths when excited with electrons (Fig. 6.22).



RGB Colour Display

- The *gamut* of colours is all colours that can be reproduced using the three primaries

- The gamut of an colour monitor is smaller than the CIE (LAB) colour gamut on the CIE diagram.

Colour Image and Video Representations

- A black and white image is a 2-D array of integers.
- A colour image is a 2-D array of (R,G,B) integer triplets. These triplets encode how much the corresponding phosphor should be excited in devices such as a monitor.

Display of a Colour Cube

Beside the RGB representation, **YIQ and YUV** are the two commonly used in video.

YIQ Colour Space

- YIQ is used in colour TV broadcasting, it is downward compatible with B/W TV.
- Y (luminance) is the CIE Y primary.

$Y = 0.299R + 0.587G + 0.114B$

- the other two vectors:

$I = 0.596R - 0.275G - 0.321B$ $Q = 0.212R - 0.528G + 0.311B$

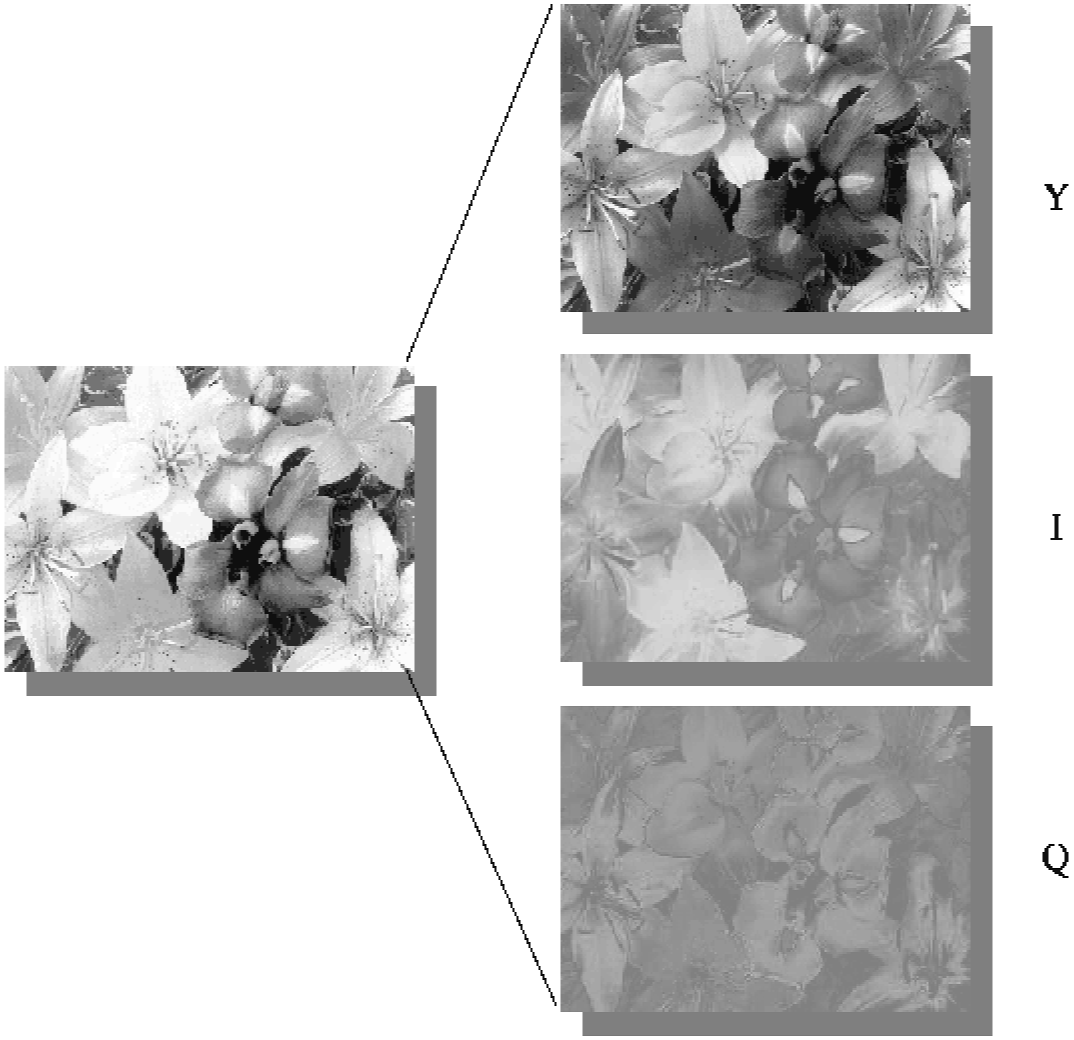
- The YIQ transform:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

YIQ Transform of a colour image

- I is red-orange axis, Q is roughly orthogonal to I.

- Eye is most sensitive to Y, next to I, next to Q. In NTSC, 4 MHz is allocated to Y, 1.5 MHz to I, 0.6 MHz to Q.
- An Example YIQ Decomposition is shown in Fig. 6.24.



Example YIQ Decomposition

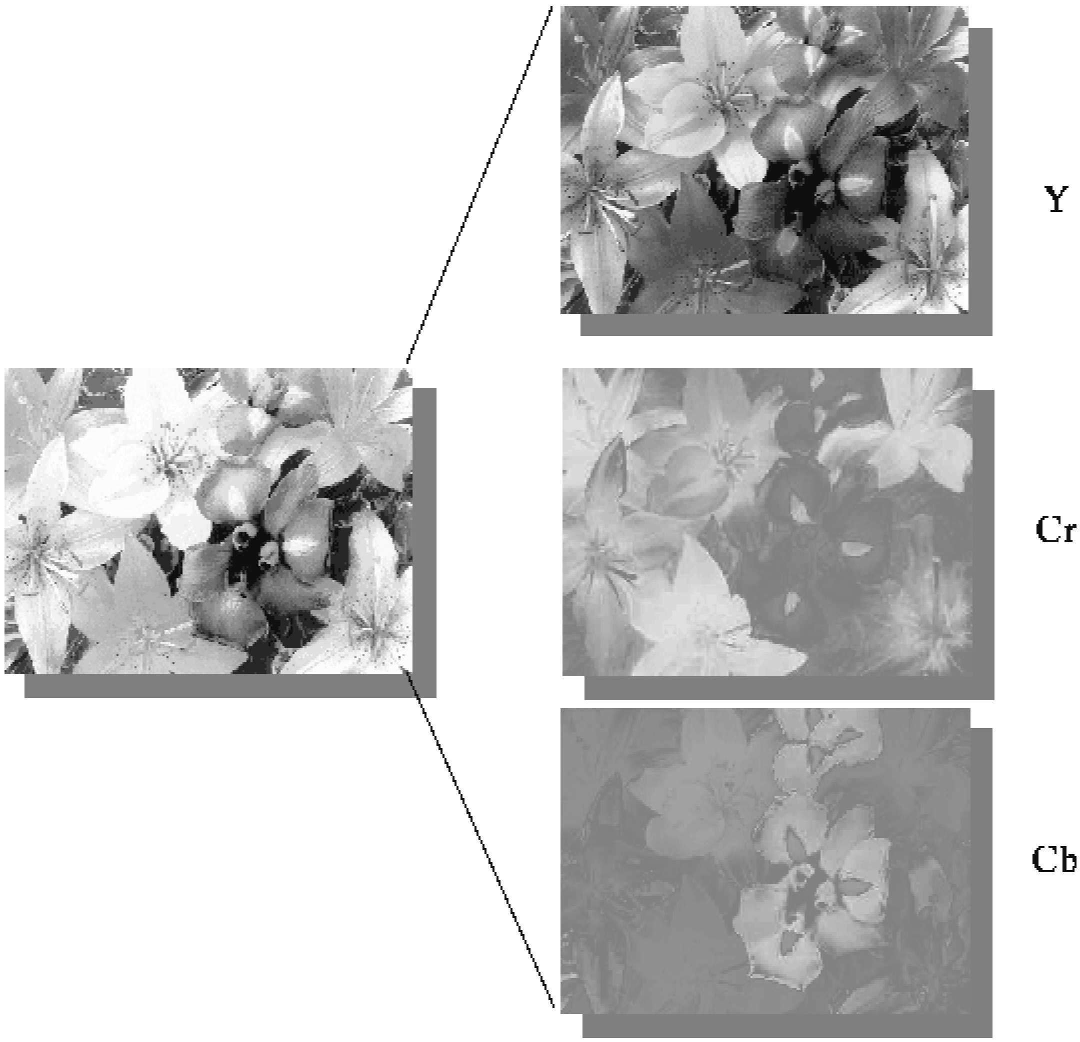
CCIR 601 (YUV)

- Established in 1982 to build digital video standard
- Video is represented by a sequence of fields (odd and even lines). Two fields make a frame.
- Works in PAL (50 fields/sec) or NTSC (60 fields/sec)
- Uses the Y, Cr, Cb colour space (also called YUV)

- *Y = 0.299R + 0.587G + 0.114B Cr = R - Y Cb = B - Y*
  - The YCrCb (YUV) Transform:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- CCIR 601 also defines other image parameters, e.g. for NTSC, Luminance (Y) image size = 720 x 243 at 60 fields per second Chrominance image size = 360 x 243 at 60 fields per second
- An example YCrCb Decomposition is shown in Fig. 6.25



YCrCb Decomposition of a colour image