
FAULKES TELESCOPE

## Colour Imaging

# Background Science for Colour Imaging and CCDs

EU-HOU

Education and Culture

Socrates

*Author: David Bowdley*

This project has been funded with support from the European Commission.
This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

# Colour Imaging

## Background Science for Colour Imaging and CCDs

***This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.***

### *What is Colour?*

For humans, colour is the perception of certain frequencies of light and is comparable to pitch, which is our perception of the frequency of sound. The human eye perceives light using two different types of cells. Colour information is sensed by cone cells, whilst rod cells can only see light intensity and not colour (though they are more sensitive to low level light than cone cells). Cone cells come in three types and each type is sensitive to a particular part of the visible spectrum. Broadly speaking, the cells are sensitive to red, green and blue, the primary colours of light. When the signals from these cells reach the brain, they can be interpreted as a wide range of colours. This is how colour vision is achieved in humans.

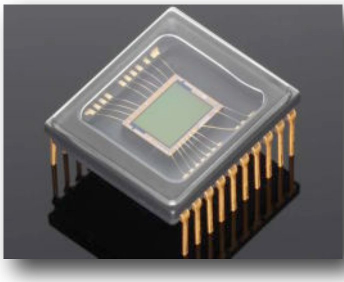
At low light levels, the cone cells are not sensitive to see colour. The rod cells take over and you see in black and white. The table on the left shows the frequencies that represent different colours in the visible spectrum. You can also see the associated wavelength measured in nanometres ($10^{-9}$m).

| color | wavelength interval | frequency interval |
|---|---|---|
| red | ~ 625-740 nm | ~ 480-405 THz |
| orange | ~ 590-625 nm | ~ 510-480 THz |
| yellow | ~ 565-590 nm | ~ 530-510 THz |
| green | ~ 500-565 nm | ~ 600-530 THz |
| cyan | ~ 485-500 nm | ~ 620-600 THz |
| blue | ~ 440-485 nm | ~ 680-620 THz |
| violet | ~ 380-440 nm | ~ 790-680 THz |

To achieve the same result with colour film in a camera, different layers of light sensitive film are sandwiched together. Each layer is sensitive to a different colour, and as such, the colour information about an object or scene can be recorded. However, in our particular circumstances we are interested in how a colour image can be recorded electronically. This is where the Charge-Coupled Device (CCD) comes in.

## *What are CCDs?*

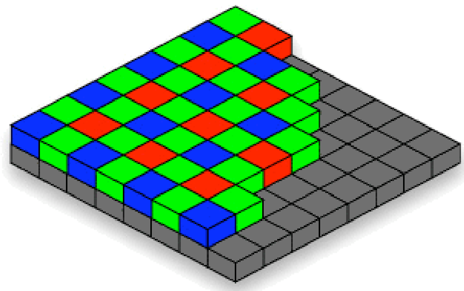
CCD is short for charge-coupled device. In essence, it is an array of capacitors that are coupled together so that they can transfer charge between themselves. The CCD was invented in the late 1960s as part of work being done on “bubble” memory. The researchers produced a device that was able to store information in the form of charge. However, they realised that not only could you put charge in to a chip using electronics, you could also get the chip to record charge using the photoelectric effect. Soon it was possible to use these memory chips to take images.

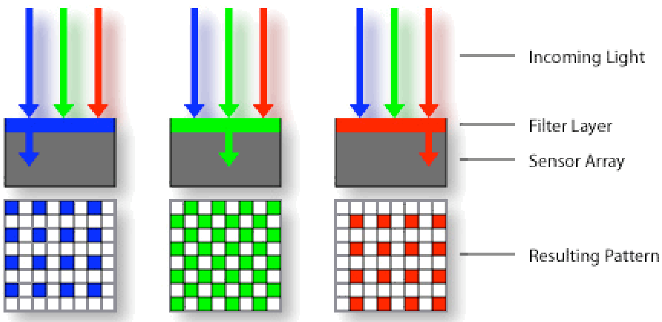


Today, CCDs are used in a wide range of devices.

Standard digital cameras, such as those you would take on holiday to take photographs of your adventures, use a CCD. The CCD is sensitive to light and converts light to electrical charge. The electrical charge is then measured and recorded in a computer file.

This is a very simple way of looking at how colour images are taken so let's have a closer look at what a CCD actually is and how it works.



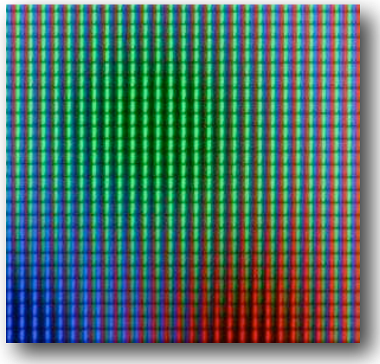



We have already said that a CCD is an array of capacitors. Each of these capacitors has the ability to store electrical charge. The capacitors form picture elements (pixels) on the CCD. The pixels are charged using the photoelectric effect. The photoelectric effect occurs when a material converts incoming photons of light in to electrical charge. The pixels store this electrical charge until an external circuit is connected to the CCD. When this happens, the value of charge on each pixel is converted in to a numeric value and passed on to a computer for recording in a computer file.

Once all the data has been recorded, the original image can be reproduced on a computer screen as shown in the next section. CCDs are very sensitive to light compared to photographic film. For this reason CCDs have replaced film in many applications.

If you look at the diagram above, you can see the layout of the pixels on a colour CCD. You will notice there are red, green and blue pixels, just like the human eye has cone cells that are sensitive to red, green and blue light. The pattern above is known as the Bayer filtration pattern and is used in most colour CCD cameras. Each pixel has a coloured filter on top of it so that only light that is the colour of the filter can pass through. The pixel below the filter then records the intensity of the light. As we know which pixels have which filter, we can then determine the intensity of red, green and blue light at any point on the CCD. This information can then be used to reproduce the image “seen” by the CCD on a computer screen or other device.

## *How is an Image Displayed on a Monitor?*



The image on the right is a close up of a computer screen. Looking carefully at the image, you can see that the computer screen is made up of red, green and blue pixels. Once again, the primary colours of light are performing an important role in producing a colour image. Television pictures are also formed in exactly the same way.

Using just three colours, almost any other colour can be made on a computer or television screen. This is called additive colour mixing.

## *How Does Colour Printing Work?*

Colour printing relies on subtractive colour mixing. Instead of light being added together from light emitting pixels, colours are made by using inks of different colours where each ink absorbs light of some frequencies and reflects light of other frequencies. To print an image on to paper, some conversion has to be done from the primary colour of light for additive mixing (red, green and blue) to the primary colours for inks for subtractive mixing (magenta, yellow, cyan and black). The image below shows how subtractive mixing works for a printed image.

## *But....*

## *Faulkes Telescope colour images are made from three separate black and white images....!*

Yes, this is where the consumer colour CCD and the astronomical CCD differ.

Consumer CCDs only need to record colour in the visible spectrum. Astronomers rarely need colour images (and many astronomers have never even made colour images) but they do need to be able to image in regions outside of the visible spectrum (e.g. infrared, ultra-violet etc...).

Therefore an astronomical CCD does not have any colour filters built in to it, and is sensitive to a wide range of frequencies.

However, if you take images of an object with the whole CCD looking through a red filter, you know that all the light falling on the CCD is red and you can get an image that shows the intensity of red light at every point on the CCD. If you then do the same with a green and blue filter in front of the whole CCD, you have the same sort of information that you would get from a consumer CCD. The big difference is that THE colour resolution will be better because all the pixels will be involved in recording light through each filter. The photograph on the right shows the filter wheels on Faulkes Telescope North in Hawaii. You can see an animation of how the filter wheels work with the CCD on the Faulkes Telescope website.

On the next page you will see how the colour image is made from the original images from the telescope.

## *Making Colour Images from Three Monochrome Images Taken Through Filters*

As detailed in the previous section, In order to make a colour image, the Faulkes Telescopes take three images, one with each of the red, green and blue filters. Technically speaking these filters are R, V and B. The green filter is called V as it is actually the Visual filter and matches the green-yellow response of the human eye.

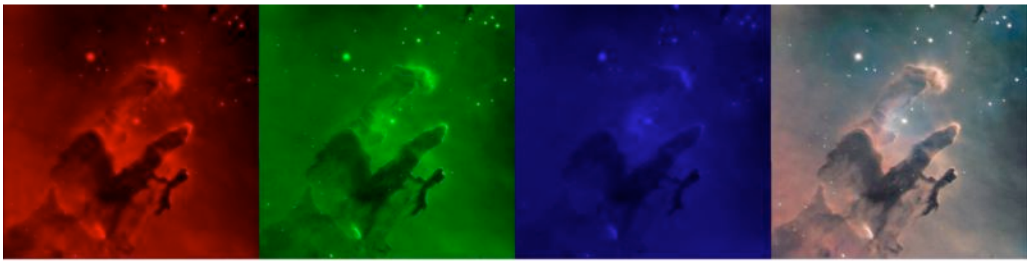
So:

R = Red
V = Visual (green)
B = Blue

From left to right below you can see three exposures taken through the R, V and B filters with Faulkes Telescope North.

Red Visual Blue

The images show the intensity of light in each of those colours, but are not actually coloured red, green and blue as you might expect. To make a colour image, we have to add colours to the separate images and then add them all together to make one final colour image. Below you can see the result of doing this.



Red Visual Blue Colour

Instructions and multimedia demonstrations showing how to produce colour images from Faulkes images can be found on the Faulkes Telescope website.

---

***This document was produced by the Faulkes Telescope Project (a part of Las Cumbres Global Telescope Network) for European Hands on Universe.***