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Camera Optoelectronics Quick Start Guide

What's it all about then?

This experiment gives students a general introduction to optoelectronic devices through an investigation into how digital cameras work. Students begin by exploring the most basic of all cameras - the pin hole camera - before experimenting with different sized apertures and lenses with different focal lengths. Building on this, students then investigate image capture and processing by using a photo diode array. Using computer software students investigate the effects of light intensity on detector array and resolution**.** Finally students investigate a range of devices, including a webcam and thermal camera.

There is a more detailed version of this document, providing background information on the experiment, available to download from the Lab in a Lorry wesbite:

http://www.labinalorry.org.uk/volunteer_information/downloads.cfm

How to present it

This is a guideline of how to present the experiment to the students. You do not have to follow it exactly, just ensure you allow the students to explore the concepts outlined below. You can expand or shorten this experiment as necessary to fill the time allocated.

Remember - the emphasis here is to ensure the students interact with the equipment and try things out for themselves rather than you just demonstrating. Ask plenty of questions and encourage suggestions and ideas that can be tested. Challenge the students to come up with feasible explanations rather than you just telling them what's going on.

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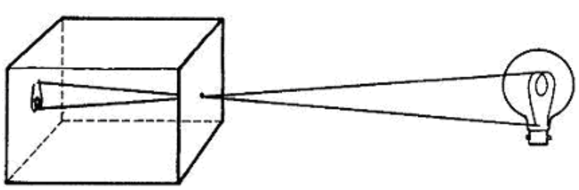
Introduction

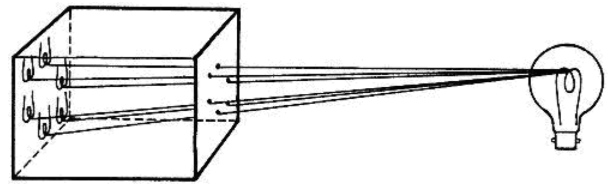
Start by asking the students a few quick fire questions to get them energised and involved. Ask what different types of camera they know and discuss the differences between film and digital cameras. Explain that a camera is just a box that allows light in and records it somehow and that they will investigate this today.

Make a Pin Hole Camera - 8 minutes

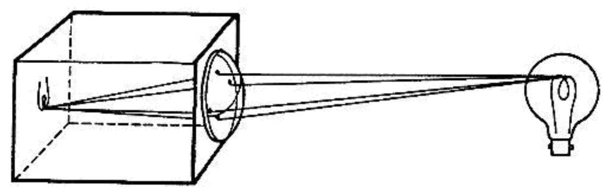
Give each student a camera kit and instruct them how to put it together. Tell them to *carefully* use a pin to create a hole. Switch on the bulb and tell them to find the image. *What can you see? What is strange about the image?* The image is inverted. Turn off the bulb (to give their eyes a rest) and draw the diagram to explain how the light travels into the box from each section of the filament.



The image is quite faint, how can we let more light in? Use the pin to create a larger hole and a few more holes. *What happens? Can you work out which is the largest hole just by looking at the image?* The brightest image is from the larger hole. *But at what cost?* The image has become blurred. More holes leads to multiple images. Again draw a quick diagram to explain.



How can we make the image sharp again? Introduce the lenses and give each student one to slot in front of their pin holes. *What has happened?* Explain how a lens works and what the focal length is.



There are two different types of lens for the students to investigate. Ask them to try and image the lights on the ceiling onto the table (telling them to try and burn a hole in the table usually makes them realise what to do quickly) and observe how the focal length changes for the two different thickness lenses.

By using a lens we can have a larger hole in our camera as the light is brought into focus on the screen. Allow the students to make their hole larger, use a pencil and finally remove the paper entirely. At this point they will be able to see the detail of the room around them and their friends faces on the screen, all upside down of course, much to their amusement!

You can also chat about the human eye and its similarities to this experiment. Ask them how we see the world...upside down! Feel free to shorten this section if it takes up too much time.

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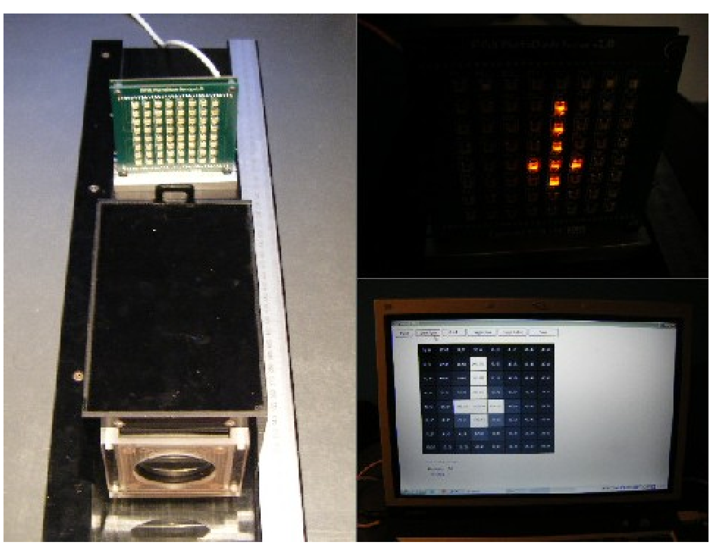
Optoelectronic Devices - 8 minutes.

Introduce the photo diode array as an Charge Coupled Device (CCD) converting light signals into electrical signals. A CCD transports the charge across the chip and reads it at one corner of the array. An analog-to-digital converter (ADC) then turns each pixel's value into a digital value by measuring the amount of charge at each photosite and converting that measurement to binary form. The relative quantity of photons at each photosite are then sorted into various intensity levels, whose precision is determined by bit depth (0 - 255 for an 8-bit image). The larger the number, the lighter the square on the screen, giving a black and white image.

Ask the students to project an image from the LED light source through a camera and onto the perspex screen, then replace the screen with the detector to shoot their image. Make sure the lights in the room are off otherwise the detector is flooded with light. By experimenting with different orientations, they should produce a clear image of the LED source on the screen.



We can now extend this to produce a colour image. Swap the single colour LED source for the multi-coloured one and allow the students to repeat the experiment. We still only get a greyscale image because the detector is unable to distinguish how much of each colour is visible. In order to produce a colour version, we must take a red, green and blue shot individually and then combine them. Use the coloured filters in front of the photodiode array to do this. The students should be able to produce an accurate full colour image, depending how accurate they are setting it up.

How many photodiodes are on the array? The photodiode array produces a 64 pixel image, so we have a 64 pixel camera, is this good or bad? Can they compare this to a digital camera they own? They may have cameras in their pockets, if so allow them to get them out. Modern cameras have Megapixel resolution. *What does "Mega" mean?* Explain this and how more pixels leads to a sharper image and show example images. *It is estimated that 35mm film cameras equate to 20 Megapixels, so why do we use digital cameras?*

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Other Devices - 8 minutes.

Webcam - You can explore resolution further using the webcam and computer software. Two images are shown on the screen, by changing the "pixel size" dial, students increase and decrease the size to see how it affects the resolution of the image.

Most digital cameras have infra red filters, but the webcam does not, so you can use the TV remote controller to show that while we can't see what it is emitting, the webcam can.

Finish by showing the examples of CCDs from mobile phones to show the real world size of them. These were manufactured in Edinburgh by ST Microelectronics, the largest example is from an iPhone, with a resolution of 2.0 Megapixels (1600 by 1200 pixels).

Time Filler - The eye can be thought of as an optoelectronics device with the retina acting in a similar way to the photo-diode array. The retina consists of photoreceptor cells which capture and process light, enabling people to see.

Keywords: Optoelectronics, lens, focal length, focus, aperture, exposure, shutter, photo diode, current, voltage, semi-conductor, CCD (Charge Coupled Device) analogue, digital, bit, resolution, pixel, megapixels, spectrum, wavelength, infra red, ultra violet.

Thermal Camera - Ask the students to guess what type of camera they are looking at and allow them to use it. When switched on they should soon realise it is detecting Infra Red radiation, the heat emitted from their body.

They can use a plastic bag to hide their arm which the camera can still detect though. There is a large piece of Perspex to hold in front of them which we can see through but the camera can not as it will not allow the IR through. It is to replicate glass, which allows the wavelengths of visible light to pass but not the slightly longer IR wavelengths. If you or anyone is wearing glasses point the camera at them or use the glass lenses and hold them in your hand to show this effect, it is very dramatic.

You can use it to measure exact temperatures, the light bulbs are good for this. They can also make hand prints on the table or wall.

Thermal camera lenses are not made out of glass but more exotic materials like germanium, silicone, saphire, etc. The Irisys 1011 is an entry level camera with a 16 x 16 pixel detector array.