Ultraviolet and infrared...

A guide to practical work on the two hidden parts of optical radiation – ultraviolet and infrared – has been placed on the SSERC website [1]. This article gives an overview of its contents. The full guide contains detailed descriptions of all experimental set-ups and, where appropriate, lists product codes and shows circuit diagrams.

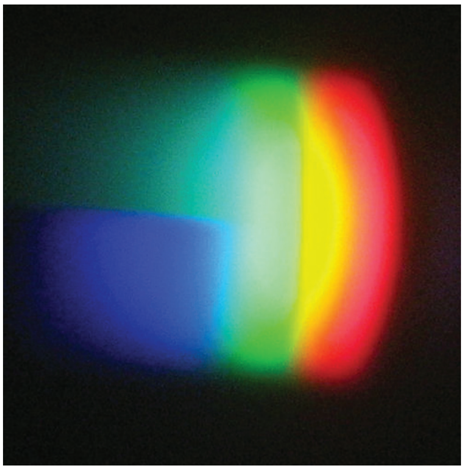

***Figure 1** – Spectrum focused on split screen.*

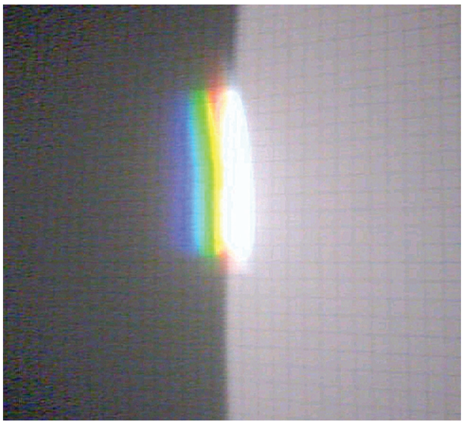

***Figure 2** – Webcam – filter removed.*

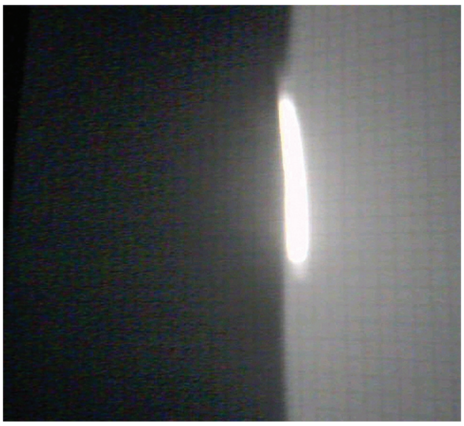

***Figure 3** – Webcam with longpass filter.*

Showing the three parts of optical radiation

A hot filament tungsten-halide lamp is a good source of all three types of optical radiation (ultraviolet, visible and infrared). To show all three components, a spectrum should be produced in the standard way (vertical slit, converging lens and crown glass prism). If the spectrum is focused on a split screen whose upper half is fluorescing, fluorescence is seen far beyond the limit of visible violet (Figure 1). Our photograph misleads. Whereas the bottom half is a fair representation of what the eye sees, although it renders violet blue, the top half, because of contrast, fails to show the weak fluorescence which extends far to the left of visible violet.

With the same spectrum, if a silicon photodiode is moved across the spectrum, the signal it picks up increases as the device is scanned from violet across to red, and continues to rise when moved into the dark region to the right of red. This shows the presence of an invisible radiation (which we call infrared) beyond red and it suggests that the lamp's output is more intense in infrared than in visible. However we have to be careful in how we interpret this. One complication is that a photodiode's spectral response may not be flat (it probably peaks in the near-infrared). Another complication is that the colours in a spectrum are packed together more tightly at the red end when the spectrum is produced with a prism.

A webcam is just a 2-d array of silicon photodiodes with some optics. It is usually fitted with a shortpass filter to transmit visible radiation but block infrared. When the filter is removed, the image of the spectrum has a bright white section to the right of, and partly overlapping, the red section (Figure 2). The bright white part is the infrared component.

When a longpass filter (one which blocks visible but transmits infrared radiation) is held in front of the camera, only the infrared component of the lamp's output is seen on the modified webcam's image (Figure 3).

UV optics

A convenient source of ultraviolet radiation in optics experiments is a 370 nm LED. This is a narrow-band radiation emitter (from 350 nm to 390 nm), most of whose output is invisible (the pale violet glow is perhaps less than 1% of the total output). (You can get UV LEDs whose output is invisible, but they are more expensive than the one we recommend.) It is a simple soldering job to wire it up (Figure 4). Ensure that it can be set up at the same height as the lenses and mirrors you will be working with.

UV radiation of wavelength 370 nm causes photocopier paper to fluoresce strongly. Although the radiation is invisible it is easy to track by searching with a small slip of this paper type.

A converging lens in front of the UV LED (Figure 5) collimates the radiation, directing it on a concave mirror one metre distant. The reflected radiation is

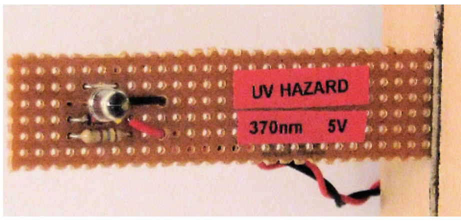

***Figure 4** – Ultrviolet LED.*

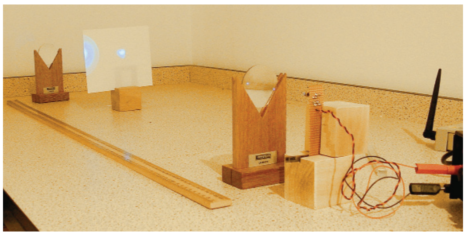

***Figure 5** – Optics with ultraviolet LED - reflection.*

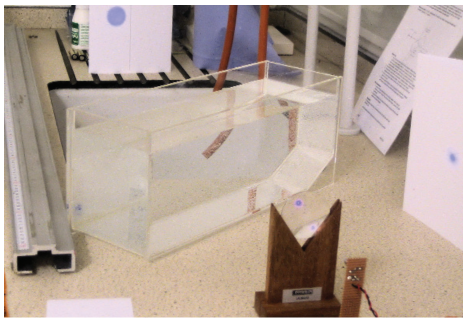

***Figure 6** – Optics with ultraviolet LED - refraction.*

brought to a focus on a paper screen, seen as an intense circular patch above the wooden block that supports the screen. The left-hand edge of the screen clips the collimated beam before the main part of it reaches the mirror.

A collimated beam of UV radiation (Figure 6) is directed to fall, centrally, on the vertical line on the screen. If a rectangular tank of water is placed in the radiation and turned about a vertical axis, the beam is displaced because it refracts when it enters and exits the tank. Some of the radiation is reflected rightwards off the front surface of the tank.

The set of interference fringes (Figure 7) were formed by focusing radiation from a vertical array of four LEDs (in ascending order: infrared, red, green and ultraviolet) on a white paper screen through a grating (80 lines/mm). The UV fringes show as a result of fluorescence, being cyan-coloured. The IR fringes are invisible. They can be found by searching for them with a photodiode.

Near-IR optics

In order of difficulty, visible is the easiest optical radiation to work with, UV is next because you can search for it with a slip of fluorescing paper, and IR is the hardest because to find it you need an electronic or heat-detecting sensor. In this section we will restrict our discussion to near-infrared radiation with a wavelength between 700 nm and 1.1 μm). The reason for this is that sources and detectors are cheap and simple. An infrared LED is a convenient source. An infrared phototransistor or photodiode is a convenient detector.

Apparatus for showing the inverse-square law with infrared radiation is shown in Figure 8. The source is an IR LED mounted on the hidden side of the circuit board at the right-hand side of the photograph. The 35 mm slide mount holds a diffuser and acts as the point source in the experiment. The detector, a photodiode, is moved along the metre scale. Both it and the emitter are raised off the bench to avoid the radiation at the detector being augmented with reflections.

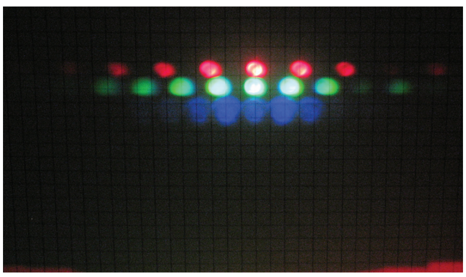

Figure 7 *– Interference fringes from vertical array of 4 LEDs.*

Heat radiation

Historically it was known at the time of Newton that heat rays could be focused like light. An experimental challenge is how to show that heat radiation from a non-luminous source – either a 2 inch diameter steel ball heated until just short of red hot, or a flask of near-boiling water – can be reflected and focused by polished metal surfaces, but not transmitted by glass. One simple heat-sensing detector is a black-bulb thermometer. Another is a miniature, blackened thermistor. Yet another is the thermopile (Figure 9). The output of this one is calibrated in watts per square metre.

The radiant efficiency of a lamp can be found by an energy audit. The hot-filament lamp is immersed in water (Figure 10). The heat dissipated by the lamp is found from the rise in temperature of the water. This is compared with the electrical energy transmitted to the lamp.

The seasons are explained by a model of the Earth orbiting around the Sun, which it does once a year. The Sun is represented by a radiant heater of the type that radiates in all directions equally (isotropically). A globe made from heat-sensitive paper is moved in a horizontal plane from position to position taking care to keep the inclination and direction of the polar axis constant (Figure 11).

Details of thirty experiments, the common theme being that they all are with invisible optical radiation, have been placed on the SSERC website. More may be added. Please contact us for further help, to suggest improvements, or to submit new ones.

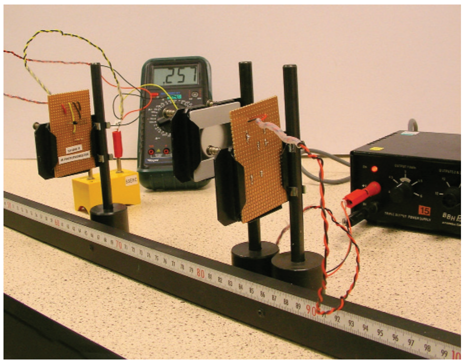

Figure 8 *– Showing the inverse-square law with infrared radiation.*

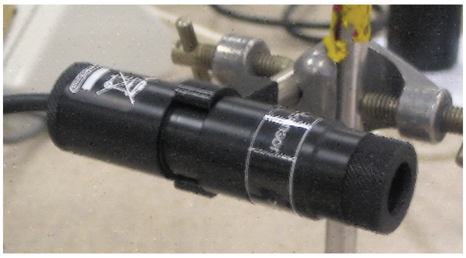

Figure 9 *– Thermopile.*

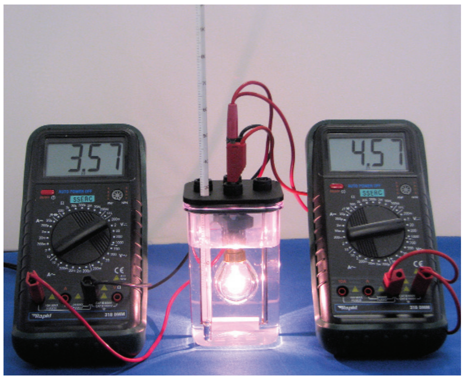

Figure 10 *– An energy audit to determine the radiant efficiency of a lamp.*

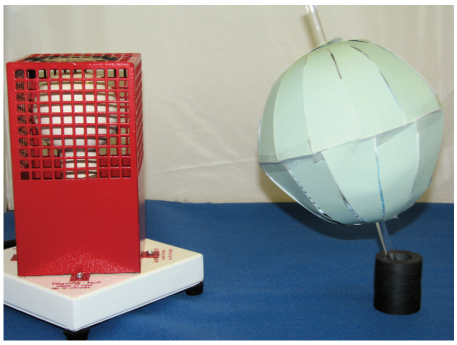

Figure 11 *– Sun and the seasons model.*

Reference

[1] http://www.science3-18.org/sserc/index.php?option=com_content&view =category&id=126&Itemid=120