Properties of Light Sources

Introduction

For nearly a century, the incandescent filament light bulb was the dominant form of artificial light. It is now rapidly being displaced by newer forms of lighting, particularly fluorescent lamps and light emitting diodes. In this experiment, you will make some quantitative measurements on the light emitted by old and new light sources, to see how close a replacement the new ones are – and how close they need to be. You will learn about intensity and spectral measurements, perception of colour, and what the inventors of light sources still need to do.

This manual describes the apparatus and several measurements that can be done with it. However it does not specify exactly how you should do each measurement, what data you should record or how you should analyse the results. These are left to your judgement; bear in mind that clean *quantitative* graphical data, thoughtfully analysed, is the desired outcome.

Safety

The light sources provided are mains voltage lamps in a standard domestic fitting. Use normal caution with the light fitting: do not remove the lamps from their sockets or interfere with their wiring. Note also that the lamps will be hot after running for a while, so you should wait for them to cool before adjustment.

1 Intensity measurements

The photodiode module produces an output voltage that is proportional to the intensity of light it is exposed to. It has a gain control that can be set to give a reasonable size of output signal. Beware of setting it too high, because the output will saturate at 10 V. The control is calibrated in decibels (dB); 10 dB corresponds to a voltage increase of a factor of $10^{10dB/20} = \sqrt{10} \simeq 3.16$.

1.1 Luminous efficiency

You are provided with a set of light sources: incandescent filament, white LED, and compact fluorescent lamps of different colour. Use the photodiode to compare the intensity of light they produce, and their relative efficiencies. Pay attention to:

- Light intensity - not only at the center of the beam, note also how wide a beam is being produced. What fraction of the output does the detector measure at any one time?
- Electrical input power (marked).
- Whether the optical power reading of the silicon detector is consistent with the impression of your eyes. Notice that the response of the photodiode as a function of wavelength is very different to that of your eyes (see appendix). A filter that blocks infra-red light is provided to help with this.

A cardboard tube or shield should be sufficient to exclude light from all but one of the sources. The spectral content of the light will be studied more carefully in the second part of this experiment.

1.2 Flicker

Traditional fluorescent lighting is considered dangerous near machine tools because it can have a stroboscopic effect which makes the machine appear stationary while it is in fact rotating. Some (possibly defective) lights cause people to complain about flicker. Use the photodiode along with an oscilloscope to quantify the amplitude of the flicker of the different light sources, and its frequency (or frequencies). You should evaluate the flicker as a fraction of the average intensity, and carefully examine the waveforms, which may have more than one frequency.

Comment on the probable causes and effects of the flicker you measure.

1.3 Start-up time

A common complaint about compact fluorescent lamps is that they take some time to attain full brightness. After the lights have been off for long enough to cool down, use the photodiode, along with either a voltmeter and stopwatch, or (better) the STRIPCHART software, to see how significant this effect is. Again, you should produce quantitative data and consider the likely explanations for what you see.

2 Spectral measurements

The spectrometer provided takes in light through a glass optical fibre, measures the intensity as a function of wavelength, and sends the data via USB to the THORSPEC application on the PC. Figure 1 shows schematically how the optics works. The fibre is only 62 μm in diameter, but the lights

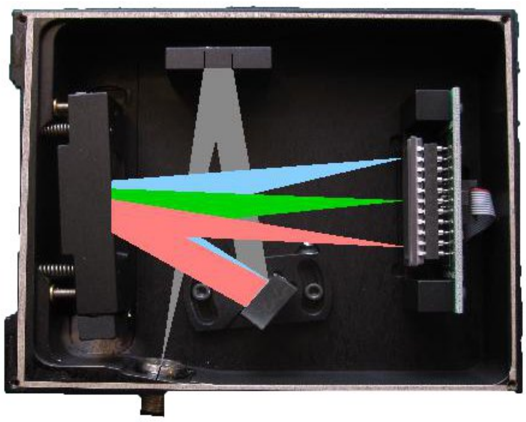


Figure 1: *Inside the spectrometer. Two curved mirrors and a diffraction grating disperse the light and focus the spectrum on the photodiode array.*

are so bright that it will probably collect plenty of light. For distant light sources, you might find a collimator gives more signal, at the expense of needing good alignment.

2.1 Spectra of light sources

Use the spectrometer to obtain spectra for the different light sources. Be aware that it is possible to saturate the output if the light is too bright or the exposure time is too long. You can also try to get a spectrum of the overhead lights in the lab, and any other sources you may have.

Notice that the lamps have spectra that differ much more than you might guess from their perceived colours.

- Attempt to identify the spectral lines in the light from the fluorescent lamps.
- Why do spectra that are so different appear of similar colour to your eye?

2.2 Planck's constant using LEDs

It is claimed that with a few LEDs, as provided, one can make an approximate measurement of Planck's constant, h. The argument is that the energy of each photon emitted comes from the recombination of an electron and hole in the diode junction, and the energy involved in this process is given by the potential difference V across the junction multiplied by the electronic charge e, thus $\frac{hc}{\lambda} = eV$, where c is the speed of light and λ the wavelength of the light.

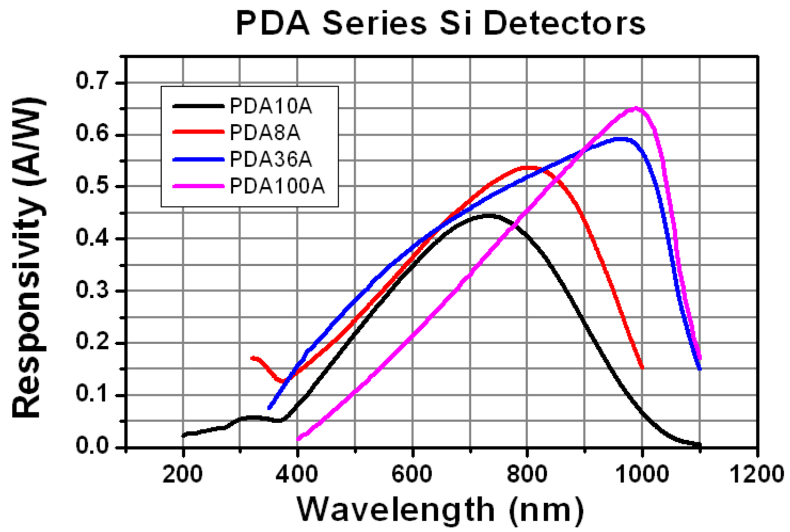
Make measurements of the voltages across the LEDs and the spectrum they emit, and see how good a value you can get. Comment onthe robustness of the argument given above, given what you know about LED characteristics and the light that they emit.

Bibilography

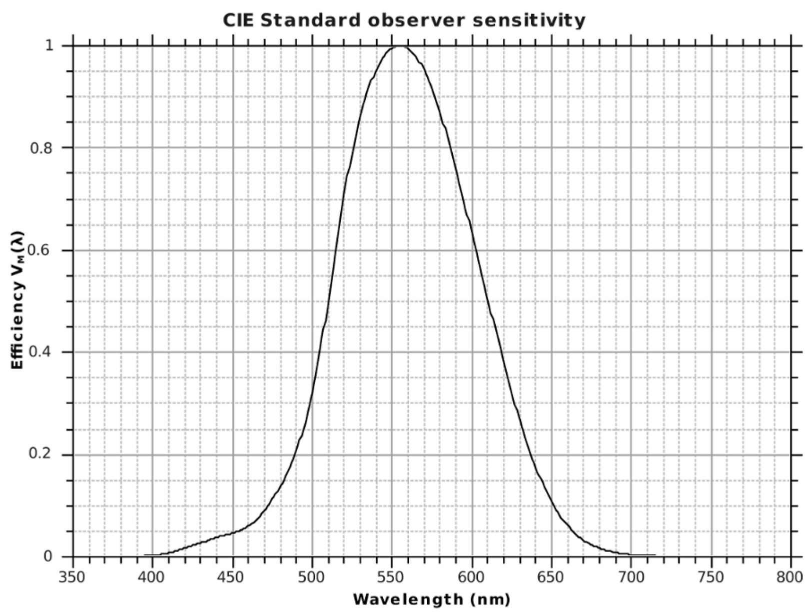
- http://fp.optics.arizona.edu/Palmer/rpfaq/rpfaq.pdf (photometry)
- http://www.cvrl.org/ (colour vision)

3 Appendix

3.1 Silicon photodiode sensitivity



3.2 Sensitivity of human eye



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