Optics with LED sources

A method for doing ray optics experiments with a high-power white LED source is described.

Introduction

The conventional raybox source – a 12 V, 24 W tungsten filament lamp with vertical filament – has disadvantages. Its radiation is redder than normal sunlight and, because the light diverges in all directions, only a tiny fraction is made use of. Also the lamp is less than 15% efficient and its relatively high wattage can cause the lamphouse to get rather hot. In principle a white LED should do better. It is an efficient, very-low power source whose radiation can be highly directional and match the colour content of sunlight.

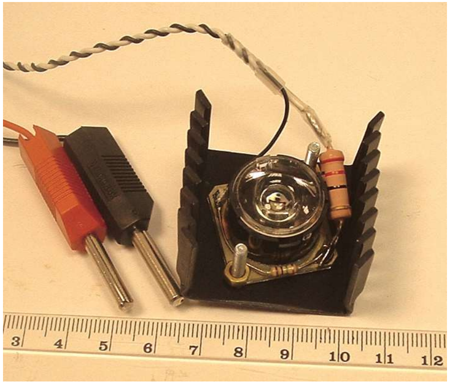


Figure 1 - Lumiled (type: Luxeon 1W Star with Optic (Low Dome Batwing)) fastened to heatsink and with series resistors.

LED source

The recommended LED source is a 1 W white Lumiled with optic (low dome batwing). The source has a continuous broad-band spectrum generated by exciting a phosphor with blue radiation and the resulting colour matches sunlight

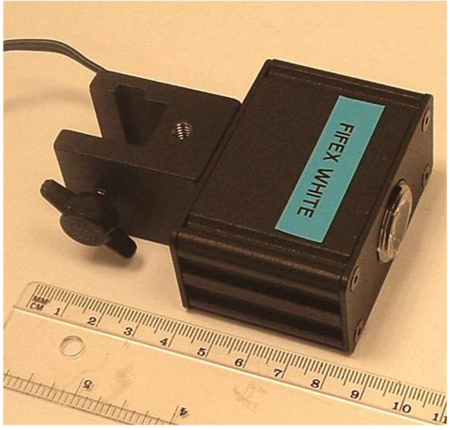


Figure 2 - White LED source from Harris (L87348) (made by FifeX).

as if from a black-body source at 6000 K. The LED has a primary lens to collect and direct the radiation in one direction with little spreading. The 'batwing' description refers to the shape of intensity versus angle of divergence for a cross-section of the beam. A secondary lens further collects and shapes the radiation resulting in a narrow, slightly-diverging, intense beam of uniform brightness – rather like a searchlight.

This LED source (RS 467-7519, £5.56, product type LXHL-NWE8) has greatly dropped in price since it was first marketed. Details of how to wire it up and mount on a heatsink (Fig. 1) can be found in the Bulletin articles section of SafetyNet on the SSERC website:

http://www.sserc.org.uk/members/SafetyNet/bulls/212/physics2.htm

It is also now made ready-assembled in a chunky black mount from FifeX (Fig. 2) (with the encouragement of SSERC), and sold through Philip Harris (L87348, £65) (the price includes a plugtop power supply).

Method

The Lumiled source was placed on its side on a sheet of white card and a single slit (S1), 1.0 mm wide, was placed directly against it, the slit centred on the lens (Fig. 3). The mid point of the LED source is 15 mm above the benchtop, giving it enough height to illuminate the surface. Because of the divergence of light from the LED, the vertical slit effectively becomes the source. A cylindrical convex lens whose focal length lies between 100 mm and 150 mm is sat on the bench in front of the source. (If a higher-power lens is used, distortion can be significant.). The lens used had a focal length of about 110 mm. When placed 110 mm from the slit, it produces a collimated beam of light. When a plate with 3 vertical slits (S2) (each 1.0 mm wide) is placed a little beyond the lens in the collimated beam, there are three parallel rays, well defined and clearly seen, running for at least 500 mm along the white card on the benchtop's surface. Each ray diverges a little, but by an amount which is acceptably trivial. The width of the ray is 1.0 mm at S2 and 3.0 mm 300 mm from S2. If a converging lens is placed in the rays, the resulting convergence narrows the rays. In consequence, the rays are generally all between 1 and 2 mm wide where they would be worked with.

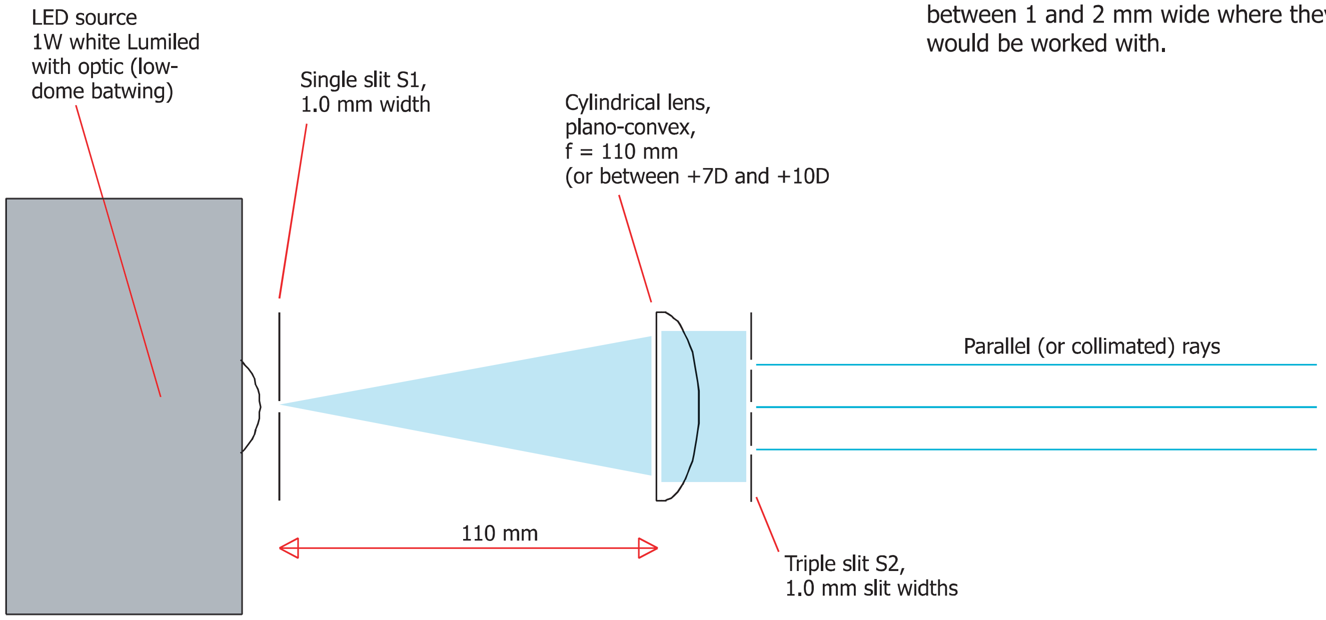


Figure 3 - Optical setup to produce three parallel rays from a LED source.

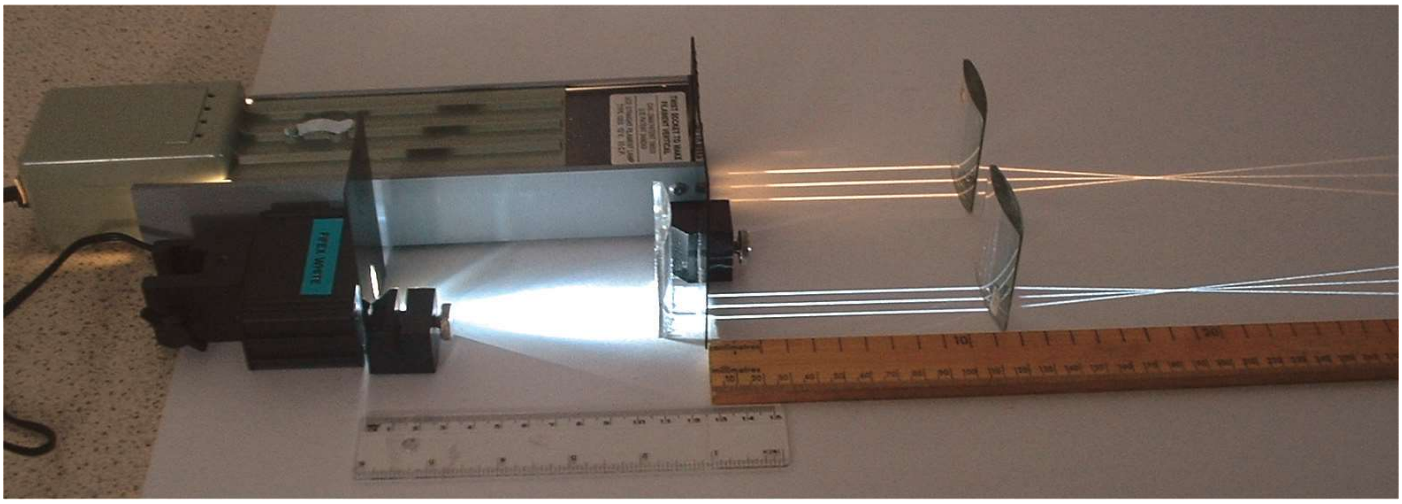


Figure 4 - Photographic comparison of rays made by a LED source with ones from a conventional raybox.

A comparison was made with one of the best conventional rayboxes (Fig. 4). The tests were made in shaded daylight where the daylight was reduced by grey louvered blinds. Relative to it, the Lumiled optical source resulted in:

- rays that were much whiter;
- rays more uniform in intensity;
- rays continuous rather than broken;
- a longer working length of ray;
- rays that diverge slightly more, in the sense of becoming thicker (by 1 mm every 150 mm versus 1 mm every 200 mm);
- trivial heat generated.

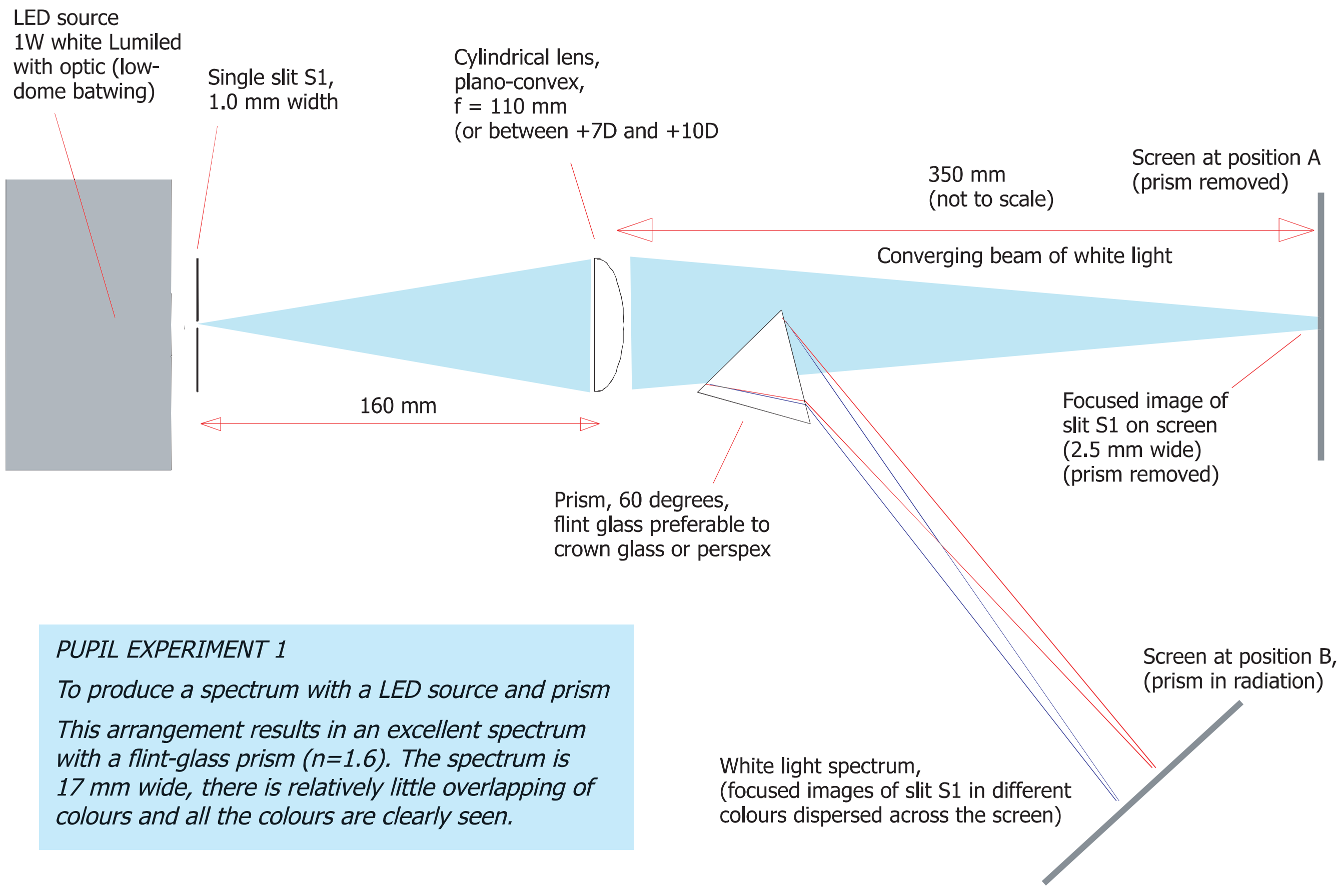
With five improvements and one small detriment, a 1 W LED is better than a 24 W tungsten filament lamp as the source of radiation in ray optics.

Other applications

The method can be applied to many demonstrations in 2-dimensional optics, some of which will use a single ray, some a set of rays (collimated, diverging, or converging), and some a broad beam of light. For the last of these, slit S2 should be removed. Here are two examples of pupil experiments:

1. Dispersing white light with a prism (Fig. 5).

2. Raindrop analogue with a circular perspex disk (Fig. 6 / over).



PUPIL EXPERIMENT 1

To produce a spectrum with a LED source and prism

This arrangement results in an excellent spectrum with a flint-glass prism (n=1.6). The spectrum is 17 mm wide, there is relatively little overlapping of colours and all the colours are clearly seen.

Figure 5 - Optical setup to produce a spectrum with a prism.

PUPIL EXPERIMENT 2

To make a 2-d model of the deviation of light with a raindrop

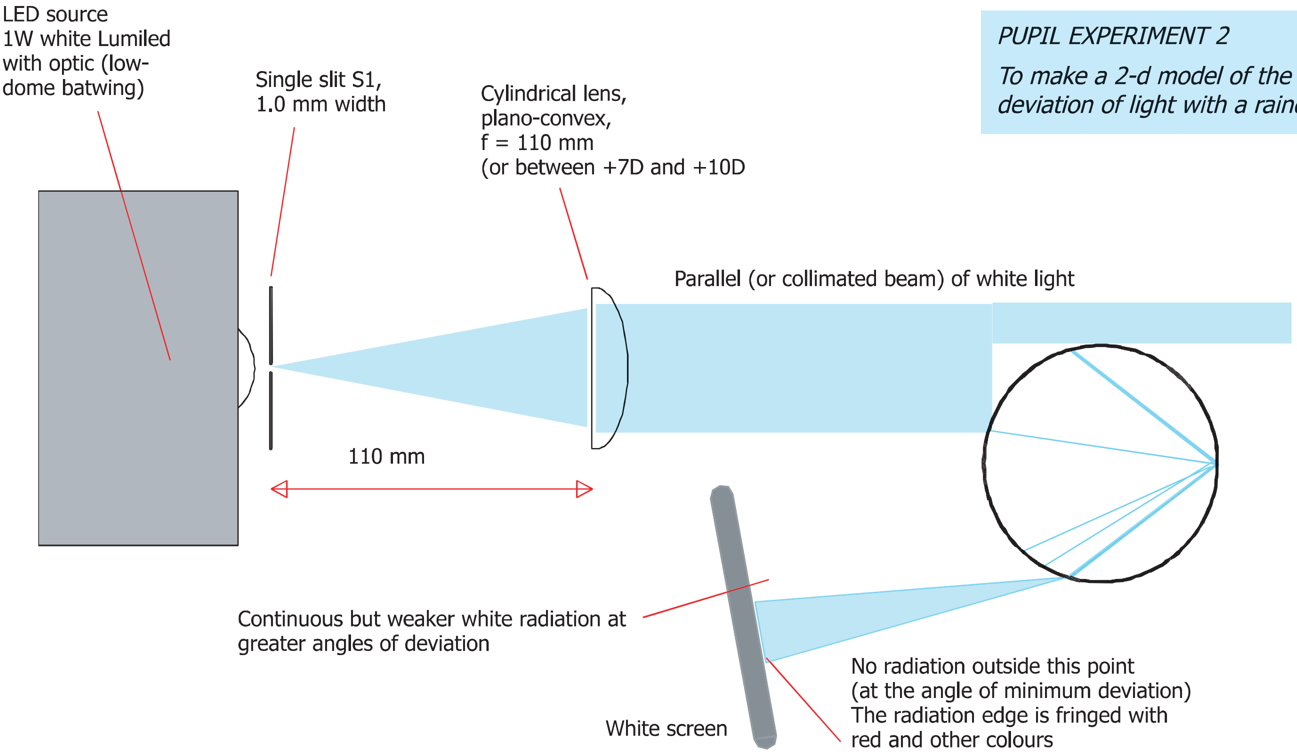


Figure 6 - Optical setup to show effects of double refraction and total internal reflection with a circular Perspex block (sunlight on raindrop model).

Summer Schools 2007

We are delighted to announce that funding has been made available from the Scottish Executive Education Department to enable Biology, Chemistry, Physics and Primary Summer Schools to go ahead. A two-day residential for all the PGDE science students studying at Scottish universities will also be held. All the Summer Schools are well-suited for inclusion in a CPD portfolio and aim to offer participants the opportunities to:

- Explore activities that will support the aims of 'A Curriculum for Excellence'.
- Raise the levels of knowledge and confidence in the teaching of Science throughout the curriculum.
- Update their knowledge and skills in Science through a range of interactive sessions that include group tasks, practical activities, discussions, lectures and visits.

The Summer Schools are being supported by the partners* in the Support for *Science Education through CPD Project*.

Fliers and registration forms can be downloaded from www.sserc.org.uk or further information is available from sheila.maclellan@sserc.org.uk Tel: 01383 626070

Details	Biotechnology and Biosciences	Chemistry	Physics
Who is it for?	Biology teachers and technicians	Chemistry teachers and technicians	Physics teachers and technicians
When ?	25th-29th June	25th-29th June	16th-19th May
Where?	King's Buildings, University of Edinburgh	King's Buildings, University of Edinburgh	Lauder Business and Learning Conference Centre (LBCC), Dunfermline
Accommodation	Pollock Halls of Residence, University of Edinburgh	Pollock Halls of Residence, University of Edinburgh	Holiday Inn Express, Dunfermline
Cost	£190 to include dinner, bed and breakfast for four nights	£190 to include dinner, bed and breakfast for four nights	£190 to include dinner, bed and breakfast for three nights
Programme incl.	• exciting and relevant practical work • interesting lectures • visits: Roslin Institute, Scottish Agricultural Science Agency Royal Botanic Garden, Edinburgh • discussions - social events	• exciting practical work • interesting lectures • industrial visits • discussions • social events	• Physics beyond the school gate • breaking down the boundaries • innovation in learning through ICT • social events
Websites	www.saps.org.uk	www.sserc.org.uk	www.sserc.org.uk

* Partners in the Supporting Science Education through CPD initiative and involved in the organisation of the Summer Schools include *Development to Update School Chemistry* (DUSC), the *Institute of Physics*, *Science and Plants for Schools* (SAPS), the *Scottish Initiative for Biotechnology Education* (SIBE) and *SSERC*.