Builder's Booklet

DETAILED CONSTRUCTION OF SPECTROMETER

The base was a 24 × 16 Lego® baseplate (3334). For the light source, we used a bright white-light LED (5 mm, 15° viewing angle, OVLEW1CB9, TT Electronics) mounted inside the central hole of a Lego® Technic 1 × 4 brick (3701). Three AA batteries in series (4.5 V total) and two 33 Ω (33R0) resistors in series were used to drive the LED. These were mounted on a small PC board with holes to allow the board to be screwed into the Technic 1 × 4 brick (3701) (see Figure 1). Note, however, that the LED fit is snug and does not need the additional fixing screws. The batteries are contained in a battery holder (black box in Figure 1a and b).

The slit is simply constructed by the gap between two 1 × *n* bricks. We trialled a variable slit with micrometre resolution and also constructed slits from pairs of razor blades in a 3D-printed holder, but ultimately found comparable and more consistent performance using the Lego® slit.

The lens is a plano-convex 50 mm focal-length lens (LA1255-A, Thorlabs) that is glued in a 3D-printed mount. The bottom of the mount has the dimensions of a 2 × 2 Lego® brick. To alter the focus, the lens is mounted on an optical rail that was constructed from a pair of 2 × 4 Lego® flat tiles (87079) placed end-to-end and guided by placing a pair of 1 × 4 Lego® brick (3010) on either side of the flat tiles. A technical drawing of the lens mount is shown in Figure 2. The mount was printed using PLA and the cost of printing a single mount <£1. Note that the lens can be glued directly onto a 2 × 2 Lego® brick (3003), but this was less sturdy, especially for use in an undergraduate laboratory. The core requirement for the lens is that it is at the height of the LED which is 33.6 mm (taking into account the 2 × 4 L Lego® flat tiles (87079) in the optical rail).

As a dispersing optic, we chose to use a low-cost polymer transmission grating (1000 lines/mm, Sciencestore), which was mounted on a 23 × 34 mm card and simply blu-tacked onto a 1 × 4 Lego® brick (3010). In principle, this can be permanently glued on, but we considered it useful for the students to see how light diffracts and have left it to the student to insert the optic in the correct orientation.

As a sensor, we opted to use a simple webcam (Logitech C270), which was used to capture an image (either fluorescence or the dispersed light projected on a viewing screen). The focus of the webcam needed to be altered for the best resolution. For this we removed the front cover, which give access to an adjustable lens in front of the CMOS sensor (1920 × 1080 pixels). This only need to be done once and should not be adjustable by the students as the distance to the screen/fluorescence cuvette can be defined in the experiment.

Finally, the liquid samples were held in a standard 1 × 1 cm plastic cuvette and placed in the light path as described below. To capture images of sufficient quality, a ‘light-tight’ box is constructed from Lego® bricks around the detection area with an open area made for the webcam to offer a view inside the box.

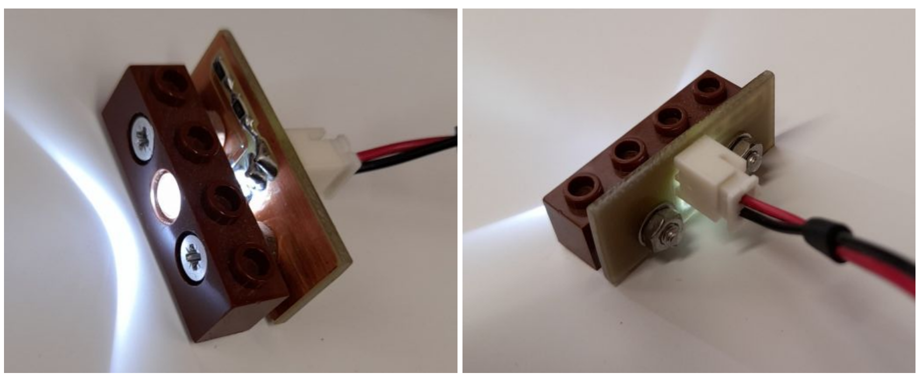

Figure 1: Photo of LED mounting

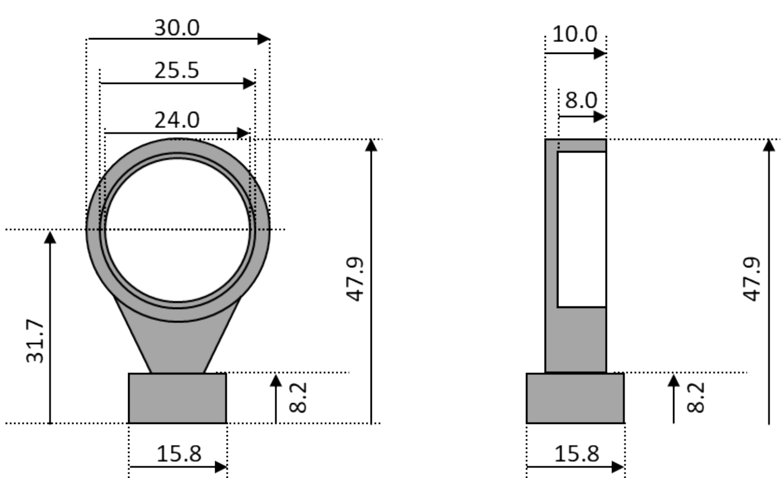

Figure 2: Technical drawing of lens mount. All dimensions are in mm.

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The construction of the two different set-ups is detailed below using diagrams. The basic structure is shown below:

Key:

Yellow = bricks;

Pale pink = flat tiles for optical rail (only require for absorption spectrometer).

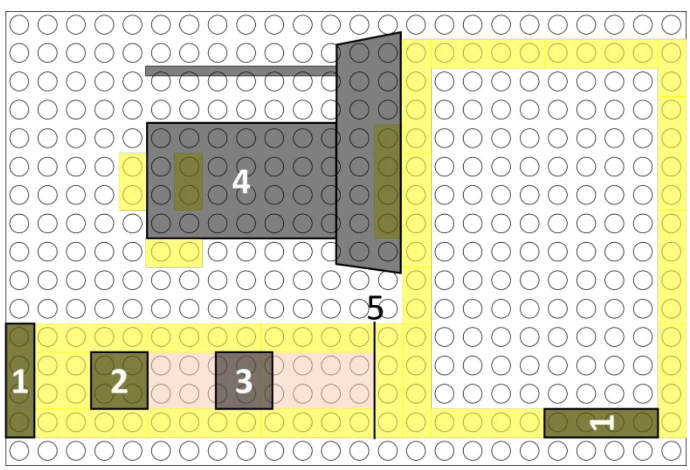
1 = LED brick (can be in two places for differing experiments (see below);

2 = sample holder (cuvette) (for absorption spectrometer, different in fluorescence imaging (see below);

3 = lens with mount (only require for absorption spectrometer);

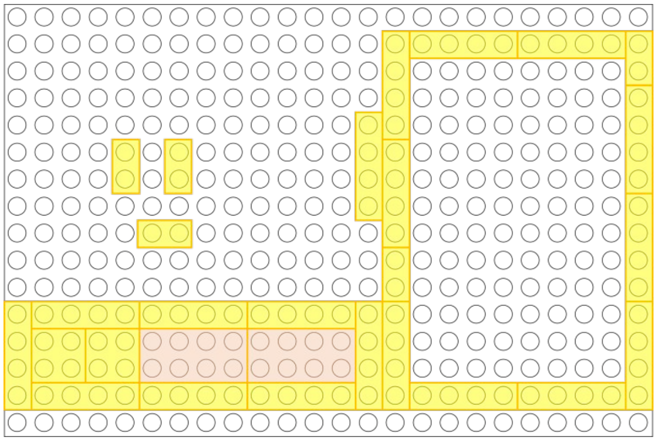
4 = webcam (same place for both experiments);

5 = grating (only require for absorption spectrometer).

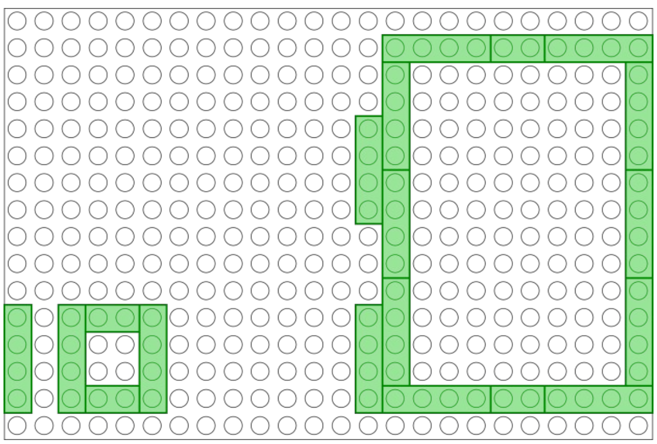


Below is a description of how to construct each layer to yield very good overall results.

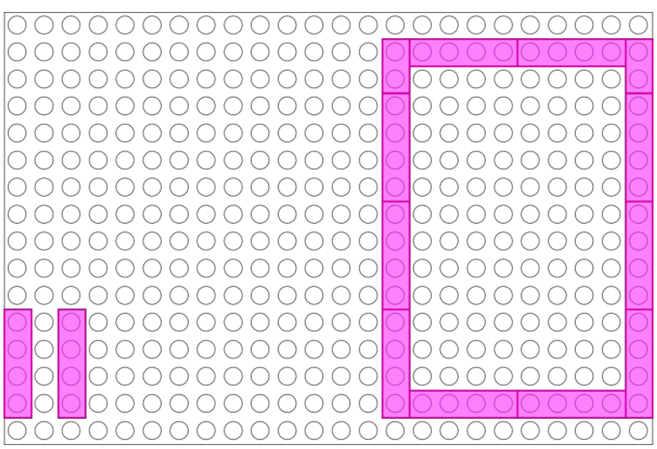
Layer 1 (Key: yellow = bricks; pale pink = 2 × 4 flat tiles)



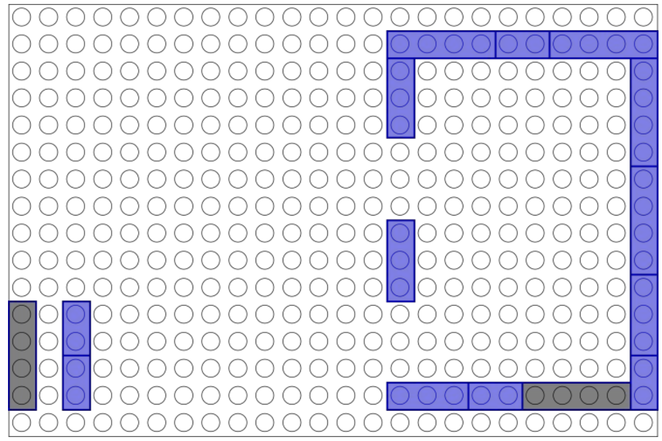
Layer 2 (Key: green = bricks)



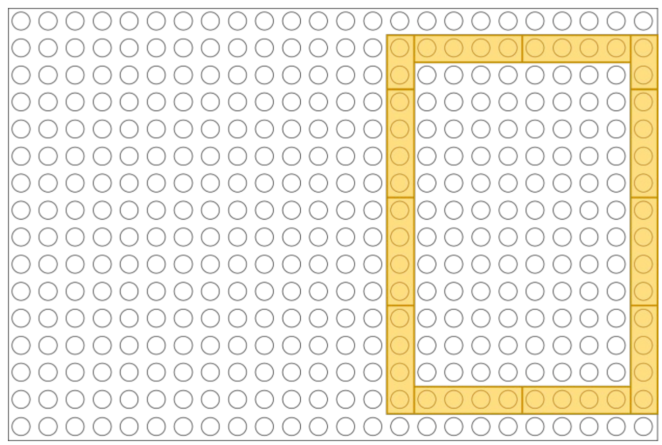
Layer 3 (Key: pink = bricks)



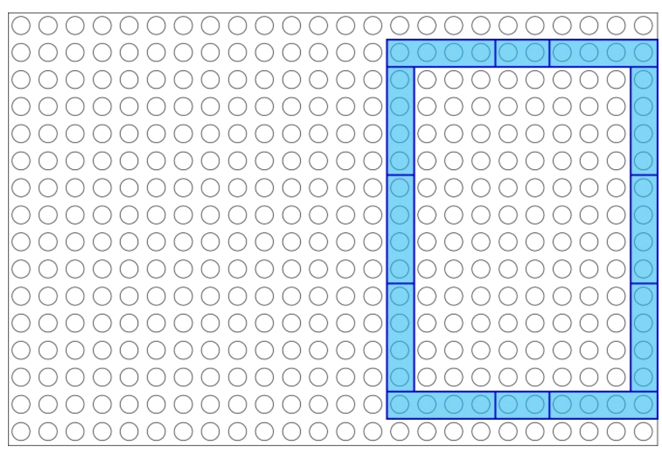
Layer 4 (Key: blue = bricks; black = LED brick in two possible positions)



Layer 5 (Key: orange = bricks)



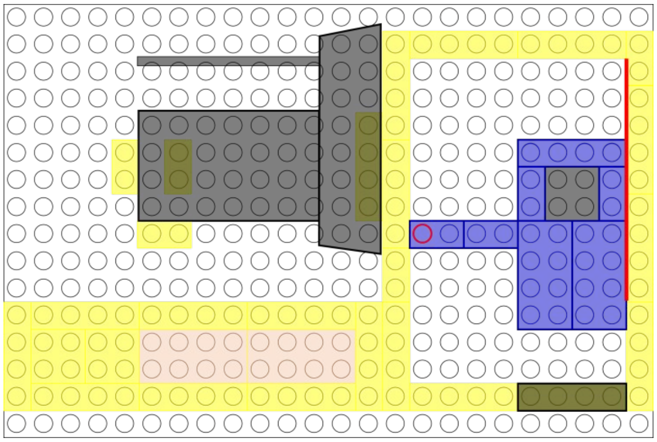
Layer 6 (Key: blue = bricks)



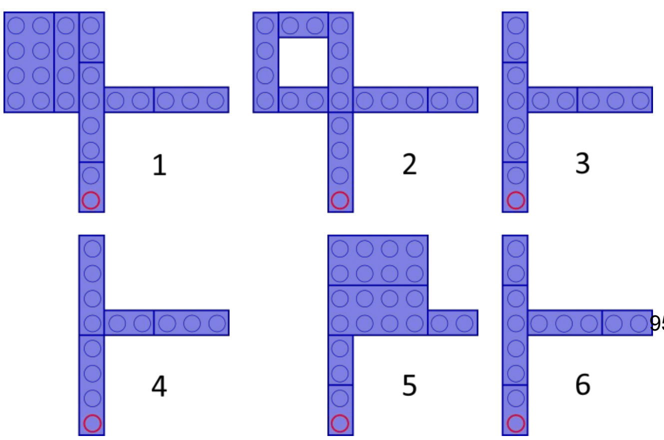
Fluorescence imaging: Set-up #1

Key: yellow-bricks (above); black = webcam, LED and sample (above); blue = insert.

Solid straight red line = white card.



Insert by layers (numbered)

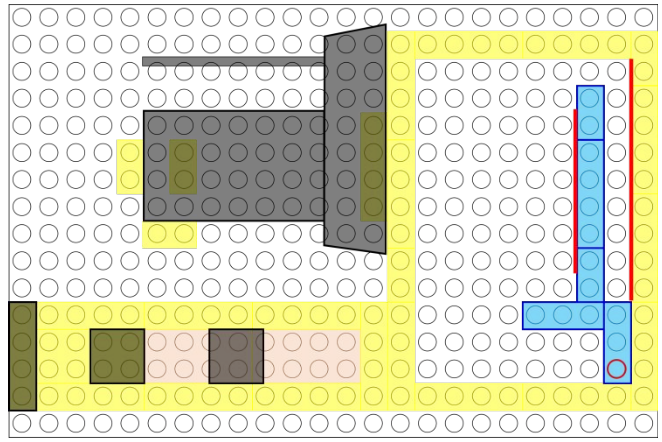


Red circle to indicate orientation in set-up.

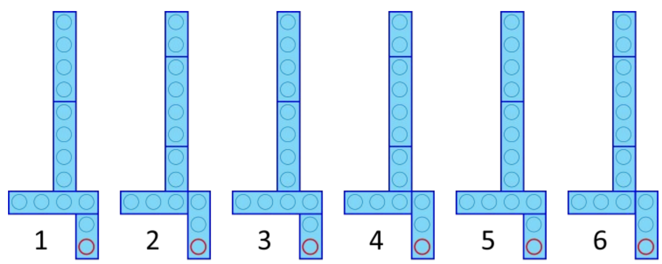
Absorption spectrometer: Set-up #2

Key: yellow-bricks (above); black = webcam, LED and sample (above); blue = insert.

Solid straight red line = white card.



Insert by layers (numbered)



Red circle to indicate orientation in set-up.