# It's all done with mirrors

**Dr Colin Fowler** creates a low cost retinal camera using the Thorner system

Modern ophthalmic fundus cameras are generally table-mounted devices, linked to a computer database for storing images, and are very expensive. This article describes an attempt to make a portable, inexpensive camera.

It can sometimes be the case, particularly with elderly patients, that it can be difficult to obtain a fundus photograph with traditional style instruments due to an inability to locate the subject in the head rest. For some time I have felt the need to have a completely portable lightweight instrument, with no trailing wires, thus battery operated and with an inbuilt image storage facility.

The advent of digital cameras with high resolution and excellent low-light sensitivity sensors has revolutionised photography, and no more so than in fundus cameras. No longer do you need the high intensity flash to cope with colour film with poor sensitivity that was common 50 years ago. Nor do you have to wait for the images to be processed to see if your photography was successful.

One of the aims of the current exercise was to see if a flash unit could be dispensed with altogether, and simply use a bright light emitting diode (LED) for illumination. A major benefit of using LED illumination is that these devices have very low power consumption, thus batteries will last a very long time.

A major aim of any fundus camera is to produce an image which does not show unwanted image artefacts, principally corneal reflections. Perhaps the best known fundus imaging system is that of the Gullstrand indirect lens. In Figure 1, a camera is shown viewing an image of the fundus formed by the indirect viewing lens. An illumination system aligned close to the camera viewing axis provides the retinal illumination. If designed carefully, the illumination source will be imaged in a different part of the pupil to the viewing axis, hence no corneal reflection will be imaged by the camera. Unfortunately, there will still be reflections off the imaging lens, as shown in the diagram.

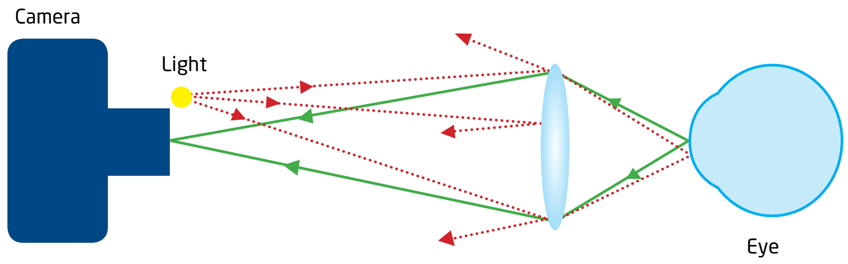


**Figure 1** Schematic diagram of fundus camera using imaging lens showing reflections

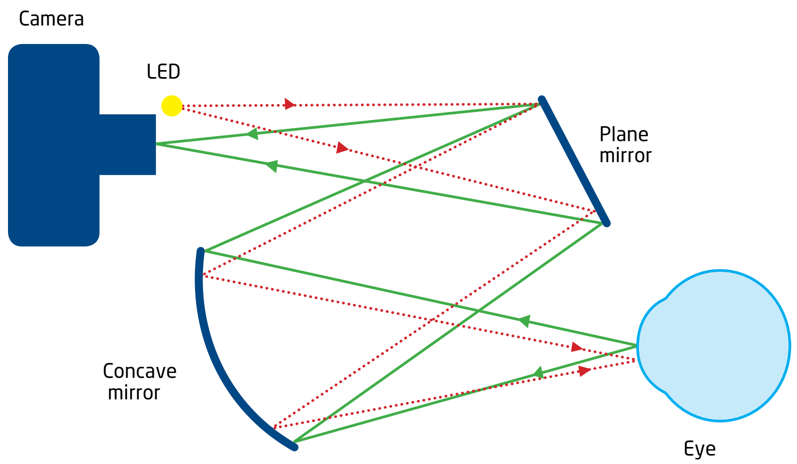


**Figure 2** Schematic diagram of fundus camera using mirrors

Various methods have been used by manufacturers of fundus cameras to reduce or eliminate this unwanted reflection, including the use of coatings and stops, as well as placing the illumination system between the imaging lens and the eye. One recent paper describing a hand-held fundus camera[1] uses a crossed polarising system to remove the unwanted reflection. The only problem with that approach is that a very bright light source is required to overcome the light losses from the polarising filters.

An alternative approach to using a lens to produce the fundus image is to use a concave mirror. This method was first suggested by Walter Thorner at the end of the 19th century[2] for producing a reflex-free ophthalmoscope. The Thorner design enables a very simple optical system to be used, comprising two mirrors. Figure 2 is a schematic diagram of a Thorner reflex-free fundus camera. A concave mirror images the fundus, with a plane mirror reflecting light back to the camera. As with the Gullstrand approach, a light source needs to be positioned close to the viewing axis.

## Camera construction

The starting point for the construction of a fundus camera using the Thorner system was a Panasonic compact digital camera model DMC-FX60. This has a zoom lens, a 12 megapixel sensor, and can operate as an automatic 'point and shoot' device or with various options for manual control. Images are recorded on a removable SD card. Illumination is supplied by a 3mm white LED, this being bright enough to obtain a good fundus image with an equivalent sensor setting of 400 ASA. The inbuilt camera flash was not used. Figure 3 shows the interior of the finished camera, built into a plastic box 215 x 130 x 85mm (Maplin). The mirrors are both front surface silvered, the concave mirror having a focal length of 100mm (Edmund Optics). Both mirrors are

**Figure 3** Interior of the finished camera

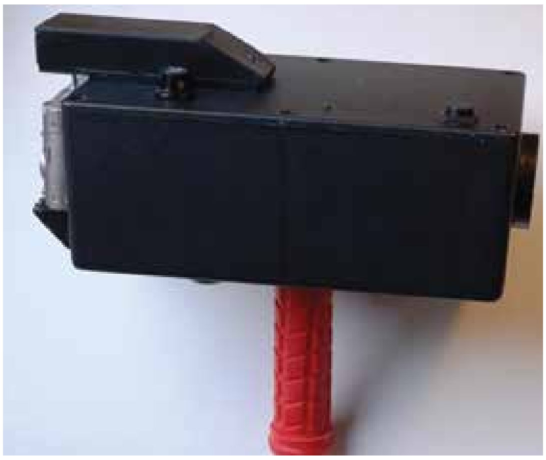

**Figure 4** Hand grip for one-handed operation

**Figure 5** Thumb-operated shutter release

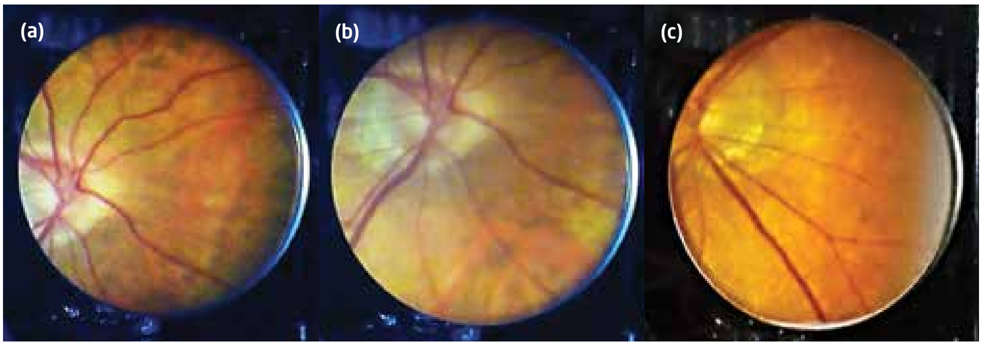


**Figure 6** Sample images from the camera

fixed to three axis adjustable mounts on linear slides to enable precise alignment. A 9v PP3 battery powers the LED through a current reducing resistor. Somewhat surprisingly it was found that the illumination from the 3mm LED was too bright at full intensity, so an additional dimming rheostat was installed in the lid of the box. Total weight of the camera is 1.23kg.

In order to operate the camera successfully it had to be capable of one-handed operation, the other hand being used to steady the instrument relative to the patient's head. This was achieved by using a hand grip and thumb-operated shutter release (Figures 4 and 5). The thumb push button operates the camera shutter release by means of a push rod, activating a rocker mechanism built into the lid of the box.

The optical components of the finished camera were aligned using a model eye. To check the reflex-free capability of the camera a model eye was constructed to resemble a human eye. A rigid contact lens was glued to the base of a plastic pill tube, with an 8mm aperture to simulate a dilated pupil. A transparent 'retina' was glued on the other end of the tube which could be used with a transparency image to check the camera imaging function, or with an opaque backed image to assess the illumination effectivity. The whole tube was filled with water. This gave a better simulation of the human corneal reflections than other model eyes tried which appeared to use a biconvex 'cornea'.

## Operation

The Panasonic camera is switched to 'macro zoom' mode and adjusted to obtain the optimum image size. The camera is steadied with one hand against the patient's head, and the brightness adjusted to the maximum comfortable level. The camera is operated by pressing the thumb switch in two stages. An initial pressure operates the autofocus mechanism, further pressure stores the image. Sample images are shown in Figure 6. As with any instrument, some practice is required to position the camera correctly to obtain a clear image.

## Discussion

The camera achieved the desired design aim of being capable of producing reflex-free fundus images from a hand-held battery operated device, at a total cost (in addition to the Panasonic camera) of £70.

There are limitations, of which perhaps the most significant is the limited field of view. This is approximately three disc diameters, so that the camera can only be used for looking at specific features rather than giving a wide-angle fundus view. This limitation is mainly due to the distance that the concave mirror must be kept from the eye so that the image can be reflected back to the camera. In an ingenious patent[3] (assigned to Kowa) a design is shown where a concave mirror is used which reflects the image downwards by 90 degrees to the imaging camera. This enables the mirror to be much closer to the eye, enhancing the field of view, although a complex aspheric mirror design will be needed to give good image sharpness.

A less significant issue with the present camera is that it can only be used with a dilated pupil. It would be better if there was an option to use it as a non-mydriatic instrument, and this is being pursued in a modified design. Further improvements could be also made to image sharpness by reducing the inevitable oblique astigmatism resulting from the oblique ray path through the mirror system. This is very much a prototype, and work continues.

**References**

**1** Richard Keeler, Arun D Singh, Harminder S Dua. Battling with reflections: the Busch stereoscopic reflexless binocular ophthalmoscope. *Br J Ophthalmol,* 2013;97:2 119-120.

**2** Kenneth Tran,Thomas A Mendel, Kristina L Holbrook, Paul A Yates. Construction of an inexpensive, hand-held fundus camera through modification of a consumer 'point-and-shoot' camera. *Invest Ophthalmol Vis Sci,* 2012;53:7600-7607.

**3** Suzuki, Takayoshi Hamamatsu-shi Shizuoka. Hand-held ocular fundus imaging apparatus. *EP* 1 870 025 B1, 2012.

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