LED lighting for microscopes: discrete illuminators and lighting for low-power instruments

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Introduction

In a previous paper [1], I discussed adapting compound microscopes to use built-in LEDs to replace incandescent bulbs for transmitted light microscopy.

This paper considers the use of LEDs for low-power (stereo) instruments, and for discrete illuminators for both transmitted light and epi-illumination.

Stereo-microscopes

(a) Basic stands

Many Instruments are supplied for work with top lighting only, and have a plain flat stage on which the specimen can be placed for examination.

The versatility of such instruments can be considerably enhanced by adding a source of transmitted light. Compact 100x125mm slim light panels using cold cathode fluorescent lamps with a colour temperature of 5000°K and powered by AAA batteries are readily available from professional photographic dealers. They are less than 15mm thick and can be placed on the stage to provide excellent large field structureless illumination [Fig.1].

Providing dark-ground illumination for such instruments requires a little ingenuity, for as far as I know there are no commercial products available to do this. However, a very effective

FIG. 1. **A basic stereo stand used with a transmitted light panel.**
A battery/mains powered flat light panel intended for illuminating photographic transparencies, here placed on the stage of a basic stereo stand to examine pond life in a Petri dish. It is 150x155x12 mm, and the light panel area is 126x100mm: it produces a very even daylight-type source.

FIG. 2. **LED ringlight darkground illuminator.**
A bespoke darkground illuminator utilising a 45 LED ringlight mounted on a 60mm diameter MDF plug with a matt black paper disk cemented to its top. A black baffle with a 50mm aperture ensures that no direct light from the ringlight enters the instrument.

FIG. 3. **Watson "Spot-Lens" small portable darkground illuminator.**
A pre-war darkground condenser intended for use with very low magnification objectives, lit by a 12 LED array and reflector from a small torch, powered by batteries and contained in a plastic box measuring 15x80x60mm makes an excellent self-contained illuminator.

dark-ground stage can be constructed using a suitable housing with an LED ringlight facing the objective lens, with the specimen at its focus [Fig.2]. This provides a dark-ground of up to 50mm diameter.

Until the 1960s a "Spot Lens" was sold by Watson and other manufacturers; it is a single lens darkground condenser that was intended for use with very low power objectives. I have one of these mounted over a small 12 LED array taken from a head torch, powered by 3 AAA batteries, all contained in a small plastic box. It makes an excellent small portable darkground illuminator for specimens up to 25mm in diameter. [Fig.3]

I have discussed the construction and use of these devices elsewhere [2].

(b) Stands with transmitted light bases

More modern instruments with built-in transmitted lighting usually have a low- voltage 20 watt incandescent bulb directly illuminating a translucent glass plate, and sometimes an epi-illuminator with a similar bulb.

Replacing these with 4.5v LED arrays powered by AA batteries or a small DC power supply is often beneficial.

Round panel arrays of up to 100 LEDs are readily available by disassembling torches and using the board on which the LEDs are mounted, together with the associated silvered plastic reflector [Fig.4]. Such torches are sold in camping shops and over the internet direct from China: searching "LED Torch" on eBay will produce a plethora of suppliers, all selling torches at remarkably low prices. It is important to buy torches with multiple LEDs and a

FIG. 4. **A torch, disassembled to show the LED array and reflector.**
Many LED torches have easily removed arrays with silvered reflectors that are ideal for use as illuminators in stereo microscopes. This 4.5 volt array of 42 LEDs has a diameter of 50mm and provides more than enough light adequately to illuminate the translucent disc in most instruments with transmitted light bases.

FIG. 5. **A stereo microscope fully equipped with LED illumination.**
The stand is completely self contained with both transmitted and epi illumination. Within the base is a battery holder containing 3 AA cells providing 4.5volts to either a 45 LED array for transmitted light, and, via a socket in the base, to the 21 LED epi-illuminator or to the ringlight. Illumination can be readily switched between the two systems and a 2.1mm auto cut-off socket mounted on the back of the base allows a small 4.5v DC power supply to be used instead.

flat reflector and *not* torches with fewer LEDs and parabolic reflectors which, like traditional torches, provide uneven fields of light.

An array of suitable size evenly to illuminate the translucent plate is fitted into the base together with a holder for the batteries, replacing the bulb assembly and transformer. The epi-illuminator is likewise replaced by a smaller array.

A 2.1mm auto cut-off socket can be fitted into the circuit to allow input from a 4.5volt 400mA DC mains supply.

The result is a very versatile instrument that can be used both in the laboratory and in the field remote from mains electricity and is, incidentally, much safer should liquid be spilled into the base [Fig.5].

Some stereo microscopes are supplied with a fitted (sometimes detachable), so- called "Trans-illumination base". These usually have a mirror assembly to reflect the light from either a free standing microscope lamp or a bulb fitted into the rear of the stand, powered by an external transformer. Many of these stands can be much improved by replacing these arrangements with a suitable white light LED array within a circular angled array to provide darkfield illumination and even Reinberg colour contrast. LED ringlights are ideal for this purpose.

Any base that has enough depth for the LED ringlight to focus in the specimen plane, and a sufficiently large aperture not to impede these oblique rays can be readily converted [Fig.6]. Alternatively a transmitted light box can be

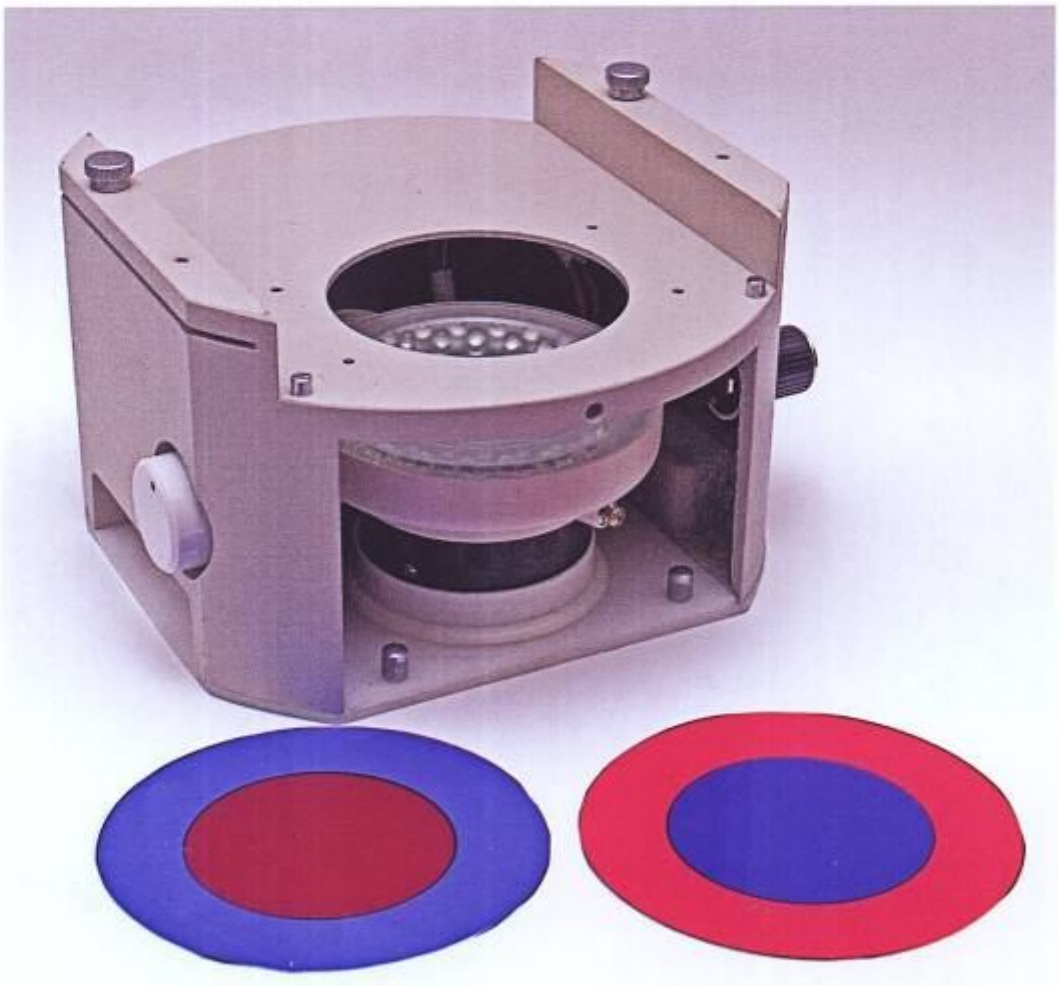

FIG. 6. **A self-contained trans-illumination base.**
A converted Olympus X-DE trans-illuminator base that can be used with both their stereo microscopes and the VST-1 photomacrographic stand. Three AA batteries and a 50mm diameter 49 LED array are mounted on a removable sliding plate. A translucent filter is mounted 25mm above the array on a circular housing of 58mm external diameter to which the ringlight is attached. A four-position switch can be seen on the left of the device and the black knob on the right controls the brightness of the transmitted light. The plate is secured in the correct position by the two hand screws. Brightfield, darkground, mixed or, with appropriate colour contrast filters, Reinberg illumination can be employed.

fabricated on which any stand can be placed if it has an aperture in the base to take a reversible black/white disc or a clear glass plate.

The constructional requirements are similar whether a unit is converted or built from scratch:

A sufficiently rigid box on which to stand the instrument, deep enough to take the LED array and its translucent filter, and to allow the ringlight to focus in the specimen plane of the instrument.

Some means of ensuring that the optical axis of the microscope is centred over the illumination.

Room for the associated wiring, batteries, switches etc: A potentiometer to regulate the intensity of the transmitted light is essential both to dim the transmitted field for Reinberg colour contrast and to protect the eyes of the observer from excessive brightness.

In the 1960s Olympus produced the "Transilluminator base X-DE". It can be used with most Olympus stereo microscopes and the Olympus photomacrographic stand. The illumination is provided by a 12v 20w pearl bulb fitted into the back of the unit, and a cylindrical mirror or matt white flat in a rotating mount to deflect the light upwards. The result is somewhat dim and uneven. These units, however, often turn up secondhand and are ideal for conversion into a much more effective LED illuminator.

The conversion of such a base will serve to illustrate the process of making any similar LED light base.

First the bulb holder, mirror and its support arm are removed and set aside. A detachable base on to which the LED illumination is to be fitted is made and the centre of the optical axis marked.

A circle the size of the LED torch array is scribed around this axis point, and the array is cemented in place with the leads in a convenient orientation. I find hot melt glue ideal for this purpose.

A translucent disk the size of the array needs to be supported at a sufficient distance so that the discrete LEDs are not discernable when illuminated (25–30 mm above the array). Old metal photographic lens hoods are ideal for this purpose, and also provide a support for the ringlight.

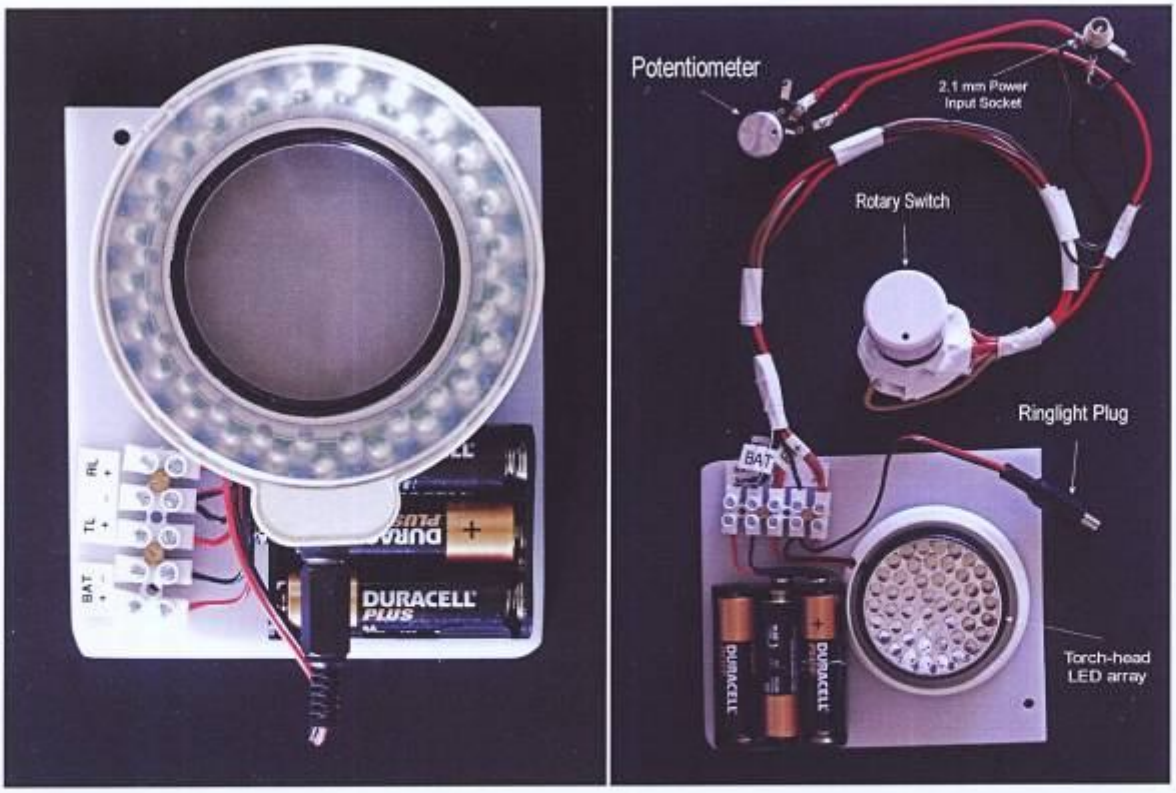

FIG. 7. **The base-plate and wiring for the trans-illumination base.**
The sliding base-plate with the ringlight in position is on the left, and on the right the wiring loom is shown with the ringlight and filter holder removed to show the LED array. Note the auto cut-off socket to take power from a DC power supply.

The ringlight is fitted at the required height and fixed in place. This is not as critical as might be supposed as the focus is somewhat inexact. The essentials are that no light from the ringlight shines directly on to the microscope objectives and that the specimen is properly illuminated. For portable use a battery holder to take 3 AA cells can be mounted on the base and the wiring completed.

A four position rotary switch provides the following combinations;

1. Everything off
2. Transmitted light only (via a dimming potentiometer)
3. Darkground illumination only
4. Both transmitted and darkground illumination for Reinberg colour contrast

A 2.1mm auto cut-off socket to allow input from a 4.5volt 400mA DC mains supply should also be incorporated [Fig.7].

A stereo microscope and the Olympus VST-1 photomacrographic stand can be easily exchanged for visual observation or photography in the field [Fig.8].

Top lighting

The use of commercially-produced LED ringlights and the conversion of built-in epi-illuminators provide very good top lighting for stereo microscopes, but the use of single LEDs on flexible arms can also be beneficial.

They effectively replace the traditional fibre-optic illuminator with its large, heavy and hot bulb housing, and because of the lens-like struc-

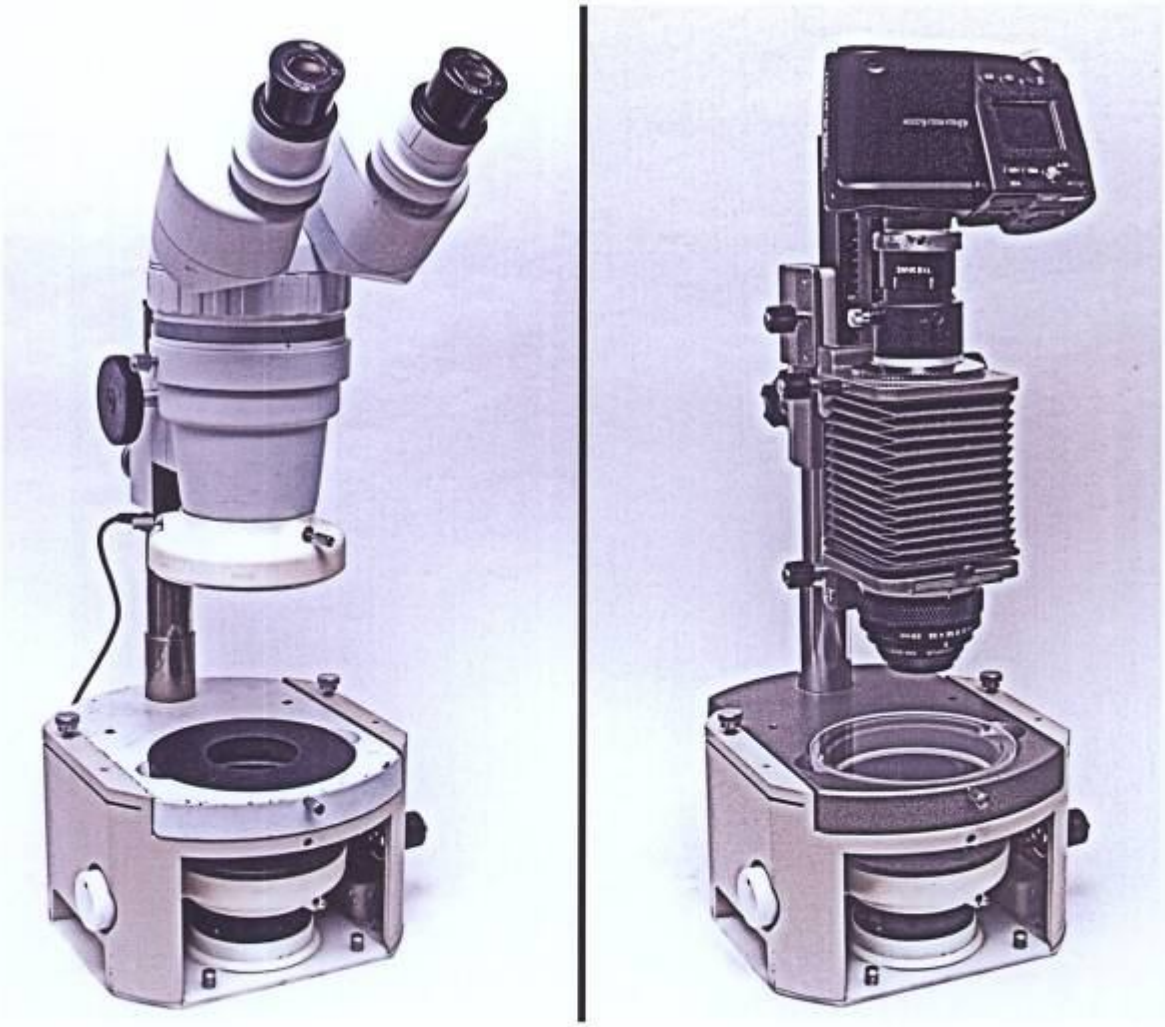

FIG. 8. **The trans-illumination base in use.**
On the left the base is supporting a stereo microscope, and the ringlight providing top lighting is powered independently from the base illuminator. On the right the base is set up for photomacrography with the VST-1 bellows stand and a Coolpix 4500 digital camera.

ture of the LED capsule no additional focusing lens is required.

10mm narrow-beam LEDs with four diode chips are now available. They are considerably brighter than earlier versions and such LEDs with a 40 degree beam angle [3] produce a 25mm diameter bright disc at a distance of about 40mm which is ideal for illuminating most opaque mounts. Flexible goosenecks intended for microphones or for 12v 20w tungsten halogen desk lamps can be used to support the LED; the advantage of the desk lamp option is that the two holes for mounting the bulb have a similar spacing to the LED leads; for added security the LED can be cemented in place or secured with electrician's tape [3].

They can either be mounted on the instrument or be free-standing [Fig.9]. Computer suppliers sell LEDs mounted on flexible arms with a USB socket intended as lights to use with laptops, but these are inadequate for microscope illumination because they are not bright enough.

Discrete Illuminators

Free-standing microscope lamps can have their incandescent bulbs replaced with LEDs as described in my earlier paper [1], and torch head arrays or even small LED torches can be mounted on a variety of supports to make useful illuminators. These can produce a larger pool of light than can be achieved by using single LEDs [Fig.10].

Torches with LED arrays intended to be worn on the head or used as bicycle lamps make useful self-contained illuminators that can be mounted directly onto specialised instruments where trailing leads are inconvenient or dangerous [Fig.11].

Figs.12, 13, and 14 show specimens lit by the devices described.

Conclusion

LED technology is advancing rapidly. It has even been postulated that organic light-emitting diodes (OLEDs) providing large very thin illuminating sheets of very low power consumption are the domestic lighting of the future. High-brightness LEDs have transformed automobile lighting, and LEDs are now the standard for illuminated road signs. One a recent visit to Chatsworth House I noted that the large specimen trees in front of the house were brightly lit by LED arrays – unthinkable a decade ago.

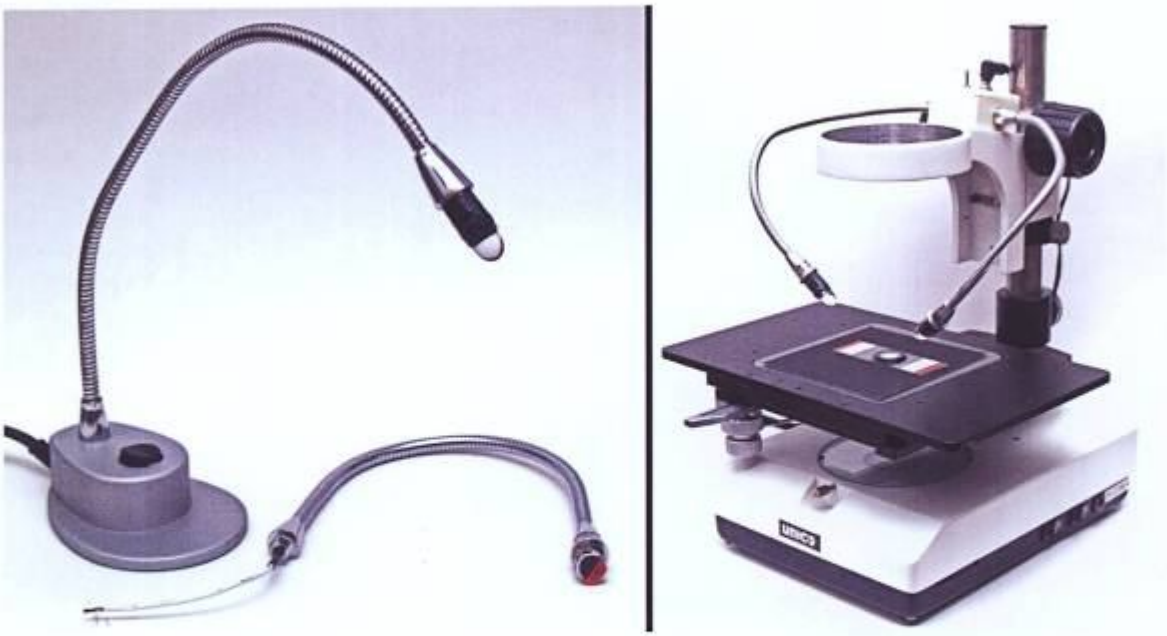

FIG. 9. **Top lighting with single 10mm LEDs.**
Provided that they are bright enough, single LEDs with a small beam angle can be used to replace traditional fibre-optic illuminators. A desk lamp with a flexible gooseneck is shown on the left; the bulb has been replaced with a 10mm 4 chip 11 lumen white LED with a 40° beam angle. Note the red marker to identify the positive contact on the unused gooseneck. A pair of gooseneck LED illuminators is fitted to the stereo stand on the right. The microscope has been removed to show the Mounting box, switch and power input socket.

FIG. 10. **A selection of discrete LED illuminators.**
Five different approaches to LED top lighting are shown. Note that three are in stands with quick release mounts so that they can be used for a variety of applications including mounting on camera flash shoes:

1. Very effective illuminators can be made by mounting small LED torches on appropriate stands; they have the advantage that they require minimal DIY skills, are self contained and provide a large pool of light.

2. A head sawn from a small torch has been mounted on an articulated arm with a flash shoe fitting as its base. This is smaller and lighter but requires a remote power supply.

3. A Zeiss flash illuminator on a bespoke column (the flash tube housing has been removed for clarity). The original bulb has been replaced with a 10mm wide beam LED.

4. A Sartory Instruments top light illuminator converted to take a 10mm wide beam LED. The transformer in the base has been replaced by a CR123A Lithium 3 volt battery, and the original cable hole now takes a 2.1mm auto cut-off socket.

5. A camping head-torch with the head band removed and the articulated mount fixed to a plate which fits a flash shoe. This is a small self-contained light source which can be used in situations where cables are inconvenient.

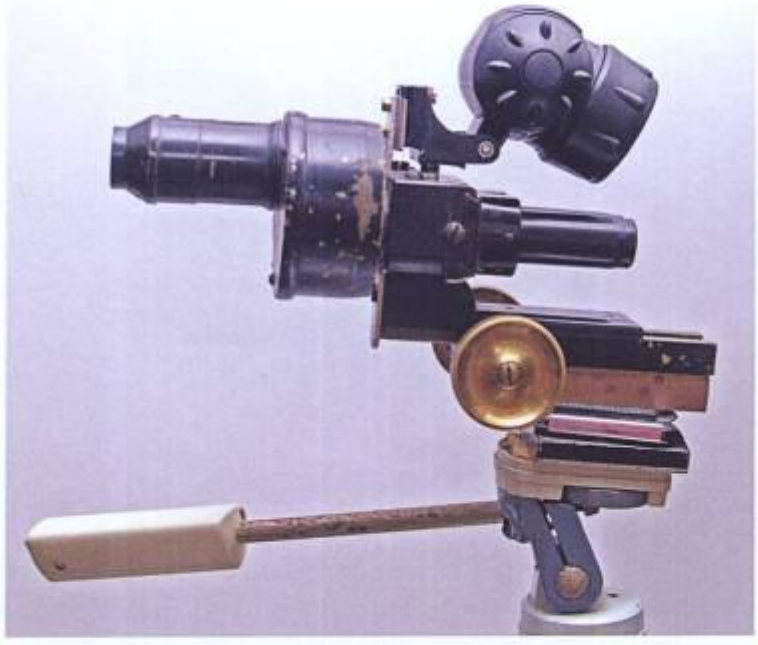

FIG. 11. **A tank microscope with a self-contained LED light.**
A converted LED head torch fitted to a stereo microscope used for examining aquariums. The microscope is mounted on a vertical moveable column mounted on an optical bench so that the whole face of the aquarium can be covered. A cable would be very inconvenient in such circumstances and the self-contained unit is ideal.

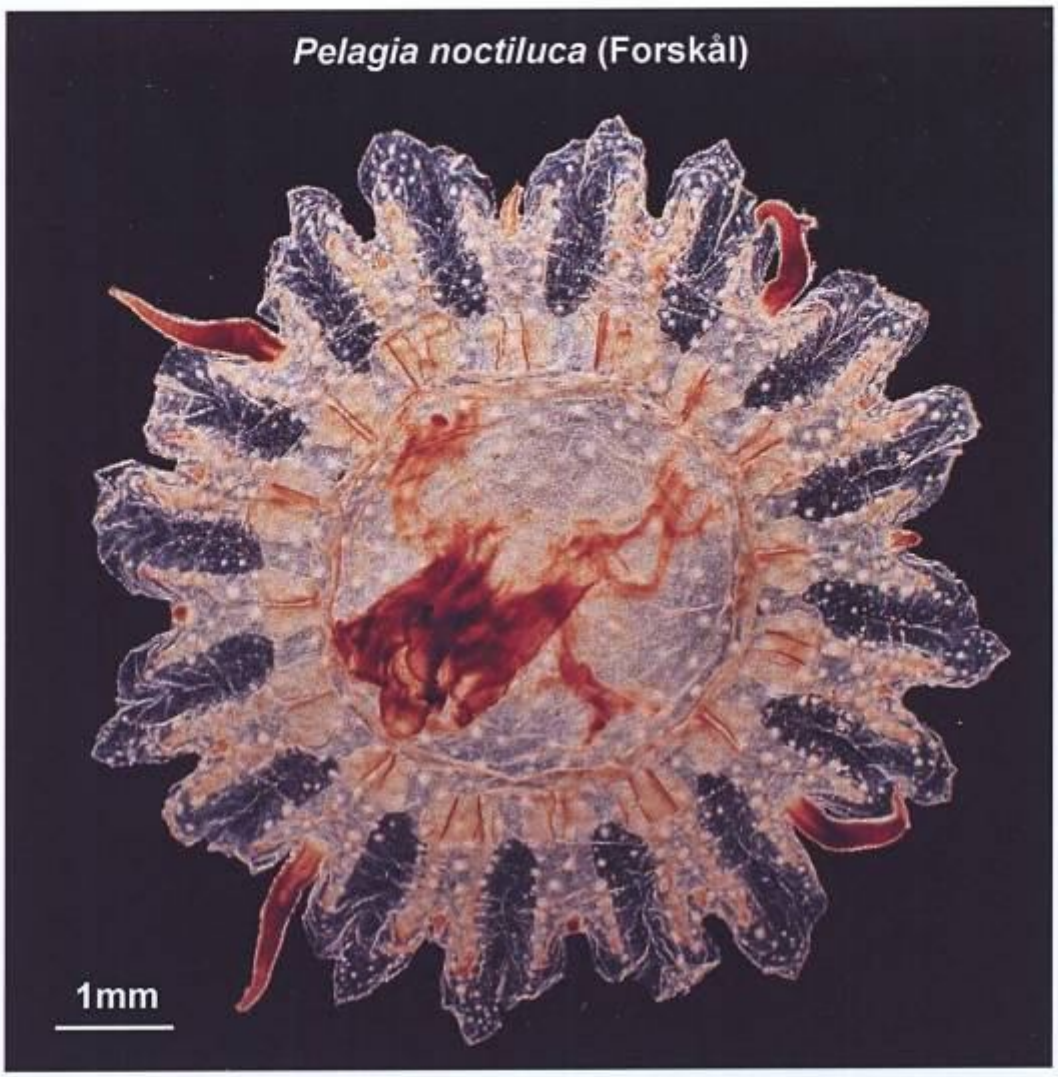

FIG. 12. **A large mount lit by the LED ringlight darkground illuminator.**
A Clarke & Page deep-cell whole-mount of the ephyra of an oceanic jellyfish. Several images were exposed and combined with HeliconFocus[9] to produce this picture, which demonstrates the effectiveness of the darkground illuminator for such comparatively large subjects.

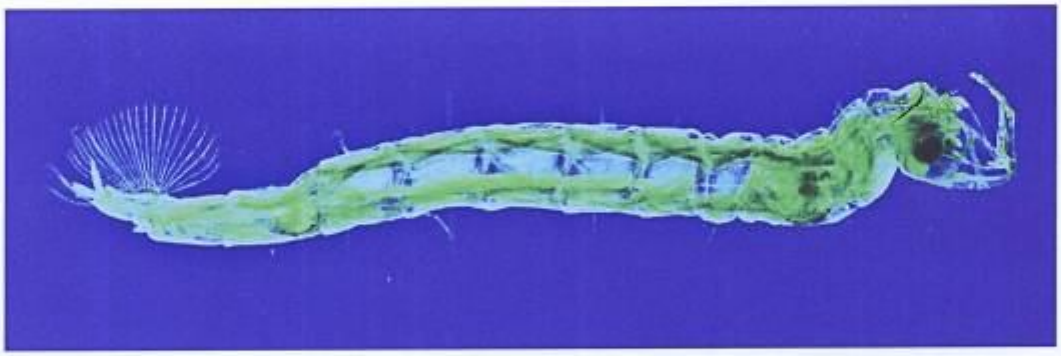

FIG. 13. **Rheinberg illumination with the trans-illumination base.**
The "phantom larva" of a midge (*Chaoborus* sp.) lit by the converted Olympus X-DE trans-illuminator base. Rheinberg colour contrast is produced by using a 100mm diameter filter with a 40mm blue centre to colour the transmitted illumination, surrounded by a 10mm black ring and a 20mm wide green ring to tint the oblique illumination. The filters are made using a computer drawing program and printed onto OHP transparency sheets. Two filters are printed, cut out and combined to increase the density of the colours.

FIG. 14. **Top lighting with a 4 chip 10mm LED.**
The large Nummulite specimen (15x10mm) is lit by the converted desk lamp illustrated in fig 9. A single 10mm four-chip LED provides the illumination.

Until recently LEDs were too dim to be considered for microscope illumination. The new generation of small high-power multi-chip LEDs are becoming brighter almost by the month, and their very modest power requirements make them an excellent lighting option.

References

1. C F Sartory (2008) – LED lighting for microscopes, *Quekett Journal of Microscopy*, 40: 701-711
2. C F Sartory (2006) – Cool Pixels (2), *Balsam Post* 71: 10-20
3. The 10mm LEDs used for these gooseneck illuminators are a new generation of 4-chip LEDs that are significantly brighter than conventional single chip LEDs. The clear acrylic 'lens' is the same size and shape, and the LEDs look remarkably similar, however examination with a hand-lens reveals eight very thin wires instead of the conventional two.

   They have a forward current requirement of 80mA at 3.4volts and have a claimed viewing angle (beam pattern) of 50°, however consulting the data sheet reveals that it is about 40°. Maximum intensity is claimed to be 11 Lumens.

Appendix: Suppliers of suitable LEDs.

Luckylight Electronics Co. Ltd.
[www.luckylight.cn].
Manufacturers and suppliers of many types of LEDs and ancillary equipment and they provide excellent data sheets as downloadable pdf files.

Winger Electronics GmbH & Co. KG trading as LED1.de
[www.led1.de]
A first class European supplier of all things LED related, including the four-chip LEDs referred to in text. They mail pdf data sheets on request.

GoodwillSales Ltd
[www.goodwillsales.com]
A good UK supplier.

Light of Victory LED Store
[http://stores.shop.ebayco.uk/Light-of-Victory-Led-Store-lvehk]
Reliable eBay supplier of single LEDs.

Gain Express holdings Ltd
[www.gainexpress.com]
Hong Kong based supplier of electronic laboratory equipment including LED ringlights.

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