The Use of the Philips 'Mirror-condenser Lamp' in Microscopy

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SUMMARY

The primary source of light is a coiled filament. Ellipsoidal and spherical mirrors collect nearly all the light it produces and project it on to an area of about $4\frac{1}{2} \times 3\frac{1}{2}$ mm outside the bulb. One end of a solid glass rod is placed in or near this area. The light travels along the rod by internal reflexions. A bull's-eye lens, placed beyond the other end of the glass rod, focuses the emerging light on the lower focal plane of the substage condenser of the microscope. Very intense illumination is produced. It is moderated by a variable resistor.

The lamp is suitable for use with objectives of focal lengths from 16 mm downwards. It is particularly adapted to high-power microscopy of all sorts. It is easy to use.

THE purpose of this paper is to show how the new Philips 'mirror-condenser lamp' (Alphen and Bierman, 1958), which is intended for use in cinematography, can serve as a very intense and convenient source of light in microscopy.

The 'lamp' or bulb consists of a filament inside a glass container of special shape (see fig. 1). The filament consumes 50 watts (8 volts, 6·25 amps). The bulb is constructed in such a way that nearly all the rays emitted by the filament are concentrated into a roughly rectangular area measuring about $4\frac{1}{2} \times 3\frac{1}{2}$ mm.

The inside of the bulb is silvered, except over a circular area of clear glass, about 17 mm in diameter. The side on which the clear glass area is situated will be called the front of the bulb. This front side of the bulb is hemispherical. The opposite or posterior side of the bulb is ellipsoidal. The filament—a single spiral wire—is placed in the primary focus of the ellipsoidal mirror. The light that reaches this mirror from the filament forms an image of the latter at the secondary focus, outside the bulb, about 11 mm in front of the clear glass. The light that strikes the silvered part of the hemispherical front of the bulb is reflected back to the ellipsoidal mirror and comes to a focus in the same place as the light that passes directly from the filament to the ellipsoidal mirror.

Only the central point of the filament is accurately imaged at the secondary focus. The image formed by the rest of the filament suffers from coma. Since the filament is spiral, it does not lie wholly in one plane, and this also interferes with the formation of an accurate image at the secondary focus. The image is therefore blurred, and a nearly evenly illuminated area results.

An intense, fairly large, evenly illuminated source of light is ideal for

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microscopy. It was therefore decided to try to use the mirror-condenser bulb in Köhler illumination. A bull's-eye lens was set in front of the image cast by the bulb in such a position that an image of the blurred image at the secondary focus was thrown on to the lower focal plane of the substage condenser of the microscope. It was found, however, that the bulb could not be used in this

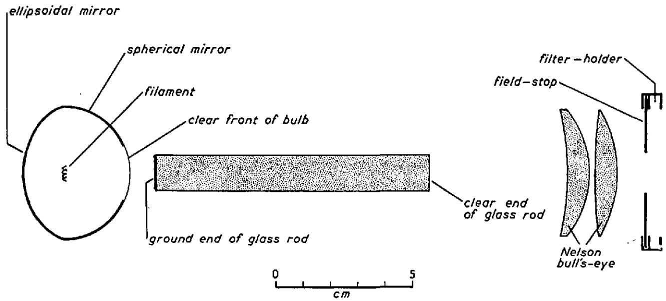

FIG. 1. Diagram of the new lamp (accurately to scale).

way. The field of view was unevenly illuminated, for the following reason. An image of the filament itself (not of its blurred image) was thrown by the bull's-eye on to a plane situated between the latter and the mirror of the microscope, and this image was picked up by the substage condenser and reproduced (out of focus) in the plane of the object on the stage of the microscope.

In order to get rid of this unwanted image of the filament, use was made of the internal reflexions of a solid, cylindrical glass rod, as suggested by Gordon (1908) and Welch (1930). The rod, 12½ mm in diameter and 10 cm long, was put in front of the lamp, in such a position that one end of it was in or near the plane of the secondary focus of the ellipsoidal mirror, while its axis was in a direct line with the centre of the filament. It was found best to grind the end of the rod that was placed in or near the focus of the ellipsoidal mirror, while the other end was left clear. It would be possible to focus the clear end of the glass rod directly on the object, by means of the substage condenser of the microscope, but this was found to be inconvenient. The field of view produced in this way was too small for low-power objectives, and was not quite evenly illuminated. Also, a lot of light was scattered too widely to be received by the substage condenser. For these reasons a bull's-eye was placed in front of the clear-glass end of the rod, in such a position that an image of this end was thrown at or near the lower focal plane of the substage condenser. Thus Köhler illumination was established, the clear end of the glass rod serving as the effective source of light. A Nelson aplanatic bull's-eye of diameter 25 mm and focal length 45 mm was chosen, though a simple plano-convex lens could be used instead. It was found convenient to place the whole illuminating system in such a position that the distance from the front lens of the bull's-eye to the lower focal plane of the substage condenser, by way of the mirror, was about 20 cm. Field-stops of convenient sizes can be placed in a slot in front of the bull's-eye, or an iris diaphragm may be used instead. A filter-holder may be placed in front of the field-stop or between the bull's-eye and the clear end of the glass rod.

An advantage over the Pointolite and other bulbs commonly used for high-power microscopy is the relatively large size of the illuminated area that is imaged by the bull's-eye on the lower focal plane of the substage condenser. Also, there is no obstruction between this area and the bull's-eye, and the latter can therefore have any desired aperture and focal length. The glass bulb of the Pointolite is large, and a bull's-eye cannot be brought close to the tungsten ball or balls. In the case of the Pointolite bulb adapted to alternating current, the minimum distance is 37 mm. Bull's-eyes of short focus and large aperture can therefore not be used. Most of the light emitted by the tungsten ball or balls is wasted.

A comparison was made between the intensity of the light available from a Pointolite and that available from the new lamp described in the present paper. The Pointolite chosen for the comparison was the Baker-Longworth lamp (Baker, 1956), which embodies a two-ball 150 c.p. bulb working on alternating current. A field-stop 14 mm in diameter was placed in front of the bull's-eye lens of each lamp, and these lenses were both focused to give a brilliantly illuminated circle 3 cm in diameter. (Since highly corrected optical systems were not used, the brilliant circle was in each case surrounded by an area of less intense illumination; this was particularly marked with the new lamp.) This circle of brilliant illumination would suffice to cover the aperture of any ordinary substage condenser. The intensity of the light in the two circles was measured with a Weston 'Lightometer', model E 703. To render this meter capable of measuring very bright light, the effective aperture of its photosensitive surface was reduced by the use of a stop. In the circle illuminated by the Pointolite the intensity of the light was 360 foot-candles; in that illuminated by the new lamp, 588 foot-candles. It must be mentioned, however, that to produce a circle of bright light 3 cm in diameter, it was necessary to place the Pointolite further away from the circle than the new lamp, and the field-step therefore subtended a smaller angle at any point in the bright circle than did the field-stop of the new lamp.

The whole illuminating system (bulb, glass rod, bull's-eye, field-stop, and filter-holder) can easily be mounted on a board measuring $26 \times 6\frac{1}{2}$ cm, and this can be placed in the grip of an ordinary retort-stand. The bulb is pre-centred in its holder, and a new one can therefore be put in its correct position without any need for re-centring. There is so little stray light that no elaborate shielding is required. The bulb itself may be freely exposed to the air, and this prevents overheating.

It is best to fix the position of the bulb and bull's-eye permanently, but to mount the glass rod in such a way that it can be moved to and fro through a distance of about 1 cm in the direction of its axis. In focusing the lamp one should slide the rod until the image of the clear end of it is thrown on the lower focal plane of the substage condenser of the microscope. In practice it suffices to regard the substage filter-holder of the microscope as lying in the lower focal plane of the condenser. A circular piece of white cardboard placed in this filter-holder makes it easy to focus and aim the light (Galbraith, 1955). The exact position of the ground end of the glass rod in relation to the secondary focus of the ellipsoidal mirror is of no importance. The filament can equally well be focused on the ground glass, or a few mm short of it, or a few mm beyond it (within the glass rod).

It is necessary to use a variable resistor to moderate the intensity of the light. We have used a Curtis 100-watt rotary rheostat in conjunction with a G.E.C. transformer no. XT. 5409 (240 to 8 volts). Provided that the filament is always heated gradually, the bulb seems to last indefinitely, though its life is said to be short if the current is switched on directly without the use of a variable resistor.

The new lamp gives good illumination with objectives of focal lengths from 16 mm downwards, without change of bull's-eye. It is particularly adapted to high-power visual and photographic work in phase-contrast, interference, and dark-ground microscopy.

The bulb, made by Philips Electrical, is obtainable through all camera-shops; the pre-focusing bulb-holder (P 15S/19, with round base) from Carpenter and Richardson, Paduoc House, Beresford Avenue, Wembley, Middlesex.

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