

A new ophthalmoscope

This content has been downloaded from IOPscience. Please scroll down to see the full text.

1921 Trans. Opt. Soc. 22 53

(<http://iopscience.iop.org/1475-4878/22/2/302>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 130.237.165.40

This content was downloaded on 01/10/2015 at 03:30

Please note that [terms and conditions apply](#).

A NEW OPHTHALMOSCOPE

BY PROF. J. K. A. WERTHEIM SALOMONSON

(Communicated by the President)

Read and discussed, 13th January, 1921

SINCE the discovery of the ophthalmoscope by Helmholtz, disclosing the interior of the living human eye, many different attempts have been made to keep a permanent record of the aspect of the retina on a photographic plate. This has proved to be much more difficult than viewing the background of the eye. The greatest difficulty has been caused by the reflections from the surface of the cornea and the anterior and posterior surfaces of the lens. Different ways have been tried to get rid of these reflections and after more or less successful attempts by Bagnérís, Guilloz, Gerloff and others, Dimmer succeeded in obtaining satisfactory results. Shortly afterwards Thorner, and also Wolff, working on different lines, showed photographs of the living human retina which were nearly as good as those of Dimmer; his photographs are generally excellent. Nicolaew was also successful in obtaining good negatives of the eyes of animals, but his method did not yield satisfactory results with the human eye, the fundus of which is infinitely more difficult to photograph than the animal fundus. For practical purposes as yet only Dimmer's and perhaps Wolff's methods have to be considered, but Dimmer's method necessitates a costly instrumentarium, requiring much room and skilled assistance. I do not know of its being used outside his own clinic, except by a very few specialists (e.g. Hess).

The different methods for obtaining an image of the fundus, free from reflections, have been ably discussed by Gullstrand, who gave a clear and critical review of the general and special conditions necessary for getting clearly defined ophthalmoscopic images, free from any reflection. Finally his results were embodied in his large demonstration-ophthalmoscope, constructed by Zeiss, which shows the ophthalmoscopic appearance of the human eye with less difficulty, more extensively with a higher magnification and yet more clearly than any other instrument of the same kind. As yet this instrument cannot be used for photographic purposes, but it seemed to me that it might possibly be rendered suitable for such. After a few preliminary trials I had an instrument made for me, differing in many respects from the original one.

The Nernst lamp was discarded and was replaced by a lamp of greater intrinsic brilliancy. The arrangement of the illumination-tube was slightly changed so as to allow a relatively greater part of the light to reach the eye. A suitable small camera having been adapted to the instrument, I got, after a few failures, usable negatives of a diameter of 26 to 30 millimetres, showing about 27 degrees of the fundus and covering an area of $4\frac{1}{2}$ times the diameter of a normal optic disc. The negatives were sometimes good, though very often blurred, owing to the long

exposure of 0.4 to 0.5 of a second. I have tried to get better results in quite another way, but still using the principle of indirect ophthalmoscopy. The greatest difficulty lies in the elimination of the reflections from the ophthalmoscope lens. I have succeeded in this and constructed the photographic instrument. Before considering it, however, I shall describe another instrument, which is used solely for viewing the retina and for showing it to students as yet unskilled in the art of ophthalmoscopy (Fig. 1).

For illumination a small 25 candle-power gas-filled lamp (Fig. 2) with a straight tungsten spiral filament is used, normally burning on a 4-cell accumulator or on a small alternating current transformer for 8 volts secondary. The light intensity is generally reduced by means of a sliding contact variable resistance. A condenser projects the image of the filament on a narrow slit. A lens placed on the slit projects the condenser aperture on the ophthalmoscope lens, the light being deflected through 90 degrees by a small totally reflecting prism placed beneath the slit, so as to permit of placing the illuminating tube at a right angle to the axis of the viewing tube which contains the ophthalmoscope lens. The real image of the retina, formed by the ophthalmoscope lens, can be examined through an aperture beneath the prism. We inspect that image with a kind of short microscope, the objective of which has a focal length of 55 millimetres, the eyepiece being one of the Huygenian type as used in the ordinary microscope. The magnification is altered by using different eyepieces.

In order to eliminate the images reflected by the ophthalmoscope lens, the following arrangement is used. A small achromatic double image prism of calcite and glass is placed between the condenser and the slit, causing two images of the filament to be projected in the plane of the slit. Only one of these, formed by the ordinary rays, falls on the slit; the other falls on one of the slit plates and is arrested. Consequently the eye is illuminated with polarised light and the images reflected by the ophthalmoscope lens are also polarised. By means of a nicol prism placed in the microscope tube these reflections are extinguished. The light illuminating the retina and reflected from the fundus of the eye has become depolarised and can be observed with the microscope. As a matter of fact the retina is clearly seen without any appreciable disturbing reflections from the surfaces of the intervening media. Also the retinal reflections, which in young patients are nearly always very noticeable, seem to be very slightly lessened.

With this instrument we can see at once 27° of the fundus of an emmetrope eye, corresponding to about $4\frac{1}{2}$ diameters of the papilla nervi optici. The whole field is remarkably flat, and is sharp up to the edges. The magnification is generally about 14 diameters, or about the same as when the eye is examined with the direct method, but with an angle of view many times greater. By using stronger eyepieces the image, which is in the upright position, can be magnified up to about 50 times, the angle of view of course being somewhat reduced. As the illuminating filament can be regulated to any desired degree of brightness we can even with this high magnification get a profusion of light, and exceedingly clear and sharply defined images of the fundus.

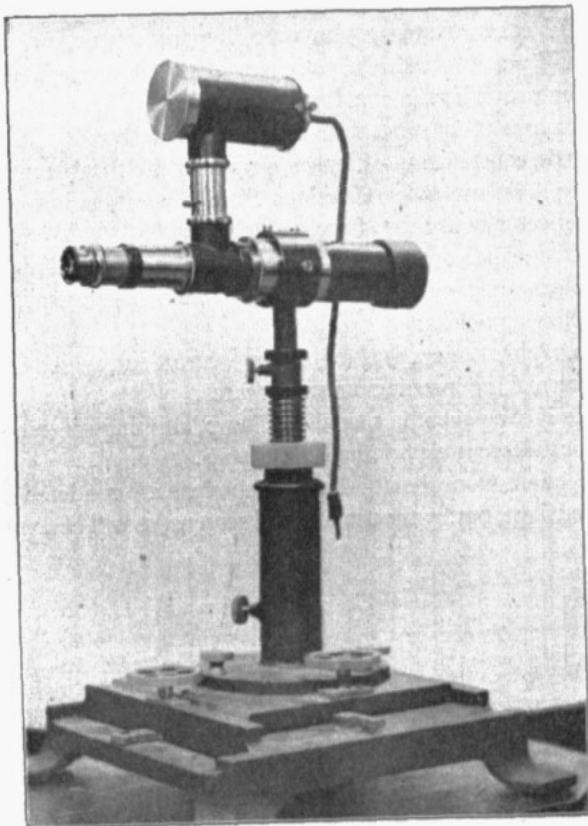


Fig. 1

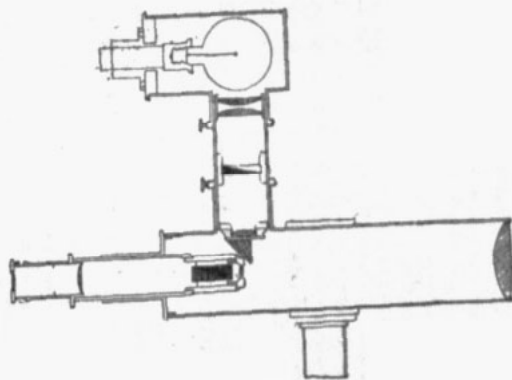


Fig. 2

When in use the distance from the patient's eye to the instrument is about 90 millimetres. The only change necessary when examining different patients is the focussing. In cases of strongly myopic, hypermetropic, or astigmatic eyes, examination is still possible with the patient wearing his own glasses.

The ophthalmoscope lens in this instrument is one of the well-known aspheric aplanatic single lenses of 43 mm. clear aperture, made by Zeiss. One might use any other aplanatic combination of lenses, provided the focal length and aperture were satisfactory. The multiple reflections from a combination of lenses would be obscured as effectually as those from a single lens.

We can now return to our photographic ophthalmoscope. This has been constructed on the same principle as the demonstration instrument, from which it differs in the following points:

- (1) A photographic camera is fitted to the instrument, which is also provided with a shutter for making instantaneous exposures.
- (2) The illuminating agent is a small arc lamp, running on some 5–6 amperes, instead of the incandescent electric half-watt lamp.
- (3) The reflections from the ophthalmoscope lens are rendered innocuous, not by using polarised light, but by the use of small screens, as will be explained later on.

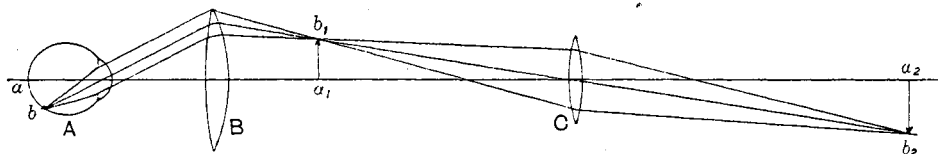


Fig. 3

The photographic apparatus contains two different optical systems—one for viewing or photographing the retina and a second one for illuminating it. The former optical system is diagrammatically represented in Fig. 3. The rays starting from a point b on the retina pass through the lens of the eye and the cornea and leave the latter as a bundle of parallel rays. These reach the ophthalmoscope lens which forms a real inverted image a_1b_1 at its back focus. An image of a_1b_1 is then formed at a_2b_2 on the photographic plate by means of the photographic lens C . The distance of the ophthalmoscope lens from the eye must be made such as to form a sharp inverted and enlarged image of the iris and eye pupil in the plane of the photographic lens C . The combination of these conditions demands that there should be a definite relation connecting the diameter of the eye pupil, the aperture of the photographic lens, the focal length of the ophthalmoscope lens, and the final magnification of the retinal image, if we wish to get the maximum of light on the plate. This condition is expressed by the formula

$$\frac{d_2}{f_2} = \frac{d}{f_1} \left(1 + \frac{1}{V_2} \right),$$

in which d_2 is the opening, f_2 the focal length of the photographic lens, d the diameter of the pupil, f_1 the focal length of the ophthalmoscope lens, and V_2 the total magnification.

Let us assume that we wish to take a photograph showing the retina with an enlargement of, say, four times. We can do this by taking a short focus ophthalmoscope lens with a low initial magnification of, say, two times, which is compensated by enlarging the image twice again with the photographic lens. But we might also have taken a longer focus ophthalmoscope lens, enlarging the retina four times, and reproducing this image on the same scale with the photographic objective. Assuming that the pupil was dilated in both cases to 8 millimetres, the formula shows that with the low primary magnification an exceedingly high aperture photographic lens of something like $f/2.5$ would be necessary, whereas with a long focus ophthalmoscope lens an aperture of $f/4.5$ would be sufficient for the photographic objective. In my apparatus I have therefore used the ophthalmoscope lens

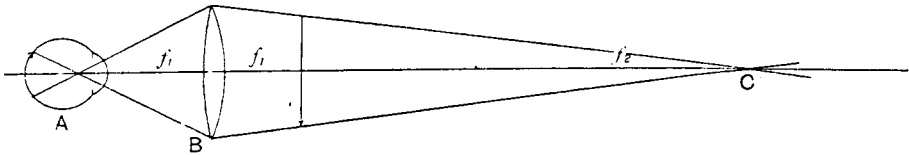


Fig. 4

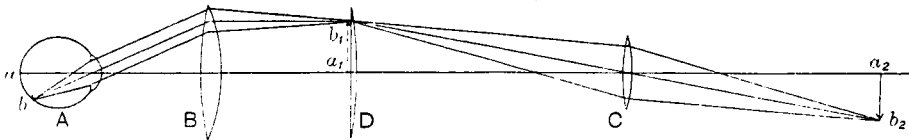


Fig. 5

with the longest focus I could get. As this lens must give aplanatic images I have taken an aplanatic aspheric ophthalmoscope lens of 7 cm. focal length and 5 cm. diameter, made by Zeiss. For my photographic lens I could take any good lens working at about $f/4.5$, but I had still to fix on a proper focal length for the objective. This point will be best understood from a study of Fig. 4, in which *C* represents the cardinal point of the photographic objective. By taking an objective of very short focal length, we get only a small part of the image of the retina on the plate. In this respect it is a decided advantage to have as great a focal length as possible. But, on the other hand, this renders the whole apparatus unmanageable, as its dimensions become too great. I have therefore taken an objective with a focal length of 15 cm., giving an image of nearly 41 mm. out of a possible 50 mm., and covering 5.4 diameters of the optic disc. The entire length of the viewing tube is now 67 cm., to which 8 cm. must still be added for the focussing eyepiece. I might have got a larger field of view with a shorter focus photographic objective by using a field lens (*D* in Fig. 5), but I could not do this as I should have had to eliminate also the reflections from this field lens.

The illuminating system is diagrammatically represented in Fig. 6, *K* being the crater of the arc lamp, *E* the condenser, *G* a diaphragm with a lens, and *F* an aplanatic lens. An image of the crater is projected in the plane of the diaphragm

G , an image of which is projected at the end of the illuminating cone by the lens F . The lens at G is not necessary, but it serves to form an image of the surface of the condenser in the plane of the aplanatic lens F . A shutter is placed in front of G . This illuminating system, in combination with the viewing system, is shown in Fig. 7. Both systems have one point in common; the ophthalmoscopic lens B and the aplanatic lens F are one. This is made possible by inserting the totally reflecting

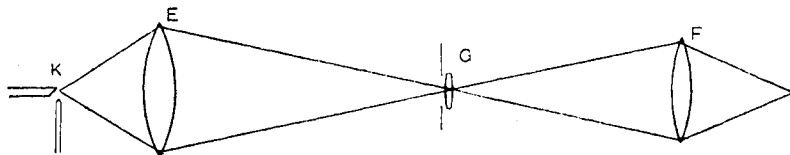


Fig. 6

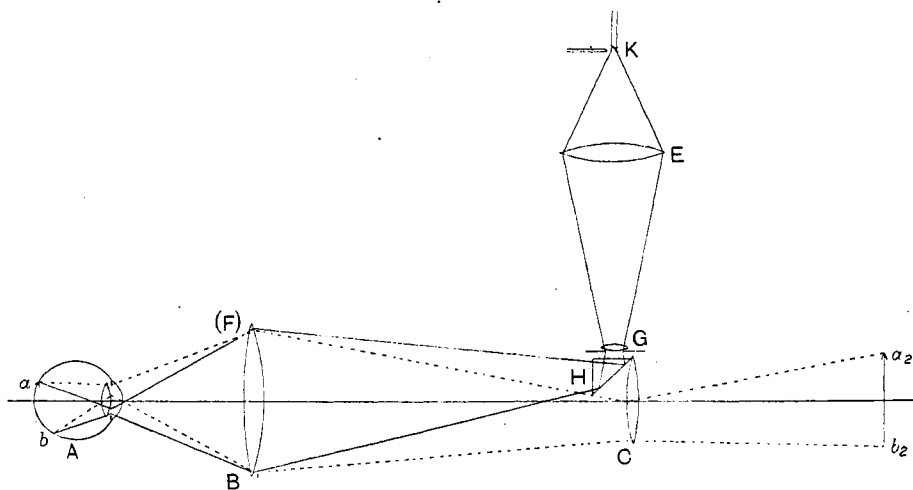


Fig. 7

prism H in the path of the illuminating rays, so as to place the arc lamp with the condenser perpendicular to the axis of the viewing tube.

By placing the prism H in front of the objective, part of this objective is not used for reproduction of the ophthalmoscopic image. As the ophthalmoscope lens reproduces the pupil of the eye in the plane of the photographic lens, we have divided the pupil into two parts, one part transmitting the illuminating rays and the other part transmitting the rays from the retina to the photographic plate. In my apparatus these parts are arranged as shown in Fig. 8 *a*, where rs is the section of the narrowest part of the bundle of illuminating rays, tu being the section of the bundle of visual rays which start from the retina and reach the objective. Assuming for the pupil a diameter of 8 mm., for the section of the illuminating cone 2 mm., and leaving 2 mm. clear space between the illuminating and image

forming rays, we get only 0.162 of the theoretically obtainable luminosity in a case where exactly one-half of the surface of the pupil is used for passing each of the two light cones. We might have got a better economy by using divisions of the surface of the pupil as shown in the next figures, the economy factor being only 0.109 in Fig. 8 *b*, but growing to 0.391 in Fig. 8 *c* and 0.468 in Fig. 8 *d*. I have not used these economically better forms as they would have caused some trouble with the construction. Also there is some advantage in using the best part of the eye for photographic purposes, which would not have been possible with an arrangement such as the one shown in Fig. 8 *d*.

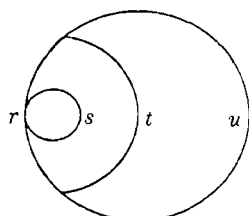


Fig. 8 *a*

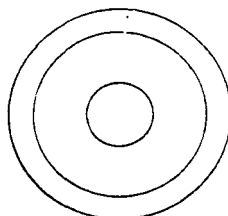


Fig. 8 *b*

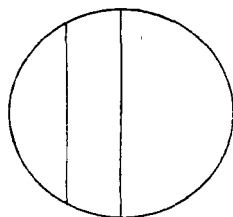


Fig. 8 *c*

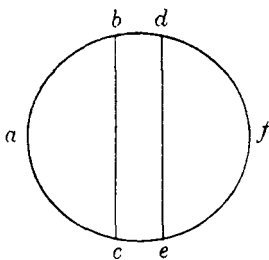


Fig. 8 *d*

We must now turn our attention to the reflections from the surfaces of the different lenses. The reflections from the cornea and the eye lens have already been eliminated by our arrangement of the illuminating and the reproducing cones of light. From a consideration of Fig. 7 we find that, if only the clear space of about 2 mm. between the cones be preserved, no illuminated part of the cornea or the eye lens can be seen by the photographic objective. But this means that no reflection from the cornea or the eye lens disturbs the reproduction of the retinal image.

The reflections from the ophthalmoscope lens must be eliminated. In the scheme reproduced in Fig. 9, where *A* represents the eye, *C* the photographic lens, and *B* the ophthalmoscope lens, the reflections from which are formed at *c* and *d*, we get the first retinal image at a_1b_1 . The photographic lens gives a sharp reproduction of a_1b_1 on the plate at a_2b_2 , whereas the reflections are sharply reproduced

at c_1 and d_1 . On the plate they would show, as crescent-shaped spots, the form of the transparent part of the photographic lens. We can eliminate these reflections by causing them to fall on very small screens placed at c_1 and d_1 . These screens, with diameters of about 1 and 2 millimetres, are mounted either on a glass plate or on a pair of very fine wires, and can be carefully centered. But when this has been done we discover that a small quantity of light is diffracted round the small screens. In order to minimise the effect of this diffracted light, I placed a small screen on the condenser E . This was reproduced on the lens B by means of the small lens G (Fig. 7). The place and dimension of this last screen were carefully calculated so that its image just covered the part of the lens from which the reflections took place. By taking a lens G of slightly larger focal length than necessary I prevented this last screen from causing a gap in the final picture. Furthermore, I do not use an absolutely opaque screen, but a yellow transparent one, which does not hamper the illumination of the retina and yet greatly diminishes the action of the diffracted rays on the plate.

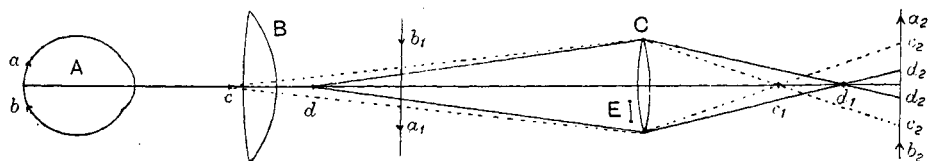


Fig. 9

As yet I have not mentioned a third reflected image which is formed by double reflection from the ophthalmoscope lens. This image is visible as a very thin light line in the form of an exceedingly narrow crescent. It has the peculiarity of being completely polarised perpendicular to its direction. The intensity is so slight that there is no need to consider this reflection. We can just see it on most negatives, but it does not cause any trouble.

There are still a few points which must be mentioned. In my instrument an arc lamp using about 5–6 amperes is employed. Would it perhaps be advantageous to use a heavier current? The answer is that this should not be the case, at least if we have the right to assume that the intrinsic luminosities of 5 and 25 ampere arc lamps are the same. Now I am willing to admit that there may perhaps be a very slight difference, but I am not quite convinced of it. We can easily prove that we cannot get more light with any modified form of illuminating lens system.

Before photographing we must first focus the image. We can do this only if the intensity of the light has been much reduced, for the patient would not be able to suffer the prolonged action of so strong a light. I have overcome this difficulty in a very simple way. The instantaneous shutter, with which the instrument is fitted, is placed in front of the prism in the illuminating tube. When in the position of being set the shutter presents an opening covered with a smoked and varnished mica plate, through which enough light passes to enable us to examine carefully

the fundus of the eye and focus the image. A ground glass is not needed; the image is directly viewed with a magnifying glass, magnifying $3\frac{1}{2}$ times and showing the whole image of 40 mm. diameter at once. As soon as the focussing seems to be satisfactory, the magnifying glass is slid sideways and an already opened plate-holder is brought in its place. At the same moment the shutter is released and a plate is exposed.

The exposures can be varied from $\frac{1}{20}$ — $\frac{1}{4}$ second—generally $\frac{1}{10}$ or $\frac{1}{12}$ of a second exposures are used. With good panchromatic plates we usually get fully exposed negatives. Of course there is a slight loss of light at the peripheral parts of the

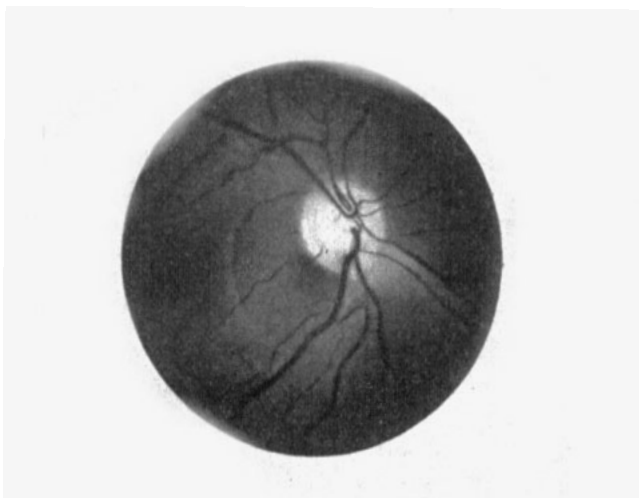


Fig. 10

negative, the central parts being more strongly exposed. I do not think that this can be remedied in any effectual way, yet with some care pretty good prints may be got from the negatives.

The diameter of the negatives is about 40 millimetres. They are mostly sharp enough to stand a magnification of two to three times. Fig. 10 is a reproduction from a negative showing a normal eye.

The apparatus can be used for both eyes without any alteration except the ordinary focussing. The whole instrument is mounted on a stand which allows of careful adjustment in three directions. Its use is not any more difficult than the making of an ordinary photograph with a stand camera.

DISCUSSION

Mr J. Pizzala asked if all the photographs exhibited were of eyes treated with atropin, and whether it was necessary to use atropin for direct ophthalmoscopy.

Professor Cheshire said that some years ago Prof. von Rohr had told him that Prof. Gullstrand had discovered that the zone of the pupil with a radius of 4 mm. was free from spherical aberration. He thought that this might possibly explain the extraordinarily good definition the author had obtained with his instrument.

Mr F. Whitehead asked if any special process had been adopted in sensitising the photographic plates to render them panchromatic or sensitive to the red, and if a colour screen or filter had been employed.

The author, in reply, said the eye under test was always dilated, by means of atropin, to at least 7 mm. aperture. He did not, however, use atropin unless when taking photographs.

The photographic plates employed were panchromatic, mostly of German make ("Agfa" brand), but similar results had been obtained with English panchromatic plates. None had been specially treated before using and all makes had been used without any screen or filter.