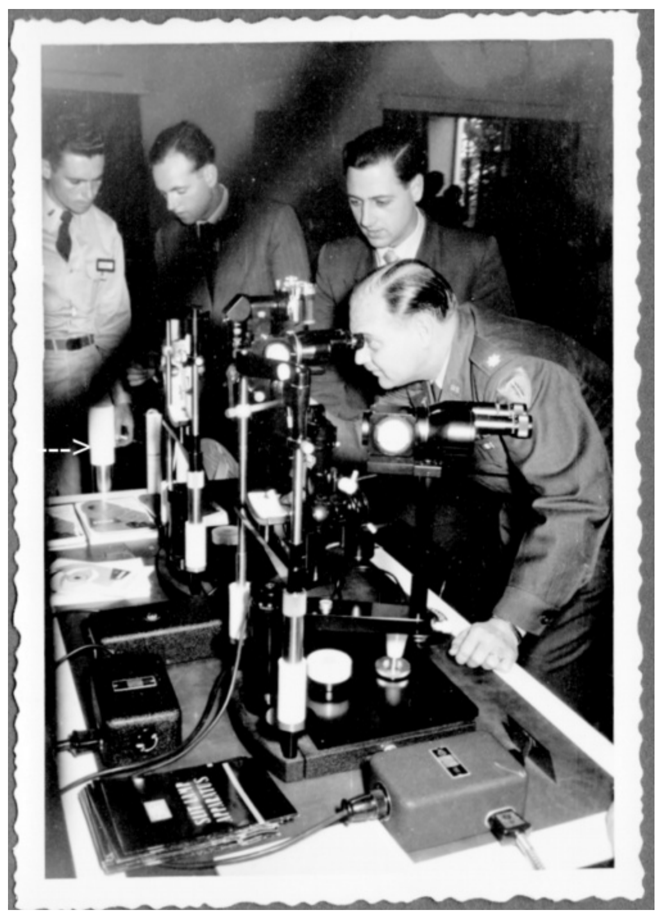
How the Humble Stereomicroscope Found its Way into Modern Surgery: The Zeiss Operating Microscope

Fritz Schulze, 2012

Introduction

This paper deals predominantly with compound and stereomicroscopes, antique and modern, and their application. Our lives have all been touched indirectly by discoveries and research work done with these microscopes in such fields as bacteriology, pathology, histology, haematology, anatomy and others. There is, however, another less well known type of microscope which affects some of us in a more direct way and of which we hear or read very little: *the operating or surgical microscope*.
I daresay that many of our older readers have had cataract surgery and an IOL (intra-ocular lens) implanted to restore their eyesight. Some less fortunate readers may have had a brain aneurism or tumour operated on, had surgery on their spine, or an organ transplant, not to talk about even a reimplantation of a severed digit. Another likelihood lately is dental surgery or plastic surgery with the transplantation of a piece of skin for example after burn injury.
You had your operation and, when recovered, went home and never spent a thought on how your surgery would not have been possible without the operating microscope and up-to-date microsurgical techniques. With this in mind, and with my work at the Zeiss company having been with operating microscopes from the very beginning, I thought it appropriate to share my knowledge with you.



Picture on right: The author demonstrating a Zeiss Slit Lamp to an American doctor at the US Army Hospital in Stuttgart, 1954 (arrow: colposcope)

Credits:
All illustrations not otherwise credited are from Zeiss publications such as brochures, hand books, instruction manuals, Zeiss Information etc. I also wish to thank my wife Eleanor for proofreading this opus.

Note:
Although the following is a rather lengthy, and in many points boring, enumeration of the many Zeiss operating microscopes and accessories developed over the course of nearly 40 years, it is by no means all encompassing. There were many minor changes, special accessories, and modifications it would be too tiresome to list. My intention is to show how the modern Zeiss operating microscopes evolved over the years, not least by the input of many surgeons, from a simple floor stand-mounted stereomicroscope to a sophisticated motorized computer-supported operating machine, how together with microsurgery it developed into a new and indispensable new medical discipline.

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The Operating Microscope (Part 1)

The Early Beginning

The history of mankind can be likened to a large tree with many branches: there is the conquest of fire, the development of agriculture and animal-husbandry, the advent of metallurgy and glass making, the beginning of a written language, of architecture and engineering, and, of course, of medicine, which is what concerns us here.

Since the earliest days of mankind there have been witches, shamans, high priests, and other clever men and women who knew about the healing power of certain plants and minerals and practised their kind of healing. Particularly in the Near and Far East medicine was practiced in many forms long before its knowledge reached Europe where in the beginning it was restricted to monks. Gradually the barbers began also to extract teeth, couch or cut cataracts, and amputated limbs. The barbers were, however, scorned by the “real doctors”, considered quacks even if highly successful as surgeons. It is, perhaps, because of this prejudice that in Great Britain surgeons today are still addressed as Mr. and not as Dr.

Surgery has come a long way since these dark “barbarous” times, especially since anaesthesia and asepsis were introduced. Now the surgeon did no longer have to rush and could attempt more complicated procedures. But he met a limit when it came to delicate, small parts like blood vessels, nerves or the ossicles in the inner ear.

Enter the Microscope

The first surgeon to use the aid of a microscope was the Norwegian otolaryngologist Carl-Olof Siggram Nylén (1892-1978) who adapted a monocular Leitz-Brinell microscope (designed to be used for hardness testing and having a low magnification and long working distance) in 1921 for inner ear surgery. Shortly thereafter he switched to a binocular stereomicroscope.

The first German doctor to use a stereomicroscope was Dr. Hans Hinselmann (1884-1959, Fig.1), Prof. of Gynaecology under Dr. Otto von Franqué at the University Clinic, Bonn, who adapted in 1925 a Leitz stereomicroscope with coaxial illumination to a movable floor stand. He named his design “colposcope” and used it to visualize the female genital organs particularly for cancer of the cervix. Dr. Hinselmann had at first used a head mounted “von Eicken’s” loupe, also made by Leitz. But the magnification of 1.8x was insufficient. The colposcope he configured with the aid of the local Leitz representative, Hans Hilgers, allowed magnifications from 3.5x to 30x (Fig.2). Thanks to Dr. Hinselmann's work the early detection of cervical cancer increased three times, nevertheless, resistance by the medical establishment to his findings slowed the introduction of colposcopic examinations from becoming routine for some time and were practically unknown in America till the 70s. I remember being astonished upon my coming to Canada in 1963 to find that the colposcope was virtually unknown while in Germany almost every gynaecologist used one in his or her office!

Fig 1

Dr. Hans Hinselmann (1884 – 1959), Oberarzt at the Frauenklinik Bonn
(Picture BILD & FUNK Magazine 1980 (?), article by Dr. Silló-Seidl)

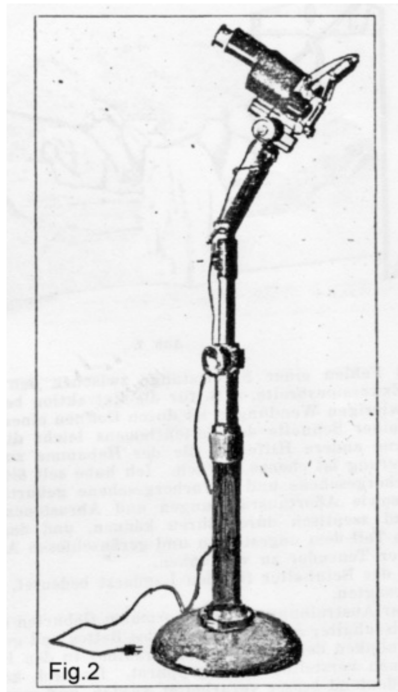


Fig.2

Dr. Hinselmann's "Colposcope" (Greek *colpos* = vagina, *skopein* = to observe) 1924,

picture from "Verbesserung der Inspektionsmőglichkeiten von Vulva, Vagina und Portio"

Dr. H. Hinselmann, Münchner Medizinische Wochenschrift, Vol.73,1926

This article also describes how he developed his colposcope.

The First Commercial Operating Microscope

As the need for visual aids in surgery became more pressing, Dr. Hans Littmann (1908 – 1991) (Fig.3), head of Med-Lab at Zeiss Opton Oberkochen, West Germany (now Carl Zeiss A.G.) and his team of technicians designed in 1953 their first operating microscope. It was based on the well received Stemi 1 with Galilean magnification changer, designed shortly after the restarting of production in the West (Fig.4). Their instrument had already the principal features required for a practical operating microscope: a versatile, mobile floor stand, magnification changer, coaxial illumination, and a choice of working distances (Fig.5). The first application was again otolaryngology, this time by Dr. Horst L. Wullstein (1906-1987) of the Würzburg Policlinic, Dept. of Otolaryngology and the "Mecca" of ENT surgery. It was an instant success, used in the beginning mostly for stapes mobilisation (restoration of hearing) and similar inner ear procedures, and due to Dr. Wullstein's teaching there developed a great demand for this new instrument. Almost immediately, Dr. H. Harms of the Eye Clinic, University Tübingen, thought the new operating microscope useful for eye surgery, in particular corneal transplants. However, he found the reflex caused by the coaxial illumination irritating and upon his suggestion a modified operating microscope with external oblique illumination (Fig.6) , later even a slit illuminator, was designed especially for ophthalmic surgery (Figs. 7 and 8).

One fact became immediately apparent: the existing instruments were by far too crude and large to be used under magnification. A fine tweezer under the microscope looked like a fence post! Much smaller and more precise instruments had to be made, and not only that, the sutures and needles had to be miniaturized. In fact an entire new branch of Micro-Surgery developed involving new techniques opening the door to a multitude of new procedures hitherto thought impossible. Just imagine having to join the ends of two slippery veins (anastomosis) of 1mm diameter with 5 stitches without a leak and allowing the blood to pass freely! Some sutures with needle attached are so small (0.025mm diam. less than half the average thickness of a human hair) as almost invisible to the naked eye!

Fig.3

Dr. Hans Littmann (1908 – 1991),
Head of Med-Lab (Medical Department), Zeiss-Opton, Oberkochen, West-Germany,
(as of 1954 Carl Zeiss), and his team developed the first operating microscope in 1954.
Picture Carl Zeiss Archive

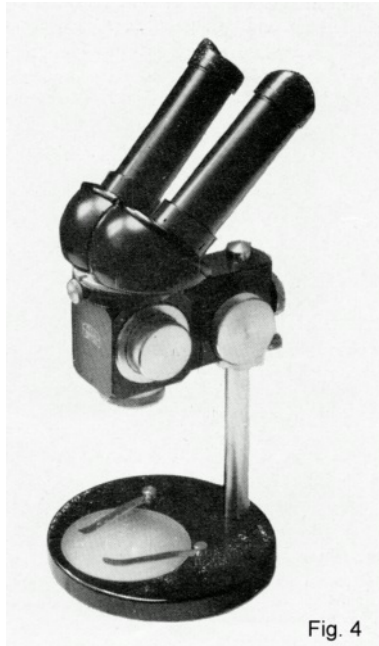


Fig. 4

The Zeiss-Opton stereo microscope, the first post-WW II development. It featured 5 different magnifications at constant working distance

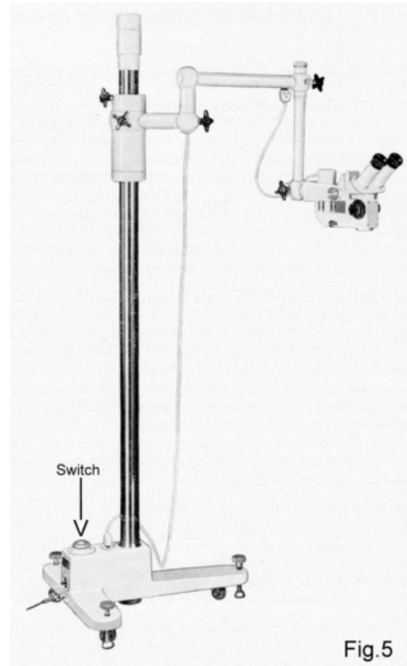


Fig.5

First Operating Microscope
Notice the binocular tube with the 30mm ID eyepieces, levelling screws and central foot switch for high-low light intensity.

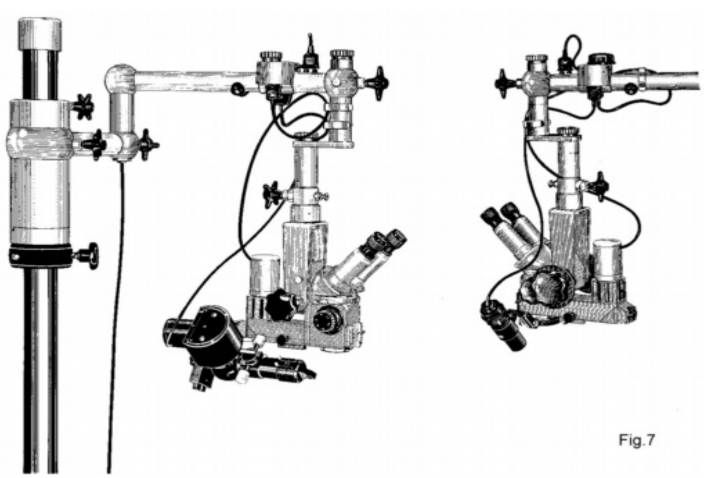


Fig.7

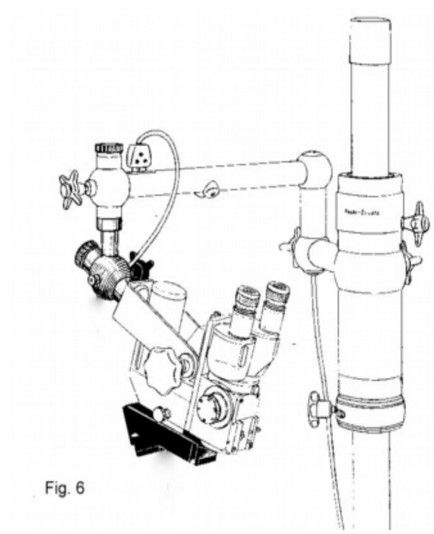
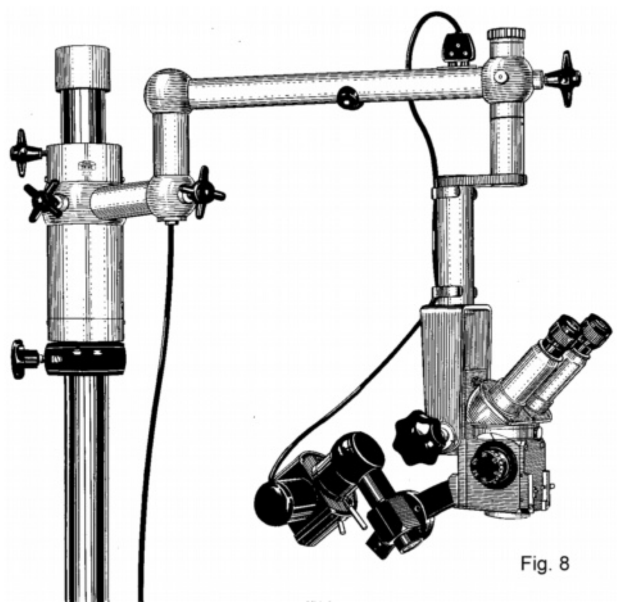


Fig. 6

Left: The first slit lamp attached to the back of the Opmi.

On the right, a simple low voltage lamp borrowed from the stereomicroscope.
Notice the large sterilizable rubber covers on the control knobs.
Both microscopes show the cranked coupling (suspension) used for ophthalmic surgery. The lamp housing shows the cooling slots of the earlier models.

Opmi 1 with the 45° illuminating prism. The straight binocular tube has already the smaller 25mm ID eyepieces. Notice also the larger focusing knob and the safety clamp ring on the column.



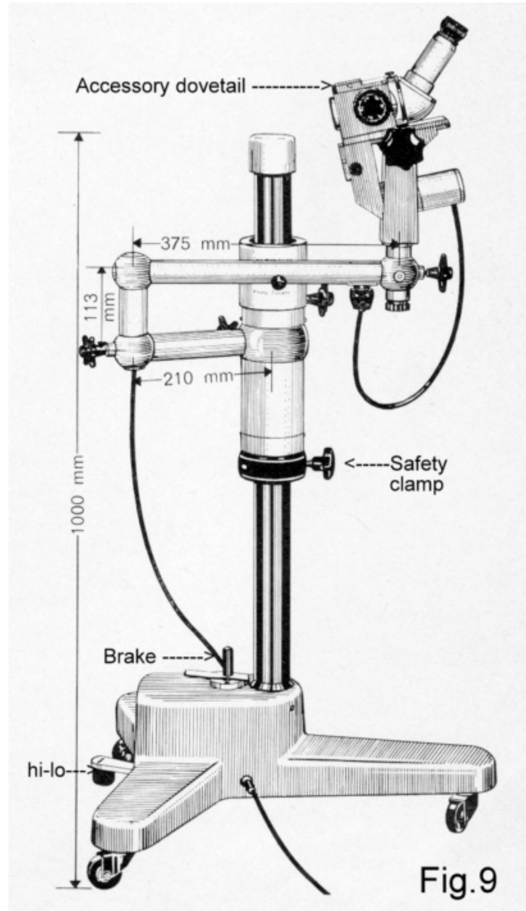


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Fig. 8
The Operating Slitlamp after Harms, w/o coaxial illuminator, but with off-set, cranked coupling.

Fig. 9
The first Colposcope. Note the central brake on the base and, at left, the switch for high-low light to be kicked over by foot

Whoever dissected an object under a stereomicroscope may not have been aware of another effect: unconscious hand – eye – coordination. At first you would expect that your hand movements are also magnified and your instrument would be jerking around with little control. However, this is not the case. It is simply miraculous how the fingers unconsciously follow the slightest movement observed. One can indeed thread the finest needle under high magnification without jittering. Without this effect modern microsurgery would be impossible.

A range of accessories for the Zeiss operating microscope followed in due course: co-observer-tubes, camera attachments for still and cine-photography, a double microscope, special modifications for neurosurgery, a ceiling mount, halogen illuminators, motorized zoom, assistant's microscope, and so on. The instrument was also adapted for forensic and technical work (art restoration), with a table stand for lab work, or with a short floor stand as colposcope for gynaecology (Fig. 9).

The Zeiss operating microscope was an immediate worldwide success and became the bench mark for all future designs. It took several years before the highly successful Zeiss operating microscope was copied first by a Brazilian firm (an almost exact copy of the Zeiss with parts interchangeable !) and then a Japanese one. Another German firm then started production of a competitive instrument and a few years later an American competitor arrived on the scene. In 1981 Wild-Leitz introduced their operating microscope which by now has cornered a fair share of the market while both the American, Brazilian, and the other German manufacturers stopped production or became insignificant on the international market. I think there are still Japanese and Chinese operating microscopes being built. They all help today's microsurgeons do their meritorious work for the benefit of mankind (Fig.10).

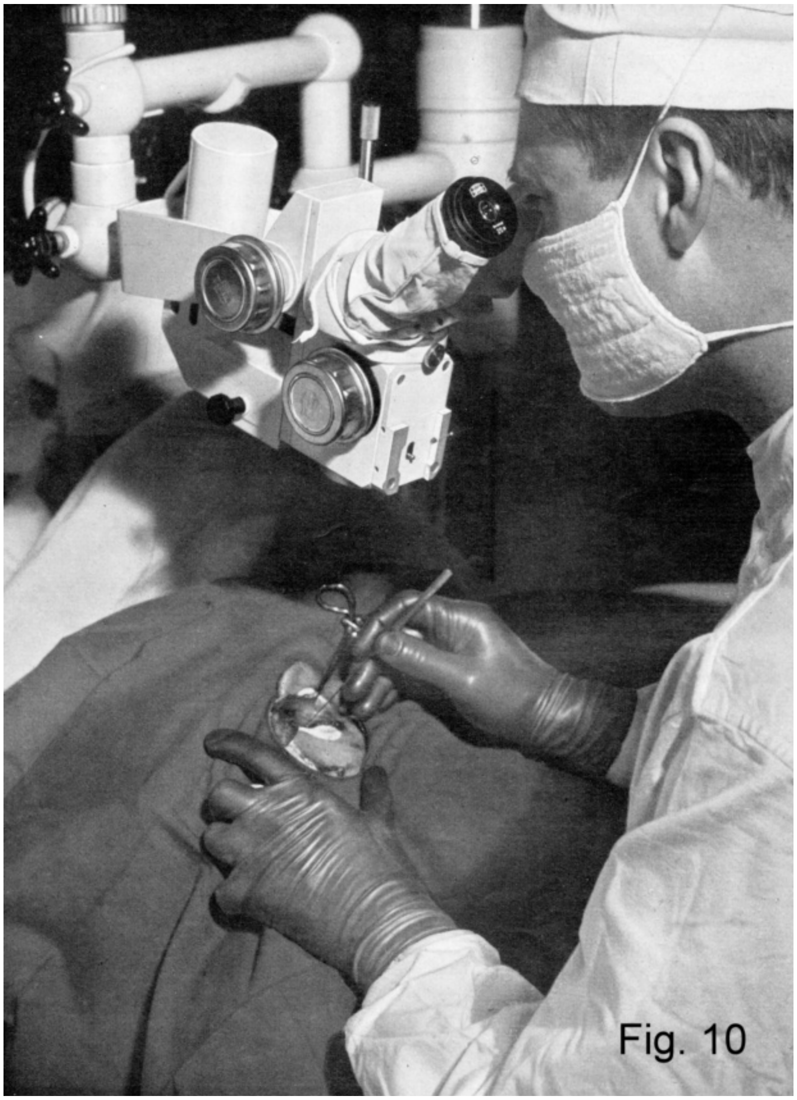


Fig. 10

The modern versions of operating microscopes are hardly recognizable with their space-age gimbal stands, fibre illuminators, motorized controls, and computer-assisted navigators. Their application now includes apart from otolaryngological (ENT – ear, nose and throat) and ophthalmic surgery also neurosurgery, plastic and reconstructive surgery, fertility surgery, dental surgery, and in a very simple version, electrolysis (hair removal).

Surgery with Opmi 1.
Notice the sterilizable stainless steel caps on the control knobs and the sterilizable linen cover on the binocular tube.

The Requirements of an Operating Microscope

Several parameters define a practical operating microscope:

1. It must have stereoscopic visualisation
2. It must have a comparatively long working distance
3. It must have an illuminating system that evenly illuminates the operating field
4. It must have a stable but mobile stand, with an articulated and balanced suspension.

Further desirable features are:

1. The possibility for an assistant to co-observe
2. The possibility to document the procedure
3. The possibility to adapt it to a wide range of procedures
4. The possibility to keep it sterile.

The Zeiss Opmi 1 (Fig.5)

The stereomicroscope from which Dr. Littmann developed his operation microscope is the one described in R. Jordan Kreindler's series on Stereomicroscopes (Micscape no. 203, Sept. 2012, Fig. 59). It was the first modern stereomicroscope constructed by Zeiss Opton, Oberkochen/West Germany, after WW II. It is based on the Galilean principle and has a 5 step magnification changer with constant working distance (Fig.4). First a coaxial illuminator was added with the light from a 6V 30W tungsten bulb exiting through the main objective and focused on the operating field. Next the rigid mount was changed to a swivel mount to allow the instrument to be positioned easily both horizontally and vertically in a wide range of angles. For work in the horizontal position a straight binocular tube could be used.
The achromatic "common main objective" (R. J. Kreindler's term) could be exchanged for any objective of 150mm (ophthalmic), 200mm (general microsurgery and otology), or 300 + 400mm (laryngology) focal length. The corresponding magnifications ranged from 4.4 – 32.5x . As more applications for this new microscope were found, the range of objectives was extended from 50mm to 2000mm* with a corresponding range of magnifications from 3 – 165x.

* For observation in "hot = radioactive chambers".

The 5 - step magnification changer in the cube-shaped body had the factors 0.4 – 0.63 – 1.0 – 1.6 and 2.5 with a stereo base of 22mm (distance between the optical axes of the two Galilean systems). Fig.11 shows the schematic optical system.

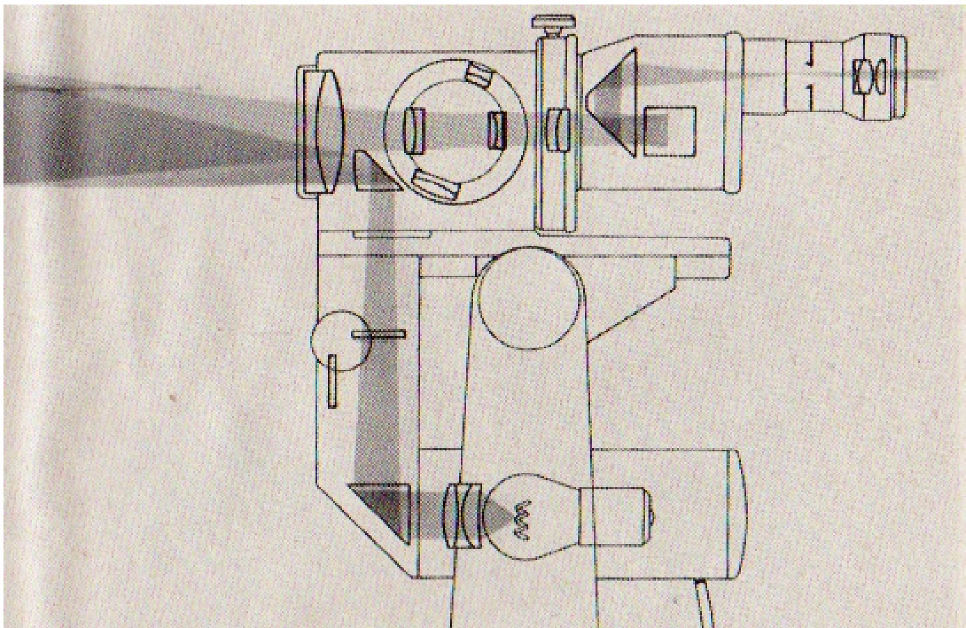


Fig.11

Schematic of the Opmi 1 showing the arrangement of the optics and the light paths.
Notice that the meniscus lens of the objective is on the object side (the object being in the focal plane), the biconvex lens on the infinity side. In a camera lens it would be reversed, the object being on the infinity side and the film in the focal plane.

The straight and binocular tubes, also derived from the Stemi 1 had initially a tube ID of 30mm which was reduced shortly after to 25mm. Two eyepieces were offered, 12.5x and 20x, both focusable and equipped to accept reticules, a demonstration eyepiece 10x came later. Several years later Zeiss changed over to high-eyepoint eyepieces with collapsible rubber eyecup which could be used by spectacle wearers.

The binocular tubes, which when equipped with an eyepiece actually form a telescope, had the focal length of f = 160mm. A second shorter set with f = 125mm came out later in order to maintain the compactness of the microscope as more accessories became available.

For the technically minded among the readers, the total magnification of the operating microscope can be calculated as follows:

$$M_{microscope} = f_{tube} / f_{objective} \times V_{mag.\ changer} \times V_{eyepiece}$$

M = total magnification, f = focal length, V = magnification factor

The field of view diameter is obtained by dividing 200 by M.

The control knobs of the magnification changer had the most common total magnifications engraved: 6 – 10 – 16 – 25 and 40x which corresponded to an objective f = 200mm and 20x eyepieces. In practice, the surgeon does not bother about which setting to select (unless he needs the exact values for a publication) but merely turned the knob until he arrived at the most suitable magnification for his work. The last version had the actual magnification factors engraved on somewhat smaller knobs (Fig.13).

On the body of the Omi 1 there were attached 2 receiver dovetails for accessories. The one in the front accepted a photographic attachment, the one underneath was intended for an electronic flash or a diverting prism to obtain 45° illumination (Fig.12). Finally, the range of the focusing mechanism was 45mm .

The “horseshoe” fork for the tilting was later replaced by a one-sided suspension arm in order not to limit the tilting range, a feature desired for neurosurgery. At the same time, the microscope body was redesigned and obtained a cylindrical shape and simpler lamp socket (Fig.13).

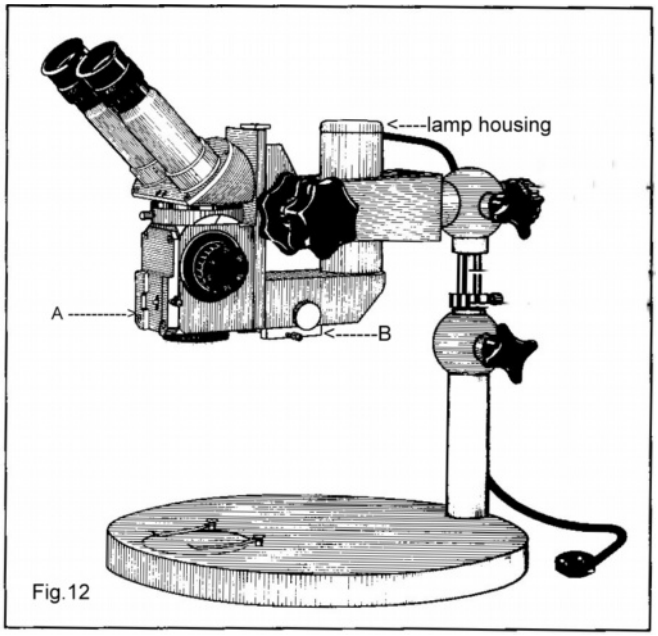


Fig.12

The Opmi 1 on table stand. The accessory dovetail A is absent on the new version. The model shown has already the larger plastic ergonomically shaped knobs for focusing.
The next generation of table stand was square.

Fig.13

The new shape of the Opmi 1 with the redesigned lamp housing, small knobs for the magnification changer, and single lateral suspension arm instead of the original fork.
The picture also shows a geared tilt coupling.

The Illumination

The original Opmi 1 had an integrated illumination system attached to the side opposite the operator. It consisted of a pre-centred 6 V 30 W tungsten bulb (Fig.14), a collector (the diameter of which defined the illuminated field), one each of a green (“red-free”) and a day-light filter, to be selected as desired, and a prism to divert the light through the objective onto the operating field. This prism which had one lenticular surface and acted as condenser was arranged parallel to the two Galilean systems immediately above the objective and the filament of the bulb filled its opening exactly. (You could compare this prism with the condenser aperture of a compound microscope)(Fig.11). Later models had a larger lamphousing with a 12 V 100W halogen bulb, recommended for video- and photography (Opmi 1 H – Fig.16) or a separate light source with an optical fibre guide ending directly at the illuminating prism (Opmi 1 F – Fig. 51 in Part 2)). The latter had the advantage of keeping the heat of the light source away from the microscope and the sterile drapes (see below).

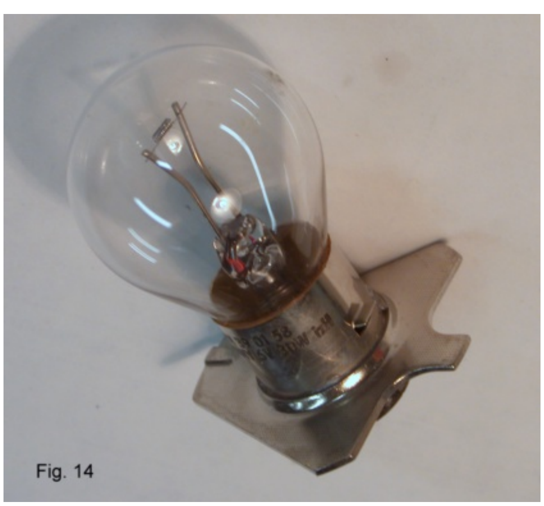


Fig. 14

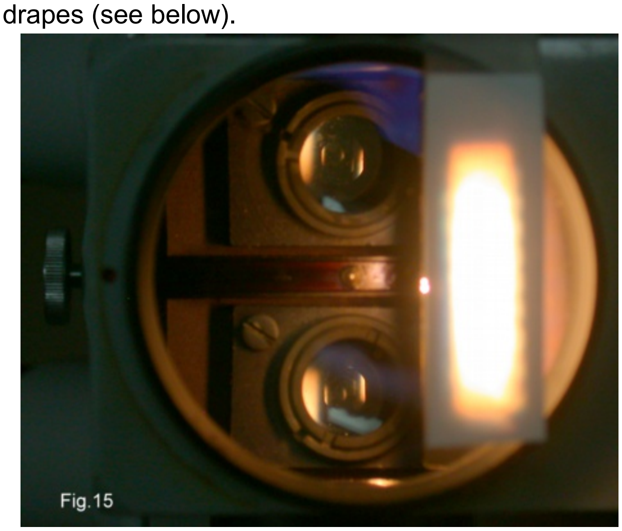


Fig.15

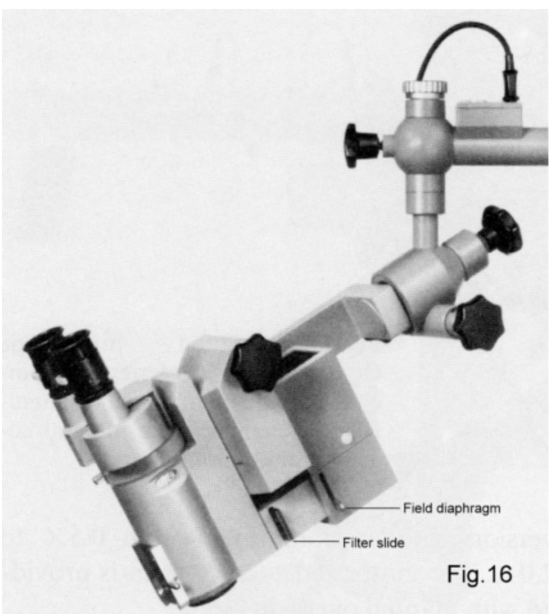
The precentred tungsten bulb 6V 30 W with its distinctive triangular bayonet

A view of the Opmi from below showing one Galilean system of the magnification changer and the illuminating prism (an overlaid paper is to show the lamp filament filling the prism)

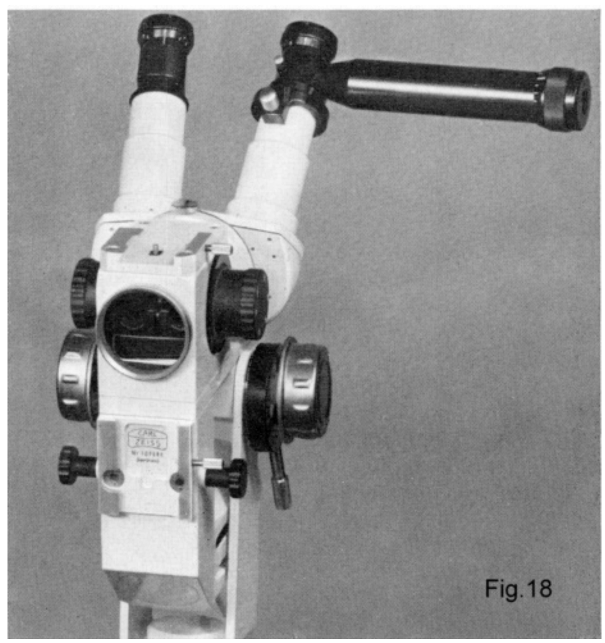
The oblique angle of the illumination was equal to half of the angle between the two Galilean systems, therefore, any cavity large enough to allow its base to be visualized stereoscopically also allowed the light to reach it. The so-called red-free filter increased the contrast in the mostly red operating field while the daylight filter reduced the red part of the tungsten light and provided a “colder” light preferred by some surgeons.

As mentioned earlier, ophthalmologists work almost exclusively with a vertically arranged microscope and oblique illumination. Several solutions were provided for this case. The first one was an attachable prism “diverter” which, clamped under the microscope, diverted the light emanating from the prism so that it fell onto the operating field under an angle of 45° (Fig.6). An objective of f = 200mm was a precondition for this accessory.
The second solution was to attach a simple 6 V 15 W low voltage microscope illuminator by means of an articulated holder to the microscope body, not a very satisfactory solution (Fig. 7 R).

Much better was an attachable slit illuminator that provided not only bright oblique illumination but also slit illumination, most desirable when operating on the anterior parts of the eye. This slit lamp with its 6 V 25 W bulb could be moved on an arc-shaped slide to select a suitable angle of incidence. As with the diverting prism, the slit illuminator required an objective of f = 200mm (Fig. 7 L).
There were two versions of this arrangement: one where this slitlamp was attached to a regular Opmi 1 on the back of the coaxial illuminator, and one which used a special Opmi body without the built-in coaxial illuminator and a fixed off-set (cranked) suspension coupling. The latter version was marketed under the name of *Operation Slitlamp* (Fig.8).



The Opmi 6-H with the large lamp housing for the 12 V 100 W halogen bulb.
The Opmi 1 could also be had with this light source.

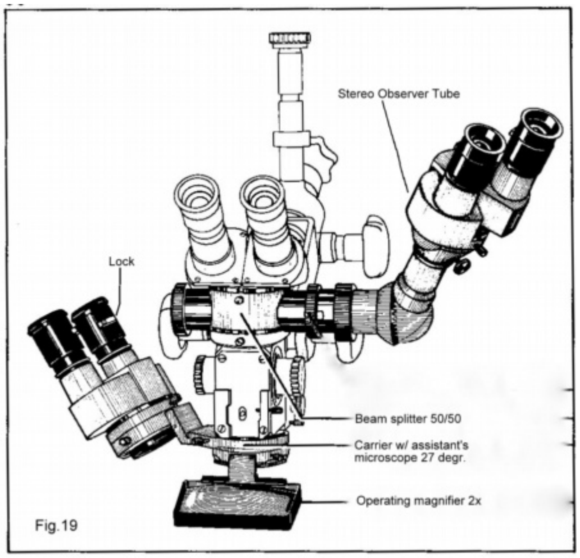


The demonstration eyepiece 10x and its matching second eyepiece 10x.

Co-observation/Assistance

Many surgical procedures require the presence of an assistant. This assistant must be able to see the same operating field as the surgeon and oriented for his own position. In some cases it is desirable that he or she has a larger view with a lower magnification. While in a strictly teaching or co-observer situation stereoscopy is not

absolutely essential, an assistant has to have stereo vision. Such considerations resulted in two different systems: one monocular for observation only and one stereoscopic for an assistant.
The first attempt for providing co-observation was the *demonstration eyepiece 10x* (Fig.18), an eyepiece with a small internal splitting prism and a lateral extension arm with a second eyepiece. A matching regular 10x eyepiece balanced the system. The orientation of the visual field varied with the position of the demonstration eyepiece which is a definite disadvantage.
For cases where the operating field is fairly flat and accessible, the *assistant's microscope 27°* (Fig.19), can be used. This accessory is mounted on a carrier ring which is either screwed above the objective or which incorporates the objective (f = 150 to f = 200mm only). It is a self-contained microscope which can also be fitted with a simple 3- step magnification changer and which can be rotated from side to side, providing considerable flexibility of the set-up. The focal length (working distance) of its main objective is 25mm longer than that of the main microscope.



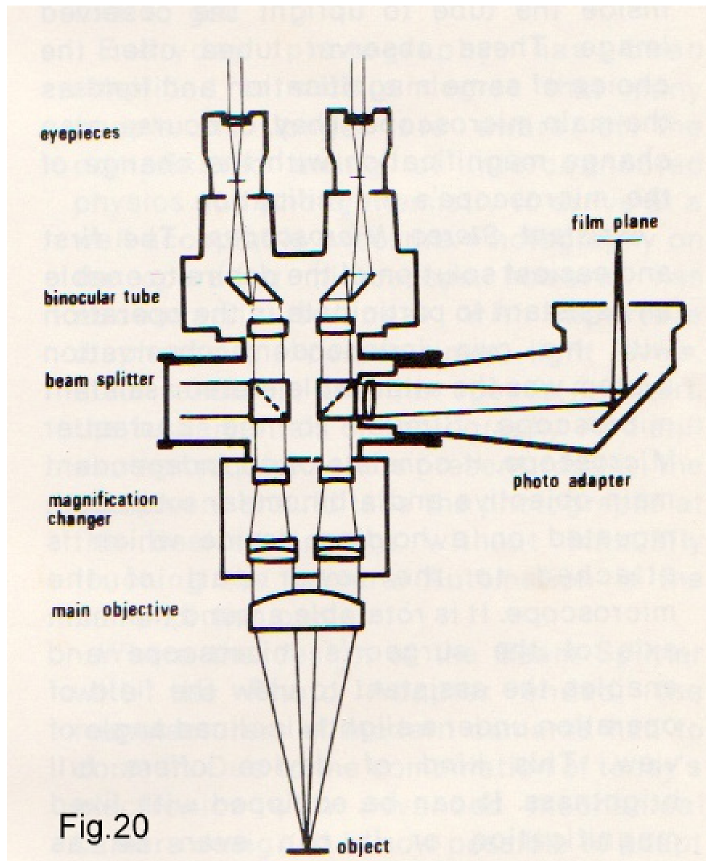


Fig.19
Assistant's Microscope 27°
Note new eyepieces with a ratchet lock to prevent inadvertent change of diopter setting.
Also shown is the Operating Magnifier 2x and the beam splitter with short monocular observer

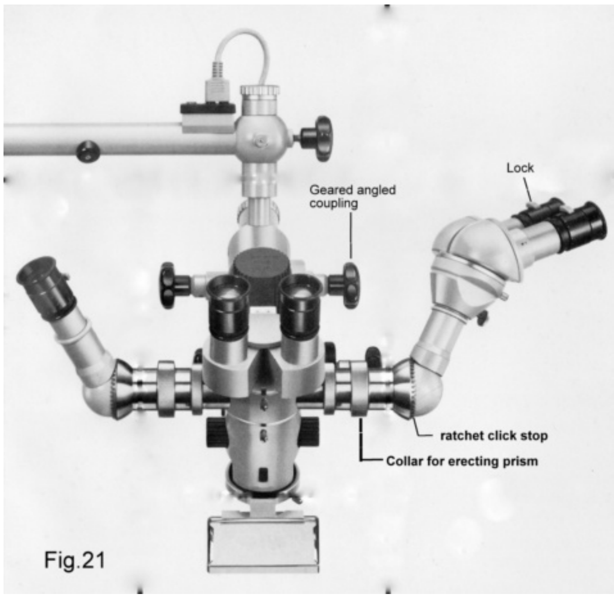
Fig. 20
Schematic of beam splitter with photo adapter

A great step forward was accomplished with the introduction of the *beam splitter* (Figs.20 and 21). This accessory is inserted into the parallel light path between the microscope body and the binocular tube. It contains two beam splitting prisms, one for each optical system, diverting the light sideways. A 50/50 split, mostly chosen for co-observation, and a 70/30 split for photography are available. To the lateral ports of the beam splitter can be attached a variety of accessories:

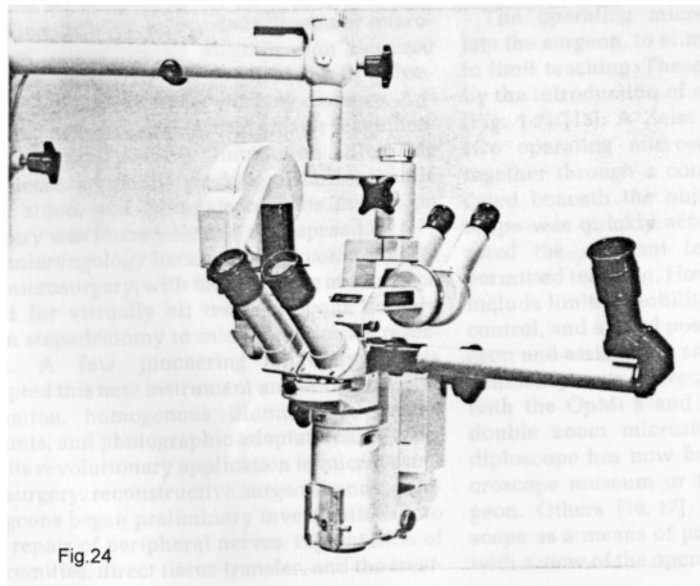
1. A short monocular observer tube (150mm) with an eyepiece of choice
2. A long monocular observer tube (~ 300mm) with an eyepiece of choice
3. A stereo-observer tube (83mm w/o tube) which requires in turn a binocular tube with eyepieces
4. A photo-adapter f = 220mm for 35mm photography via a standard 35mm camera body*
5. Cine-adapters f = 74mm (Super 8 format), 107mm and 137mm (for 16mm format or video)

Both the short and long monocular observer tubes as well as the stereo-observer tube incorporate a rotating (erecting) prism which allows the observer to orient the field of view either for observation/teaching – in which case the orientation corresponds to that of the surgeon – or assistant, in which case the view is oriented toward their position. This is an important point for when the surgeon says, for example: "See the nerve at 3 o'clock" , the co-observer must also see it at 3 o'clock. When assisting, on the other hand, it would be 6 o'clock or 12

o'clock depending whether he was located to the right or the left of the operating surgeon (Let us hope they do not depend on digital watches!!).
The long observer tube (~300mm) is intended for a nurse "out of the way" to follow the procedure and be able to have the next instrument ready.



New Opmi 1 with beam splitter, short observer tube, and stereo obserever tube.
Also shown is the operating magnifier 2x



House-Urban Quadroscope attached to an Opmi 6.
It consists of their own "stereo beam splitter" with lateral ports, the left having the HU cine camera and the right their new monocular observer tube with tiltable eyepiece. Their standard observer tube had a fixed eyepiece at right angle.
(Courtesy of Urban Engineering Co.)

The stereo-observer tube employs the same trick to obtain stereoscopy as the main microscope: the one optical beam is again bisected by means of a double prism with a reduced stereobase of 7mm, resulting in a considerably diminished stereo impression, inadequate for assistance but better than no stereopsis at all. The total overall length of this accessory and the distance of the observer from the operating field makes it impractical for assistance. All these three accessories can be rotated around the optical axis of the port of the beam splitter and secured in any position by a ratchet click-stop. The binocular tube of the stereo observer tube can itself be rotated to a convenient position.

Independently from Zeiss the American company *Urban Engineering Co., Burbank, California*, designed in consultation with a Dr. House a range of observer-, photographic-, and cine attachments which became quite popular.
The "House-Urban Observer tubes" were integrated into the eyepiece of a modified straight or inclined binocular tube which had to be sent to California for the alteration. The laterally arranged tubes were ca. 200mm long with the eyepiece parallel to the binocular tube. The observer's view was identical to the surgeon's. Another version utilized a multi-port beam splitter (Fig.24).

Documentation

The first attempt for documentation was a self-contained, independent *photo-attachment*, not availing itself of the microscope optics (Fig.22). It consisted of a main body or camera carrier attached to the accessory dovetail at the front of the microscope body. At the upper end it had a receiver dovetail for regular 35mm camera bodies, at the lower end a smaller receptacle for individual photo objectives of f = 125mm f/45 - 64 (1x) and f = 125mm f/45 - 90 (2x) as well as f = 200mm f/32 – 64 (1.25x). The former were intended for ophthalmic versions of the operating microscope, the table stand, and the slitlamp of similar design. The objective f = 200 was the standard one for surgery. Each objective had an iris diaphragm for depth control and a narrow prism located opposite the illuminating prism under the principal objective and in between the two Galilean systems. A reticle fitted into one eyepiece served to assure the correct focus. For higher magnifications a 2x converter could be inserted between camera carrier and camera body.

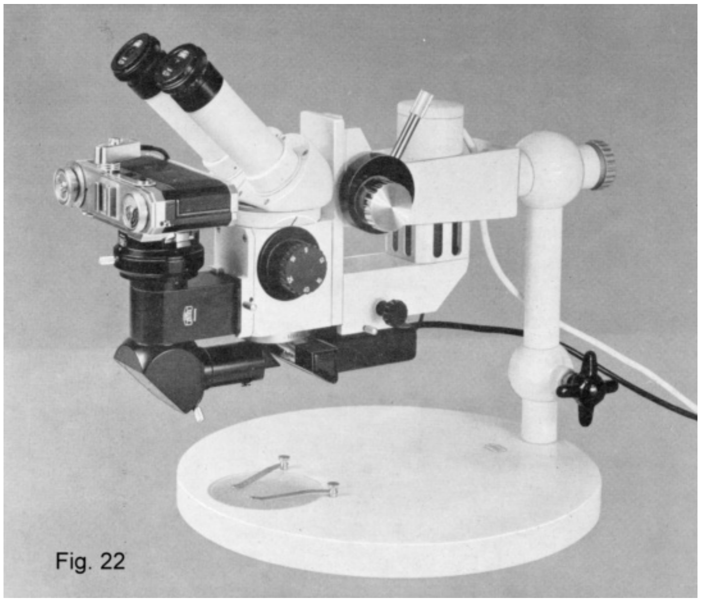


Fig. 22

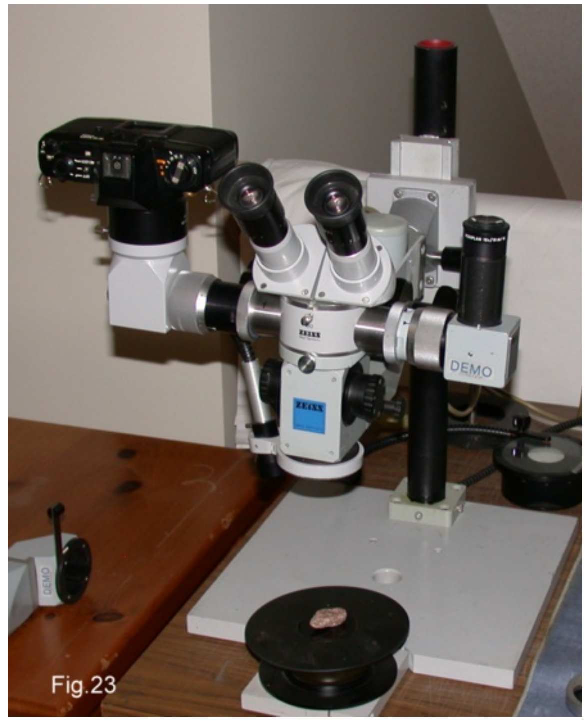


Fig.23

Opmi 1 with photo attachment with Contax camera body and electronic flash.
The inclined tube takes eyepieces for 30mm ID. A special clamping lever serves to lock the tilting mechanism to prevent accidental tipping.
In this case both microscope and camera objective would be f=150mm.

The author's own reconstructed Opmi 1 with 50/50 beam splitter, camera attachment with 2x converter and Contax 137MD on the left, a cine adapter f=137mm modified to take a Leitz Periplan 10x/18 (high eyepoint) eyepiece for attaching a Nikon Coolpix 995 digital camera.
The main objective f=150mm with carrier ring holds an oblique fibre illuminator.
The object lies on a tiltable ball stage. For coarse height adjustment the entire assembly can be raised on a dovetail on the black supporting column.

The electronic flash 80WS was attached to the other dovetail receptacle on the underside of the microscope, then connected to a special flash power supply unit. For photography of narrow cavities it could be slipped forward into the path of the illuminating prism, the light of which then passed through the flash tube arrangement..

With the arrival of the beam splitter a more versatile and practical *photo adapter* became available, this one utilizing the microscope optics and its range of magnifications and working distances (Figs.20 and 23).
The beam splitter being inserted into the parallel beam path of the microscope means that any image lies at infinity. The photo-adapter required merely an objective to focus this image at the right size into the required focal plane. Adapters for commercial 35mm camera bodies were provided, the preferred being initially the Zeiss Ikon Contax, later on the motor driven Yashica Contax RTS or 137 MD. Normally the image had a diameter of 22mm only, but a supplementary 2x converter provided a full 35mm image at the expense of longer exposure times (a 1.6x converter offered a compromise). All documentary adapters had an adjustable iris diaphragm. To do away with all manual setting of the photographic attachment, particularly awkward with a draped microscope, an automatic adapter could be chosen. This one controlled the iris diaphragm through a light sensor covering a central 12mm diameter area and powered by two long-life batteries. Only 10% of the available light was diverted for the sensor. The surgeon could now change the magnification without worrying about the correct exposure.
For cinematography specially modified Beaulieu Super8 or 16mm cameras controlled the diaphragm motor by their own sensor.

The Urban *quadroscope* beam splitter (made by the Urban Engineering Co. mentioned earlier) had two lateral ports, one for a 35mm camera or a video- or cine-camera, leaving the other port of the beam splitter available for an observer tube. The opposite main port was for a second binocular tube (Fig.24).
Urban Engineering also sold a very compact 16mm cine camera attachment for the Zeiss beam splitter, with easily interchangeable magazines. This accesssory also proved to be quite well received (Fig.26).
Another Urban accessory was the *stereo-photoadapter* which divided the standard 35mm frame in two stereo-halves which could be observed in a stereo viewer or projected with the appropriate equipment. This particular adapter fitted under the binocular tube while the optics diverted the image back and up “behind” the microscope (Fig.25).

Fig.25

The House Urban Stereo Photo Adapter on the author’s Opmi 1. The camera is a Contax 139.

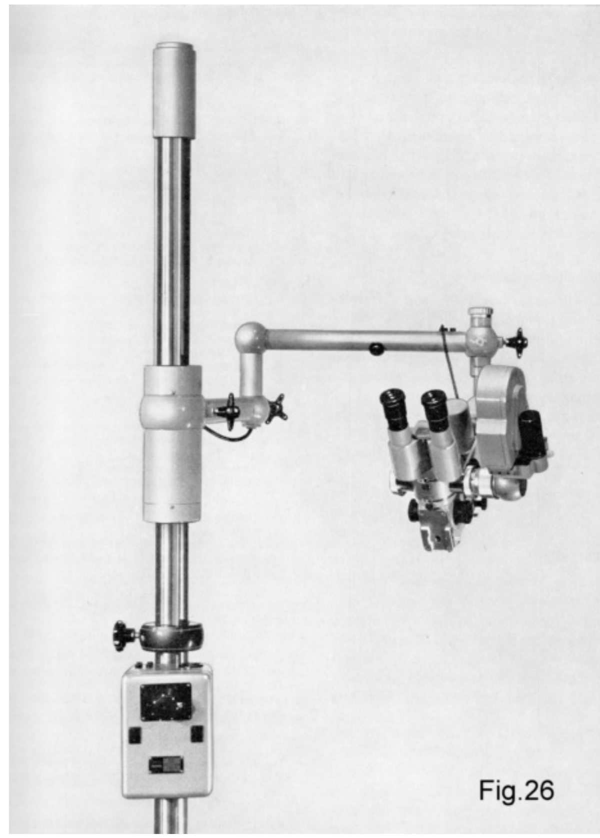


Fig.26

The House-Urban 16mm Cine Camera on an Opmi 1.The black cylinder on the right is the drive motor. The film magazine itself could be exchanged in seconds. A special power supply to control camera and light source was part of the system.

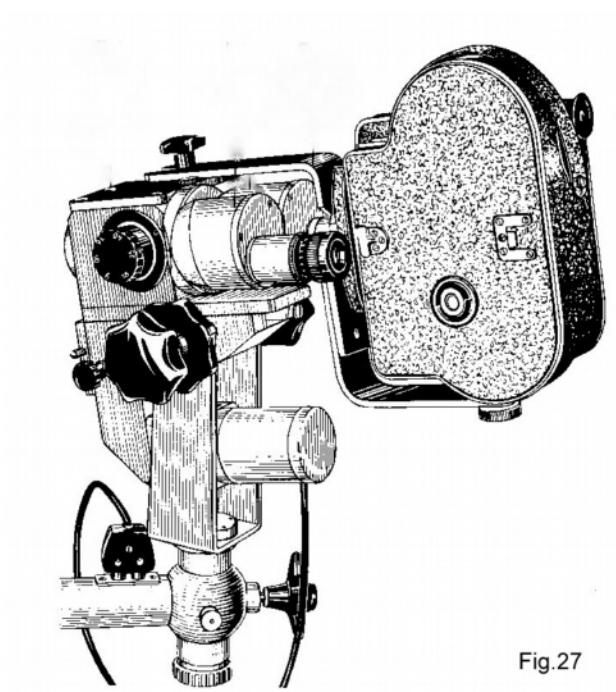


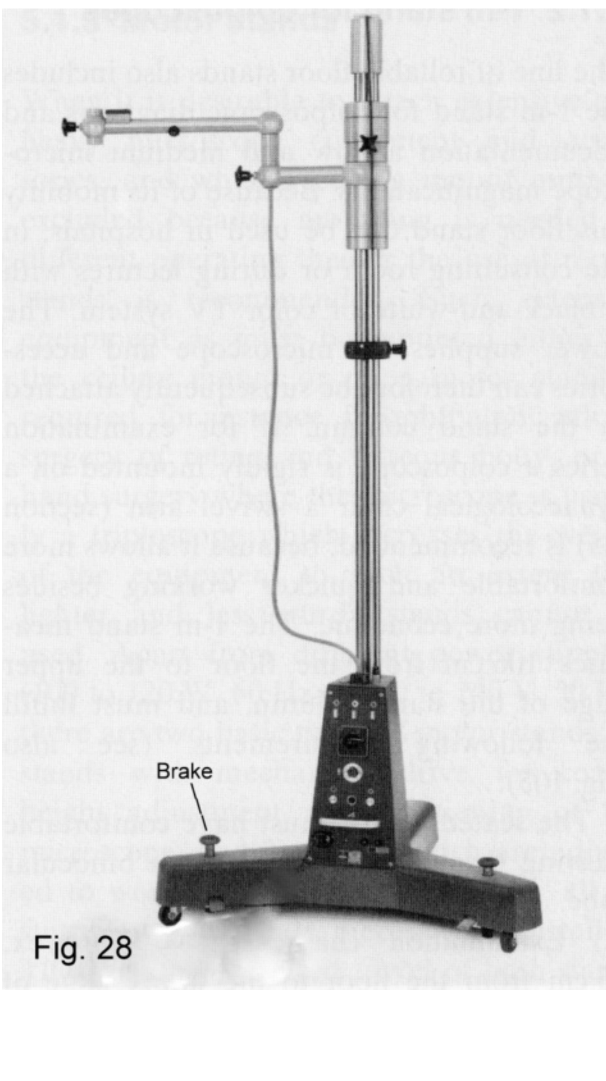
Fig.27

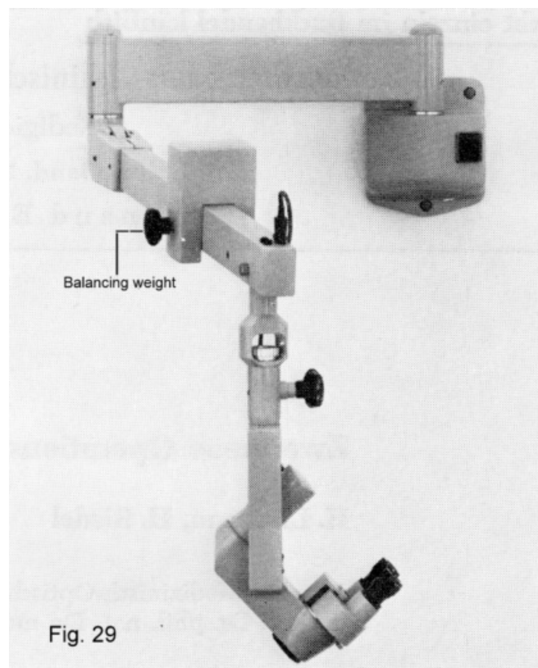
The first attempt to mount a 16mm cine camera (Bolex H 16) on an Opmi 1.
The heavy camera, carried by a special bracket, fitted over a modified straight binocular tube, with the film plane being in the image plane of the binocular tube (compare Fig. 20)

I should mention here that the very first attempt of cinematography was a rather primitive one: a straight binocular tube was modified in so far as one eyepiece tube was replaced by a simple sleeve that could accept a Bolex H 16 camera, supported by a special bracket (Fig.27). The film plane was located in the image plane of the binocular tube. The standard 6 V 30 W bulb was replaced by a 6 V 50 W bulb run off a special power supply that boosted the light output during the actual filming. The operator had to squint through the remaining eyepiece which was, of course, pretty close to the camera body. It is obvious that such an arrangement could only be used by pioneering experimenters willing to endure any inconvenience to achieve a result. It is also indicative of the company's philosophy for a long time to meet new demands by simply modifying existing apparatus instead of designing bespoke instrumentation, perhaps for fear of incurring high development costs for a non-profitable short-lasting fad. It is amazing what progress has been made since. All this paraphernalia has been replaced by a tiny integrated fully automatic high resolution video camera with instant display and recording!

The Stand/Suspension Systems

The original floor stand (Fig.5) consisted of a T-shaped base on castors with screws for leveling and locking. These screws were soon replaced by a central brake. The base also contained the power supply unit 40VA and the optional 80Ws flash generator. A vertical column to a height of 1.9m was later supplemented by one 2.1m. The colposcope version featured a column of 1.0m (Fig.9).
A carriage running on 6 ball bearings held the articulated 3-jointed lockable arm and was balanced in its up-and down-movement on the column by internal lead counterweights suspended on dual perlon ribbons. Several removable counterweights were provided. These could be taken off to maintain equilibrium when heavy accessories were attached to the microscope. As a safety feature a clamp ring under the carriage prevented the microscope from falling should the nylon ribbons break (which to my knowledge never happened).
A number of special couplings could be chosen from to either extend the articulated arm, allow different configurations of the microscope or arrange its axis of rotation to coincide with its optical axis as desired for ophthalmic surgery. The latter type of surgery was also simplified by the optional addition of a so-called "motor head" to the top of the column. The ophthalmic surgeon could now focus easily up or down by a foot switch.





Wall mount with Opmi 9 (No magnification changer, no focusing mechanism),
A 3-step magnification changer was optional. Vertical range 1000mm. The sliding balancing weight was mainly intended for adding and removing accessories such as observer tubes

Fig.28
The second generation of floor stands Standard II with power supply for illuminators and motor head 5mm/sec. as well as for an electronic flash. A more versatile floor stand Universal could also power motorized microscopes

The built-in power supply had a low-high switch that could be activated by foot. The much improved floor stands Standard I and II (Fig.28) and Universal, introduced ca. 1967, incorporated a larger, more versatile power supply for up to 3 light sources and electronic flash but retained all mechanical features of the previous versions. The Standard Universal accommodated the motorized operating microscopes as well. A wall mount (Fig. 29), specifically designed for doctors' offices appeared later.

In an effort to reduce the clutter in the operating theatre, Zeiss introduced in the mid 70s a *ceiling mount* for its operating microscopes. The first version was electro-hydraulic, one consideration being that it had to be explosion-proof (Fig.30). The control unit was, therefore, located outside the operating room. The vertical range was 500mm with an adjustable speed of 4mm/sec to 25mm/sec.
If desired, one or two HANAU operating lights could be attached to the ceiling mount. The ultimate comfort for the surgeon came in form of a special operating chair with integrated foot controls for the microscope, with motorized height adjustment, and arm rests.

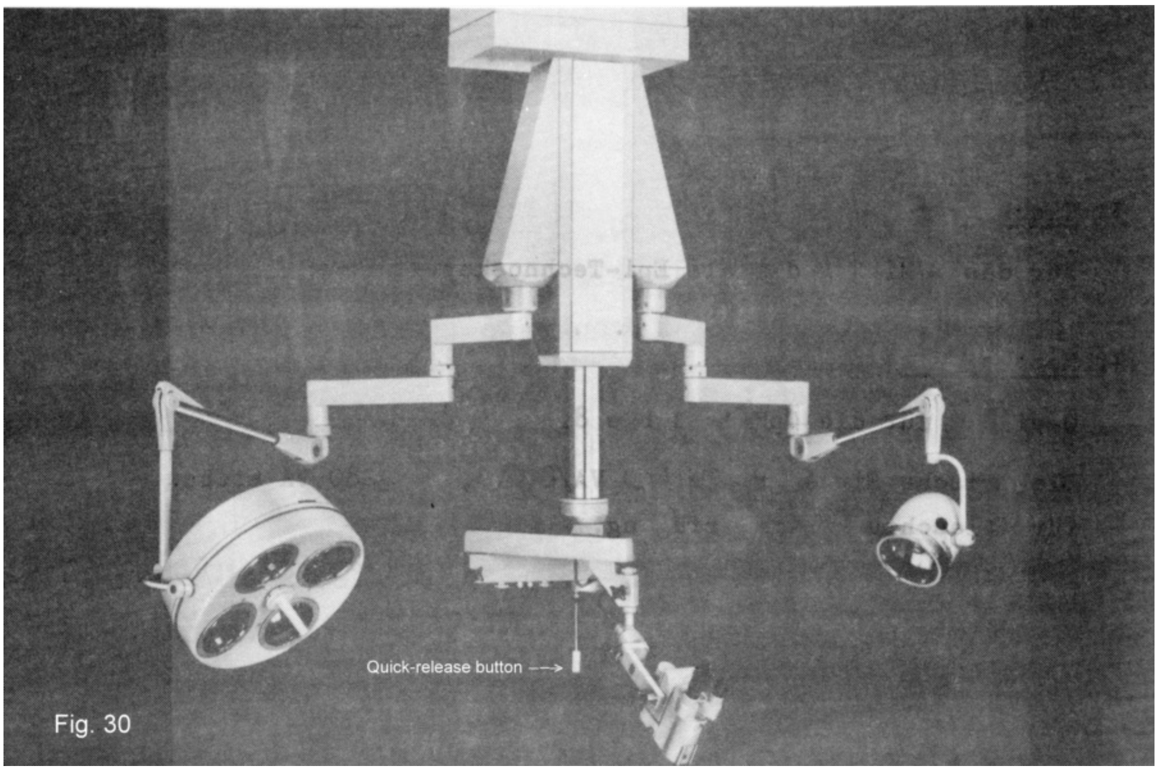
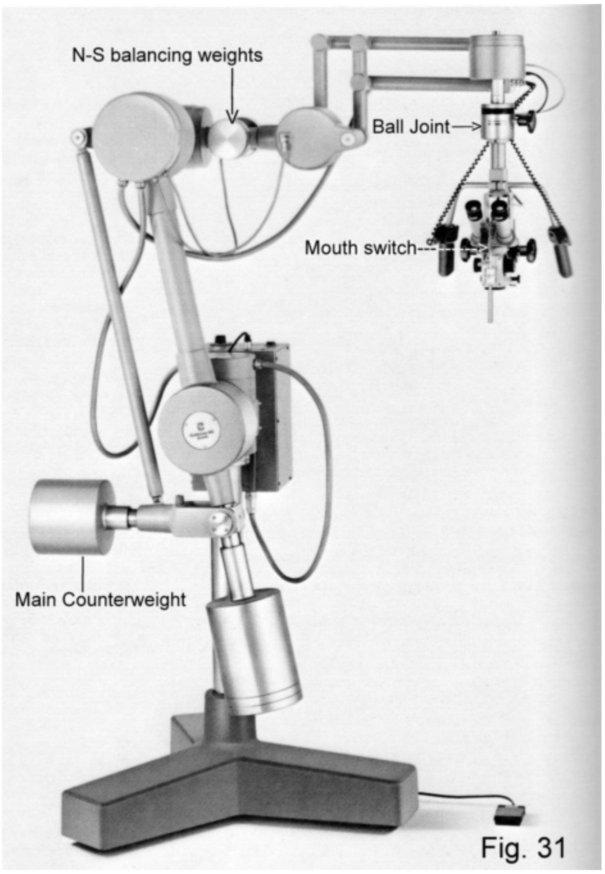


Fig. 30

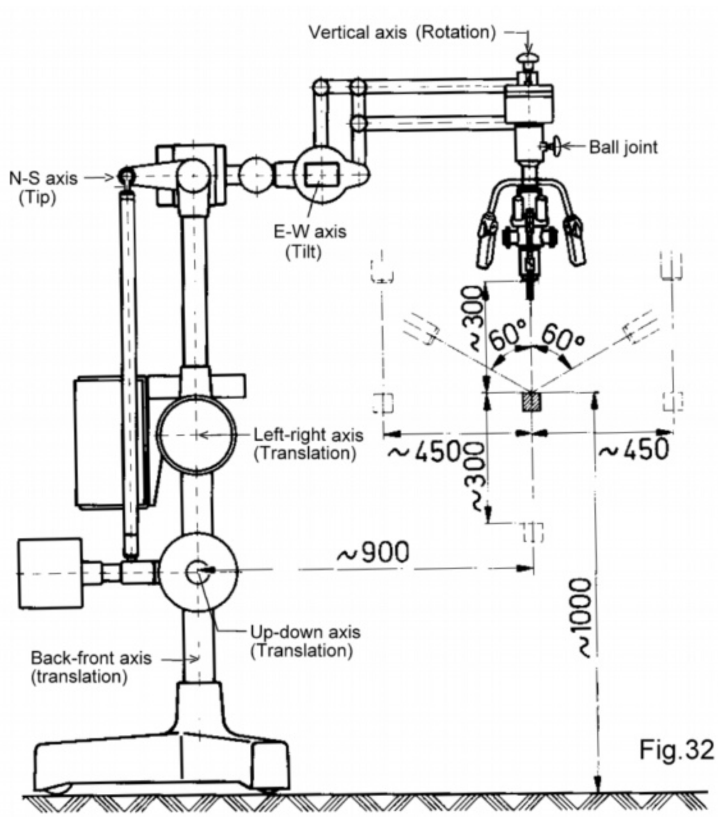
Electro-hydraulic Ceiling Mount, with two optional Hanau operating lamps.

One special development I would like to mention here. Based on an idea by Prof. Dr. Mahmut Gazi Yaşargil, the world-renowned founder of microneurosurgery of the brain, at the University of Zũrich, Switzerland, the Swiss company Contraves designed a free-floating suspension stand for the Opmi (~ 1976). Its principle is strikingly simple, though surprisingly little understood (Figs. 31and 32):
A balancing arm in form of a parallelogram carries on one end the microscope and on the other an equivalent counterweight. By screwing this weight further in or out the system can easily be balanced if extra accessories are attached to the microscope.
The microscope in turn is suspended in a sort of three-dimensional (3 axes) gimbal arrangement in such a way that the centre of gravity of the entire instrument including whatever accessories are used can be brought into the intersection of the three spatial axes – in which case it becomes "weightless", in other words, there will be no momentum in any direction if moved. This adjustment will not affect the original balancing.
The microscope can now be moved "weightlessly" without any effort in 3 translational directions and 3 rotational axes. The surgeon guides the microscope with two handgrips with switches. To secure it in the desired position electromagnetic locks are activated. Microsurgery of aneurisms in the brain requires high magnification with

concomitant little depth of field. The soft brain tissue also easily deforms and frequent refocusing becomes necessary. It is nearly impossible for the surgeon to interrupt his delicate procedure to refocus the microscope, so Dr. Yaşargil designed a mouth switch with which to unlock and refocus/reposition the microscope. Zeiss soon obtained the rights to this so-called *"Contraves-Stand"* and began to manufacture it both as a floor stand and a ceiling mount. A simplified version designed for otolaryngologists followed shortly after.



"Contraves" mobile floor stand for Neurosurgery. The mouth switch for easy manipulation is indicated. The ball joint, when loosened let the microscope assembly find its vertical axis for the centre of gravity. The microscope assembly could be moved up or down to bring the centre of gravity into the E-W axis, a dumb-bell balancing weight acted on the N-S axis. A corresponding ceiling mount was also made. The first version did not have the second large lower counterweight.



Functional schematic for Contraves floor stand with indication of ranges of movement

Asepsis

One important consideration was how to keep the microscope over the operation field in a sterile condition. The first attempts to wipe it with an antiseptic solution were soon discarded as the instrument became rather sticky. Sterilization in a gas chamber overnight was both expensive and impractical. Then sterilizable linen bags with appropriate openings for the objective and eyepieces were employed. These were often designed by the hospital's nurses on an individual basis. Zeiss provided sterilizable stainless steel caps (Fig.10) for the magnification changer knobs and similar autoclavable rubber caps for the locking knobs and sleeves for the eyepiece tubes.

A major improvement were the disposable clear plastic antistatic drapes (Fig. 33) marketed by an American firm in the late 60s. These were offered in a variety of designs to accommodate different observer tubes and other accessories. Each drape had a rubber mount with a removable clear acrylic window that could be slipped over the microscope objective to secure the drape without obstructing the surgeon's view. Should the window become splattered with blood or another liquid, it could quickly be removed. The drapes used adhesive strips or

Fig. 33

A nurse fitting a disposable transparent drape over a microscope. The red buttons on the eyepieces on the right are the locks that prevent the diopter setting from changing inadvertently.

rubber bands to secure them around the microscope, articulated arms, and observer tubes or assistant's microscopes.

There remained still the problem of heat accumulation inside the drape from the microscope's illuminator. As more and more microscopes came equipped with fibre light sources mounted away from the actual instrument, heat was no longer a problem.

Different Versions of the Opmi

The basic modular principle of the Opmi made its adaptation to new and specialized surgical procedures a fairly simple matter. Among the famous names connected with the development of the operating microscope we find also Dr. Ignacio Barraquer (sen.), who in 1969 founded the Barraquer Institute of America in Colombia, a centre for ophthalmic surgery. He is famous for his contributions to cataract surgery. His son José Barraquer is known as the "father of modern refractive surgery". Dr. I. Barraquer suggested early on a simple operating microscope without magnification changer and internal illumination, but instead with two external angled light sources, one a homogeneous illuminator providing an evenly illuminated circular field, the other being a slit-illuminator familiar to all ophthalmologists . Both could be rotated around the microscope axis. A simple 3-step magnification changer could be interposed under the inclined binocular tube if so desired. This particular version was called **Opmi 3** or **"after Barraquer"** (Fig. 34)**.** It was suspended vertically with the optical and rotational axes coaxial and had no internal focusing mechanism but used a motor head instead. A special accessory was a large rectangular 2x magnifier, arranged in front of the microscope body, to overlook the operating field in preparatory work.

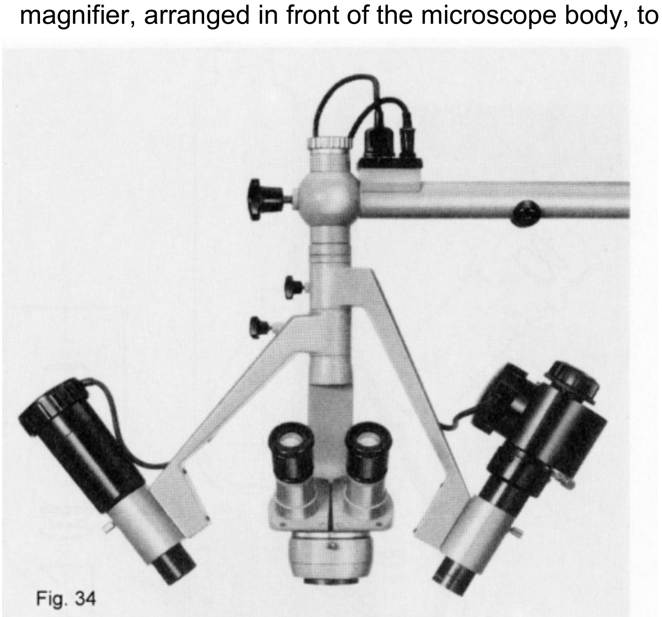


Fig. 34

Opmi 3 "after Barraquer", with homogeneous illuminator (left) and slit lamp (right). A 3-step magnification changer was optional

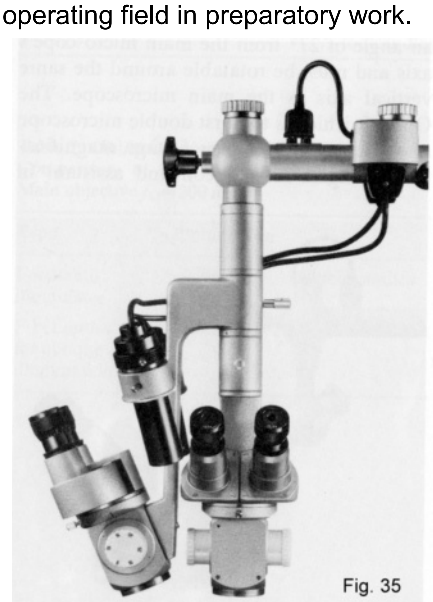


Fig. 35

Opmi 5 or "double microscope after Harms" with two basic Opmi 1 bodies w/o internal illuminator on one common rotational axis. Two low voltage microscope lamps provided oblique illumination

The **Opmi 4 after Barraquer** enjoyed only a short life, being superceded by more versatile equipment. The Opmi 4 was a simple arrangement of a microscope body without magnification changer or focusing mechanism, a homogeneous illuminator and a cine camera with close-up objective, all arranged in a triangular form. It was supposed to facilitate cinephotography of ocular surgery. The arrival of the beam splitter with a choice of cine-adapters spelt the end of the Opmi 4.

The **Opmi 5 "after Harms"** (Fig. 35) consisted of an Opmi 1 body without focusing mechanism and built-in illuminator, suspended for ophthalmic surgery vertically with coaxial mechanical and optical axes and an inclined binocular tube. On the suspension shaft was mounted a second rotatable arm at 27º carrying a second microscope body with 5-step changer and a straight binocular tube. The objective of this microscope had a focal length 25 mm longer than that of the main microscope.
Two external 5 V 15 W illuminators, focused on the operating field, complemented the set-up.
As with the Barraquer microscopes, focusing was done by means of the foot controlled motor head.

In 1961 the **Diploscope** was introduced (Fig. 36). This was a true double microscope for surgery by two opposing surgeons, each one having his own control over focusing and choice of magnification. The Diploscope consisted of two regular Opmi 1s with straight binocular tubes joined together vis-à-vis in a common fork with gear tilt. A large prism combined the optical paths so that both surgeons could see practically the same field under an angle of approx. 12º. The Diploscope was intended for neurosurgery and such cases where documentation, particularly cine- or video-documentation, would have been too intrusive on a regular microscope. In order to obtain a reasonable working distance, the objectives used were either f = 320mm for an effective working distance of 150mm and f = 400mm for a WD of 230mm. Magnifications ranged from 2 – 20x for eyepieces 12.5 and 20x resp. The suspension fork was in turn mounted on an asymmetric arc that allowed the microscope to be tilted sideways 45º max. or 25º either way if mounted accordingly. The entire double microscope could be tilted by the gear in the fork ca. 25º both ways (Fig.37).
The floor stand had to be fitted with extra counterweights and power supplies, particularly if additional illuminators were attached. For asepsis small sterilizable linen covers for each microscope body or a large linen drape for the entire double microscope were available in addition to the usual sterilizable caps for the various control knobs.

Bulky as it was, the Diploscope was nevertheless well received as it offered, for the first time, the possibility for two surgeons to work together in deep cavities or to film certain procedures conveniently (Fig.38). Still, it did not survive long as it was soon made redundant by the arrival of the stereo beam splitter.

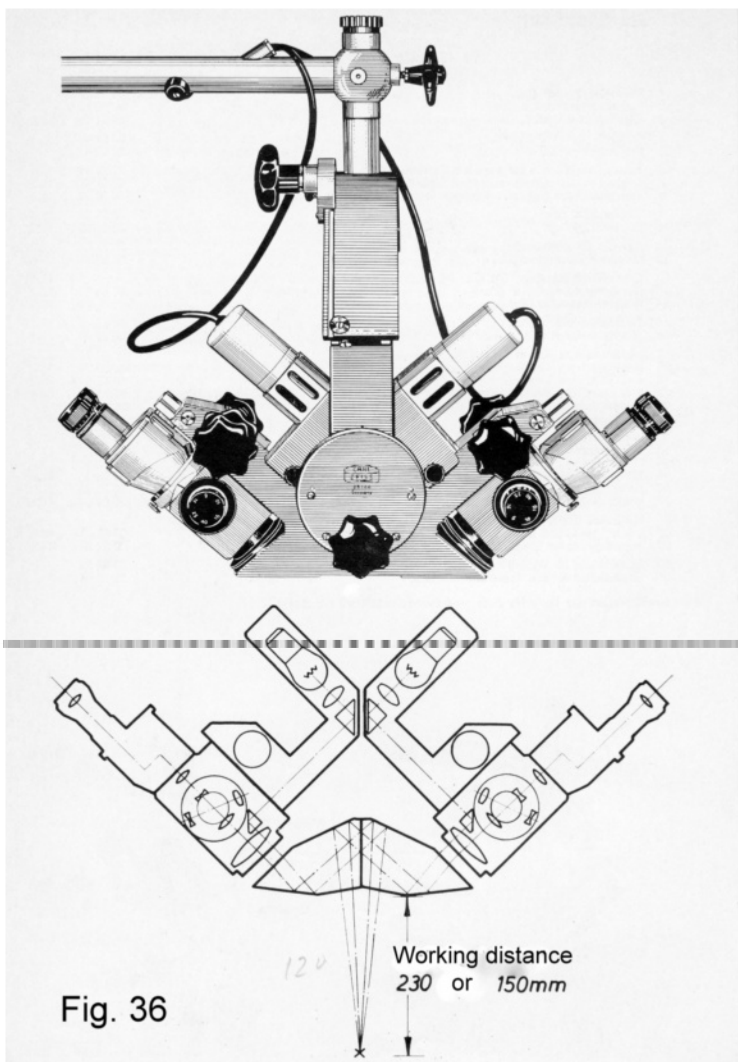


Fig. 36

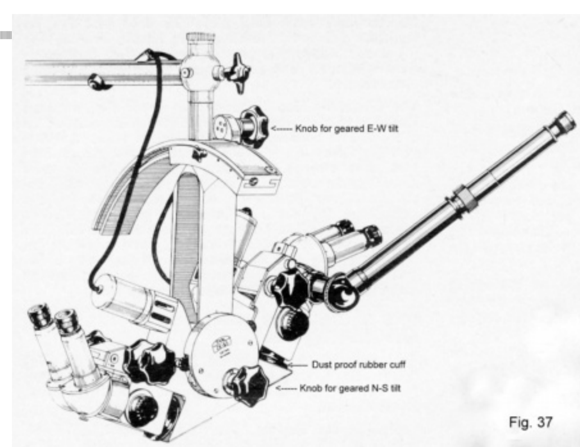


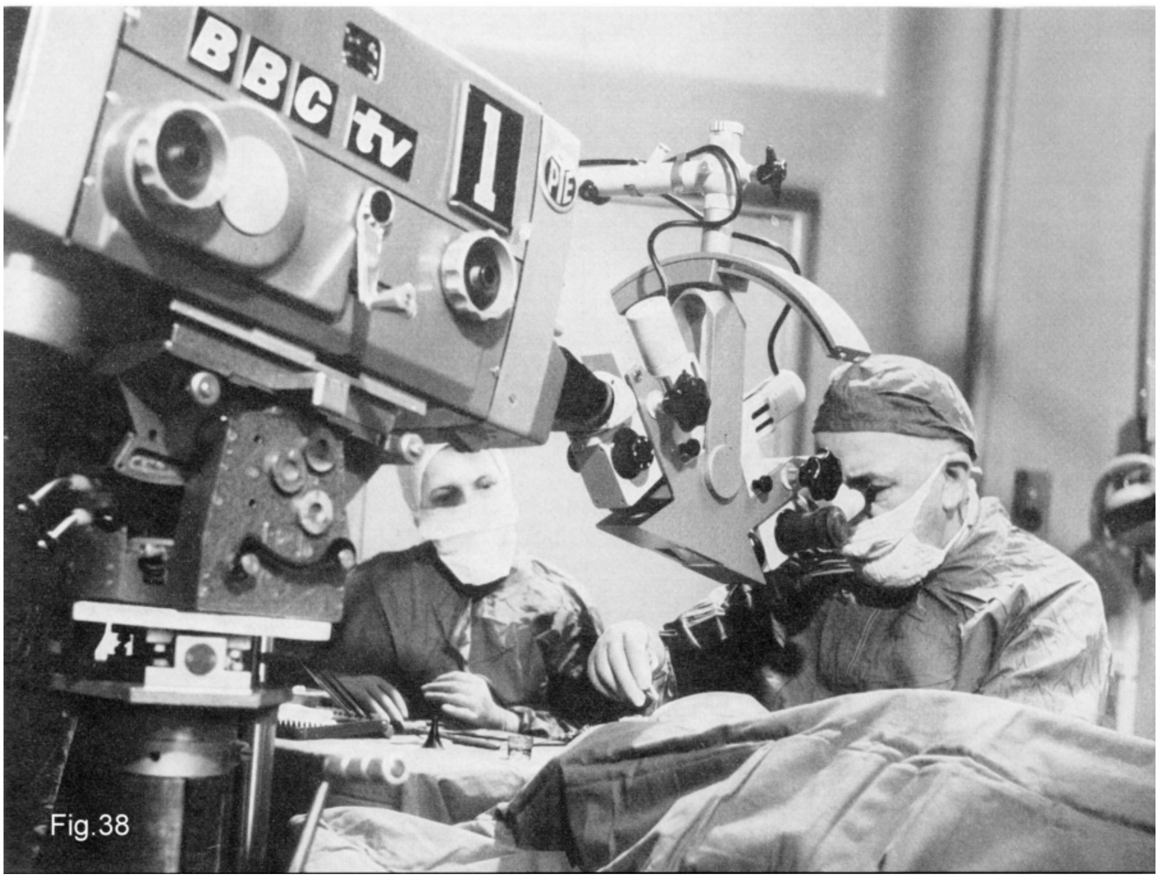
Fig. 37

Fig.36

The Diploscope and its schematic. By means of the large black knob in the centre the diploscope can be tilted N-S. The optical schematic also shows that each surgeon sees the object from his partner's side at a slight angle of approx. 12 degrees.

Fig.37

The Diploscope angled N-S, with inclined binocular tubes and one long observer tube, The arc for E - W tilt is clearly shown.



The Diploscope during an early TV documentation by the BBC at the King’s College Hospital, London, on Feb. 5 ,1962 , operating surgeon Mr. Cawthorne.

In Part 2 of this article the motorized and zoom versions of the operating microscopes among others will be discussed, ending in the period of the mid 1980s.

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