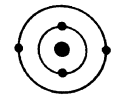

Appendixes

A

The Zeiss Operating Microscope

The optical principles of the Zeiss OPMI 1, 6-S, and 7 P/H operating microscopes are discussed, along with standard and fiberoptic illumination systems and the range of currently available support systems.

JOURNAL OF MICROSURGERY 1:364–369 1980

THE OPERATING MICROSCOPE I. OPTICAL PRINCIPLES, ILLUMINATION SYSTEMS, AND SUPPORT SYSTEMS

PETER HOERENZ, Dipl.-Ing.-Phys.

Editor's Note: This is the first in a series of five articles by Mr. Hoerenz on the basic principles and construction of the operating microscope. Future articles will discuss the individual parts of the microscope, accessories, methods for documentation, and maintenance and cleaning.

Since the invention of the operating microscope and the spread of microsurgical procedures through the various surgical disciplines, a large number of specialized operating microscopes have appeared in the world marketplace. The discussion here will focus on three operating microscopes manufactured by Carl Zeiss, the OPMI 1, 6-S, and 7 P/H, which are designed to meet the needs of otorhinolaryngology, neurosurgery, gynecology, urology, plastic surgery, and the other surgical disciplines (figs. 1–3).

OPTICAL PRINCIPLES

The optical principles of the OPMI 1 instrument are presented in figure 4. At the front end of the microscope, a large-diameter main objective lens receives an image of the object situated at the objective's focal point and projects this image to infinity. This means that the light rays leaving the front objective are parallel to each other. Behind the front objective there is a miniature telescope system, the magnification changer, which, much like field glasses of the Galilean design, takes the parallel-ray image from the main objective lens and increases or decreases its magnification. The rays that leave the Galilean system are again parallel and are picked up by another telescope system—the binocular tubes. The objectives of the binocular tubes transmit intermediate images of the object to the eyepieces, or oculars, under repeated magnification.

In effect, within each microscope, a multiple-step magnification takes place, and this is expressed in the magnification formula:

$$M_v = \frac{f_T}{f_0} \times M_E \times M_C$$

In order, therefore, to calculate the visual magnification (M_v) of a microscope, it is necessary to have data on the focal length of the binocular tube (f_T), the magnification factor of the magnification changer (M_C), the focal length of the principal objective (f_0), and the magnification power of the eyepieces (M_E). The Zeiss OPMI 1 microscope provides five magnification steps in a range of 1:6, the Zeiss OPMI 6-S zoom system provides a continuous magnification range of 1:4, and the OPMI 7 P/H zoom system provides a continuous magnification range of 1:5. The data for the factor M_C of the magnification changers in these three systems are presented in table 1.

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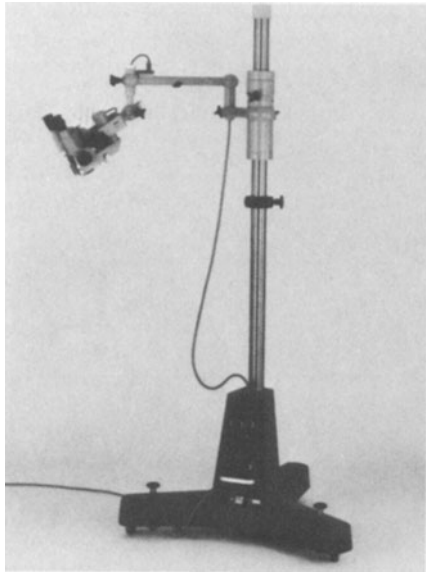


Figure 1. A Zeiss OPMI 1 with moveable floor stand.

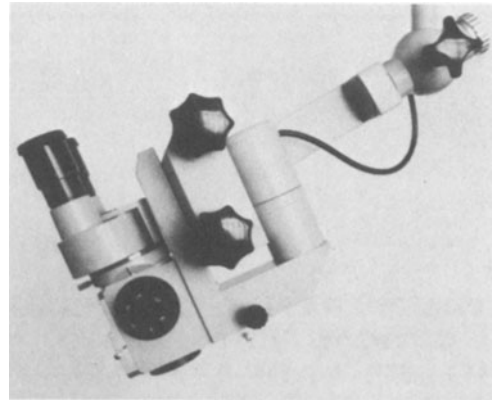


Figure 2. A Zeiss OPMI 1 microscope.

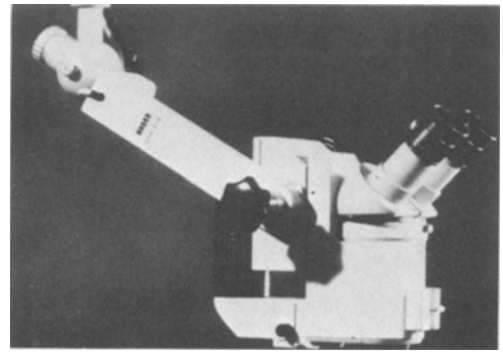


Figure 3. A Zeiss OPMI 6-S with inclined binocular tubes.

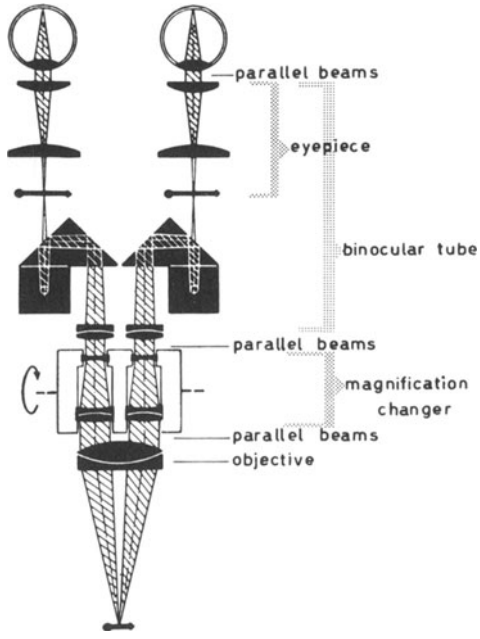


Figure 4. A schematic diagram demonstrating the optical principles of the Zeiss OPMI 1 microscope.

Table 1. Magnification factors (M_c) for the OPMI 1, OPMI 6-S, and OPMI 7 P/H magnification changers.

Microscope	Magnification changer dial setting	M_c
OPMI 1	6	0.4
	10	0.6
	16	1.0
	25	1.6
	40	2.5
OPMI 6-S (zoom)	0.5	0.5
		1.0
	2.0	2.0
OPMI 7 P/H	0.5	0.5
	1.0	1.0
	2.5	2.5

Table 2. The size of the field of view (mm) and the total magnification power of an OPMI 1 equipped with 125-mm binocular tubes and 20× eyepieces.

	Magnification changer dial setting									
	6 (0.4)[a]		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
Focal length of the main objective	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
200 mm	40	5×	27	7.5×	16	12.5×	10	20×	6	31×
225 mm	44	4.5×	30	6.5×	18	11×	11	18×	7	28×
250 mm	50	4×	33	6×	20	10×	12.5	16×	8	25×
275 mm	57	3.5×	36	5.5×	22	9×	14	14.5×	9	23×
300 mm	67	3×	40	5×	25	8×	15	13×	10	21×

[a]*Numbers in parentheses are the factors on the new OPMI 1 magnification changer knobs.*

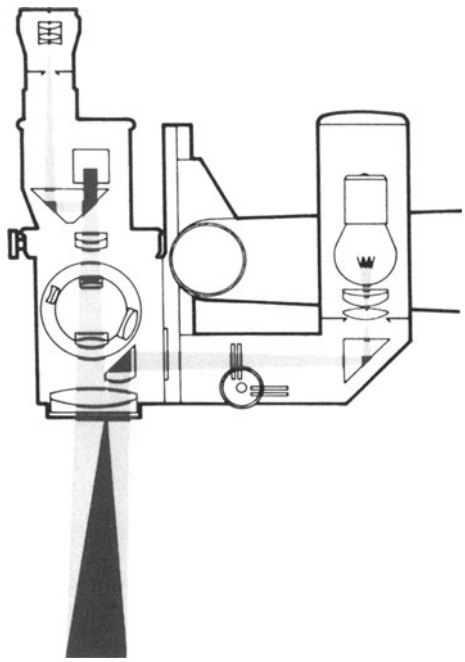


Figure 5. A diagram demonstrating the coaxial illumination system.

The focal lengths of main objectives used in microsurgery are graduated from f_o = 150 mm to f_o = 400 mm in steps of 25 mm. It should be noted here that the focal length of the objective is equal to its working distance, and it is therefore necessary to bring the object to be viewed to the exact distance of the focal length of the lens (see fig. 4).

Binocular tubes, either straight or inclined, are available in two lengths or focal lengths of f_T = 125 mm and f_T = 160 mm.

Finally, one needs the magnification power (M_E) of the oculars in order to complete this simple calculation. Four different ocular magnifications are available: 10×, 12.5×, 16×, and 20×.

With this information, it is easy to determine the minimum and maximum magnifications of the most frequently used combination of microscope components. For example, an OPMI 1 equipped with a 300-mm objective, 125-mm binocular tubes, and 20× eyepieces produces a minimum magnification of:

$$M_{v\ min} = \frac{125}{300} \times 0.4 \times 20 = 3.3$$

and an upper-range magnification of:

$$M_{v\ max} = \frac{125}{300} \times 2.5 \times 20 = 20.8$$

Data for other combinations are presented in table 2.

The size of the field of view, which obviously changes as the magnification changes, is equally simple to calculate. The formula for determining the diameter of the field of view is

$$F = \frac{200}{M_v}$$

so that in the example above, the microscope at its lowest magnification has a maximum field of view of about 60 mm (diameter) and, at its highest magnification, a field of view of about 10 mm (table 2).

ILLUMINATION

The illumination of the operating field is supplied by an additional built-in ray path in the microscope (fig. 5). A low-voltage incandescent bulb (6 V 30 W or, formerly, 6 V 50 W) is situated in a precentered lamp socket in the lamp housing on the back side of the microscope. A collecting system and two reflecting prisms transmit the light through the front objective in the immediate vicinity of the ray paths of the image, without, however, in any way interfering with these rays. The illumination finally reaches the surgical wound almost parallel to the viewing axes and, under ideal conditions, produces a bright, uniformly illuminated, circular spot. This spot is concentric with the microscope's field of view. This type of illumination, termed "coaxial," is capable of providing shadow-free illumination even in very deep and narrow wounds. The low-voltage incandescent lamp receives its power through a cable connected to an outlet on the microscope's horizontal arm. A transformer is built into the base of the microscope stand.

In the last few years, glass fiber illumination sources have both supplemented and displaced the incandescent lamp coaxial system. One reason for this is the problem of heat build-up from the incandescent lamp inside the microscope, especially when the microscope is fully draped. In addition, many surgeons find the heat radiating from the lamp housing uncomfortable when they are using the short, straight binocular tubes.

A second and perhaps more important reason is the difficulty of replacing the 6-V bulb if it burns out during an operation. Under such circumstances, replacing the bulb can result in a time-consuming procedure, because it is necessary to redrape the microscope. Because the glass fiber illumination housing is mounted outside the microscope drapery and is designed with a practical drawer system, a bulb change is possible in seconds.

Additional advantages of glass fiber illumination are an increase of the diameter of the illuminated field and a major gain in light intensity. At the moment, a combination of glass fiber illumination and built-in incandescent lamp gives the highest attainable light level. This is especially useful when film and photographic attachments on the microscope are being used. (More details on the subject of fiber illumination will be provided in a future article on accessories.)

An important point to remember when evaluating light sources is not only their brightness but also their life spans. Unfortunately, brightness, also called luminance, and life span have a detrimental relationship to one another. If the surgeon wants to increase the light intensity by overloading the bulb, he sacrifices the life span of the bulb. For example, by doubling the light output—thereby doubling the illumination level in the operating field—the life span of the lamp is reduced by 93%. For this reason, increasing the brightness by raising the voltage is limited by natural boundaries, namely, the point at which the life span of the lamp is reduced to a few hours and falls within the time period required for completing the surgical procedure. Under no circumstances, therefore, should the voltage be raised so high that the life span of the bulb is reduced to less than 10 hours.

Manufacturers of bulbs are very hesitant to give statements on the life span of bulbs. Therefore, the only way to establish absolute clarity on this subject is through a series of tests. This also applies to the adjustment of the primary voltage in the transformer, and naturally, of course, to the use of voltage controls in instruments with voltmeters. It has been established that most of the 6-V incandescent bulbs whose life span at 6 V amounts to 200 hours, will have their life span reduced to zero if the voltage they receive reaches about 10–11 V, i.e., they burn out at those levels. Overloading of these bulbs beyond a 9-V limit should therefore never be allowed. Moreover, the voltage level noted here must be measured at the socket of the lamp. Measurements made at the outlet on the microscope's horizontal arm usually give values that are higher by 0.5 to 1.0 V. The voltage drops before it reaches the lamp socket because of resistance in the connecting cable. For example, readings of 9.5 to 10 V at the outlet will drop to 9 V at the lamp socket.

Regarding illumination of the operating field and observed brightness, it must be mentioned that a change in the working distance resulting from a change to an objective with a different focal length changes the illumination levels attainable in the operating field. As a general rule, the longer the focal length, the less brightness is attainable. Thus, a change in working distance from 200 mm to 300 mm produces a 58% loss in "viewed," i.e., observable brightness. This is caused by two factors: the illumination intensity in the operating field itself is decreased by the increased working distance, and the effective

Table 3. Reduction of brightness with increasing working distance.

Working distance of the main objective lens	Measured light value	% of light lost
200 mm	100%[a]	0
250 mm	64%	36%
300 mm	42%	58%

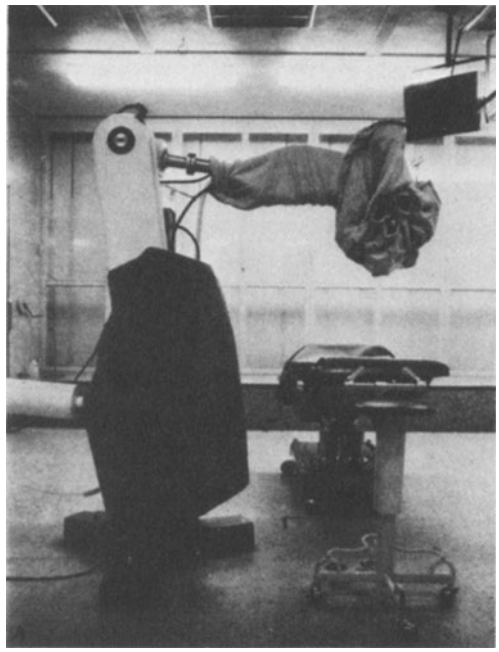
[a]*The measured light value at 200 mm is set at 100%; the point of measurement is behind the eyepiece.*

aperture of the optical viewing system is also diminished. Table 3 provides a summary of these relationships.

The need for more light with increased working distances is, therefore, widely felt. The human eye is physiologically capable of adapting itself to different light levels, and especially to low light levels, and is consequently able, even under unfavorable light conditions, to make work possible. On the other hand, movie cameras, still cameras, and television cameras record light losses more objectively and register them immediately with underexposures. A knowledge of these illumination-reduction relationships is therefore extremely important to anyone interested in photography through the microscope.

MICROSCOPE SUSPENSION SYSTEMS

There are a variety of support systems available for mounting the operating microscope. Among these are moveable floor stands with internal counterweights and manual up and down movement; motorized floor stands with mechanical up and down movement controlled by foot pedal; ceiling mounts with manual and electromechanical height adjustment; and finally, the microscope stand developed by the firm of Contraves A.G. in Zürich, Switzerland, which is equipped with an electromagnetic clutch system, permitting an absolute equilibrium condition and, consequently, free movement of the balanced microscope with or without accessories (fig. 6). This instrument's position adjustment is controlled by a mouth-operated switch that also serves as the microscope control stick.



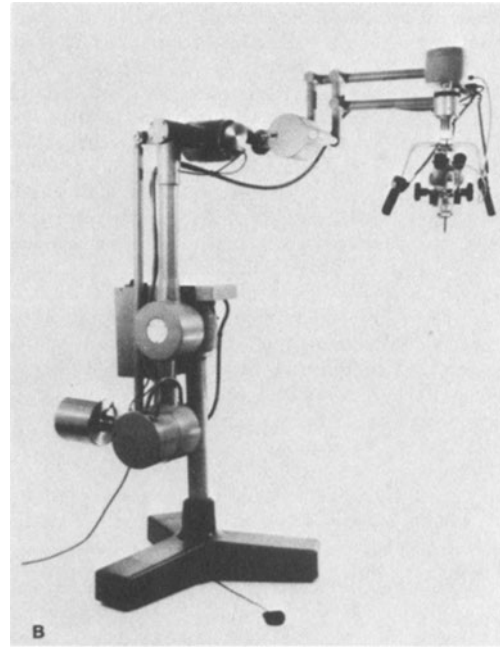


Figure 6. (A) Prototype of the Contraves stand in the operating room of the Kantonsspital Zürich. (Courtesy of Prof. Dr. M.G. Yasargil, Neurochirurgische Universitätsklinik, Kantonsspital Zürich, Switzerland.) (B) The Contraves stand.

The special advantage of this microscope support is that it drastically reduces the effective operation time because maneuvers in repositioning the microscope can be carried out easily and swiftly.

All floor stands are moveable and, depending upon the various patient positions for the different microsurgical operations, can be set up in different places around the table so that they interfere as little as possible with the surgeon and the assisting personnel. Once the microscope support is brought into position, it is made stationary through the use of brakes. In the case of the Contraves microscope stand, its massive weight alone provides for a safe stationary position. Furthermore, because of the extensive reach of the Contraves arm system, it is always set up on the upper left end of the operating table when used by right-handed surgeons and on the upper right side for left-handed surgeons.

The latest additions to the line of microscope suspension systems are those that are mounted on operating room ceilings. They allow absolute freedom of movement around the operating table and they come equipped with additional features such as auxiliary outlets for cameras, flash attachments, and 6- and 12-V illumination systems. However, they have one disadvantage: they restrict microsurgery to that particular operating room since removal of the microscope for use in other rooms is no longer possible.

There are two types of ceiling-mounted suspension systems available: (*a*) the electromechanical ceiling mount for use in ophthalmology, plastic surgery, and neurosurgery; and (*b*) the Contraves ceiling mount specifically applicable to neurosurgery but also useful in most other surgical disciplines.

The electromechanical ceiling mount consists of a telescoping horizontal arm system with a motorized or manual vertical travel of 48 cm. The arm system is internally counter-balanced, and the microscope can be moved up and down manually, much like the movement on a counterbalanced floor stand. For those who prefer motorized movements, the vertical travel at 3 mm/sec can be controlled by a foot switch. All controls of the fully motorized OPMI 6-S, namely, zooming and focusing, are remotely controlled by means of a foot-control panel.

The ceiling-mounted Contraves suspension system offers exactly the same features as the Contraves floor unit with the addition of extra free space on the floor next to the operating table. All operating microscopes, motorized and manual, can be attached to the Contraves ceiling mount, and, in the case of the motorized microscope, the function of the zoom magnification changer is controlled with a simple two-action foot switch since the internal focusing of the microscope body is no longer needed on the Contraves stand. Naturally, all accessories normally used with microscopes mounted on floor stands can be attached and counter-balanced on the ceiling suspension systems.

Ideally, ceiling mounts are best installed in operating rooms during the construction of the operating suite. They may be installed in existing operating rooms, but finding the appropriate point of attachment may be complicated by the presence of existing lighting fixtures, electric wiring, overhead tubing for anesthesia, air-conditioning ducts, and heavy traffic areas overhead that could cause ceiling vibrations. Therefore, because of the potential for protracted construction problems and the subsequent long-term closing of the operating room, it is of the utmost importance that sufficient time be allowed to analyze the situation with all concerned parties, including the architect, the construction firm, the manufacturer's representative, and the microsurgeons. This detailed and long-range planning should minimize the downtime of the operating room facility.

The major components of the Zeiss OPMI 1, OPMI 6-S, and OPMI 7 P/H are discussed along with details on handling and assembling the components, changing couplings, focusing, and balancing the microscope system prior to use.

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THE OPERATING MICROSCOPE. II. INDIVIDUAL PARTS, HANDLING, ASSEMBLING, FOCUSING, AND BALANCING

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Editor's Note: This is the second in a series of five articles by Mr. Hoerenz on the basic principles and handling of the operating microscope. The first article, on optical principles, illumination systems, and support systems, appeared in Journal of Microsurgery *1:364–369, 1980. Future articles will discuss accessories, methods for documenting surgical procedures, and maintenance and cleaning.*

The importance of the optical and illuminating properties of the operating microscope in the successful use of the instrument is often underrated. In order to put these technical properties to full use, however, it is extremely important to have a knowledge of the separate parts of the operating microscope and to be able to handle and assemble these parts, to focus, and to balance the instrument.

Basically, the operating microscope is composed of three major components: the main objective, the microscope body, and the binocular tube system. These three components can be seen clearly in figures 1 and 2.

THE MAIN OBJECTIVE

The main objective is a lens system that is attached to the front or lower end of the microscope body by means of a threaded mount. The focal length of the lens system is engraved on the side, for example, f = 300 mm. This lens number simultaneously gives the focal length of the lens and the free working distance available between the microscope and the surgical field when that lens is used. The objectives are easily interchangeable, and they are available in various focal lengths (and, therefore, various working distances) in graduated steps of 25 mm. It is advisable to begin equipping the microscope with objectives properly selected for the various specific tasks it will encounter. The most commonly used focal lengths are 150, 175, and 200 mm in ophthalmology; 200, 225, 250, 275, and 300 mm in neurosurgery; 200, 300, and 400 mm in otolaryngology; 250, 300, and 320 mm in gynecology; and 200 mm in hand and reconstructive surgery.

Use of the proper working distance can greatly lessen strain, especially in operations of long duration, and a difference of 25 mm often can determine the body comfort or the positioning of the arms and hands of the surgeon. Therefore, tests should be conducted by every user of the instrument to determine exactly which objectives provide the most comfortable working distances.

THE MICROSCOPE BODY

The microscope body, which includes the magnification changer, makes up the middle section of the instrument. The body is attached mechanically to a support yoke that allows the instrument to be tilted. On the outside of the body of the OPMI 1 are knobs for manual focusing.

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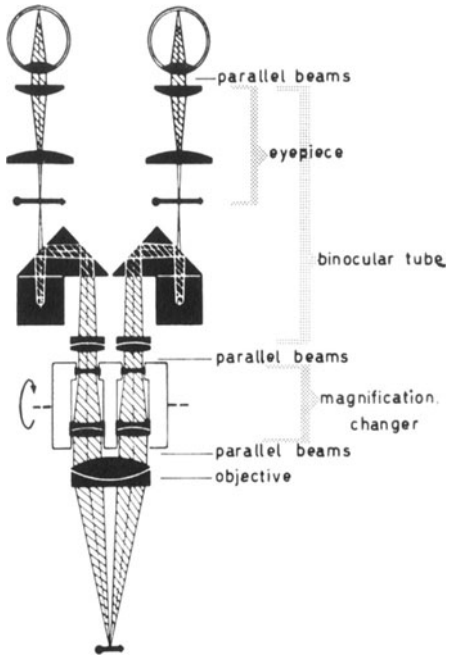

Figure 1. Schematic diagram of the optical principles of the Zeiss OPMI 1. Note the three major components of the microscope: the main objective, the microscope body (housing the magnification changer), and the binocular system.

Motorized microscopes, such as the OPMI 6-S and the OPMI 7 P/H, are focused via electric hand or foot switches.

In the center of the microscope body are manual control knobs for changing the magnification; this is stepwise on the OPMI 1, and continuous on the OPMI 6-S. The OPMI 7 P/H (a microscope especially designed for plastic and hand surgeons) has no external manual controls (fig. 3). All focusing and magnification adjustments are made electrically and are controlled by remote switches. By eliminating all external knobs, it was possible to devise a microscope of such slim design that two surgeons working at positions 180° from each other both have unobscured, unhindered access to the surgical field.

On the lower end of the microscope body is the threaded receptacle for the front objective. On the upper end of the microscope body is a dovetail receptacle with a knurled clamping screw, which serves as a receptacle for the attachment of accessories, or in the simplest case, for the attachment of the binocular tube system (fig. 4).

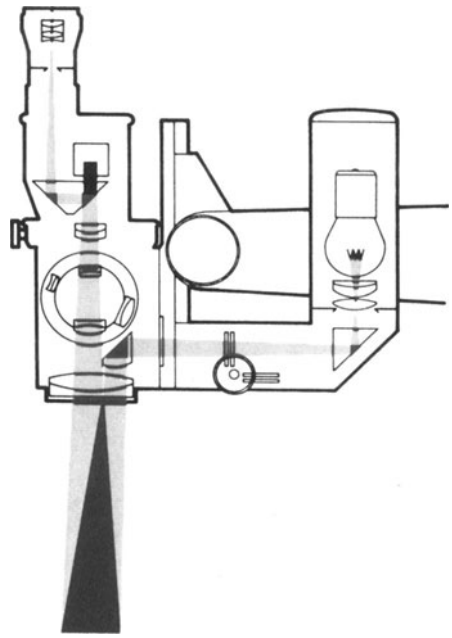

Figure 2. A cross-section diagram of the Zeiss OPMI 1, demonstrating the three components and the coaxial illumination system.

THE BINOCULAR TUBE SYSTEM

The binocular tube system permits stereoscopic viewing. The system is comparable to a telescope; in fact, it is constructed on the same principle and can be used as field glasses. On the lower side of the system, there is a dovetail that is the counterpart of the dovetail receptacle on the microscope body and serves to fasten the system to the microscope and ensure that the optical axes of the binocular tubes align precisely with those of the microscope body when the clamping screw has joined the two parts together. The two objectives of the binocular tubes, visible as two blue-colored lens surfaces 16 mm wide, are built into the system's dovetail (the blue color results from a nonreflective optical coating).

Inside the upper end of the binocular tubes are spring-loaded supports for the eyepieces or oculars. Mechanical clamps ensure that the oculars always sit securely inside the tubes and do not fall out when the microscope body is tilted into a horizontal position (or lower). The

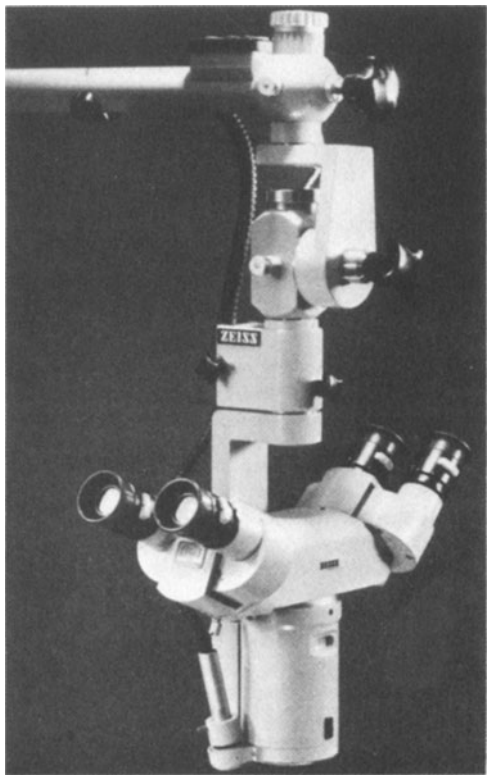

Figure 3. The Zeiss OPMI 7 P/H with no accessories. The OPMI 7 P/H is designed for plastic and hand surgery and allows two surgeons to work simultaneously at positions 180° opposed to each other. Note the lack of external focusing and zoom controls.

distance between the binocular tubes can be adjusted inward or outward to allow for differences in the pupillary distance of different users. This is especially important for the basic focusing procedure of the microscope.

The oculars make up the last part of the assembled microscope (fig. 5). They are, as already mentioned, interchangeable and are available in four different magnifying powers: 10×, 12.5×, 16×, and 20×. In procedures with long working distances and small surgical fields (such as in neurosurgery), the 300-mm objective is used with the 20× oculars. With shorter working distances, where one needs lower total magnifications for a relatively large surgical field (such as in ophthalmology), eyepieces with a lower magnification are recommended. In such cases, 12.5× eyepieces will be preferred.

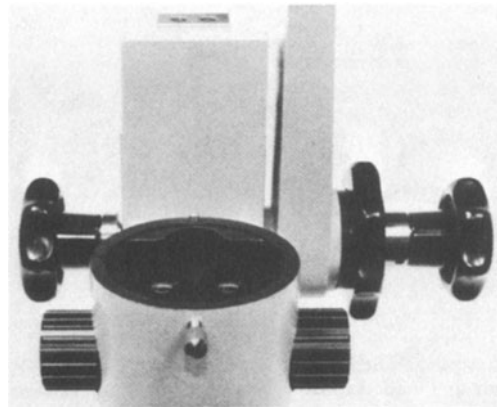

Figure 4. The dovetail receptacle of the microscope body.

HANDLING AND ASSEMBLING THE SEPARATE PARTS OF THE MICROSCOPE

Changing Objectives. The objectives are equipped with a very fine thread that must be very carefully engaged into the threaded receptacle on the microscope body. This task can be simplified by turning the objective first in a counterclockwise direction until a soft "click" is heard, which indicates that the thread is engaged, and then by carefully turning the objective in a clockwise direction until it is completely screwed into the microscope body and comes to its end stop. It is essential that one take care not to leave fingerprints on either the lenses of the magnification changer or the objective itself when changing objectives. In the event a lens is soiled, it can be cleaned (the cleaning of lenses will be discussed in a future article on cleaning and maintenance of the operating microscope).

Magnification Changer. After inserting the objective, one should make certain that the movement of the magnification changer is in order, namely, that it moves between magnification steps with light force and audible engaging clicks on the OPMI 1 and that it zooms smoothly on the OPMI 6-S and OPMI 7 P/H. A sharp rubbing or squeaking sound (or a faulty zoom) indicates that the mechanical guides are dry. In this case, servicing the instrument is immediately necessary.

The magnification changer of the OPMI 1 has the capacity to magnify as well as reduce the image received from the main objective in five different steps. The numbers engraved on the magnification changer (6, 10, 16, 25, and 40) serve only as coefficients and indicate the actual

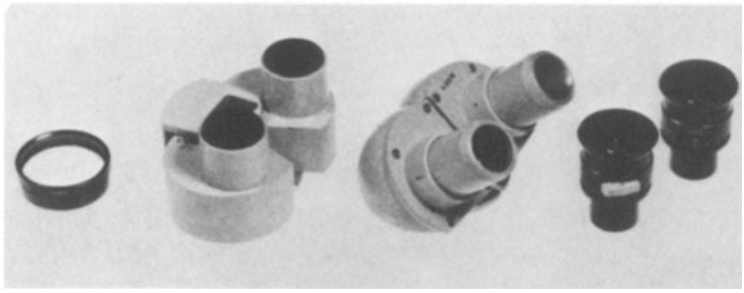

Figure 5. A 300-mm main objective, straight and inclined binocular tube systems, and 20× oculars.

magnification only for a definite optical combination (see table 1). On the magnification changer knob of the newer OPMI 1, the factors 0.4, 0.6, 1, 1.6, and 2.5 have replaced the old numbers and serve for the computation of total magnifications as discussed in the previous article (*J Microsurg* 1:364–369, 1980).

Binocular Tubes. Binocular tubes are available in straight and inclined forms and in two different lengths, short tubes of 125 mm and long tubes of 160 mm (fig. 6). The long tubes produce a slightly higher magnification than the short tubes; the short tubes, on the other hand, have the advantage of reducing the total length of the microscope by 25 mm. How the microscope is to be used, i.e., in the horizontal, inclined, or vertical position, will determine whether straight or inclined binocular tubes should be inserted into the dovetail receptacle. Before attaching the binocular tubes, one must make sure that neither the objectives of the magnification changer nor the exposed lenses of the binocular tubes are soiled by dirt or fingerprints.

The knurled screw in the dovetail of the microscope body must be screwed out quite far in order to allow the insertion of the binocular dovetail. The binocular system should be tilted slightly in order for the small cutout on the binocular dovetail to engage the positioning pin of the dovetail of the microscope body. Then, the binocular system should be inserted until the dovetails are neatly joined. The knurled screw then should be tightened carefully to fasten both parts together.

At this point the working condition of the geared movement of the binocular tubes that permits the pupillary distance to be adjusted should be checked. The adjustment mechanism should be relatively stiff but, at the same time, easily and continuously adjustable with the application of light force. If it is very loose and the gearing on both tubes is shaky—thereby producing uneven and jerky adjustments—the system must be repaired immediately. An unanticipated change in the pupillary distance during an operation can be extremely disturbing and uncomfortable.

The final step in assembling the microscope is the insertion of the oculars. Before inserting

Table 1. The size of the field of view (mm) and the total magnification power of an OPMI 1 equipped with 125-mm binocular tubes and 20× eyepieces.

	Magnification changer dial setting									
	6 (0.4)[a]		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
Focal length of the main objective	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
200 mm	40	5×	27	7.5×	16	12.5×	10	20×	6	31×
225 mm	44	4.5×	30	6.5×	18	11×	11	18×	7	28×
250 mm	50	4×	33	6×	20	10×	12.5	16×	8	25×
275 mm	57	3.5×	36	5.5×	22	9×	14	14.5×	9	23×
300 mm	67	3×	40	5×	25	8×	15	13×	10	21×

[a]*Numbers in parentheses are the factors on the new OPMI 1 magnification changer knobs.*

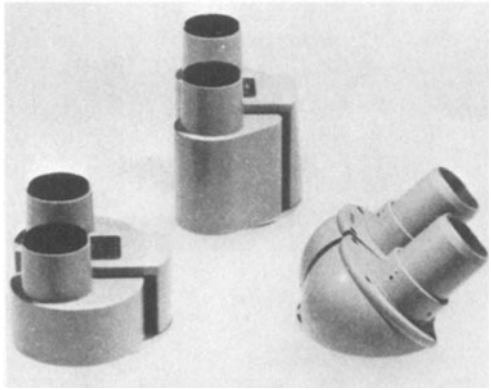

Figure 6. Interchangeable binocular systems: (left) short straight tubes, (center) long straight tubes, and (right) short inclined tubes.

the eyepieces in the binocular tubes, one should check that the lens surfaces are clean. When the oculars are inserted into the binocular tubes, they should be forced down into the sleeves of the tubes as far as possible. If the image quality is poor, a check of proper seating should be made. Often, the surgeon will be unable to achieve a clear and sharp image because one of the oculars is not fully inserted into the tube.

OCULAR FOCUSING

One of the most important steps in the basic focusing of the microscope is the correct adjustment of the oculars. Each ocular permits a spherical diopter adjustment of −9 to +9 dpt. Through these adjustments, it is possible for surgeons who wear glasses with a spherical correction to set the microscope oculars to their individual eyeglass prescription and work without spectacles. In those cases where the surgeon wears glasses that correct for corneal astigmatism, it is recommended that the oculars be set at zero correction and the surgeon wear his glasses while using the microscope. Under these circumstances, the rubber cups attached to the eyepieces must be curled down and used as supports for the eyeglasses. Surgeons with normal vision likewise set the oculars at zero; however, they would use the rubber eye cups in the normal position. The eye cups shadow the eyes and prevent the influx of disturbing outside illumination (fig. 7).

For those ametropic surgeons who do not know the correction values for their eyes, the following procedure for the basic focusing of the oculars is appropriate:

1. Remove the binocular system from the microscope body.
2. Use the binocular system as field glasses and view a distant object, such as a tree or a house.
3. Rotate both diopter scales counterclockwise to their end stop. To rotate the oculars, depress the locking button (the orange-colored button on the new oculars).
4. Close one eye and, with the open eye, view the target while simultaneously rotating the diopter ring slowly in a clockwise direction until the target appears in sharp focus. Do not go beyond this point.
5. Read and make a note of the diopter value that appears on the ocular index scale. Repeat this procedure three times and select the mean of the three readings. This value represents the individual correction for the eye tested.
6. Repeat the procedure for the other eye. The diopter correction values determined by these procedures are valid for all other oculars and microscopes.

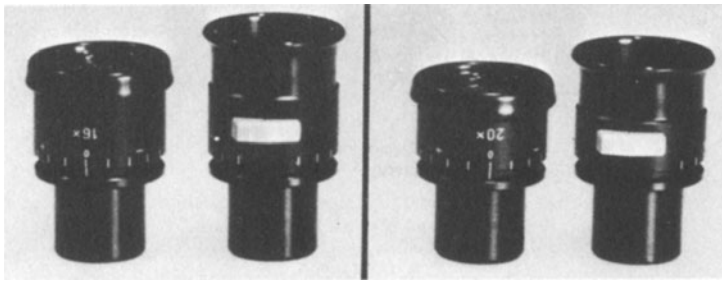

Figure 7. Interchangeable oculars of 16× and 20×. Note the diopter scale and the diopter lock. The rubber eyecups can be curled down and used as rests for glasses.

In the event that the eyepieces are not equipped with locking devices, it is advisable to tape them securely in place to prevent any inadvertent rotation and change of setting.

ADJUSTING THE PUPILLARY DISTANCE

The correct adjustment of the binocular tubes to the pupillary distance of the user is of great importance for stereoscopic viewing and maximum brightness. The most suitable object to view under the microscope for this purpose is a sheet of graph paper.

FOCUSING THE MICROSCOPE

There are several basic rules that underlie the focusing of the microscope which, if followed, will simplify the use of the instrument (especially where frequent changes are made from low to high magnification). After the ocular and pupillary distance adjustments noted above are completed, the microscope is set to its highest magnification level and, descending from above the surgical field, is focused upon an object. Focusing at the highest magnification level is done because the minimal depth of field at this magnification is extremely critical and leads to perfect focus for all other magnification levels. Thereafter, the surgeon only has to switch to another magnification and does not need to refocus the instrument. If the instrument is repositioned, however, the procedure must be repeated.

A microscope adjusted according to the procedures noted above will allow the user to work for long periods without fatigue and will ensure a minimum number of adjustments, optimum brightness, and perfect focus of all accessories attached to the instrument.

ADDITIONAL CHECKS

Before the operating microscope is used, two additional tests should be made.

First, the focusing mechanism of the manual OPMI 1 is controlled by two large hand knobs that protrude from opposite sides of the microscope body. In the event that the tension of the focusing mechanism must be changed, these two knobs must be rotated in opposite directions to one another. In order to loosen the mechanism, the knobs are rotated away from each other, i.e., in a counterclockwise direction. To increase the stiffness of the mechanism, the knobs must be turned toward each other, i.e., in a clockwise direction. The force required to accomplish these adjustments is somewhat large. The mobility of the focusing mechanism should be so smooth and exact that the instrument with its attached accessories will focus easily but will not sink under its own weight, especially when it is used in the vertical position (fig. 8).

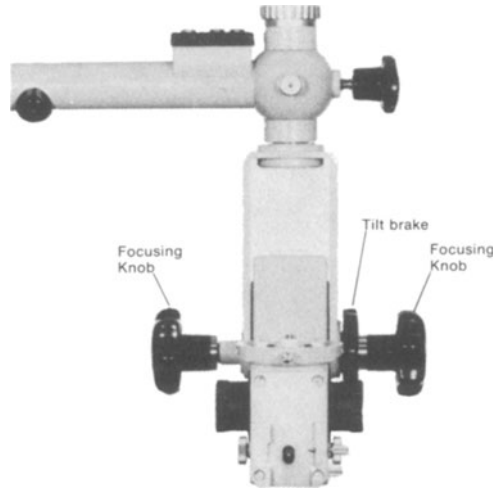

Figure 8. The body of a Zeiss OPMI 1, demonstrating the focusing knobs and tilt brake.

Second, the tilting of the microscope around the horizontal axis is controlled by a brake knob that can be adjusted for stiffness of movement. This brake knob is situated on the focusing axis between the yoke and the right-hand focusing knob. Turning this wheel clockwise increases the brake friction to the point where movement is prevented, whereas turning the knob in the opposite direction increases the mobility of the yoke to the point where it will swing freely. It is important to adjust the tilting resistance to the point where the microscope with all of its attached accessories is easily moveable, but not to where the microscope is on the verge of tipping over. The OPMI 6-S has a geared friction clutch tilting device that allows free rotation of the microscope when the clutch is unlocked and continuous tilt via a manual knob when the clutch is locked.

DISMANTLING AND CHANGING COUPLINGS

The great variety of microsurgical procedures often necessitates major changes in the outfitting and positioning of the operating microscope.

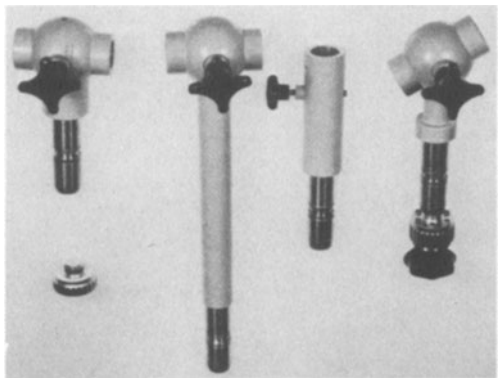

Figure 9. Couplings currently available for use with the Zeiss floor stand.

Changing objectives in order to alter the working distance and removing and replacing the binocular system have already been discussed. It is obvious that in order to use the microscope in the vertical position, inclined binocular tubes of 125 mm are preferred, and it is equally obvious that the straight binocular tubes can be used only when the microscope is used in a horizontal or inclined position. Changing the position of the microscope in many cases, however, is possible only by changing various couplings of the total suspension system.

So many couplings are available to change the position of the microscope that it is advisable to seek the optimal solution to a specific problem through experiments in the laboratory. Figures 9 and 10 illustrate couplings that are used in neurosurgery, otology, ophthalmology, gynecology, and reconstructive surgery.

Changing couplings is very simple. To disconnect a coupling, the silver safety screw should first be removed from the top side of the bolt. Next, the safety pin on the side of the ball-shaped receptacle should be pulled out of the support coupling. The coupling to be removed then can be pulled out. One coupling can be inserted into another by pushing the bolt into the receptacle until the clearly audible click of the spring-loaded safety pin is heard. The safety screw is then tightly screwed into its seat. Some couplings have a set screw instead of a spring-loaded safety pin. This set screw can be loosened or tightened with a small screwdriver.

When removing the microscope from the horizontal support arm of the floor stand, it is important to remember that the microscope has considerable weight. At the moment the safety pin is pulled, the counterweights within the column of the floor stand will pull the horizontal arm violently upward as a result of the abrupt unburdening. This can lead to damage when the heavy counterweights hit the base of the stand. It is necessary, therefore, to make certain that the star knob above the point of rotation of the horizontal arm on the carriage is securely tightened before removing the microscope from the horizontal arm. Once the carriage is locked on the column, all possible coupling combinations may be inserted between the microscope yoke and horizontal arm without the danger of the counterweights falling.

Every time a coupling is changed, one should make sure the coupling bolt in the receptacle moves easily without squeaking. This test can be made only when the star knob is loosened fully.

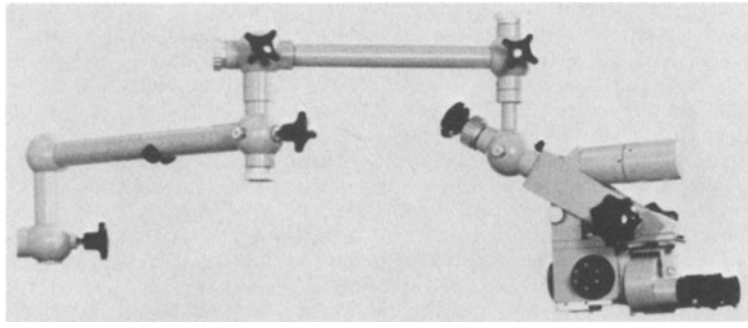

Figure 10. An OPMI 1 and couplings set up for posterior work in neurosurgery.

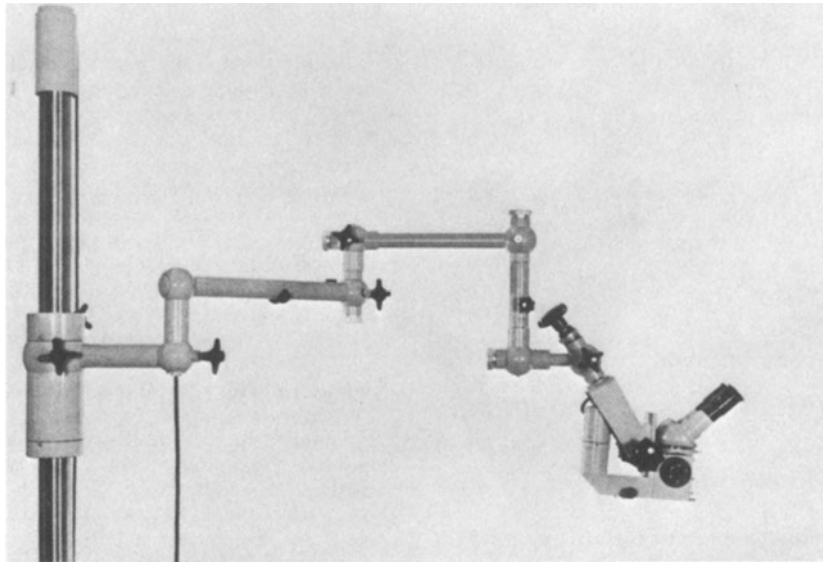

Figure 11. The motor head attachment on the floor stand column with the microscope suspended for surgery on a supine patient.

If scratching or squeaking is heard, the coupling should be removed and greased with a light coat of Vaseline.

The rotating joints of the horizontal arm may be damaged if a turning movement is attempted while the star knob is securely tightened. If movement is attempted, the locking bolt of that screw can, in an unfortunate case, mar the internal rotating axis of the coupling. This can make the movement of the coupling difficult or even impossible, even after the star knob is loosened. This type of damage can be repaired only by a service mechanic.

Another point to keep in mind when setting up the microscope is that in order to maintain maximum stability, the horizontal arm should always be positioned over the longest foot of the wheel base. When rolling the stand through the operating room, one should always push it with the longest foot pointing forward. This will minimize the possibility of tipping over the stand when crossing electric cables or bulges in the floor. When the instrument is moved, the horizontal arms should always be folded together so that the center of gravity is drawn close to the column of the floor stand. This advice is also valid for the motorized floor stand. In every case, the instrument should always be handled by two people when it is being moved.

BALANCING THE MICROSCOPE

The equilibrium of the microscope when mounted on the horizontal arm should be calculated in connection with variations in any equipment or accessories. Whenever accessories and couplings are changed, so, naturally, is the total weight of the instrument, which is concentrated at the far end of the horizontal arm. The counterweight within the column, however, remains unchanged. Consequently, when extreme weight changes are made to the instrument, it loses its equilibrium and can no longer be used in a free-moving, unfixed fashion.

It is therefore advisable, from the very beginning, to prepare the microscope in its most heavily equipped mode and then to counterbalance it with lead weights in the inner column of the floor stand. When the instrument is used with less total weight, supplementary counterweights can be placed on top of the carriage, thereby maintaining the equilibrium without changing the counterweight inside the column. When couplings and accessories are added again, weight equalization can be adjusted outside of the stand by removing counterweights from the carriage.

The problem of balance also can be solved through the use of two accessories: the motor

head and a balancing device produced by Urban Engineering (Burbank, CA).

The motor head system is based on the principle of the slipping clutch and allows either motorized or manual height adjustments of the microscope (fig. 11). Manual adjustments require a moderate expenditure of force. The friction level of the slipping clutch is adjusted so that it can control unbalanced weight on the microscope of ±3 kg. In the event, however, that the additional weight on the microscope is greater than 3 kg, the motor is not capable of moving the microscope upward. The 3-kg limit, however, is sufficient to cover most of the commonly used accessories.

The motor head, which is made in two versions with focusing speeds of 2.5 mm/sec and 5 mm/sec, can be mounted on all nonmotorized floor stands. It is especially useful for focusing the microscope in vertical or near vertical positions. The 2.5-mm/sec speed is preferred for use with the OPMI 7 P/H. When the microscope is used in a horizontal position, the motor head can only be used for centering the height of the instrument over the surgical field and not for focusing.

The mechanical device produced by Urban Engineering for assisting in balancing consists of a steel cable that is wound on a spring-loaded drum. The drum is attached to the head of the microscope column. The extreme end of the cable has a loop that is securely attached to the highest star knob on the carriage of the floor stand. The spring tension of the cable is adjustable and can easily assimilate the increased weight of the microscope and accessories. During height adjustments, the cable runs up and down the entire column without in any way being a hindrance. When spring tension is high, however, the range of vertical travel is somewhat limited.

In summary, the trouble-free use of an unhindered, free-moving operating microscope can be achieved by counterbalancing its weight through one of the following methods:

1. Compensating the weight in the inner column.
2. Use of the motor head.
3. Use of the Urban Engineering balance device.
4. Use of the motor head together with the Urban Engineering device.

The Contraves stand may be balanced by adjusting the counterweight through inward rotation if accessories have been removed and through outward rotation if accessories have been added. For extra heavy loads, such as large TV cameras, additional weights can be added to the large standard counterweight.

Proper balance is essential with the Contraves stand in order to enjoy the full advantage of a free, "floating" microscope. It is therefore imperative that the person responsible for setting up the microscope be absolutely familiar with the detailed instructions in the Contraves user manual.

In conclusion, it should be stressed that ease of using the microscope during surgery can only be achieved by properly adjusting, focusing, and balancing the system beforehand. If attention is paid to these matters, the surgeon will be able to forget the optical device altogether in the course of performing an operation.

The beam splitter, observation tubes, and assistant's microscope, available as accessories for the OPMI series of operating microscopes, are discussed.

JOURNAL OF MICROSURGERY 2:22–26 1980

THE OPERATING MICROSCOPE. III. ACCESSORIES

PETER HOERENZ, Dipl.-Ing.-Phys.

Editor's Note: This is the third in a series of five articles by Mr. Hoerenz on the basic principles and handling of the operating microscope. The first article, on optical principles, illumination systems, and support systems, appeared in Journal of Microsurgery *1:364–369, 1980. The second article, on individual parts, handling, assembling, focusing, and balancing, appeared in* Journal of Microsurgery *1:419–427, 1980. Future articles will discuss methods for documenting surgical procedures, and maintenance and cleaning.*

In all of the disciplines that use microsurgery, there is a great deal of interest in microscope systems that allow direct co-observation during an operation or that allow documentation of the progress of an operation. This interest largely has been satisfied in the OPMI microscopes by a series of accessories.

THE BEAM SPLITTER

The beam splitter is the principal part that makes possible the attachment of other observation and documentation accessories. In the first article on the operating microscope (*Journal of Microsurgery* 1:364–369, 1980), the advantages of the telecentric optical system were explained, and as shown in Figure 1, there are several points in the path of the light traveling through the microscope where parallel rays are available. A unique advantage of parallel rays is that they can be manipulated easily without unfavorably influencing the quality of the image. Consequently, it is possible to insert beam-splitting cubes in the path of the parallel rays that allow a portion of the rays to pass unhindered, yet divert another portion of the rays away from the original path to the outside at a 90° angle. Two such cube systems are found in the beam splitter pictured in Figure 2.

The OPMI beam splitter has a beam-splitting ratio of 50:50. This means that 50% of the light coming from the operating field is available to the principal observer through the binocular tubes and the other 50% is diverted for use in the accessory attached to the side of the microscope. It is important to mention that the accessory presents a view of the operating field that is identical to the view through the binocular tubes.

As in Figure 1, Figure 3 schematically shows the path of the light rays through the microscope, but in Figure 3 a beam splitter has been inserted between the binocular tube system and the magnification changer. A photo adapter tube is attached to the right side of the beam splitter. The photo adapter, which will be discussed in detail in a future article, is equipped with an objective (f = 220 mm) that focuses the incoming parallel-ray image to the film plane of the camera.

The beam splitter is approximately 50 mm in depth, and, therefore, adds little to the overall length of the entire microscope. The beam splitter is attached to the microscope body in the same manner as the binocular tube system (see *Journal of Microsurgery* 1:419–427, 1980). Again, it is worthwhile to point out that one should ex-

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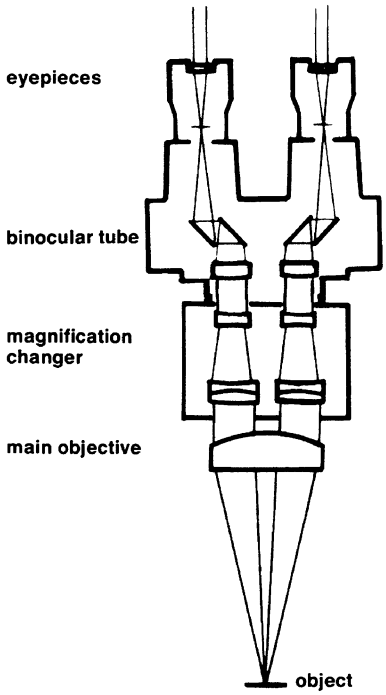

Figure 1. A schematic diagram demonstrating the optical principles of the Zeiss OPMI microscopes. Note the parallel rays between the main objective and the magnification changer and between the magnification changer and the binocular tubes.

amine all glass surfaces and clean any that are soiled before assembling the components. In the case of the beam splitter, there are six glass surfaces that must be checked.

CO-OBSERVATION WITH THE BEAM SPLITTER

Three different systems are available to make possible direct co-observation during an operation. Two of these systems are monocular, and the third is binocular and stereoscopic.

The monocular tubes are differentiated by their lengths. The shorter tube can be used by an assisting surgeon, while the longer tube is more suitable for a guest observer.

The stereoscopic co-observer tube is ideal for an assisting surgeon in neurosurgical, ophthalmologic, and otologic procedures. It is shown attached to the right side of the beam splitter in

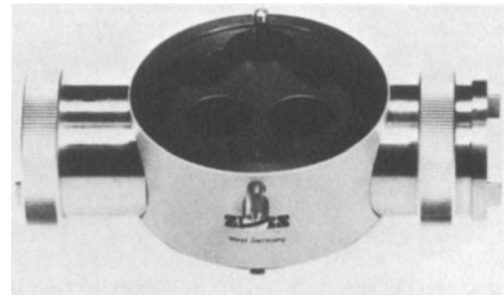

Figure 2. The beam splitter for the Zeiss microscope with two openings for attachment of accessories.

Figures 4 and 5. It makes it possible for an assistant to take an active part in the operation by providing him with a stereoscopic view. The stereoscopic depth perception available to the assistant through the stereo tube is somewhat shallower, however, than that available through the main binocular system. This is because the two viewing axes of the stereo co-observer tube run through only one side of the microscope body. The observer will be able to accustom himself to the given stereopsis in a short time, however, and will begin to see the operating field in three dimensions.

All three of the co-observer systems are constructed in a manner that allows the observer to obtain the same magnification and field of view as the microscope operator by selecting the proper ocular and, in the case of the stereo adapter, the proper binocular tubes. Since the beam splitter is mounted on top of the microscope body, the magnification and the field of view through the co-observer tubes change when the magnification changer is set at a new magnification. In many cases, however, it is desirable and possible to give the observer a wider field of view of the operation with less magnification by choosing eyepieces with a lower power.

The lower portion of the co-observer tube, which is inserted into the beam splitter and secured with a screw ring, has a rotating joint that allows the observer to find a comfortable position and to align the viewing direction accordingly. This viewing position is set by raising the sliding sleeve on top of the joint of the tube, rotating the tube to the desired position, and securing it by releasing the spring-loaded sliding sleeve. This maneuver causes the image being viewed to rotate, but this can be straightened

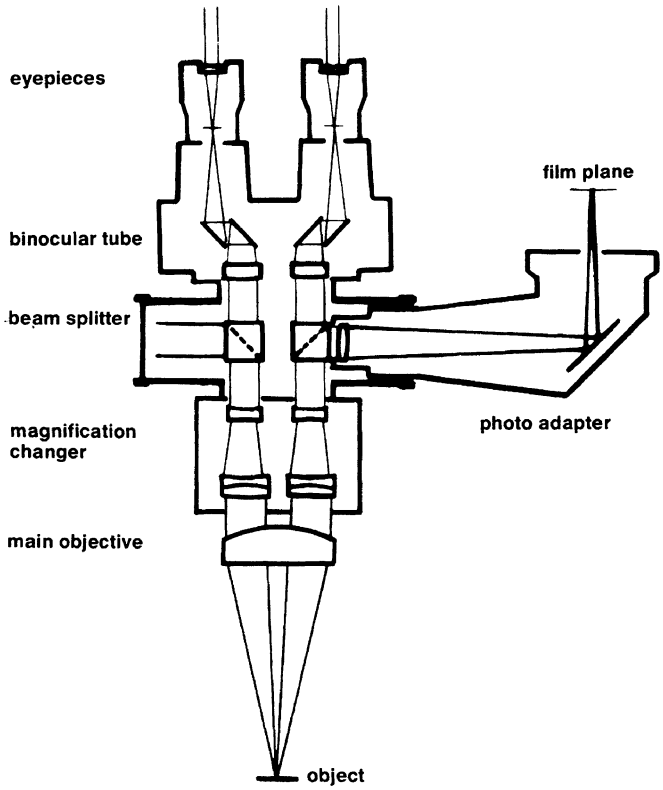

Figure 3. The path of the light rays in an OPMI microscope with a beam splitter inserted between the magnification changer and the binocular tube system.

again with the aid of the rotation prism system, which is located inside the tube and which is operated by a corrugated metal ring located around the tube. This ring can be turned until the view of the operating field through the co-observer tube is at exactly the same angle as the view without the microscope. Positioning of the image is made easier for the observer if the microscope operator describes the position of an object in the operating field in relation to the position on a clock face, e.g., the location of a specific vessel coursing across the field is from 7 to 2 o'clock.

The instructions given in a previous article (*Journal of Microsurgery* 1:419–427, 1980) on basic focusing of the binocular tube system are also valid for the focusing of the ocular and binocular co-observer tubes. It is also important that the observer set his personal diopter values on the diopter scales and his pupillary distance on the binocular co-observer tube. Only through these necessary presettings can the "parfocality" of the surgeon and the observer be guaranteed. These preparations are especially important in a situation in which the assistant is responsible for photographic documentation of the procedure. In this case, he should be responsible for supervising the focusing of the entire system. As in all such situations, it is especially recommended that the beginner experiment thoroughly with the focusing relationships in the laboratory before applying them to a clinical situation.

Important Hint. The screw retaining ring on the beam splitter is loosened by turning it clockwise, that is, towards the right when viewing the beam splitter from the side of the accessory. This retaining ring belongs to the beam splitter and is not a part of the accessory. Confusion on this point often leads to a mistake in the proper di-

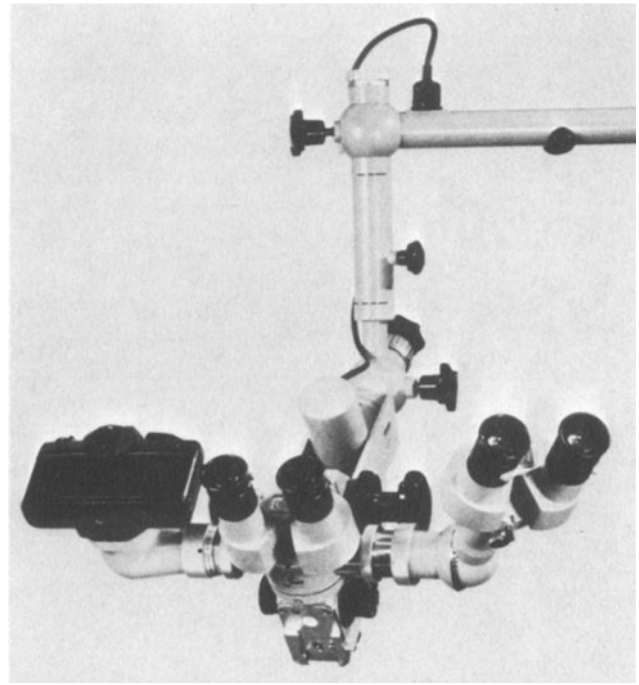

Figure 4. A stereo co-observer tube and photo adapter attached to the beam splitter on an OPMI 1 microscope.

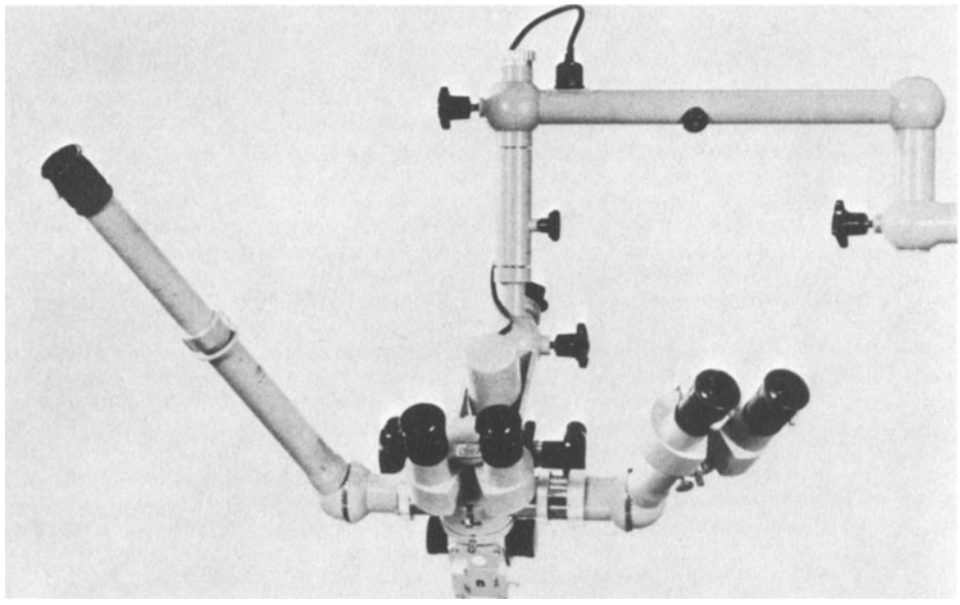

Figure 5. An OPMI 1 microscope with a stereoscopic binocular tube and a long guest observer tube attached to the beam splitter.

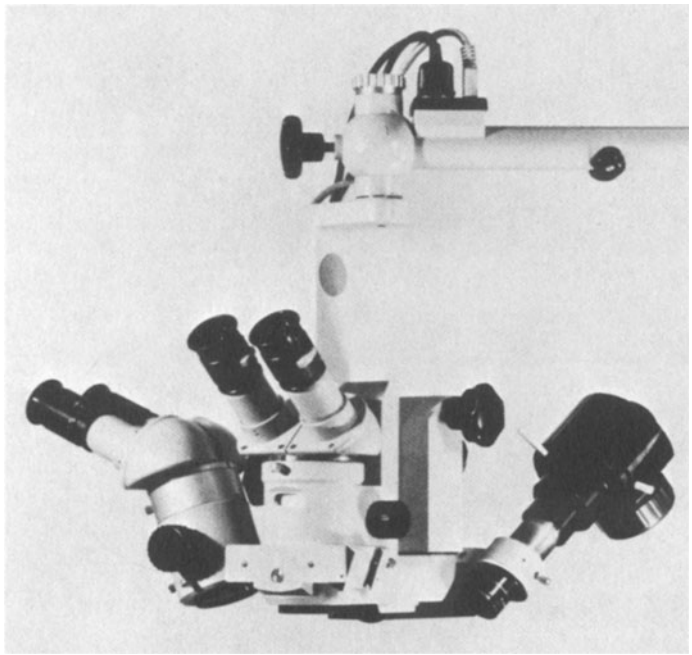

Figure 6. The assistant's microscope for co-observation mounted at a 90° angle to the main microscope.

rection for turning the ring. One should never attempt to loosen this ring forcefully with a wrench or other tool. The ring usually is turned easily in the proper direction by using a rubber cloth for a secure grip and expending a medium amount of force. Some of the newer beam splitters have an arrow engraved on the ring that indicates the proper direction for turning the ring to tighten it over the mount of the accessories. The ring may be loosened by turning it in the opposite direction.

CO-OBSERVATION WITHOUT THE BEAM SPLITTER

In ophthalmic microsurgery, co-observation through the stereo co-observer tube is essential in intraocular work. For operations on the anterior segment of the eye, however, a separate microscope, mounted at a 90° angle on either side of the main microscope, is preferred (Fig. 6). This separate microscope is mounted on a bracket by means of a sliding dovetail and provides an angle of observation of 19°. It is essential that this assistant's microscope (which basically has one fixed magnification of approximately 6×) is carefully aligned so that it is in focus with the main microscope (parfocality) and its field of view is concentric with the field of view of the main microscope. Adjustment screws in the sliding dovetails allow proper alignment on both sides of the holding bracket. An optional 3-step magnification changer can be attached to the assistant's microscope body to provide magnifications of 4×, 6×, and 10×. The magnification changer is controlled manually like the one on the OPMI 1 series microscopes. For uninhibited use of the "Assistant's Microscope 19°," it is important that before surgery the eyepieces be set at the appropriate diopter values and the pupillary distance be carefully adjusted.

The assistant's microscope can be rotated around its own axis, thereby enabling the assistant to seek out a comfortable position during surgery. It offers full stereo perception similar to that provided by the main instrument and provides the same brightness of image, since light losses resulting from beam splitting are avoided. This kind of assistant's microscope also can be used in other microsurgical disciplines where operations are performed on surface areas and where the assistant can be placed at 90° to the primary surgeon.

The methods of documenting microsurgical procedures with 35-mm photography, Super 8 (8-mm) and 16-mm motion pictures, and television are discussed for the Zeiss OPMI 1, OPMI 6-S, and OPMI 7 P/H.

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THE OPERATING MICROSCOPE. IV. DOCUMENTATION

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Editor's Note: This is the fourth in a series of five articles by Mr. Hoerenz on the basic principles and handling of the operating microscope. The first article, on optical principles, illumination systems, and support systems, appeared in Journal of Microsurgery *1:364–369, 1980. The second article, on individual parts, handling, assembling, focusing, and balancing, appeared in* Journal of Microsurgery *1:419–427, 1980. The third article, on accessories, appeared in* Journal of Microsurgery *2:22–26, 1980. The fifth article, on care and cleaning, will appear in a future issue.*

The increased application of microsurgery has brought with it an increased interest in methods that allow surgical procedures to be documented. The OPMI series microscopes are designed to allow documentation with a variety of methods:

1. Standard still photography on 35-mm color transparency film with a 35-mm camera back.
2. Stereoscopic still photography on 35-mm color transparency film with two 35-mm camera backs.
3. Stereoscopic still photography on 35-mm color transparency film with the 35-mm half frame method.
4. Super 8 (8-mm) cinematography on color film with interchangeable film cartridges.
5. Cinematography on 16-mm film using the negative-positive method.
6. Television picture transmission and recording in black and white or color on videotape.
7. Stereoscopic television transmission and recording in color for special use in teaching.

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35-mm PHOTOGRAPHY

The OPMI series microscopes can be readily adapted for standard still photography or stereoscopic still photography on either whole or half frames using 35-mm cameras (the first 3 methods listed above). The theoretical and practical discussions below are applicable to all 3 methods.

The Photo Adapter. The Zeiss photo adapter or the Zeiss/Urban Dual Camera Adapter shown in Figure 1 is required for 35-mm photography. The Zeiss photo adapter is equipped with a 220-mm focal length objective, which, like a normal camera objective, has an aperture diaphragm with *f*-stops of 14, 16, 22, 32, 44, and 64. Figure 2 demonstrates the path of the light rays through the microscope and the photo adapter to the film plane of the camera.

The objective end of the photo adapter is inserted into the side of the beam splitter. Guide slots make it possible to position the photo adapter so that the camera is positioned either above the microscope body or in front of it at a 90° angle (Fig. 3). The retaining ring of the beam splitter should be tightened securely over the

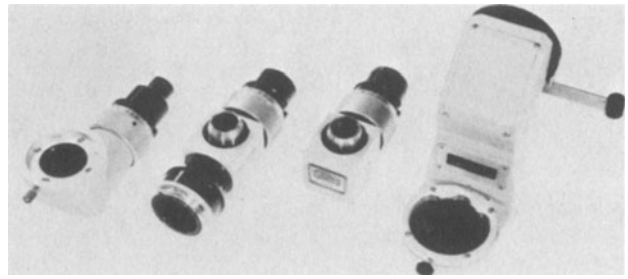

Figure 1. Adapters for the OPMI series microscopes that permit documentation of surgical procedures. (Left to right): The standard Zeiss photo adapter (f = 220 mm); the Zeiss/ Urban Dual Camera Adapter (f = 137/300 mm); the Zeiss cine adapter (f = 74 mm, also available in 137-mm or 107-mm focal lengths); the Urban stereo photo adapter.

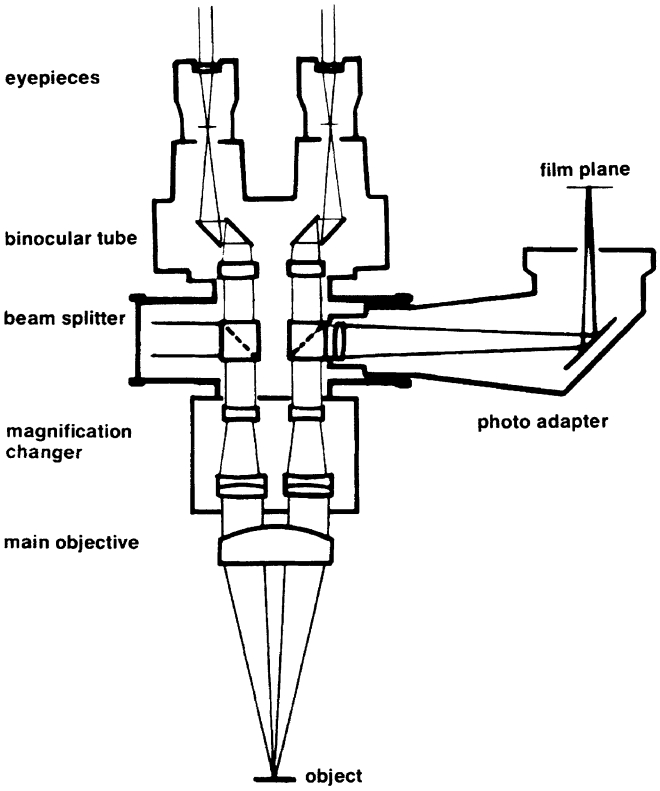

Figure 2. The path of the light rays in an OPMI microscope with a beam splitter inserted between the magnification changer and the binocular tube system and with a photo adapter attached to the beam splitter.

adapter. The camera end of the photo adapter has a simple dovetail receptacle to which the camera body, minus its own objective, is attached. It can be securely fastened by means of a knurled thumb screw.

There are many camera types that can be used with this photo adapter: for example, the Zeiss-Ikon Contarex, the Zeiss-Ikon Ikarex, the Yashica FR, the Contax RTS, the Contax 139 quartz, all Leica M-series cameras, the Leicaflex, Olympus OM series cameras, the Asahi Pentax, all Nikon F-series cameras, and the Exacta Varex. Zeiss also manufactures a special 35-mm magazine for the photo adapter. A special

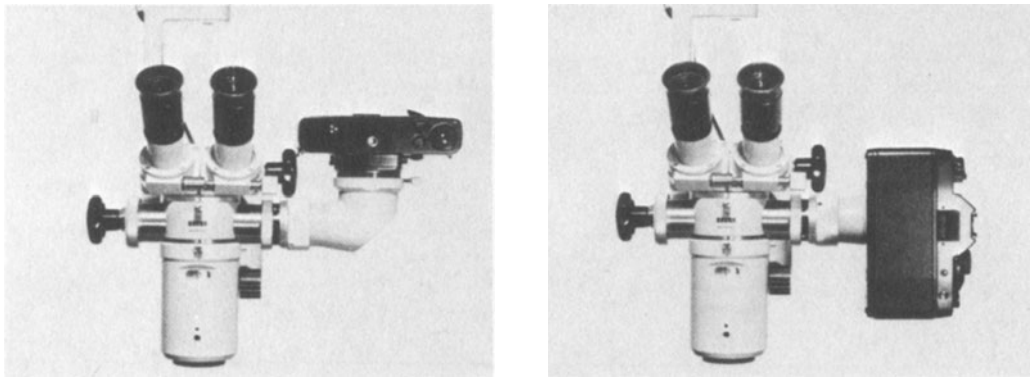

Figure 3. The two ways of mounting the photo adapter and the camera on the beam splitter. Note the cover over the viewfinder of the camera to prevent false light meter readings.

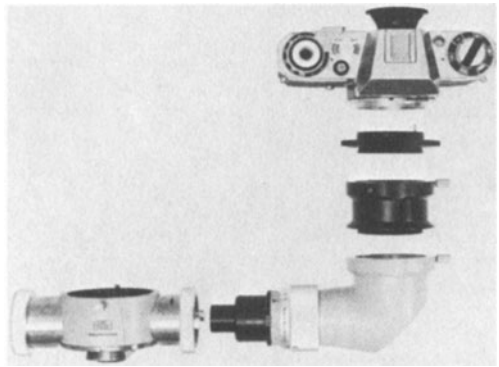

Figure 4. An exploded view of the parts necessary to attach a 35-mm camera back to the beam splitter. (Top to bottom): Special adapter ring to match the camera back to the photo adapter; optional 2× auxiliary lens for enlarging the image; the photo adapter; the beam splitter.

adapter ring is available for each of these camera backs that matches them to the dovetail system of the photo adapter as demonstrated in Figure 4.

The camera is attached to the photo adapter once the adapter is installed on the beam splitter in accordance with one of the positions shown in Figure 3. The photo adapter does not have any focusing mechanism. The film plane of the camera is automatically in focus when it is properly mounted on the microscope. When the microscope is focused, the camera is focused. This is called camera parfocality.

In the event that focusing difficulties are encountered, a special ocular is available that contains a cross hair and may be used in the binocular tube as an aid in focusing. If the ocular has been properly focused beforehand, and both the object and the cross hair are in sharp focus, the camera is in focus and the photograph will be at its optimum sharpness.

Proper Exposures. The primary cause of unsatisfactory photographs is negligent focusing. Attention must be paid, however, to other potential causes of blurry photographs, for example, movement of the object or of the microscope. Furthermore, foreground and background blurriness due to insufficient depth of field may be caused by choosing a level of magnification that is too high, or by an aperture setting that is too large. Finally, over- and underexposures may be caused by choosing either the wrong shutter speed or the wrong aperture setting for the available illumination.

Blurs caused by movement can be observed and eliminated by using the cross-hair ocular. The camera shutter should be released only when no relative movement is observed between the cross hair and the object, that is, when the object and microscope are absolutely still. When using a cable release, particular care must be taken that the cable is not pulled or jerked when the shutter is released. This can cause movement of the camera and a ruined photograph.

Blurring caused by insufficient depth of field is more complicated. Image depth will be discussed in greater detail below, and Table 5 gives

Table 1. Exposure table for an OPMI 1 equipped with a 300-mm objective and the camera set at 320 ASA (ASA 160 film for ESP 1 processing), shutter speed 1/15 sec, and a 30-W lamp on overload.[a]

	Magnification changer				
	6(0.4)[b]	10(0.6)	16(1)	25(1.6)	40(2.5)
Aperture setting	44	52	64	52	44

[a]*This table serves only as an example for the preparation of exposure tables. The values shown are only approximate.*
[b]*Numbers in parentheses are the magnification factors on the knobs of the newer OPMI 1 instruments.*

information on the image depth (also known as "depth of field" or erroneously "depth of focus") in relation to the aperture settings of the photo adapter.

It is important to remember that a deviation of half a stop in the aperture setting can lead to noticeable over- or underexposure of the film. This is especially critical when using color films with emulsions in the lower to middle light sensitivity brackets. Incorrect exposure of color film leads to color shift. Therefore, when using a camera that does not have a built-in exposure meter or fully automatic exposure capabilities, it is absolutely necessary to conduct a series of exposure tests beforehand and to prepare an exposure table based on these test results (Table 1). This exposure table should be arranged so that the aperture setting for the photo adapter is given for the particular type of film, for a particular shutter speed (e.g., 1 second), and for a certain level of illumination (e.g., bulb on overload) in connection with the 5 magnification changer positions of the OPMI 1 or certain positions of the zoom system on the OPMI 6-S and 7 P/H.

The test exposure series should be conducted as follows: With the film speed (ASA or DIN rating), shutter speed, and illumination level set and held constant and with the microscope at the highest level of magnification, focus on an object that resembles as closely as possible the actual object to be photographed. Switch to the lowest level of magnification and take 1 photograph at each of the aperture settings: 16, 22, 32, 44, and 64. Then, switch to magnification level 10, or zoom position 0.6, and again take 1 photograph for each aperture setting. Repeat this procedure for each of the remaining magnification levels. This type of exposure test is best conducted with an animal experiment in the laboratory.

The first series of test exposures should be made on a film of high light sensitivity, such as Kodak Ektachrome 160 (160 ASA, 23 DIN, Tungsten Light Type for artificial light). This makes it possible to use higher aperture settings and to achieve optimum depth of field. (It should be noted that because of certain physical properties of the magnification changer system and light, the aperture settings of 14, 16, and 22 on the photo adapter are not effective at the higher magnification levels because of vignetting.)

It is advisable to prepare a small reference sheet, on which the magnification setting and the aperture setting have been noted, and to photograph it along with the object in the series of test exposures. This will eliminate any errors when evaluating the slides after they have been processed.

The test exposure slides should be evaluated by projection on a screen in a darkened room whenever possible. Only under such conditions is it possible to determine the best rendition of the color and, therefore, the best exposure. The exposure data photographed with the object may also be easily recorded.

In the event that any of the constant factors, such as working distance (i.e., main objective), film speed, shutter speed, or illumination level, are changed for any reason, it is advisable to conduct a new series of test exposures and prepare a new table.

Semiautomatic Cameras. The use of cameras with semi- or fully automatic exposure systems eliminates the need for conducting the series of test exposures described above. Moreover, these types of cameras provide a convenient method for determining the correct exposure factors when changes are made in working distance, film speed, and illumination levels.

Most of the modern semiautomatic single lens reflex camera bodies contain a light metering system that measures the amount of light that comes through the objective (or, in this case, the microscope). This system normally has a needle pointer that must be properly positioned over a mark in the viewfinder. To determine the proper exposure, one proceeds as follows: First, set the film speed of the film being used (e.g., ASA 160) and the shutter speed (e.g., 1 second). Then adjust the aperture of the photo adapter

until the needle aligns with the mark in the viewfinder. The camera is then properly adjusted for that particular situation.

Even with semiautomatic cameras, it is advisable to draw up an exposure table because, during the operation, the camera may be covered by a sterile drape and it may be impossible to look into the camera viewfinder and see the exposure meter. To produce an exposure table for a semiautomatic camera, set and fix as constants: the illumination level, the film speed on the camera body, and the shutter speed. Then, focus the microscope over the object at the highest magnification level. Switch the microscope to its lowest magnification level and adjust the aperture of the photo adapter until the light meter needle aligns with the mark in the viewfinder. Make a note of the magnification level and the aperture setting. Then proceed in exactly the same way for all other magnification levels. This method is very quick, and the exposure table can be prepared in a few minutes. In addition, when changes are made in shutter speed, or in the illumination level, the new requisite aperture settings can be determined quickly.

Cameras without light metering systems and semiautomatic cameras both require constant supervision during the operation to ensure that the correct aperture setting is used for the corresponding magnification level. Ideally, a photographer should assist the surgeon.

Fully Automatic Cameras. The new cameras with fully automatic exposure control that have come on the market in the past few years are ideal for use with the operating microscope. These cameras instantly measure and evaluate the light present in the operating field before the shutter is released, and the shutter speed automatically is matched exactly to the available light. If the amount of light reaching the camera changes, whether through changes in the working distance, the illumination level, the magnification level, or the aperture setting, the automatic exposure control will instantly match the shutter speed exactly to the conditions. The only thing that one should monitor when using an automatic camera is the duration of the shutter release noise, based upon which one can estimate the length of the exposure time. Exposure times that far exceed 1 second present a risk of blurring because of possible movement of the object or equipment. Opening the aperture or increasing the illumination level will immediately shorten the shutter speed.

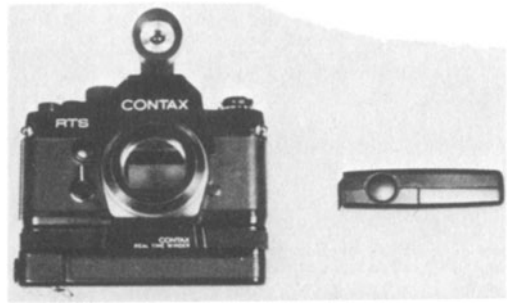

Figure 5. The Contax RTS 35-mm camera with autowinder. Note the infrared sensor shutter release on top. The remote trigger mechanism is on the right.

It must be remembered that when using a fully automatic camera, the ocular of the camera viewfinder must be sealed with a cover cap in order to prevent stray light from the operating room illumination from entering the viewfinder and being measured along with the light arriving through the objective of the photo adapter.

Motorized Cameras. The camera systems that have been described up to this point depend upon manual operation of the film advance and shutter release. Such manipulations can disturb the continuity of the operation. Several new motorized camera bodies that can be triggered by a foot or hand switch and that advance the film automatically overcome such difficulties. These cameras receive power from a transformer or an internal battery pack. The transformer for these cameras is either set up on the instrument table or fastened to the microscope column. The power cable and the shutter release cable travel to the motor mechanism over the horizontal arm, and the shutter release switch is plugged into the transformer. The shutter release can be activated by the surgeon or, on his command, by some other member of the surgical team.

Most of the motorized cameras on the market do not have fully automatic exposure systems, so, here again, one must observe the interrelationships between magnification level and aperture setting.

One new camera system that has been introduced recently, the Contax RTS, fulfills all of the requirements of microsurgical photography. This camera not only has a fully automatic expo-

sure system, but it also has a motorized film transport system (Fig. 5). Moreover, its power supply is provided by a battery pack inside the autowinder, and it no longer needs a shutter release cable because the shutter is triggered by a wireless, infrared release system. The infrared receiver is placed in the hot shoe on top of the camera's viewfinder. This receiver can be turned in different directions so that it can be triggered by a hand-held remote triggering device from any point in the operating room. The astounding advantage of the infrared trigger device is that it can function through the sterile drape covering the camera and microscope. It can also be operated by a person standing far away from the microscope and camera. When the button is pressed, the following events take place: an infrared pulse is sent out and is intercepted by the receiver on the camera, the exposure factors are measured by the exposure meter and the exposure mechanism is adjusted, the electronic shutter is triggered, the film frame is advanced, and the shutter is cocked by the autowinder. The camera then is ready for the next photograph. This system allows a series of photographs to be made quickly, one after the other, which is so often necessary for the presentation of consecutive steps in a microsurgical procedure.

Flash Photography. Occasionally, electronic flash photography is preferred over tungsten light photography to avoid any possibility of blurring caused by movement of the object or microscope. In electronic flash photography, daylight type film must be used because the spectrum of the light from the xenon gas discharge in the flash lamp is very similar to natural sunlight.

In many of the older microscope floorstands, a power supply and connector plug were provided for the electronic flash lamp in the base of the microscope stand. These older stands supply the flash with 80 Ws (watt seconds) of flash energy. All newer floorstands have flash power supplies of 160 Ws. The higher flash capacity is always preferable.

The exposure time in flash photography is determined by the duration of the flash discharge; this lies in the range of 1/3,000th of a second. Synchronization between the flash and the open shutter must be achieved. The shutter speed of the camera is therefore set at 1/60th or 1/30th of a second. Many cameras have a special symbol or shutter speed numbers of a different color to indicate shutter speeds that are synchronized. All shutter speeds slower than the one marked also are synchronized.

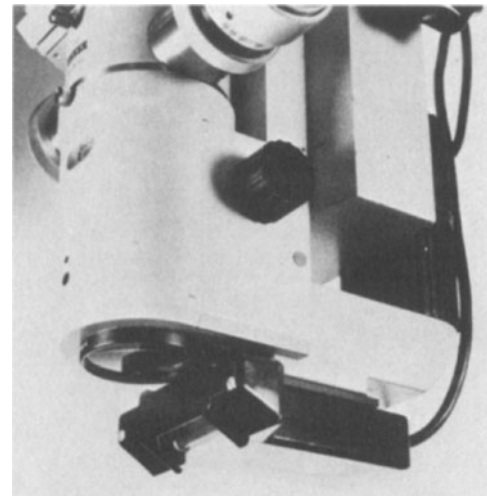

Figure 6. The electronic flash mounted on the dovetail on the lower end of the microscope body. Note that the flash housing should not interfere with the coaxial illumination.

The electronic flash is attached to the dovetail on the lower end of the microscope body and is positioned so that it just touches the cone of light produced by the coaxial illumination (Fig. 6). The angle of incidence of the light from the electronic flash is, therefore, somewhat more inclined than the light of the coaxial illumination. It is important to make certain that the upper window of the electronic flash is covered with a metal shield to prevent the flash from being thrown upward into the objective of the microscope.

On the OPMI 7 P/H and 6 P/H, the flash unit is positioned between the 2 fiberoptic illuminators and is held in place by a special flashholder that rotates.

One of the variables in flash photography is the aperture setting of the photo adapter. A series of test exposures should be conducted in the following manner: For every magnification step and every aperture setting, a flash photograph is taken, so that 25 photographs are made in all. Again, a miniature data sheet should be photographed with the object.

The power source for the electronic flash requires at least 10 seconds to fully charge the

Table 2. Magnification factors (M_C) for the OPMI 1, OPMI 6-S, and OPMI 7 P/H magnification changers.

Microscope	Magnification changer dial setting	M_C
OPMI 1	6	0.4
	10	0.6
	16	1.0
	25	1.6
	40	2.5
OPMI 6-S (zoom)	0.5	0.5
	1.0	1.0
	2.0	2.0
OPMI 7 P/H	0.5	0.5
	1.0	1.0
	2.5	2.5

flash capacitors to their maximum load. The flash may be triggered before the maximum load is reached, however, and thus may underexpose the frame. Firing the electronic flash more than 6 times per minute can lead to overheating and damage to the flash unit. Therefore, if a series of photographs is made in a short span of time, the flash unit should be allowed to cool for a few minutes.

Whenever changes are made in the focal length or film speed, or when the optional 2× objective is used, it is recommended that a new series of test exposures be made.

MAGNIFICATION, CAMERA FIELD OF VIEW, AND DEPTH OF FIELD

It is, of course, very important that whatever is viewed in the operating field of the microscope also be photographed. The focal length of 220 mm was chosen in the design of the photo adapter so that the field of view of the camera would approximate the field of view of the microscope in its most commonly equipped form.

Magnification. The calculation of the field of view of the camera is derived from knowledge of the magnification of the object in the film plane of the camera. The formula for camera magnification (M_{35}) is:

$$M_{35} = (f_p/f_o) \times M_C$$

where f_p = 220 (the focal length of the photo adapter), M_C = the magnification factor, and f_o = the microscope working distance (the focal length of the main objective). The magnification of the object in the film plane of the camera is therefore reduced each time the focal length of the main objective (f_o), that is, the working distance, increases, and is proportionate to the magnification level (M_C) of the magnification changer. The magnification factor (M_C) can be taken from Table 2, and with it the magnification in the film plane of the camera for the usual working distances of 200 mm and 300 mm can be determined (Table 3).

For example, if the magnification changer is set at 16 (M_C = 1), an object 1 cm in size in the operating field will be projected onto the film plane of the camera as 1.1 cm (1.1×), or slightly larger than its real size, with the 200-mm objective, and as 0.7 cm (0.7×), or slightly smaller than its real size, with the 300-mm objective. The comparative values for the visual magnification from Table 4 are 12.5× and 8×, respectively.

Camera Field of View. By comparing the fields of view of the camera and the microscope, it becomes clear that the differences in magnification between the visual and the photographic systems are meaningful. The following formula is helpful for determining the size of the field of view of the camera (F_{35mm}):

$$F_{35\,mm} = (24 \times 36\ mm)/M_{35}$$

It can be seen that the field that the camera "sees" is determined by dividing the film format

Table 3. The size of the field of view of the camera (small side × large side in mm) and the magnification (M_{35}) of an OPMI 1 with the standard photo adapter.

Working distance (f_o) (focal length of main objective)	Magnification changer dial setting									
	6 (0.4)[a]		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
200 mm	60 × 90	0.4×	34 × 51	0.7×	22 × 33	1.1×	13 × 20	1.8×	9 × 13	2.7×
300 mm	80 × 120	0.3×	60 × 90	0.4×	34 × 51	0.7×	20 × 30	1.2×	13 × 19	1.9×

[a]*The numbers in parentheses are the magnification factors on the knobs of the newer OPMI 1.*

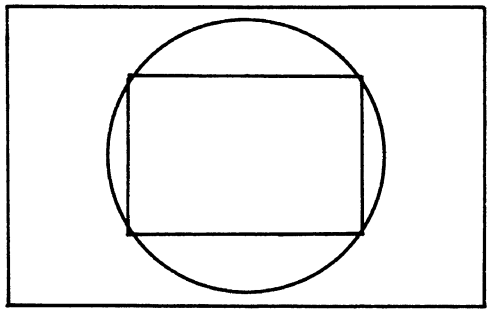

Figure 7. This sketch was traced while looking through both the oculars of the operating microscope and the viewfinder of the camera. The visual field of the microscope is represented by the circle (125-mm binocular tubes and 20 × oculars); the large rectangle represents the field of the 35-mm camera mounted on the photo adapter (f = 220); the small rectangle represents the field of the 35-mm camera with the auxiliary 2× lens attached to the photo adapter.

by the magnification. Returning to the example we used above, with the magnification changer set at 16, we find that rectangular fields are produced that have border lengths of 22 × 33 mm for the 200-mm objective, and 34 × 51 mm for the 300-mm objective (Table 3). For comparative purposes, we determine from Table 4 that the round fields of view of the microscope with these objectives have diameters of 16 and 25 mm, respectively. This means that the visual field of view is totally covered by the field of view of the camera and that all the details that can be seen through the microscope can also be photographed.

Practical hint. With most of the commonly used single lens reflex cameras, it is possible to determine the field of view of the camera directly through the camera viewfinder. It is best to use a piece of graph paper marked in millimeters as an object when doing this. This will enable one to easily determine both the field size and the magnification by counting the millimeters pictured in the viewfinder. For example, when 12 millimeter elements are visible along the short edge of the 35-mm frame, the magnification factor is 2, because this edge is 24 mm. In other words, one divides 24 by the number of millimeters visible along this edge. The total camera field can easily be determined by counting the millimeters visible along both frame edges. While doing this test it is of course possible to also determine the diameter of the microscope field by looking through the oculars. One can also take a pencil and trace both fields on the graph paper while looking through the camera viewfinder and the oculars (Fig. 7). This supplies an immediate document of the available conditions.

Depth of Field. Depth of field in the object viewed is of great importance in microsurgical photography. It is especially important when making photographs for publication, where the levels of the operating field both above and below the detail of interest must be presented in sharp focus. The formula for determining the depth of field (T) for the 35-mm camera is as follows:

$$T_{35} = T'/M_{35}^2$$

where $T' = 2k \times u$ (image depth or depth of focus), and $M_{35} = (f_p/f_0) \times M_C$ (camera magnification). Through transposition we arrive at the following formula:

$$T_{35} = (2k \times u \times f_0^2)/(f_p^2 \times M_C^2)$$

where k = the photo adapter aperture number (14, 16, 22, 32, 44, and 64), u = the maximum allowable diameter of the circle of diffusion

Table 4. The size of the field of view (mm) and the total magnification power of an OPMI 1 equipped with 125-mm binocular tubes and 20× eyepieces.

	Magnification changer dial setting									
	6 (0.4)[a]		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
Focal length of the main objective	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
200 mm	40	5×	27	7.5×	16	12.5×	10	20×	6	31×
225 mm	44	4.5×	30	6.5×	18	11×	11	18×	7	28×
250 mm	50	4×	33	6×	20	10×	12.5	16×	8	25×
275 mm	57	3.5×	36	5.5×	22	9×	14	14.5×	9	23×
300 mm	67	3×	40	5×	25	8×	15	13×	10	21×

[a]*Numbers in parentheses are the factors on the new OPMI 1 magnification changer knobs.*

Table 5. The depth of field (in mm) in relationship to the magnification of the photo adapter with settings of 16, 32, and 64 and working distances of 200 mm and 300 mm.[a]

Working distance (f_0)	Aperture setting	Magnification changer dial setting				
		6 (0.4)	10 (0.6)	16 (1)	25 (1.6)	40 (2.5)
200 mm	16	8.3	3.7	1.3	—	—
	32	16.5	7.3	2.6	1.0	0.4
	64	33.0	14.7	5.3	2.1	0.8
300 mm	16	18.6	8.3	3.7	—	—
	32	37.0	16.5	7.3	2.6	0.9
	64	74.0	33.0	14.7	5.2	1.8

[a]*See Table 3 for* M_{35} values.

Table 6. The size of the field of view of the camera (small side × large side in mm) and the magnification of an OPMI 1 equipped with the standard photo adapter and the auxiliary 2× lens.

Working distance (f_0) (focal length of main objective)	Magnification changer setting									
	6 (0.4)		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
200 mm	30 × 45	0.8×	17 × 25	1.4×	11 × 16	2.2×	6.5 × 10	3.6×	4.5 × 6.5	5.4×
300 mm	40 × 60	0.6×	30 × 45	0.8×	17 × 25	1.4×	10 × 15	2.0×	6.5 × 9.5	3.8×

(agreed upon measurement: 0.05 mm), f_0 = the focal length of the main objective on the microscope, f_p = the focal length of the photo adapter (220 mm, or 440 mm with the 2× auxiliary lens), and $M_{f\cdot}$ = the magnification changer factor (0.4, 0.6, 1, 1.6, and 2.5).

This formula demonstrates that the depth of field is influenced by 2 variables: (*a*) the diameter of the diaphragm (k) of the photo adapter aperture, and (*b*) the magnification. Specifically, the depth of field changes linearly with the aperture number, i.e., it increases as the aperture number (k) increases. On the other hand, the depth of field is unfavorably affected by the degree of magnification, in inverse proportion to it, and, what is more, quadratically, i.e., when the magnification is doubled, the depth of field is reduced 4 times. Again, returning to our example above, we obtain a depth of field of 2.6 mm with the magnification changer set at 16, the photo adapter aperture set at 32, and a working distance of 200 mm. For the working distance of 300 mm, the depth of field is 5.9 mm. When using *f*-stop 64 on the photo adapter, the depth of field is 5.3 mm for the 200-mm objective and 12 mm for the 300-mm objective.

As long as sufficient light is available, it is always advisable to close the aperture of the photo adapter as far as the longest tolerable exposure time permits. It is also always advisable to work with the highest possible illumination in order to reach this goal.

One must always keep in mind the influence that the magnification and the aperture setting have on the depth of field when making photographs for publication. In such cases it makes sense to work with a low camera magnification to ensure that the depth of field includes the entire operating field and to produce the desired image scale for reproduction through subsequent enlargement of the photographs. These relationships are clearly shown in Table 5. The use of magnifications that exceed 1× are especially critical, particularly when aperture settings 44 and 64 are no longer usable because of insufficient light.

Auxiliary 2× objective. In the event that a higher magnification in the film plane of the camera in relation to the visual field is desired, an auxiliary 2× lens is available that fits between the photo adapter and the camera. This lens doubles the

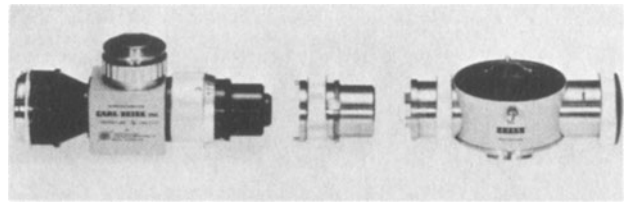

Figure 8. The Dual Camera Adapter manufactured for Zeiss by the Urban Engineering Co. Note the piece in the center for extending the adapter if bulky TV systems are employed.

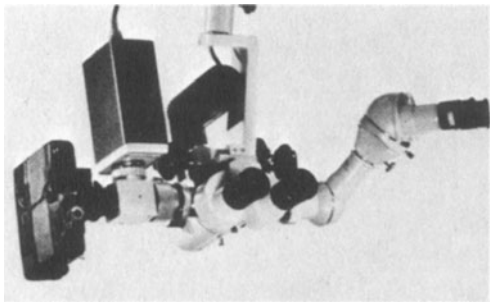

Figure 9. The Dual Camera Adapter mounted on an OPMI 1 with a Contax RTS 35-mm camera and a TV camera.

focal length of the photo adapter to 440 mm and converts the magnifications and fields of the camera to the values given in Table 6.

Again, using the example with the magnification changer set at 16, and comparing the fields of view of the microscope with the fields of view of the camera, it becomes clear that the rectangular camera field now has its corners cut off by the circular microscope field. This size field of view may be preferred when the actual object to be viewed is relatively small in comparison to the total field of view, as is often the case in neurologic and otologic surgery.

THE DUAL CAMERA ADAPTER

A versatile adapter for documentation that has recently been introduced is the Zeiss/Urban Dual Camera Adapter (Fig. 8). This adapter simultaneously accepts a TV or movie camera and a 35-mm camera, using only one opening of the beam splitter (Figs. 9 and 10). This dual capability is especially important to the OPMI 7 P/H in reconstructive surgery and also for the other models in ophthalmic and neurologic microsurgery, where the use of the stereo co-observer tube is mandatory.

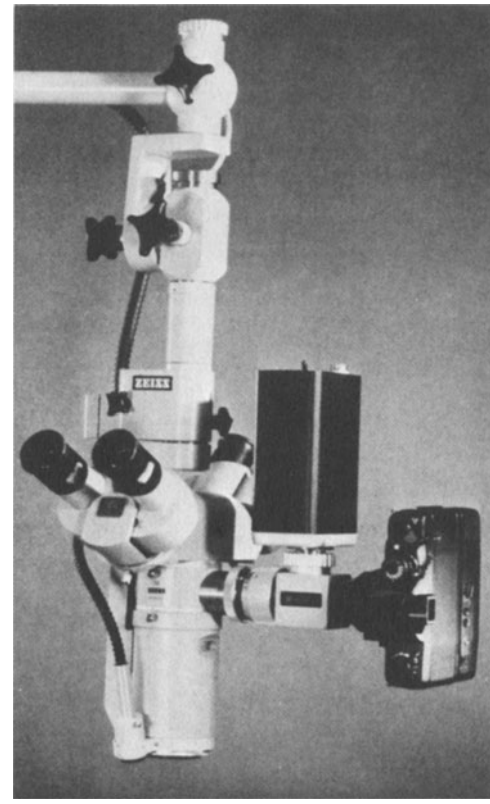

Figure 10. The Dual Camera Adapter mounted on an OPMI 7 P/H for documenting reconstructive surgical procedures.

The Dual Camera Adapter has 2 focal lengths, (*a*) 137 mm for movie and TV cameras and (*b*) 300 mm for 35-mm cameras (Table 7), and it contains a beam splitter that divides the incoming light evenly 50/50 between each camera system.

Table 7. Magnifications at the film planes of a 35-mm camera and a 16-mm motion picture camera with the Zeiss/Urban Dual Camera Adapter on the OPMI 1, OPMI 6-S, and OPMI 7 P/H.

Working distance (f_0)	Magnification changer dial setting				
	6 (0.4)	10 (0.6)	16 (1)	25 (1.6)	40 (2.5)
OPMI 1					
35-mm camera					
200 mm	0.6×	0.9×	1.5×$_{\infty}$	2.4×	3.8×
300 mm	0.4×	0.6×	1.0×	1.6×	2.5×
400 mm	0.3×	0.5×	0.8×	1.2×	1.9×
16-mm camera					
200 mm	0.3×	0.4×	0.6×	1.0×	1.6×
300 mm	0.2×	0.3×	0.5×	0.7×	1.1×
400 mm	0.1×	0.2×	0.3×	0.5×	0.9×

	Magnification changer (zoom)	
	0.5	2.0
OPMI 6-S		
35-mm camera		
150 mm	1.0×	4.0×
200 mm	0.8×	3.0×
300 mm	0.5×	2.0×
16-mm camera		
150 mm	0.5×	1.8×
200 mm	0.3×	1.4×
300 mm	0.2×	0.9×

	Magnification changer (zoom)	
	0.5	2.5
OPMI 7 P/H		
35-mm camera		
200 mm	0.8×	3.8×
225 mm	0.6×	3.0×
16-mm camera		
200 mm	0.4×	1.7×
225 mm	0.3×	1.5×

The advantages of this design are obvious. It is possible to perform 35-mm photography without interrupting the TV system. This means continued TV tape recording as well as uninterrupted observation on the TV screens. The instant readiness of the 35-mm camera relieves the physician or assisting photographer from making manual adjustments on the microscope or adapter system that unavoidably cause the microscope to vibrate. A Yashica bayonet mount for the 35-mm camera permits the fully automatic Contax RTS camera back to be attached without any additional adapter ring. Any TV or movie camera equipped with a standard C-thread lensmount can be attached via the C-thread adapter ring.

Exposure factors for 35-mm photography are the same as for the standard photo adapter. However, High Speed Ektachrome 160 (160 ASA, Tungsten Light Type) should be used and the ASA scale on the camera should be set at 320. Kodak ESP 1 processing should then be specified when the film is sent to the processor. Regarding exposure factors for movie cameras, no changes are required, except that the diaphragm should be opened one *f*-stop. Movie cameras with automatic light meters connected to the motorized diaphragm control will function as on the regular single cine adapter.

Regarding TV cameras, the procedure for selecting the appropriate diaphragm setting remains the same. The automatic 35-mm camera is not influenced in the process of determining the proper exposure.

Details regarding the use of the movie and TV cameras will be discussed below.

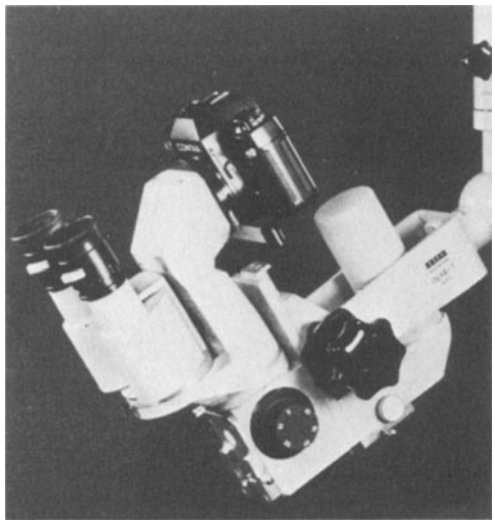

Figure 11. An OPMI 1 equipped with the Zeiss-Urban stereo photo adapter and a Contax automatic camera. Note that the binocular tubes are moved forward approximately 25 mm.

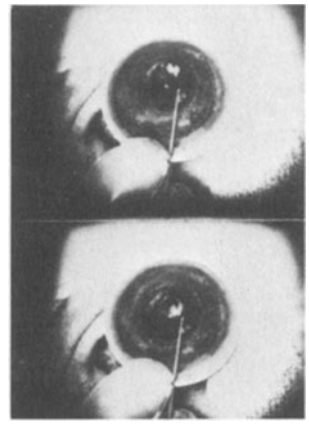

Figure 12. A black and white copy of a stereo color slide taken with the Zeiss/Urban stereo photo adapter.

STEREO PHOTOGRAPHY

The 2 methods available for producing stereoscopic photographs, that is, the full-frame method with 2 cameras and the half-frame method with 1 camera, deliver a perfect 3-dimensional perception of the microstructures in the operating field that is identical to the stereoscopic image viewed through the microscope by the surgeon. This is of special advantage in teaching.

Both methods of stereo photography rest upon the following principle: the light rays in each of the binocular tubes of the microscope produce a slightly different image. These 2 images produce a stereoscopic effect when they are viewed simultaneously through the oculars or when the 2 photographs of the images are viewed in a special viewer.

In the full-frame method, 2 photo adapters are attached to the 2 openings of the beam splitter, and two 35-mm cameras are mounted on the adapters. The two 35-mm cameras must be carefully aligned so that they are parallel to each other, and their apertures must be set at the same *f*-stop, so that the 2 full-format photographs that are obtained will have the same color values. These 2 photographs are a stereoscopic pair and can be viewed with a special stereo viewer. Stereo projection is also possible. One advantage of this method is that each of the photographs can also be used for monoscopic viewing.

The second method is based on the simultaneous recording of both images on a single 35-mm frame. This involves equipping the microscope with a special stereo photo adapter developed by Urban Engineering (Burbank, CA). This adapter has 2 objectives with focal lengths of 175 mm, and is attached directly to the microscope body in place of the standard beam splitter. The use of this special stereo adapter moves the binocular tube system forward approximately 25 mm; this, however, does not affect the use of the instrument in any way (Fig. 11). Any camera that can be used with the standard photo adapter can be used with the stereo adapter if it is attached with the special adapter ring that ensures horizontal alignment. Cameras with automatic exposure control are best suited. The stereo photo adapter reduces the dimensions of the image from each of the 2 light ray paths to 16 × 24 mm. This permits each image to be recorded on one half of a standard 35-mm frame without mutual interference (Fig. 12).

The method of viewing such a stereo photograph with a stereo viewer is simpler than full-frame stereo viewing. Stereo projection is also possible with a normal projector equipped with a special stereo projection attachment in front of the projector lens. In order to view projected stereo photographs, one needs to wear special polarized eyeglasses.

Table 8. Camera magnifications and camera fields of view (in mm) for Super 8 (8-mm) and 16-mm motion picture cameras mounted on an OPMI 1 with the standard motion picture adapters (f = 74, 107, or 137 mm) at working distances of 200 mm and 300 mm.

	Magnification changer dial setting									
	6 (0.4)		10 (0.6)		16 (1)		25 (1.6)		40 (2.5)	
Working distance (f_0)	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification	Field of view	Magnification
Super 8, 74-mm adapter										
200 mm	42 × 55	0.1×	21 × 28	0.2×	11 × 14	0.4×	7 × 9	0.6×	5 × 6	0.9×
300 mm	46 × 16	0.09×	42 × 55	0.1×	21 × 28	0.2×	11 × 14	0.4×	7 × 9	0.6×
16-mm, 107-mm adapter										
200 mm	38 × 52	0.2×	25 × 34	0.3×	15 × 21	0.5×	8 × 11	0.9×	6 × 9	1.3×
300 mm	75 × 103	0.1×	38 × 52	0.2×	19 × 26	0.4×	13 × 17	0.6×	8 × 11	0.9×
16-mm, 137-mm adapter										
200 mm	25 × 34	0.3×	19 × 26	0.4×	11 × 15	0.7×	7 × 9	1.1×	4 × 6	1.8×
300 mm	38 × 52	0.2×	25 × 34	0.3×	15 × 21	0.5×	10 × 15	0.7×	6 × 9	1.2×

CINEMATOGRAPHY

The production of motion pictures during an operation for use in teaching, discussions, and seminar lectures is also possible on OPMI instruments. Both Super 8 (8-mm) and 16-mm camera systems can be employed. Special adapters, similar to the 35-mm photo adapter, are available that contain their own objectives and are inserted into the standard beam splitter.

For Super 8 motion pictures, a cine adapter with a 74-mm focal length is used; for 16-mm photography, cine adapters with focal lengths of 107 and 137 mm are used. The cine adapters are equipped with an intermediate ring for accommodating movie cameras equipped with the standard C-thread, which permits the direct attachment of these cameras to the cine adapter.

To simplify the setting of the exposure, the cine adapters can be equipped with a fully automatic exposure system, which can be used in connection with the Super 8 and R 16 cameras produced by the Beaulieu Company in France.

The special advantage of the Super 8 system lies in the use of the short objective (f = 74 mm), which means good image brightness and relatively large depth of field. Equally advantageous is the comparatively uncomplicated and fast exchange of film cartridges during an operation. On the other hand, Super 8 movie film cannot be projected onto screens wider than 1.20 m without a definite loss of quality and, therefore, is suitable only for presentation to small audiences. Super 8 is relatively inexpensive, however, which means that films of operations can be produced routinely.

The advantage of the 16-mm film system lies in its high quality when screened for large audiences and in its potential for copy production from color negative material and, thereby, wide distribution. As already noted, the cine adapters with 107- and 137-mm focal lengths are used for 16-mm photography. The 107-mm adapter is preferred in ophthalmology, because its lower magnification permits a wider field to be filmed. The 137-mm Cine Adapter is employed in most other surgical disciplines.

Urban Engineering has developed a special movie camera that can be attached directly to the cine adapter or the Dual Camera Adapter without the use of the intermediate adapter ring. This camera is triggered by a foot pedal and is powered by its own source attached to the microscope column. The correct exposure is provided by a simultaneous increase in the electric current supplied to the incandescent bulb in the microscope. A special characteristic of the Urban camera is its interchangeable film magazines. These magazines are carefully loaded before the operation, and after the film in one magazine is used up, it can be exchanged in seconds without in any way disturbing the continuity of the operation. A warning light on the

magazine comes on when the magazine is nearly empty, indicating that only 5 feet of film remain.

To determine the magnification and field of view of the movie camera, we can use the formula given in the section on 35-mm photography. In this case, instead of the photo adapter focal length of 220 mm, we substitute the focal lengths of the cine adapters for Super 8 and 16-mm film, i.e., 74, 107, and 137 mm. For the calculation of the field of view of a movie camera, we must proceed from the size of the film frame, which is 4.2 mm × 5.5 mm for Super 8, and 7.5 mm × 10.3 mm for 16-mm film. Table 8 is based upon calculations using these values: f_{Cine} = 74 mm, 107 mm, and 137 mm; and working distance = 200 mm or 300 mm.

TELEVISION CAMERAS

In the past few years the electronics industry has made major progress in the miniaturization of TV cameras and in the improvement of color rendition even at low light levels. This means that black and white and color TV cameras weighing as little as 250 g (approximately 1/2 lb) can be permanently installed on the beam splitter of a microscope by means of the 137-mm cine adapter.

Through use of the television camera, the operation may be transmitted to a television screen in the operating room for the orientation of the assisting personnel, or to more distant places, such as the doctor's lounge or the office of the chief surgeon. Audiovisual communication between these locations allows the progress of the operation to be discussed. For teaching institutions, this type of set-up is an absolute necessity. It also makes possible the production of video tapes for teaching.

A large number of color television cameras with excellent color reproduction and resolving power are being offered on the commercial TV market at the moment. It is quite obvious that, like all highly complicated electronic instruments, TV cameras require maintenance, and, therefore, the choice of a system should go to the firm that provides good local service.

The optimum in life-like documentation is seen in color stereo television. This method, up to now, has only been performed on a more or less experimental basis and serves purely the purpose of microsurgical instruction. In the future it will make it possible for numerous observers to experience simultaneously the progress of an operation in color with true 3-dimensional depth perception.

TV cameras to be used with the microscope must be equipped with a standard C-thread mount. They are attached to the cine adapter or the dual camera adapter by means of the C-thread mount adapter ring, which allows them to be locked securely in place. Orientation of the TV camera can be checked on the screen and the camera may be rotated to match the field of view with 12 o'clock on the TV monitor. The diaphragm *f*-stop on the cine-adapter can be rotated to check for the best color reproduction while the microscope illumination is run on regular load. Of course, the specimen used should closely represent the actual object when adjusting the camera before an operation. A larger *f*-stop number may be selected if the color reproduction at higher magnifications tends to fade out. The *f*-stop that is finally selected can be maintained during all procedures, even on the Dual Camera Adapter, since the 35-mm camera automatically adjusts its own exposure.

Methods of cleaning and caring for the Zeiss OPMI series microscopes are discussed.

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THE OPERATING MICROSCOPE. V. MAINTENANCE AND CLEANING

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Editor's Note: This is the fifth and last article in a series by Mr. Hoerenz on the basic principles and handling of the operating microscope. The first article, on optical principles, illumination systems, and support systems, appeared in Journal of Microsurgery *1:364–369, 1980. The second article, on individual parts, handling, assembling, focusing, and balancing, appeared in* Journal of Microsurgery *1:419–427, 1980. The third article, on accessories, appeared in* Journal of Microsurgery *2:22–26, 1980. The fourth article, on documentation, appeared in* Journal of Microsurgery *2:126–139, 1980.*

Although the Zeiss operating microscopes are designed to give years of trouble-free service, routine maintenance and cleaning will ensure optimal performance each time the instrument is used.

THE OPTICS

Before each use of the microscope, all external lens surfaces should be inspected and, if need be, cleaned. The internal glass surfaces also should be inspected for cleanliness if the binocular tube system is changed, if the beam splitter is installed, or if the oculars are changed.

Not much can be done, of course, to eliminate mechanical damage, such as scratches in the lens or chips near the lens flange, that may result from improper handling or dropping the lens. If such damage is sustained in the region of the optical light ray paths and illumination ray paths of an objective lens, the objective will have to be replaced.

The lens surfaces of the microscope are susceptible to 3 types of dirt: (*a*) loose deposits such as dust; (*b*) water-soluble substances such as spots of blood, irrigating solutions, or water; and (*c*) substances not soluble in water, such as oil from eyelashes and fingerprints.

To remove loose particles, especially dust, a small rubber blowing bulb can be used. This bulb should be held at an inclined angle approximately 1 cm from the lens surface and squeezed briskly. This will produce strong blasts of air that should blow most of the particles away. The advantage of this method is that it is not necessary to touch the lens surface in order to clean it.

Loose particles of dust on the objective also can be removed with a brush made of badger hair. This brush must be dipped in a chemical cleaning solution in order to clean it and remove any oil. The cleaning solution must be allowed to evaporate completely before the brush is used, and the brush should be cleaned frequently.

Very often, after dust has been removed from a lens, a thin film remains on the surface of the

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lens. This film precipitates from the air and can only be removed by wiping the lens. Clean cotton balls are the most suitable material for wiping optical surfaces; linen cloths that are lint-free and have been repeatedly washed also are suitable.

The film on a lens may be removed by breathing carefully onto the surface of the lens to fog it and wiping slowly in a circular fashion from the center of the lens outward to the edge with a clean cotton ball. This procedure should be repeated with new material until the film is gone. In most cases, this type of cleaning is sufficient for all of the lens surfaces except the objective and possibly the eyepieces. The objective should never be cleaned in this manner because the breath may contaminate the lens and the objective cannot be covered by sterile draping in the operating room.

The degree of soiling usually is heavier on the objective and oculars. For example, the objective often becomes soiled during an operation from spattered blood or spots of irrigating solution. It may also become soiled from fingerprints when the instrument is handled after the operation.

A small quantity of cotton applicators, known commercially as "Q-tips," should be used to clean such soiling of the objective or eyepieces. Q-tips are short wooden sticks that have a small portion of cotton wrapped on the ends. (Note: cotton applicators made with *plastic* sticks should not be used, as some of the cleaning solvents tend to dissolve the plastic.)

In order to clean an objective or ocular, one end of a Q-tip should be moistened with distilled water; however, it should not be moistened to the point of being dripping wet. This Q-tip then is used to wipe the lens in a circular motion to remove water-soluble dirt. The surface of the lens then should be wiped with a clean, dry Q-tip. When this has been completed, the dirt that is not soluble in water is removed with a cleaning solvent consisting of 25% denatured alcohol, 10% ether, and 65% acetone. When mixing a stock solution of these highly volatile components, extreme care should be taken. The solvent should be stored in a glass bottle. In applying this cleaning solvent to the optical surface, it is *very* important that the cotton applicator be only lightly moistened with solvent and never dripping wet. Here again, the Q-tip is used to wipe outwardly from the center to the edge of the lens in a circular fashion. This procedure must be repeated as many times as necessary to render the glass surface absolutely free of streaks.

If it is determined that the inner surface of the objective, which is inside the microscope body, also requires cleaning, the objective should be carefully screwed out of the microscope. The inner surface should be cleaned and the objective reinstalled before the outside surface is cleaned.

Important Reminder. It must be mentioned again that the cleaning fluids should never be used on the objective in such quantities that excess amounts of the solvent flow between the lens and the lens mount. These excess fluids could damage the internal cemented surfaces of the objective. Certain aggressive cleaning substances, such as 100% acetone or pure alcohol, even in small quantities, are powerful enough to destroy the cemented surfaces and therefore should never be used. It also is important that the cleaning substance itself be absolutely clean, and that it contain no foreign material. The cotton applicator should never be dipped into the bottle of stock solution; solvent should be poured into a Petri dish for the cleaning procedure.

CLEANING THE OPERATING MICROSCOPE

The rule of never using an excess amount of cleaning fluid also applies in cleaning the mechanical parts of the microscope. It is, however, permitted and recommended that the external surfaces of the microscope be washed regularly with clean linen cloths that have been dipped in mild soap and water or nonaggressive disinfecting solutions and then wrung out well. The horizontal arm and floor stand may be cleaned in the same manner. As a last step, all parts should be wiped with a dry, lint-free, linen cloth.

Microscopes that are subjected to this maintenance on a regular basis will, over the years, always maintain a factory-new appearance and, above all, will deliver the highest optical performance whenever they are used.

When the surfaces of the microscope are being cleaned, the mechanical functions of the arm joints, the carriage, the casters underneath the base, the base brakes, and the nylon tapes, also should be inspected. It has been mentioned in previous articles that the coupling joints can

be greased with petroleum jelly. Should other nonaccessible joints grind or squeak, service by a trained technician is needed.

The up-and-down movement of the carriage should be smooth and rattle-free. Bumpy movement of the carriage indicates that one of the roller-ball bearings has been damaged. Again, service by a technician is needed.

While the carriage is being checked, special attention should be paid to examining the double nylon tape. Should one of the two tapes show any signs of marring, cracking, or other damage, the microscope should be taken out of the operating room *immediately* and a technician should be called.

The three casters underneath the base should roll evenly. A bumpy ride on a smooth floor indicates that the rubber wheels have started to deteriorate and must be replaced; all three casters should be replaced at the same time.

Occasionally, the locking brakes become loose. This condition also should be corrected by a service technician.

CARE OF THE ILLUMINATION EQUIPMENT

Anyone who has ever had to change a burned-out bulb during an operation will know how important it is to inspect the illumination system on a regular basis before surgery.

The following items must be checked on the coaxial and external illumination systems: the 6-V 30-W regular tungsten bulb with centering socket and the 12-V 100-W halogen bulb with centering socket.

The lamp cable, which runs from the lamp holder to the plug receptacle on the horizontal arm, must be free of kinks or breaks. Its 2-pin plug must sit firmly in the receptacle on the horizontal arm and be free of movement. Both contact pins of the plug must be free of corrosion; that is, their metal surfaces should look shiny and should not have any black or brown spots that would indicate contact resistance and sparking in the plug contact. Plugs that contact poorly reduce the amount of current reaching the lamp and hence reduce the amount of light in the operating field. Moreover, corrosion on the pins can build up heat and melt the material, leading to a breakdown in the lighting system.

The lamp cable normally stays cold when the microscope is in use. Should a hot lamp cable be discovered at the end of a long operation, it should be exchanged for a new one through the repair service. A hot cable may indicate that a high electrical current is passing through the cable; this might be caused by a shorted circuit in the lamp housing. In any case, the components of the lamp housing should be examined carefully.

It is recommended that a new bulb be used for operations of long duration (4 or more hours) or whenever a bulb is to be used for a long period on overload. The risk of burning out a bulb during the operation thus will be sharply reduced.

Changing the bulb in the bayonet socket of the lamp house must be done carefully; only a perfectly inserted bulb guarantees shadow-free, even illumination of the operating field. In order to change a bulb, the upper lamp housing is turned approximately 90° in a counter-clockwise direction. It then may be lifted in an upward direction from the microscope illuminator. On microscopes manufactured before 1979, the bulb should be pressed against the bulb housing and turned toward the left; it then will slip out of the bayonet mount. It can be removed by lifting it up and out. On the newer OPMIs, the bulb is sitting in the lower part of the illuminator and can just be lifted out.

A new bulb should not be handled with bare fingers during insertion; rather it should be gripped with a cloth or the carton in which it is packaged. The 3-corner centering plate on the base of the bulb allows it to be inserted in only one way, that is, in the guide grooves of the lamp housing. On the microscopes manufactured before 1979, the pressure of the spring-loaded contacts will be noticeable before the bulb reaches the bayonet grooves. The bulb then should be gently pushed down until it touches the bayonet and turned in a clockwise direction until an obvious click is heard. The correct positioning of the bulb in the socket of the lamp housing should be checked. If a red or blue shadow appears in the field of illumination, the seating of the bulb should be rechecked. On the newer microscope models, the lamp is dropped into the opening in the illuminator and its socket wings are aligned between the locating pins.

Changing the halogen bulb is equally easy. First, the fan housing, which is the upper portion of the halogen illuminator, is lifted off by depressing the two Teflon buttons on the sides of the housing. The socket and connecting pins of the bulb point upward from the lower illuminator

part and the bulb is held in place by a spring-loaded clip. The clip is unlocked by turning the white nylon locking button 90°. Then the button and the clip can be raised and the bulb removed. When "dropping" the new bulb into place, the cut-out in the bulb centering socket should be engaged with the tong on the rim of the opening. Finally, the clip is replaced over the bulb socket and turned 90° to lock it. The fan housing is reinstalled by engaging the two guidebars in the holes of the illuminator housing and pushing downward until an audible click indicates full engagement.

Today, fiberoptic illumination systems are being used in great numbers on operating microscopes. In these systems the lamp housing is positioned outside of the sterile microscope drape, and access to the bulb has been simplified by use of a sliding drawer system. This means that a bulb change, together with its drawer, is possible in a few seconds. Therefore, it is not necessary to insert a new bulb before each operation. A spare lamp drawer with a fresh bulb installed in it, however, must always be kept within reach.

The fiberoptic cable of a fiberoptic illumination system should never be bent too sharply; this could lead to fracturing of the thin glass fibers inside the cable. The loss of a large number of such fibers over the years will reduce the illumination level.

Keeping the fiberoptic light cables clean is very easy. Only the polished surfaces at the end of the cable must be kept free of dirt. Here again, cotton applicators can be used for cleaning. When inserting the fiberoptic cable into the lamp housing or into the illumination prism on the microscope, the metal tip of the cable should be pressed in until it is firmly seated against the end stop. The illumination prism of the Vertolux system must be cleaned thoroughly in the same manner as the front objective of the microscope. Here too, cotton applicators and cleaning solutions can be used to clean the surfaces accessible from the outside.

Important Note. The codes of UL 544 (medical and dental equipment) on electrical equipment that is listed by Underwriters Laboratories, Inc. (UL) require that no lay person be able to open and tamper with the electrical power supply if a malfunction occurs. A label on the outside warns: "Not a user-serviceable item." This warning should be taken seriously and no unqualified person should attempt to trouble-shoot such a device. On the other hand, the UL listing assures you that the device has been built in compliance with the strict rules established for equipment that can be used safely in the environment of the operating room. This protects both the user and the patient from possible harm.

B

Patient Information: Laser Surgery

Laser treatment for various gynecologic diseases is a new application of a very important scientific and new therapeutic tool. For the past several years, research and development have made it possible to use the CO_2 laser to treat a wide variety of benign and early malignant diseases of the vulva, vagina, and cervix.

The laser is a beam of infrared light, invisible to the eye, which has the ability to be focused to a minute spot size (1–3 mm). This is similar to focusing sunlight with a magnifying lens to a bright spot. With infrared light from the CO_2 laser so focused, generally by means of an operative microscope, the energy of the laser beam on impact with the cells causes their instantaneous vaporization to a small depth predetermined by the operator. This depth is very shallow and will cause little or no damage to the surrounding cells. Therefore, the healing is very rapid since the remaining cells are healthy and can multiply to heal the area removed. The treatment is generally quick and painless on the cervix and vagina. Most patients are treated in 4–8 min.

The procedure is generally done on an outpatient basis (patients come to the clinic and leave a short time after the procedure). If an anesthetic is required, the treatment will be done in the operating room on an outpatient basis (again allowing patients to leave after the procedure when their recovery from the anesthetic is satisfactory).

C

Discharge Instructions

For the patient who has had laser surgery to the cervix, vagina, vulva, and/or rectum, the following instructions are to be followed very carefully.

C.1. Laser Surgery to Cervix and/or Vagina

If you have had laser surgery of the cervix and/or vagina, you may have a moderate amount of reddish watery discharge during the first 10 days after treatment. A protective sanitary napkin *(not a tampon)* will be necessary. If heavier bright red bleeding occurs, please call your doctor for instructions.

Do not put anything into the vagina (birth canal) for 3 weeks
No douching
No sexual relations (sexual relations can usually be resumed after 3 weeks)
No Tampax or other tampons

You may experience a few cramps somewhat like menstrual cramps. This is to be expected and may require some oral analgesics. If severe, please call your doctor for further instructions.

C.2. Laser Surgery to Vulva and/or Rectum

Do not wear slacks, jeans, or any constricting clothing. A dress is preferable.

Do not wear nylon underpants. Wear *cotton* underpants if you have to go out, otherwise wear no underwear around the house.

Sitz bath: sit in a tub of warm water, without any additions, three times a day for about 10–15 min. Make sure the tub is clean before and after use.

Use a hair dryer to dry the perineal area. *Do not rub* with a towel. When using a hair dryer, put one foot up on a chair and blow the area dry.

Frequently 4–6 weeks are required for the vulva and perineal area to heal. Sexual relations are restricted for this period of time.

Usually one laser treatment is necessary to restore the area treated. The first follow-up visit will be 2 months after treatment.

D

Informed Consent

As laser surgery is now an integral part of otolaryngology, ophthalmology, and gynecology, we believe that a "special or experimental" informed consent is *not* necessary. In fact, the Federal Food and Drug Administration approved this form of surgery for third-party reimbursement under federal insurance programs in 1976. The gynecologist should obtain a routine informed consent that contains all the criteria as set forth for his community. If the instrument is to be used outside of the hospital in a clinical setting, then the individual surgeon may or may not elect to have a *signed* consent. However, in an institutional setting, a signed and witnessed informed consent form should be considered mandatory.

E

Laser Certification

Today, because of medicolegal pressure, the laser surgeon must demonstrate his new capabilities by fulfilling certain prescribed requirements. We have, therefore, set down guidelines that we feel are necessary to qualify a surgeon for CO_2 laser surgery in gynecology.

First, as the CO_2 laser is coupled to the colposcope, the surgeon must be an accomplished colposcopist. Today, as many fine colposcopists have, by virtue of their years of experience, sufficient diagnostic acumen to be considered expert, a definition of who qualifies is best left to the legal community. These surgeons are usually referred to under the grandfather clause, and their skill would stand the test of legal inquiry should the question arise.

However, for surgeons who are younger, the following is suggested. First, a surgeon should submit proof of completion of a basic and advanced course in colposcopy to his credentials committee. Second, he should submit proof of his being a member of the American Society of Colposcopy and Cervical Pathology. Moreover, the successful intra-abdominal microsurgical use of the laser demands that the laser surgeon be a competent microsurgeon, and, when the laser is used in oncology, also an experienced oncologist. In each aspect, basic understanding of the disease process, training in laser surgical techniques and procedures, and familiarity with the laser instrument are mandatory.

The Bureau of Medical Devices of the Food and Drug Administration of the United States Department of Health and Human Services has

approved the use of lasers in humans without limiting the applications to disciplines or to types or extent of diseases; voluntary performance standards are in effect. Therefore, at present, it is encumbent upon the providers and users of these medical devices and the institutions in which they are housed, to monitor their applications and to determine their appropriate usage and therapeutic effectiveness.

The Gynecologic Laser Society has prepared the following recommendations for hospital laser programs. Each laser surgeon should obtain appropriate and adequate training in laser surgery. Laser privileges should be issued only to those trained surgeons demonstrating proficiency with the laser instrument. Therefore, one-to-one training with a knowledgeable laser surgeon is suggested. This one-to-one training is believed to be necessary to guide the new surgeon with actual case performance. A minimum of five cases should be completed, or a sufficient number of cases to demonstrate the surgeon's capabilities. The instructor should then give, in writing, a certificate of completion and/or a letter stating that the physician has successfully completed this course. Today, the Gynecologic Laser Society has undertaken this instructional task.

Finally, it is encumbent upon each new laser institution to consider the following minimal criteria before a surgeon is given laser privileges:

1. Certificate of completion of Basic and Advanced Colposcopy Course
2. Certificate of membership in the American Society for Colposcopy and Cervical Pathology
3. Certificate of training under the auspices of the Gynecologic Laser Society

In addition, the following requirements are recommended:

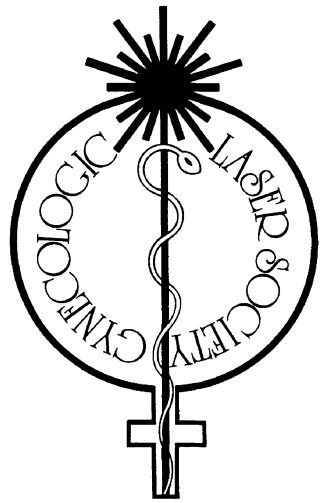
1. Preoperative histologic diagnosis be present in the chart
2. Periodic review by a medical audit committee to evaluate persistence and recurrence rates of precancerous lesions
3. Documentation and careful case follow-up

These requests may seem strenuous, but, in view of our frequent encounters with the legal profession, we feel these precautions should be an adequate demonstration of our continued concern for our patients and for ourselves.

Today, courses sanctioned by the Gynecologic Laser Society are available. Interested physicians and paramedical personnel should write the current president (or his secretary), or:

Joseph H. Bellina, M.D., Ph.D.
Former President and Founder
Gynecologic Laser Society
3439 Kabel Drive, Suite 7
New Orleans, Louisiana 70114

These seminars are structured to include biophysics, instrumentation, and patient care. Most seminars include hands-on training.



Gynecologic Laser Society emblem.

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Societies

Listed below are some of the currently active agencies that are using lasers in medicine:

1. Gynecologic Laser Society
   500 Blue Hills Avenue
   Hartford, Connecticut 06112
2. American Society of Laser Medicine and Surgery
   425 Pine Ridge Boulevard
   Suite 203
   Wausau, Wisconsin 54401
3. International Society of Lasers in Surgery and Medicine
   William Aronoff, MD
   Medical Towers Building
   712 North Washington
   Dallas, Texas 75246
4. Italian Society for Laser Surgery and Biomedical Applications
   R. Pariente
   Rome University School of Medicine
   Department of Plastic Surgery
   Policlinico Umberto I
   00161 Rome, Italy
5. Laser Center of Medical Application of the National Research Council
   National Cancer Institute
   Via Venezia 1
   20133 Milan, Italy

Internationally, notably in Japan, Germany, England, and France, new societies that are dedicated to laser medicine have been formed. Soon we expect all countries involved in laser medicine to have their own societies. Each society has annual or biannual meetings. The exact place and time of year vary from country to country. Currently there are more than 1000 surgeons performing laser surgery in all fields of medicine.

The laser is gaining acceptance as a surgical tool by surgeons in all disciplines. As this energy transfer system is explored and tested, its potential application in medicine increases. In gynecology, the laser is being used increasingly and with much success by colposcopists in the management of neoplastic disease of the external genitalia.

Tissue ablation is accomplished both through excision and vaporization procedures. The several advantages of this mode over conventional surgery and cryotherapy include:

1. An unobstructed operating field
2. Cauterization and coagulation of small vascular channels thereby preventing bleeding (which may also aid in preventing metastasis)
3. Minimal damage to adjacent normal tissue and subsequently reduced postoperative sequelae
4. Reduced cost to patients in many instances
5. The lowest recurrence rate (i.e., *highest success rate*) of all standard treatments

Gynecologists employing the molecular gas laser, principally the carbon dioxide laser, have recently formed a professional association, the Gynecologic Laser Society, to serve as a forum for the exchange of information between clinicians and researchers working with the laser. Physicists, laser manufacturers, biomedical engineers, and other interested parties are also invited to participate in the society by becoming associate members and/or by attending the various tutorial seminars and congresses sponsored by the society.

The society is also establishing an international registry of detailed information on etiology, diagnosis, treatment, and outcome, based on patients with gynecologic neoplastic diseases who are treated using the carbon dioxide laser. The society hopes to aid physicians in improving the quality of medical care for their patients by monitoring laser applications and treatment complications, determining the efficacy of this treatment, providing a peer review mechanism, and following up patients. The registry will also serve as a research and teaching data base for continuing education within the society and assistance in preparation of the publications by the members.

G

Publications

Lasers in Surgery and Medicine, published by Alan R. Liss, Inc., New York, is currently the only journal that publishes work exclusively in laser surgery and medicine. The major journals in obstetrics and gynecology lack articles in the fields of gynecologic laser use.

Laser Beam is a newsletter published by the Gynecologic Laser Society that has become a rapid communication system for members of the Society.

H

Glossary of Laser Terminology

absorption—change of radiant energy to a modified form of energy by interaction with matter resulting in decrease in power of light passing through a substance.

active medium—the atomic or molecular substance that can provide gain for laser oscillation, often called the laser or lasing medium, or active material.

angstrom (Å)—a unit of length utilized to express wave length or electromagnetic waves: An angstrom is equal to 10^{-10} m, 10^{-8} cm, 10^{-4} μm, or 10^{-1} nm.

atomic laser—a gas laser in which the medium is of atomic form rather than molecular.

attenuation—the decrease in the radiant flux of an optical beam as it traverses an absorbing and/or scattering substance.

axial mode—the mode of frequency of a laser governed primarily by cavity length between the end mirrors, that is, along the cavity length. The mode will have a wavelength which meets the condition that $n\gamma/2 = L$ where γ is the laser wavelength, L is the length between the mirrors, and n is an integer.

beam—a group of light rays that can be parallel, or diverge, or converge.

beam diameter $(1/e^2)$—the diameter of that particular irradiance contour in a laser beam of which the irradiance has fallen to $1/e^2$ (13.5%) of the peak or axial irradiance.

beam divergence—the full angle of the beam spread between diametrically opposed $1/e$ (or $1/e^2$) irradiance points: usually measured in milliradians (1 mrad = 3.4′ of arc).

beam shutter—device used to enclose a laser beam without shutting the laser off.

beam splitter—an optical device which uses controlled reflection to produce two beams from a single incident beam.

beam spot size—the diameter of the laser beam between the $1/e^2$ power points; sometimes used loosely to mean the area of the beam cross section between the $1/e^2$ points.

black body—a body that absorbs all of the incident radiant energy.

bolometer—a radiation detector of thermal type in which absorbed radiation produces a measurable change in the physical property of the sensing element. The change in state is usually that of electrical resistance.

brightness—the power emitted per unit area per unit solid angle ($W/cm^2 \cdot sr$).

calorie—the quantity of heat required to raise the temperature of 1 g of water by 1 °C (1 cal = 4.184 J).

calorimeter—a device for measuring the total amount of energy absorbed from a source of electromagnetic radiation.

cavity—the device (resonator) that supplies feedback for laser oscillations. The most common form is a laser medium between two reflecting surfaces.

chemical laser—a laser that obtains population inversion directly by a basic chemical reaction.

Class I laser product—any laser, or laser system containing such a laser, that cannot emit laser radiation levels in excess of P_{exempt} or Q_{exempt} for the maximum possible duration inherent in the design of the laser or laser system.

Class II laser product—(1) visible (0.4–0.7 μm) cw laser or laser system which can emit a power exceeding P_{exempt} for the maximum possible duration inherent in the design of the laser or laser system (0.4 μW for emission duration greater than 3×10^4 sec), but not exceeding 1 mW; (2) visible (0.4–0.7 μm) repetitively pulsed laser or laser systems which can emit a power exceeding the appropriate P_{exempt} for the maximum possible duration inherent in the design of the laser or laser system but not P_{exempt} for a 0.25-sec exposure.

Class III laser product—(1) infrared (1.4 μm–1 mm) and ultraviolet (0.2–0.4 μm) laser and laser system which can emit a radiant power in excess of P_{exempt} for the maximum possible duration inherent in the design of the laser or laser system, but cannot emit an average radiant power in excess of 0.5 W for $t_{\max} > 0.25$ sec or a radiant exposure of 10 $J \cdot cm^{-2}$ within an exposure time ≤ 0.25 sec; (2) visible (0.4–0.7 μm) cw or repetitively pulsed laser or laser system producing a radiant power in excess of P_{exempt} for 0.25-sec exposure (1 mW for a cw laser), but cannot emit an average radiant power greater than 0.5 W; (3) visible and near-infrared (0.4–1.4 μm) single-pulsed lasers which can emit a radiant energy in excess of Q_{exempt}, but which cannot emit a radiant exposure that exceeds 10 $J \cdot cm^{-2}$; (4) near-infrared (0.7–1.4 μm) cw lasers or single repetitively pulsed lasers which can emit power in excess of P_{exempt} for maximum duration inherent in the design of the laser or laser system, but cannot emit an average power of 0.5 W or greater for periods in excess of 0.25 sec.

Class IV laser product—(1) ultraviolet (0.2–0.4 μm) and infrared (1.4 μm–1 mm) laser and laser systems which emit an average power in excess of 0.5 W for periods greater than 0.25 sec, or a radiant exposure of 10 $J \cdot cm^{-2}$ within an exposure duration of 0.25 sec; (2) visible (0.4–0.7 μm) and near infrared (0.7–1.4 μm) laser and laser systems which emit an average power of 0.5 W or greater for periods greater than 0.25 sec, or a radiant exposure in excess of 10 $J \cdot cm^{-2}$, or that are required to produce a hazardous diffuse reflection for periods less than 0.25 sec.

coherent light—radiation in which there is a fixed phase relationship between any two points in the electromagnetic field.

collimated beam—a beam of light where the rays are parallel with very small divergence or convergence.

conductivity (thermal)—thermal property of a substance, depending upon the material of which it is made. It is the quantity of heat which flows in unit time through unit area of a layer of the substance of unit thickness with unit difference of temperature between its face [units of $(cal \cdot cm)/(cm^2 \cdot sec \cdot {}^\circ C)$].

continuous wave (cw)—a laser whose output lasts for a comparatively long uninterrupted time, while the laser is actuated (as compared to a pulsed laser); occasionally, a laser emitting continuously for greater than 0.25 sec.

controlled area—an area where occupancy and activities are controlled and supervised to give protection from optical radiation hazards.

crystal laser—a laser whose active medium is an atomic substance in a crystal, such as ruby.

diffraction-limited—an optical device free of aberrations to a very great extent and limited only by diffraction that unavoidably occurs at the aperture. Diffraction-limited spherical lens in conjunction with a circular aperture will focus a uniform intensity monochromatic light beam to a *spot* (Airy disc) of radius $r = (1.22f\lambda/D)$ where λ equals the wavelength, f equals the focal length of the lens, and D is the lens (or beam) diameter. A laser beam of gaussian intensity variation can be focused to a spot radius of $r = (0.64\, f\lambda/D)$ where r is the $1/e^2$ power point.

diffusivity (thermal)—thermal property of a substance depending upon the material of which it is made. It measures the change of temperature which would be produced in unit volume of the substance by the quantity of heat which flows in unit time through unit area of a layer of the substance of unit thickness with unit difference of temperature between its faces (unit of cm^2/sec).

dye laser—a laser for which the medium is an organic dye, usually in solution, with the solution flowing or contained within a cell. Experimental gas dye and solid lasers have been constructed; sometimes called organic dye and tunable dye lasers.

electromagnetic radiation—energy flow formed by vibrating electric and magnetic fields at right angles and lying transverse to the direction of energy. Examples are X rays, ultraviolet light, visible light, infrared radiation, and radio waves, all of which occupy various portions of the electromagnetic spectrum and differ in frequency, wavelength, and energy of a quantum.

electrooptic—describes modulators, Q switches, and other beam control devices that depend on changes in a material's refractive indexes by applying an electrical field. In a Kerr cell, the index variation is proportional to the square of the applied electrical field, with the controlled material generally a liquid. In a pocket cell, the substance is a crystal whose index change varies linearly with the electric field.

emission duration—the temporal duration of a pulse, a series of pulses, or continuous operation, expressed in seconds, during which human access to laser or collateral radiation could be permitted as a result of operation, maintenance, or service of a laser product.

energy(Q)—the capacity for doing work; energy content is commonly used to characterize the output from pulsed lasers, and is generally measured in joules (J).

energy density—the energy per units area expressed in units of joules per square centimeter ($J \cdot cm^{-2}$) (*see* radiant exposure).

error function—a mathematical function defined as:

$$\operatorname{erf}(x) = \frac{2}{\pi} e^{-u^2}\, du$$

exposure—the product of irradiance and the time it lasts.

extinction length—the thickness of the layer of a substance absorbing 90% of the incident radiant energy.

fluorescence—emission of electromagnetic radiation that it is caused by transition from an excited state to the state of molecule or atom. Light emission follows immediately (10^{-6}–10^{-9} sec) the absorption of the exciting radiation. An afterglow of the same or a different wavelength which extend from millisecond to hours or more is called phosphorescence.

focal length—the length between the secondary nodal point of a lens and the primary focal point. For a thin lens, the focal length is the length between the lens and the focal point.

focal point—the focus point toward which light waves converge or from which they diverge or appear to diverge.

gas laser—a laser for which the medium is a gas, of either atomic or molecular form. This laser type is subdivided by medium into atomic (such as helium–neon), molecular (such as carbon dioxide), and ionic (argon, krypton, xenon, and other types such as the metal–vapor helium–cadmium laser). Frequently, "ion" is taken to mean argon or krypton.

gaussian distribution—a frequency distribution curve for a population or collection of variable data, frequently shown as a bell-shaped curve symmetrical about the mean of the data; frequently called normal distribution. A beam having a gaussian irradiance profile is given by an equation of the form $I = I_0\, e^{-2r^2}/w^2$, where I_0 is the beam centerline irradiance, e is the base of the natural system of logarithms, r is the radius of the contour for irradiance I, and w is the radius of the $1/e^2$ irradiance contour by which beam radius is defined. Both r and w are measured in a plane perpendicular to the beam.

infrared radiation—electromagnetic radiation the wavelengths for which are within the spectrum range of 0.7 μm to 1 mm. This portion of the spectrum is often separated into three bands by wavelength: IR–A (0.7–1.4 μm), or near infrared; IR–B (1.4–3 μm); and IR–C (3 μm–1 mm), or far infrared.

integrated radiance—the radiant energy per unit area of a radiating surface per unit solid angle of emission, stated in joules per square centimeter per steradian ($J \cdot cm^{-2} \cdot sr^{-1}$).

ion laser—a laser for which the active medium is an ionized gas, such as argon or krypton.

ionizing radiation—radiation that can produce ionization; sufficiently energetic charged particles such as alpha and beta rays, and wave-type radiation such as X rays.

irradiance(E)—the radiant power that falls on a surface divided by the area irradiated, expressed in watts per square centimeter ($W \cdot cm^{-2}$).

joule (J)—a unit of energy; 1 joule = 1 watt for one second ($W \cdot sec$) or 10^7 ergs, or 0.239 calorie.

joule/cm^2 (J/cm^2)—a unit of radiant exposure utilized when measuring the amount of energy per unit area of surface or per unit area of a laser beam.

Kerr cell—a beam modulator that uses the Kerr effect. The extent of the modulation varies with the square of the applied electric field (*see* electro-optic).

laser—acronym for light amplification (by) stimulated emission (of) radiation. Lasers generate or amplify electromagnetic oscillations at wavelengths from the far infrared (submillimeter) to the ultraviolet. The laser oscillator needs two basic elements: an amplifying medium and a regeneration or feedback mechanism (resonant cavity). The amplifying medium can be any of a variety of substances, such as a gas, semiconductor, dye solution, etc. Feedback is generally created by two mirrors. The distinctive properties of the resulting electromagnetic oscillations include monochromaticity, extremely high intensity, very small bandwidth, very tight beam divergence, and phase coherence.

laser cavity (optical or resonant cavity)—the enclosed volume (resonator) that enables feedback for laser oscillation and light generation. Frequently, the configuration is formed of two reflecting mirrors, separated by the cavity length, L. The lasing medium is positioned between the end mirrors.

laser safety officer—one who is knowledgeable in the evaluation and control of laser hazards and has authority for supervision of the control of laser hazards.

maser—acronym for a device for radio microwave amplification (by the) stimulated emission (of) radiation. In contrast to a laser which emits light, a maser emits microwave radiation.

maximum permissible exposure (MPE)—the radiant exposure to irradiance of laser radiation that, in accordance with present medical knowledge, is not expected to cause detectable corneal or other bodily injury to an individual at any time during his lifetime.

micrometer (μm)—a length equal to 10^{-6} m or 10,000 nm, often termed micron.

microsecond (μsec)—a unit of time equal to 10^{-6} sec.

millisecond (msec)—a unit of time equal to 10^{-3} sec.

monochromaticity—the condition of containing or generating light of only one wavelength from a range of wavelengths present in a beam.

multimode—output or emission at several frequencies simultaneously, usually closely spaced, where each frequency represents a different mode of laser oscillation in the cavity.

nanometer (nm)—a unit of length equal to 10^{-9} m, 10^{-7} cm, 10^{-3} μm, or 10 Å. The nanometer is beginning to replace the angstrom as the principal unit of electromagnetic wavelength.

nanosecond (nsec)—a unit of time equal to 10^{-9} sec.

optical fiber—a long, thin thread of fused silicon or other transparent substance, used to transmit light.

P_{exempt}—that output power (Q_{exempt} that output energy per pulse) of a laser such that no applicable MPE for exposure of the eye may be exceeded, with or without optical instruments.

picosecond (psec)—a unit of time equal to 10^{-12} sec.

photon—the quantum of electromagnetic energy, equal to the product of Planck's constant and the frequency of the radiation.

power (W)—the time rate at which energy is given off, received, or used in some fashion; expressed in watts or in joules per second.

power, average—with a pulsed laser, the pulse energy (joules) times the frequency of the pulse (Hertz), expressed in watts; as compared to the average power of a pulse.

power density—denotes the power per unit area (e.g., $W \cdot cm^{-2}$) contained in a laser beam, or falling on a given target area (*see* irradiance).

Q switch—a device that exhibits a shutter-type effect which prevents laser emission until it is opened. "Q" denotes the quality factor of the laser's resonant cavity. "Active" Q-switching can be accomplished with kerr or pockels cell, a rotating mirror, rotating prism, or acousto-optic devices. "Passive" Q-switching is accomplished using a saturable absorber substance such as a gas or a dye. In a pulsed laser, a Q switch greatly

increases pulse power by lessening pulse duration while maintaining the energy constant.

radian—a unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle: 1 radian = 57.3°; 2 radians = 360°. One milliradian (10^{-3} radian) subtends an arc whose length is equal to 1 mm at the distance of 1 m.

radiance (L)—the radiant power per unit area of a radiating surface per unit solid angle of emission expressed in watts per square centimeter per steradian ($W \cdot cm^{-2} \cdot sr^{-1}$).

radiant energy (Q)—the energy given off, received, or used in some manner, in the form of radiation, expressed in joules (J).

radiant exposure (H)—the radiant energy irradiating a portion of a surface divided by the area of that portion, in joules per square centimeter ($J \cdot cm^{-2}$).

radiant power (W)—power given off, received, or used in some fashion, in the form of radiation; the time rate of transfer of radiant energy. Expressed in watts (W). Also called radiant flux.

radiant intensity (I)—radiant power of a source in particular direction; ratio of the radiant flux leaving the source transmitted in a portion of the solid angle containing the given direction, and the portion of the solid angle; expressed in watts per steradian ($W \cdot sr^{-1}$).

reflection—the casting back, turning back, or deviation of radiation following its hitting a surface.

semiconductor laser—a laser formed from an active material that is a semiconductor, which can be a diode or homogeneous. Commercial types are usually diodes in which lasing takes place at the junction of n- and p-type semiconductors, typically gallium aluminum arsenide or gallium arsenide. Homogeneous types are composed of undoped semiconductor material and are energized (pumped) by an electron beam.

specific heat—the specific heat of a substance at temperature (t) is defined as dQ/dT where dQ is the quantity of heat necessary to raise the temperature of unit mass of the substance through the small temperature range from t to $t + dt$ (unit of $cal/g \cdot °C$).

steradian (**sr**)—the unit of measure for a solid angle. There are four steradians in a sphere.

stimulated emission—emission (radiation) of electromagnetic energy during a transition from a higher-energy state to a lower-energy state in an activated laser medium. The emission is made possible by the presence

of a radiation field (stimulating radiation). The stimulated emission is practically the same in every way (frequency, wavelength, momentum, phase, polarization) to the stimulating radiation.

TEM_{00}—the radiation from a laser operating in the fundamental transverse mode. The energy possesses a gaussian (bell-shaped) distribution. All the emitted energy is in one spot, with no side lobes.

transverse modes—laser cavity oscillation modes which give rise to various irradiance distribution in the output beam. These modes are designated TEM_{mn}, where m and n denote the number of nulls in two orthogonal directions within a plane perpendicular to the cavity axis. TEM stands for transverse electromagnetic, since in these modes both the electric and magnetic field vectors are approximately transverse to the cavity axis.

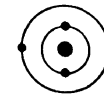
tunable laser—a laser that allows continuous variation of lase emission across a broad wavelength region. A single laser system can be "tuned" to radiate laser light over a continuous spectrum of wavelengths or frequencies.

ultraviolet radiation—electromagnetic radiation that has wavelength from soft X ray to visible, violet light. The spectral region is frequently categorized into three separate bands by wavelength: UV-A (315–400 nm), UV-B (280–315 nm), and UV-C (200–280 nm). Ultraviolet wavelength is shorter than wavelength for visible radiation.

watt (W)—the unit of power or radiant flux; 1 J/sec.

watt/cm^2—a term used as a unit of incident power density or irradiance to express the amount of power per unit area of absorbing surface, or per unit area of a cw laser beam.

wavelength (λ)—the distance between two points in a periodic wave which have the same phase.



Index