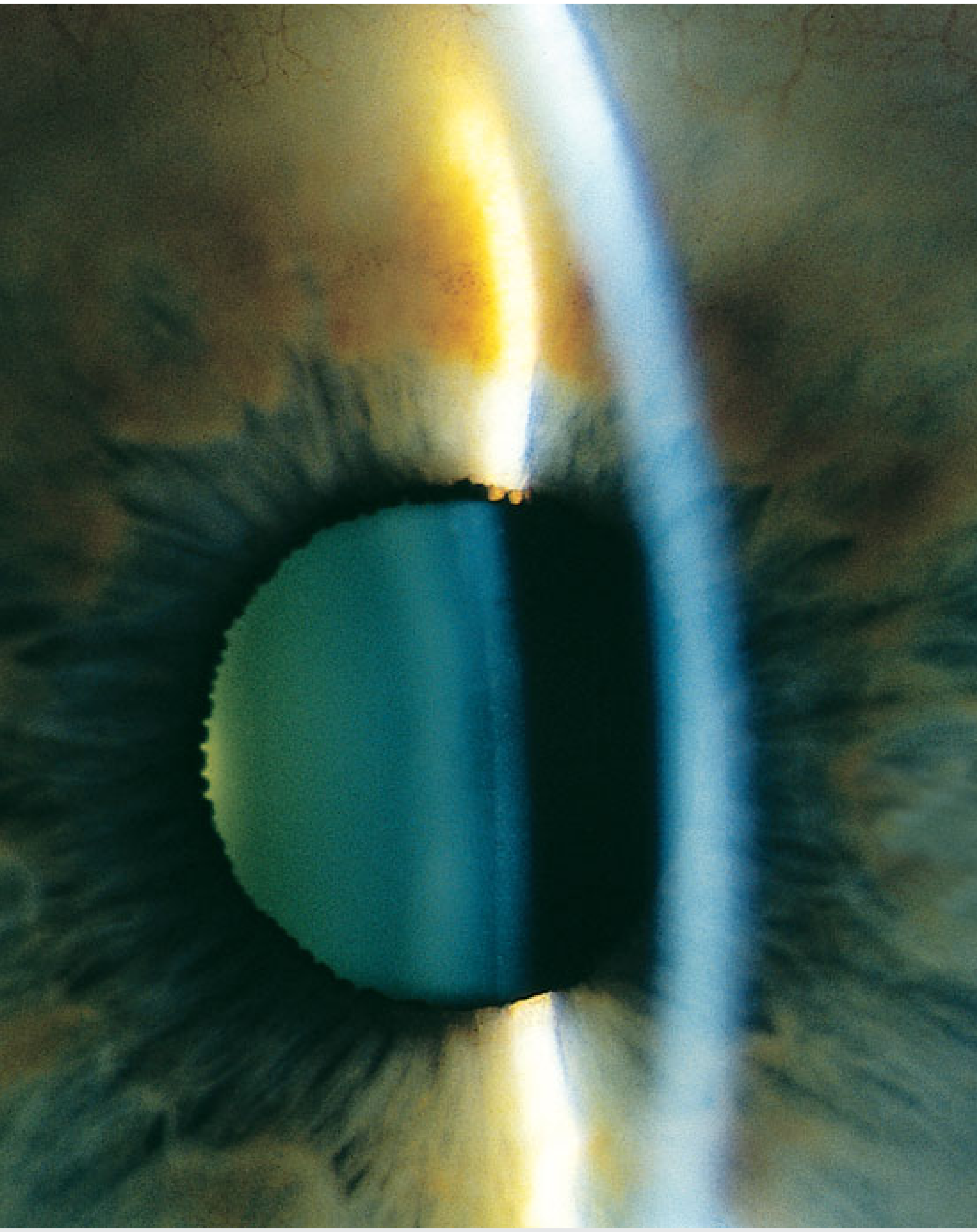
Eye Examination with the Slit Lamp.



In memory

of Prof. Allvar Gullstrand
Nobel Prize Winner in Physiology and Medicine

05.06.1862 – 28.07.1930

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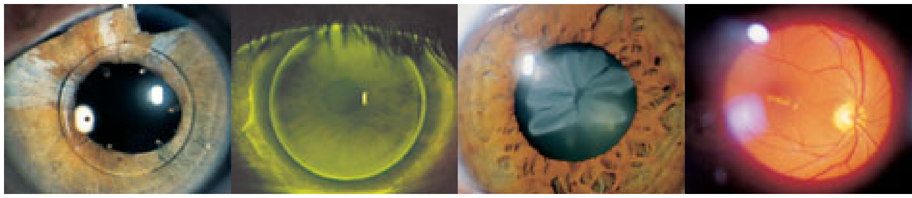


Contents

1. Overview of applications.

Fig. 1
Application of
SL 120 Slit Lamp

Today the slit lamp is the ophthalmologist's most frequently used and most universally applicable examination instrument. The most important field of application is the examination of the anterior segment of the eye including the crystalline lens and the anterior vitreous body.

Supplementary optics such as contact lenses and additional lenses permit observation of the posterior segments and the iridocorneal angle that are not visible in the direct optical path.

A number of accessories have been developed for slit lamps extending their range of application from pure observation to measurement, such as for measuring the intraocular pressure.

The documentation of findings on electronic media is increasingly gaining importance as it provides a convenient medium for keeping track of a disease's progress. It also facilitates the communication between physician and patient or between physicians.

The use of the slit lamp in contact lens fitting is an important recent application worth mentioning. The modern instrument has increasingly gained applications beyond the traditional ophthalmologist´s practice.

2. Design principles.

2.1 Slit illumination system

The illumination system is intended to produce a slit image that is as bright as possible, at a defined distance from the instrument with its length, width, and position being variable. Today this is achieved using optical imaging with the so-called *Köhler illumination* (Fig. 2). The light source **L** is imaged in the objective **O** by the collector system **K**. The objective in turn produces an image at **S** in the mechanical slit located next to the collector system. The image of the light source at **O** is the exit pupil of the system. Köhler illumination provides a very homogeneous slit image even with a structured light source. This is an advantage over illumination systems imaging the light source in the slit and projecting the latter into the eye together with the image of the light source. This method was used in 1911 in the first *Gullstrand slit lamp* and is therefore only of historical importance.

The brightness of the slit image is characterised by the illuminance of the slit image which depends on the luminance of the light source, the transmission of imaging optics, the size of the exit pupil, and the distance between exit pupil and slit.

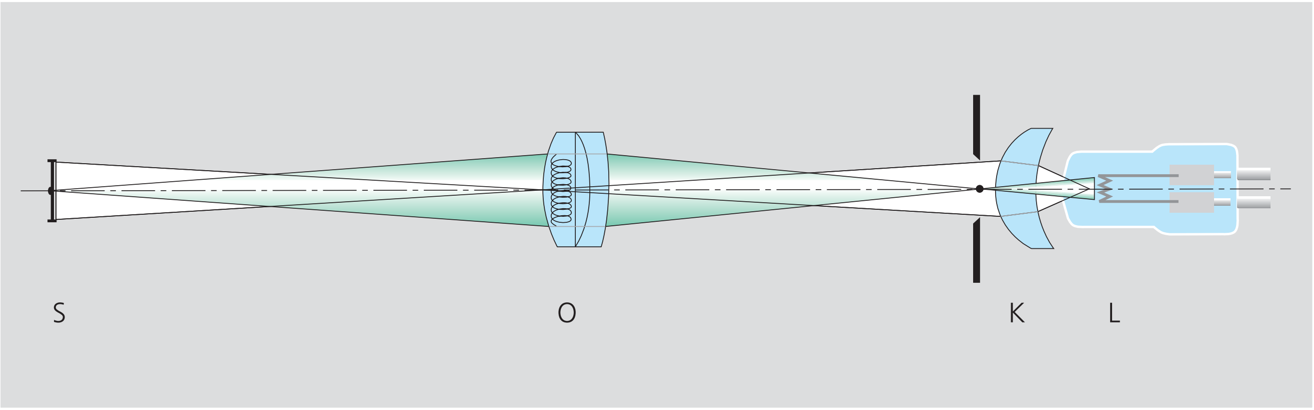
The standard slit lamp is comprised of three elements:

1. **Slit illumination system**
   Giving the instrument its name

2. **Stereomicroscope**
   Similar to that used on other ophthalmic instruments, e.g. surgical microscopes

3. **Mechanical system**
   Connecting the microscope to the illumination system and allowing for positioning of the instrument

Fig. 2
Principle of Köhler illumination



The optical transmission is increased by anti-reflection coatings on all glass surfaces. The light loss caused by reflections is subsequently reduced to 1.5% or even down to 0.5% in the case of high-grade antireflection coatings. The total gain in brightness of the slit illumination compared to an uncoated system is about 20%, thus demonstrating the advantages offered by modern specially coated optics.

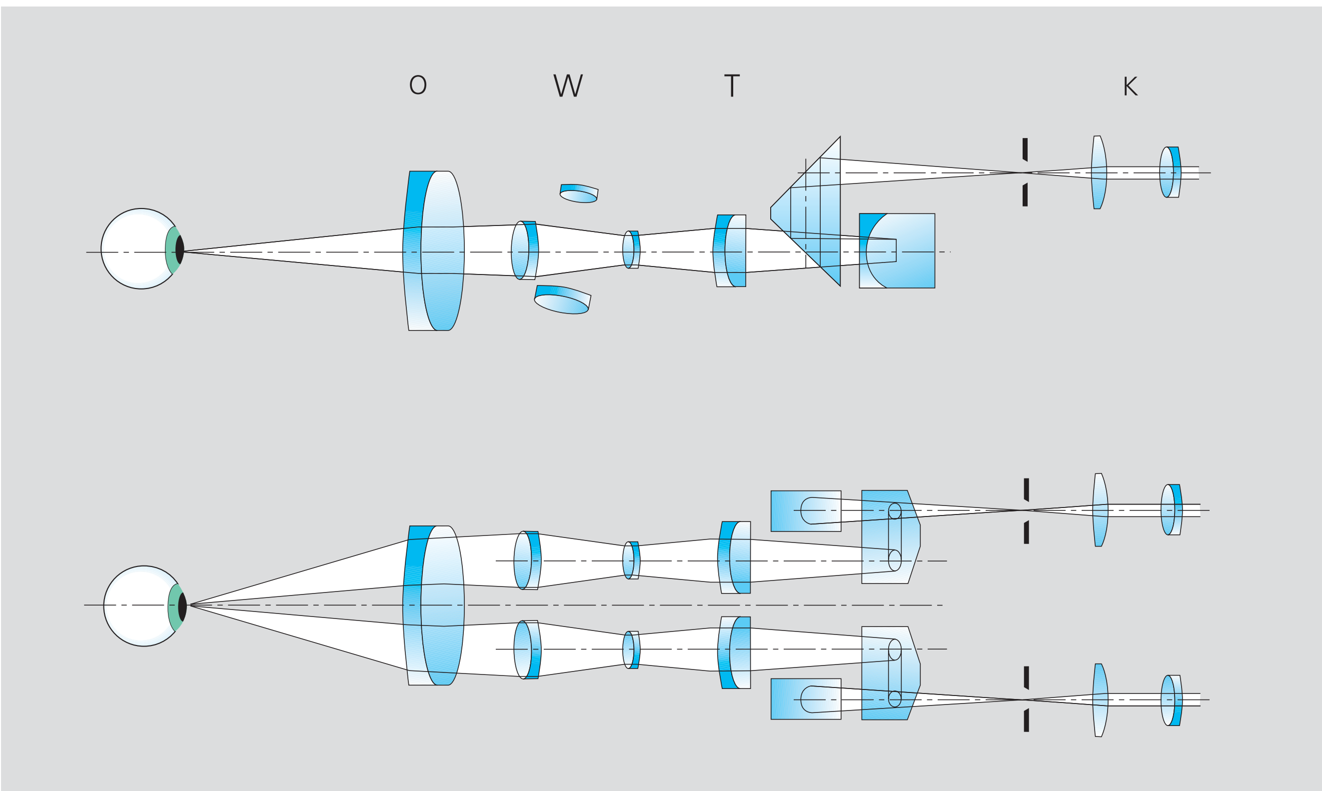
The light source used on a slit lamp is either a low-voltage incandescent lamp or a halogen lamp. The latter being preferred because of its high luminance and colour temperature.

According to physical laws the light scattering ability and fluorescence of transparent media is enhanced by such high luminance and colour temperature, allowing diagnostically important changes in colour to yellow to be much more easily recognised. Modern slit lamps (see Figs. 7 - 10) therefore employ halogen light sources.

For certain examinations it is not so much an intense slit illumination that is required but a large-field diffuse illumination. For this reason some instruments provide an insertable ground glass screen at the plane of the exit pupil and of the filament image. The optical path is thus interrupted with the ground glass screen acting as a secondary source.

Other examination methods require the spectral composition of the light to be changed (e.g. for fluorescence observation in contact lens fitting). For this purpose various filters are provided in the illumination system which can be easily swung into the beam path. The range of filters include exciter filters for fluorescence, green filters for contrast enhancement, and sometimes grey filters for reducing the illumination intensity while maintaining colour temperature.

Fig. 3
Optical path
in the stereomicroscope
of a slit lamp



2.2 Slit lamp microscope

The user expects the slit lamp microscope to provide optimum stereoscopic observation with selectable magnification. The size of the field of view and the depth of field are expected to be as large as possible, and there should be enough space in front of the microscope for manipulation on the eye.

Fig. 3 shows the optical path of a stereomicroscope designed on the principle of the telescopic lens.

With telescopic lens systems, larger working distances can be achieved when compared to simple magnifying systems. These systems consist of a telescope and an object-side magnifying lens. The object is located in the object-side focal point of the magnifying lens that magnifies the object image projecting it virtually to infinity. This image is then viewed with the respective magnification through the telescope.

Explanation of Fig. 3:

Between objective **O** (focal length f_1) and tube lenses **T** (f_2) there is a separate, parallel optical path for each eye. Hence, the object is located in the focal plane of **O**. Between **O** and **T** a telescopic system **W** each may be fitted (magnification factor g) to vary the total magnification.

Stereoscopic vision requires a defined convergence angle between the two visual axes. This convergence angle is obtained by a prismatic power in the objective transmitted off axis by both beams. The intermediate images produced by tube lenses **T** through rotatable prisms are viewed with eyepieces **K** (f_3).

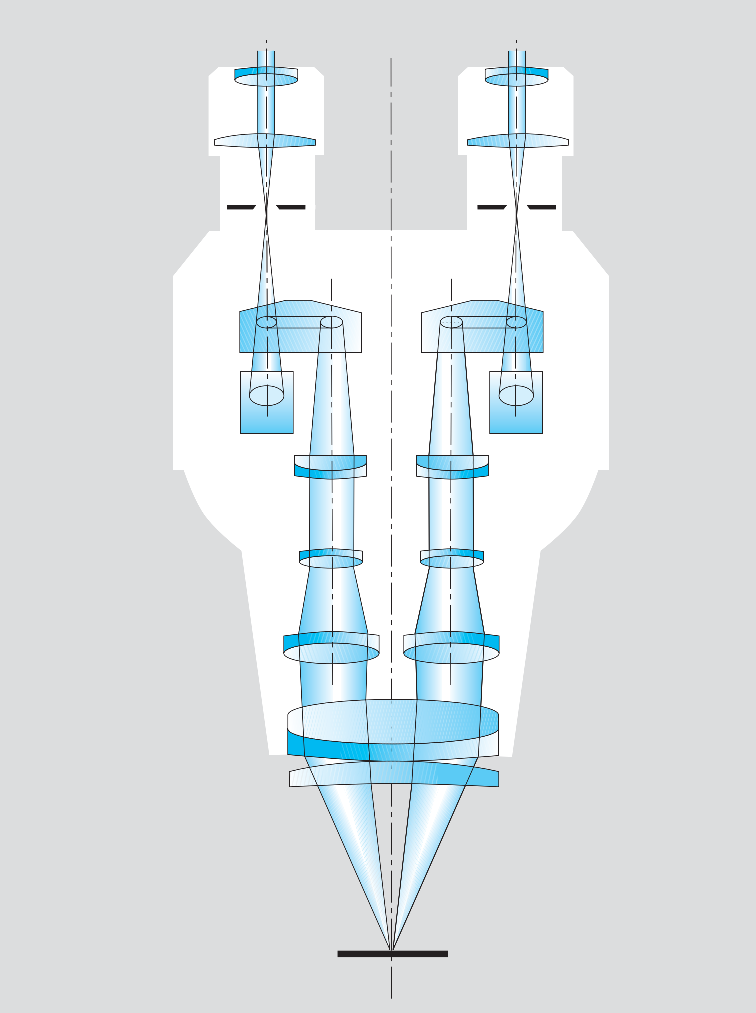


Fig. 4
Optical diagram of telescopic system

The total angular magnification G of the system is calculated by the following formula:

$$G = \frac{f_2}{f_1} \times g \times \frac{250\ \text{mm}}{f_3\ (\text{mm})}$$

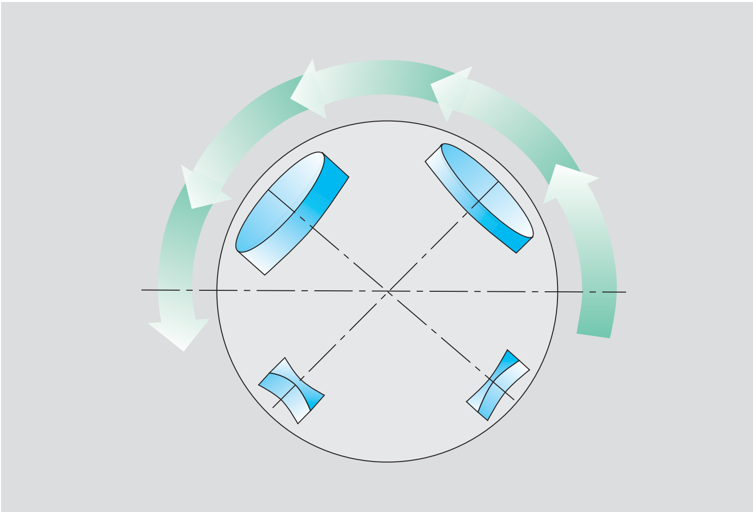


Fig. 5
Galilean system

The stereomicroscopes of our slit lamps use the following instrument principle:

Telescopic system

Galilean system with telecentric optical path (Fig. 4)

On this system, both optical paths have a common or main objective. This objective projects the object image to infinity which is viewed by a stereo tube that is basically a pair of telescopes. In practice the slit lamp requires magnifications of between 5x and 50x, the most commonly used being 10x, 16x, and 25x. The microscope magnification can be varied by changing the eyepieces, but a simpler and more elegant solution is however, a magnification changer using variable optical elements. When the magnification is changed, the position of the object plane must of course not change. A tried and tested means of changing the magnification is a Galilean telescope. Here, in a rotatable drum whose axis is perpendicular to the optical axes, two small Galilean telescopes are arranged that are inclined to each other and can be looked through in either direction. Thus, they provide four different magnifications. A fifth magnification results from the free aperture available on the drum.

The magnification changers of the SL 115 Classic, SL 120 and SL 130 Slit Lamps are based on this principle.

The binocular tube of the slit lamp holds the eyepieces at the same time ensuring a defined distance between them and the main objective (= mechanical tube length).

In recent years, slit lamps that employ a stereo-microscope combined with a telescopic system have been successful. These stereomicroscopes have a straight binocular tube (parallel tube) that enables fatigue-free viewing through the slit lamp when used over longer periods.

For examinations where the ophthalmologist observes the patient's eye alternately through the slit lamp and with the unaided eye (accommodated!), a convergent light path is recommended (convergent tube). It is known that there is a relationship between the focal distance of the observers adjusted eye to the viewed object, i.e. the accommodation, and the convergence of their eyes to that object.

The standard SL 120 and SL 130 Slit Lamps are supplied with a convergent tube of f = 140 mm. Parallel tubes being available as accessories.

Besides the magnification, the user is usually interested in the following optical criteria:

- Resolution
- Brightness
- Depth of field
- Stereo angle or stereo base
- Back focal distance

The **resolution** of a microscope (the smallest distance between two points that can be separated) is determined by its numerical aperture. With a given aperture it is ineffectual to increase the microscope magnification beyond a certain point, the so-called useful magnification, over this the image will just be larger without an increase in resolution. On the other hand it is not advisable to increase the aperture beyond the value specified by a given magnification either, as in this case the resolution is limited by the acuity and pupil size of the observer, also the performance of the optics would not be fully utilised. The exit pupils of a good slit lamp microscope range from 0.8 to 2.7 mm depending on magnification.

The **depth of field** of the microscope is of great importance in the use of the slit lamp. It has three components:

- Depth of focus
- Depth of accommodation
- Depth of resolution

Within the eye there exists a smallest resolvable angle (or minimum angular separation) at which an image point and its circles of least confusion are seen equally sharp. This is the **depth of focus**. The **depth of accommodation**, however, results from the change in refractive power of the eyepiece/eye system, whereby the point of best visual acuity is shifted relative to the eyepiece plane. The **depth of resolution** is due to the diffraction of light at the microscope aperture. As a result of diffraction, object differentiation within the depth range is impossible, the depth of resolution is therefore similar to the depth of field.

As with illumination, the demand for maximum brightness conflicts with that of maximum depth of field. Thus, a "brighter" slit lamp may have the serious drawback of a lower depth of field if its brightness is not based on lamp brightness alone. The aperture of a good slit lamp microscope is near to 0.05 for medium magnifications. The aperture of the new slit lamps ranges from 0.05 to 0.08.

Stereoscopic vision is the basis of slit lamp microscopy. The wish to make the **convergence angle** as large as possible is counteracted by the demand for observation through limited apertures such as the pupil and contact lens mirrors (cf. 3.6 "Fundus observation and gonioscopy"). For this reason good slit lamp microscopes work with a convergence angle of between 10° and 15°. The SL 120 and SL 130 Slit Lamps have a convergence angle of 12.5°, the SL 115 Classic Slit Lamp employs a convergence angle of 10°.

The **backfocal distance** is another parameter of the slit lamp microscope that is of special interest. The back focal distance is the distance of the subject from the front lens surface of the microscope. The back focal distance must have a certain minimum length to give the operator sufficient space for manipulation. If it is too long, manipulations on the eye are difficult, because of the resulting extended and uncomfortable position of the arms. Moreover, with a given objective aperture, the numerical aperture is reduced and thus the brightness. The back focal distance of a slit lamp should range between 90 mm and 120 mm. On the SL 120 and SL 130 Slit Lamps, it is approx. 106 mm; on the SL 115 Classic Slit Lamp it is approx. 118 mm.

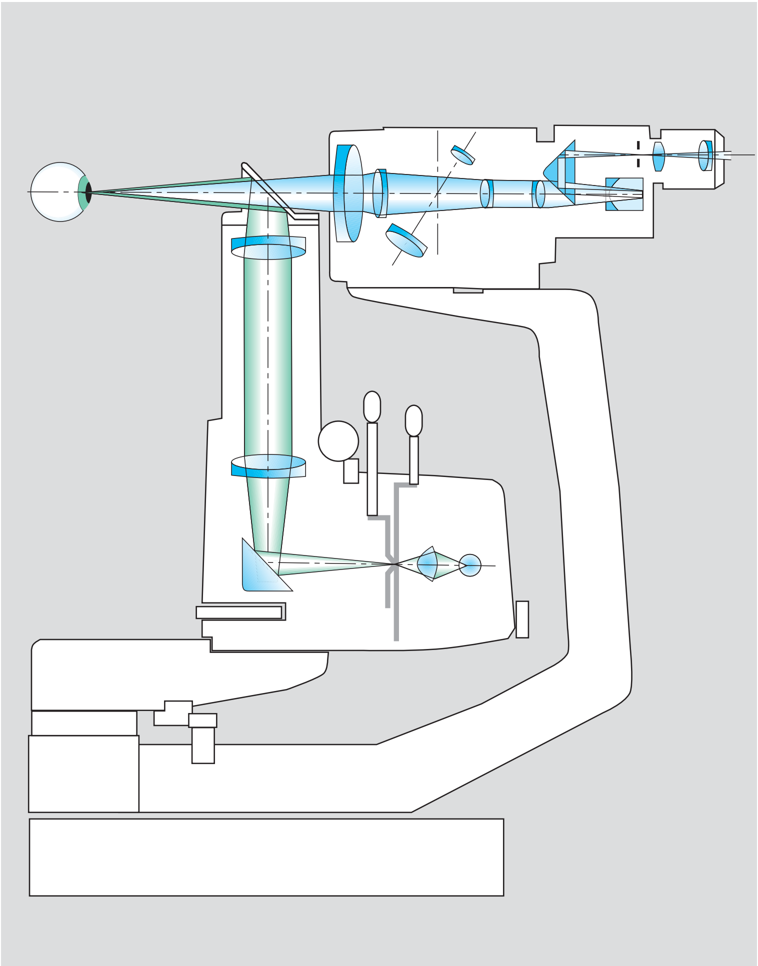


Fig. 6
Optical path of
SL 120 Slit Lamp

2.3 Mechanical system

The mechanical system of the modern slit lamp has developed over 80 years and combines the requirements of operating comfort and universal application.

Fig. 6 shows the functional connections of the illumination system to the stereomicroscope by means of the mechanical support. The illumination system and the microscope can both be swung about a common vertical axis independent of each other. The visual axis is a virtual extension of the mechanical instrument axis, the rotational point being located below the patient's eye. The slit is normally focused to the axial plane and can be seen sharply defined at the microscope focal point. During an examination, this axis of rotation is moved to the position of the object to be observed. This is achieved with the aid of a mechanical instrument base containing a cross-slide system and carrying the mechanical support axis of the illumination system and the microscope. The instrument base is moved horizontally with a single control element - the joystick control. Additionally the instrument base contains a vertical control mechanism allowing the slit and the viewing axis to be adjusted vertically. This vertical control is typically integrated into the joystick and operated by rotating it. Thus, the operator can adjust the instrument to the object in all three space coordinates (3D joystick control lever).

Modern slit lamps not only permit the illumination system to be swung through in front of the microscope, they also have a middle position with a click stop which locates the illuminating prism between the two microscope beams. This prism being extremely narrow, allows stereoscopic observation through the microscope around the prism.

There are a number of other important functions provided by the mechanical system:

a) The slit image which is normally in a vertical position can be rotated continuously through ± 90° to the horizontal position.

b) In the horizontal position the direction of the slit illumination can be changed so that there is a defined angle between the microscope axis and the axis of the slit illumination. On some instruments, this is effected by a tilting prism (15° from below). Other instruments, such as the SL 120, and SL 130 slit lamps, have a vertically adjustable prism head (tiltable between 0 and 20°). This is useful for examinations with mirror contact lenses.

c) For retro-illumination the prism head can be rotated from the central click stop to the right and left. This allows the slit image to travel laterally.

As mentioned above, almost all slit lamp types have a common mechanical axis of rotation. The various makes only differ in the arrangement of the illuminating beam to either below the microscope body or above it, or by the configuration of the illumination beam being folded once or twice by prisms or mirrors.

Two other special types of slit lamp:

- The hand slit lamp is a handy portable unit providing for slit lamp examinations on sitting or recumbent patients in or out of the ophthalmologic practice (Fig. 10, page 11).
- The bedside or surgical slit lamp is a combination of an operating microscope with a swivelling slit illumination system designed for the examination and treatment of recumbent patients. For this reason there is no real axis of rotation of the illumination system but rather a curved mechanical guide with a virtual axis.

2.4 Electrical system

The only electrical unit a slit lamp requires normally is a low-voltage supply (mains power pack) for powering the low-voltage filament lamp or the more modern and brighter halogen lamp.

It is also an advantage to have a rheostat which varies the lamp voltage within a certain range to enable the brightness to be adjusted to the specific requirements.

2.5 Range of Carl Zeiss slit lamps

The slit lamps from Carl Zeiss feature outstanding performance. The optical transmission of the observation system is extremely high. This results in a minimal light loss in observation and documentation, which in turn reduces light levels for the patient. Due to the high resolution, even the finest structures become visible with a high contrast. The stereo angle of 12.5° provides for the improved three-dimensional differentiation of details to assist in obtaining a reliable diagnosis.

Eyepieces with an exit pupil lying far beyond the optical surfaces (super high-eyepoint eyepieces) also allow spectacle wearers to operate the slit lamp without restriction. Practice-oriented operating comfort is ensured by the single-hand joystick control for fast and precise positioning of the instrument in all three coordinates as well as conveniently positioned controls allowing for sensitive adjustment of the slit image. These Carl Zeiss slit lamps have been developed down to the last detail to provide an instrument designed to aid a sound diagnosis.

Fig. 7
SL 115 Classic Slit Lamp

Fig. 8
SL 120 Slit Lamp

The SL 115 Classic Slit Lamp

is the practice-oriented routine instrument for examination and measurement of the eye. The integrated yellow filter and the slit length of 14 mm provide optimum conditions for contact lens fitting. The revolving objective changer allows overall magnifications of 8x, 12x and 20x. The handy plug-and-play concept – the slit lamp is supplied completely mounted – minimizes set-up work. The SL 115 Classic Slit Lamp may, of course, be retrofitted with a compact video camera.

The SL 120 Slit Lamp

is the powerful universal instrument with 5-step magnification changer. In combination with 10x eyepieces, the magnification is adjustable from 5x to 32x. As standard the instrument has a convergent tube of f = 140 mm, a parallel tube of f = 140 mm being available as an option. The slit width is continuously adjustable from 0 to 14 mm. The slit length may be varied continuously from 1 – 6 mm and in steps of 0.5, 3.5, 8 and 14 mm.

Fig. 9
SL 130 Slit Lamp

Fig. 10
HSO 10 Hand Slit Lamp

The SL 130 Slit Lamp

is a universal diagnostic instrument with versatile accessories for measurement and documentation.

The slit lamp differs from the previously described models in the different position of slit controls. Slit adjustment is possible from either the right or left and permits viewing with the slit illuminator in the middle position. This enables efficient and sensitive operation particularly when using this slit lamp for laser treatment.

The applications of this slit lamp extend from the anterior segment through the vitreous body to the fundus.

The HSO 10 Hand Slit Lamp

being a portable instrument completes the slit lamp range. It is the ideal combination of a binocular slit lamp with an indirect ophthalmoscope, for the examination of the anterior and posterior eye segment of sitting or recumbent patients. Its special feature is the bilateral lockable arc guide providing true, convenient single hand operation of the instrument. A rechargeable battery further increases the mobility of this slit lamp.

Instrument specifications
Zeiss slit lamps in detail

SL 115 Classic Slit Lamp

Magnifications	8x, 12x, 20x
Field of view	25 mm – 10 mm
Eyepiece magnification	10x high-eyepoint eyepieces, ± 8D compensation of ametropia
Width of slit image	0 – 14 mm, continuously adjustable
Length of slit image	0.5, 3.5, 8, 14 mm, in steps 1 – 14 mm, continuously adjustable
Angle of slit image	± 90°, continuously adjustable
Decentration of slit image	Variable, with click stop at 0°
Swivel range of slit prism	180°, scale for angular difference, click stop at 0°
Angle of incidence	0°, horizontal
Filters	Blue, green (red-free) and swing-in diffusing screen; barrier filter (yellow), swing-in type; UV protection filter, heat-absorbing filter
Free working distance exit prism to patient eye	73 mm
Travel of instrument base	Vertical: 30 mm, X-axis: 110 mm, Y-axis: 90 mm
Vertical travel of headrest	58 mm
Light source	6V 10W halogen lamp
Lamp brightness	Continuously adjustable
Power requirements	100V to 240V ±10%, self-sensing, 50-60 Hz
Weight	Basic unit: 9.75 kg; headrest: 1.25 kg

SL 120 Slit Lamp

Magnifications	5x, 8x, 12x, 20x, 32x (6x, 10x, 16x, 25x, 40x with optional 12.5x eyepiece)
Field of view	40 mm – 6 mm
Eyepiece magnification	10x super high-eyepoint eyepieces, ± 8D compensation of ametropia
Width of slit image	0 – 14 mm, continuously adjustable
Length of slit image	0.5, 3.5, 8, 14 mm, in steps 1 – 6 mm, continuously adjustable
Angle of slit image	± 90°, continuously adjustable, Tabo angle scale
Decentration of slit image	± 4° horizontal, click stop at 0°
Swivel range of slit prism	180°, scale for angular difference
Angle of incidence	0° – 20°, with tiltable prism head (optional)
Filters	Blue, green (red-free) and swing-in diffusing screen; heat-absorbing filter
Free working distance exit prism to patient eye	60 mm
Travel of instrument base	Vertical: 30 mm, X-axis: 110 mm, Y-axis: 90 mm
Vertical travel of headrest	60 mm
Light source	6V 20W halogen lamp
Lamp brightness	Continuously adjustable
Power requirements	100V to 240V ±10%, self-sensing, 50-60 Hz
Weight	Basic unit: 9.25 kg; headrest: 1.25 kg

SL 130 Slit Lamp

Magnifications	5x, 8x, 12x, 20x, 32x (6x, 10x, 16x, 25x, 40x with optional 12.5x eyepiece)
Field of view	40 mm – 6 mm
Eyepiece magnification	10x super high-eyepoint eyepieces, ± 8D compensation of ametropia
Width of slit image	0 – 14 mm, continuously adjustable
Length of slit image	0.3, 2.5, 3.5, 7, 10, 14 mm, triple slit
Angle of slit image	± 90°, continuously adjustable
Decentration of slit image	± 4° horizontal, click stop at 0°
Swivel range of slit prism	180°, scale for angular difference
Angle of incidence	0° – 20°, tiltable
Filters	Blue, green (red-free), grey (neutral) and swing-in diffusing screen; heat-absorbing filter
Free working distance exit prism to patient eye	66 mm
Travel of instrument base	Vertical: 30 mm, X-axis: 110 mm, Y-axis: 90 mm
Vertical travel of headrest	60 mm
Light source	6V 20W halogen lamp
Lamp brightness	Continuously adjustable
Power requirements	100V to 240V ±10%, self-sensing, 50-60 Hz
Weight	Basic unit: 9.85 kg; headrest: 1.25 kg

HSO 10 Hand Slit Lamp

Microscope	Straight binocular tube f = 80 mm with 50 – 75 mm pupillary distance scale
High-eyepoint eyepiece (firmly mounted)	f = 13 mm with +8 to –4D compensation of ametropia
Objective	f = 125 mm
Slit width	Steps of 0.15 and 0.75 mm
Slit length	2 – 12 mm, continuously adjustable
Angle of incidence	0 – 30° to right or left, with clamp
Total weight	850 g (without battery)
Case	Carrying case
Power requirements for battery charger	110V, 220V; 50 – 60 Hz

3. Examination methods – types of illumination.

Biomicroscopy of the living eye is a routine ophthalmologic examination. The slit lamp enables the user to inspect individual eye segments in quick succession to obtain a general impression of the eye and make a diagnosis.

In a slit lamp, the most important type of illumination is the optical section. All other techniques are variations.

For survey examination of the anterior segment the slit is adjusted to full aperture. This results in a circular, very bright and evenly illuminated field that is slightly smaller than the microscope's field of view. By placing a ground glass into the optical path the entire field of view is illuminated.

It is well known that the structure of transparent objects such as the cornea, anterior chamber, eye lens, and vitreous body can only be seen poorly in transmitted or reflected light, as the relative amplitude modulation of light is too weak and the phase modulation is not perceived by the eye. However, such objects can generally be observed well in scattered or fluorescent light.

The basic methods of examination can be classified by the following illumination techniques.

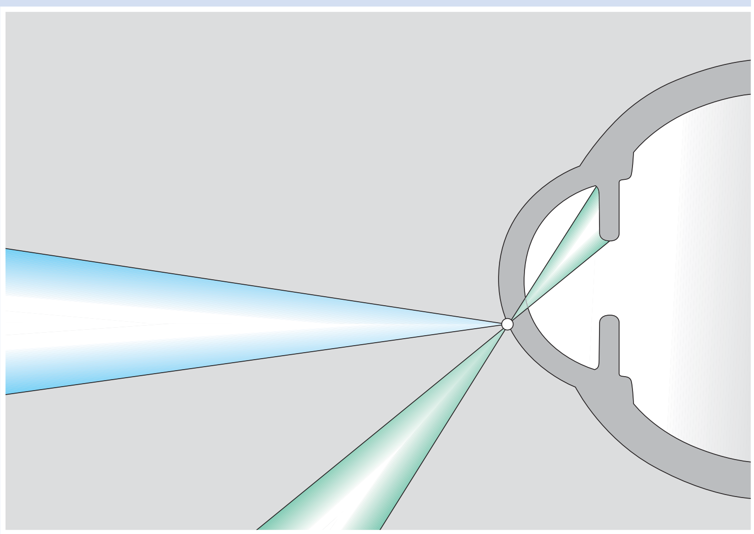


Fig. 11
Direct focal illumination

3.1 Observation by optical section

Observation with an optical section or direct focal illumination (Fig. 11) is the most frequently applied method of examination with the slit lamp. With this method, the axes of illuminating and viewing path intersect in the area of the anterior eye media to be examined, for example, the individual corneal layers.

The angle between illuminating and viewing path should be as large as possible (up to 90°), whereas the slit length should be kept small to minimise dazzling the patient. With a narrow slit (about 0.1 mm to 0.2 mm) and a sufficiently small angular aperture, the illuminating beam takes the form of two knife blades placed edge to edge. Scattered light appears only in this "optical section". The intensity of scattered light depends on the object structures and increases with increasing slit brightness and the higher proportion of short-wave light obtained by an increased colour temperature of the light source.

For good quality observations with a slit lamp it is very important that the light source delivers sufficient short-wave light containing a high as possible blue element, the colour temperature of the lamp therefore should also be high, a requirement normally satisfied by modern halogen lamps.

In conjunction with the stereomicroscope an optical section permits very precise depth information providing precise data of the shape of interfaces of transparent media. With a narrow slit and clear media, the images of slit and object appear sharply focused at the same time. Slit width and magnification may be varied depending on the object to be examined. With this method, brilliant optical section images can be obtained from the cornea through to the rear face of the crystalline lens.

With a narrow slit, the depth and position of different objects (e.g. the penetration depth of foreign bodies, shape of the lens etc.) can be resolved more easily. With a wide slit their extension and shape are visible more clearly (e.g. depth extension of injuries). It is therefore useful to vary the slit width during the examination.

At the cornea an optical section gives a luminous prismatic tissue section. The corneal epithelium is visible in a very thin precisely focused optical section as a thin blue streak right in front of the parenchyma. Examinations of the anterior chamber are performed with wider slit. At low magnification the Tyndall light (Tyndall phenomenon in aqueous humour) is visible in front of the dark pupil. Cells in the aqueous humour, however, are visible only at higher magnifications. During observation it is important that the background always remains as dark as possible.

The crystalline lens is particularly suited for viewing via an optical section. where the discontinuity zones can be made visible with a narrow slit. For examination of the anterior segments of the vitreous body it is advisable to use the smallest possible slit length to avoid dazzling of both patient and examiner. In these examinations, slit brightness should be high.

The slit lamp is specially configured for observation with an optical section. As both microscope and illumination system are mechanically coupled, the slit image is always located in the focal plane and the centre of the field of view of the microscope independent of focusing and selected magnification. Experience has shown that this relationship, if true in air, also applies with sufficient accuracy to the refracting ocular media, provided the operator has adjusted the eyepieces correctly to match his own refraction.

The optical section is rotatable about the slit axis. The slit itself can be aligned vertically or horizontally. Horizontal positioning of the slit however, is an exceptional case in optical section examinations, mainly because stereoscopic vision is restricted if the slit is aligned horizontally. The reason for this is that the slit is no longer perpendicular to the plane in which the viewing axes of the microscope and the lateral disparities of the observer lie.

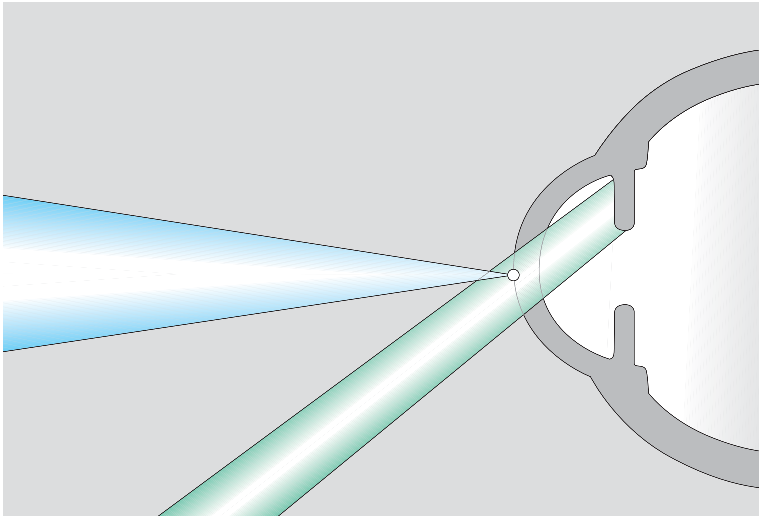


Fig 12
Direct diffuse illumination

Main applications

- Illumination methods for features that stood out in diffuse illumination but could not be observed in detail; particularly suitable for the assessment of cataracts, scars, nerves, vessels, etc.
- Observation by optical section is also of great importance for the determination of the stabilisation axis of toric contact lenses (in connection with a micrometer eyepiece or an appropriately inclined slit).
- Optical sections through the crystalline lens are also particularly good. Capsule, cortex, lens star and cataracts can be observed without difficulty.

Recommended settings
Illumination

- Narrow slit
- Angle of slit illumination system 0° - 45° (for reflected light bright field illumination)
- Angle of slit illumination system 45° - 90° (for reflected light dark field illumination)

For direct focal illumination with wide slit

Slit width: > 0.5 mm
Magnification: approx. 20x - 32x, if necessary, higher
Observation of details, e.g. stromal striae.

For direct focal illumination with narrow slit:

Slit width: 0.1 - 0.3 mm
Magnification: maximum

This is the ideal illumination for minute details providing sufficient contrast and little glare. With this method however, the reduction of the depth of field caused by kerato-ectasia is all too noticeable. In the centre of the image however this effect is not so marked. The narrow slit should also be used for corneal profile observations

3.2 Direct diffuse illumination

If media, especially that of the cornea, are opaque, optical section images are often impossible depending on severity. In these cases, direct diffuse illumination (Fig. 12) may be used to advantage. For this, the slit is opened very wide and a diffuse, attenuated survey illumination is produced by inserting a ground glass screen or diffuser in the illuminating path.

Main applications

This illumination method is applied for:

- general surveys of anterior eye segments
- general observation of the surfaces of crystalline lens and cornea
- assessment of the lachrymal reflex
- assessment of soft contact lenses

Recommended settings
Illumination

- Slit fully opened (annular diaphragm)
- Inserted diffuser
- Microscope positioned at 0°
- Angle of slit illumination system approx. 30° - 50°

Magnification

M = 5x - 12x (for surveys rather less)
M = > 30x (assessment of lachrymal film)

3.3 Indirect illumination

With this method, light enters the eye through a narrow to medium slit (2 to 4 mm) to one side of the area to be examined. The axes of illuminating and viewing path do not intersect at the point of image focus, to achieve this, the illuminating prism is decentred by rotating it about its vertical axis off the normal position (click stop). In this way, reflected, indirect light illuminates the area of the anterior chamber or cornea to be examined (Fig. 13). The observed corneal area then lies between the incident light section through the cornea and the irradiated area of the iris. Observation is thus against a comparatively dark background.

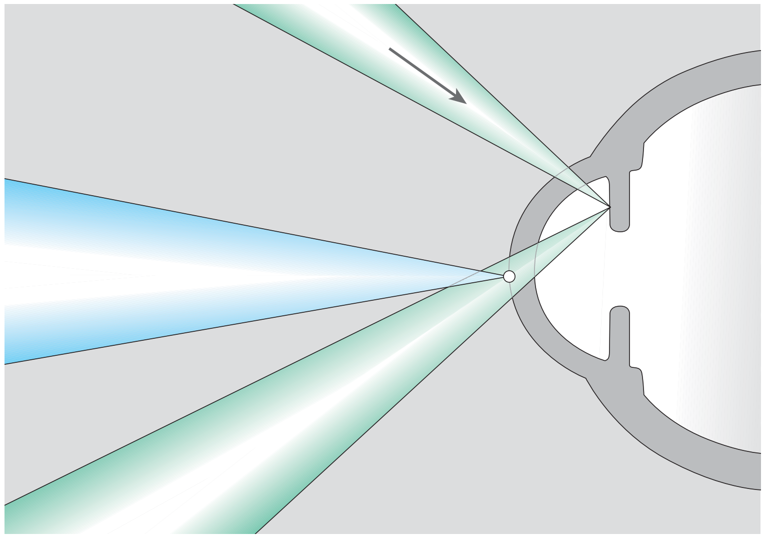


Fig. 13
Indirect illumination

Main applications

- Examination of objects in the direct vicinity of corneal areas of reduced transparency (e.g. infiltrates, corneal scars, deposits, epithelial or stromal defects).

Illumination

- Narrow to medium slit width
- Decentred slit

Magnification

Approx. M = 12x (depending on object size)

3.4 Retro-illumination

In certain cases, illumination by optical section does not yield sufficient information or is impossible. This is the case, for example, when larger, extensive zones or spaces of the ocular media are opaque. Then the scattered light that is not very bright normally, is absorbed. A similar situation arises when areas behind the crystalline lens are to be observed. In this case the observation beam must pass a number of interfaces that may reflect and attenuate the light.

In such cases, retro-illumination (Fig. 14) often proves to be useful. In his type of illumination, similar to conventional bright-field microscopy, observations are made with transmitted light where the object structures are recognised by differences in absorption. Transmitted light requires a light source on the other side of the object. With retro-illumination, the light is produced secondarily by irradiation. There are two types of retro-illumination. Direct retro-illumination caused by direct reflection at surfaces such as the iris, crystalline lens or the fundus, and indirect retro-illumination caused by diffuse reflection in the medium, i.e. at all scattering media and surfaces in the anterior and posterior segments.

For setting retro-illumination, almost all types of slit lamp have a facility for decentring the slit horizontally. This facility permits lateral adjustment of the slit (which in focal illumination is arranged in the centre of the field) to the left or right of the field of view. The illumination beam is directed past the object onto the fundus.

Retro-illumination from the iris can be used to make visible corneal bedewing and opacity as well as foreign bodies in the cornea. As retro-illumination from the iris is strong, the slit is kept narrow. Structures in the crystalline lens obtain their retro-illumination either through reflection at the back surface of the lens or from the fundus. To utilise the fundus light, the angle between observation and illumination should be

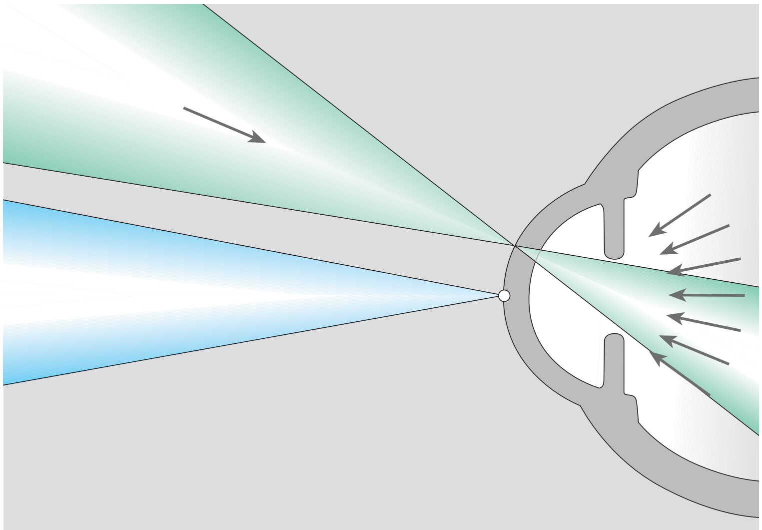


Fig. 14
Indirect retro-illumination

kept small and the passage of the light beam kept far as possible from the object to be observed so that the scattered light from adjacent areas does not disturb observation (Fig. 29). In this way pigmentation, vacuoles and water chinks in the crystalline lens are clearly visible. Indirect illumination is also important for the examination of iris structures.

If the scattered light of the crystalline lens is to be used to make defects in the pigment leaf of the iris visible, the illumination beam of a wide open slit must be shone through the pupil at a wide angle relative to the observation direction without touching the iris.

Adjustment of direct retro-illumination:
Iris reflection (examination in yellow field)

Initially, direct focal illumination is set up, the slit illuminating system is then swung aside temporally until the light reflected by the iris lightens the object to be examined from behind through the cornea. If the microscope remains in the initial position of direct focal illumination (approx. 90° relative to the patient's eye), then this "yellow field illumination" corresponds to transmitted light dark field illumination in normal microscopy. If the viewing background is formed by the pupil, microcysts and vacuoles are seen particularly well via this type of illumination.

If the angle between illumination and observation is increased, by moving the microscope nasally, the resulting illumination corresponds to an examination in transmitted light bright field with the microscope.

- Slit width: 1 - 2 mm
- Magnification: medium to maximum

Observation of

vascularisations, micro cysts, vacuoles, oedemas, particles in lachrymal film, flow rate of lachrymal film, Descemet's membranes.

Lens reflection (examination in white field)

The greyish-white reflected light from the front surface of the crystalline lens lends the name to this type of illumination.

Observation of

superficial corneal defects, scars, particles in the lachrymal film.

Retinal reflection (examination in red field)

Illumination system and observation axis are set to 0°. Similar to skiascopy (or ophthalmoscopy), a reddish corneal reflection appears that is not as bright. This reflection reminds one of the so-called "red eye effect" in normal flash photography. With this type of "red field illumination" it is essential that the pupil is dilated as otherwise the resulting relatively small field of view through a normal size pupil makes observation almost impossible. The colour of the reflection may also "migrate" to yellow if the light is reflected by the papilla.

Observation of

superficial corneal defects, scars, particles in lachrymal film, dystrophy, cataract in neutral corneal area.

3.5 Scattering sclero-corneal illumination

With this type of illumination, a wide light beam is directed onto the limbal region of the cornea at an extremely low angle of incidence and with a laterally decentred illuminating prism. Adjustment must allow the light beam to transmit through the corneal parenchymal layers according to the principle of total reflection allowing the interface with the cornea to be brightly illuminated (Fig. 15). The magnification should be selected so that the entire cornea can be seen at a glance. The slit illumination system is temporarily directed to the scleral region directly adjacent to the limbus.

In its normal physiological state, the cornea is fully transparent and appears completely clear. If the eccentricity of the light is properly adjusted a bright shining ring is visible around the entire limbus.

With irregularities in the structure caused by inclusions, scars, opacities, foreign bodies, etc., light scatter occurs allowing any disturbances, including weak oedemas, small scars and very fine opacities to be located by illumination or shadowing.

- Slit width: > 0.5mm
- Magnification: medium
- Illumination: maximum

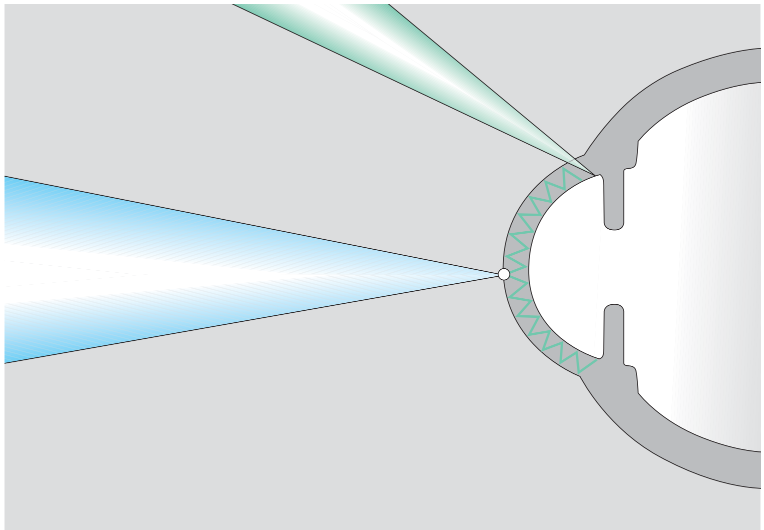


Fig. 15
Scattering sclero-corneal illumination

3.6 Fundus observation and gonioscopy with the slit lamp

Fundus observation is known by ophthalmoscopy and the use of fundus cameras. With the slit lamp, however, direct observation of the fundus is impossible due to the refractive power of the ocular media. In other words: the far point of the eye (punctum remotum) is so distant in front of (myopia) or behind (hyperopia) that the microscope cannot be focussed. The use of auxiliary optics - generally as a lens - makes it possible however to bring the far point within the focusing range of the microscope. For this various auxiliary lenses are in use that range in optical properties and practical application. These lenses are classified in two groups:

- Concave and
- Convex optics.

Concave optics

Concave lenses provide an upright, virtual intermediate image of the fundus. Due to this property, the normal working distance of the slit lamp to the patient is only changed slightly. As the pupil acts like a diaphragm, the stereoscopic field of view is limited with concave lenses.

There are two types of concave lenses widely in use today:

- Fundus contact lens and
- Goldmann 3-mirror or
  4-mirror contact lens = gonioscope.

Concave lenses are divided into negative contact lenses and high-power positive lenses.

The Goldmann fundus contact lens is classified as a negative contact lens. It has a refractive power of - 64 D thus compensating approximately for the refractive power of the cornea and permitting the examination of the posterior pole of the eye to about 30° from the axis.

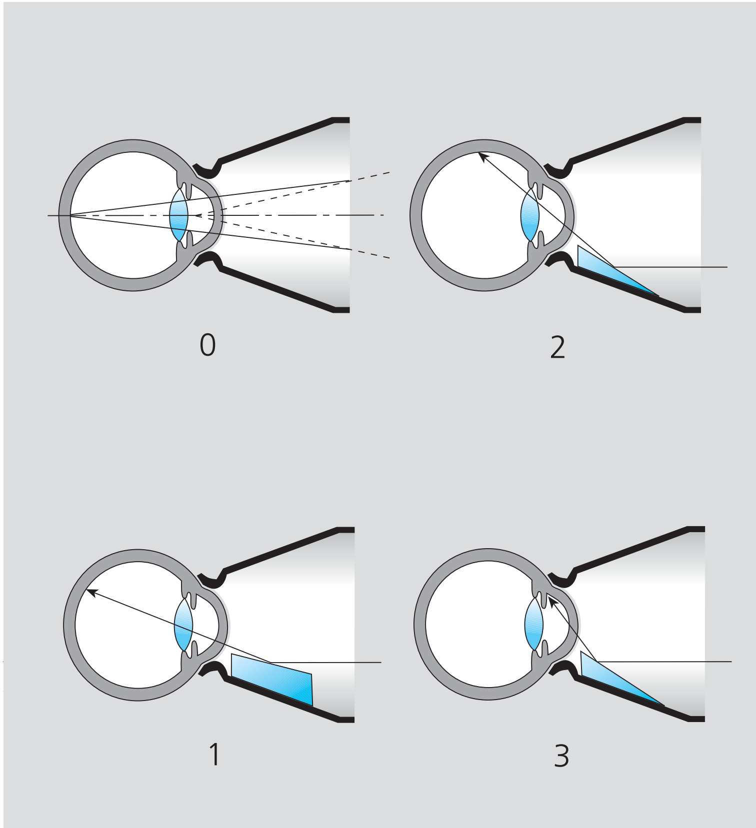


Fig. 16
Scheme of
3-mirror contact lens

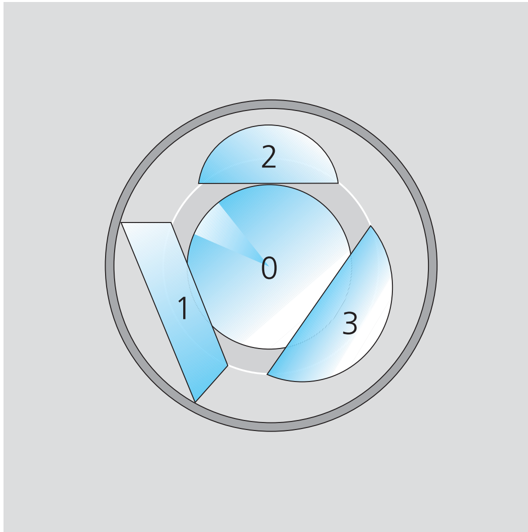


Fig. 17
0 = Observation of central areas of retina
1 = Observation of off-centre areas of retina
2 = Observation of external periphery of retina
3 = Observation of iridocorneal angle

The lateral magnification for the normal eye is 0.91, the axial magnification 0.62. An advantage of the Goldmann fundus lens is that lateral and axial magnification is virtually independent of the patient's refractive power. This is of particular importance when examining the vitreous body. This lens also has a wider monocular and binocular field of view than, for instance, the Hruby lens.

However, contact lenses cannot be used on very sensitive patients and particularly patients just after surgery.

For fundus observation of a myopic patient with one of the concave lenses, the microscope must be moved towards the patient. With myopia of -20 D, the displacement is 18 mm, but only 7 mm for the Goldmann fundus lens.

With a fundus contact lens, only the central region of the fundus can be observed. Therefore, concave lenses are also available with built-in mirrors for observation of the different peripheral fundus regions and sections of the vitreous body or observation of the iridocorneal angle (gonioscopy).

These lenses are available with three mirrors (three-mirror contact lens, Figs. 16 and 17) and also with four (four-mirror contact lens). (Single and double mirror contact lenses being not so popular.) The axial regions of the vitreous body and fundus can be observed by looking through the central area of these lenses (without a mirror), however, a simple fundus contact lens should be preferred in this instance for two reasons. First, it provides better image quality because of its reduced glass thickness, and secondly, the lens is easier to handle than the somewhat larger three-mirror contact lens. The angles of the reflecting surfaces of the Goldmann three-mirror contact lens are 59°, 67° and 73°.

The four-mirror contact lens is a small pyramid, mainly of glass with the vertex removed, in its place is a ground-in recess with a radius of about 8 mm which corresponds to the curvature of an average cornea. The angle of the reflecting surfaces is approximately 62°.

With these lenses, objects are seen as mirror images. Small peripheral holes in the retina that one may fail to see with an ophthalmoscope are easily discerned with a three-mirror contact lens.

Convex optics

Convex lenses produce a reverse, real intermediate image of the fundus. For this reason, a longer distance is necessary between the slit lamp and patient's eye. Most modern instruments however allow for this.

Convex lenses have very large monoscopic or stereoscopic fields of view. This is because the convex lens images the entrance pupil of the microscope at reduced size in the patient's pupil which therefore does not act as a field stop.

Two types of convex lenses are available:

- Contact lens (e.g. contact lens after Schlegel; Panfundoscope) or
- Aspheric plus lens (e.g. auxiliary lens after Bayadi; 90 D Volk lens, aspheric ophthalmoscopic lens AOL 90 D).

The latter are used in indirect ophthalmoscopy where the lens is held by hand about 9 mm in front of the patient's eye. Both slit projector and microscope should be set to a middle position, the slit fully opened, and a medium magnification (about 12x) set on the microscope. The distance between ophthalmoscopic lens and illuminating prism should be about 80 mm. The lens is illuminated in direct focal illumination. It produces a reversed, real image of the fundus that is reduced in size. Without dilation of the pupil the retinal image is visible through the left-hand or right-hand eyepiece. Initially, this image will be obscured by reflections from the cornea. These reflections, however, are eliminated more easily than with the Hruby lens by moving the joystick of the slit lamp laterally. Focusing is as with normal slit image observation. The small fundus image can be further magnified considerably using the magnification changer of the microscope. With a dilated pupil of > 5 mm, the fundus of the eye can be viewed stereoscopically. The field angle is 60° at medium magnification and 40° at a magnification of 20x. With this method even for the inexperienced operator it is relatively easy to see the fundus, its visibility is better than with indirect ophthalmoscopy.

Convex lenses are particularly well suited for the examination of strongly myopic eyes if positioned correctly, lateral and axial magnifications becoming independent of the refractive power of the patient's eye. Simple convex lenses, however, exhibit abnormal field curvatures making them unsuitable for examination of the vitreous body.

Illumination

So far the conditions and methods of fundus observation with the slit lamp have been discussed, but without illumination, observation is impossible. Special requirements have to be met for illumination of the fundus through auxiliary lenses. For all types of auxiliary lens, the size of the pupil limits the maximum adjustable angle between observation and illumination though to a varying degree. This means it will not be possible in every case to bring both observation path and the illuminating beam together in the patient's pupil.

The assessment of peripheral fundus areas that must be viewed under the widest possible angle involves particular difficulties. This is because the entrance pupil of the eye takes a vertically oval form because of the oblique viewing direction thus making it impossible to place both observation and the illuminating paths side by side within the pupil.

This can be remedied by positioning the illuminating beam between the observation beams. This configuration does not allow observation by optical section, but this is not important in fundus examination.

Another practical solution is to examine the peripheral fundus areas with horizontal slit illumination. To achieve focal illumination, it is necessary to rotate the slit to the horizontal plane and then swivel it vertically.

This feature is not provided by all slit lamps on the market.

With concave auxiliary lenses, homocentricity of observation and illumination beams on the fundus can no longer be achieved as strong spherical aberration displaces the slit laterally and vertically. Lateral displacement is generally not disturbing as it can be compensated for by lateral decentration of the slit. Vertical displacement, however, results in an unsharp slit image. It can be brought into focus again by readjustment of both eyepieces.

For concave lenses, the maximum illumination angle (for a given pupil diameter) is wider the higher the refractive power of the auxiliary lens and the shorter its distance from the eye. The maximum adjustable illumination angle becomes smaller with increasing myopia. Convex lenses permit comparatively larger illumination angles with smaller pupils and higher myopia than concave lenses. Convex lenses with their real intermediate image plane, the homocentricity on the fundus between observation and illumination beams is better than with concave lenses.

With all methods of examining the peripheral areas of the vitreous body and the fundus the regions above and below are more easily examined than the lateral regions. This is a result of perspective distortion of the pupil. When observed from above or below, the pupil appears as a horizontal oval through which the two observation paths of the binocular microscope and the illumination path can easily pass but when viewing through the pupil from the side, it appears as a vertical oval, and the three beams cannot pass through together, for this reason the side regions are seen only monocularly. The same refers to gonioscopy (Fig. 18).

Gonioscopy

The iridocorneal angle of the anterior chamber is not visible without additional optical aids as a result of total reflection at the corneal surface. If, however, the eye were immersed in water or the anterior chamber filled with air, the iridocorneal angle would become visible. The same effect is achieved with contact lenses of which different types have been seen in the past. Most of them, however, did not find a general acceptance. Today only the mirror contact lenses as introduced by GOLDMANN are of major importance in slit lamp examinations. Fig. 16 shows the beam paths in a mirror contact lens.

Meanwhile this examination method has become a standard. Its importance having grown since the introduction of laser trabeculoplasty for glaucoma treatment (laser mirrored contact lens).

The mirror contact lens is either held by hand or with a special holder. With this lens the region of the retina or the iridocorneal angle that is opposite the mirror used, becomes visible as a mirror image. By rotating the lens about its axis the complete iridocorneal angle can be seen. To view the angle more from the iris plane or along the inner corneal surface, the lens must either be slightly tilted relative to the corneal axis or the patient must slightly change the direction of vision. Illumination is by means of the slit illuminator. For good reflex-free illumination it is useful to rotate the slit so that it is perpendicular to the iridocorneal angle. It may be necessary to set an appropriate angle between the illumination and observation beams. With a horizontal slit this is not possible on all instruments. The examination of the iridocorneal angle requires good stereoscopic observation through the microscope. In optical section, the iridocorneal angle can best be seen at the 12 and 6 o'clock position.

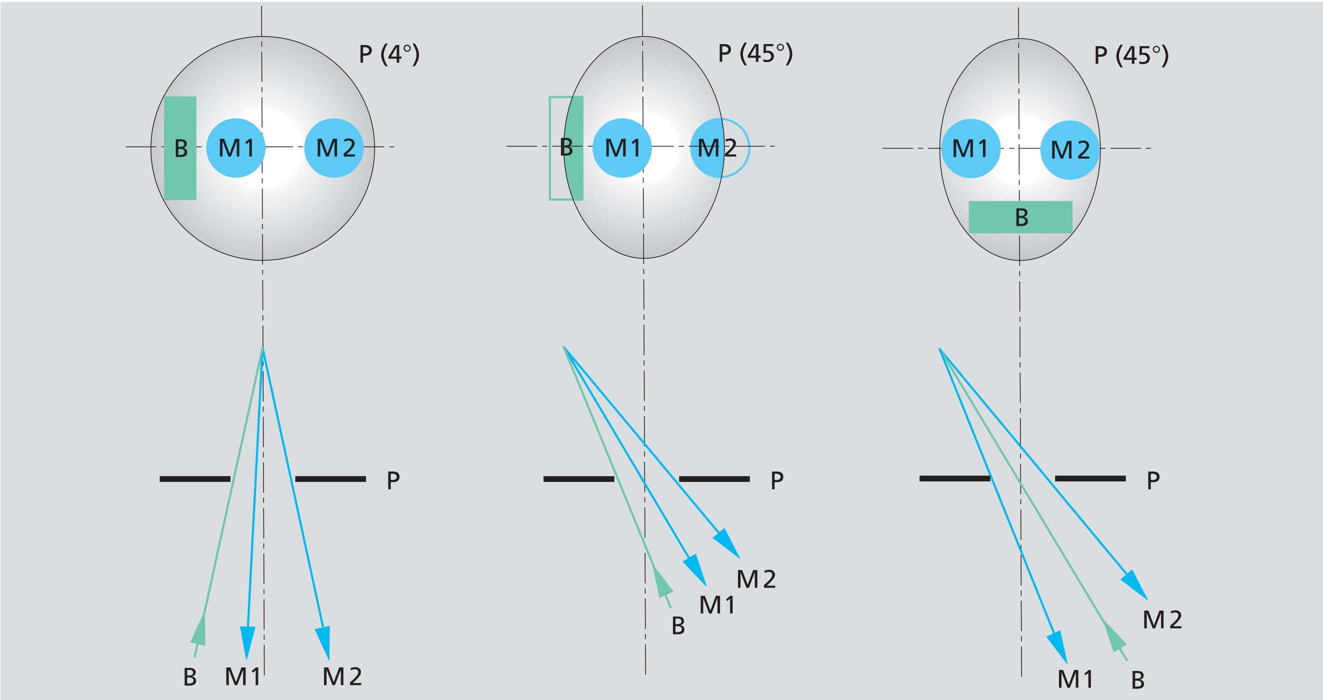


Fig. 18
Stereoscopic observation with the slit lamp

Notes on handling the contact lens

Before fitting a contact lens, the eye to be examined must be anaesthetised in an appropriate manner. In addition the pupil must be fully dilated for examination of the ocular fundus.

As the concave contact surface of a contact lens normally has a radius of curvature that is higher than that of the cornea, the intermediate space should be filled with 2 drops of physiological saline or methyl cellulose.

It is easier to put the contact lens onto the eye, if the patient looks upwards and the eyelid is lifted slightly. Any air bubbles will disappear if the contact lens is slightly twisted and tilted.

If, after the examination, the lens should adhere, then one should slightly impress the globe at the margin of the sclera (with a glass rod or similar implement).

After use, the contact lens must be cleaned with water and a cotton swab to prevent any residues, e.g. methyl cellulose, from drying out and adhering.

For disinfection, disinfectants such as CLORINA (manufactured by Lysoform, Dr. Rosemann GmbH, Berlin) may be used (5% solution, for 10 minutes). The lens must then be rinsed with distilled water and dried with a sterile swab.

Contact lenses must on no account be boiled or heated excessively in any way. Similarly, alcohol should not be used for cleaning or disinfection.

3.7 Fluorescence observation and slit lamp microscopy in contact lens fitting

Sodium fluorescein has been used as a dye in medicine for more than 100 years for physico-chemical and biological investigations. In 1881, EHRLICHER introduced it to ophthalmology. Since about 1938, it has also been applied to contact lens fitting. The method is based on the fact that the fluorescence light can be spectrally separated from an exciting light. Structures absorbing the fluorescein dye are contrasted much better against the non-fluorescing environment. Fluorescein, for example, stains damaged cells and fills intercellular spaces.

Especially in contact lens fitting this method is used to check the fit of hard contact lenses as well as the inspection of the cornea after contact lenses have been worn. This method not only permits the fit of contact lenses and the lachrymal flow to be assessed, but also allows superficial injuries of the corneal epithelium to be detected. Even minute corneal defects that may remain undiscovered by normal slit examination can be revealed in this way.

Correct fluorescence observation requires a suitable excitation light source and a properly dosed concentration of fluorescein in the lachrymal film, fluorescein is inserted into the conjunctival sac either by drops or with a fluorescein strip.

The yellow-green fluorescence light is not monochromatic, the emission maximum is at l= 530 to 535 nm. Hence, for excitation a radiation of l< 530 nm is necessary. The efficiency of fluorescence is highest with blue light excitation in the wavelength range l= 450 to 500 nm. The halogen lamp of the slit lamp serves as excitation source. A cobalt blue filter is swung into the optical path of the slit lamp serving as an exciter filter. Stray light that would reduce contrast must be blocked for observation and photographic documentation by using a barrier filter. For this, a yellow filter with l= > 530 nm is used. This filter blocks the blue exciting light and transmits only the yellow-green fluorescence and longer wavelengths.

Concentration of sodium fluorescein

The optimum fluorescence effect is achieved with a sodium fluorescein concentration of 0.2 to 0.4% in the lachrymal fluid.

This concentration is obtained by dripping 1 drop of 2% sodium fluorescein into the conjunctival sac of a patient with normal lachrymal secretion. The reaction time is about 1 to 2 minutes. In the case of hyposecretion, however, this concentration will be too high. As a result there will be no fluorescence, but only a brownish coloration of the lachrymal film. This can be remedied by either using 1% sodium fluorescein or by adding a drop of physiological saline.

In the case of hypersecretion, the above mentioned concentration of sodium fluorescein will be too low. Thus, a higher dose should be applied.

In essence the use of fluorescence observation with the slit lamp in contact lens fitting has the following applications:

- Inspection of the outer anterior segment of the eye before inserting a contact lens
- Inspection of the fit of the contact lens on the eye with and without sodium fluorescein
- Inspection of the anterior eye segment and particularly of the cornea on removal of the contact lens after it has been worn over a long period
- Thorough inspection of the contact lens.

These inspections can be performed as follows:

Inspection of the anterior eye segments

This inspection is carried out using diffuse or direct focal illumination with a wide, fully opened slit. The cornea is examined for scars, vascularisation, neovascularisation, infiltrates, abnormal changes of the tissue of the corneal back surface, ring-shaped lipoid inclusions at the corneal limbus, and inclusions with keratoconus. Sclera and lids are examined for irregularities, the conjunctiva for congestion and possible anomalies. It is also possible to assess the lachrymal fluid.

Inspection of contact lens fit

Conditions: diffuse illumination and a magnification of approximately 12x. The following parameters may be assessed: fit of the lens and centration, lens movement (direction and speed), presence of air bubbles or foreign bodies under the lens and the state of the lachrymal fluid.

With hard contact lenses, the size of the contact lens relative to the palpebral fissure, the hydrophobic state of the contact lens and the distribution of the lachrymal fluid under the contact lens (fluorescein image) can be assessed. Also lenses may be checked for any grease or dirt deposits. With soft contact lenses, the size of contact lens movement in the region of the limbus, the size of the contact lens relative to the cornea and the state of the edge of the contact lens (wrinkled or wavy, tightly fitted, pressure exerted on conjunctiva) are assessed. Furthermore, blood vessels can be examined to determine if the contact lens dislocates or squeezes them which may cause irritation of the conjunctiva.

Inspection of the cornea

The examination is performed with direct focal illumination (by optical section), direct or scattering sclero-corneal illumination. The cornea is checked for dots, abrasions, and erosions as well as possible deformation (air bubble pits, oedemas). Furthermore it can be examined for changes in the deeper corneal layers, in the conjunctiva (pressure sores, allergic reactions, problems with caring agents) and of the eye-lids.

Inspection of contact lens

Contact lenses are inspected with diffuse and direct focal illumination. The lens should be supported during the inspection. The surfaces of the contact lenses are checked for scratches, burr and polishing marks. The edges of the contact lenses are examined for cracks, chips, defects and possible deposits.

Interpretation of fluorescence patterns under contact lenses with a spherical back surface

Flat fitting

The fluorescence image of a flatly fitted contact lens on a spherical cornea shows a round, dark contact zone in the centre surrounded by a wide fluorescing ring that becomes brighter towards the periphery. The fluorescence intensity increases continuously towards the edge (intense yellow-green). A flatly fitted spherical contact lens on a toric cornea forms a central dark contact zone in the shape of an ellipse, the long axis of which corresponds to the flatter corneal meridian. With increasing toricity the ellipse becomes flatter and longer. With a steeper meridian, the contact lens juts out from the cornea and shows a zone of increasing fluorescence.

Parallel fitting

A contact lens fitted parallel to a spherical cornea shows a central, evenly round, dark contact zone surrounded by a fluorescing ring that becomes brighter towards the periphery. The dark zone covers about

70 to 72%, the yellow-green ring about 28 to 30% of the area. The marginal area must jut out gently and continuously from the cornea with smooth transitions. If this is not so, the contact lens surface has a defect and should be removed immediately from the cornea.

The fluorescence image of a parallel fitted contact lens on a toric cornea shows a central, dark contact zone with peripheral indentations in the steeper meridian. With increasing toricity of the cornea, a dark bone-shaped or butterfly-shaped contact zone is created. The contact lens rests on the flatter meridian, in the steeper meridian it juts out from the cornea. The marginal zone must project gently.

Steep fitting

The fluorescence image of a steeply fitted contact lens on a spherical cornea shows a central fluorescing "lake", surrounded by a paracentral, narrow and dark fluorescence ring. This dark ring is adjoined by a fluorescing ring (at the marginal zone of contact lens) having a brightness that increases continuously towards the edge.

All transitions must be smooth.

The fluorescence image of a steeply fitted contact lens on a toric cornea shows paracentral, dark, sickle or kidney shaped contact zones towards the steeper meridian. They are surrounded by a lachrymal lake that becomes increasingly oval with increasing toricity. At the periphery it merges with the fluorescing ring of the marginal zone of the contact lens which becomes brighter towards the edge.

After every observation with sodium fluorescein the eye should be rinsed thoroughly with physiological saline to avoid infection.

3.8 Assessment of lachrymal film

The assessment of the lachrymal film and the inspection of the lachrymal apparatus should be performed at the very beginning of the examination, particularly before contact lens fitting, as the quantity and composition of the lachrymal fluid may change in the course of examinations and measurements as well as during the lens fitting process.

The daily lachrymal secretion amounts to about 0.5 ml to 1.0 ml. During sleep, however, no lachrymal fluid is produced. If the daily secretion rate is less (hyposecretion), there is the danger of hypoxia of the cornea as the aqueous phase as oxygen carrier is too weak. With soft contact lenses, additionally dehydration occurs. In the case of hypersecretion of lachrymal fluid, there are generally no problems in contact lens application.

Before the first application of contact lenses, the ophthalmologist must check whether the quantity of the lachrymal fluid of the eyes allows the wearing of contact lenses and the composition of the lachrymal secretion lies within the normal range. Every contact lens needs a certain lachrymal film so that it can float with minimal friction. Soft contact lenses additionally require a certain tear humidity to remain elastic. Depending on lens type, material and wearing mode a daily quantity of up to 1 ml lachrymal fluid is necessary. This quantity corresponds to the daily production of a healthy person. A lack of tears may make wearing contact lenses a risk.

The quality and quantity of the lachrymal film can be examined simply and reliably with the slit lamp. The break-up time and thus the stability of the lachrymal film is an important criterion for symptom-free wearing of contact lenses. To determine this break-up time, the lachrymal fluid of the patient is stained with sodium fluorescein drops without application of a local anaesthetic. A cobalt blue filter is brought into the optical path of the slit lamp. While the corneal surface is continuously observed through a yellow filter, the time between lid blinking and the appearance of the first dry spots (breaking up of the lachrymal film) is measured. This interval is described as break-up time (BUT). During this examination, one must ensure that the patient is not dazzled (retinal irritation - reflex secretion) as this would falsify the examination result. If the break-up time is between 0 and 10 seconds, the patient suffers from an acute lack of mucin. If this time is between 10 and 25 seconds, mucin production is disturbed and the lachrymal film is labile. With a break-up time of more than 25 seconds the lachrymal film is regarded as stable.

This examination can be performed more conveniently, if a video system (such as the Model 020 Video Compact Camera) is used on the slit lamp. In this way, details of the observation process can be differentiated and assessed more easily by slow motion or single frame sequences on the monitor screen. When the examination is recorded on a video recorder with an integrated electronic counter the BUT can be determined easily and precisely. This recording method is an instant user-friendly, low-cost solution preferable to normal photography which provides only "still pictures" with no continuous visualisation and requires time for film processing.

3.9 Other examination methods

Apart from the examination methods covered so far, slit lamps may also be used for other examinations and treatments. To enhance the contrast of objects with a high portion of red (e.g. fundus), green filters (red-free filters) are required.

Observations in polarised light have also been performed but so far these examinations have not resulted in generally useful applications. For this reason polarising filters are not incorporated in slit lamps as standard.

Of particular interest and special importance is the use of the slit lamp not only for observation but, with suitable accessories, as a measuring instrument.

As the slit lamp is such a widely used instrument, the cost of a measuring instrument can be reduced considerably by making use of the mechanical and optical elements of the slit lamp. The most popular example is the applanation tonometer used to measure the intraocular pressure. Further examples are attachments for measuring the thickness of the cornea, the depth of the anterior chamber as well as length and angle measurements on the cornea. These instruments will be covered in detail in section 5.

The slit lamp, however, is not only used as examination instrument. The corneal microscope, can assist in, for example, minor operations on the cornea, such as the removal of foreign bodies. With the slit illuminator the affected area can be appropriately lit. Thanks to the large working distance between microscope and eye, procedures are simplified.

4. Documentation of findings.

Fig. 19
Model 020
Video Compact Camera

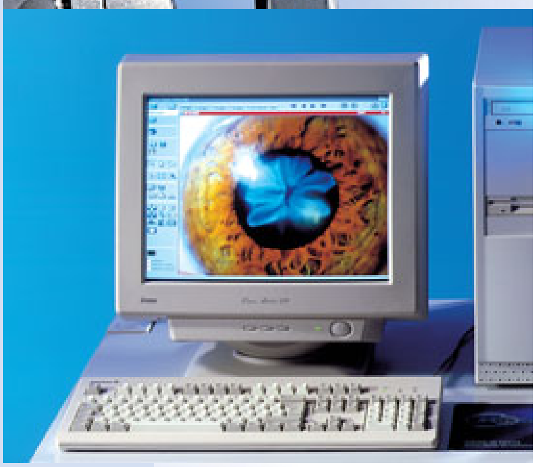


Fig. 20
VISUPAC Software

Fig. 21
TV-attachment
with 3CCD camera

4.1 Video documentation

In recent years, video documentation has gained general acceptance for slit lamp examinations because a "still" photograph is much less meaningful than a dynamic film record. Only with this technique can the progress of slit lamp examination be represented realistically as the examiner sees it or he is used to seeing it: as a complex picture.

Further advantages over photographic records include lower light levels for the patient as well as the fast availability of results. As film development is not necessary, costs are also reduced. Often it is useful to explain to the patient, findings or the condition and fit of a contact lens during an examination. This saves time-consuming theoretical explanations later. This modern technique is well suited for documentation, information and educational purposes.

For the SL 115 Classic, SL 120/130 various options of video documentation are available.

For SL120/130 Slit Lamps:

- Commercial 1/2" TV cameras mounted via a 50/50 beam splitter with a sliding prism, TV adapter f=75 mm and TV coupling (standard C thread/ C mount). Cf. Fig. 21. For special requirements a 3CCD camera can also be fitted easily.

- The Model 020 Video Compact Camera constitutes a decisive milestone in the development towards an integrated video documentation system. It mounts directly between the microscope body and binocular tube without the need for an intermediate piece or TV adapter. This miniature camera has an outstanding resolution. Due to its low weight, it does not impair the mobility and ease of handling of the slit lamp.

- Retrofitting of the SL 115 Classic with a 1/2” miniature camera mounted via a video compact adapter.

Fig. 22
SL 120 Slit Lamp with video recording equipment and video printer

In addition to slit illumination, fill-in illumination should be used to achieve better illumination of the whole eye.

To fully utilise the available image quality a TV system that transmits and records the colour and synchronising signals separately is used, such as S-VHS or HI 8 (Y/C). A complete video system for slit lamps consisting of Model 020 Video Compact Camera, monitor, video recorder and video printer is shown in Fig. 22.

The VISUPAC digital image recording and editing system for slit lamps rounds off the range of documentation options.

4.2 Digital image recording and editing

VISUPAC

The VISUPAC digital image recording and editing system for slit lamps (Fig. 20) allows convenient storage, editing and management of images obtained with the slit lamp. The integration of a professional SQL database ensures fast access to all data at high system stability. Besides, the functionally designed graphic user interface adds to fast operation.

Software features include extensive image editing functions such as sharpening, blurring, zoom, inverting, contrast and brightness adjustment, slide show, etc., thus providing optimum postprocessing of images.

Graphic and text elements are easily created and inserted. These elements are part of a layer overlaid to the image. They may at any time be revealed or hidden, edited and deleted.

Another function allows transfer of a contour, such as a circle or rectangle, from one image to other images for comparison of a region of interest. Reference marks ensure geometrically correct transfer of the contour in terms of position, size and orientation.

For data import and export, of course, the DICOM standard (**D**igital **I**maging and **CO**mmunications in **M**edicine) can be used. This allows patient information to be included and transferred along with the image file.

5. Accessories.

The uses of a slit lamp can be extended by a wide range of accessories for measurement, examination and documentation.

The most widely used accessories are:

Applanation tonometers
for measurement of intraocular pressure

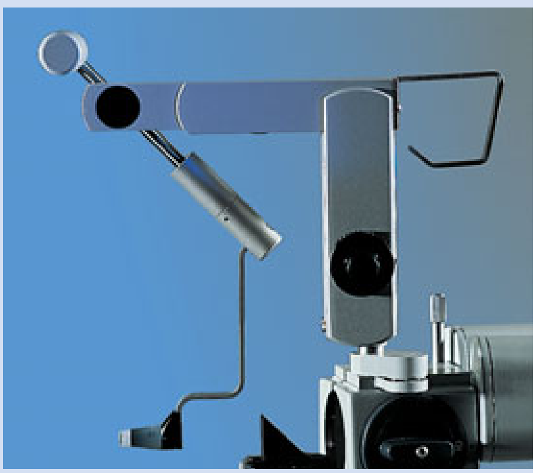
Micrometer eyepieces
for length and angle measurements on the eye, particularly for contact lens fitting

Contact lenses
for examination of the iridocorneal angle, central and peripheral fundus

TV cameras, co-observation tubes
for the documentation of findings and for educational and training purposes

Digital image archiving
for the documentation of findings, image processing and storage

Fig. 23
AT 020
Applanation Tonometer



5.1 Measurement of intraocular pressure

The most widely used accessory for the slit lamp is the Goldmann applanation tonometer. It is used for measuring the intraocular pressure. Today, compared with other techniques, this method is characterised by high accuracy, reliability and simplicity. The design and measuring principle of this instrument is well known as many papers have been published on it.

In practical use it is important that the tonometer is correctly mounted on the slit lamp. For routine measurements, it must be possible to move the applanation tonometer into a working position quickly and easily. On the other hand, it should not hinder normal work with the slit lamp. These requirements are met by the applanation tonometer models AT 020 (Fig. 23) and AT 030 (Fig. 24) that have been specially designed for the slit lamps SL 120/130. With an appropriate tonometer holder however, the AT 020 Applanation Tonometer may also be used on earlier slit lamp models and the SL 115 Classic Slit Lamp.

Tonometer measurement

Before the measurement of the intraocular pressure the illumination of the slit lamp must be adjusted: maximum illuminated field, open slit, a blue filter, and the slit projector swung out laterally to about 50°, 8x or 12x microscope magnification.

The patient's eyes must be anaesthetised as usual, and to avoid blinking, both eyes should be anaesthetised. If necessary, the fixation light should be used to fix the gaze. Next, a drop of sodium fluorescein solution is to be dripped into the conjunctival sac of both eyes, if necessary, by means of a strip of blotting paper.

The patient should look about 6° to the right. During measurement, the patient's eyes must be wide open. The examiner can assist in this by opening the

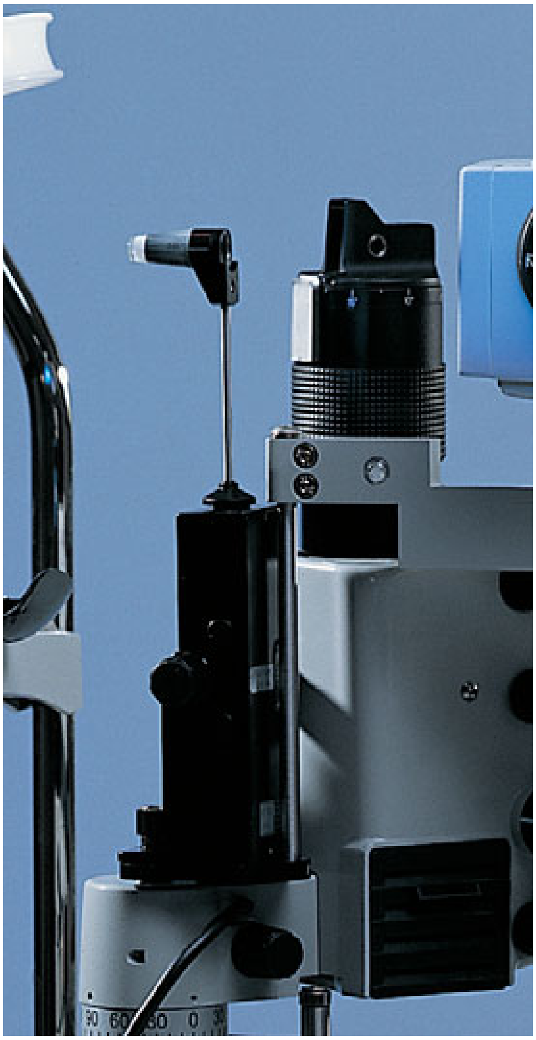


Fig. 24
AT 030 Applanation Tonometer

patient's eyelids with thumb and forefinger.

Care should be taken however not to exert inadvertent pressure on the globe by the fingers which should rest only on the bony eye socket.

The measuring body of the applanation tonometer contains an image doubling prism. With this prism, the lachrymal film ring between measuring body and cornea is divided into two green fluorescing semicircles.

Both semicircles must be the same size.

The corresponding vertical adjustment is performed with the slit lamp.

The width of the rings should be about 0.2 - 0.3 mm and should oscillate with the pulse beat.

For measurement, the measuring cell is brought into contact with the cornea. The pressure on the cornea is increased, starting from scale division 1 on the measuring drum, until the inner edges of the rings just contact each other (Fig. 25). The corresponding value is then read from the measuring drum and converted to kPa using a conversion table.

It is advisable to take a trial measurement first on both eyes. Then three measurements are taken successively on each eye to cover short-term variations of the intraocular pressure. Finally, the mean value should be calculated.

If the measurement takes too long, the corneal epithelium will dry out to a greater or lesser extent and in this case, measurements will be invalid. Therefore, the measuring time should be short and measurements should be taken on each eye alternately. Any symptoms caused by drying out will disappear quickly without further treatment.

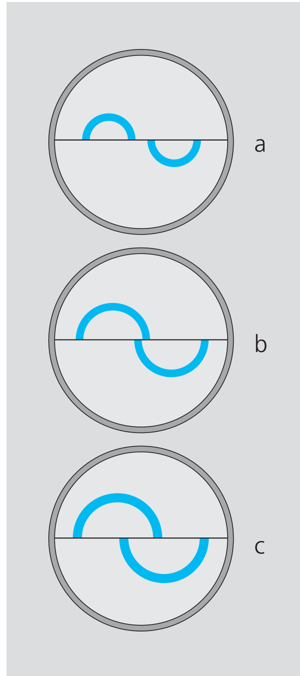


Fig. 25
Measuring patterns of applanation tonometer

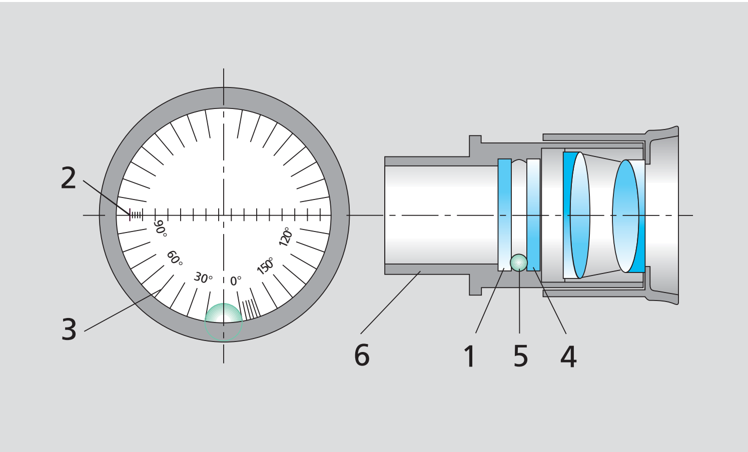


Fig. 26
Micrometer eyepiece
(eyepiece field of view)

Fig. 27
Slit lamp
with co-observation tube

1 Reticle
2 Linear scale, 0.2 mm interval
3 Tabo angle scale, 2° interval
4 Front window
5 Reading ball
6 Eyepiece socket

5.2 Length and angle measurement

Not only for the ophthalmologist, but also for the contact lens fitter it is of great advantage that he can take length and angle measurements on the SL 115 Classic/ 120/130 Slit Lamps with the appropriate accessories. It is possible, for example, to measure the diameter of cornea and pupil or the height of the palpebral fissure, and to determine the axis of a toric contact lens. These measurements are taken with a special eyepiece (Fig. 26) that fits into the binocular tube of the slit lamp in place of the standard eyepiece. To take measurements a medium magnification of 12x should be selected.

The image scale in the eyepiece plane is then 1x. With other magnifications, an appropriate scale factor must be applied. The eyepiece contains a reticle with a linear diameter scale of 15 mm graduated in 0.2 mm intervals. The angular scale of 360° for the measurement of the inclination angle is graduated in 2° intervals. The artificial horizon required for the angle measurement is provided by a gravity ball.

For the measurement of the inclination angle the image scale does not matter, it is only important that the object field is sufficiently large for setting the magnification on the slit lamp.

Additionally 10x micrometer eyepieces are available. The reticle in this eyepiece has a 10 mm linear scale graduated in 0.1 mm intervals. For routine check-ups it is also possible to take survey length measurements by placing an appropriately sized slit on the object to be measured and the slit length read from a scale (SL 115 Classic/120/130).

5.3 Miscellaneous

Beside the wide range of accessories for the slit lamp discussed above, the co-observation tube should be mentioned as it is particularly useful for educational and training purposes (Fig. 27).

6. History of the slit lamp

and development of the photography of the optical section

As important as the slit lamp is for today's ophthalmologic practice, as interesting, is the history of its development allowing its special technical features to be understood by those who are familiar with the function and operation of the modern slit lamp.

In judging the historical development of the slit lamp one must consider that the introduction of the instrument always had to be accompanied by the introduction of new examination techniques. These, however, were influenced not so much by the work of the engineers but rather by the efforts and foresight of the ophthalmologists involved. In other words, it was not so much the quality and performance of a slit lamp that was important for its general acceptance, but rather the practicability of the relevant examination methods.

Accordingly there were two conflicting trends in the development of the slit lamp. One trend originated from clinical research and aimed at an increase in functions and the introduction and application of increasingly complex and advanced technology. The other one originated from ophthalmologic practice and aimed at technical perfection and a restriction to useful methods of application.

Diseases of the eye are best diagnosed by visual inspection than by palpation. For visual inspection of the outer eye, magnifying aids had been used in the past. However, it was not as easy to observe the inner eye, particularly the fundal retina and choroid.

The first to succeed in this was Hermann von HELMHOLTZ (1850) with the invention of the ophthalmoscope. This is regarded as the birth of modern ophthalmology. Up to this fundamental invention, it had been a long road for medicine and especially for ophthalmology.

Fig. 28
Carl Zeiss

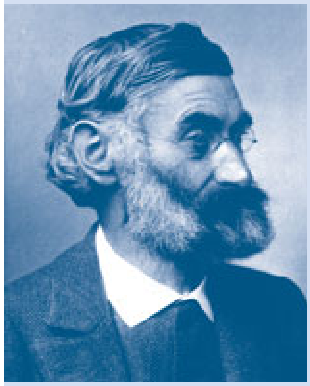


Fig. 29
Ernst Abbé

Fig. 30
Allvar Gullstrand

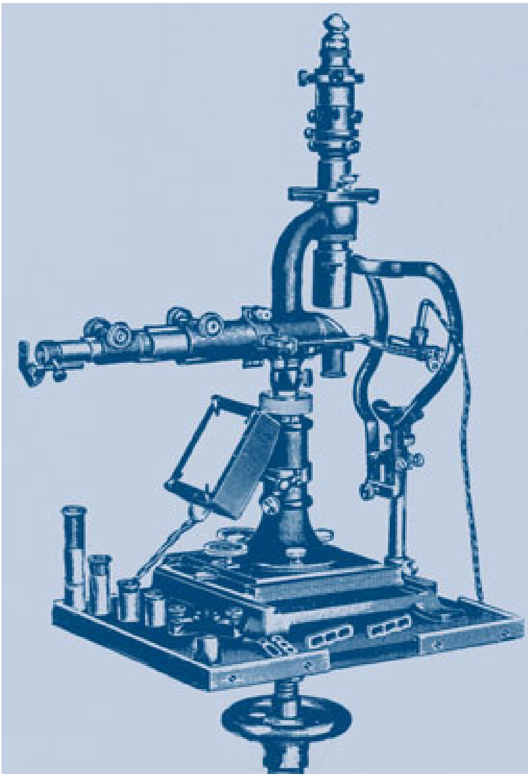


Fig. 31
Large Gullstrand Opthalmoscope (1911)

In ophthalmology, the term "slit lamp" is almost the only one used today. It would be more correct, however, to call it a "slit lamp instrument". Today's instruments are a combination of two separate developments, that of the corneal microscope and that of the slit lamp. The corneal microscope is the older instrument.

Magnifying visual aids – even binocular ones – were known, of course, before the eighties of the previous century, such as the sphere loupe (approx. 50 D) by HARTNACK.

Periscopic "plug lenses" (Steinheil-Coni; about 1866) were the predecessors of telescopic spectacles. They could, however, also be used as a loupe after HARTNACK. Around the turn of the century, these devices were followed by assorted types of binocular loupe. Before 1872, LIEBREICH used a monocular microscope as cornea microscope. The first independent development in this field however was the "corneal loupe" the Rostock mechanic WESTIEN made for W.v. ZEHENDER in 1886. It enjoyed great popularity and underwent several technical changes. Its optics classified the instrument as telescopic spectacles with a power of 10x. In ZEISS, at this time a GREENOUGH type reflected light microscope was made. In 1899, the Jena physicist CZAPSKI developed a new stand with an illumination system for horizontal use. Soon it was fitted with an arc guide permitting the instrument to be swivelled and a wooden cross-slide stage with face frame. By changing eyepieces and objectives, magnifications between 13x and 35x could be selected.

The major difference compared with the instrument of v. ZEHENDER was the image reversing prism system according to the French engineer PORRO. Because of this, it was possible to use the astronomical KEPLER telescope system that allows higher magnifications. On corneal microscopes, the magnification is intentionally limited to 40x to avoid the problems of patient movement. Today's cornea microscopes are mostly a combination of a KEPLER telescope with a GALILEAN magnification changer.

The first concept of a slit lamp dates back to 1911 and the great ophthalmologist Alvar GULLSTRAND and the "large reflection-free ophthalmoscope". In the same year, GULLSTRAND was awarded the Nobel prize. The instrument was manufactured by ZEISS. It consisted of a special illuminator that was connected by a small stand base through a vertically adjustable column. The base was freely movable on a glass plate. The illuminator employed a Nernst glower which was converted into a slit through a simple optical system. This slit was imaged into the eye by an aspheric ophthalmoscopic lens. A binocular telescopic lens was used for observation. The ophthalmoscope lens and telescopic lens were both held in one hand. Image contrast arose from differences in light scattering from different media. This instrument, however, did not receive further attention. The term "slit lamp" did not appear again in the literature until 1914.

There is no description of slit lamp findings by GULLSTRAND himself. The first relevant description was found in 1914 in the "Klinische Monatsblätter" written by ERGGELET.

In the period after 1912, also the first retina camera was developed after NORDENSON. The first photographs are known to have been published by NORDENSON in 1915. In 1925, the first retina camera containing an arc lamp as a high-intensity light source was produced at ZEISS by closely following the principles of the "large reflection-free ophthalmoscope" of GULLSTRAND.

Up until 1919, various improvements to the GULLSTRAND slit lamp were made by HENKER, VOGT et al. First, a mechanical connection was made between lamp and ophthalmoscopic lens. This illumination unit was mounted to the table column with a double articulated arm. The binocular microscope was supported on a small stand and could be moved freely across the tabletop. Later, a cross-slide stage was used for this purpose. VOGT introduced KOEHLER illumination, and the reddish shining Nernst glower was replaced with the brighter and whiter incandescent lamp (nitra lamp).

In 1914, Henker devised an experimental setup whose principle was rejected at first but regained importance in a modified form many years later. With this system the double articulated arm of the microscope illumination system was not fixed to the table spindle but to the microscope column. This was the first combined connection of microscope and illumination system for co-ordinate motion.

Special mention should also be made of VOGT's experiments between 1918 and 1920 with a GULLSTRAND slit lamp produced by ZEISS. On this instrument, the nitra lamp was replaced with a carbon arc lamp with a liquid filter. At this time the great importance of colour temperature and the luminance of the light source for slit lamp examinations was recognised and the basis created for examinations in red-free light.

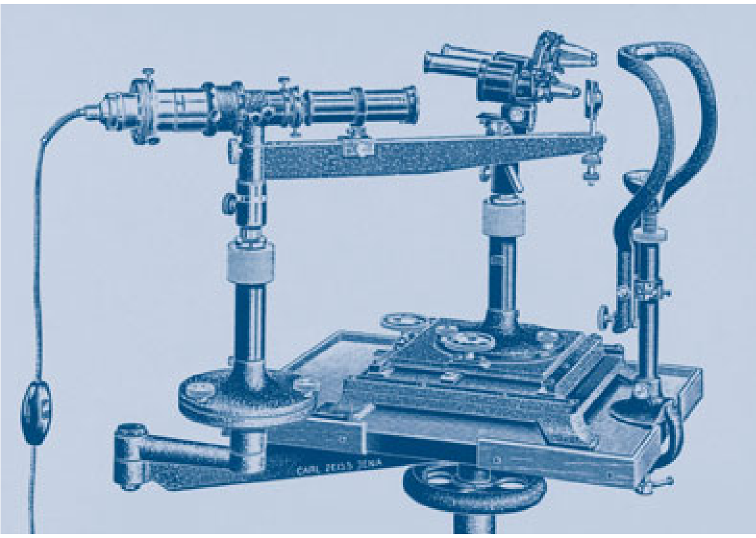


Fig. 32
Slit lamp after Gullstrand with corneal microscope after Koeppe (1911)

It seems that KOEPPE was the first to really recognise the value of the invention of GULLSTRAND. He was the author of the most important publications in GRAEFE's archive between 1916 and 1919. His research work culminated in the book "Mikroskopie des lebenden Auges" (1920; 2nd vol. 1922).

In 1920, KOEPPE also tried to use the slit lamp for examination of the posterior segments of the eye by introducing contact lens examination of the fundus and compared the technique with the more advanced methods of ophthalmoscopy. In co-operation with HENKER, he also complemented the GULLSTRAND slit lamp with a binocular corneal microscope to form a slit lamp instrument.

About 1926, the slit lamp instrument was redesigned again. The vertical arrangement of the slit projector (slit lamp) made it an easy to handle instrument. With this instrument ZEISS made a comparatively small, compact instrument – the slit lamp after COMBERG (1933). For the first time, the axis through the patient's eye was fixed as the common swivelling axis for both slit lamp and

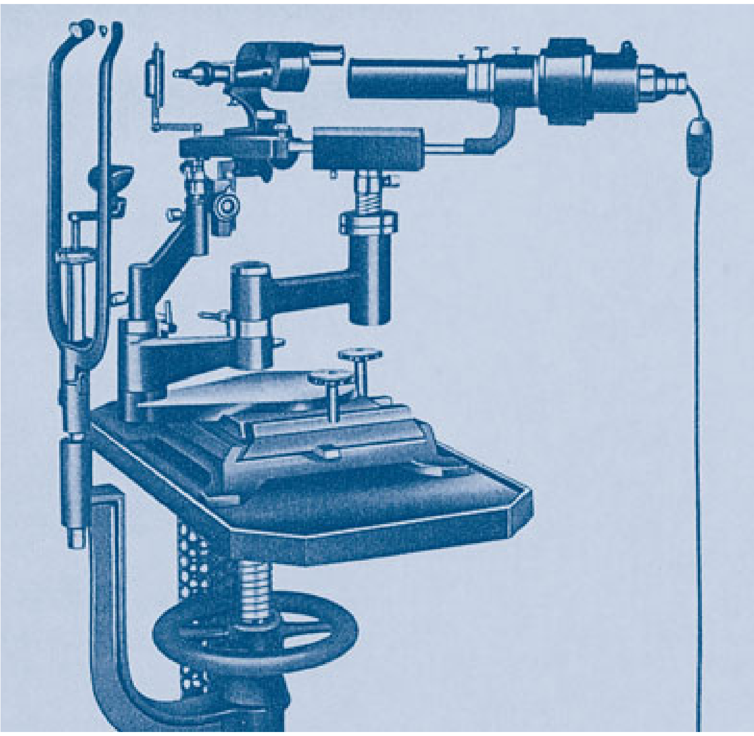


Fig. 33
Bausch & Lomb slit lamp after Koeppe (1926)

microscope – a fundamental principle that was adopted for every slit lamp instrument developed later. The instrument, however, did not yet have a co-ordinate cross-slide stage for instrument adjustment but only a laterally adjustable chin rest for the patient. The importance of focal illumination had not yet been fully recognised.

On this instrument, the advantages of the GULLSTRAND slit lamp were restricted by the fixed connection between microscope and illumination system.

In 1926, BAUSCH&LOMB built a slit lamp based on KOEPPE's investigations with some advanced features, but this instrument nevertheless did not gain acceptance by the market. It had a common swivel axis for the microscope and the illumination system below the patient's eye and a common horizontal adjusting facility with cross slide for both these subassemblies.

The vertical adjustment of illumination system and microscope had to be performed with the table spindle with the headrest remaining fixed. Here, although rather awkwardly, the coupling of the microscope and illumination system was achieved for the first time with regard to adjustment of the instrument in all three co-ordinates.

In 1927, ZEISS introduced the iris stereo camera developed by HARTINGER. This camera constituted a considerable step forward compared to the commonly used home-made instruments.

The documentation of findings at that time was still confined to drawings. It must be said, however, that the atlases and textbooks were dominated by masterly drawings by ophthalmologists or specially trained scientific artists (e.g. the slit lamp atlas by MEESMANN, 1927). Without the illustrations of the painter BREGENZER which are equally instructive even today, the standard work of VOGT "Lehrbuch und Atlas der Spaltlampenmikroskopie" (1931) would have been only a dry representation of precisely observed changes, requiring a lot of imagination by the reader.

In 1930, about 20 years after the introduction of the first slit lamp by GULLSTRAND, Rudolf THIEL presented the first optical section photographs ("photographed slit images") to the 48th Session of the Deutsche Ophthalmologische Gesellschaft. This was the beginning of slit lamp photography. For illumination, THIEL used an arc slit lamp customary at that time, the photographic apparatus consisting of a photomicrographic eyepiece and a ZEISS Biotar lens (f = 4 cm, 1 : 1.4 aperture). Using a tube socket, he obtained a camera extension of 20 cm, so that the image on the screen could be observed with a magnification of 3.5 to 4x. The exposure time was 1/25 s at a slit width of 0.5 mm. By narrowing the slit to 1 to 1.5 mm, the exposure time could be reduced to 1/50s.

Although the depth of field was very low, the photographs of the crystalline lens made visible fine structures such as opacities with Cataracta coerula. With photography of the optical section THIEL hoped to develop an objective method for recording particularly lens opacities and their progression. This would provide information allowing him to contribute to the disputed question of medicinal treatment of the grey cataract.

Shortly after this, the Argentinian PAVIA, who had worked particularly on fundus photography from 1929 also showed photographs of the optical section. Similarly he also used a slit lamp with an arc light source. With "ultrasensitive" photographic plates and very short exposure times he succeeded in presenting the Tyndall phenomenon in the anterior chamber and took a photograph of the individual layers of the crystalline lens.

Around 1930, LEITZ introduced a telescopic loupe on the market that was built on the principle of the GALILEAN telescope; improvements such as an increased working distance and wider field of view were included. The longer path needed was reduced by a prism system. This principle was used until recently.

For the focusing loupe that was initially hand held HENKER made a holding bracket in Jena. And for the loupe itself, ARRUGA had a fine adjustment mechanism made in 1925. The diaphragm tube located in between was recommended by KOEPPE to reduce scattered light. Later he mounted a disk with colour filters in front of this tube. In 1936, the colloidometer after RÖNNE was made as an accessory for comparative assessment of opacities of aqueous humour.

From 1933 onwards, further development of the slit lamp was stimulated in a decisive manner by GOLDMANN, his ideas being put into practice by HAAG-STREIT. Horizontal and vertical co-ordinate adjustment being performed with three control elements on the cross-slide stage. Here, too, the common swivel axis for microscope and illumination system was connected to the cross-slide stage, which allowed it to be brought to any part of the eye to be examined.

A further improved slit lamp made by the same company was launched on the market in 1938. On this instrument a control lever (joystick) was used for the first time to allow for horizontal movement. The instrument had no double articulated arm for the illumination system or other facilities for separate adjustment, which are considered superfluous today. It is one of GOLDMANN's merits to have discovered the importance of focal illumination in the examination of the ocular media, and as a result, stimulated improvements in the instrument and the simplification of its operation.

In relation to fundus examination by means of additional lenses, advancements were made by VALOIS and LEMOINE in 1933, and by HRUBY in 1941. Similarly the pyramid gonioscope after VAN BEULEN should be mentioned, and finally the three-mirror contact lens introduced by GOLDMANN in 1948.

In 1939, realising the importance of the close relationship between the depth of field and photographic representation, GOLDMANN introduced an instrument that allowed a sharp slit photograph to be taken of cornea and crystalline lens simultaneously. The instrument was based on a sequential method where the slit movement and a film advance were coupled mechanically. This method was developed to begin with for measuring purposes. With this instrument GOLDMANN and his pupils opened up the field of photographic measurements on the eye and in the following years expanded it further.

In 1940, HEINZ was the first to report on substandard cine film records of the optical section. Later (in 1951) JONKERS also turned to slit lamp cinematography. On the whole, however, this method did not gain wide acceptance.

After World War II the slit lamp after COMBERG was developed further by CARL ZEISS in Jena. On this instrument, the slit projector could be swivelled continuously across the front of the microscope.

Fig. 34
Zeiss slit lamp after
H. Littmann (1950)

Among the microscopes, first the PM XVI preparation microscope (1946 – 1949) and later the SM XX stereomicroscope with a Galilean magnification changer was used (from 1949/1950 onwards). Despite modern ZOOM optics, the principle of a magnification drum and a telescope system is still used for slit lamps and surgical microscopes.

In 1950, at ZEISS in Oberkochen the slit lamp was redesigned by LITTMANN. He also adopted the control mechanism after GOLDMANN and the vertical illumination path of rays bent through a prism according to COMBERG. During observation, the slit illumination system could be swivelled through in front of the microscope. Additionally the stereo telescope system with a common objective and Galilean magnification changer was used.

Following state-of-the-art photography, other methods followed in the photography of optical sections, firstly, black/white stereo photography, colour photography and later stereo colour photography.

In 1952, BELMONTE-GONZALEZ was the first author to report on experiments in biomicroscopic stereo photography. He placed a stereo camera (ICA 45/107 with Tessar lens of 1 : 4.5 and f = 6.5 cm) directly to the eyepieces of a microscope of a LITTMANN slit lamp. An additional light source served to illuminating the area surrounding the slit. The photographs were taken with a 16x magnification. At 1/5 to 1 s, the exposure times were comparatively long.

NORTON (1964) also coupled a twin-lens stereo camera to the eyepieces of a slit lamp. Later, LEE-ALLEN developed a similar system by coupling two cameras with the optical system of a slit lamp. The transparencies, that were obtained as single images had to be placed very accurately side by side however, to yield the stereoscopic effect.

In 1961, MATTHÄUS however preferred a beam splitting attachment in combination with a multi-purpose instrument manufactured by IHAGEE/Dresden. The set-up additionally had an annular flash and an SM XX slit lamp, on to which the camera was mounted in place of the microscope.

At the same time, various authors (PRINCE in 1965, LOISILLIER, SCHIFF-WERTHEIMER in 1957, DUGAGNI in 1957, STEPANIK in 1959, and OSSWALD in 1959) worked on replacing the incandescent lamp illumination with an electronic flash for photography.

In 1965, based on the slit lamp after LITTMANN, the Model 100/16 Slit Lamp was produced, followed by the Model 125/16 Slit Lamp in 1972. Both models only differ by their working distances of 100 mm and 125 mm.

With the development of the photo slit lamp the first instrument was launched onto the market in

1966. This instrument, being a normal slit lamp with an integrated flash lamp, enabled photographs of slit images to be taken both monoscopically and, by a simple switch, stereoscopically. The same objective was used for photography and observation. This instrument was further developed in 1970 with the introduction of the Model 69 Slit Lamp for routine examinations.

At the same time, a photo slit lamp model was introduced with which photography (monoscopic) was possible only via a camera adapter. On this instrument, stereo photographs could be only taken via an optical beam splitter accommodating 2 cameras.

In 1976, with the development of the Model 110 Slit Lamp and the 210/211 Photo Slit Lamps an innovation was introduced whereby each instrument was constructed from standard modules allowing for a wide variety of different configurations to be produced. At the same time the illumination systems were converted to halogen lamps, which deliver a considerably brighter light of near daylight quality.

The 10 SL Slit Lamp was also launched in 1976. This simple slit lamp, when fitted with an ophthalmometer attachment, resulted in the combination model 10 SL/O. This instrument was followed by the 30 SL Slit Lamp in 1977 and as the model 30 SL/M it became universally applicable in measurements of the eye. In 1977/1978 the 75 SL Slit Lamp was introduced, specially designed for clinical research and education and was further developed in 1987 to provide the Model 40 SL/P Photo Slit Lamp. In 1988, the Model 20 SL Slit Lamp was introduced to the professional world. This comfortable routine instrument considerably assisted in the daily work of the ophthalmologist.

From 1994 onwards, the new slit lamp range was launched by CARL ZEISS including the simple slit lamp SL 105, the routine slit lamp SL 120 and the universal slit lamp SL 160.

Fig. 35
Model 69 Slit Lamp (1970)

In 1996, this range was complemented by the SL 130 Slit Lamp that made the advantages of the new slit lamp optics accessible to users working in the field of laser treatment.

In 1999, CARL ZEISS introduced the SL 115 Classic Slit Lamp as ideal instrument for routine examinations and contact lens fitting.

The primary field of application of the slit lamp is the inspection of the anterior segments of the eye including crystalline lens and the anterior vitreous body and with a contact lens, deeper lying eye segments become visible, particularly the iridocorneal angle that cannot be seen via a direct optical path.

The development of the applanation tonometer for the measurement of the sitting patient's intraocular

Fig. 36
SL 115 Classic Slit Lamp
(1999)

pressure has extended the range of applications of a former pure observation instrument, the "slit lamp", into a measuring instrument. Further accessories for measuring cornea thickness and the distance between cornea and crystalline lens (anterior chamber depth) further extend this trend. A special attachment for the inspection of the corneal endothelium has made the slit lamp an even more indispensable tool than before. In 1918, VOGT was already able to see the corneal endothelium in vivo with a magnification of 40x by examining the surface structure of the reflecting layer, the so-called area of specular reflection.

Reticles are used for measurements on the anterior segment of the eye and for assessing tissue and cell structures. A special eyepiece serves for length and angle measurements. Ports for connecting co-observation tubes and TV cameras complete the range of accessories for education and research.

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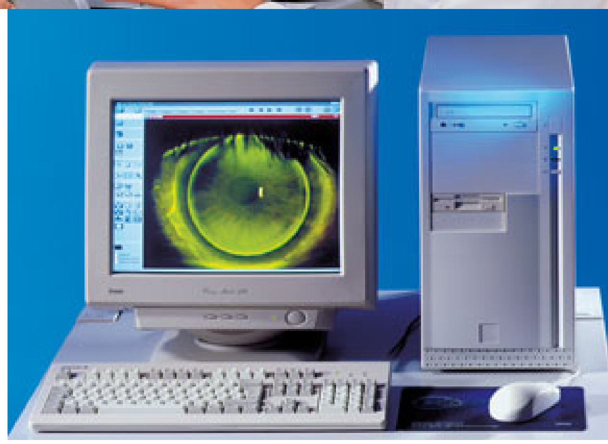

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