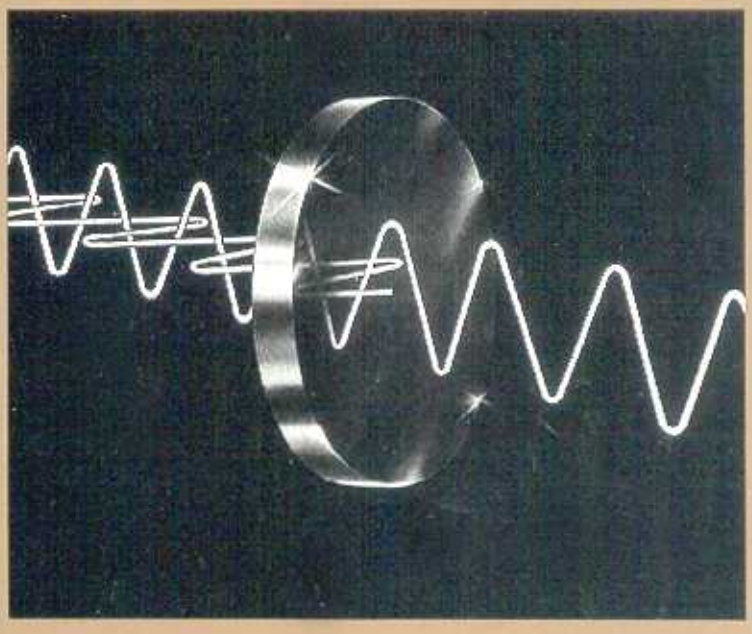
KÄSEMANN E/90



Polarisation Elements in Glass and Plastic

B+W FILTER
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The process used for the manufacture of Kaesemann polarisers was first introduced by Erwin Kaesemann in 1955, since then it has been continually improved.
Compared with conventional polarisers Kaesemann film polarisers are distinguished by their consistant neutrality of colour and excellent polarisation properties. They can be produced in practically any size required while retaining a high degree of mechanical strength.

The polarisers are produced from high polymer, light transmitting colloidal film made from polyvinyl alcohol (PVA). The film is subjected to a stretching process which causes the rod shaped molecules in the film to become aligned in parallel so that it behaves like an optically uniaxial crystal. This forms the supporting structure for the polarisation matrix itself which is made from a light absorbing substance. This is deposited on the film by a dyeing process and produces dichroic, i.e. direction dependent, absorption.

To protect the polariser it is either covered on both sides with cellulose acetobutyrate (CAB), known as a Type P film polariser, or it is cemented between sheets of glass, designated a Type KS. Retardation films are manufactured in a similar manner, but without the dyeing process.

This brochure gives a summary of our standard ranges of polarisers.

If you do not see filters suitable for your applications here, please contact us directly. We will make filters specially designed to accommodate the polarisation properties and qualities of glass you require.

The optical data are average values, and are subject to variation due to production requirements.
All dimensions are in millimetres.

We are always available to answer any questions.

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* Source: Naumann/Schroeder "Bauelemente der Optik", Carl Hanser Verlag, Munich - Vienna

1. Terms and Basic Relationships in Polarisation Optics

Electric Field Vector E: Lies in a plane perpendicular to the direction of propagation Z of an electromagnetic wave. Determines the position and intensity of the electric field.

Magnetic Field Vector H: Lies in a plane perpendicular to the direction of propagation Z of an electromagnetic wave at right angles to the E vector and determines the position and intensity of the magnetic field.

Direction of Vibration: Is the same as the direction of the E vector.
In contrast to earlier representations this direction is today designated as the direction of polarisation.

Pass Direction of a Polarlser: Light vibrating in the pass direction is slightly absorbed i.e. high transmittance, designated r pol. The E vector of the incident light and the pass direction of the polariser are parallel to each other.

Absorption Direction of a Polariser: Light vibrating in the absorption direction is heavily absorbed. This gives the low transmittance, *T* absorb. The E vector of the incident light and the pass direction of the polariser are perpendicular to each other.

Extinction Coefficient for one Polariser E: The ratio of maximum transmittance, *T* pol, and minimum transmittance, *T* absorb, measured against completely linearly polarised light.

Light Setting: Arrangement of two polarisers of the same type such that their pass directions are parallel.

Dark Setting: Arrangement of two polarisers of the same type such that their pass directions are perpendicular.

Extinction Coefficient LV: The ratio of maximum to minimum transmittance for two polarisers of the same type, determined in the light and dark settings.

The following correlations are given when **one polariser** is used.

Transmittance τ for unpolarised light:

$$\tau = \frac{\tau_{pol} + \tau_{sperr}}{2} \approx \frac{\tau_{pol}}{2} \qquad (1.1)$$

Degree of Polarisation P for unpolarised light:

$$P = \frac{\tau_{pol} - \tau_{sperr}}{\tau_{pol} + \tau_{sperr}} \qquad (1.2)$$

Extinction E:

$$E = \frac{\tau_{pol}}{\tau_{sperr}} \tag{1.3}$$

When **two polarisers** are used the following equations apply:

Transmission for unpolarised light in the light setting:

$$\tau_{0°} = \frac{\tau_{pol}^2 + \tau_{sperr}^2}{2} \approx \frac{\tau_{pol}^2}{2} \tag{1.4}$$

Transmission for unpolarised light in the dark setting:

$$\tau_{90°} = \tau_{pol} \cdot \tau_{sperr} \tag{1.5}$$

Extinction Coefficient LV:

$$LV = \frac{\tau_{0°}}{\tau_{90°}} = \frac{\tau_{pol}^2 + \tau_{sperr}^2}{2 \cdot \tau_{pol} \cdot \tau_{sperr}} \approx \frac{\tau_{pol}}{2 \cdot \tau_{sperr}} \tag{1.6}$$

Taking the reverse situation the following is found for **one polariser** if $\tau_{0°}$ and $\tau_{90°}$ are known for **two polarisers of the same type:**

Transmission for light vibrating in the absorption direction:

$$\tau_{sperr} = \sqrt{\tau_{0°} - \sqrt{\tau_{0°}^2 - \tau_{90°}^2}} \tag{1.7}$$

Transmission for light vibrating in the pass direction:

$$\tau_{pol} = \sqrt{\tau_{0°} + \sqrt{\tau_{0°}^2 - \tau_{90°}^2}} \approx \sqrt{2\tau_{0°}} \tag{1.8}$$

Degree of polarisation P after passing through one polariser:

$$P \approx \frac{2 \cdot LV - 1}{2 \cdot LV + 1} \tag{1.9}$$

Transmittance for unpolarised light for any angle θ between the pass directions of two polarisers of the same type:

$$\tau_\theta = \tau_{90°} + (\tau_{0°} - \tau_{90°}) \cdot \cos^2\theta \approx \tau_{0°} \cdot \cos^2\theta \qquad (1.10)$$

or

$$\tau_\theta = \tau_{pol} \cdot \tau_{sperr} + \frac{(\tau_{pol} - \tau_{sperr})^2}{2} \cdot \cos^2\theta \approx \frac{\tau_{pol}^2}{2} \cdot \cos^2\theta \qquad (1.11)$$

Attenuation function of a polarising filter compared to completely linearly polarised light with

$$\tau_\theta = \tau_{sperr} + (\tau_{pol} - \tau_{sperr}) \cdot \cos^2\theta \approx \tau_{pol} \cdot \cos^2\theta \qquad (1.12)$$

2. Film Polarisers

2.1 Linear Polarisers

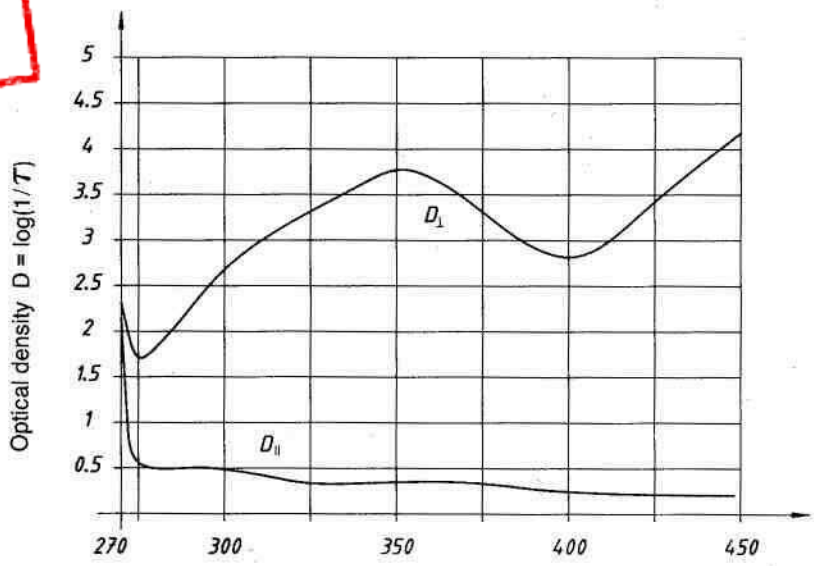
Film polarisers are homogeneous plastic plates, mechanically produced as large format rectangles. In this instance the actual polarisation film is covered on both sides with cellulose acetobutyrate (CAB) and is therefore mechanically stable.

It is recommended for use wherever there is a requirement for large areas of light-weight, easily workable material (e.g. which are to be punched, perforated, cut, bent etc.). If necessary several layers can be combined with their axes parallel or at different angles to each other and joined together with clear, dry adhesive tape.

Additional cementing between glass covers is not usual and only possible in special cases. If necessary, slightly warmed film can be placed between completely dry glass covers and sealed at the edges to protect it from moisture.

We expressly advise against use of the film in image forming optical systems since the surface of the plastic is not suitable and results in a reduction in quality. For high quality work we manufacture and supply optically perfect, glass Type KS polarisation filters without any type of plastic covering, as well as quarter-wave plates and whole-wave plates.

The density curves shown below relate to measurements for a single polariser against completely linearly polarised light both in the pass direction and in the absorption direction.
The transmittance against unpolarised light is reduced by a factor of 2 in accordance with formula 1.1 on page 2.

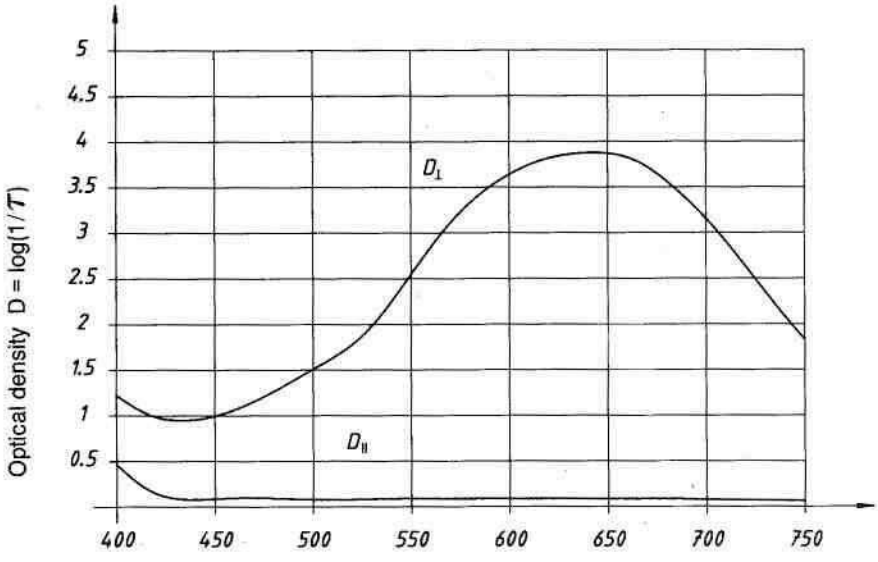


$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Wave length A [nm]

The P-UV 2 linear polariser is a filter in which the PVA structure has been modified for the UV range. It is intended for use predominantly in the UV-A range centred on 350 nm, although it also displays excellent polarisation properties in the visible range. The transmittance in the UV range is about 25% for unpolarised light with a maximum extinction coefficient of 1:2 500. The residual light when irradiated with white light is neutral in colour.

P-W 84



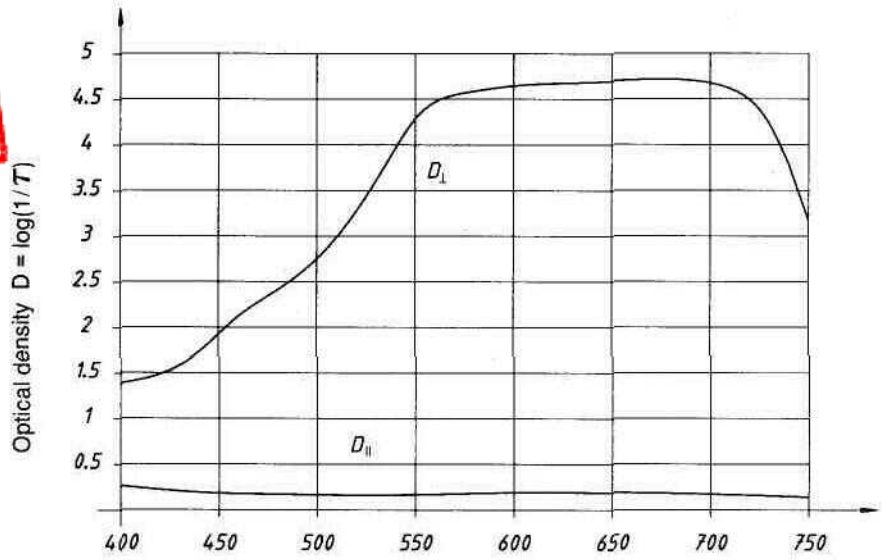
$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Wave length λ [nm]

Linearly polarising, faintly blue-grey film with 42% transmission for unpolarised white light. The particularly high transmission with relatively low extinction coefficient makes this type of film particularly suitable for special applications in spectroscopy and special photographic techniques (e.g. flow imaging technology) as well as for display models, anti-dazzle work bench lighting and wherever there is a requirement for high light efficiency with a relatively low degree of polarisation.

Transmission for two films for unpolarised light: in the light setting is about 35%, in the dark setting approximately 0.5%, extinction coefficient consequently about 1:70, corresponding to a degree of polarisation P of approximately 98.6%. The residual colour in the dark setting under normal viewing conditions when irradiated with white light is light blue.

P-W76

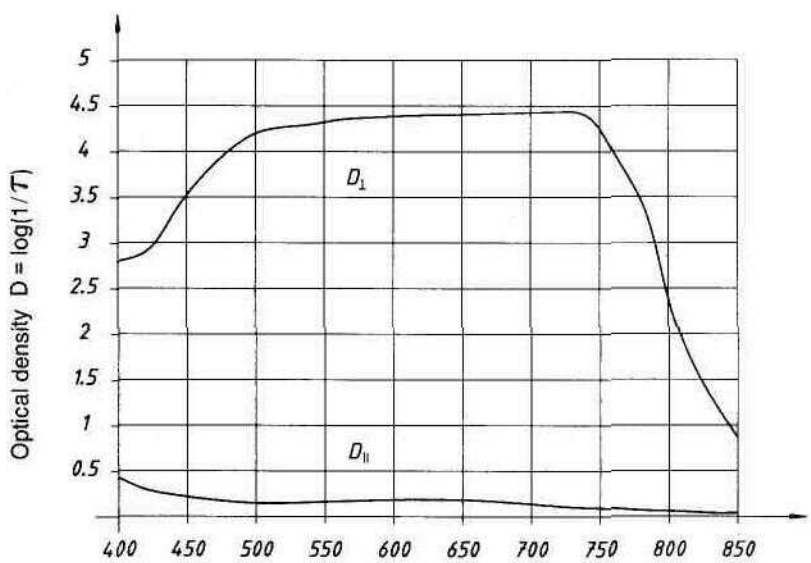


$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Linearly polarising film in a neutral shade of grey with 38% transmission for unpolarised white light: practically neutral in colour. This type of film is particularly suitable for reflection-free lighting by incandescent lamps or flashes (with or without the addition of KAESEMANN glass filters in front of the camera or before the eyes) as well as for stereoscopic image separation, sun visors and other uses which require a high light efficiency with a relatively moderate degree of polarisation.

Total transmission for the two films in the light setting is about 30%, in the dark setting barely 0.05%, the extinction coefficient is approximately 1:400, corresponding to a degree of polarisation of about 97.7%. The residual colour in the dark setting when irradiated with white light under normal viewing conditions is blue.

P-W64

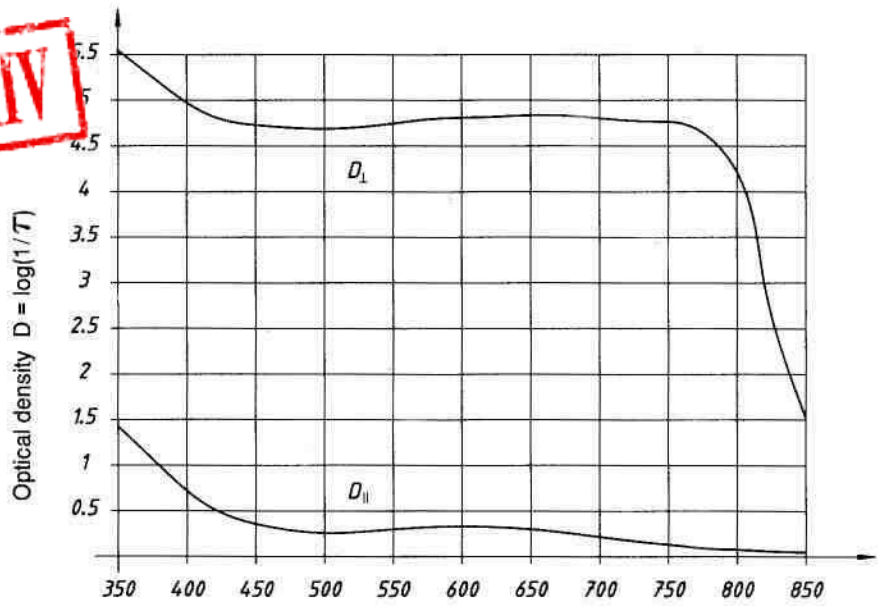


$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Linearly polarising, faintly green-grey film with 32% transmission for unpolarised white light. This type of film represents the best possible balance between relatively high transmission and high extinction coefficient. It is particularly suitable for demonstration and experimental purposes and is also recommended for use in study of photoelasticity, for rotating diaphragms of variable density and for other apparatus for infinitely variable attenuation of light without alteration of the aperture.

Total transmission for the two films in the light setting is about 20%, in the dark setting approximately 0.005%, extinction coefficient consequently about 1:4000, corresponding to a degree of polarisation P of over 99,97%. With white light, the residual colour in the dark setting is dark blue. In sodium light it is black.

P-W 44

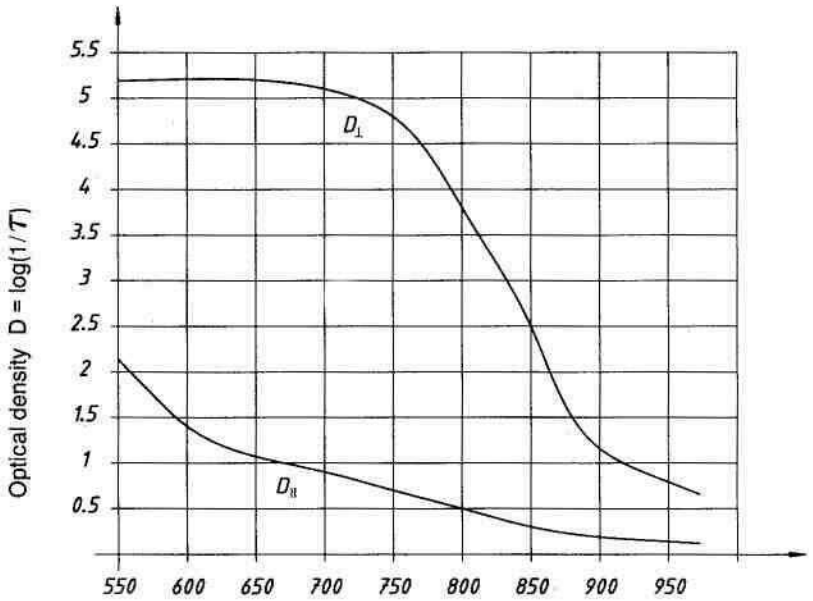


$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Linearly polarising, green-grey film with 23% transmission for unpolarised white light. This type of film is distinguished by its particularly high extinction coefficient and correspondingly low transmission and is particularly suitable for producing neutral dark grounds. Its plastic covering, however, limits it to auxiliary use in apparatus such as polariscopes, Kerr cells, sextants etc. In order to avoid loss of quality, this film must be carefully distinguished from KAESEMANN glass filters.

Total transmission for the two films in the light setting is about 12%, in the dark setting approximately 0.0005%, extinction coefficient consequently up to 1:20,000, corresponding to a degree of polarisation of about 99,99%. The residual light at normal intensity of radiation is neutral in colour.

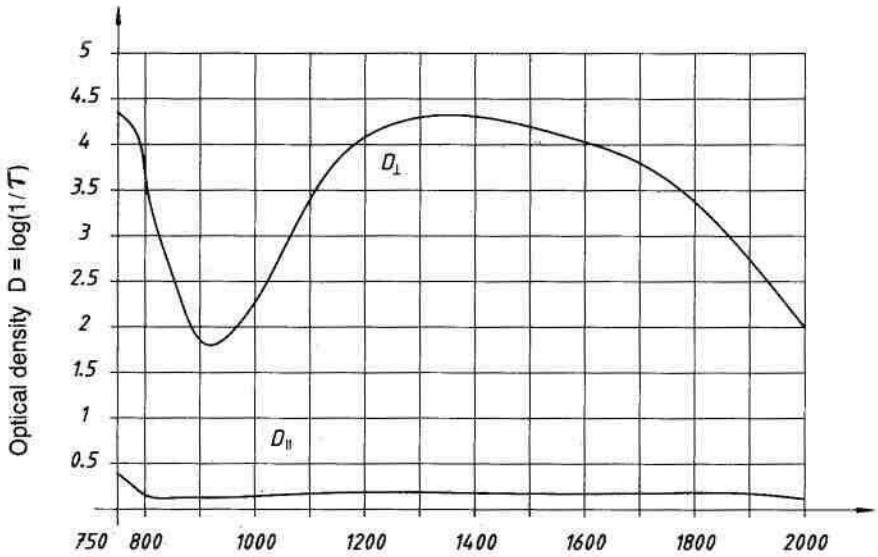
P-W 40



$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Linearly polarising, deep green film with 20% transmission for unpolarised light in the red and infra-red spectral range.

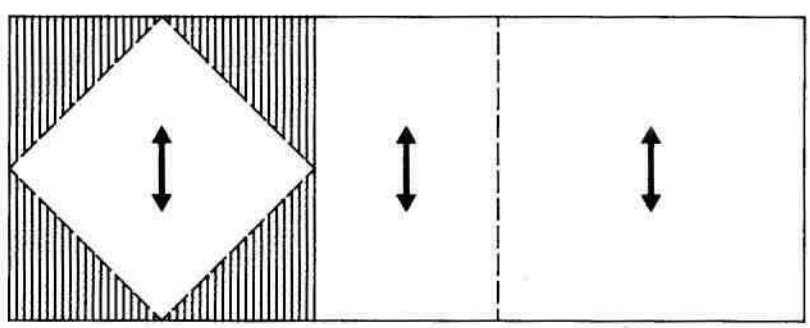
P-IR2



$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Linearly polarising, deep red-brown film for use in the near infra-red and particularly for wavelengths of around 1300 nm. When used in pairs the residual radiation is less than 1 percent — The inhomogeneity seen in the visible light has practically no effect in the infra-red.

The direction of vibration of the film polarisers runs parallel to the short sides.



Film with the direction of vibration parallel to the longer sides can only be produced in widths of over 48 cm wide by cutting and joining pieces, thus requiring the inclusion of joints.

Please specify if square film is required with the path of the axis at 45° to the sides. In such cases we recommend film Type PW 70. Pieces of film with the axes incorrectly positioned because of unclear orders cannot be returned.

All film types listed here can be delivered within a short period. The prices given are ex-factory: Bad Kreuznach, W. Germany.

Linearly polarising, faintly green-grey film with approximately 35% transmission for unpolarised white light. In contrast to all other types of film, the direction of vibration in this case lies at 45° and not parallel to the sides. It is therefore not necessary to join individual pieces of restricted size and makes it particularly easy to add retardation film, in which the axis is parallel to the sides, at the correct angle. Right and left circularity can be exchanged simply by turning the P-W 70 film around. The spectral properties correspond approximately to the intermediate values of P-W 76 and P-W 64.

Total transmission for the two films in the light setting is about 25%, in the dark setting approximately 0.03%, extinction coefficient consequently approximately 1:1,000, corresponding to a degree of polarisation of approximately 99.9%. The residual colour in the dark setting, when irradiated with white light and when observed under normal conditions. is dark blue.

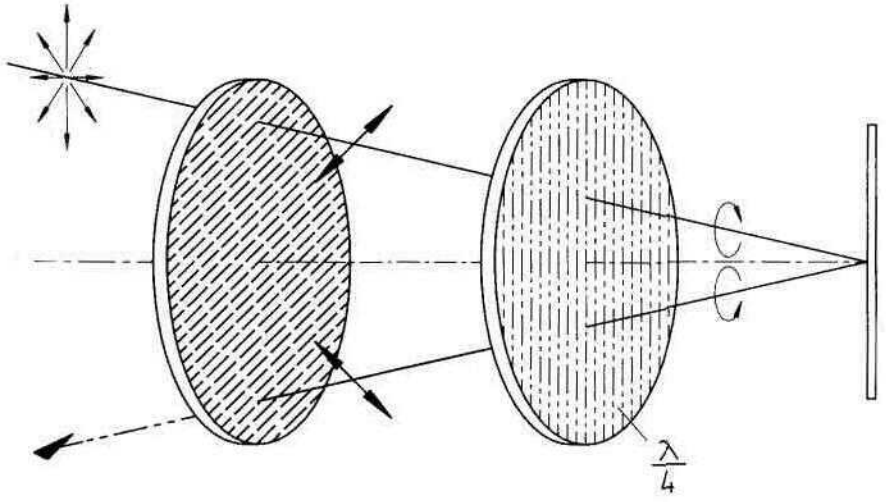
2.2. Circular Polarisers

KAESEMANN circularly polarising films are Type P plastic films with the addition of Lambda/4 retardation film at an angle of 45°.

Linearly polarised light is light in which the direction of vibration lies in one plane and can therefore be represented as a double arrow. If linearly polarised light falls on a retardation element at an angle to its preferred direction, it is split into two subsidiary waves, which exit with different phases. The superposition of the two exiting waves normally results in elliptically polarised light. If the phase difference is exactly Lambda/4, circularly polarised light is produced, represented by a helical line. The sense of its direction is reversed when reflected from a boundary surface. The process can be compared to the visible left handed travel of a reflected helix with a right-hand thread.

The increase in contrast and reduction in reflection on electrical data displays, for example, is based on the effect described below:

The incident extraneous light strikes the reflecting boundary surface (glass sheet) and the sense of rotation received on passage through the circularly polarising filter is now reversed. if it now strikes the Lambda/4 layer of the circularly polarising filter again, it is converted back into linearly polarised light. The direction of vibration now lies at right angles to that of the original polariser and is therefore absorbed.



Principle of extinguishing reflection using circularly polarising filters.

This applies only to those wavelengths for which the double refracting layer is rated. In practice, however, the absorption effect extends to the adjacent spectral ranges and thus to a large part of visible radiation.

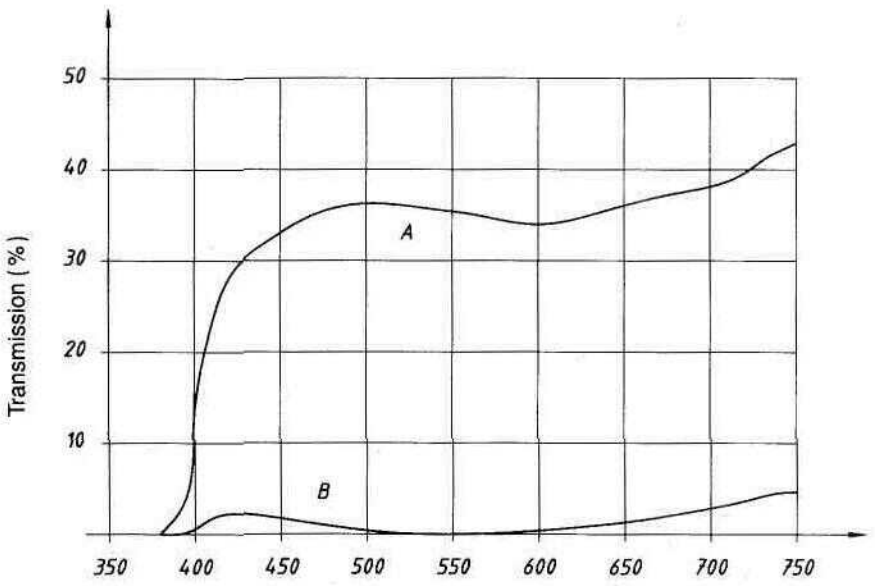
Circularly polarising filters can be supplied in neutral grey and for particular spectral ranges:

		Range of Application
P-Zirk R	red	630 nm and above
P-Zirk B	brown	560 nm and above
P-Zirk G	green	from 500 to 570 nm
P-Zirk N	grey	from 420 to 750 nm

These films are not suitable for use in optically image forming systems. Additional cementing between glass covers is not usual and is only possible in special cases. To meet the requirements of high quality and very high quality work in optical systems, we have available neutral grey circularly polarising filters cemented between glass covers without protective plastic layers. See page 17.

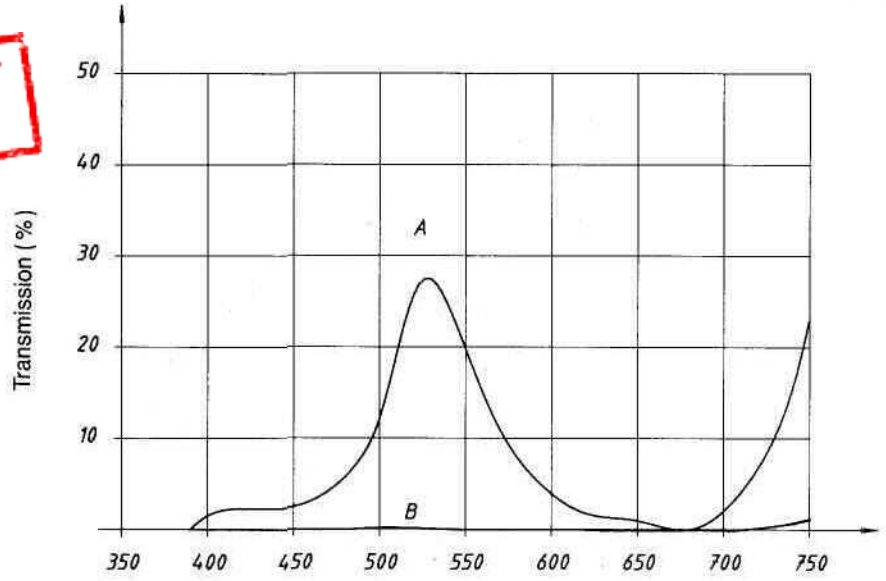
Our standard range does not include polarising filters with glass adhered on one side only or matte finished circularly polarising filters, but these can be supplied on request.

P-ZIRK N



A = Transmission for unpolarised incident light
B = Transmission for reflected extraneous light

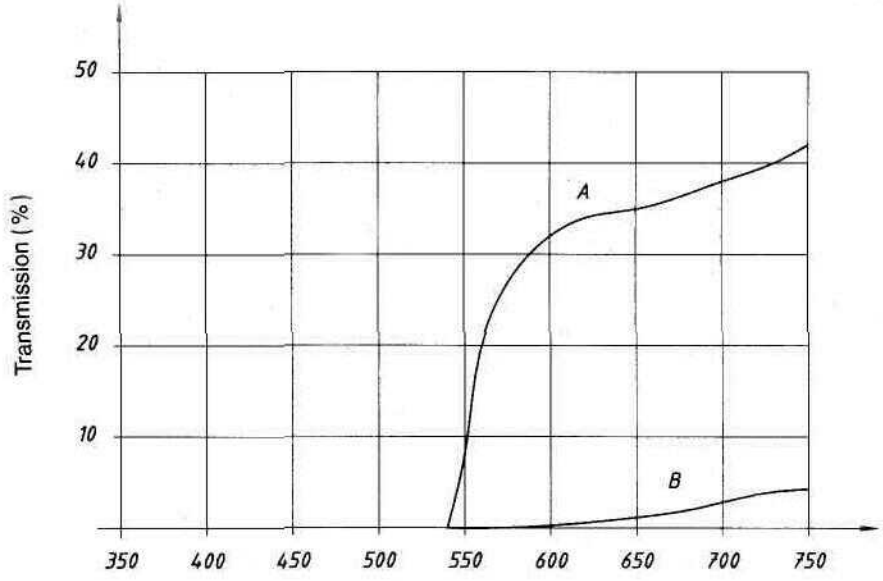
P-ZIRK G



A = Transmission for unpolarised incident light
B = Transmission for reflected extraneous light

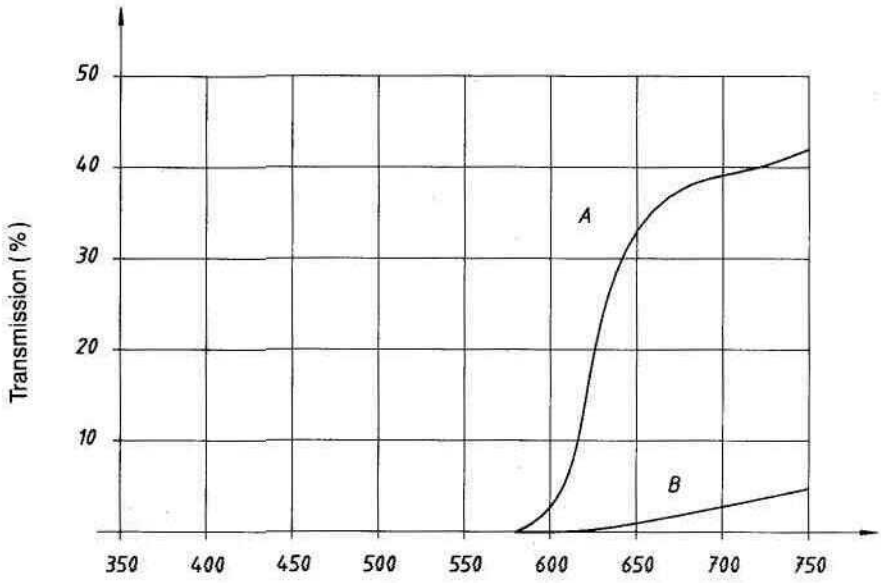
Wave lenght X [nm]

P-ZIRK B



A = Transmission for unpolarised incident light
B = Transmission for reflected extraneous light

Wave lenght λ [nm]



A = Transmission for unpolarised incident light
B = Transmission for reflected extraneous light

2.3 Retardation Elements

Kaesemann retardation elements are colourless, clear film 0.8 mm thick. They are manufactured by a similar process to that used for polarisation filters, i.e. by stretching, but without the addition of a dye. The action is similar to that of the traditional gypsum or mica platelets but without their restriction in size. They produce a path difference in polarised radiation which agrees with the relevant type designation (V = retardation value) with an accuracy of +/- 20 nm. It is not possible to supply retardation elements with only plus or minus tolerances. If necessary the theoretical value of the retardation can be altered by not positioning the film perpendicular to the light radiation but inclining it around its slow or fast axis so that it is more or less at an angle.

P-V 140 Quarter-wave film for 480 - 640 nm. When combined with a linear polariser at 45° it can be used to generate circularly polarised light. In combination with P-V 280 it acts as the corresponding half-wave combination for 760 to 920 nm or as quarter-wave film for 1520 - 1840 nm.

P-V 200 Quarter-wave film for 720 - 880 nm. When combined with P-V 140 it can be used as a half-wave combination for 600 to 760 nm or as quarter-wave film for 1200 - 1520 nm. In combination with P-W 40 it can be used as an infrared circular polariser.

P-V 280 Half-wave film for polarised white light, used to rotate its direction of vibration or to lighten polarised dark backgrounds. Also quarter-wave film for 1040 -1200 nm.

P-V 560 Full-wave film for the "sensitive colour" first order red and also half-wave film for 1080....1160 nm.

It is also possible to combine films to produce a very large number of different retardation values. In order to obtain uniform retardation over the whole irradiated area the path of the rays must be approximately parallel and the angle of observation must be relatively small.

The maximum size of the films is 304 x 304 mm. The axes are always orientated parallel to the sides. If pieces are required which are not square, please specify the desired positioning for the fast or slow axis.

The axes are only marked on the film if this is specifically requested. The mark will indicate the slow axis.

3. Glass Filters for Polarisation

3.1 Linear Polarisers

Kaesemann polarising glass filters are film polarisers which have been cemented directly between pairs of optically flat, low-stressed glass covers. Appropriate edge sealing keeps the filters secure under tropical conditions and free of haze. The average refractive index is 1.52. Our filters are resistant to temperatures of up to + 80° C (+176°F), assuming heat is applied over the whole surface and not at localised areas.

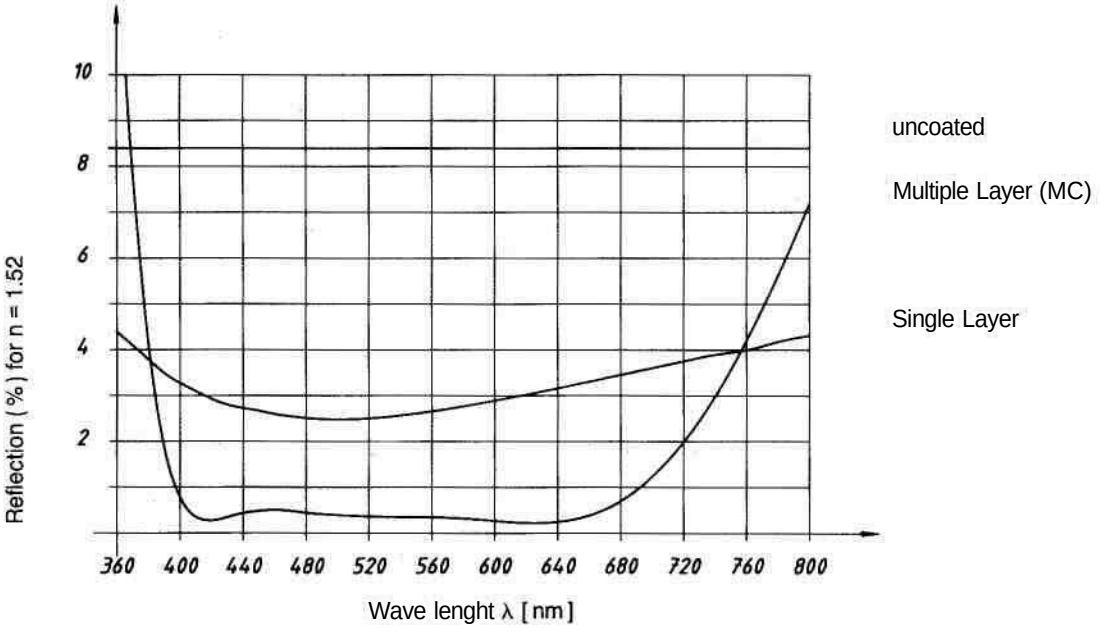
The optical properties differ according to the application. This applies equally to the degree of polarisation as well as to the transmittance and the surface quality of the glass covers. This results in a variety of different filter types, of which only the standard series are described here. If customers require different polarisation properties or qualities of glass we will be able to meet their requirements provided sufficient quantities are ordered.

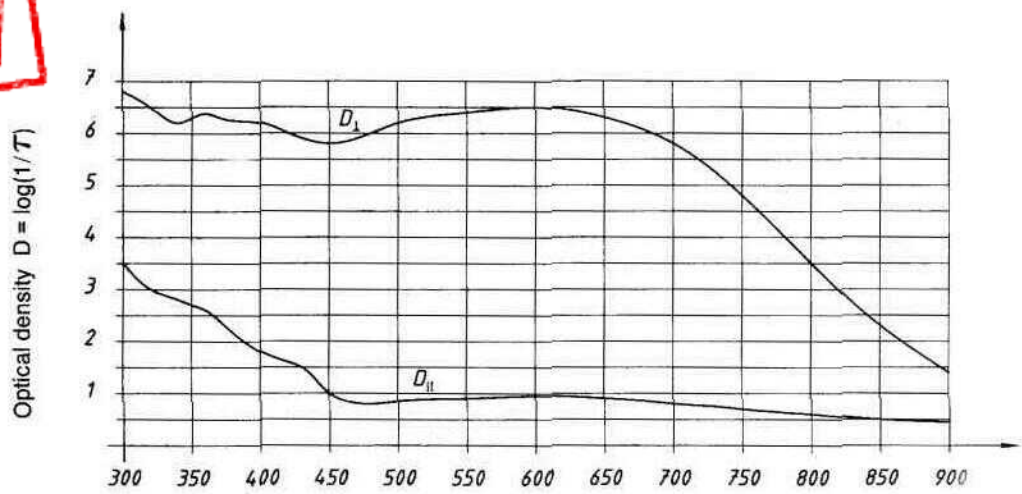
For the UV range of 300 nm and above we have available filter Type KS-W. Please ask for the relevant data sheet.

To improve the anti-reflection qualities the deposition of single or multiple layer coatings is possible.

Single Layer
Clear reduction in reflection depending on the refractive index of the glass. Residual reflection of < 1.55% for nd = 1.52. The main residual reflection can be seen in the range between 400 and 800 nm.

Multiple Layer
Use of a multicoating (MC) process allows a large reduction in reflection over a large wavelength range. The residual reflection between. 420 and 680 nm averages < 0.4% for nd = 1.52.





$D_\perp$ = Density in absorption direction
$D_{||}$ = Density in pass direction

Wave length λ [nm]

Ks-MIK

For microscopes, photometers, Kerr cell shutters and high extinction coefficient in imaging systems. The surfaces of the carefully selected low-stressed glass covers are ground parallel to at least 4 minutes of arc and precision polished. The average single filter transmittance for unpolarised white light is 27%. The total transmission for two filters in the light setting is about 15%, in the dark setting less than 0.00015%, extinction coefficient therefore over 1:100,000, corresponding to a degree of polarisation of practically 100%.

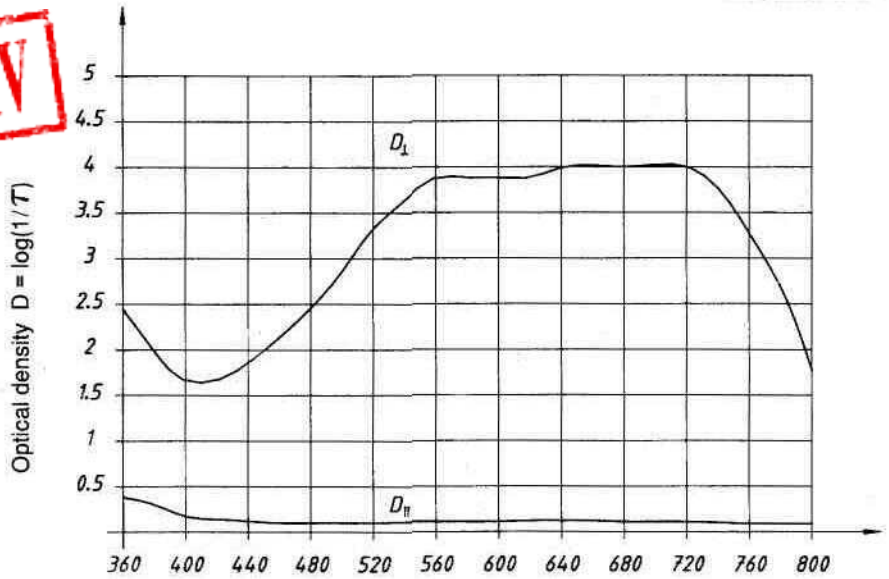
Axis marking for the direction of vibration (E vector), if required, has an accuracy of + 0.5°. This is best done on the mounting, and only on the filter as an auxiliary measure.

In cases where the quality of the glass is not important, Ks-MIK film can also be cemented in unpolished, optically flat glass, and is then called Ks-LAB.

Ks-KON

For microscopes with a conoscopic path of light (Bertrand lenses) and for special applications where the highest level of surface homogeneity is required. Polarisation properties as for Ks-MIK, but with covers of special double annealed glass to remove any type of residual stress. High quality edge protection afforded by standard edge seal, the width of which, 0.3 mm, is taken into account when measuring the diameter of the glass covers.

If requested we will mark the optimum side of the filter type with a spirit soluble coloured dot, which is to face the partner element in the polarisation optical system (therefore the second polarisation filter). In order to make full use of the properties of the Ks-KON filters it is important that they are set without stress into mountings which provide sufficient support. The systems in which they are used should also be free from stress. Anti-reflection multicoating on both sides is available on request as are diameters of over 30 mm.



Ks-AUF

For use in surveying cameras for extinguishing reflection and increasing in contrast, as well as for rotating diaphragms with high transmission in imaging systems. The surfaces of the carefully selected low-stressed glass covers are ground parallel to at least 4 minutes of arc and precision polished. Average transmission = 38%, corresponding to an elongation factor of 2.5 corresponding to 1.3 light values. Total transmission for two single filters in the light setting when used in pairs for stopping up and stopping down without altering the focus is about 30% — elongation factor 3, corresponding to 1.6 light values,

Ks-AUF filters are neutral in colour with a maximum variation in transmission of 3% (standard limit 5%) between the measured wave lengths 450 nm - blue, 550 nm - yellow-green and 620 nm - red. Their extinction coefficient is more than 9 diaphragm stops above the normal density, residual colour blue.

Note:
Linear polarisers can cause false readings in cameras which have polarising elements in the path of the light for measuring exposure or for automatic focussing. In such cases circularly polarising filters should be used. See page 17.

Ks-PRO

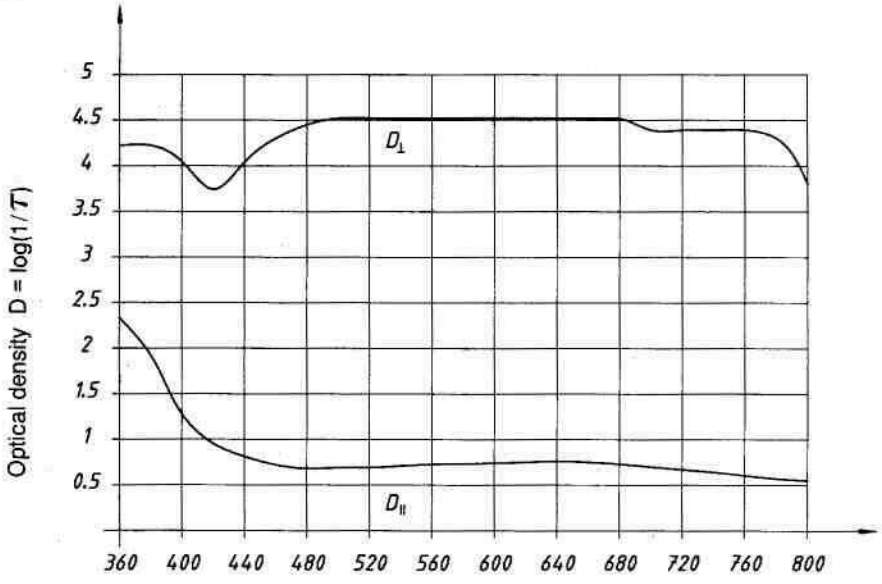
For projectors and other apparatus for stereoscopic (3-D-) image separation. (Double field versions with V or L shaped axes in both filter halves on request). Polarisation properties and total thickness as for Ks-AUF. With the thicker types of glass a special order for the glass covers on each filter to be made in different thicknesses can be placed at an increased price. This prevents double refraction at constant heating. The thinner glass cover must be turned away from the light source and is marked on the front.

In order to make full use of the filter capability, it is necessary to align the axes as accurately as possible, and also to avoid all depolarising effects from imaging or deflecting optical elements, unsuitable projection screens and inadequate viewing spectacles. The matching spectacles are described on page 17. The guarantee of fault-free operation must therefore be limited to filters supplied by us and excludes products made by other manufacturers.

Ks-BEL

For all types of lighting installation, preferably with the addition of appropriate analysers or polished surfaces below the angle of polarisation. Carefully selected optically flat drawn, low-stressed, unground glass covers. Average single filter transmittance for unpolarised white light = 36%. Extinction coefficient depending on extraneous polarisation up to 1:500, residual colour is blue. Use if possible at a sufficient distance from the light source and/or with a heat protection filter without physical contact or with ventilator or fan.

Ks-DEM Polariser



$D_\perp$ = Density in absorption direction
$D_\parallel$ = Density in pass direction

Ks-DEM

For demonstrations, general laboratory use, stress testing, polarimeters and high extinction coefficient in non-image forming systems. Carefully selected optically flat drawn, low-stressed, unground glass covers. Average transmission for a single filter for unpolarised white light = 32%. Total transmission for two filters in the light setting is over 20%, in the dark setting below 0.002%, extinction coefficient accordingly is more than 1:10,000, corresponding to a degree of polarisation approximately 99.99% residual light is colourless as with Ks-MIK/KON/LAB.

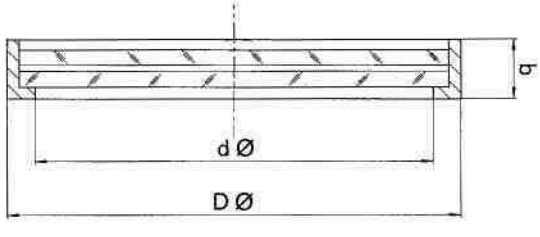
Kaesemann Glass Polarisation Filters in Standard Mounting

The polarisation filters are glued into the mountings so that they are not under stress. The diameter and height of the matt black, anodised aluminium mountings are manufactured to DIN 19030.

The direction of vibration in engraved on the edge of the mounting.

Types KS-AUF/ BEL/ PRO and KS-DEM. KS-MIK and KON are however only available in series 4 and 5.

Series	b	D Ø	d Ø
4	4,0	20,6	16,9
5	4,3	30,2	26,5
6	4,8	41,3	38,1
7	5,3	50,8	45,4
8	5,6	63,5	58,0
9	6,0	82,6	76,0



3.2 Circular Polarisers and Retardation Elements

In addition to the glass covered linear polariser listed so far we also manufacture transparent quarter-wave and full-wave plates with retardation values of 135 and 540 nm respectively. These can be used on their own and brought together with separate linear polarisers with their axes in the required position depending on the particular application. If requested we will cement such single elements with the axis displaced at 45° into double compound units to produce either circularly polarising filters with singls sides and non linear depolarisation effect, or compensators for first order red. Unless instructed to the contrary we will mark the slow axis of separate retardation plates and will always supply circularly polarising filters with left circularity. Series production of this item is limited to instrumentally correct diameters up to 35 mm. The total thickness depends on the type and is generally twice the thickness of the single element.

For large format circularly polarising filters we supply Type P-Zirk N film cemented between glass covers. For the spectral data see page 10. The dimensions are the same as those of Type KS-AUF. Additional edge sealing is possible if desired.

Apart from science and technology, these circularly polarising filters are used predominantly in photography. In cameras which have internal instrumentation in which parts of the measuring system have themselves a polarising action, only circularly polarising filters can be used. Linearly polarising filters would cause false readings. The same applies to use of polarising filters on auto-focussing SLR cameras.
Reduction in reflection matching that of linearly polarising filters can be provided. See page 13.

4. Accessories

Polarisation spectacles in the international V setting (135°/45°) are available in three different versions. They are used for 3 D projection in order to guide the polarised images projected on a screen to the left and right eyes of an observer. In connection with stereoscopic projection we recommend the use of KS-PRO polarisation filters in front of the projection lenses.

We can supply spectacles for stress testing with the appropriate polarising filters and red I compensators on request.

5. Summary

Film	τ	τ_{pol}	$\tau_{sperr.}$	P	LV	$\tau_{90°}$	$\tau_{0°}$
PW 84	0,42	0,84	$6 \cdot 10^{-3}$	0,986	70	$5 \cdot 10^{-3}$	0,35
PW 76	0,38	0,76	$9 \cdot 10^{-4}$	0,997	400	$7 \cdot 10^{-4}$	0,29
PW 64	0,32	0,64	$8 \cdot 10^{-5}$	0,999	4000	$5 \cdot 10^{-5}$	0,20
PW 44	0,22	0,44	$1 \cdot 10^{-5}$	0,999	20.000	$5 \cdot 10^{-6}$	0,10
PW 40	0,20	0,40	$7{,}5 \cdot 10^{-6}$	≈ 1	>15.000	$3 \cdot 10^{-6}$	0,05
Glass filter KS - AUF							
KS PRO							
KS - BEL	0,38	0,76	$1{,}9 \cdot 10^{-4}$	0,998	>500	$1{,}5 \cdot 10^{-4}$	0,29
KS DEM	0,32	0,64	$3{,}1 \cdot 10^{-5}$	>0,999	10.000	$2 \cdot 10^{-5}$	0,20
KS KON							
KS MIK							
KS LAB	0,27	0,54	$2{,}7 \cdot 10^{-6}$	≈ 1	100.000	$1{,}5 \cdot 10^{-6}$	0,15

		Retardation
PV 140		140 nm ± 20 nm
PV 200		200 nm ± 20 nm
PV 280		280 nm ± 20 nm
PV 560		560 nm ± 20 nm

Size (mm)	Thickness (mm)	Application
482 x 1270	0,3 0,8	Lighting purposes, flow imaging technology, spectroscopic tasks
482 x 1270	0,3 0,8	Reflection-free lighting with incandescent lamps or flashes, stereoscopic image separation, no colour spots
482 x 1270	0,3 0,8	Photoelasticity, rotating diaphragms with variable densities, demonstration and experimental purposes
482 x 1270	0,3 0,8	High extinction coefficient, production of neutral dark backgrounds, use in polarisation microscopes, sextants
304 x 304	0,4	Polariser for red and near infra-red
-Ø40	$3{,}0^{+0{,}1}_{-0{,}3}$	For photographic purposes without splitting rays in the light metering system, neutral grey, minimal colour deviation
-Ø60	$3{,}5^{+0{,}1}_{-0{,}3}$	
-Ø103	$5{,}5^{+0{,}1}_{-0{,}3}$	
>Ø103	$8{,}0^{+0{,}1}_{-0{,}3}$	
-Ø60	$3{,}5^{+0{,}1}_{-0{,}3}$	For image projection for stereoscopic (3D) image separation
>Ø60	$5{,}5^{+0{,}1}_{-0{,}3}$	
-Ø60	$2{,}0^{+0{,}4}_{-0{,}3}$	For lighting in conjunction with polarisers in front of the imaging optical system for reflection-free photography
>Ø60	$3{,}0^{+0{,}4}_{-0{,}3}$	
-Ø50	$2{,}0^{+0{,}4}_{-0{,}3}$	For demonstration purposes, stress testing, polarimeters
>Ø50	$3{,}0^{+0{,}4}_{-0{,}3}$	
-Ø30	$2{,}0^{+0{,}1}_{-0{,}2}$	For microscopy in the conoscopic path of light where there is a high demand for surface homogeneity
>Ø30	$3{,}0^{+0{,}1}_{-0{,}2}$	
-Ø30	$2{,}0^{+0{,}1}_{-0{,}2}$	For microscopes, photometers, opto-electronic shutters and laboratory, e. g. Kerr cells
>Ø50	$3{,}0^{+0{,}1}_{-0{,}2}$	
-Ø50	$2{,}0^{+0{,}4}_{-0{,}3}$	
>Ø50	$3{,}0^{+0{,}4}_{-0{,}3}$	

304 x 304	0,8	Quarter-wave film for ca. 480 - 640 nm, in combination with PW 64 as a circular polariser in the central visible range
304 x 304	0,8	Quarter-wave film for 720 - 880 nm, in combination with PW 40 as circular polariser for red and near infra-red
304 x 304	0,8	Quarter-wave film for 1040 -1200 nm Half-wave film for 480 - 640 nm for rotation of the direction of vibration of linearly polarised light
304 x 304	0,8	Quarter-wave film for 1 st order red Half-wave film for 1080 -1160 nm

Applications of the Kaesemann Polarisation Elements:

Materials Testing

For determining molecular structures and mechanical stresses in transparent workpieces or for investigation of surface anisotropies in opaque materials.

Photoelasticity

For determination of tensile and compressive stresses on static or mechanical construction elements by comparison with scaled transparent plastic models or of opaque building elements by the surface layer method.

Electronics

As a component for Kerr cell shutters and infinitely variable diaphragms for light signals, as circularly polarising filters for removal of reflection in oscilloscopes and seven segment and liquid crystal displays.

Space Exploration

For automatic steering of satellites using polarisation of light from fixed stars and for separation of certain light wavelengths using Lyot filters in a very narrow bandwidth.

Ophthalmic Optics

As polarising lenses in sunglasses and sun visors with and without correcting action as well as in instruments for eye investigation, particularly for testing ability to see equally well with both eyes.

Stereoscopy

As a separation filter for still pictures and film projectors as well as for 3 D viewing spectacles for separate association of related superimposed images.

Microscopy

For investigations in physics, chemistry, biology and mineralogy into dichroism and double refraction in incident and transmitted light.

Polarimetry

As half-shade polarimeters and analysers for quantitative determination of materials using optical rotatory power, especially in saccharimeters.

Photometry

For controlled light attenuation of comperative paths of light by opposed distortion of pairs of particularly high quality polarisation filters in accordance with Malus' Law.

Surveying

For transfer of distance, particularly of direction values on the basis of polarised dark backgrounds, especially in daylight.

Photography and Film

For the removal of glare and reflection, for increased contrast in colour and b/w photography and in photographic reproduction. For infinitely variable stopping down in cameras and copying devices without affecting the focussing.

Advertising and Instruction

For experiments on the principles of optics in the field of polarisation.

Laser Technology

For polarisation and attenuation of a ray of laser light of low-power.