Richtlinien

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Technical Guidelines

Parameters for the classification of HD-lenses for ARD, ZDF, ORF und SRG

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Preface

This document summarises and extends the results of the adhoc group “HD-Objektive” of ARD, ZDF, ORF and SRG.

Practical experiences in current HDTV productions showed that visible impairments are caused by the lenses used for shooting. As a consequence, this experts group was setup to figure out and evaluate parameters which are responsible for those impairments.

In SDTV productions impairments introduced by lenses do not form a visible problem, since the limitations are given by the SDTV sampling structure and bandwidth rather than by the optical system. With the take up of HDTV productions with its higher resolution, some annoying and -even for non-experts - visible effects can be observed as a result of some lenses not fitting the overall system requirements. As a target anchor, the experts group defined parameter ranges (chapter 3) so that any effects introduced by the optical lens system should be less than the resolution of the overall HDTV system, i.e. they should be “invisible” for the camera respectively the CCD sensor.

The group is very much aware that it is very difficult to fulfil all parameters for this target anchor outlined in this document at the same time by one lens because some of the parameter limits are still very tough for practical implementation. Discussions with the manufacturers and measurements have given indications what can be achieved, and also have confirmed the “ideal” target that should be reached so that a camera system with a 2/3" sensor and HD resolution is no longer limited by the lens. In principle, each parameter range defined in this document is physically reachable and even reality today in some lenses. However, typically not all maximum performance requirements are fulfilled by a single lens product at the same time.

The group is also aware that there exist dependencies between parameters identified, i.e. the improvement of one parameter causes the degradation of another parameter. Another challenge is to keep the costs and/or physical dimensions and the weight of the lens acceptable for the broadcaster, i.e. it is not adequate to create a "perfect lens" without any aberration because such a lens might cost millions of euros and weigh hundreds of kilograms.

Therefore, each broadcaster has to define its own needs: Which is the application scenario the lens is needed for, which parameter limits could be lowered (because they are not important in a particular case) and which price the broadcaster is willing to pay for the lens. As an example, a broadcaster may wish to define a ranking and weighting for individual parameters and to enclose this ranking in a tender. The manufacturer coming the closest to the weighted overall needs might have the best selling point.

The adhoc group has prioritised the parameters in the following order (this order could of course be weighted in a different way by the broadcaster who wants to buy a lens).

(1) Resolution and Sharpness

(2) Chromatic aberration

(3) Zoom tracking errors

(4) Vignetting

(5) Aperture scales and transmission factor

(6) Geometry and Picture height distorsion

(7) Spectral transmittance

(8) Flare, veiling glare

Special requirements:

The following items may have additional importance to the user. Depending on the application scenario, some of the items are indispensable, others could be accepted by the user.

- Lens Breathing characteristics

  Changing the field viewing angle respectively the focal length is a typical characteristic of a lens while focussing. The effect could be reduced but may cause higher costs and/or an increase of the weight of a lens. The user should decide depending on the particular application scenario the lens is needed for.

- Ramping characteristics

  Ramping means that zooming leads to loss of light at the telephoto end. Some lenses have the characteristic to show ramping after a certain focal length at full aperture. To evaluate the effect it is desirable that lens manufacturer provides information on iris ramping characteristics.

- Support of chromatic aberrational correction

  The chromatic aberrational correction is a function of the camera to reduce colour fringing by electronic means based on knowledge about the lens characteristics. It is desirable that lens manufacturer support this function via the implementation of the needed data interface between a lens and the camera, or via provision of the required data to the camera manufacturer by some other mechanism. The user should decide about the need of the chromatic aberrational correction depending on the particular application scenario of the lens (depending on the support of camera manufacturer).

1 Introduction

This document is structured into 2 major sections with different purposes:

- The first section (chapter 3 of this document) is intended as a requirements document that can be used by broadcasters to prepare a tender for buying lenses.

  Note: Broadcasters may have their own ranking of the parameters due to their individual needs (see above)!

- The second section is intended to give background information on parameters for clarification and for readers less experienced with the terminology used.

The already above mentioned parameters are addressed in each of the two main sections as sub-items:

- Resolution and Sharpness
- Chromatic aberration
- Zoom tracking errors
- Vignetting
- Aperture scales and transmission factor
- Geometry and Picture height distorsion
- Spectral transmittance
- Flare, veiling glare

2 Literature

[1] EBU Tech 3249-E, Measurement an analysis of the performance of film and television camera lenses

[2] ISO 9335:1995 (E), Optics and optical instruments – Optical transfer function – Principles and procedures of measurement

[3] ISO 9334:2007 (E/F/R), Optics and photonics – Optical transfer function – Definitions and mathematical relationships

[4] EBU Tech 3294 (July 2002): Offsets in back focal distances for television cameras with CCD sensors

[5] TV Optics III, The CANON Guide Book of Optics for Television System, 2007

[6] Special Report: HDTV Lens Design, Management of light transmission, Canon White Papers, May 2006

3 Parameter

This chapter presents the type of parameters for HD lenses and the range that should be reached by HD lenses complying with the requirements by German public broadcasters. This information was collected by the German “adhoc-AG HD-Objektive”-group which is a group of experts within the ARD.
For each identified parameter (ordered by priority from top down) the following information is given:

- Definition — a short description
- Requirements — general identification of the requirement that shall be fulfilled by lenses (without giving the parameter range, since this is typically dependent and given in ‘parameter range’)
- Measurement — description how the measurement is conducted, or reference for description
- Parameter range — the exact figure or a range of figures that shall be fulfilled by an HD lens for a specific application area, such as ENG.
- Dependencies — lists any design dependencies from other parameters. Having this background information may be helpful to evaluate and establish compromises between different parameters.

3.1 Sharpness and Resolution (Auflösung)

A major factor contributing to the sharpness of a lens, i.e. its ability to faithfully reproduce fine details of a scene in the image, is the resolution. The resolution is typically measured by the modulation transfer function (MTF).

<u>Definition:</u> The modulation transfer factor is the ratio of the image modulation to the object modulation at a particular frequency, for a sine–wave target or grating. The modulation transfer function is the variation of the modulation transfer factor with spatial frequency. This function is normalized to unity at zero spatial frequency.

<u>Requirements:</u>

(a) Maintain a high MTF ratio for the frequency range up to the cut-off frequency as possible.

(b) Maintain a high MTF ratio over the full image field

(c) Maintain a high MTF ratio over the range of the focal length

(d) Maintain a matching MTF ratio over the spectral range (colours)

(e) Minimum astigmatism

Measurement: The MTF shall be measured according to Tech 3249, section 2.1.2. It is permitted to re-adjust the flange-back in order to separately measure and identify a field curvature. The following parameters shall be documented:

(a) The integral area below the MTF function plotted of over the spatial frequency shall be used as a measure for the overall resolution. It shall reach or exceed the limits defined below

(b) The MTF function for defined positions off-axis in the image field shall match or exceed the limits given

(c) The MTF ratio for positions 1 and 3 plotted over the range of the focal length shall match the template as defined below. Note: The back focus and the focus ring shall be adjusted only once at the beginning of the measurement (see Tech 3249, section 2.1.2).

(d) The MTF ratio measured on axis for red, green and blue shall match or exceed the limits as given below

(e) The astigmatism, expressed as |R-T|*100 / R (in %) of the radial (R) and tangential (T) MTFs, shall have figures below a given limit.

Parameter range:

The following parameters are defined for a sensor size of 2/3” in the green channel.

a) MTF integral up to cut-off frequency: It should be measured at 28 lp/mm, 56 lp/mm and 100 lp/mm.

b) MTF at field positions: For “full facility” studio lenses, the average MTF (R+T)/2 should be at least [85%] on axis, and [65%] at field position 3 [1)].

   For lightweight lenses (e.g. ENG zoom lenses), the MTF should be at least [75%] on axis and [55%] at field position 3 [1)]

   The given figures are measured at 56lp/mm, at full aperture and at F/4.0, in the green channel and at twice the minimum focal length

c) MTF over focal length: The MTF over focal length shall be provided by the manufacturer similar to diagram as in Tech 3249, p.17, fig. 6c.

   For “full facility” studio lenses, the on-axis MTF should be at least 80% over the full zoom range.

d) The MTF values for the red channel should be at least 90% of that for the green channel at twice the minimum focal length. Due to the physical limitation the MTF value of the blue channel should be at least 80% of that for the green channel.

e) The astigmatism shall be less than 5% for position 1 and less than 30% for position 3 [1)] at full aperture and at F/4.0, and twice the minimum focal length.

Notes: [1)] Field positions are defined in figure 1.

Dependencies:

- Chromatic aberration
- MTF and astigmatism

3.2 Chromatic Aberration (Chromatische Aberration)

Definition: Chromatic aberrations can degrade the MTF of a lens and their most obvious effect is the appearance of coloured fringes at the edges of the picture. They can be separated into lateral components and longitudinal components.

Lateral chromatic aberration (German: Farbquerfehler) is a wavelength–dependent radial displacement of the image of a point in the object plane, when imaged at the image plane. As a result of this aberration, the red, green and blue images in a television camera are formed at different positions relative to the optical axis and the effect is seen as colourfringing.

Longitudinal chromatic aberration (German: Farblängsfehler) is a wavelength–dependent axial displacement of the image of a point in the object when imaged at the image plane. This causes colour–tracking errors, especially at long focal lengths of zoom lenses with high zoom ratios. Excessive longitudinal chromatic aberration will impair the picture sharpness and cause colour halation.

Requirement: No visible chromatic aberration over the whole HD field area (especially no lateral chromatic aberration).

Measurement: To be measured according to "Tech. 3249", section 2.5.2.

Parameter range:

Lateral chromatic aberration:

± 5 µm for 2/3" , at aperture f/4.0, position 3

It is recommended that the measurement is to be carried out at a distance of 3m.

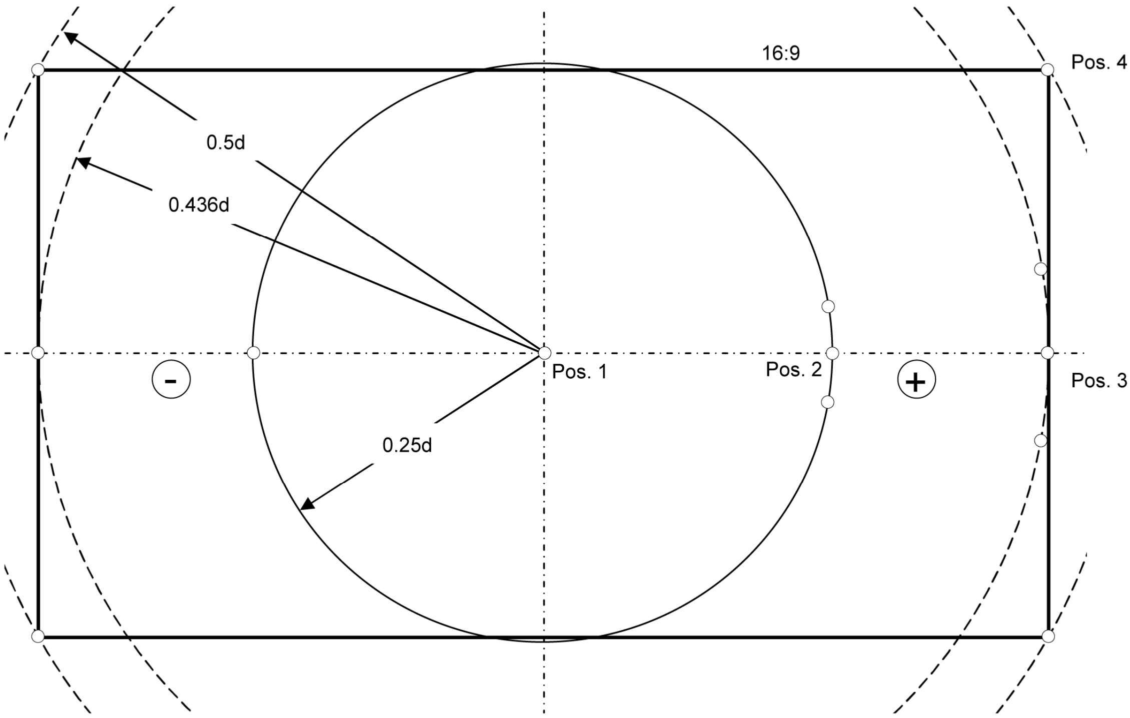


figure 1: Measurement positions

Longitudinal chromatic aberration [3) 4)]:

± 2 µm for 2/3'' (at minimum focal length)
±15 µm for 2/3'' (at maximum focal length) for green – red
±20 µm for 2/3'' (at maximum focal length) for green – blue

Dependencies:

- Longitudinal und lateral aberration are design dependent and can be predicted in the design phase of a lens.
- chromatic aberration impacts the MTF

Notes: [3)] CCD cameras have a pre–defined axial (focal plane) offset of the red and blue sensors with respect to the green sensor. These are defined in Tech 3294.

3.3 Zoom tracking errors (Schärfenebene)

3.3.1 Zoom tracking errors – axial

Definition: The axial zoom tracking error is an axial shift of the back focus as a function of the focal length. The image plane of the lens should either coincide with the light–sensitive layer of the film, or with the active layer of the CCD sensor. If this coincidence is not maintained over the full zoom range, the focus will be lost at various points in the zoom range. This will be apparent in the graphs of MTF.

Requirement: Constant displacement of focal plane at varying focal lengths.

Measurement: As defined in "Tech. 3249" sections 2.3.2

Parameter range: The axial zoom tracking error for a television camera lens (2/3" CCD) shall not exceed, in the green channel, the values in the Table 1, over the full range of operation of the zoom.

Focal length (mm)			**Displacement (μm)**
Minimum	to	15	±5
> 15	to	50	±7,5
> 50	to	Maximum	±10

Table 1: Displacement depending on the focal length

Dependencies:

- Zoom tracking errors are design dependent
- And also dependent on mechanical tolerances of focusing group and on lens mounting process

3.3.2 Zoom tracking errors – lateral

Definition: The lateral zoom tracking error is a lateral shift of a point at the centre of the image, as a function of the focal length.

Requirements: The alignment of the lens components shall be such that the centre of the image is not visibly displaced when zooming over the full zoom range.

Measurement: As defined in "Tech. 3249" sections 2.4.2

Parameter range: The displacement of the centre of the image when zooming over the full zoom range, shall not exceed 1% of the picture width.

Dependencies: Zoom tracking errors are design dependent (Alignment of a lens)

3.4 Relative Field Illuminance (Bildfeldausleuchtung)

Definition: The relative field illuminance is the ratio of the illuminance for off–axis field positions to the illuminance in the centre of the field, for an object of uniform illuminance. The relative field illuminance is determined by two factors: Vignetting which is design dependent and the cosine 4th-power law.

Requirement:
For the whole range of the focal length and over the whole sensor area the relative field luminance must exceed a certain limit.

Measurement: As defined in "Tech. 3249" , section 2.9.2

Parameter range: The illuminance at position 4 of the image plane (the extreme corners, 0,5d, see Fig. 1) should be no less than 75% of the illuminance at the centre, at the nominal aperture.

Dependencies:

- Vignetting is dependent on diameter of lenses (weight), position of the exit pupil and coating.
- 4th-power law

3.5 Aperture scales and transmission factor (Blendenöffnung, Transmissionsfaktor)

Definition: (source: Tech 3249, section 2.8.1)

The aperture scale of a lens is calibrated in relative aperture stop markings, known as f–stops, as determined by the geometric configuration of the lens. It gives an indication of the depth of field that can be obtained. However it does not give a measure of the light transmission. The optical transmission of a lens is important because it governs directly the amount of light reaching the film or pick–up device. Light is lost by absorption and surface reflection in its passage through a lens. Other effects such as vignetting and a natural decrease of field illuminance (see Section 3.4) may further reduce the resultant light flux, especially in the corners of pictures taken with high–speed lenses operating at full aperture.

a) Relative aperture
   The relative aperture of a lens is the ratio of the diameter of the lens entrance pupil to the focal length.

b) f–stop
The stop number (commonly called the “f–stop”) is the reciprocal of the relative aperture.

c) Transmission factor
The transmission factor is the ratio of the light flux delivered from the back of the lens to the light flux incident upon the entrance pupil.

d) T–stop
The transmission stop (T–stop) is the ratio of the stop number, f, (determined from the geometrical configuration of the lens) and the square root of the transmission factor, T–stop = $\frac{f}{\sqrt{\tau}}$

Requirement: The maximum relative aperture of zoom lenses should be constant over the whole zoom range.

Measurement: As defined in "Tech. 3249", section 2.8.2

Parameter range: There should be an engraved marker indicating the nominal aperture with an accuracy of ± 5%. The f–stop numbers and the maximum T–stop should also be marked. These markings should be easily visible when the lens is mounted on the camera.

For a good lens it is expected that the axial transmission factor will exceed 70% in the red and green channels and 65% in the blue channel, and that these values will not vary by more than 5% throughout the zoom range.

Note: To reduce the size and weight of a zoom lens, it is common to allow a certain amount of F-drop (ramping). The ramping point should be told to the customer.

Dependencies:

- The relative aperture is design dependent

3.6 Picture height distorsion (Geometrie)

Definition: The picture height distortion is the largest positional shift Δ H of a corner of the image, in the vertical direction, expressed as a percentage of the actual height H of the image (see Tech 3249, 2.11.1).

A zoom lens usually has negative (barrel) distortion at the wide–angle end of its zoom range, and positive (pin–cushion) distortion at the narrow–angle end. Zero distortion will occur at a zoom position somewhere between these extremes. These effects are especially evident in zoom lenses with high zoom ratios.

Requirement: The picture height distorsion should be within the parameters specified in EBU Tech 3249.

Measurement: As defined in "Tech. 3249", section 2.11.2

Parameter range: In order to prevent noticeable picture impairment, the measured values of picture height distortion shall be within the limits of –1% to +1%; this tolerance applies to all lenses except wide–angle types, for which a tolerance of –2% can be tolerated.

Dependencies:

- Picture height distorsion is design dependent (e.g. can be reduced by use of aspheric lenses)

3.7 Spectral transmittance (Lichtdurchlässigkeit)

Definition: The axial spectral transmittance factor of a camera lens is the ratio of the radiant flux of wavelength λ transmitted by the object to the radiant flux of wavelength λ that reaches the film or pick–up device, in an axial beam of light passing through the lens.

Requirement: Keep the spectral transmission constant over the wavelength

Measurement: As defined in "Tech. 3249", section 2.7.2. Measurement should be undertaken with a monochromatic measurement device.

Parameter range: High transmittance throughout the spectrum is desirable from the point of view of sensitivity. Differences in the transmittance at wavelengths of 605 nm, relative to that at 540 nm, should not exceed 20% and at wavelengths of 445 nm relative to that at 540 nm should not exceed 30%

Dependencies:

- Design dependent (glass material, coating)
- Age of lens (e.g. dust)

3.8 **Flare, Veiling glare** (Streulicht)

Definition: The veiling glare index is defined, for the purposes of the present document, as the ratio of the illuminance in the image of a black area and the illuminance in a surrounding bright field.

Requirement: The veiling flare index should be a minimum.

Measurement: As defined in "Tech. 3249", section 2.10.2

Parameter range: The veiling glare factor at field positions 1,2, or 3 measured under the appropriate conditions, should not exceed 2% (Tech 3249, section 2.10.4).

4 Tutorial for optical parameters

4.1 Resolution (Auflösung)

The imaging performance of the lens is often expressed as its resolving power. Resolving power is determined by photographing a chart with lines of various widths and seeing how far down the lens can still separate and reproduce the lines. It is common knowledge, however, that a lens with high resolving power does not necessarily give good image quality. Resolving power expresses only the limit value of the lens. It says nothing about the lens' performance at comparatively low spatial frequencies, below the limit value. This fact is particularly important in connection with television zoom lenses. A television camera converts an image to electrical signal. The bandwidth of the signal transmission path limits the fineness of detail (spatial frequency) that can be reproduced. Because the electrical bandwidth is dependent on the underlying transmission system, the total performance of a lens is evaluated by its modulation transfer function (MTF, also called optical transfer function, or OTF). [5]

4.2 Chromatic aberration (Chromatische Aberration)

Chromatic aberration arises from dispersion – the property that the refractive index of glass differs with wavelength. There are two types of chromatic aberration: longitudinal aberration (which corresponds to tracking error) and lateral aberration (which corresponds to registration error).

<u>Longitudinal chromatic aberration:</u>

This form of aberration causes different wavelengths to focus on different image planes. It corresponds to tracking error. In a zoom lens, the amount of the longitudinal chromatic aberration varies as the lens is zoomed. The aberration is largest at the telephoto end. If a large longitudinal chromatic aberration is left, tracking error will occur on the blue and red channels and cause color blurring, even when the tracking adjustment is optimal.

In the lenses for HDTV, the longitudinal chromatic aberration at the focal length between wide-angle end and the middle are designed to match with the standard of the CCD fixation positions mentioned above, so that the best efficiency on the CCD surface can be obtained for entire focal length. [5]

<u>Lateral chromatic aberration:</u>

Lateral chromatic aberration occurs because the magnification of the image differs with the wavelength. In a televison camera it causes registration error.

For a zoom lens, it is required that the good correction conditions of the principal points and focal length are maintained as a whole even with movement of the inside elements in the zoom. The use of fluorite or extraordinary dispersion glass is also effective in reducing lateral chromatic aberrations. [5]

4.3 Zoom tracking errors (Schärfenebene)

The image plane of the lens should either coincide with the light–sensitive layer of the film, or with the active layer of the pick–up tube or CCD sensor. If this coincidence is not maintained over the full zoom range, the focus will be lost at various points in the zoom range. This will be apparent in the graphs of MTF. [5]

The lateral zoom tracking error is a lateral shift of a point at the centre of the image, as a function of the focal length. [1]

4.4 Vignetting (Vignettierung)

An important aspect of the design of camera lenses is the uniformity of illumination over the image area. Any un–evenness of the relative field illuminance is due to obstruction of the beam of light entering the lens as its obliquity increases. It may therefore be caused by mechanical obstruction of marginal rays (vignetting) or by the natural cosine–law of illumination. The effect is a reduction in image illumination away from the centre of the image plane, and it becomes especially apparent at full aperture.

The measurement of relative field illuminance provides a means of verifying white shading which could occur at the edges of the picture. It may vary with focal length and aperture setting; it becomes especially apparent at full aperture and is normally reduced by stopping down. For a zoom lens operating at the wide–angle end of the zoom range the centre of the image may be evenly illuminated but there is a rapid reduction in illumination towards the corners. At the narrow–angle end of the zoom range there is a gentle drop in illumination from the centre towards the edges of the picture. [1]

4th-power law: The second factor, the cosine 4th-power law, is present even in a lens that has no vignetting. The light reaching the margin of the image decreases as the 4^{th} power of the cosine of the angle of view. This effect therefore increases as you zoom towards the wide angel direction [5]

4.5 **Aperture scales** (Blendenöffnung)

F-Number (Blendenzahl): The F-number indicates the brightness of the image formed by a lens. A smaller F-number means a brighter image. If f is the focal length an D is its effective aperture, then the F-number F_{NO} is: $F_{NO} = \frac{f}{D}$. For a given focal length the aperture of the lens is, the smaller its F-number is. The stop ring of the lens is marked with a series of numbers with a ratio of $\sqrt{2}$: 1.4, 2.8, 4, 5.6, 8, 11, 16, 22. Each time the ring is turned one number up the F scale, the brightness is decreased by half. [5]

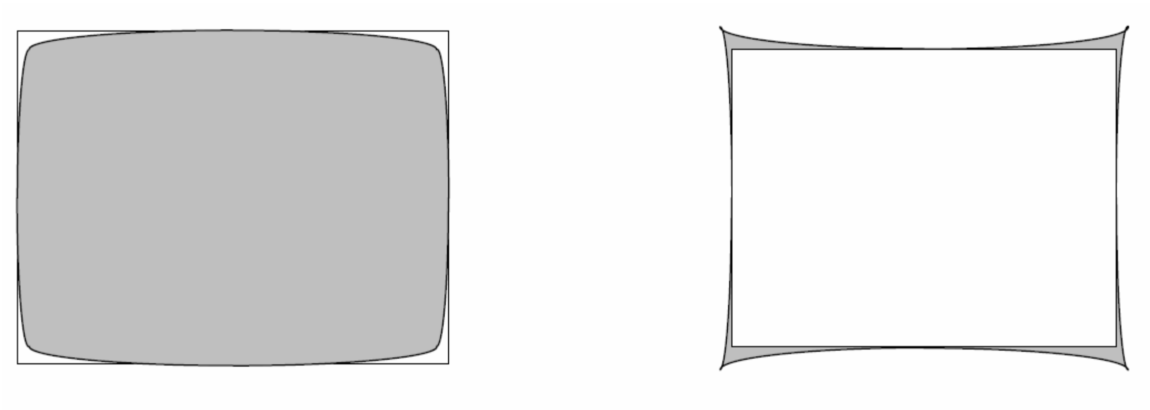
F-Drop (German: Blendenabfall): If you have zoomed with a zoom lens open to full aperture, you may have noted a drop in video level at the telephoto end. This is called F drop. To eliminate F drop completely, the focusing lens group has to be larger than the entrance pupil at the telephoto end of the zoom. It has to be at least equal to the focal length at the telephoto end divided by the F-number. To reduce the size and weight of a zoom lens, it is common to allow a certain amount of F drop. For better composition effect, however, in some studio zoom lenses the focusing group is made large enough that no F drop occurs. [5]

T-Number (T-Blende): As many people know, movie camera lenses are rated by a T-number instead of an F-number. The F-number expresses the speed of the lens on the assumption that lens transmits 100% of the incident light. In reality, different lenses have different transmittance, so two lenses with the same F-number may actually have different speed. The T-number solves this problem by taking both the diaphragm diameter and transmittance into account. Two lenses with the same T-number will always give the same image brightness. [5]

4.6 **Geometry** (Verzeichnung)

Optical distortion is in general a variation of the magnification of the image which is dependent on the distance from the optical axis. The effect is to cause straight lines in the object to appear curved in the image. Two forms of geometric errors can be determined on a rectangular object:

- a negative distortion, in which the points of the object are displaced from their theoretical position in a direction towards the optical axis (barrel distortion).
- a positive distortion, in which the points are displaced in a direction away from the optical axis (pincushion distortion).



4.7 **Spectral transmission** (Lichtdurchlässigkeit)

The shape of the spectral transmittance characteristic of lenses for colour television cameras is less important because the colour can be balanced electronically. However, it is desirable for the transmittance to be high throughout the visible spectrum because this contributes to the overall sensitivity of the lens/camera combination. [1]

The spectral transmittance depends on the lens design, the age of a lens and The wavelength. A loss of transmission is either caused by a remaining bit of reflection at the lens surfaces and/or the absorption of the glass material.

Management of light transmission through two dozen or more elements is a complex task. Two aspects of that transmission system are of primary importance:

- The amount of light that emanates from the output optical port of the lens is a measure of the sensitivity (or optical speed) of the lens in question. (See section 3.5)
- The shaping of the spectral response of that light in its passage through many elements comprising the lens system has direct bearing on the color gamut reproduction capability of the lens/camera system. [6]

4.8 **Veiling glare**, **flare** (Streulicht)

Veiling glare (also commonly known as flare) is caused by light reaching the image plane as a result of scattering and reflections within the lens system.

This can have two main effects on the picture quality. The first is an increase in uniform veiling which would result in a reduction of the image contrast. The second is multiple imagery of bright sources due to multiple reflections in the lens surfaces and from sources outside the field of view (ghost images).

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