Depth of field of the Olympus E-1

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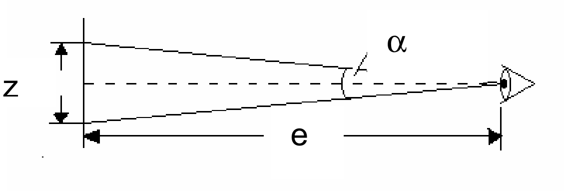
1. Depth of field

On average, the human eye can distinguish points which lie a maximum of 137 arc seconds apart. This value was calculated empirically and is utilised in all depth of field calculators and tables. Under this value, the eye views them as a single point. Using this specification, the maximum circle of confusion diameter z can be calculated based on illustration 1.



Illus. 1: circle of confusion diameter

Designations:

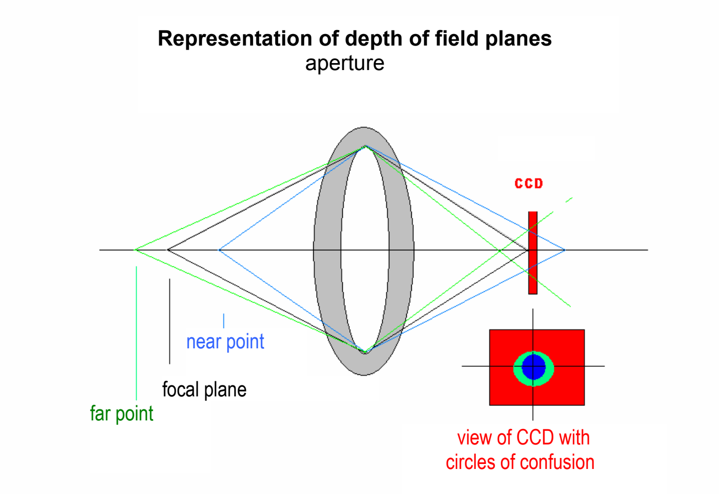
z = diameter of the circle of confusion
α = angle of vision
e = viewing distance

Hereby, the following equation is formed:

$$\tan\frac{\alpha}{2} = \frac{z}{2}e$$

where α=137 arc seconds, and the viewing distance e set at the diagonal of the sensor (e.g. for the Olympus E-1, at 22mm). Using these values, the diameter of the circle of confusion z would be calculated at 0.0147mm. This value is half as large as the diameter of the circle of confusion in the 35mm format and could also be derived from the so-called crop factor (1.98 for the Olympus E-1). The circle of confusion with diameter z is understood as a disc which is displayed on the image plane, when the object point is not focused on exactly. Strictly speaking, the focal plane is only depicted in sharp focus if one focuses directly upon it. Object points behind and in front of the focal plane are not depicted as points but rather as extended circles: as circles of confusion. The depth of field refers to the areas in front of and behind the correctly focused focal plane in which the circles of confusion depicted are smaller than the 0.0147 calculated above.

The following image illustrates this scenario:



Illus. 2: representation of depth of field

A point in the focal plane is depicted as a point in the image plane, i.e. on the CCD chip. The focal plane is therefore correctly in focus. The far point of the depth of field is now defined as the area in which a point can be depicted in such a way that its circle of confusion on the CCD is no larger than

0.0147mm. The correct (focused) image plane for this point lies in front of the CCD. A corresponding relationship is formed with the near point of the depth of field, only here the focused image plane lies behind the CCD. One can understand clearly from this geometry what would happen if one were to close the aperture (i.e. stop up): as nothing changes with the focus points, the light paths run more shallowly along the optical axis and the diameters of the points of confusion become smaller. In other words, the image becomes sharper.

1. Far and near points of depth of field

2.1 Designations

g = object distance
b = image distance
f = focal length
k = aperture number (*f* number)
z = circle of confusion diameter

Using the simple lens law

$$\frac{1}{g}+\frac{1}{b}=\frac{1}{f}$$

the far and near points of the depth of field can be calculated easily.

2.2 Near point

$$g_{near} = \frac{f^2 * g}{f^2 + k * z * (g-f)}$$

2.3 Far point

$$g_{far} = \frac{f^2 * g}{f^2 - k * z * (g-f)}$$

2.4 Total depth of field T

The total depth of field is understood as *gfar-gnear*. Using the equation above, it can be calculated as:

$$T = 2 * k * z \frac{g * (g-f)}{f^2 - (k * z(g-f)/f)^2}$$

From this equation, several important insights can be made concerning depth of field:

- **With long focal lengths, the depth of field diminishes strongly, as the focal length is squared in the denominator. For large denominators, the fraction thus becomes smaller. For parameters that otherwise remain the same, the denominator grows with increasing focal length more strongly than the numerator. The opposite is also true: the shorter the focal length, the larger the depth of field.**
- **With increasing object distance, the depth of field also increases. With growing object distance, the numerator increases whereas the denominator decreases.**
- **The larger the aperture, the larger the depth of field. On the one hand, the numerator grows while on the other, the denominator declines.**

2.5 Example

An object is located 1000mm in front of the Olympus E-1 using the Zuiko 14-54mm lens. Illustrated are the tele setting of 54mm and the wide angle setting of 14mm, each with an aperture of 3.5 and 22.

F mm	aperture	farp. mm	nearp. mm	total mm
54	3.5	1017	984	33
54	22	1117	905	212
14	3.5	1349	794	555
14	22	inf.	381	n.s.

One clearly sees that when using a zoom at close range, the depth of field is very low. With practically an open aperture, this is only 15mm in front of and behind the focal plane.

2. Hyperfocal distance

The hyperfocal distance plays an important role, as this is the distance setting for a lens which gives depth of field extending from half this distance to infinity.

The far point of the depth of field calculated in section 2.3 can approach infinity if the denominator approaches 0. This is the case when the condition

$$f^2 = k * z * (g - f) \quad (3.1)$$

is fulfilled. From this relationship, the hyperfocal distance is attained by conversion

$$g_h = f * (1 + \frac{f}{k * z}) \quad (3.2)$$

or rounded off, as the focal length is small vs. the object distance,

$$g_h = \frac{f^2}{k * z} \quad (3.3)$$

By using this distance in the equation from section 2.2 for the near point of the depth of field, the near point is expressed as

$$g_{near} = f * (1 + \frac{f}{2 * k * z}) \quad (3.4)$$

or, rounded off

$$g_{near} = \frac{f^2}{2 * k * z} \quad (3.5)$$

However, this is only half of the value from formula (3.3).

For a distance setting for the hyperfocal distance g_h, the depth of field achieved therefore runs from half of the distance set to infinity.

With the Olympus E-1, the hyperfocal distance can be calculated with z=0.0147mm from the equation

$$g_h = \frac{f^2}{k * 0{,}0147} \text{ (mm)} \quad (3.6)$$

3. Limitations

The relationships and equations represented here can only be seen as valid if the focal plane is at a large distance to the focal length (i.e. measured in meters). The reason for this is that our calculations are based on a simple optical system consisting of a principal plane and a lens. Once we move into the macro area, the principal planes of such lenses – strictly the measurement points for object and image distances – are often some distance from the front or rear lens elements. We are therefore no longer able to use such simplifications. Here, instead of the lens equations, complex lens systems must be taken into account. While this is certainly possible, it also makes little sense, as the depth of field area is so small that it will have to be set manually anyway.

Another limitation results from the wave character of light, or diffraction effects. If the f-stop is set too high, the aperture will be so small that a bending of the light rays occurs at the edges. In this case, the resulting diffraction leads to a general decrease of the level of sharpness. The "useful aperture" designates the aperture up to which stopping down does not increase the depth of focus. Further stopping down past this aperture leads to a reduction in clarity. Depending on the focal length, this aperture lies between *f* 11 and *f* 16.

5. Depth of field calculator

An Excel worksheet containing a depth of field calculator including designation of the hyperfocal distance can be obtained free of charge from the author. Two examples for selected focal lengths and distances are displayed here.

The hyperfocal distance shown is based on the aperture used as well as the given distance and focal length. This first happens with the aperture setting at which the far point reaches infinity. Naturally, at this point, a total depth of field is no longer relevant; therefore the inclusion of the notation: #VALUE!

Depth of field calculator Olympus E-1

	Input	
distance	2	m
focal length	14	mm

aperture	**depth of field**			
	near point	**far point**	**total**	**hyperfocal distance**
	m	**m**	**m**	**m**
2.0	1.54	2.85	1.31	6.67
2.8	1.41	3.43	2.02	4.76
3.2	1.35	3.82	2.47	4.17
3.5	1.31	4.18	2.86	3.81
4.0	1.25	4.95	3.69	3.33
4.5	1.20	6.07	4.87	2.96
5.0	1.15	7.84	6.69	2.67
5.6	1.09	12.06	10.97	2.38
6.3	1.03	32.46	31.43	2.12
7.1	0.97	infinity	#VALUE!	1.88
8.0	0.91	infinity	#VALUE!	1.67
9.0	0.85	infinity	#VALUE!	1.48
10.0	0.80	infinity	#VALUE!	1.33
11.0	0.76	infinity	#VALUE!	1.21
13.0	0.68	infinity	#VALUE!	1.03
14.0	0.65	infinity	#VALUE!	0.95
16.0	0.59	infinity	#VALUE!	0.83
18.0	0.54	infinity	#VALUE!	0.74
20.0	0.50	infinity	#VALUE!	0.67
22.0	0.47	infinity	#VALUE!	0.61

Depth of field calculator Olympus E-1

Input

distance	25	m
focal length	54	mm

aperture	depth of field			
	near point	far point	total	hyperfocal distance
	m	m	m	m
2.0	19.98	33.40	13.42	99.18
2.8	18.49	38.59	20.10	70.85
3.2	17.83	41.84	24.01	61.99
3.5	17.36	44.65	27.30	56.68
4.0	16.63	50.30	33.67	49.59
4.5	15.97	57.59	41.63	44.08
5.0	15.35	67.35	52.00	39.67
5.6	14.67	84.53	69.86	35.42
6.3	13.95	120.35	106.40	31.49
7.1	13.21	233.37	220.16	27.94
8.0	12.46	infinity	#VALUE!	24.80
9.0	11.73	infinity	#VALUE!	22.04
10.0	11.07	infinity	#VALUE!	19.84
11.0	10.49	infinity	#VALUE!	18.03
13.0	9.49	infinity	#VALUE!	15.26
14.0	9.06	infinity	#VALUE!	14.17
16.0	8.30	infinity	#VALUE!	12.40
18.0	7.66	infinity	#VALUE!	11.02
20.0	7.11	infinity	#VALUE!	9.92
22.0	6.64	infinity	#VALUE!	9.02

Application: The lens-to-subject distance and the focal length are entered in the fields highlighted in blue. In the table, one then finds the near and far points as well as the total depth of field area and the accompanying hyperfocal distance for the focal length and aperture.

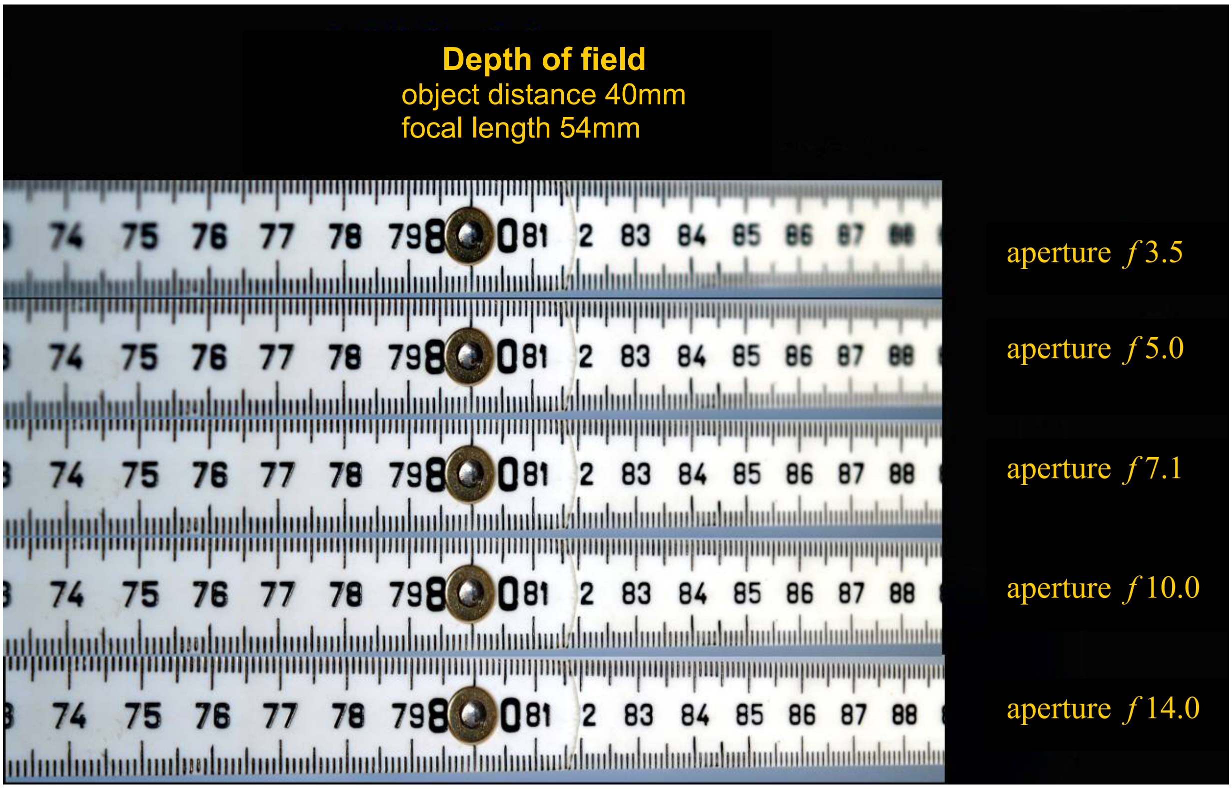
6. Comparison of the Olympus E-1 and 35mm cameras

For equivalent focal lengths and apertures, the depth of field area of the Olympus E-1 is double to that of a 35mm camera. What represents an advantage for landscape and architecture photography could be seen as a disadvantage in portrait photography, as framing by blurring (fore and) background is more difficult for higher apertures. However, with the knowledge of the effects of the settings and through corresponding enlargement of the aperture – the Zuiko lenses offer working apertures between 2.8 and 3.5 – the portrait photographer will also achieve the desired background sharpness. The following is a comparison of the Olympus E-1 with a 35mm camera for two focal lengths and two apertures. One can clearly see the larger depth of field area of the Olympus E-1 as compared to a 35mm camera.

		Olympus E-1			35mm		
focal length 35mm equivalent	**aperture**	**far point** mm	**near point** mm	**depth of field** mm	**far point** mm	**near point** mm	**depth of field** mm
108mm	3.5	1017	984	33	1008	992	16
108mm	22	1117	905	212	1051	953	98
28mm	2.8	1261	828	433	1144	888	256
28mm	22	infinity	381	n.s.	4784	558	4226

7. Examples

The following section presents a few examples showing the effect of various apertures on the depth of field. The ruler was photographed at an angle of 30 degrees (because of cosine law, 30 degrees = 0.5) at a distance of 40cm (measured from the middle of the ruler) using various apertures. The object distance can be calculated by dividing the ruler values by 2.



The following example was recorded under otherwise identical conditions, once with an aperture of *f* 3.5 and then with aperture *f* 11.

8. Contact

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Thank you in advance for your comments and suggestions.

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The coloured pencils were photographed from an angle of 45 degrees to the camera. Upper image: aperture *f* 5, lower image : aperture *f* 14.