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RODENSTOCK

Rodenstock Photo Optics – a brand of Qioptiq Photonics

Reflection reduced
Digital Center Filters

New color-neutral center filters for compensating the physically induced significant fall-off in illumination of super wide-angle lenses.

Conventional center filters for wide-angle lenses with image angles larger than 100° reduce the fall-off in illumination of 2 to 3 f-stops by reflection and absorption of their neutral density coating that gradually gets darker to the center. But this reflection produces stray light. The new Rodenstock center filters **work only by absorption**, hence they provide more brilliant and neutral pictures.



An oversized front diameter prevents vignetting

Center filter with oversized frame for images free from vignetting

HR Digaron-W 32 mm f/4

neutral gray absorbing glass, MC coated on the rear side

clear transparent glass, MC coated on the front side

The new center filters are available for the following lenses:

Mounting thread	Front thread	Exposure correction	Optimized for these Rodenstock lenses
M 72 x 0.75	M 95 x 1.0	2.5 steps (x5.6)	HR Digaron-S 23 mm f/5.6
M 72 x 0.75	M 95 x 1.0	2.5 steps (x5.6)	HR Digaron-S 23 mm f/5.6
M 86 x 1.0	M 105 x 1.0	2.5 steps (x5.6)	HR Digaron-W 32 mm f/4

Why just these new Rodenstock Center Filters?

These new center filters get their necessary radial-symmetric gray gradation from a **gray glass** instead of an evaporated dark layer.

That is why there is no reflection from the back surface of such a layer, and no contrast-reducing straylight or ghost images occur. MC coating on both surfaces minimize reflections from the glass. Images get **clearer and sharper** and **colors will be more vivid**.

Without such a layer, no interference can occur and add an increasing hue to the image dependent on the light incidence angle and a varying layer thickness. As a result, **there is no color-shift**.

The refractive indices of both lenses correspond up to five decimal places and the dispersions correspond as well in order to make the compound lens an optically perfect planoparallel plate. Therefore, the **high image quality** of the lens is **absolutely maintained**.

A generously oversized front filter frame prevents vignetting.

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A new center filter made of two lenses

In conventional center filters, a wafer-thin vapor-deposited dark coating produces the increasing density from the edge to the center. The increasing coating thickness toward the center results in an equally increasing absorption of the incident light rays. The much too high fall-off in illumination of super wide-angle lenses can thus be reduced to an amount comparable to that of standard lenses and is thus no longer disturbing.

Serious disadvantage of conventional center filter coatings
This thin coating unfortunately has slight reflecting properties. The reflection at the front side of the center filter is admittedly not a problem since the amount reflected here does not reach the camera and its loss has the same desired effect as the absorption by the coating. But when the light reflected at the lens element surfaces of even less than 0.5% in each case with the best MC coating is incident on the coating from behind, it is reflected from there into the lens and thus causes veiling glare which reduces contrast and, in the worst case scenario, even ghost images which degrade the image.

The new Rodenstock center filters work only by absorption
As the drawing at the right shows, the planoparallel glass plate of the new Rodenstock center filters is composed of two cemented lenses (one planoconvex and one planoconcave). The rear, planoconvex lens, i.e. the lens thicker at the center, is made of neutral gray glass of the same refractive index and the same dispersion as the completely transparent planoconcave lens. Both together thus have the same optical effect as a normal, homogeneous, planoparallel glass plate. However, the thickness of the gray glass increasing toward the center provides the desired development of a filter density increasing toward the center.

Unlike conventional graduated gray coatings, the gray tint of the lens does not, however, produce any additional reflection, but rather just as little at its MC coated glass-to-air boundary as the rear surface of a clear plate.

No loss of contrast and resolution and no ghost images
A first big benefit of the new Rodenstock center filters is therefore a gain in brilliance because there is no longer any veiling glare due to reflection which reduces contrast and resolution.

Better color neutrality from the image margin to the center
The second benefit is that the neutrality of the gray tint of the planoconvex lens can be maintained better than that of a vapor deposited coating (in which false colors are caused by interference effects depending on the angle of incidence due to the very small layer thickness and the reflection at both sides). The new Rodenstock center filters are therefore more color neutral.

An increased front diameter of the mount prevents vignetting
The mount of the Rodenstock center filters has an increased diameter to accept a large planoparallel filter lens at the front (a so-called "overbuilt" mount) to reduce vignetting and even to allow the use of a further filter if necessary.

Fall-off in illumination of wide-angle lenses

Every lens generates a typical fall-off in illumination toward the edge of the image circle which is negligibly low for long focal lengths relative to the taking format. But the shorter the focal length with an unchanged taking format and the wider the image angle thus is, the greater this fall-off in illumination becomes. With standard focal lengths, e.g. 50 mm with a taking format of 24x36 mm or approx. 70 mm at 37x49 mm, it can almost reach one f-stop at the edge of the image circle. With wide-angle lenses with even shorter focal lengths, e.g. 24 mm at a taking format of 24x35 mm or 23 mm at 37x49 mm, it may even be two to three f-stops. The result is then visible and annoying when the taking format extends up to the edge of the image circle.

Natural fall-off in illumination by \cos^4 law and mount vignetting
There are two causes of this critical fall-off in illumination in super wide-angle lenses: a physically induced „natural fall-off in illumination“ and „mount vignetting“.

The **natural fall-off in illumination** results from the fact that light rays incident obliquely to the optical axis

1. Are incident into an aperture which is elliptical and not circular in appearance from this direction, i.e. smaller for the light beam;
2. Its optical path from the lens to the sensor plane up to the edge of the image circle is longer than to the center of the image circle;
3. These light rays are then again also incident on the sensor surface obliquely and the image of a sphere is not a circle there, but would rather be stretched to an ellipse whereby the light is spread over a larger area and causes darkening.

The light loss due to 1. and 3. mathematically corresponds in each case to the cosine (\cos) function of the angle of incidence; the loss due to 2. is proportional to \cos^2 . Together this gives $\cos \cdot \cos^2 \cdot \cos = \cos^4$. When the image illumination at the image circle center has the value 1, it thus amounts exactly to $1 - \cos^4 \alpha$ for an image angle α . This formula is known as the „ \cos^4 law“. The blue dotted curve in the following diagrams shows the fall-off in illumination by the \cos^4 law for the Rodenstock HR Digaron-W 32 mm f/4.

The **mount vignetting** is the shadowing of the cross-section of the light beam dependent on the chosen aperture due to the mount of the front and rear lens elements. Super wide-angle lenses would have to have even bigger front and rear lens elements for a complete exclusion of mount vignetting, which would encounter technical difficulties and also cause exorbitant prices. Front and rear elements are therefore only made so large that the mount vignetting only disappears at the recommended working aperture (e.g. f-number 5.6 - 8).

Reducing illumination fall-off with a center filter

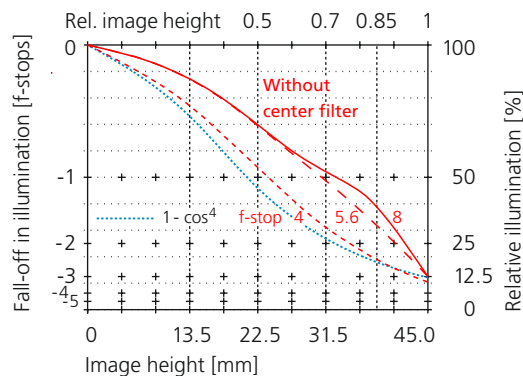
The fall-off in illumination can be reduced by a center filter which transmits less light at the center than at the margins. The required extended exposure due to the light loss at the center is 2.5 stops with the new Rodenstock center filters.



HR Digaron-S 23 mm f/5.6 with aperture f/8 without center filter.

For these comparison photos the vertical shift of the lens has intentionally been extended over the 70 mm diameter of the image circle recommended for optimum image quality due to better perceptibility of the dark corners.

Vignetting of the HR Digaron-W 32 mm f/4 without center filter



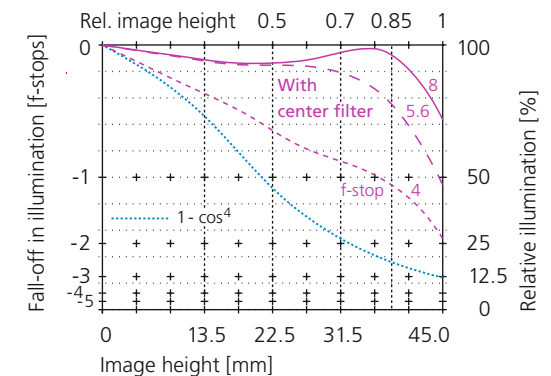
The physically induced natural fall-off in illumination in line with the \cos^4 law produces a considerable fall-off in image illumination at large image angles. The actual fall-off in illumination was, however, able to be kept smaller with the help of an optical trick (enlarging the entry pupil with an oblique incidence of light). The additional mount vignetting with an open aperture is largely eliminated by stopping down to f-number 5.6.



HR Digaron-S 23 mm f/5.6 with aperture f/8 with center filter.

Now the blue sky has an even brightness up to and a little bit beyond the recommended image circle. Visible vignetting by the filter frame and lens barrel emerges only outside a diameter of 70 mm of the large image circle.

Vignetting of the HR Digaron-W 32 mm f/4 with center filter



The same lens, HR Digaron W 32 mm f/4, already has a more favorable development of illumination fall-off at f-number 4 with the new Rodenstock center filter than at f-number 8 without a center filter. A drop-off in illumination is no longer visible in the image at f-number 5.6 without lens shift and at f-number 8, the remaining drop-off in illumination at the extreme image circle margin is less critical than with a standard lens of medium focal length.