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Practical assessment of veiling glare in camera lens system

ABSTRACT

Veiling glare can be defined as an unwanted or stray light in an optical system caused by internal reflections between elements of the camera lens. It leads to image fogging and degradation of both image density and contrast, diminishing its overall quality. Each lens is susceptible to veiling glare to some extent - sometimes it is negligible, but it most cases it leads to the visible defects in an image. Unlike the other flaws and errors, lens flare is not easy to correct. Hence, it is highly recommended to prevent it during the capturing phase, if possible. For some applications, it can also be useful to estimate the susceptibility to a lens glare i.e. the degree of a glare in the lens system. Few methods are usually used for this types of testing. Some of the methods are hard to implement and often do not lead to consistent results. In this paper, we assessed one relatively easy method for practical evaluation of veiling glare. Method contains three steps: creating an appropriate scene, capturing the target image and analyzing it. In order to evaluate its applicability, we tested four lenses for Nikon 700 digital camera. Lenses used were with the fixed focal length of 35 and 85 mm and differed by the coatings of their elements. Furthermore, we evaluated the influence of aperture on veiling glare value. It was shown that presented method is not applicable for testing the lenses with short focal length and that the new generation of lenses, equipped with Nano crystal coatings are less susceptible to veiling glare. Aperture did not affect veiling glare value significantly.

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Introduction

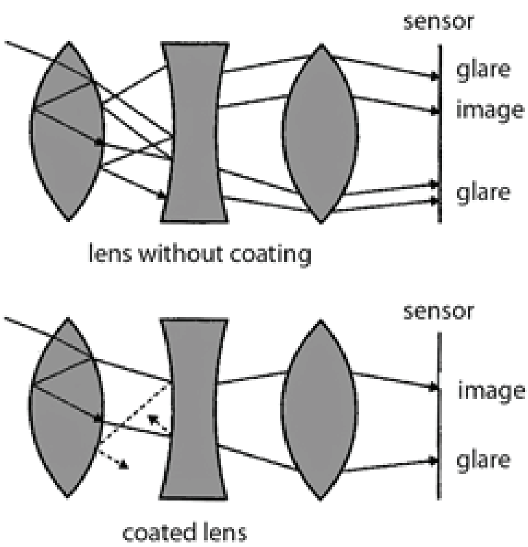
Veiling glare is defined as a light that has been reflected or scattered out of the image forming beam which ultimately finds its way to the image plane. It does not form an image, but may be fairly uniformly distributed over the image plane. Thus, it gives the appearance of looking through fog (lens flare) and the effect of reducing image contrast (Smith and Atchison, 1997). Extraneous reflections are also known as a ghost image since they appears locally and reduces the density of an image (Figure 1).

In digital camera system veiling glare can be caused by stray light reflected from the lens elements and other air/glass surfaces, by scattering of the light at air/glass surfaces due to dirt (or other impurities, scratches etc.) and by light falling on the internal mount structure and not being completely absorbed (Smith and Atchison, 1997; Geary, 1993). The latter two sources can be minimized on the user level by ensuring that the glass surfaces are as clean as possible and by placing suitably designed baffles at the appropriate position in the barrel (Smith and Atchison, 1997).

Veiling glare caused by reflections from the lens elements depends pretty much on the scene lighting and sometimes cannot be minimized to a satisfying level. Digital camera manufacturers are trying to solve this problem by enhancing the lens elements with different anti-reflect coatings. These coatings minimize internal reflections

» **Figure 1:** *Image containing lens flare, the consequence of veiling glare in lens system*

and help in preventing veiling glare (Figure 2). However, it is recommended to test the camera lens systems for its susceptibility to veiling glare in order to define the level of coatings efficiency. ISO 9358:1994 standard defines the methods and procedures for assessing veiling glare of image forming systems (ISO, 2013). Within this standard two methods for measuring veiling glare, dependent on the uniformity of the scene radiance, are defined.



» **Figure 2:** *Preventing the veiling glare by implementing the anti-reflex coatings*

Measures derived from these methods are veiling glare index (VGI) and glare spread function (GFS). Both gives reliable results, but lack the simplicity and are not so easy to implement. In order to fulfill all the requirements of the standard, integrated sphere, providing the uniform radiance, is needed, as long as the suitable photoelectric detector (Czajkowski, 2009).

In order to simplify these methods and make it easier for photographers to test the lenses, engineers from Imatest LLC company suggested another approach. This method involves taking picture of a standardized test target (containing the gray scale step chart) mounted on a white, matte background. The background should surround the test chart in all directions (approximately twice the width and height of the target) (Imatest, 2013). Besides the target and background, box lined from the inside with matte black material is needed. The purpose of the box is to capture all rays of light incident on its hatch and to serve as the darkest point of the scene (Imatest, 2013). Box should be mounted on the background, so that only its inside is visible (serving as a "black hole"). Hole should be positioned next to the darkest patch of a step chart so that the darkest point of a scene can be compared with detected gray levels. Step chart is an important part of the setup since it allows measuring the camera's tonal response and provides a reference for determining the white level from a deep gray patch (Imatest, 2013). Bright colours are interpreted differently in the processed images differently due to the non-linear response (Szeliski, 2011). Hence, it is important to have correct referent white and near white.

During the capturing, test chart and the background should be illuminated uniformly (maximum allowed deviation in the illumination across the scene is 20%). Test image needs to contain test chart and some part of the background and should be sharp and without noise. From the test image veiling glare is calculated as (Imatest, 2013):

$$V = \frac{Pixel\ level\ (black)^{\frac{1}{gamma}}}{Pixel\ level\ (white)} \tag{1}$$

In (1) V denotes veiling glare, black is the darkest part of an image (hole of a black box) and white is inferred from the region where the pixel level is between 0.1 and 0.6 of the brightest areas. Gamma value is calculated by comparing referent and obtained gray values from the step chart. When capturing the target for veiling glare assessment ISO standard requires the full aperture, so that more light can reach the sensor (Czajkowski, 2009). In other methods, aperture is not standardized and can be chosen according to the scene. Kondo and his co-workers (Kondo et al., 1984) suggested measuring with five different apertures. McCann and Rizzi stated that veiling glare values for the most of commercial camera lenses are in the range of 1 to 10 %, depending on the lens and the aperture (McCann and Rizzi, 2006). Wang found that the aperture is in direct relation to veiling glare index (if it decreases, veiling glare index also decreases) (Wang, 1994).

The goal of this paper was to evaluate the veiling glare assessment method explained before in terms of simplicity, time- and cost-effectiveness. Also, we wanted to assess its applicability to different types of lenses (with different focal length). Also, we wanted to determine how the aperture would affect the results. Since the procedure of assessment differs from methods defined by ISO (ISO, 2013), we assumed that the aperture would not affect the veiling glare values significantly. In order to test it, we choose to evaluate four different lenses for Nikon D700 digital camera (Nikkor 35mm f/1.4G, 35mm f/2D, 85mm f/1.4G, and 85mm f/1.8D). Method and the materials are presented as follows.

Methods and materials

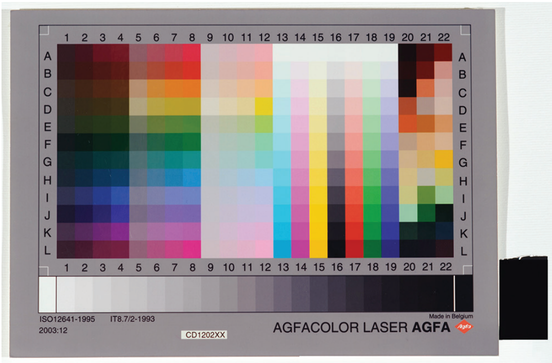
For the purpose of this study, we use one digital camera body (Nikon D700) and four lenses of the same manufacturer. Chosen lenses differed in their focal length (35 and 85 mm) and anti-reflex coating quality. Lenses that belong to a series marked as "D" use so-called "Super integrated coating," while those belong to "G" series uses a new kind of Nano crystal coating in addition to Super integrated. It is stated that nano-crystals implemented in the new kind of a coating reduce stray light significantly, which leads to better performance in terms of veiling glare reduction (Nikon, 2013). Summation of tested lenses characteristics is given in Table 1.

Table 1

Tested lenses characteristics

Lens	Construction	Coating(s)	Min aperture	Max aperture	Min focus
Nikkor 35 mm f/2D	6 lenses in 5 groups	Super integrated coating	F 22.0	F 2.0	0.25 mm
Nikkor 35 mm f/1.4G	10 lenses in 7 groups	One aspheric lens with Nano crystal coating	F 16.0	F 1.4	0.30 mm
Nikkor 85 mm f/1.8D	6 lenses in 6 groups	Super integrated coating	F 16.0	F 1.8	0.85 mm
Nikkor 85 mm f/1.4G	10 lenses in 9 groups	Nano crystal coating Super integrated coating	F 16.0	F 1.4	0.85 mm

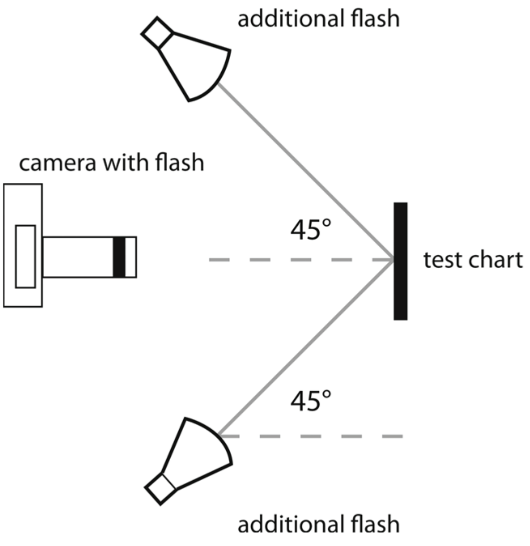
Background for the test chart was made from matte, 300 g coated paper (type 2 by ISO 12647-2:2004/Amd 1:2007), mounted on a Styrofoam board. On the centre of this board, dimensions of 70x45 cm, we placed Agfa IT8.7/2 test chart. This chart was chosen since it contains adequate grayscale transition. "Absolute black hole" was made within the box dimensions of 200x85x100 mm. Box was lined with black plush in order to minimize the reflection of a light that reach the hole. It was placed in the background cut, perpendicular to its surface, so that light falls directly to a black hole during the capturing (Figure 3).



» **Figure 3:** *Background, test target and "absolute black hole" for the veiling glare assessment*

Lighting of a scene consisted of ambient light and 3 Nikon SB-900 SPEEDLIGHT flashes. One was mount on the camera while additional two were placed at each side of the test chart, illuminating its surface at 45° roughly (Figure 4). This setup helped in obtaining the uniform illumination across the scene; the maximum deviation in background illumination measured relative to the centre of the target (measured with Sekonic L-358

Flash master light meter) was 10%. Camera to test chart distance was 2 m. Imatest method does not define any recommendation about the distance, stating that it does not affect the results. Hence, we chose the distance that allowed getting the sharpest image for each lens tested.



» **Figure 4:** *Scene setup*

An important part of the test was also the camera setup. In order to minimize the noise, we chose to use low ISO value and the rest of the options were chosen according to the illumination of a scene. These settings were kept constant for each shot and are given in Table 2.

Table 2

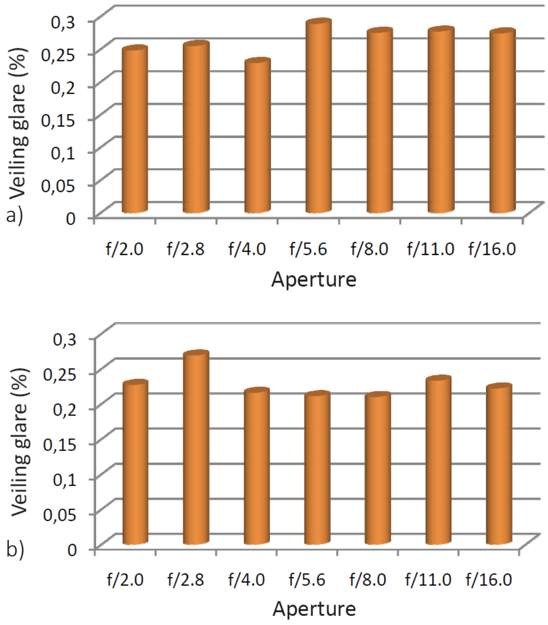
Digital camera setup

Resolution	4256x2832
Exposure	0.0040 s (1/250)
ISO value	200
White balance	automatic

Capturing the test images with each lens were performed with the apertures of f/2, f/2.8, f/4, f/5.6, f/8, f/11 and f/16. Lenses were used without lens hoods and filters, focussing the centre of a test chart. Images were recorded as RAW files and compress to lossless TIFF in dcraw software (Coffin, 2013) prior the analysis. Image analysis was performed in Imatest 3.8 Master software (Stepchart module) by assessing the grayscale, white and black values (26 steps in total). Veiling glare values were obtained as in (1) and are presented in the next section.

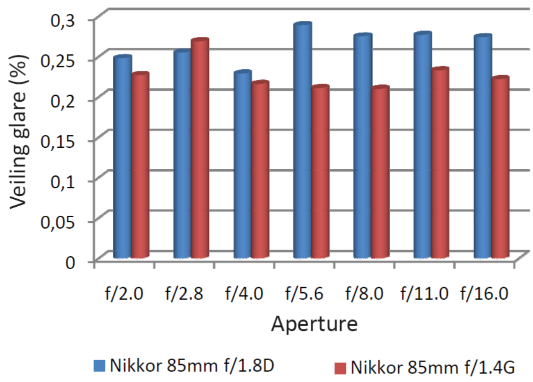
Results and discussion

Results of a veiling glare assessment for lenses with the focal length of 85 mm are given in Figure 5. It can be seen that in case of Nikkor 85 mm f/1.8D lens the most quality image, with the least veiling glare, was obtained for f/4.0 aperture. In the next step (f/5.6) veiling glare drastically changed, reaching its maximum value. In this case, smaller aperture leaded to the higher glare, but there was no clearly defined trend. In the case of the other lens, Nikkor 85 mm f/1.4G, lowest glare value was found at f/8 while its peak was reached for f/2.8.



» **Figure 5:** *Results of veiling glare percent for (a) Nikkor 85 mm f/1.8D and (b) Nikkor 85 mm f/1.4G lens*

Again, there were no trend in these values- high values are noticed at larger apertures while decreasing the aperture had no significant impact on veiling glare percent. Comparison of veiling glare values for these two lenses is given in Figure 6.



» **Figure 6:** *Comparison of veiling glare percents for Nikkor 85 mm f/1.8D and Nikkor 85 mm f/1.4G lenses*

From the Figure 7 it is clear that better results for almost all apertures were obtained for the lenses that belong to class G. However, if order of the magnitude of these values is assessed, the biggest difference is only 0.7%, which can be characterized as negligible. Same stands for the differences obtained when changing the aperture.

Hence, it can be concluded that in the case of lenses with a focal length of 85 mm aperture do not have a significant influence on veiling glare. Improved anti-reflex coating can help minimizing the internal reflection, reducing the lens flare in captured images. However, the question that should be posed is: how efficient it is and whether those differences can be perceived in actual photography? If we observe the results shown in Figure 7, the differences between the tested lenses can, probably, be noticed only at the lower aperture shots. This fact was not confirmed by a visual estimation of the captured images performed by the author of this work.

When testing the lenses with a focal length of 35 mm, we were not able to make adequate test images. Due to the lens viewing angle it was impossible to capture the whole scene (as demanded) and to obtain a sharp image. This fact can be noted as a drawback of the tested method.

Conclusion

Veiling glare is a phenomenon that may occur in any optical system, even the human eyes. It can be minimized to a certain extent, by adequate scene and camera setting, but it most cases it cannot be completely avoided. Lens flare, a flaw that occurs in images, as a consequence of veiling glare in lens system, is not easy to correct. It takes some time and skill to remove this error from image. Therefore, it is recommended to avoid it during the capturing phase and to use the lens that is less susceptible to veiling glare.

In this paper, we tested a practical method for assessing veiling glare in optical systems. Method is developed by Imatest, as a surrogate to ISO 9358:1994. Method was used to evaluate four lenses with fixed focal length for Nikon D700 digital camera. Instructions explaining the realization of the assessment were very clear and easy to follow. Preparations and testing itself do not require a lot of time, and ones prepared, background with the target and the black box can be used again. Besides the material (Styrofoam, black plush, cardboard box etc.), two flashes together with the one on a camera, light meter and image analysis software were required. Later is the biggest outgo of a procedure, if all the expenses are taken into account.

When assessing the influence of the aperture on veiling glare values, we did not obtain any results that will confirm findings of Wang (Wang, 1994). There was no clear trend between these values. Hence, it was concluded that (if the results are obtained by using the defined procedure) aperture do not affect veiling glare significantly. Same stands for the anti-reflex types of coatings tested in this work. Another important note to be taken is that presented method is not applicable for lenses with short focal length. Due to the position of its focus, it is impossible to capture the whole scene as demanded. This fact is indeed the biggest drawback of the method. To create a perfect photography, besides talent and an adequate scene, one must take certain care to photography equipment and its quality. Many manufacturers are trying to solve problems that occur due to the lens design and its elements structure by implementing new materials and special coatings that compensate micro-imperfections. Even though these improvements help in reducing veiling glare, chromatic aberration, different kinds of distortions etc., they still do not prevent these flaws completely. Hence, it is recommended to test the lenses and other equipment for their susceptibility to errors.

Method explained in this paper is just one suggestion of how the veiling glare assessment can be performed, especially for lenses with long focal length. Based on our results if the focal length is around 35 mm or shorter, we recommend following the methods defined in ISO 9358:1994.

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