Technical Bulletin

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Cast Effects in Wide Angle Photography

Overview

Shooting images with wide angle lenses and exploiting large format camera movements can result in lens fall-off and color cast, as illustrated at the edges of the image below:

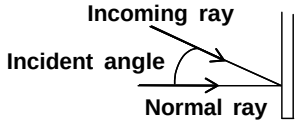
This document explains the reasons behind this phenomenon and describes how to overcome it.

- To read more about the phenomenon, see the Technical Primer, below.
- To correct cast and/or lens falloff, see Correcting Cast Effects on page 5.

Technical Primer

The way the light hits the sensor affects how the image looks. This section describes different optical setups that cause cast effects.

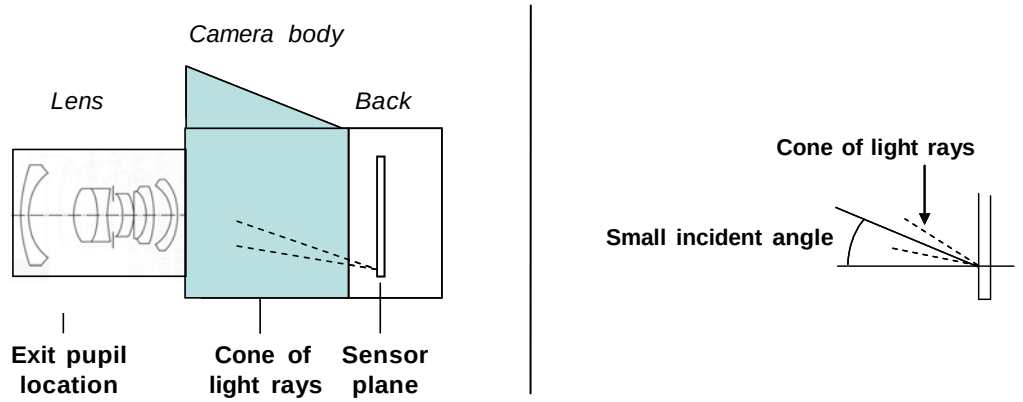
The key characteristic differentiating these optical setups is the incident angle. The incident angle is the measurement of the deviation of a light ray from “normal”; that is, the deviation of the light ray from hitting the sensor straight on.



Wide Angle Lenses and Incident Angle

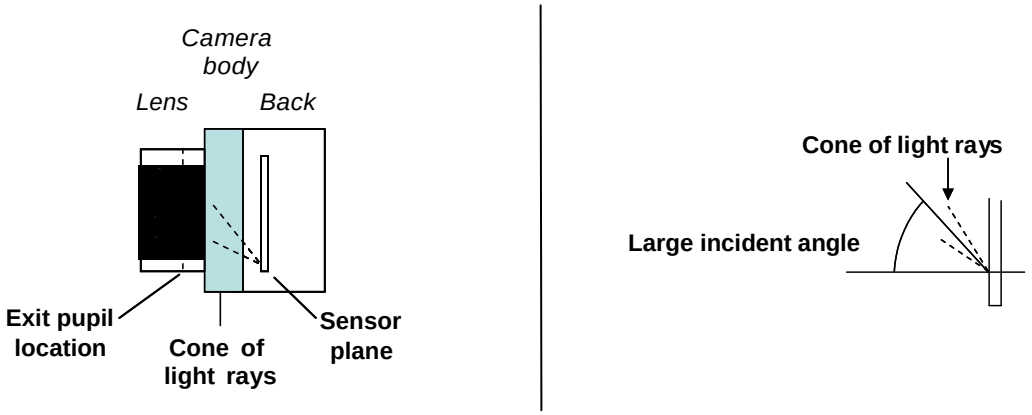
Regular Medium Format Lens

With a regular medium format lens, the cone of rays striking the sensor is relatively narrow and the incident angle is not large, as illustrated below[1]. This is because the **exit pupil**[2] is far from the sensor surface.



Wide Angle, Non Retro-Focal Lens

With wide angle lenses used on a thin, mirror-less body suitable for shifts and/or tilts and swings, the exit pupil is very near to the sensor plane, as illustrated below. The cone of rays striking the sensor is relatively wide and the incident angle is large. When the lens is shifted or tilted, the incident angle is made even larger.



[1] In these and later diagrams, the incident angle is illustrated at the edge of the sensor where the effect is greatest.

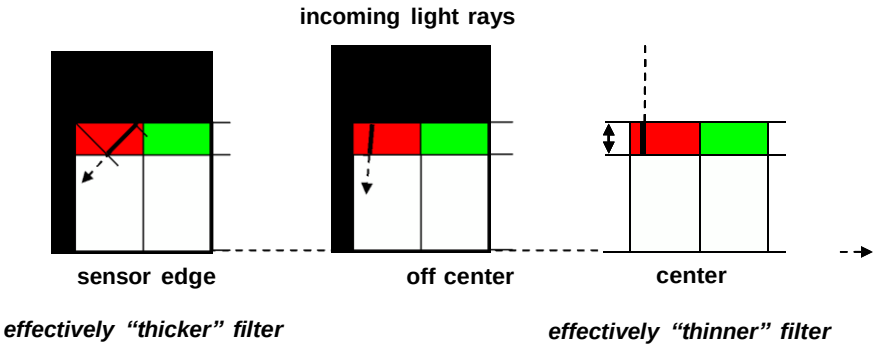
[2] The exit pupil is the image of the aperture stop of an optical system and defines the cone of light rays.

Incident Angle and the Cast Effect

Sensor Technology

All camera sensors are more or less sensitive to the incident angle of the light falling on them. Some sensors will exhibit perceptually invisible cast and others will show marked cast, depending on the sensor technology and the size of the incident angle.

A small cast effect inherent in all sensors is caused by the layer of color filters on top of the sensor surface. Rays of light striking pixels at the large incident angles (especially towards the edge of the sensor) will pass through a thicker section of filter than rays striking straight on the sensor, as illustrated below. This will create an effectively "thicker" filter at the edge.



Effective filter thickness at various sensor locations

The effectively "thick" filter at the sensor edge will filter the light slightly differently to the effectively "thin" filter at the center of the sensor. This difference can result in a small cast effect.

The effect is of course dependent on the incident angle of the incoming cone of rays. When the exit pupil of the lens is far from the sensor, the incident at the edge will be small and similar to the center, as illustrated to the right, and there will be no cast effect.

The differential thickness described above results in slowly changing cast effects across the sensor. In some sensors, an abruptly changing cast effect seen as a faint line in the center of the image may be observed[3].

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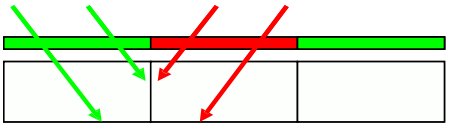
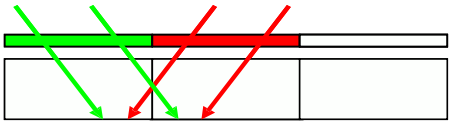
[3] This effect is sometimes called the "centerfold" effect.

Crosstalk Effect

A common reason for strong cast in a sensor is known as the **crosstalk effect**. This happens when there is no barrier preventing light rays from crossing from one pixel to another in the deeper layers of the sensor surface, as illustrated below.



Barrier = no crosstalk



No barrier = crosstalk

The crosstalk effect is strongest at the sides and corners of the sensor where the angle of incidence is largest. **Leaf imaging module sensors have barriers and do not suffer from crosstalk.**

Factory Calibration

The cast effect found in regular lenses is fixed during factory calibration of the Leaf imaging module. With factory calibration, most regular lenses and some specialty lenses will not exhibit cast effects on Leaf imaging modules.

However, when a lens with significantly different optics such as a wide angle lens or a macro telephoto lens is mounted, the factory calibration will not be correct and cast effects may arise.

Note: The cast effect may sometimes be seen when using a long macro lens. This is again caused because of a marked difference between the incident angle for a regular lens length and the incident angle for the telephoto macro lens.

The cast effects for a specialty lens can be fixed by a suitable tool, as described in the following sections.

Summary

- Wide angle lenses create large incident angles of incoming rays
- Large incident angles cause a significant difference in the color filtering of rays falling at the center versus rays falling at the edge of the sensor.
- Differences in color filtering between the center and edges of the sensor result in a cast effect across the sensor, which may be slowly or abruptly changing, or both.
- Cast problems exist in **all** high-end digital backs or cameras that use physically large sensors. In general, Leaf imaging module sensors do not show significant cast effects with regular lenses, which gives them an advantage over other high-end sensors.

Correcting Cast Effects

All the cast effects caused in Leaf imaging modules by the phenomena described in the Technical Primer section can be corrected. This is because cast effects are consistent and predictable. There are two methods of correcting cast effects: before shooting, and after shooting.

Correcting Cast before Shooting

Usually, a series of diffused shots is taken and the results of the cast effects, as well as the lens falloff, are recorded in a control file. The control file is used to calculate the final cast-free image. (The control file may be referred to as “gain”; in Leaf terminology the control file is called "lens calibration".)

Since **any** lens will have a cast effect that must be corrected, all digital camera backs come with a default lens calibration. This default lens calibration is stored in the imaging module and is automatically used when producing every image. In Leaf terminology, the default lens calibration is called "factory lens calibration ".

The factory lens calibration of an imaging module can be used with most regular and long lenses because the lenses are retro-focal and the exit pupil is far from the sensor plane, meaning the effect is small and differences between lenses are negligible. Therefore one factory lens calibration "fits all".

Correcting Cast after Shooting

For wide angle lenses (and in some cases, macro telephoto lenses), especially with camera movements such as shift or tilt, a single factory lens calibration is not sufficient. A different lens calibration is needed to ensure that a wide angle shot is also cast free. It is theoretically possible to create factory lens calibration for each lens and camera movement. However, the quantity of control data that would need to be stored on the imaging module, and the work required from a photographer who uses non-electronic, large format camera bodies, would be prohibitive.

Leaf provides a practical solution to this problem in the Leaf Capture software. You can correct the cast effect after the shoot, using a diffuse calibration shot that is taken with each camera and lens setup during scene capture.

For a technical bulletin describing the workflow download the Creating Lens Calibration Files in the Field Technical Bulletin from http://www.leaf-photography.com/files/support/LensCalibrationGuide.pdf