# Stray Light Correction

The dynamic range of a system and the contrast within an image are often confused. The “dynamic range” is defined as the possible range of values for any given pixel including the saturation and various different integration or exposure times. The term “contrast” is the difference between two areas in one image. This figure represents an instrument’s ability to measure both bright and dark signals accurately.

For example, an LMK system can measure sources radiating several Mcd/m² very accurately, such as a bright LED or the sun. However, with the same instrument, it is also possible to measure very low values of 1 cd/m² with high accuracy such as dark symbols or the reflected luminance from a street at night. In the former, we have very short integration times (~ 100 µs) and several seconds without the sensor being well saturated in the latter. This represents a dynamic range of 1:10,000,000. However, a contrast of 1:10,000,000 specification would mean it would be possible to measure the same dark symbol simultaneously, placed next to the sun. The system would provide accurate measurements of the sun in several Mcd/m² and the symbol with only 1cd/m² in the same image which is physically impossible. Hence, the measurement results of the symbol will be wrong.

The reason is both sources cannot be measured at the same time is due to stray light. In any such measurement, light is scattered from all surfaces inside and outside of the instrument. This is also true in the case of ILMDs (Image Luminance Measurement Devices) such as an LMK.

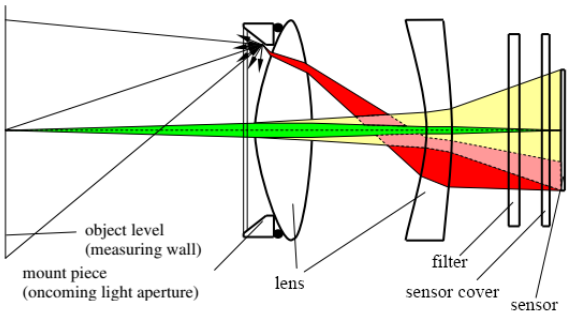



*Figure 1: Sources of stray light within an ILMD*

The green region represents the light from the source of interest to be measured. However, other light scattered at the surfaces of lenses as shown in yellow, contribute to it. Moreover, there are components of additional light to the sensor, which are caused by reflections indicated in red. Reflections from the sensor's surface are a major contributor of scattered light. This is indicated in orange below.

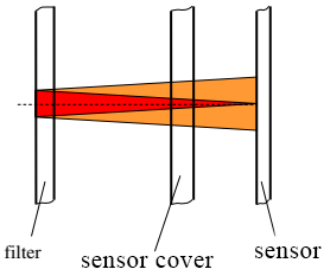
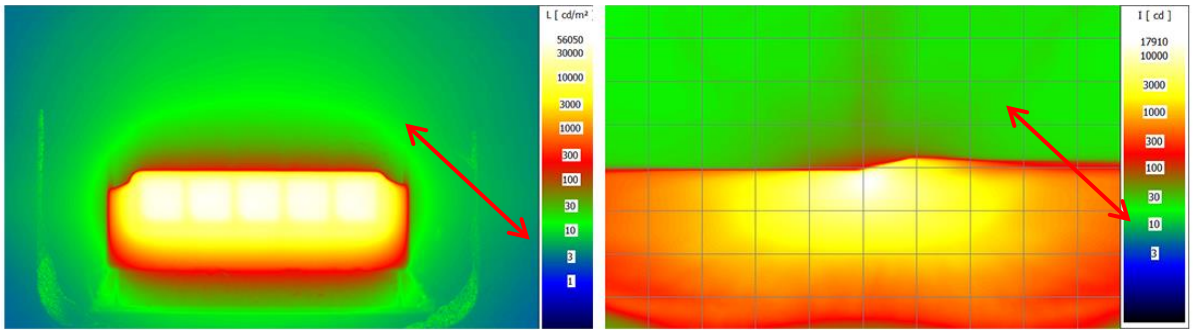


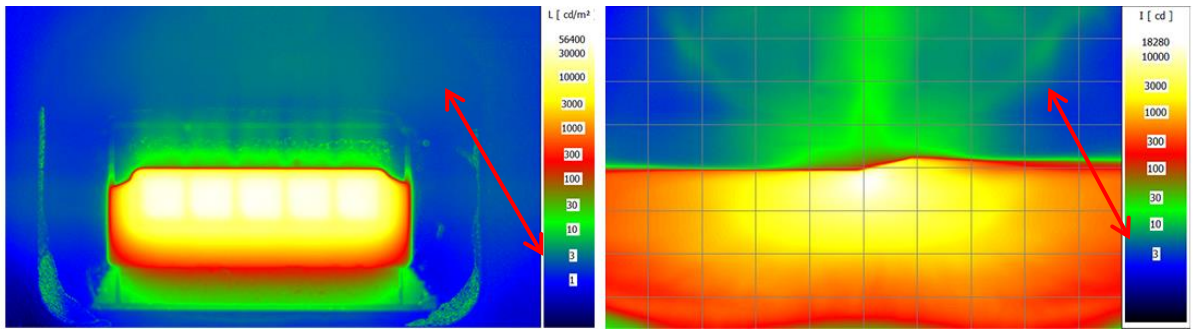

*Figure 2: Reflected Light from the sensor surface in an ILMD*

These effects may be minimized by usage of anti-reflection coatings and well-designed apertures within the lens but never completely. A good anti-reflection coating still contributes ~0.5% reflection per surface. Adding this up from all lens surfaces results in a total of 1% or more stray light. This is of course higher for poorly designed lenses and coatings.

TechnoTeam has decades of proven experience in the measurement of high-contrast images both in product development and in production. By developing innovative calibration methods, stray light models and correction algorithm we have been able to significantly reduce the effect of stray light. See below:




*Wrong values in dark zones! Here, 30 cd and more*




*Accurate values in dark zones! Here, 3 cd and below*

The results of these efforts are published in CIE244:2021. This document contains the definition of several quality indices for characterizing camera systems. With such indices, customers are able to compare systems. For example, new quality indices $f_{23}$, $f_{24}$ and $f_{25}$ address the contrast in camera systems.

| | Description | Standard System | SLC System |
|---|---|---|---|
| $f_{23}$ | **Effect of surrounding field** | **1:1 000** | **1:2 000** |
| $f_{24}$ | **Stray light influence for negative contrast** | **1:100** | **1:2 000** |
| $f_{25}$ | **Edge function** | **1:1 500** | **1:15 000** |

*Table 1: Table of quality indices related to stray light*

While most manufacturers are unwilling to disclose such quality indices for their systems, TechnoTeam freely does so. Compared with other camera systems, we have determined that the LMK can measure contrast ~10 × more. When considering a system, users should inquire about the quality indices and contrast values and make comparison measurements, if at all possible.

For nearly two decades TechnoTeam has focused on achieving the highest performance through rigorous analysis of all components and the processes that go into designing the finest light metrology tools in the industry. If getting it right the first time and every time matters, contact us to learn more.

*Precision and accuracy are how we measure our success!*