# TECHNICAL NOTE TN2021_9 – STRAY LIGHT

## Introduction

Stray light is a major issue in all imaging system. In this TN, causes are depicted, and solution are discussed to limit its effect.

*FOV = FIELD OF VIEW*

> *The field of view is determined by the angle of view from the lens out to the scene and can be measured horizontally or vertically. Usually expressed in degrees (angle).*

## Article

Let start first with few definitions:

***Straylight*** can be defined as unwanted light power caused by out of field of view sources, mechanical structures or non-perfect optical surfaces. It can also be thermal emission emanating inside the optical system. In imaging spectral instruments this stray light is measured at the detector and it can, due to its random nature, mix with actual measurement signal. In general stray light does not form an image but is fog like contribution reducing spatial and spectral resolution.

***Flare*** is defined as reflected light; from lens elements, metal surface, etc. Flare usually appears as non-uniform haze or bright spots on the detector and it often has the shape of the aperture. The use of uncoated or poor quality coatings make lenses more prone to flare.

***Ghost images*** are seen as out-of-focus like secondary images usually caused by reflections from lens surfaces. Stray light in imaging spectrographs is more dominant error than in single channel spectrographs. This due to the fact that in imaging spectrograph the spectrum is imaged from one narrow part along the slit (spatial axis) but stray light contribution is coming from the whole length of the slit.

There are a few distinctive sources that should be considered. This document present these and possible corrections.

**SOURCES OF STRAY LIGHT AND CORRECTION**

**a. TARGET**

Due to operation principle the spectral camera is seeing only a narrow line at the target (sample). This line is selected by the input slit of the spectrograph. However, the fore optics is transferring the image of the whole scene to the slit area as 2 –dimensional image. Part of this light is absorbed by the black slit (it is not perfect absorber) and part is reflected back to objective and target direction. There are two possible sources of stray light:

1. Light reflected back from the slit may cause additional reflection inside the objective lens surfaces
2. Light reflected back from the slit can contribute to the illumination on the target. Bright source outside the field of view can therefore contribute spectrally to dark areas.

***Corrective action***: One should have a black baffle limiting the field of view to the target and thus prevent signal outside the slit field of view entering the objective. If possible, one should only illuminate a very narrow line from the sample surface area.

### b. OBJECTIVE LENS

Spectrograph wavelength range is usually wider than the design range of common objective lens. Objectives designed for standard machine vision inspection are usually manufactured only for the visible wavelength range having coatings optimized from 400 to 700 nm region. Any light penetrating the objective from target direction or outside this field of view can have multiple reflections inside the lens group and occasionally enter the slit and contribute to measurement signal.

***Corrective action***: One should use objective lens that is designed and coated to the wavelength range of the spectrograph.

### c. SPECTROGRAPH

The spectrograph has a specific numerical aperture (F-number) defining the maximum angle of rays that can be transferred through its optics without vignetting. Any rays entering the spectrograph in an angle greater than this will end up to baffles, lens edges or walls of the spectrograph interiors. Commercial objective lenses may be designed for lower F-number (meaning higher incoming angle) than the spectrograph. This may cause additional straylight due to overfilling the spectrograph numerical aperture.

***Corrective action***: One should always use the same F-number in objective lens than in the spectrograph.

### d. CAMERA

The camera detector may reflect light back to spectrograph. The amount depends on the reflectivity of the detector element and possible windows / AR-coatings. This light may in some occasions introduces unwanted reflections from the lenses and grating that contributes to straylight.

If there are mirror like surfaces like bonding pads, frame transfer area etc… these can in some case add contribution to ghost images or flare.

***Corrective action***: Baffles that prevent these reflections (not always possible).

**STRAY LIGHT IS THE MOST VISIBLE AND TYPICALLY OCCURS WHEN:**

- There are bright and dark objects in the same image (i.e. frame). Then stray light can be an issue in data quality at low signal areas. There will always be some stray light and reflections inside the camera optics (as discussed previously). If signal level in data is low at spectral or spatial range, they will have a relatively high level compared to actual signal and make these artifacts visible in the final image.
- Low signal level may be due to low camera sensitivity at the end of the wavelength ranges, low energy from the illumination or low sample reflectance. Adjusting the integration time does not affect the amount of stray light.

Stray light is a common feature in all imaging instruments and depends a lot on how sensitive the camera is at the end ranges. It is annoying, but unfortunately there is little that can be done to eliminate it totally. The light can't be prevented from reflecting back and forth at least a little bit, regardless of how good anti-reflection coating is used.

You may also see that all bright objects in the image will "smear" across the image over the dark background at these wavelengths with low spectral sensitivity.

Ways to decrease stray light:

- Increase SNR (better illumination)
- Remove bright objects from the target area
- If possible, place white reference panel (or other bright objects) in the imaging area so that they are not in the same position in scan direction as the meaningful targets (Figs. 3a & 3b)
- If the white reference panel interferes with your target, capture white reference data separately with Custom White reference mode (Specim IQ).
- If the white reference panel cannot be positioned so that it would not overlap spatially with the target, position the white reference panel so that it only covers a small portion of the image area to reduce its impact on the target (*Figure 3c)*

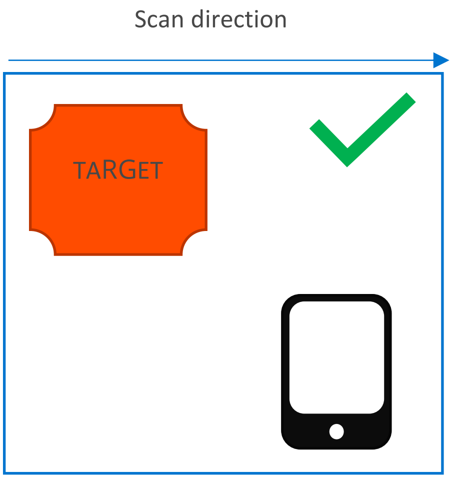


*Figure 3a: Correct white reference placement*


*Figure 3b: Incorrect white reference placement*

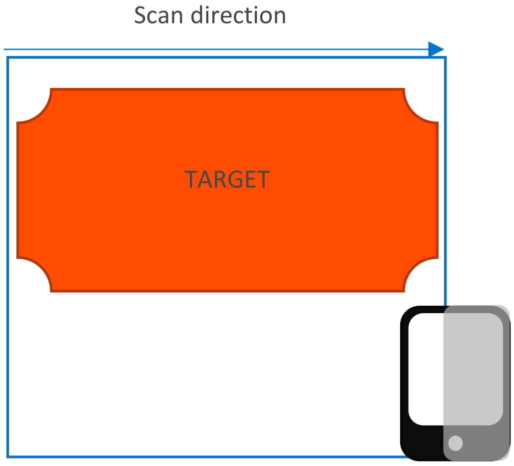


*Figure 3c: Place white reference only partially within the imaging area*

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Version history

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