

UNCERTAINTY ANALYSIS OF STRAY-LIGHT CORRECTION

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ABSTRACT

Measurement errors from stray light within an instrument are often inevitable but can be corrected by using a stray-light correction matrix that is derived by characterizing the instrument for a set of spectral line spread functions (SLSFs). The correction reduces stray-light errors for one to two orders of magnitude. A stray-light corrected and well characterized array spectroradiometer can achieve measurement uncertainties in photometry and colorimetry which are comparable to that of a conventional double-grating scanning-type spectroradiometer. The uncertainties of stray-light correction are determined by the uncertainty of the measured SLSFs that depend mainly on the quality of an instrument and the quality of spectral line sources used for characterization of stray light. This paper identifies the sources of error in stray-light correction and analyzes the overall uncertainty of the correction results.

Keywords: stray light; spectrometer; uncertainty

1. INTRODUCTION

Stray light within an instrument is a well-known problem of an array spectroradiometer due to its single-grating optical scheme. Stray-light errors arise when an instrument is used to measure a test source that is spectrally quite different from the calibration source. There are a variety of sources to be measured, but there are only very few types of calibration sources available. Thus, errors due to stray light are often inevitable.

We developed a simple matrix method for correcting stray-light errors, which is based on characterization of a spectroradiometer for a set of spectral line spread functions (SLSFs) used to derive the stray-light correction matrix. The stray-light correction is simply a matrix multiplication of the correction matrix to the measured raw spectra [1].

Dozens of array spectroradiometers, ranging from scientific grade to consumer grade, have been characterized and corrected for stray light at the NIST tuneable laser facility since the matrix method was developed in 2004. The results of the stray-light correction have been satisfactory, with a reduction of stray-light errors from one to two orders of magnitude. This paper identifies the sources of error in stray-light correction and analyzes the overall uncertainty for a stray-light correction.

2. UNCERTAINTY OF STRAY-LIGHT CORRECTION

The uncertainties of stray-light correction are determined by the uncertainties of the measured SLSFs that depend on the quality of the instrument, the quality of spectral line sources, and the technique used to characterize the instrument for stray light.

The uncertainties of the measured SLSFs are typically dominated by the contributions from the instrument itself. The sources of error related to the quality of the instrument are 1) out-of-range stray light that comes from beyond the instrument's spectral range and can be significant, 2) blooming, smearing, linearity, dark signal (a cooled detector or not), and the accuracy of the readout electronics (12 bit or 16 bit A/D convertor) of the array detector, 3) sensitivity of SLSFs to the input optics such as fiber optical bundles, diffusers, and optical filters, etc, 4) sensitivity of SLSFs to illumination geometry, and 5) long-term stability of SLSFs (years).

The measurement errors of SLSFs can also come from a spectral line source if its optical power is too low, or if its background emission is too high compared to the level of instrument's stray light, or if its bandwidth is as wide as the bandpass of the instrument.

A spectroradiometer has a limited dynamic range, 12 or 16 bit A/D typically, which limits the uncertainty of measured SLSFs. To reduce the uncertainty, a technique, called electronic

bracketing, should be used to characterize the instrument for stray light so that the dynamic range of a SLSF can be increased by approximately two orders of magnitude.

Those SLSFs that are interpolated from the measured SLSFs are subject to interpolation errors. The amount of error introduced by the interpolation depends on the total number of measured SLSFs across the instrument's spectral region and the design/quality of the instrument.

Stray light is the dominant source of error for a scientific grade spectroradiometer. As a verification, four high-power LEDs (blue, green, red, and white) were measured for CIE chromaticity coordinates by using a stray-light-corrected CCD-array spectroradiometer and by using a scanning double-grating spectroradiometer. The preliminary results of this comparison are shown in Table 1. The differences of the measured CIE chromaticity coordinates, x and y , are well within the measurement uncertainties of the two instruments, and the measured CIE chromaticity coordinates, x and y , by the two instruments, are virtually the same to the red and white LEDs.

LED Color	Difference of measured CIE chromaticity coordinates	
	Δx	Δy
Blue	-0.0002	0.0005
Green	0.0004	0.0009
Red	0.0001	-0.0001
White	0.0000	-0.0001

3. SUMMARY

The uncertainty of stray-light correction lies in between one to two orders of magnitude. The correction uncertainties are determined by the uncertainty of the measured SLSFs that depend mainly on the quality of an instrument and the quality of spectral line sources used to characterize stray light within the instrument. A scientific grade instrument can be corrected for stray-light errors for two orders of magnitude, corresponding to a relative uncertainty of 1 % in measurement of stray light. A stray-light corrected and well characterized array spectroradiometer can achieve measurement uncertainties in photometry and colorimetry which are comparable to that of a conventional double-grating scanning-type spectroradiometer.

REFERENCES

1. Zong Y, Brown SW, Johnson BC, Lykke KR, Ohno Y (2006). Simple spectral stray light correction method for array spectroradiometers, *Applied Optics*, **45**(6), 1111-1119

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