

Stray-light correction of array spectroradiometers using tunable pulsed and cw lasers

A. Sperling, O. Larionov, U. Grusemann, and S. Winter
PTB, Braunschweig, Germany

Abstract. Array spectroradiometers are widely used in radiometry and photometry as tools for rapid measurements of the spectral distribution of lamps and other signal sources. Unfortunately, the stray-light rejection of such devices is often less than that of a scanning double or even single grating monochromator system. In addition, as array spectrometers are more or less monolithic systems, other device dependent side-effects, e. g. evoked by special order filtering in front of the diode or CCD array, by fluorescence, etc. may affect the measured spectrum.

With the availability of high power narrow bandwidth sources, tunable over the entire spectral range of a spectroradiometer from UV to IR, the possibility of correction procedures are reconceived [1,2]. A powerful new method for stray-light correction was recently presented by Y. Zong et al. [2]. He implemented a stray-light correction matrix, where the elements of the matrix have to be determined by successive measurements of the entire spectrum produced by wavelength-tunable single monochromatic laser lines.

The purpose of this contribution is to compare the results of the achievable stray-light correction based on Zongs method for different array spectrometers using the TULIP (Tunable Laser in Photometry) facility of the PTB, where a setup with tunable cw-lasers as well as a setup with pulsed lasers is used.

TULIP Facility

TULIP was build as a cw laser-based calibration setup for measurement of irradiance responsivity of large-area photometric and radiometric detectors [Figure 1]. To cover the spectral range from less than 360 nm up to 960 nm different types of cw lasers are necessary [Figure 2]. Although the spectral range of TULIP is only a small part of the range covered by SIRCUS [3], the well-proved laser facility at NIST, it is sufficient for most photometric and radiometric tasks in the visible and adjacent spectral ranges.

As cw laser-based facilities are not easy to automate for this wide spectral range and in order to overlap the spectral range between 460 nm and 560 nm with durable tunable solid state lasers, TULIP was complemented by a pulsed laser system based on optical parametric oscillators (OPOs), covering the spectral range from 410 nm to 2400 nm.

This pulsed laser system is much easier to handle than the complex cw lasers systems. In addition, the spectral range of this system is larger and tuning is very easy to automate. The disadvantage of this laser, the short pulse duration (about 4 ns only), is reduced by pulse stretching using

fiber delay lines and an integrating sphere with high spectral reflectance.

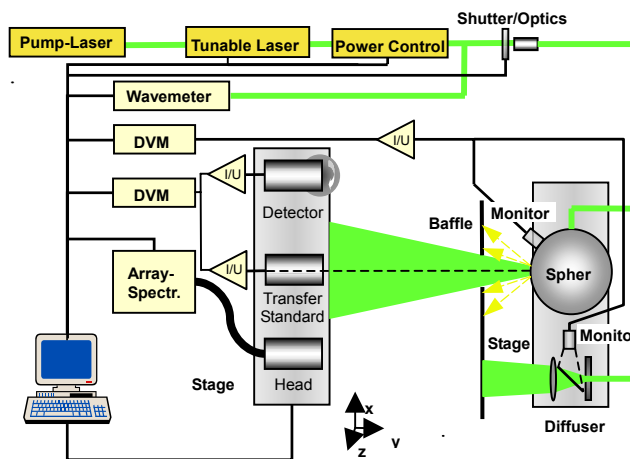


Figure 1. TULIP facility for calibration and characterization of detectors and spectroradiometers using the uniform radiation field in front of a sphere or a transparent (holographic) diffuser for higher radiation levels.

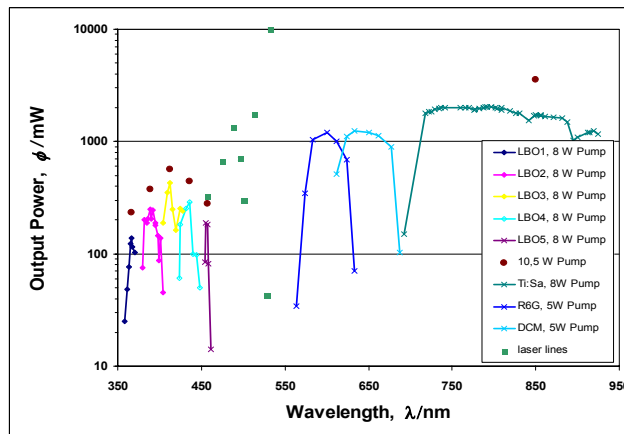


Figure 2. Output Power of the TULIP cw-laser setup. Between 358 nm and 460 nm the frequency of a Ti:Sa laser which operates between 690 nm and 960 nm is doubled. Dye laser are used in the range from 560 nm to 685 nm. Between 457 nm and 532 nm single laser lines from Argon ion and Nd:YVO₄ lasers are available.

As a result of this simple setup, the pulse length is stretched to more than 0.1 μs at a repetition rate of 22 Hz.

Comparison between Pulsed and CW Lasers

Using the setup shown in Figure 1 and provided that the correction matrix can be handled as a stable device

characteristic, both the correction of stray-light (including fluorescence) and second order images is possible. Moreover, with information about the linearity of the array spectroradiometer an absolute calibration against trap detectors can be performed.

Although it is expected that the best results for the generated correction matrix are obtained if measurements are carried out using a stable cw laser system, tuneable over the whole spectral range, the respective effort may be too large for many calibration laboratories. Therefore, we applied and tested our pulsed laser system for the measurement of the spectra [Figure 3] for different kind of array spectroradiometers. The calculated correction matrices are analysed and compared with cw laser-based measurements.

It is shown that even with CCD array spectroradiometers (CCD not gated) the results of the stray-light reduction with pulsed lasers are comparable to that, which are obtained based on calibration using a cw laser system.

wavelength setting of the irradiating laser may result in big differences (peaks) within the stray-light spectrum.

Acknowledgments The authors thank Yuqin Zong from the NIST Optical Sensor Group for helpful discussions.

References

- [1] Brown, S. W., B. C. Johnson, M. E. Feinholz, M. A. Yarbrough, S. J. Flora, K. R. Lykke, D. K. Clark, Stray light correction algorithm for spectrographs, *Metrologia*, 40, pp 81-83, 2003.
- [2] Zong, Y., S. W. Brown, B. C. Johnson, K. R. Lykke, Y. Ohno, A Simple Stray-light Correction Method for Array Spectroradiometers, *Applied Optics*, to be published.
- [3] Brown, S. W., G. P. Eppeldauer, K. R. Lykke, NIST facility for Spectral Irradiance and Radiance Responsivity Calibration with Uniform Sources, *Metrologia*, 37, pp 579-582, 2000.

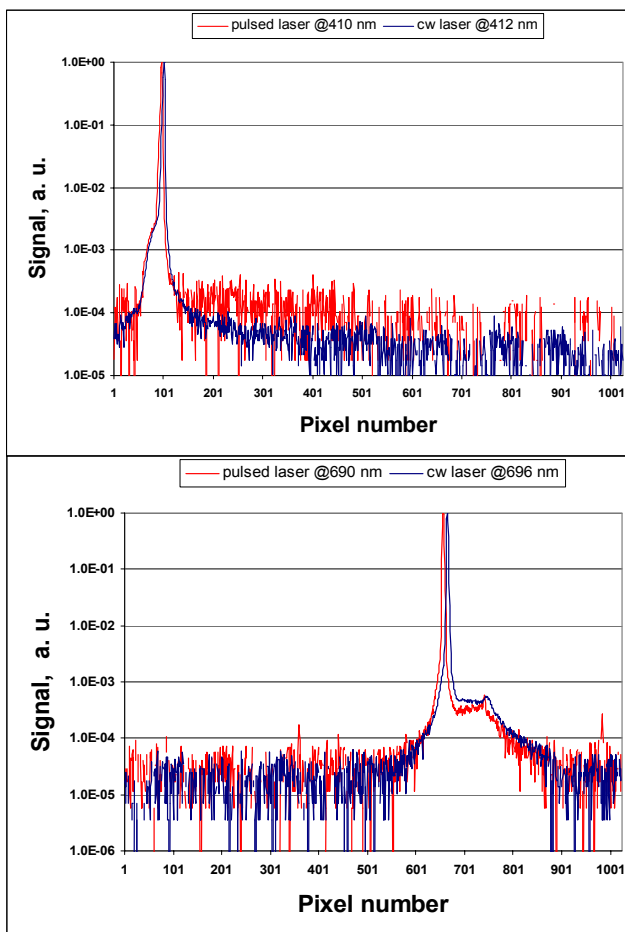


Figure 3. Measured data of pairs of slightly different (and therefore distinguishable) laser lines from a CCD array spectroradiometer (CCD not gated) a) blue: 412 nm cw, red: 410 nm pulsed; b) blue: 696 nm cw, red: 690 nm pulsed.

It is important to note that depending on the reflection path within the array spectrometer even small changes in the