Stray light characterisation of a hyperspectral spectrometer for airborne remote sensing applications

Saulius Nevas[1], Stefan Nowy[1], Armin Sperling[1], Karim Lenhard[2], and Andreas Baumgartner[2]

[1] Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin, Germany,
[2] German Aerospace Center (DLR), Earth Observation Center (EOC), Remote Sensing Technology Institute (IMF), Oberpfaffenhofen, Germany
Corresponding e-mail address: saulius.nevas@ptb.de

Stray light characterisation and correction of hyperspectral imagers are needed for their use in remote sensing applications. This presentation describes such a work carried out in collaboration between PTB and DLR. A hyperspectral instrument of DLR was characterised and corrected for the spectral-spatial stray light effects using the tuneable laser setup PLACOS at PTB.

INTRODUCTION

Hyperspectral sensors for airborne remote sensing of the Earth's surface have become a commercial commodity. As they are used for method development for spaceborne imagers, the same level of scrutiny needs to be applied to the calibration and characterization of the devices in both cases.

Large systematic errors caused by stray light have been reported for some hyperspectral instruments (ROSIS, SeaWIFS) [1, 2]. This information motivated an investigation of the stray light properties in flight geometry of a hyperspectral instrument operated by DLR in a way that would allow a subsequent correction of this effect in the measurement data [3, 4]. An instrument chosen for the studies was the HySpex VNIR-1600 of NEO [5], one of the two devices acquired for the development of physically-based inversion algorithms, atmospheric corrections, for calibration/validation activities as well as for the preparation of the EnMAP mission [6]. Furthermore, a quantification of the stray light properties is essential for an assessment of the measurement uncertainties.

In this contribution, measurements of the stray light characteristics of the instrument of DLR using the PLACOS facility at PTB [7] as well as a derivation of a correction tensor and the validation of the applied corrections will be discussed.

MATERIALS AND METHODS

The essential properties of the instrument with an expander lens that is normally used during airborne operations and approximately doubles the instrumental field-of-view (FOV) are listed in Table 1. Additional information about the sensor and other characterization results can be found in [8].

Table 1. Properties of the HySpex VNIR-1600 instrument with the FOV expander. The values for spectral bandwidth and the IFOVs are valid only at the center of the FOV and degrade toward the edges of the FOV.

	HySpex VNIR-1600
Detector technology	Si CCD
Spectral range	416 nm – 992 nm
Spectral sampling interval	3.6 nm
FOV	34.5°
IFOV (across track)	0.37 mrad
IFOV (along track)	0.5 mrad
Pixels	1600
Channels	160

To match the geometry requirements of the hyperspectral instrument during the stray light characterisation, a high quality mirror collimator with a focal length of 750 mm and a clear aperture of 100 mm was used. A 0.5 mm slit at the focal point of the collimator was irradiated by a fiber bundle (see Figure 1). The laser beam was coupled into the fiber using a micro-lens beam homogeniser. By turning the HySpex VNIR instrument and tuning the laser wavelength, any detector pixel within its FOV could be targeted (see Figure 2) yielding line spread functions (LSF) both in the spatial and the spectral domains (see Figures 3 and 4). The measurements were carried out at seven angular positions (spatial pixels) throughout the whole spectral range of the instrument. Based on the recorded LSFs, a tensor for the stray light correction was determined following the approach of [3, 4]. To cope with the large amounts of data, the 2D data of the hyperspectral sensor was interpolated and binned in the spatial domain reducing the dimensions of the data frames from 1600*160 to 16*160. Details on the necessary data processing steps and results of the validation measurements will be presented at the conference.

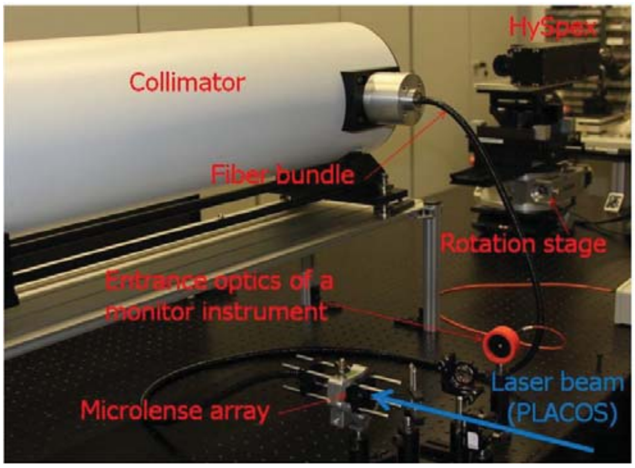

Figure 1. Arrangement of the instruments during the stray light characterisation of HySpex VNIR-1600.

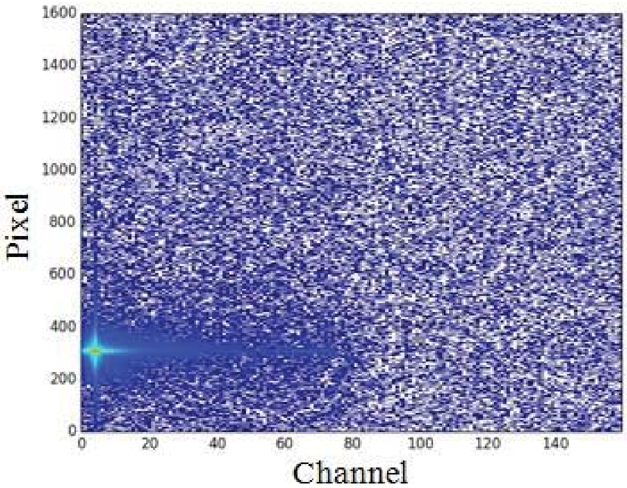

Figure 2. Dark value-corrected signal of the instrument; pixel No. 308 is irradiated at 430 nm.

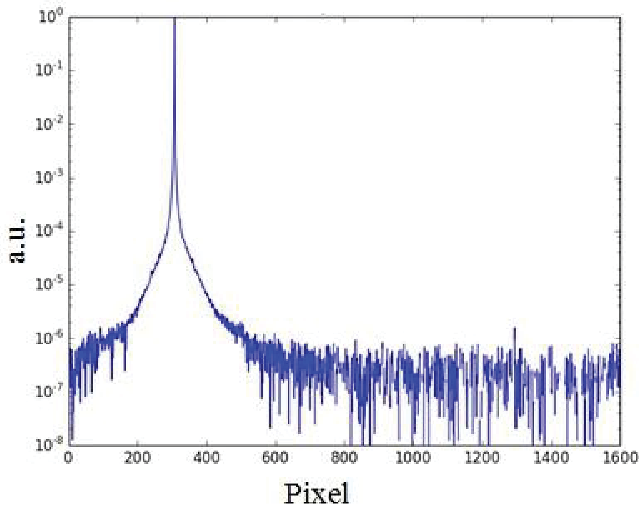

Figure 3. LSF of spectral channel No. 5 (430 nm) in the spatial domain.

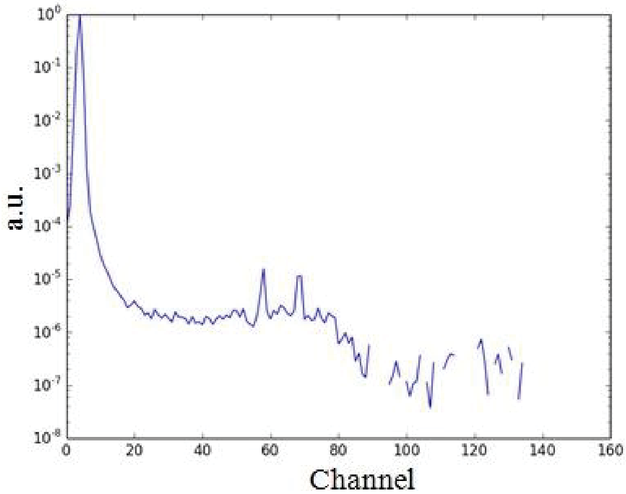

Figure 4. LSF of pixel 308 in the spectral domain.

ACKNOWLEDGEMENT

Part of this work has been supported by the European Metrology Research Programme (EMRP) within the joint research project Metrology for Earth Observation and Climate (MetEOC). The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

REFERENCES

1. G. Acker, B. Hooker, R. Firestone, A. Barnes, W. Holmes, and E. Esaias, Stray Light in the SeaWiFS Radiometer, Memorandum SeaWiFS Volume 31. Nasa Technical Memorandum, 1995.
2. K. Lenhard, P. Gege, and M. Damm, Implementation of algorithmic correction of stray light in a pushbroom hyperspectral sensor, in Proceedings of 6th EARSeL Workshop on Imaging Spectroscopy, Tel Aviv, 2009.
3. Y. Zong, S. W. Brown, B. C. Johnson, K. R. Lykke, and Y. Ohno. Simple spectral stray light correction method for array spectroradiometers, Appl. Opt., 45, 1111–1119, 2006.
4. M. E. Feinholz, S. J. Flora, S. W. Brown, Y. Zong, K. R. Lykke, M. A. Yarbrough, B. C. Johnson, and D. K. Clark. Stray light correction algorithm for multichannel hyperspectral spectrographs, Appl. Opt., 51, 3631-3641, 2012.
5. Norsk Elektro Optikk. NEO HySpex website. http://www.hyspex.no/, Dec. 2013.
6. H. Kaufmann, K. Segl, S. Chabrillat, S. Hofer, T. Stuffler, and A. Mueller. EnMAP, A hyperspectral sensor for environmental mapping and analysis, in Proceedings of IGARSS, Denver, CO, USA, 2006.
7. S. Nevas, M. Lindemann, A. Sperling, A. Teuber, R. Maass, Colorimetry of LEDs with array spectroradiometers, MAPAN - Journal of Metrology Society of India, 24, 153-162, 2009.
8. K. Lenhard, A. Baumgartner, and T. Schwarzmaier, Independent laboratory characterization of NEO HySpex Imaging Spectrometers VNIR-1600 and SWIR-320M-E, *submitted to* IEEE TGRS, 2014.