Out-of-range stray light and NiSO$_4$ filter characterization of single-monochromator Brewers

Tomi Pulli, Petri Kärhä, Anna Vaskuri, Maksim Shpak, Farshid Manoocheri
Metrology Research Institute, Aalto University, Finland

Tomi Karppinen, Juha M. Karhu, Kaisa Lakkala
Finnish Meteorological Institute, Arctic Research Centre, Finland

Joop Mes
Kipp & Zonen, The Netherlands
Contents

1. Background
2. Measurement results
   1. Out-of-range stray light measurements
   2. Solar blind filter transmittance measurements
3. Stray light analysis
4. Conclusions

This work has been supported by the European Metrology Research Programme (EMRP) within the joint research project EMRP ENV59 Atmoz “Traceability for atmospheric total column ozone.”
Background

Stray light

Brewer MKIV Spectrophotometer Operator’s Manual

**Background**

**Stray light**

- Differences between single- and double-monochromator Brewer results at short wavelengths.
- Some differences even after *in-range* stray light correction.
  - Measurement range stops at about 340 nm.
- How about *out-of-range* stray light?
  - *Higher irradiance level* in visible than in UV region.

Background

Stray light


Double Brewer

Single Brewer

5 wavelength correction

Single Brewer

325 nm laser correction
Measurement results
Stray light measurement of FMI Brewer

**Measurement setup**

- Stray light characterization of Brewer MKII #037 of FMI in Sodankylä.
- One in-range (325 nm) and multiple out-of-range wavelengths.
- Different input ports utilized.
Stray light measurement of FMI Brewer

In-range stray light

- **Fixed laser line** at 325 nm contributes to the signal at other monochromator positions.

- How does radiation at different wavelengths contribute to the signal at a fixed monochromator position?
  - Flip the figure and take into account the spectral responsivity of the instrument.
Stray light measurement of FMI Brewer

**In- and out-of-range stray light**

- **Fixed monochromator position** at 325 nm sees contribution from other wavelengths.
- Part of the stray light profile can be determined from the measurement at 325 nm.
  - Assuming that slit scattering function retains its shape in-band.
- No detectable signal with out-of-range lasers, i.e. limited by the noise floor of the measurement.
  - Worst-case estimates!

![Graph showing normalized reading against wavelength (radiation) in nm.](image-url)

- Steep drop because the responsivity of the instrument decreases rapidly after 325 nm.
Solar blind filter characterization

Background

- Solar blind filter consists of a NiSO₄ piece sandwiched between UG-11 glass filters.
- Used in single-monochromator Brewers to prevent out-of-range radiation from entering the PMT.
- Questions:
  1. Are there any leaks in the stopband?
  2. What happens when the filters age?

(Thanks to Kipp & Zonen and AEMET for providing the samples.)
Solar blind filter characterization

*Spectral transmittance*

- Measured using a spectrophotometer.
- *No leaks in the stopband*, i.e. noise limited.
- Differences in the shapes of the pass- and transition bands between different filters.
Solar blind filter characterization

Spatial uniformity of transmittance

Measured by scanning the surface with HeCd laser at 325 nm.
Solar blind filter characterization

Spatial uniformity of transmittance

Measured by scanning the surface with HeCd laser at 325 nm.

- Higher than average transmittance.
- Lower density of NiSO$_4$ and thus higher stopband transmittance?
- UG-11 filters still in good condition.
Stray light analysis
Stray light analysis

**Parameters and assumptions**

- How much of the stray light we can get rid of when we extend the stray light correction to 325 nm, 340 nm and 350 nm?

- **Instrument parameters**
  - **Slit scattering function:** 325-nm HeCd measurement
    - Assumption: retains its shape at other wavelengths. Constant base-level of \(2 \cdot 10^{-5}\).
  - **Responsivity of the instrument (UV and visible):** Combination of a typical PMT responsivity and the measured filter transmittance (with worst-case stopband transmittance).
    - Ignores the effect of other optical components.

- **Sources**
  - **Measured spectrum:** Typical solar spectrum (AM1.5)
  - **Calibration source:** Tungsten filament lamp.
Stray light analysis

Effect of in- and out-of-range light

Measured irradiance spectrum
- With and without stray light correction
- Effect of stray light correction cutoff (deconvolution limit)

Difference between measured (+corrected) signal and the actual spectrum
Conclusions

• Out-of-range stray light properties of single-monochromator Brewers measured and analyzed.
  • Out-of-range stray light itself should not be an issue.
• **Careful stray light analysis in the passband required.**
  • Transition band (325–350 nm) still affects the stray light correction to some extent.
  • Open question: Does slit scattering function retain its shape in the passband?
• **Solar blind filters may exhibit large spatial nonuniformity.**
  • NiSO$_4$ (salt) absorbs humidity? → Areas of high and low NiSO$_4$ density
  • Possible stopband leaks in areas with low NiSO$_4$ density?