Contents

• Spectral features overview

• Speckle theory vs spectral features

• Diffuser trade-off study
On-board diffuser on earth observation satellites

- Instruments for atmospheric space research measure the sunlight diffusely reflected and absorbed in the atmosphere and at the Earth’s surface.

- As a reference spectrum for atmospheric measurements the diffuse reflection of the sun is measured via an ‘on-board diffuser’ in the satellite sensor.

- On-board diffusers add a spectral signature to the diffusely scattered sunlight that may resemble certain spectral characteristics of the atmosphere, the so-called SPECTRAL FEATURES.
Spectral features on diffusers

Spectral features dedicated set-up

*spectral features* on Aluminium diffuser

GOME 2 FM2 *spectral features* on Aluminium diffuser
Theoretical approach: speckle effect

Speckle effect = *interference of coherent (or partially coherent) beams of radiation from many secondary light point sources located on the rough surface of an object.*

Speckle contrast

\[
C = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} = \frac{\Delta I}{I}
\]

Speckle size

\[
d_s = 0.61 \cdot \frac{\lambda}{N.A.} = 1.22 \cdot \lambda \cdot f_#
\]
Speckle with (partially) coherent light

Speckle pattern in partially coherent light, from LASER SPECKLES, J.C. Dainty (1975).
Spectral features vs speckle effect

Entrance slit of the spectrometer

Detector pixels

Dispersion

(Partially) coherent light on a rough surface

Diffuser surface

Variation of the number of speckles on a detector cell

Spectral features on Aluminium diffuser

Ratio

Wavelength [nm]

0.0% - 6.0%

360 460 560 660 760
Spectral features empirical formula

\[ V_{SF} = C \cdot \frac{V_{\text{speckles}}}{\# \text{speckles}} \cdot \frac{f(\bar{e})}{\sqrt{\# \text{Ind. Spectra}}} \cdot \frac{P}{Q} \]

- Scaling factor
- Contrast in the speckle pattern
- Wavelength effects
- Effect of the polarization
- Number of independent speckle patterns that are being averaged during a recording
- Diffuser quality factor
**Diffuser trade-off**

**Objectives**: establish appropriate diffuser technology for on-ground calibration/validation and for the on-board calibration systems to be used in future earth observation mission.

**Measurement programme**:

- Measurement and analysis of Spectral features of 5 diffusers over the spectral range 250-1600 nm (2400).
- Measurement of the effect of environment (air/vacuum/degradation) on diffuser’s BSDF accuracy over the spectral range 280 –1000 nm.
<table>
<thead>
<tr>
<th>Diffuser type</th>
<th>Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aluminium</em></td>
<td>TNO TPD</td>
</tr>
<tr>
<td>Material = Aluminium</td>
<td></td>
</tr>
<tr>
<td>Space qualified = Yes (SCIAMACHY, …)</td>
<td></td>
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<tr>
<td><em>SPECTRALON</em></td>
<td>Labsphere</td>
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<tr>
<td>Material = PTFE</td>
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<tr>
<td>Space qualified = Yes (MERIS, …)</td>
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<tr>
<td><em>FLUORION</em></td>
<td>Avian Technology</td>
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<tr>
<td>Material = PTFE</td>
<td></td>
</tr>
<tr>
<td>Space qualified = No</td>
<td></td>
</tr>
<tr>
<td><em>White Tile</em></td>
<td>NPL</td>
</tr>
<tr>
<td>Material = Depolished white ceramic</td>
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<tr>
<td>Space qualified = No</td>
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<tr>
<td><em>QVD</em></td>
<td>TNO TPD</td>
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<tr>
<td>Material = Quartz</td>
<td></td>
</tr>
<tr>
<td>Space qualified = Yes (GOME2, OMI, …)</td>
<td></td>
</tr>
</tbody>
</table>
SF dedicated Measurement set-up
The Test facility has been modeled using the 1D Spectral Features analysis package (in MatLab).

The modeling consists of four steps:

- A simulation of the scattering surface has to be made (the diffuser)
- The optical beam has to be propagated towards an intermediate image (free space propagation)
- Fourier Transform mode as performed by a single lens
- Integrate the intensity over the entrance slit
Conclusion

- Relationship between spectral features and speckle effect

- Spectral features measurement program:
  - 5 diffuser types (surface, volume, stacked)
  - Measured over the spectral range 250 nm – 1600 nm
  - Results extrapolated up to 2400 nm thanks to the speckle model

- Measurement campaign begins on Friday at TNO TPD

Which instruments are affected ??? ➔ bazalgette@tpd.tno.nl
Jokers
Spectral features on diffusers

Spectral features dedicated set-up

spectral features on Aluminium diffuser

GOME 2 FM2 spectral features on Aluminium diffuser
Spectral features dependencies

Wavelength

Light source characteristics

Diffuser material

Spectral features in the UV range

Spectral features measured with a point source

Spectral features on Aluminium diffuser

Spectral features in the visible range

Spectral features measured with an extended source

Spectral features on QVD (Quasi-Volume Diffuser)

Diffuser material

Light source characteristics

Wavelength

13 October 2004