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# Diffuser trade-off study vs spectral features

TNO TPD



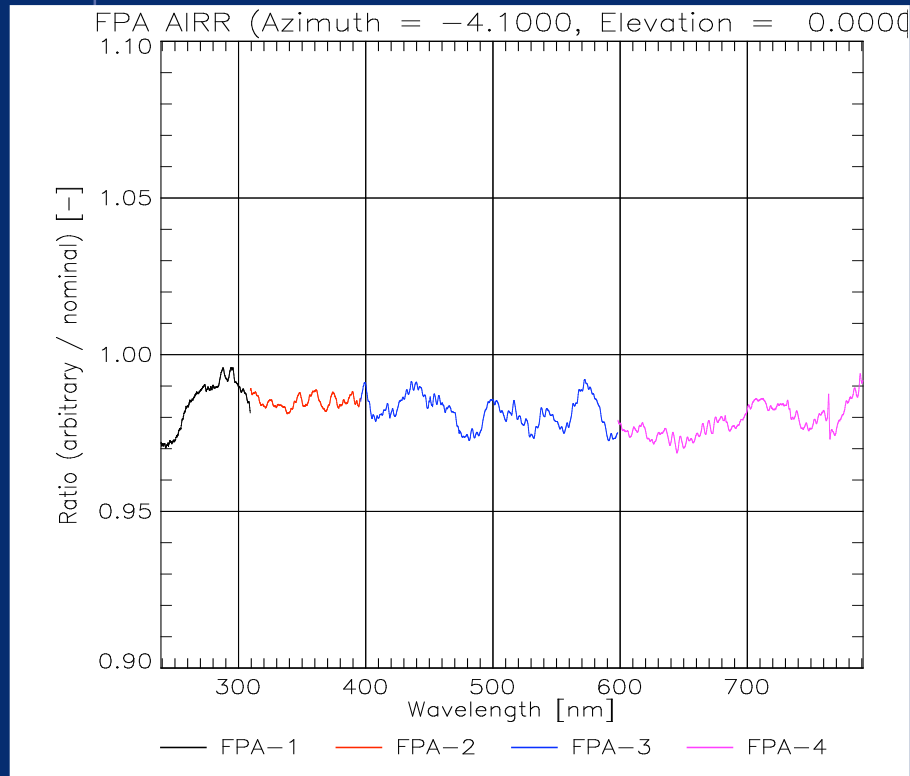
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- Spectral features overview
- Speckle theory vs spectral features
- Diffuser trade-off study

# On-board diffuser on earth observation satellites

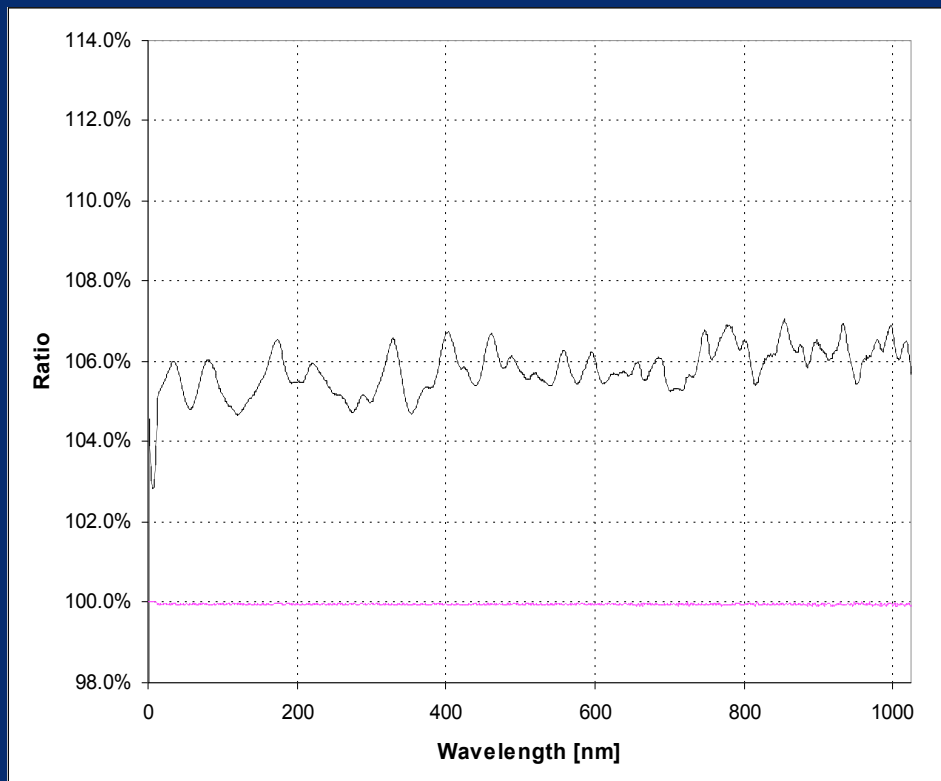
- Instruments for atmospheric space research measure the sunlight diffusely reflected and absorbed in the atmosphere and at the Earth's surface.
- As a reference spectrum for atmospheric measurements the diffuse reflection of the sun is measured via an 'on-board diffuser' in the satellite sensor.
- on-board 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



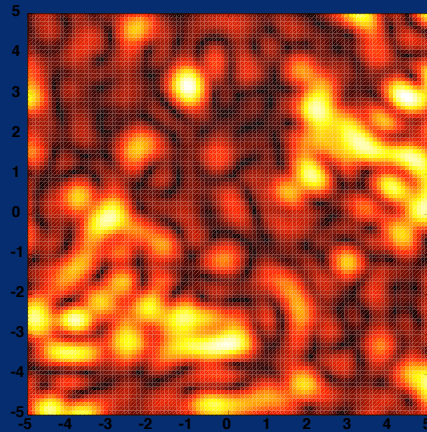
**GOME 2 FM2 spectral features on Aluminium diffuser**

**Spectral features dedicated set-up**  
***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.*

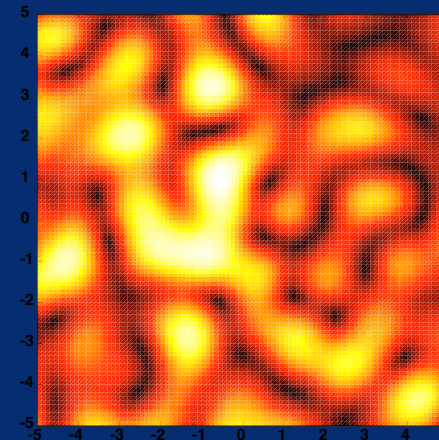


Speckle contrast

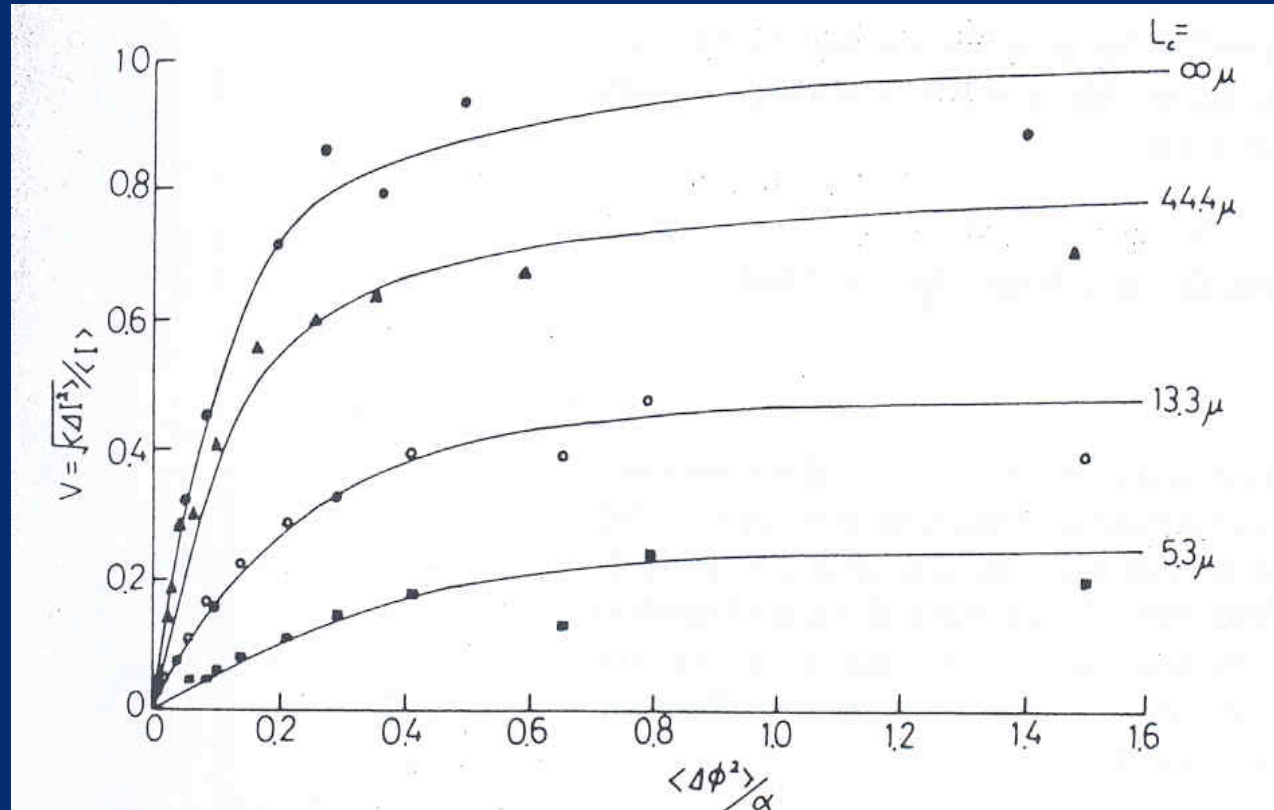
$$C = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} = \frac{\Delta I}{\bar{I}}$$

Speckle size

$$d_s = 0.61 \cdot \frac{\lambda}{N.A.} = 1.22 \cdot \lambda \cdot f_{\#}$$



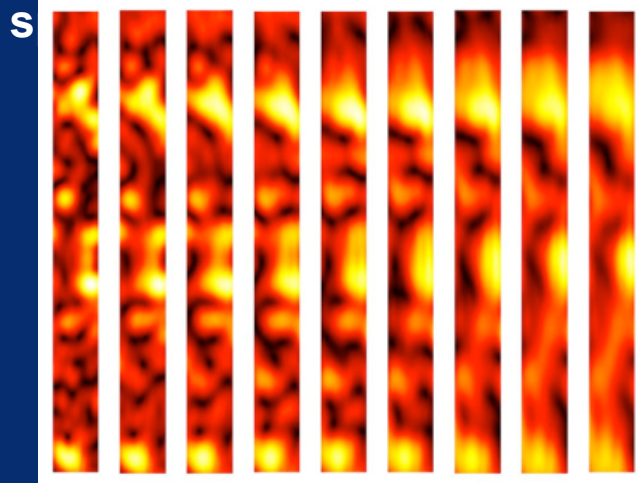
# Speckle with (partially) coherent light



*Speckle pattern in partially coherent light, from LASER SPECKLES, J.C. Dainty (1975).*

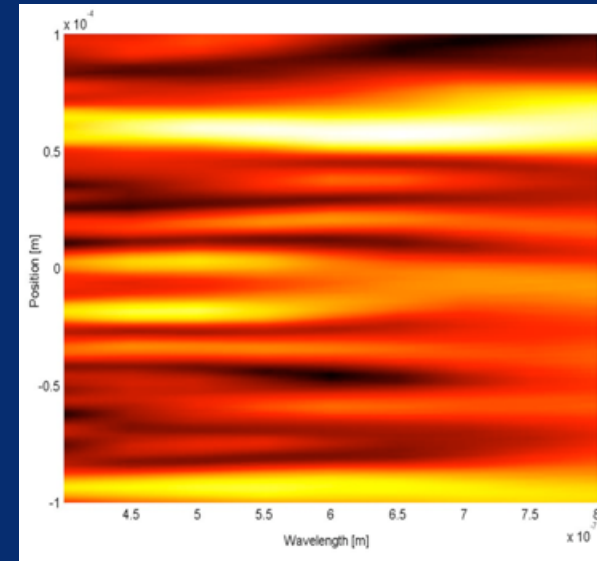
# Spectral features vs speckle effect

Entrance slit of the

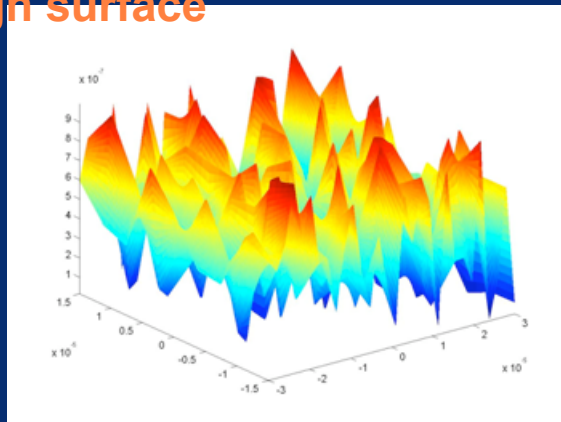


→  
Dispersion

Detector pixels



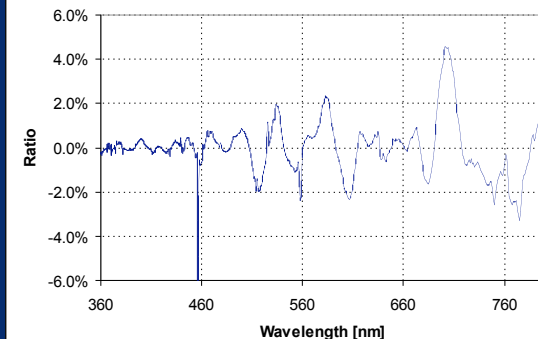
(Partially)  
coherent light on  
a rough surface



Diffuser surface

Variation of the  
number of speckles  
on a detector cell

Spectral features on Aluminium diffuser



Spectral features

# Spectral features empirical formula

Scaling factor

Contrast in the speckle pattern

Wavelength effects

Effect of the polarization

$$V_{SF} = C \cdot \frac{V_{speckles}}{\# speckles} \cdot \frac{f(\ddot{e})}{\sqrt{\# Ind. Spectra}} \cdot \frac{P}{Q}$$

Number of independent speckle patterns that are being averaged during a recording






Diffuser quality factor

# Diffuser trade-off

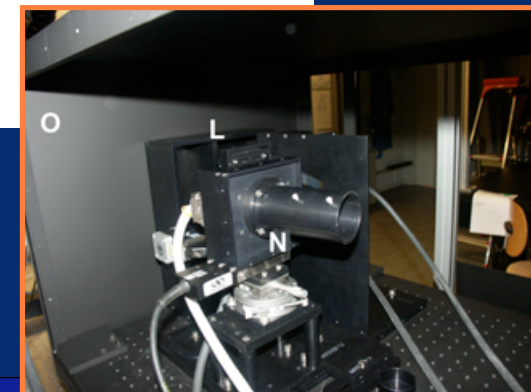
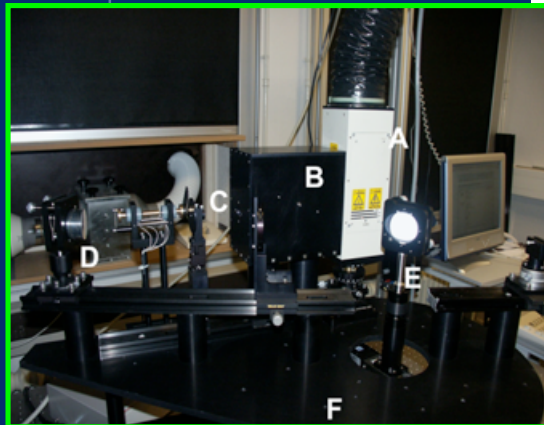
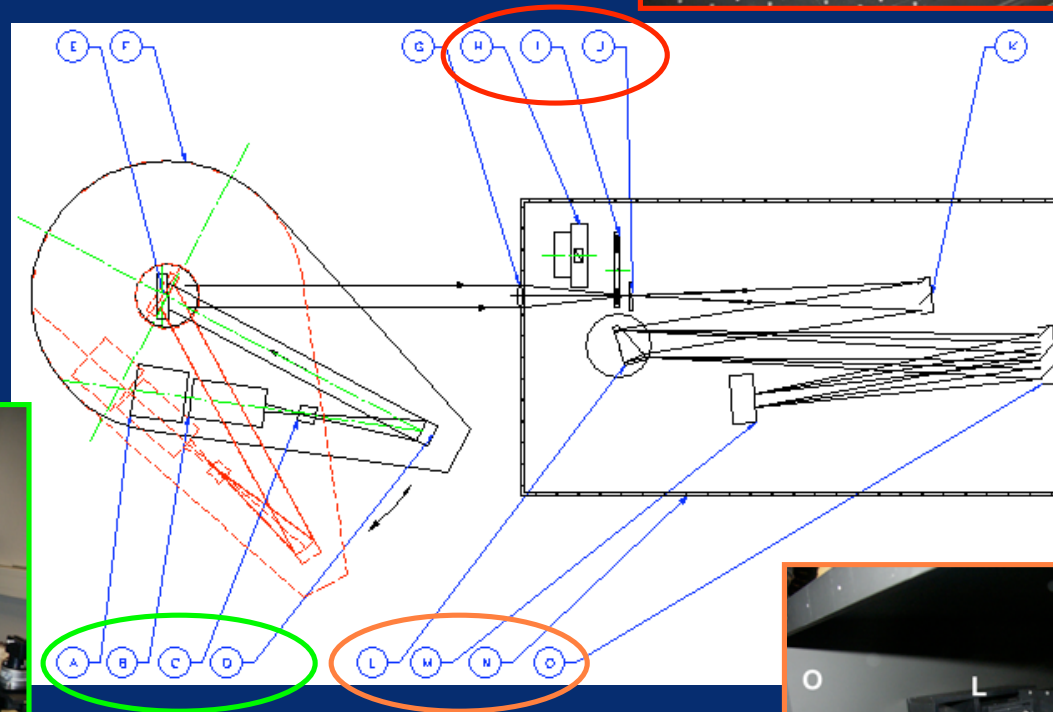
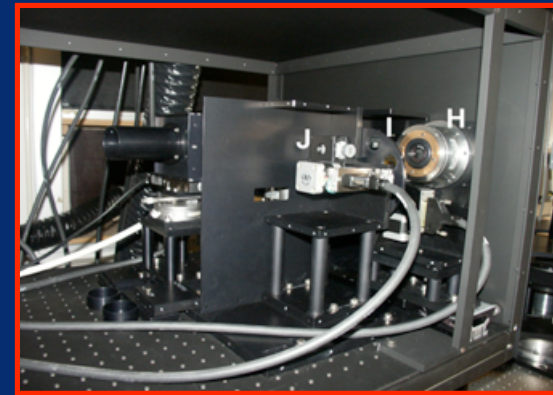
*Objectives* : establish appropriate diffuser technology for on-ground calibration/validation and for the on-board calibration systems to be used in future earth observation mission.

## *Measurement programme* :

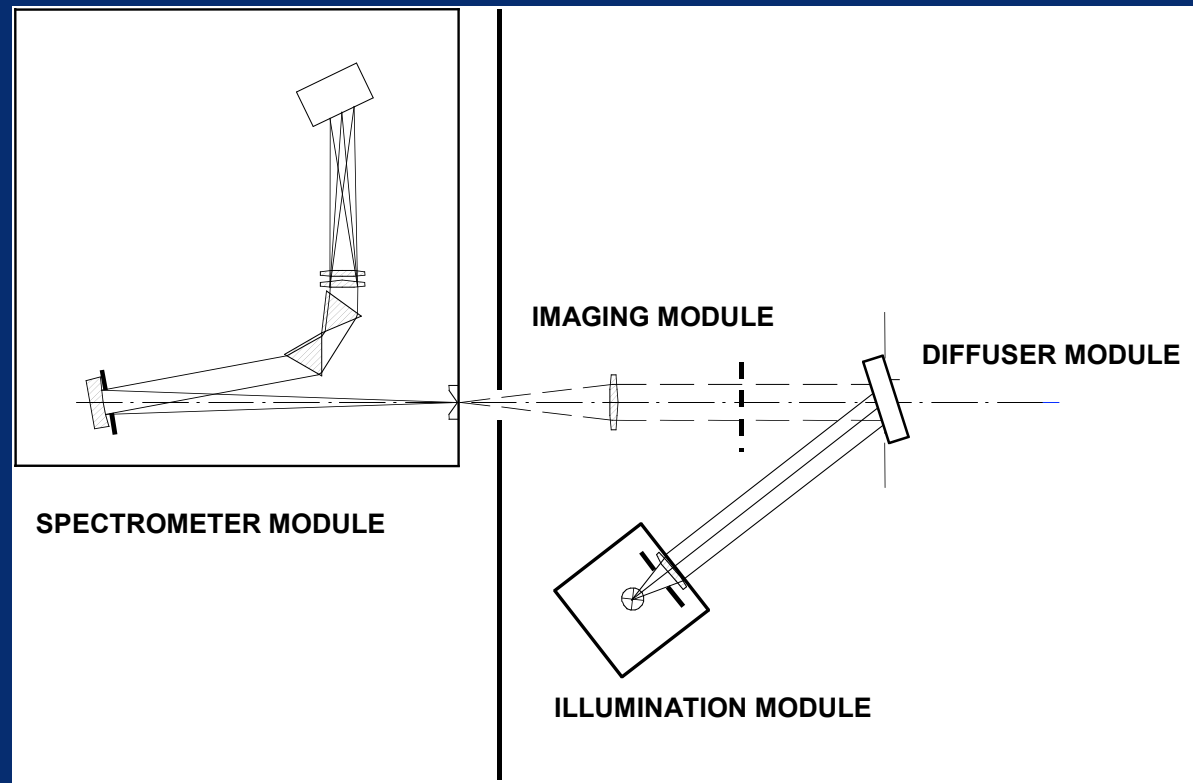
- *Measurement and analysis of Spectral features of 5 diffusers over the spectral range 250-1600 nm (2400).*
- *Measurement of the effect of environment (air/vacuum/degradation) on diffuser's BSDF accuracy over the spectral range 280 –1000 nm.*

	Diffuser type	Provider
	<i>Aluminium</i> Material = Aluminium Space qualified = Yes (SCIAMACHY, ...)	TNO TPD
	<i>SPECTRALON</i> Material = PTFE Space qualified = Yes (MERIS, ...)	Labsphere
	<i>FLUORION</i> Material = PTFE Space qualified = No	Avian Technology
	<i>White Tile</i> Material = Depolished white ceramic Space qualified = No	NPL
	<i>QVD</i> Material = Quartz Space qualified = Yes (GOME2, OMI, ...)	TNO TPD

# SF dedicated Measurement set-up



# Speckle Model (1)

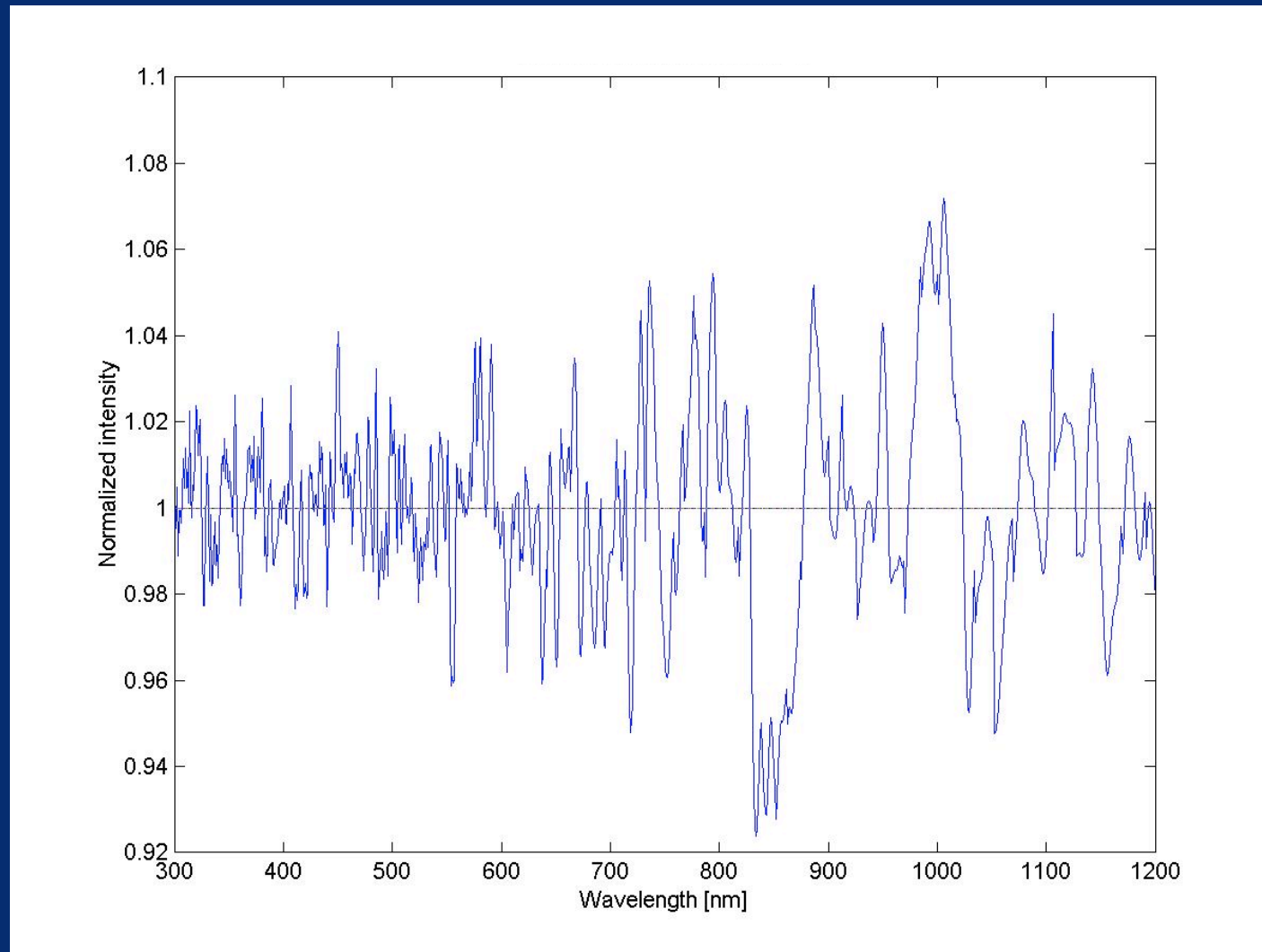


The Test facility has been modeled using the 1D Spectral Features analysis package (in MatLab).

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

# Speckle Model (2)



# Conclusion

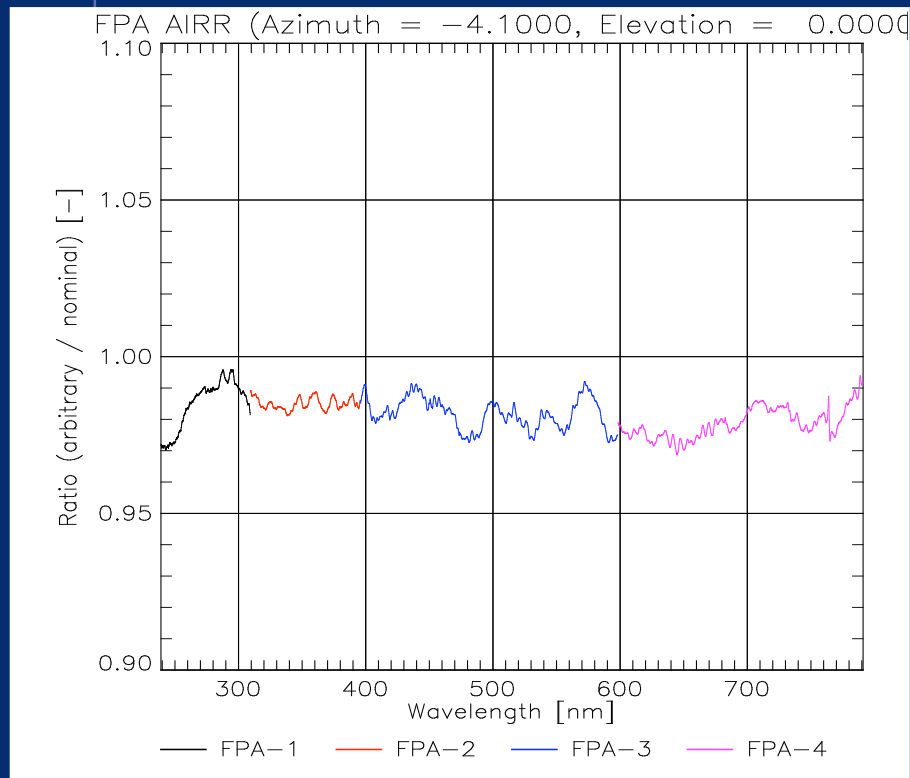
- Relationship between spectral features and speckle effect
- Spectral features measurement program :
  - 5 diffuser types (surface, volume, stacked)
  - Measured over the spectral range 250 nm –1600 nm
  - Results extrapolated up to 2400 nm thanks to the speckle model
- Measurement campaign begins on Friday at TNO TPD

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Which instruments are affected ??? → [bazalgette@tpd.tno.nl](mailto:bazalgette@tpd.tno.nl)

# Jokers

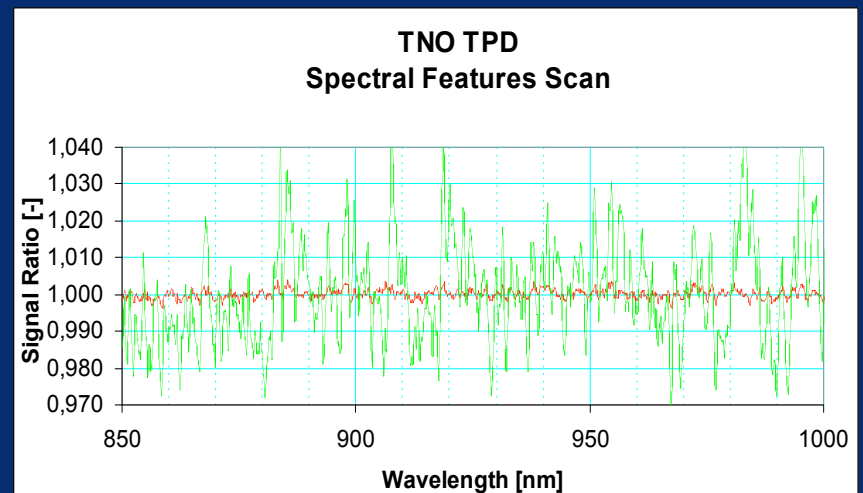
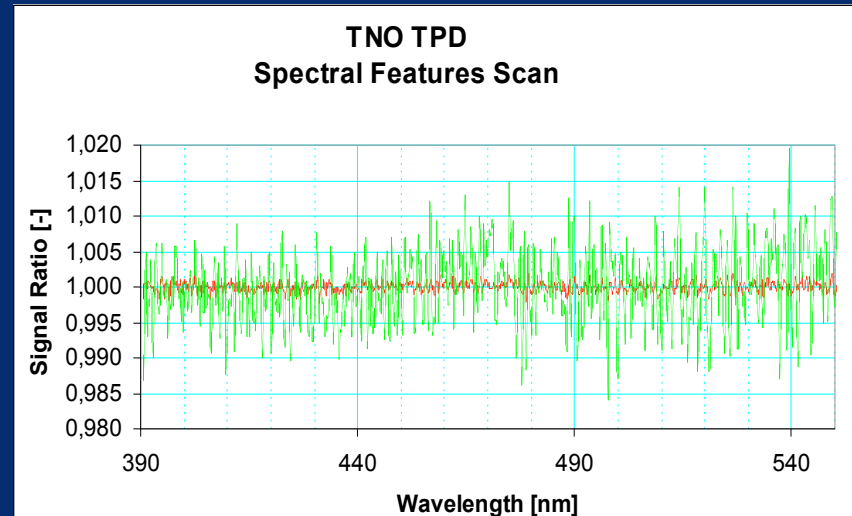
# Spectral features on diffusers



**GOME 2 FM2 spectral features on Aluminium diffuser**

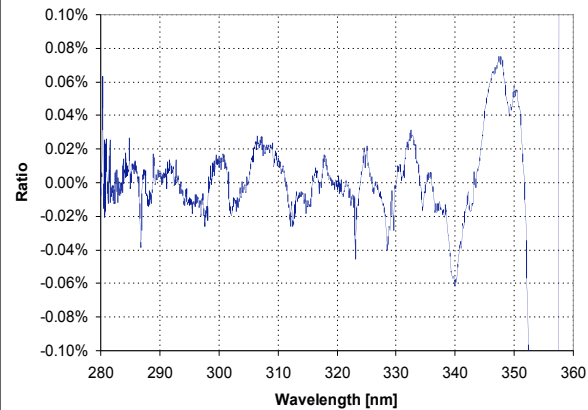
**Spectral features dedicated set-up**

***spectral features on Aluminium diffuser***

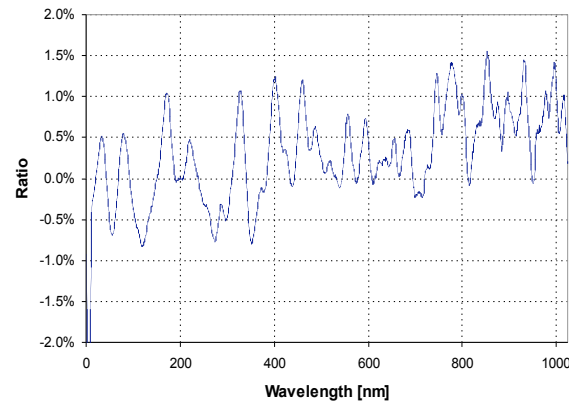


# Spectral features dependencies

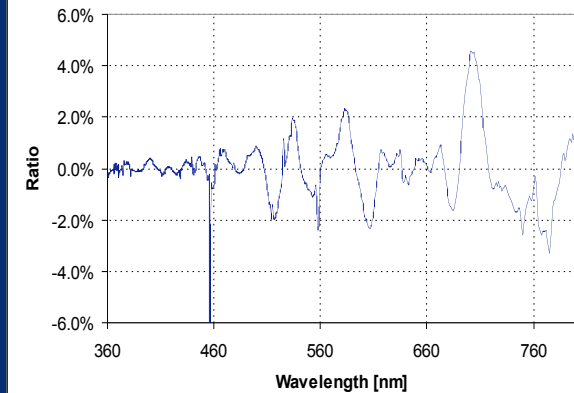
*Spectral features in the UV range*



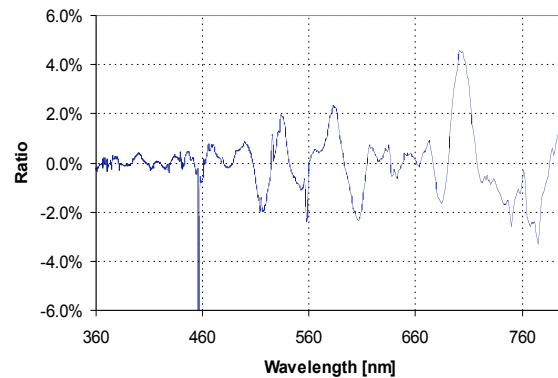
*Spectral features measured with a point source*



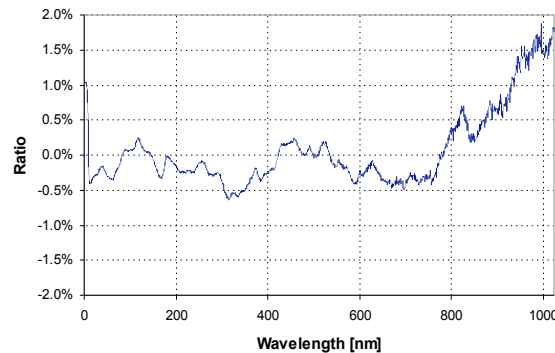
*Spectral features on Aluminium diffuser*



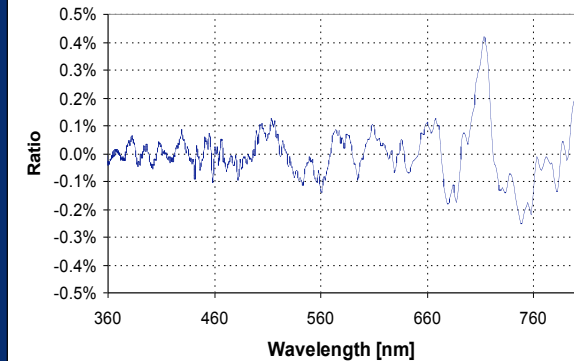
*Spectral features in the visible range*



*Spectral features measured with an extended source*



*Spectral features on QVD (Quasi-Volume Diffuser)*



Wavelength

Light source  
characteristics

Diffuser material