Presentation Overview

On-Ground Characterisation
1. Diffuser characterisation
2. Polarization sensitivity
3. Optical Transmission
4. Optical Distortion & Dispersion
5. Straylight
6. CCD Responsivity
7. MTF
8. Spectral Smile & Frown
9. Pointing

On-Orbit Characterisation
1. Offset stability
2. CCD Sensitivity to SAA
3. NEDL
Unit Level characterisation

Overview

- Er spectrum
- Diffuser BRDF
- Polarisation sensitivity
- Inverse Filter
- CCD Responsivity
- Optics transmission, Distortion & Dispersion
- Straylight
- MTF

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Diffuser Geometry

Illumination angle on diffuser maintained at 65.35 deg.

Azimuth angle varies along the year (21-35 deg)

The normal to the diffuser, the nadir pointing direction and the solar illumination direction for the nominal azimuth angle (27.5 deg) are in the same plane.
Diffuser Characterisation

Method

- Monochromator overfills the detector’s pupil - irradiance measurement
- Monochromator overfills measured area on the diffuser - radiance measurement.
- Reference detector monitors monochromator output during measurements

Error budget

<table>
<thead>
<tr>
<th>Error sources</th>
<th>Error Type</th>
<th>BRDF</th>
<th>Inter-Pixel</th>
<th>Inter-Band</th>
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<tr>
<td>Field of View</td>
<td>Bias</td>
<td>&lt;0.2%</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Angular precision</td>
<td>Random</td>
<td>0.10%</td>
<td>0.10%</td>
<td>-</td>
</tr>
<tr>
<td>Detector linearity</td>
<td>Random</td>
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<td>-</td>
<td>0.30%</td>
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<td>Beam Uniformity</td>
<td>Signed Bias</td>
<td>-0.15%</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Noise</td>
<td>Bias</td>
<td>0.35%</td>
<td>0.20%</td>
<td>0.20%</td>
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<tr>
<td>Polarisaton</td>
<td>Random</td>
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<td>0.20%</td>
<td>0.20%</td>
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<td>Straylight</td>
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<td>&lt;0.01%</td>
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<td></td>
<td>Signed bias</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bias</td>
<td>0.10%</td>
<td>0.10%</td>
<td>0.10%</td>
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<tr>
<td>Total</td>
<td>-</td>
<td>0.49%</td>
<td>0.26%</td>
<td>0.38%</td>
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</tbody>
</table>

Total error (1σ) = |ΣSb| + sqrt[ΣB^2 / 3 + Σc^2]

Double Prism Monochromator
- Beam divergence = 32 arcmin
- Beam diameter = 50mm
- Source = Xenon arc
- Polarisation < 0.5%
- Adjustable spectral bandwidth (Blue=3nm NIR=20nm)

Detector
- FoV = 1.2 deg
- Pupil = 14mm x 18mm
- Distance to diffuser = 350mm
- Polarisation < 1-4% (λ)

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Spectral dependence
BRDF Increases more toward forward scattering for longer wavelengths
Comparison with NASA

Inter-comparison with NASA (2000), agreement within measurement accuracy (1%)

MERIS diffuser characterisation data = TPD 1996

Monochromator and Detector head upgraded in 2000 at TPD.

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Comparison Diffuser 1&2

BRDF of Diffusers-1&2 at 410 nm

Ratio Diffusers-1&2 BRDF on-orbit

Ratio Diffusers-1&2 BRDF on-ground
Absorption Spectrum of Erbium doped Spectralon™ diffuser
Polarisation sensitivity

Scrambling Window Sub-Assembly (SWSA)
(In front: UV-filter & Scrambler assembly)

Scrambler residual monochromatic polarisation sensitivity [s/p]

Instrument Polarisation sensitivity < 0.3%

OSA POLARIZATION PERFORMANCE

Global OSA polarization sensitivity specification has been verified by AER at camera level.

Quantz Silica Scrambling Windows have been manufactured by FICHOU company (F).

110%
100%
The strong attenuation in the region 480nm to 620nm is due to the “inverse filter” whose purpose is to “flattens” spectrally the MERIS system response.

Orders +1, +2 and 0 are caught by light traps in the corrector block.
Optical Performances

X axis = field of view {-8, 8} mm   Y-axis = range {-8, 8} μm
(pixel=22 μm / 1.25nm, FoV = 740 pix)

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Straylight Characterisation

Total Integrated Scatter (TIS) measurements performed on all optical surfaces (and coatings) using “as built“ witnesses.

ASAP model result on axis for 585nm

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CCD Characteristics

MERIS CCD25-20
Spectral Response (Wedge Coated FM)

MERIS CCD25-20
PRNU (Wedge Coated FM)

Pixel Response Non-Uniformity (PRNU)

Architecture: Frame transfer
Size: 780 mm x [576 x 2] (V)
Pixel size: 22.5 μm x 22.5 μm
Technology: Thinned CCD
(thickness = 17 μm)
Back side illuminated

260 m
1.25 nm
Non-linearity

- Rms non-linearity < 0.1% of full range, increases to > 1% at low signal levels.

- Non-linearity primarily due to CCD output trans-impedance amplifier.

- Very low integral and differential non-linearity of the ADC.

- Plot represents NL at CCD output (4096 counts = 1.5V full range.)

Non-linearity measured performed at:
- CCD level by varying integration time
- Analogue Imaging Chain level (above) by varying distance to the light source

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Camera Level Characterisation
Overview

**Camera Level Characterisation**
(Thermal Vacuum)
- MTF
- Spectral Smile
- Spectral Frown

**Camera integration bench**

**Camera performance test bench**

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Modulation Transfer Function

MTF (22lp/mm) as a function of wavelength for:
- Full resolution (FR=300m) Along track (AL) FoV [deg] [Fnyquist=1.542]
- Full resolution (FR) Across track (AC) FoV [deg] [Fnyquist=1.496]
- Reduced resolution (RR=1200m) Across track (AC) FoV [deg] [Fnyquist=0.374]

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Localisation of spectral line #274 (B11)

- CAM FM1 spectro
- CAM FM2 spectro
- CAM FM3 spectro
- CAM FM4 spectro

- Theoretical position
- Lower limit
- Upper limit

Pixel

Max \(\text{wav} \) 760.5 nm
Min \(\text{wav} \) 759.5 nm
Max-Min 1.0 nm

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Spectral Characteristics

Deviation from linear dispersion

Spectral pixel Line shape example and associated Gaussian model

Modelled Band 13 Line shape (16 spectral pixels)

Modelled Band 11 Line shape (2 spectral pixels)

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Spectral pixel band to band registration
(in terms of 300m resolution pixels)

(*) average over all possible pairs of spectral bands
MERIS Level Characterisation

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Ground Support Equipment

Precision Manipulator

Solar Simulator
Pointing Characterisation

- Pointing Characterisation with Laser Theodolite

Along track offset (FR pixels)

West

Flying direction

East

FOV = 68.6

Overlap (FR pixels)

Specified Swath

0.4

1.6

1.1

1.3

1.0

30

32

27

29

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On-Orbit Characterisation

- CCD Temperature very stable
- VEU temperature drift 6 degrees

- Offset Control Loop converges well
- 0.6mV / 1.5 V Dynamic range

Dark Current characterisation, complete orbits with the shutter closed in Observation mode.

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Dark Current characteristics

South Atlantic Anomaly

Spikes in the dark current when flying through the SAA, more important for the smear band.

Probably due to the secondary emission from the Alumium mask on the CCD, and the Gold coating on the window.

Orbit 292 Dark Current OCL ON

Orbit 293 Dark Current OCL OFF

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Diffuser “Speckle”

Across Track

Yearly cycle of solar azimuth angle on diffuser

Speckle increases with increasing wavelength

Speckle increases with increasing azimuth differences

Raw counts [DN] relative differences

European Space Agency
Agence spatiale européenne

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Diffuser “Speckle”
Along–Track

Diffuser “speckle” confirmed by TNO study
=> Present on all diffusers

Illumination duration = 200 sec

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**SNR Computation**

**Methodology using diffuser observation:**
1. Difference from linear fit of Raw counts
2. Difference from cubic fit of selected region from 1.
3. Compute the standard deviation (1σ) of noise
4. Adjust the noise (2σ) to the specified signal level (Assuming shot noise limited)
5. Compute SNR

**Assumptions:**
The large modulations are “speckle” based only!

---

**STD=6.068 [DN]**
**Signal=17573 [DN]**
Signal to Noise Ratio

### SNR Specifications (Goal, Spec), Estimated SNR at three signal levels (Cal, Ocean, Meas) [W/m²/sr/nm]. Note that the specifications include two “Land” bands and one “cloud” bands.

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<th>Goal</th>
<th>Spec</th>
<th>Cal 2st</th>
<th>Ocean 2st</th>
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