The ICON FUV Instrument

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S. Ellis – Photon Engineering
Agenda

- ICON FUV Science
- Key requirements
  - Sensitivity.
  - Stray light rejection.
- Description of the Instrument
- Calibration Test Setup
- Calibration Results
- Instrument Performance
FUV is a two channel spectrographic imager that measures the intensity and spatial distribution of atomic oxygen (135.6 nm) and molecular nitrogen (157 nm) (Lyman-Birge-Hopfield, LBH) emissions on the limb.

- Daytime photoelectron excited neutral O and N\textsubscript{2} atmosphere.
- Nighttime recombinining O\textsuperscript{+} ionosphere
- Optical design based on IMAGE FUV (developed by UC Berkeley and CSL), detectors based on ISUAL.
  - Grating spectrometer
  - Intensified CCD detectors
At night FUV will point along the magnetic field to observe the intensity distribution of the ionospheric O⁺ ions.

- Illustration of ICON operations

FUV observes on the left (port) side of ICON. On the limb the maximum emission is seen at the tangent point. At sub limb height integrated emissions are observed.
Spectral distribution (midday nadir) in wavelength range of interest for ICON FUV [Meier, 1991]
In a spectrographic imager type of instrument, the spectral dispersion and the imaging are in “quadrature,” i.e. separate and independent of each other. The top diagram describes the spectral wavelength selection while the bottom explains the imaging operation of the same instrument. These diagrams show lenses as the optical elements for simplicity however in the FUV region it is necessary to use mirrors instead.

Spectral selection. Light enters through entrance slit. Collimator lens provides parallel light for grating. Tx grating disperses the light according to wavelength (red-blue). Exit slit defines the spectral profile of the transmitted light. Detectors pick up light arriving from exit slit.

Imaging. Collimator lens acts as an objective focusing the scene on the grating as an intermediate image. Camera lens combined with back imager small lenses re-image intermediate image on detectors.
ICON FUV is a Czerny-Turner spectrographic imager. Turret contains a movable steering mirror and a fixed entrance slit.

M1 focuses the object viewed by the instrument on the grating as an intermediate image. This image is then re-imaged on the detectors by M2 and by the back imager optics consisting of two mirrors CM1 and CM2 in each channel. There are two wavelength channels short (SW) and long (LW) wavelength. The two wavelength channels are handled by separate exit slits, back imager optics and detectors.
ICON FUV Instrument Functional Layout

ICON FUV is a Czerny-Turner spectrographic imager. Turret contains a movable steering mirror and a fixed entrance slit. M1 focuses the object viewed by the instrument on the grating. This intermediate image is then re-imaged on the detectors by M2 and the back imager optics. The two wavelength channels are handled by separate exit slits, back imager optics and detectors.
### Level 4 Requirement: Instrument sensitivity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
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<tbody>
<tr>
<td>Slit area 5mm x 32 mm</td>
<td>1.6</td>
<td>cm²</td>
</tr>
<tr>
<td>Field of view 24° x 18°</td>
<td>0.14 (truncated circle)</td>
<td>sr</td>
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<tr>
<td>Equivalent F No. = 2.3</td>
<td></td>
<td></td>
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<tr>
<td>Étendue per science rescell</td>
<td>6.85e-05*</td>
<td>cm² sr</td>
</tr>
<tr>
<td>Photon collection rate</td>
<td>5.45 (Single stripe)</td>
<td>Photons/sec/Rayleigh/rescell</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Reflective Efficiency</th>
<th>Quantum efficiency</th>
<th>Efficiency Predicts BOL</th>
<th>Efficiency Predicts EOL</th>
<th>Total efficiency measured</th>
<th>Total Counting Rate/kR/rescell/sec</th>
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<tbody>
<tr>
<td>Scan Mirror</td>
<td>90.00%</td>
<td>11.00%</td>
<td>0.54%</td>
<td>0.46%</td>
<td>0.45%</td>
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<td>Turret Fold 1</td>
<td>90.00%</td>
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<td></td>
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<td></td>
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<tr>
<td>Turret Fold 2</td>
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<tr>
<td>Spectrograph M1</td>
<td>92.00%</td>
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<td>Spectrograph M2</td>
<td>91.00%</td>
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<tr>
<td>Back Imager SW CM1</td>
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<tr>
<td>Back Imager SW CM2</td>
<td>93.00%</td>
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<td>LW fold</td>
<td>90.50%</td>
<td></td>
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<tr>
<td>Back Imager LW CM1</td>
<td>88.40%</td>
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<tr>
<td>Back Imager LW CM2</td>
<td>82.00%</td>
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<tr>
<td>Total Reflective Efficiency</td>
<td>46.42%</td>
<td></td>
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<td>Grating eff</td>
<td>17.50%</td>
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<td>Quantum efficiency</td>
<td>11.00%</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Efficiency Predicts BOL</td>
<td>0.54%</td>
<td></td>
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<tr>
<td>Efficiency Predicts EOL</td>
<td>0.46%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total efficiency measured</td>
<td>0.45%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Counting Rate/kR/rescell/sec</td>
<td>147</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
</tbody>
</table>

*Instrument Sensitivity with 300 km O emission tangent height.*
# Key Requirements and Design Considerations

<table>
<thead>
<tr>
<th></th>
<th>L4 Requirement</th>
<th>Capability</th>
<th>Implementation</th>
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<tbody>
<tr>
<td>Spectral Resolution</td>
<td>Image OI 135.6 and N2 LBH bands</td>
<td>Complies</td>
<td>2 channel grating spectrograph</td>
</tr>
<tr>
<td></td>
<td>Suppressing 130.4 to &lt; 2%</td>
<td>&lt;1%</td>
<td>Grating line density, slit width</td>
</tr>
<tr>
<td>Radiometric Performance</td>
<td>Sensitivity of: &gt;13 counts/sec/res-el/kR @135.6</td>
<td>147 @ 135.6 night 6 stripes co-added</td>
<td>Large étendue, high reflectivity coatings, high QE UV converter, contamination control</td>
</tr>
<tr>
<td></td>
<td>&gt;8 counts/sec/res-el/kR @LBH</td>
<td>52.3 @ 157 (6 stripes can be co-added)</td>
<td></td>
</tr>
<tr>
<td>Spatial coverage, FOV</td>
<td>Field aligned observations</td>
<td>Steerable FOV with range +/- 30°</td>
<td>Steerable baffle (turret)</td>
</tr>
<tr>
<td>and Resolution</td>
<td>Vertical FOV of &gt; 20°</td>
<td>Vertical 24° Horizontal 18°</td>
<td>Wide field collimator – Czerny-Turner Spectrograph</td>
</tr>
<tr>
<td></td>
<td>Vertical spatial resolution &lt;9km</td>
<td>Vertical 8 km (0.18°) Horizontal 16 km (0.37°)</td>
<td>Optical Design, Tolerance Analysis, Detector Selection</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>Dynamic range of 1,000</td>
<td>10,000</td>
<td>UV converter with fast frame read out rate camera and subsequent digital co-add</td>
</tr>
<tr>
<td>Motion Compensation</td>
<td>Maintain spatial resolution from moving spacecraft.</td>
<td>TDI motion Compensation</td>
<td>TDI algorithm - LUT instrument and geographic distortion correction, digital co-adding with address offset</td>
</tr>
<tr>
<td>and Data Compression</td>
<td>Fit in allocated ICON data budget</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• **Data Type 1: Limb Altitude Profiles.**

Illustration of limb altitude profiles. There are 6 vertical strips. In each strip the pixels are co-added horizontally. During daytime data is taken for both channels. For nighttime for the 135.6 nm channel only. Below 150 km altitude there is substantial O$_2$ absorption and it is not possible to get limb views of the atmosphere.
Limb Altitude Profiles

- Daytime for both channels. Nighttime 135.6 nm only. Below 150 km altitude there is substantial O₂ absorption and it is not possible to get limb views of the atmosphere.
- ICON prime science is measuring the altitude distribution of the thermosphere/ionosphere on a spatial scale of ~ 500 km.
- The nighttime equatorial ionosphere is often unstable producing small scale structures.
- ICON will have the capability of monitoring the ionosphere to detect ionospheric irregularities on a spatial scale of 10-20 km.
- ICON FUV has the capability of recording images using Time Delay Integration (TDI)
Data Type 2: TDI-ed emission maps

(Nighttime only)

This treatment assumes that the emissions are mapped either on the sub-limb at a constant altitude at 300 km or on the limb view tangent point associated with the elevation of the view angle.

Illustration of ICON operations (Side View)

FUV observes on the left (port) side of ICON. On the limb the maximum emission is seen at the tangent point. At sub limb height integrated emissions are observed.

During daytime-

- ICON FUV takes only altitude profiles at limb tangents (no sub-limb).
- ICON looks perpendicular to the orbit plane.
- Exposures are 12 seconds long.
- In 12 sec exposure ICON travels 96 km and the curvature of the Earth will provide less than 1 km altitude error.
TDI imaging 0 turret angle

Raw images white checks 0.6 counts per res cell per frame. Black 0.03 counts per frame.

Movie of uncorrected frames  
Co-added uncorrected images

Sub Limb  
Limb Tangent

TDI mapped images with motion compensation co-added
TDI imaging 15 degree turret angle

Raw images sublimb white 0.6 counts per res cell per frame. Black 0.03 counts per frame.

Movie of uncorrected frames

Co-added uncorrected images

Sub Limb

Limb Tangent

TDI mapped images with motion compensation co-added
**FUV Data Products**

- **Calibrated LBH & 135.6 intensities**
  - Limb Profile
  - TDI limb
  - TDI sublimb

- **LEVEL 1b**
  - 1b.3 Calibrated LBH & 135.6nm brightness

- **LEVEL 2**
  - 2.4 $[O]/[N_2]$ $O^+$ profile
  - 2.5 Nighttime $O^+$ profile

- **LEVEL 3**
  - 3.3 Summary $O/N_2$ map
  - 3.4 - 3D nighttime $O^+$
  - Satellite and SuperDARN ion velocities and ground-based magnetometers

- **O/N2 map**
  - Nighttime $O^+$
  - Nighttime $O^+$ Limb map
  - Nighttime $O^+$ Sub Limb Map

- **Nighttime $O^+$ Map**

- **Tomographic Inversions**
Atmospheric model for straylight calculations.

- Constructed source models for limb emission derived from GUVI from measurements from atmospheric vs. altitude for 121.6 nm, 130.4 nm, 135.6 nm, 157 nm

- Completed preliminary atmospheric limb irradiance calculations for both cameras at 121.6 nm, 130.4 nm, 135.6 nm, 157 nm
  - 157 nm source model used LBH lines at 153.1 nm, 155.8 nm, 158.6 nm, 160.2
GUVI data of the key day-glow features.
FUV Relative Transmission Analysis

Integrated power vs. wavelength, no ghost, no scatter
Notes

- GUVI data was used for the 121.6 nm, 130.4 nm, and 135.6 nm source models (all traced monochromatically)
- The 157 nm (LW) source model is polychromatic, with in-band wavelengths selected from the Meier spectrum data. It uses the LBH1 limb profile.
Modeling of stray light.

Step 1. Performing PSD computations. - Instrument Response to parallel incoming radiation as a function of the angle of arrival at the aperture of the instrument.

Step 2. Modeling the Limb. - Calculating the integrated stray light energy using the the PSD combined with the distribution of photon fluxes arriving at the aperture of the instrument.

2 component to stray light:
1. Out of wavelength band radiation originating in the FOV
2. In wavelength band radiation originating outside the FOV.
SW Camera PST (135.6 nm)

- Design wavelength
SW Camera PST (121.6 nm)

ICON FUV SW Camera PST

Al + MgF<sub>2</sub> Coatings
Optics Specular Level: 1
Optics Scatter Level: 2
Structure Scatter Level: 2
Analysis Wavelength: 121.6 nm
SW Camera PST (130.4 nm)

ICON FUV SW Camera PST

Al + MgF₂ Coatings
Optics Specular Level: 1
Optics Scatter Level: 2
Structure Scatter Level: 2
Analysis Wavelength: 130.4 nm

Log₁₀ PST - Total, AZ(0)
Log₁₀ PST - Total, AZ(45)
Log₁₀ PST - Total, AZ(90)
Log₁₀ PST - Total, AZ(135)
Log₁₀ PST - Total, AZ(180)
Log₁₀ PST - Total, AZ(225)
Log₁₀ PST - Total, AZ(270)
Log₁₀ PST - Total, AZ(315)
SW Camera PST (500 nm)

ICON FUV SW Camera PST

Al + MgF$_2$ Coatings
Optics Specular Level: 1
Optics Scatter Level: 2
Structure Scatter Level: 2
Analysis Wavelength: 500 nm
LW Camera PST (157 nm)

\begin{itemize}
    \item Design wavelength
\end{itemize}
LW Camera PST (121.6 nm)

ICON FUV LW Camera PST

Al + MgF₂ Coatings
Optics Specular Level: 1
Optics Scatter Level: 2
Structure Scatter Level: 2
Analysis Wavelength: 121.6 nm

Source Input Angle (deg.)

Log₁₀(PST)
LW Camera PST (149.3 nm)

ICON FUV LW Camera PST

Al + MgF₂ Coatings
Optics Specular Level: 1
Optics Scatter Level: 2
Structure Scatter Level: 2
Analysis Wavelength: 149.3 nm
Modeling the Limb

- Source radiance models are converted to intensity (flux/steradian) via ray tracing
- The trace algorithm divides the atmosphere into a series of earth-centric annular rings corresponding to different altitudes
- Each ring is oriented so that it is tangent to the line of sight for a known altitude
  - For reference the center of the field of view is tangent at an altitude of approximately 155 km
  - As the altitude increases, the ring rotate away from the spacecraft → equivalent to increasing the vertical field angle
- Ray powers are computed using the limb radiance and line of sight projections onto the baffle input
- Rays are traced to the aperture and the intensity values are computed on polar grids that are subsequently used to in the source models for the detector irradiance computations
Comments

- Visible light analysis (400 nm – 700 nm) shows nearly identical behavior for the two cameras
  - No diffraction: all light is propagated in the direction of the zeroth order (higher orders are evanescent)
  - ~7 orders of magnitude attenuation for objects inside the field of view
  - No contribution outside of the field of view

- Broadband coating results in higher backgrounds for out of band light
  - It remains to be seen if this has a significant impact on the overall performance of the system
Comments

- Because the SNR calculations are based on irradiance calculations, they are subject to statistical noise → these data should not be interpreted as absolute, but should provide a good qualitative estimate of performance.
- Integrated flux calculations are more reliable → in a ray trace, power converges more quickly than irradiance.
- Both SW and LW channels are susceptible to direct illumination from sources outside of the design field of view → this contribution is a significant source of stray light.
- Out of band rejection is very good, even for cases in which the line strength is much larger than the intended signal.
- Ghost and scatter events, in and out of band, contribute a small amount to the stray light background.
- The model assumes a diffuse black surface treatment for all opto-mechanical surfaces and structures.
Scattering Analysis Summary

Requirement: scattered light all contribution < 2%

- Model by Photon Engineering
- Calculated PST based on instrument model
- Used GUVI measurements for daytime stray light input and integrated PST
- Results better than 2% peak requirement
- Very effective out of band rejection especially in the visible ~7 orders
- Dominant stray light from in band out of FOV

<table>
<thead>
<tr>
<th></th>
<th>SW Camera</th>
<th>LW camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal (photons/s)</td>
<td>1.51E+07</td>
<td>9.42E+06</td>
</tr>
<tr>
<td>In band SL (photons/s)</td>
<td>1.47E+05</td>
<td>7.92E+04</td>
</tr>
<tr>
<td>In band SL (%)</td>
<td>0.98%</td>
<td>0.84%</td>
</tr>
<tr>
<td>Out of band SL (photons/s)</td>
<td>4.50E+04</td>
<td>3.43E+04</td>
</tr>
<tr>
<td>Out of band SL (%)</td>
<td>0.30%</td>
<td>0.36%</td>
</tr>
<tr>
<td>Total SL (%)</td>
<td>1.27%</td>
<td>1.20%</td>
</tr>
</tbody>
</table>
Atmospheric model for straylight calculations.

- Constructed source models for limb emission derived from GUVI measurements from atmospheric vs. altitude for 121.6 nm, 130.4 nm, 135.6 nm, 157 nm

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  - 157 nm source model used LBH lines at 153.1 nm, 155.8 nm, 158.6 nm, 160.2
SW Camera: Signal Irradiance

Irradiance (SW camera, Signal, photons/s/cm²)

- 24171089 to 26856765
- 21485412 to 24171089
- 18799736 to 21485412
- 16114059 to 18799736
- 13428383 to 16114059
- 10742706 to 13428383
- 8057030 to 10742706
- 5371353 to 8057030
- 2685677 to 5371353
- 0 to 2685677
SW Camera: Background Irradiance

• In band stray light, all angles

• Out of band, all angles

• Plots not on same scale
SW Camera Signal-Background

- In band, all angles
- Out of band, all angles
LW Camera: Signal Irradiance

![Irradiance Map]

<table>
<thead>
<tr>
<th>Irradiance (LW camera, Signal, photons/s/cm^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10577844.. 11753160</td>
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<tr>
<td>9402528.. 10577844</td>
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<td>8227212.. 9402528</td>
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<td>7051896.. 8227212</td>
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<td>5876580.. 7051896</td>
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<td>4701264.. 5876580</td>
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<tr>
<td>3525948.. 4701264</td>
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<tr>
<td>2350632.. 3525948</td>
</tr>
<tr>
<td>1175316.. 2350632</td>
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<tr>
<td>0.. 1175316</td>
</tr>
</tbody>
</table>

Local Y Axis (mm)

Local X Axis (mm)
LW Camera: Noise Irradiance

• In band stray light, all angles

• Out of band, all angles

• Plots not on same scale
LW Camera Signal-Background

- In band, all angles
- Out of band, all angles

Plots not on same scale
Comments

- Because the SNR calculations are based on irradiance calculations, they are subject to statistical noise → these data should not be interpreted as absolute, but should provide a good qualitative estimate of performance.
- Integrated flux calculations are more reliable → in a ray trace, power converges more quickly than irradiance.
- Both SW and LW channels are susceptible to direct illumination from sources outside of the design field of view → this contribution is, by far, the most significant source of stray light.
- Out of band rejection is very good, even for cases in which the line strength is much larger than the intended signal.
- Ghost and scatter events, in and out of band, contribute a small amount to the stray light background.
- The model assumes a diffuse black surface treatment for all opto-mechanical surfaces and structures.
Prior estimates (ICON CSR) the requirement S-3 needs an instrument of sensitivity 8.3 counts/kR/sec.

The analysis of the O/N2 requirements was revisited since PDR (R. Meier private communication) preliminary results show that the L4 requirement is conservative.

New analysis includes (1) Slit widening, and (2) Recalculated effective N₂ branching ratios (3) More realistic error assessment.
Signal to Noise

• **Area**: A res cell is equivalent to 4 km altitude and 128 km horizontal. CCD is read out in a 512 x 512 raster - res cell is equivalent to 2 x 64 CCD binned pixel.

• **Time**: We will consider a 12 second exposure.

• **Reference point**: Signal and Noise reference point is at the CCD before the A-D converter and unit is electron which is 1/16th of the A-D in the SDL GSE.

\[
SNR = \frac{P \times g}{\sqrt{P \times g^2 + I_p \times g^2 + \Sigma N_r^2 + \Sigma N_{dc}}} 
\]

• Where \( P \) = Signal in counts in the area collected during exposure time.
  
  • \( g \) = gain of the intensifier
  
  • \( I_p \) = stray light induced in counts
  
  • \( N_r \) = read out noise
  
  • \( N_{dc} \) = dark current of CCD

• Most quantities are measured using the detector prototype.

Mean Gain = 645  
Mean square = 734  
y = 40*(20+x/100)*EXP(-(((x/100-5.5)/5.5)^2))
Signal to Noise Ratio Summary

### Input quantities.

<table>
<thead>
<tr>
<th>Component</th>
<th>Final Result</th>
<th>No Mult. Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>9.11E+04</td>
<td>9.11E+04</td>
</tr>
<tr>
<td>P x mean g^2</td>
<td>1.22E+09</td>
<td>9.41E+08</td>
</tr>
<tr>
<td>Ip x mean g^2</td>
<td>2.70E+06</td>
<td>2.70E+06</td>
</tr>
<tr>
<td>Nr</td>
<td>2.56E+06</td>
<td>2.56E+06</td>
</tr>
<tr>
<td>Ndc</td>
<td>3.75E+04</td>
<td>3.75E+04</td>
</tr>
<tr>
<td>Dark current fluctuations</td>
<td>9.22E+07</td>
<td>9.22E+07</td>
</tr>
<tr>
<td>Mean square</td>
<td>1.31E+09</td>
<td>1.04E+09</td>
</tr>
<tr>
<td>RMS noise (CCD els)</td>
<td>3.63E+04</td>
<td>3.22E+04</td>
</tr>
<tr>
<td>RMS noise (PE-s)</td>
<td>3.51</td>
<td>3.12</td>
</tr>
</tbody>
</table>

- Nighttime SNR input = 30 Rayleighs.
- Instrument sensitivity 135.6 per stripe = 24.5 counts/sec/kR.
- Signal is amplified by intensifier gain.
- Photo electron noise and backgrounds are amplified by mean square intensifier gain.
- Noise components are summed as squares.
- CCD dark current and CCD read out noise are added.
- The ideal per rescel in each strip noise would be 2.97 but the resulting noise is 3.51.
- The largest contributor is multiplication noise.
 Alignment and Calibration Approach

- Coarse mechanical alignment using Faro Arm CMM.
- Benchtop alignment of spectrometer and back imager using a GSE visible grating @ 900 line/mm (UV is 3600 line/mm) and CCD detectors.
  - Initial alignment at Lockheed Martin, Palo Alto
  - Repeat post-ship at CSL in Liege, Belgium
- Alignment of turret to optics package using laser tracker system.
- Visible alignment with turret using CSL OGSE and MGSE.
- UV alignment using CSL OGSE and MGSE.
- UV Calibration at RT, 0C and 40C using CSL OGSE, MGSE, and Thermal Tent.
Benchtop Alignment at LMSAL
CSL MGSE Overview

2 axis of rotation (vertical + horizontal)
Collimated beam does not cover the entire surface of the scan mirror

For one specific field, the turret does not need to be fully illuminated

Collimated beam: 100 mm diameter
Distortion Map Calibration

<table>
<thead>
<tr>
<th>Alpha</th>
<th>Beta</th>
<th>Alpha</th>
<th>Beta</th>
<th>Alpha</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
<td>2</td>
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Alpha is the horizontal angle along the spectral direction
Beta is the vertical angle along the slit

- Pre environmental calibration map: **9 points**
- Post environmental calibration map: **29 points minimum**
UV Alignment Results

- Spot sized optimized by actuating CM2 mirrors in piston/tip/tilt at the (0,0) field.
- Extreme field angles at FOV edges verified and optimized following (0,0) field optimization.
- All fields show spots meet requirements (<180 microns, >90% encircled energy)
Spectral Sensitivity at 20°C

Shortwave (135.6 nm)

- In-Band Suppression of 130.4 line is 100% in SW Channel
- FWHM 4.73
- Difference 0.33 nm

Longwave (157 nm)

- In-Band Suppression of 149.6 and 164.1 lines is >99.8% in LW Channel
- FWHM 5.99
- Difference 0.24 nm
Distortion mapping

SW field positions measured during tests at different temperatures
Colors denote tests:
Blue: Cold Gradient
Light green: Hot Gradient
Dark green: Room Temperature
Brown: 0 C
Red: 40 C
Spots are on top of each other within 2 pixels (1 science pixel in final 256x256 science format)
Distortion Map Determination

Images at 74 field positions → Uncorrected Distortion Map → Corrected Distortion Map → Distortion Map Applied to Entire FOV
Initial out of band sensitivity measurements were performed at Lyman Alpha with high flux from the CSL OGSE. A well focused spot was observed in both channels.

Expected rejection at this wavelength was $10^5$, $\sim10^3$ was observed:

Following the initial tests, BaF2 windows were installed onto the OGSE. These filters are known to have rejection $>90\%$ at wavelengths less than 130nm. Spectral scans were performed with and without the BaF2 windows installed.
Both channels showed a reduction in counts consistent with BaF2 Transmission curves (knee is ~135 nm at room temperature) indicating that in-band light was leaking from the monochromator into the OGSE.

- 0% to 60% in SW throughput with BaF2 installed
- 72% in LW throughput with BaF2 installed
Radiometric Performance

Radiometric performance Summary

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<th>Measured instrumental</th>
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<td>Transmission</td>
<td>0.45%</td>
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<td>Count Rate from measured Tx</td>
<td>147.26</td>
<td>52.36 Counts/kR</td>
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<td>BOL from measured Tx</td>
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<td>30.21 Counts/kR</td>
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<td>Science Requirements</td>
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<tr>
<td>Margin EOL</td>
<td>483%</td>
<td>208% Margin</td>
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