What can we learn about an infrared
CDS with a monochromatic, uniform
souce?

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Monochromatic sources

ILS/spectral calibration

Blackbody emissivity

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Quantum Cascade Lasers

Harvard housing with tunable collimation

Sealed housing with permanently aligned optic

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QCL intrinsic linewidth

1982: 114 MHz = 0.0038 cm$^{-1}$

2010: 5-100 kHz = 2×10$^{-7}$ to 3×10$^{-6}$ cm$^{-1}$
QCL linewidth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (Wavelength)</th>
<th>Value (Frequency, as Wavenumber)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{d\lambda}{dT}$ (CW tuning rate, Temperature)</td>
<td>0.6 nm K$^{-1}$</td>
<td>6.7×10$^{-2}$ cm$^{-1}$ K$^{-1}$</td>
</tr>
<tr>
<td>$\frac{d\lambda}{dI}$ (CW tuning rate, Temperature)</td>
<td>30 nm A$^{-1}$</td>
<td>3.3 cm$^{-1}$ A$^{-1}$</td>
</tr>
</tbody>
</table>

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QCL requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature (T)</td>
<td>$14^\circ C &lt; T &lt; 15^\circ C$</td>
</tr>
<tr>
<td>Temperature Stability</td>
<td>0.25°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Current (I)</td>
<td>$0.4 \text{ A} &lt; I &lt; 0.6 \text{ A}$</td>
</tr>
<tr>
<td>Supply Voltage (V)</td>
<td>$8.4 \text{ V} &lt; V &lt; 10.0 \text{ V}$</td>
</tr>
<tr>
<td>Current Noise</td>
<td>$&lt;20 \text{ mA}$</td>
</tr>
</tbody>
</table>

Dykema et al. CLARREO SDT, Hampton, VA, October 2014
Bibliography

• Tilt/shear

• Deconvolution

• Metrics for spectral calibration

• Speckle
Determinants of ILS for FTS


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Spectral, position domains

![Graphs showing spectral and position domains]

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Fitting Methods

• Estimate parameters for ILS model in spectral space
  – ILS model: circular, uniformly illuminated, off-axis detectors
  – Can add tilt, shear, sampling errors

• Deconvolution method in position space
  – After Bernardo & Griffith (2005)
  – Derived for narrow absorption feature
  – More straightforward with monochromatic source
Gaussian QCL profile

Using standard ILS model for circular, off-axis, uniformly illuminated detectors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>QCL wavelength</td>
<td>1000.4 cm(^{-1})</td>
</tr>
<tr>
<td>FOV size</td>
<td>25 mrad</td>
</tr>
<tr>
<td>FOV alignment</td>
<td>10 mrad off-axis</td>
</tr>
</tbody>
</table>
Fitting performance: spectral space

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Fitting performance: position space
With additional demodulation
Radiance difference

![Graph showing radiometric error vs. demodulation coefficient]

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Altering ILS to test fit procedure

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Requirements derived from ILS fit

**SNR requirement:**
- Detector noise
- Permissible integration time
→ Sets QCL power requirement

**Impacts:**
- Thermal
- Electrical requirement

**Linewidth requirement:**
- Current noise
- Temperature noise
→ Sets QCL control requirements

**Impacts:**
- Thermal design specifications
- Electrical design

0.05 cm\(^{-1}\) requires thermal, electrical noise not to exceed 0.25 K, 1.3 mA

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On-orbit Test/Validation (OT/V) Modules

Viewing configuration providing immunity to polarization effects.

Heated Halo

On-Orbit Absolute Radiance Standard

(Used in combination with space view for instrument calibration)

On-Orbit Spectral Response Module

(Measures instrument line shape)

Ambient Blackbody

(Used in combination with space view for instrument calibration)

QCL Laser

(Used for blackbody reflectivity and Spectral Response Module)

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Emissivity measurement concept

- Laser reflected off-axis from scene select mirror into blackbody
- Requires power normalization based on blackbody temperature

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QCL power measurement

Blackbody temperature rise due to QCL absorption

Power computed from known blackbody thermal capacity

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OCEM (1)

Cross-beam

\[ \delta = 6 \pm 2 \text{ mm} \]

Along-beam

\[ \theta = 14 \pm 2^\circ \]

38 mm
OCEM (2)

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Concluding/future work

• Apply to measured spectra with different optical settings
• Combine spectral sampling and ILS analysis into combined framework
• Derive spectral characteristics for ILS misfit
• Utilize spectral characteristics in fingerprinting studies