Progress on the NGAS Photonic Spectrometer for SLI-T

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Material Identification with NG HSI Systems

NGAS HATI 2500 (0.4 – 2.5 µm): SMER Calibration Site

FERI SAMSON: HAB Signature

NGAS LWHIS LWIR HSI (8 – 12 µm)

TRWIS III (0.4 – 2.5 µm): Oxnard Crop Classification
## NGAS Hyperspectral Instrument Heritage

<table>
<thead>
<tr>
<th>Year</th>
<th>Instrument</th>
<th>Spectral Range (µm)</th>
<th>Spectral Channels</th>
<th>Bandwidth (nm)</th>
<th>Spatial Pixels</th>
<th>SNR</th>
<th>Detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>TRWIS A</td>
<td>0.43 - 0.85</td>
<td>128</td>
<td>3.3</td>
<td>240</td>
<td>-</td>
<td>Intens. CCD</td>
</tr>
<tr>
<td>1989</td>
<td>TRWIS B</td>
<td>0.46 - 0.88</td>
<td>90</td>
<td>4.8</td>
<td>240</td>
<td>40</td>
<td>Si CCD</td>
</tr>
<tr>
<td>1991</td>
<td>TRWIS II</td>
<td>1.5 - 2.5</td>
<td>108</td>
<td>12</td>
<td>240</td>
<td>-</td>
<td>InSb</td>
</tr>
<tr>
<td>1992</td>
<td>TRWIS III</td>
<td>0.4 - 2.5</td>
<td>384</td>
<td>5</td>
<td>256</td>
<td>400 - 1000</td>
<td>CCD/HCT</td>
</tr>
<tr>
<td>1996</td>
<td>SSTI HSI</td>
<td>0.4 - 2.5</td>
<td>384</td>
<td>5</td>
<td>256</td>
<td>100 - 250</td>
<td>CCD/HCT</td>
</tr>
<tr>
<td>1996</td>
<td>Hyperion</td>
<td>0.4 - 2.5</td>
<td>384</td>
<td>5</td>
<td>256</td>
<td>60 - 150</td>
<td>CCD/HCT</td>
</tr>
<tr>
<td>1998</td>
<td>LWHIS</td>
<td>8.0 - 12.5</td>
<td>128</td>
<td>6.25 SWIR</td>
<td>256</td>
<td>&gt; 500</td>
<td>CHT</td>
</tr>
<tr>
<td>2002</td>
<td>VSHCA</td>
<td>0.4 - 2.5</td>
<td>125</td>
<td>5 VNIR</td>
<td>256</td>
<td>&gt; 200</td>
<td>CCD/HCT</td>
</tr>
<tr>
<td>2004</td>
<td>HATI-2500</td>
<td>0.4 – 2.5</td>
<td>448</td>
<td>6 SWIR</td>
<td>640</td>
<td>&gt; 400</td>
<td>CCD / InSb</td>
</tr>
</tbody>
</table>

For more than 20 years NGAS has delivered state-of-the-art air and space hyperspectral systems.
Northrop Grumman-Built Hyperion on NASA EO-1 Satellite

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hyperion</th>
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</thead>
<tbody>
<tr>
<td>Weight (Kg)</td>
<td>49</td>
</tr>
<tr>
<td>Volume (L x W x H, cm)</td>
<td>39x75x66</td>
</tr>
<tr>
<td>GSD (m)</td>
<td>30</td>
</tr>
<tr>
<td>Wavelength Range (nm)</td>
<td>400 - 2500</td>
</tr>
<tr>
<td>Spectral Resolution (nm)</td>
<td>10</td>
</tr>
</tbody>
</table>

Hyperion Tech Demonstration Collected Over 90,000 Images
Hyperspectral Synthesis of Multispectral Bands

Profile at Line 2: Band 4-3-2 as Red-Green-Blue

Band 5/7 Ratio, Red in the RGB

Note: Landsat is twisted relative to Hyperion
Under the NASA ESTO SLI-T program, Northrop Grumman is building a hyperspectral sensor in which micropatterned waveguides and photonic circuits replace traditional free-space optical components. The use of photonics leads to ultra-compact instrument form factors.
SLI-T Program

• Currently in second year of a 5-year development program funded by NASA ESTO to build and test a heterogeneously integrated photonic instrument
  • Covers two SLI bands: Band 9 (1.36 – 1.39µm at 3nm resolution) and Band 6 (1.56 – 1.66µm at 6nm resolution)
  • Scalability to SLI VNIR and SWIR bands
  • Integrate NGAS novel ROIC
  • Radiometric performance estimates and testing

• Planned exit TRL = 6
• First program year included development of compact waveguides
• Detector chiplets were designed - each containing 32 detectors, metal interconnect, structural interconnect, and alignment marks
Integrated Detector Chiplets

- SLI-T waveguides and detectors have been fabricated and integrated
Testing: Cross Section Cuts
Cross-Sectional SEM: Cut Through Detector Pockets

- SEMs show very good alignment and pocket positioning
- No “bottoming out” from integration
Cross-Sectional SEMs: Cut Through Structural Interconnects Between Waveguides

Demonstrates accurate interconnect alignment and bonding
Accurate interconnect placement, alignment and bonding - shows metallization on surface of waveguide wafer
Modeling of Full 3D Waveguide Filter Structures

- Initial 2D models and 3D models (w/o gratings) implemented in **R-Soft’s BeamPROP**
  - Does not account for coupled forward and backward propagating waves in 3D
- Following new approach for modeling general 3D waveguide structures with integrated gratings using **Lumerical FDTD** package

- e.g. 3d model accurately reveals short-\(\lambda\) coupling to radiation modes
- 3d model helps predict impact of fabrication limits on the filter structure

Approved for public release; NG 18-1179 dated 5/30/18.
Developed system level sensor model to estimate radiometric and spatial performance.

Evaluate Rayleigh-Sommerfeld diffraction integral and summed over different field angles with appropriate phase relationship between field angles.

$$E(\theta_i, \nu) = A_0 e^{-ik\nu \sin(\theta_i)}$$

Square of normalized overlap integral is the coupling efficiency.

Relative offset in $x_l$ and $x_w$ (i.e. alignment offset) results in decreased coupling efficiency due to decreased overlap of the electric field with waveguide mode.
• Program is developing a custom CMOS Read Out Integrated Circuit chiplet
• Test coupons have been designed and laid out to contain multiple cell architectures and component designs
  – Designs taped out and currently in fabrication
• Parts will be wire-bonded to 16-pin Ceramic Dual In-line Packages and mounted on a custom break-out board for testing
• Actual and predicted ROIC performance will compared and an optimal design selected
• In parallel a “dummy” ROIC is being fabricated for integration and connectivity demonstration

Fabrication run will deliver multiple parts to allow performance testing as well as measurement of inter- and intra-chip variations
THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN