SLI-T Integrated Photonic Spectrometer

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Photonic Spectrometer Overview

- Approach and component demonstrations
- ESTO study – EVEREST simulations
- ESTO SLI-T status
Photonic Spectrometer Approach

- Micro-fabricated photonic filters and DAHI integrated photodetectors replace free-space optics
- Enables new image acquisition modes (staring, TDI)

DAHI Integration

Scene Image

Micro-Lens Array

Scene Photons

PS

Waveguide Filters and ROIC

N > 300 Bands

Grating

Output Waveguide

Etched Pocket

Photodetector

Silicon Substrate

To Next Grating

SiO2 Waveguide Layer

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NGAS Program for Waveguide Filter Development

Grating Detail

Input Waveguide Junction

Grating Input

Grating Exit

Exit Waveguide Junction

Idler Waveguide Terminus
NG Detector and Integration Capabilities

<table>
<thead>
<tr>
<th>Device type / configuration</th>
<th>NG Demonstrated</th>
<th>Material systems</th>
<th>NG Demonstrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device type / configuration</td>
<td>PIN photodiodes</td>
<td>Lattice-matched, strain, and metamorphic materials:</td>
<td>Device layout</td>
</tr>
<tr>
<td>Schottky diodes</td>
<td></td>
<td>InP/InGaAs</td>
<td>Mesa diode</td>
</tr>
<tr>
<td>Avalanche photodiodes</td>
<td></td>
<td>GaAs/AlGaAs</td>
<td>Surface normal coupled with front- or back-illumination</td>
</tr>
<tr>
<td>Photo-transistors</td>
<td></td>
<td>InP/InAlAs/InGaAs/InAlGaAs</td>
<td><strong>Edge coupling to diode or waveguide</strong></td>
</tr>
<tr>
<td>Quantum wells and graded superlattices</td>
<td></td>
<td>InGaAsP/InGaAsSb</td>
<td></td>
</tr>
<tr>
<td>Type-II tunnel diodes</td>
<td></td>
<td>InAs/GaSb/AlSb/AlGaSb/InAlA</td>
<td>Discrete and array of diodes</td>
</tr>
<tr>
<td>Waveguide filters and gratings</td>
<td></td>
<td></td>
<td>Integration capabilities</td>
</tr>
</tbody>
</table>

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<td>DAHI integration</td>
</tr>
<tr>
<td>InP/InGaAs</td>
<td>Monolithic integration through epitaxial design</td>
</tr>
<tr>
<td>GaAs/AlGaAs</td>
<td>Regrowth of multiple epitaxial device structures on same substrate</td>
</tr>
<tr>
<td>InP/InAlAs/InGaAs/InAlGaAs/InGaAsP/InGaAsSb</td>
<td></td>
</tr>
<tr>
<td>InAs/GaSb/AlSb/AlGaSb/InAlA</td>
<td></td>
</tr>
</tbody>
</table>

Spectrum Coverage

- Bulk GaAs
- Bulk InGaAs
- QWIP, QDIP, SL, nBn, pMp, nBp, UTC, CBI RD
- SLI-T PIN Photodiode
- Waveguide Photodiode

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Black Diamond: Waveguide-Detector Integration

- Black Diamond program demonstrated waveguide/detector integration using NG heterogeneous integration processes

BDD12A-2-1: short-flow minesweeper lot using 100mm GaAs mechanicals

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Initial Integration of Detector on Si Waveguide

Successfully integrated photodetector chiplets on to the Si waveguide wafer.
Photodiode Integration Demonstrations

Photodiode Microscope Image

Detector-Waveguide Overlay Image

75µm thickness integrated detector

Narrow-spacing detector integration

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Filter Response for Single-Filter Devices

Waveguide Design

Photocurrent Out

Grating

Light In

Light Throughput

Device W10-v-3-A

Normalized Photo Response

Theory - Filter Response

Device W10-v-1-A

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Study focused on developing designs and performance estimates for key system elements:

- Telescope
- Coupling efficiency as a function of wavelength and lenslet focal length
- Optical throughput and system Signal-to-Noise
- NGAS band aggregation algorithms
EVEREST is a Core Capability to Support Mission Concept Evaluation and System Development

NGAS Core Mission Evaluation Capability
Environmental Verification and Remote Sensing Testbed

Environmental Scenes:
- Atmospheric Conditions
- Background Conditions

Mission/Orbit Variables

Sensor Variables

Sensor/Spacecraft Factors

Radiative Transfer Models

Simulated Radiances at Aperture

Spacecraft & Sensor Models

Simulated Sensor Measurements

Performance Metrics

Evaluate End-to-End Performance

Compute Statistics

Environmental Products

Retrieval Algorithm

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### EVEREST for Land Imaging

**Basis for High Value End to End Simulations**

<table>
<thead>
<tr>
<th>Surface</th>
<th>Atmosphere</th>
<th>Radiative Transfer Model</th>
<th>TOA / SDR Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP Global Data Assimilation System (GDAS) P, T, RH, Ozone</td>
<td>Nasa Merra</td>
<td>Modtran5</td>
<td>Flexible Sensor Observation Geometries</td>
</tr>
<tr>
<td>Nasa Merra</td>
<td>MODIS 8-Day Aerosol Product Climatology</td>
<td>Successive Order of Scattering (SOS)</td>
<td>Observation Time Based on Orbit</td>
</tr>
<tr>
<td>MODIS 8-Day Aerosol Product Climatology</td>
<td>NGAS Cloud Scene Simulation Model Clouds</td>
<td>6S(V)</td>
<td>Spatial Scale Per NLCD</td>
</tr>
<tr>
<td>NGAS Cloud Scene Simulation Model Clouds</td>
<td>DISCORD &amp; ISBRDF Snow/Ice</td>
<td>HYDROLIGHT</td>
<td>Spectral Resolution &lt; 1nm</td>
</tr>
<tr>
<td>DISCORD &amp; ISBRDF Snow/Ice</td>
<td></td>
<td></td>
<td>Spectral Range ~ 0.38-13um</td>
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<td></td>
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<td></td>
<td>Landsat &amp; HSI Detector RSRs</td>
</tr>
</tbody>
</table>

**NGC EVEREST Leverages Many Community Standards**

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SLI-T Program

- Currently in first 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

- Spectral range 1360 to 1390 nm
- $\Delta \lambda = 3$ nm, 10 filters per pixel
- # of x-track pixels 128, Pixel spacing 30µm
- Active area: 3.84mm x 13.1mm

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Detector Chiplet Design

- Detector chiplet fabrication initiated
  - Each chiplet contains 32 detectors, metal interconnect, HICs, alignment marks
  - Multiple versions of chiplet per wafer with different detector sizes and offset

Detector (32 in total)

White squares = Heterogeneous Interconnects (HICs)

Green lines = Metal interconnect

Structural HICs
Detector Tiling Pattern

- SLI-T waveguides in fabrication
- Next step is waveguide/detector integration

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THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN