Integrated Photonic Spectrometer for Sustainable Land Imaging - Technology

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**Hyperspectral Imaging**

**Hyperion VNIR/SWIR, Class D; less than 12 months to delivery; more than 16 years on orbit**

**Full Hyperspectral Analysis**

**Mineral Spectra**
- Band 5/7 Ratio, Red in the RGB
- Landsat
- Hyperion Synthesis of Landsat
- Note: Landsat is twisted relative to Hyperion

**Band-Selectable Output**
- FOV
- Landsat
-Visible
-ShortWave IR
-MidWave IR
-LongWave IR
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.2
-1.8
-2.4
-4
-6
-8
-10
-12
-14

**Mimic MSI through Band Aggregation**
- Hyperion Aggregated to Synthesize Landsat 7
- Landsat 7

**Detailed Talc-Tremolite Map**
- Colours to the right indicate the relative abundance of talc/tremolite
- Red shows areas of greatest abundance and blue shows the least.

**Hyperspectral Analysis**
- No Data
- Open Field
- Mixed Conifer
- Red Oak
- Norway Spruce
- Red Maple
- Hardwood Mix
- Red Pine
- Spruce Swamp
- White Pine

**Band-Selectable Output**
- VIIRS
- Landsat

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Photonic Integration Enables HSI Acquisition in an Extremely Compact Package

- Micro-fabricated photonic filters and integrated photodetectors replace free-space optics - enables sensor integration at microelectronic device scales yielding miniature instrument packages

- Integrated spectrometer manufacturing uses standardized, repeatable microelectronic processes – enables rapid and inexpensive patterning and reproduction

- Significantly reduces size of instrument – small enough to allow integration on any platform and along-side existing payloads (including shared apertures)
Sustainable Land Imaging – Technology Program

• NG is currently executing a 5-year development program funded by the NASA Earth Science Technology Office 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). Demonstrating:
    • Scalability to SLI VNIR and SWIR bands
    • Integration of novel NG ROIC
    • Radiometric performance estimates and testing

• Planned exit TRL = 6 in September 2021
Full-Field Integration
Detector Chiplet

Detector array

Chiplet backside

Electrical Interconnects (eHICs)

Interconnect traces

Chiplet frontside

Structural tHICs
Detector – ROIC Integration

• Our integration processes have resulted in consistently high accuracy detector placement (within 0.2 µm) in the PLC

Mechanical ROIC Layout and Fab

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Integrated PIC – Detector – ROIC Configuration

Waveguides

ROIC Outline

Detector Outline

Detector to ROIC Spacing

Detector chiplet

Integrated Cirrus Chip

Mechanical ROIC

Interconnect metal on PIC

ROIC I/O Metal

Metal pads

Detector I/O Metal

Integrated Cirrus Chip

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ROIC Development

- Program is developing custom CMOS digital Readout Integrated Circuit chiplets
- ROIC requirements derived from SLI-T system requirements and sensor-level radiometric performance estimates
- Designs optimized by trading signal to noise ratio and dynamic range against size, power, complexity, and risk
- Test coupons were fabricated containing unit cells with multiple architectures and component designs
- Unit cells were mounted on a custom break-out board for testing
- Actual and predicted ROIC performance were compared and designs optimized
Unit Cell Characterization Board

Design Variant #1 Test

Test chip & substrate in package

Design Variant #2 Test

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ROIC Interconnect

ROIC Face Up: Common I/O for ROIC Variants

- Metallization on ROIC and Waveguide layer were jointly optimized to enable a closely-spaced tiling arrangement
CMOS Reticle & Dedicated Wafer

Overall Reticle

126 full reticles/wafer

SLIT

Cored down to 4"

1368 total chips from 2 wafers

Two Digital ROIC Variants are Currently in Fabrication

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Waveguide Design Optimization

- Waveguide performance impacted by fabrication process limitations
- Current program effort is focused on optimization of waveguide design geometries as driven by fabrication process capabilities
- Completed an extensive model development effort - validated 2-D and 3-D models which are used to test impact of various design parameters on waveguide throughput

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Throughput Comparisons for Waveguide Optimization

Transition Length vs Radius of Curvature: Comparing Circular and Elliptical Merge Geometries for Waveguide Input Arm
Fabrication of Updated Waveguide Near Completion

- New waveguide geometries are being fabricated - optimized to mitigate process limitations
Summary

• Completed initial prototypes: designed, fabricated, integrated, and tested devices with initial waveguide and detector designs

• Significant progress on fabrication process development
  – Demonstrated numerous successful integrations
  – Optimized etch processes (waveguide and detector)

• Completed ROIC design
  – Unit cells fabricated and tested
  – Final design in fabrication

• Developed validated 3-D waveguide models and carried out extensive design optimization efforts

• Fabricated optimized waveguide geometries – preparing devices for test
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