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Progress on the NGAS Photonic Spectrometer for SLI-T

June 14, 2018

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Material Identification with NG HSI Systems

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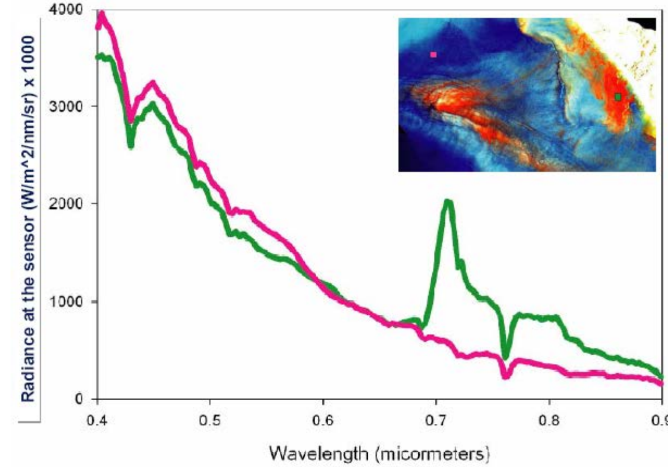
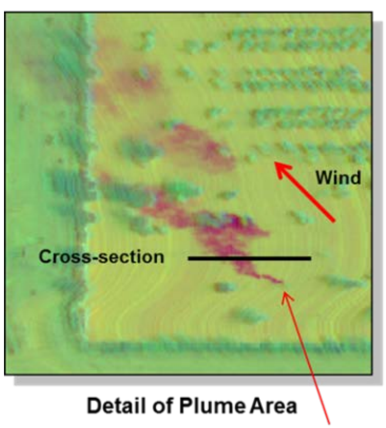
NGAS HATI 2500 (0.4 – 2.5 μm): SMER Calibration Site



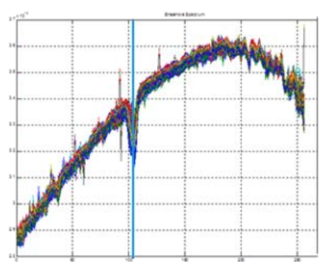
FERI SAMSON: HAB Signature

NGAS LWHIS LWIR HSI (8 – 12 μm)

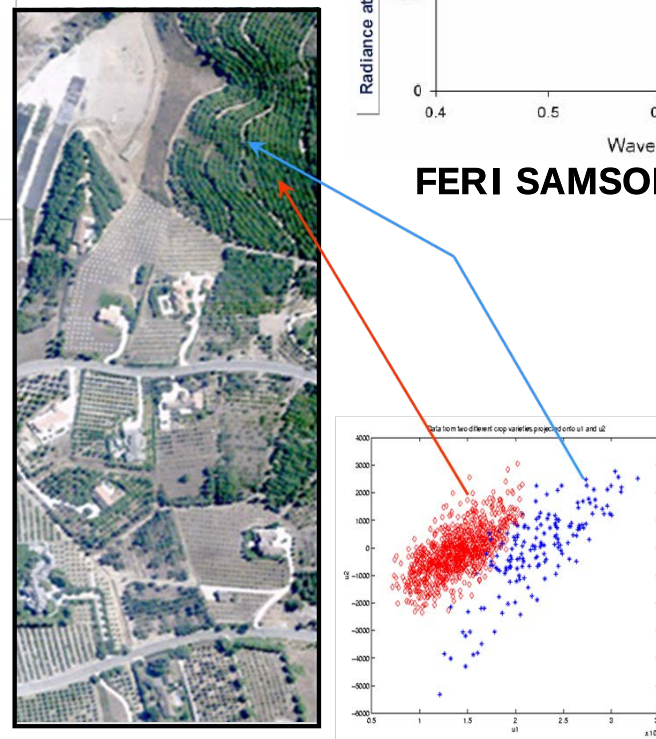


Detail of Plume Area

plume generator



Cross-section Spectra through Plume



TRWIS III (0.4 – 2.5 μm): Oxnard Crop Classification

NGAS Hyperspectral Instrument Heritage

TRWIS B

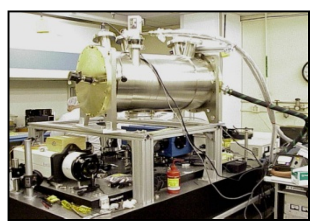
TRWIS II

TRWIS III/NVIS (Army NVESD)

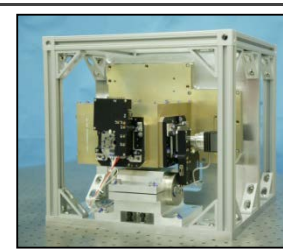
SSTI HSI (NASA)

	1989	1991	1992	1996	1996	1998	2002	2004	2013
	TRWIS A	TRWIS B	TRWIS II	TRWIS III	SSTI HSI	Hyperion	LWHIS	VSHCA	HATI-2500
Spectral Range (µm)	0.43 - 0.85	0.46 - 0.88	1.5 - 2.5	0.4 - 2.5	0.4 - 2.5	0.4 - 2.5	8.0 - 12.5	0.4 - 2.5	0.4 – 2.5
Spectral Channels	128	90	108	384	384	384	128	125	448
Bandwidth (nm)	3.3	4.8	12	5 VNIR	5 VNIR	5 VNIR	35	10 VNIR	3 VNIR
				6.25 SWIR	6.25 SWIR	6.25 SWIR		20 SWIR	6 SWIR
Spatial Pixels	240	240	240	256	256	256	256	640	890 / 640
SNR	-	40	-	400 - 1000	100 - 250	60 - 150	> 500	> 200	> 400
Detectors	Intens. CCD	Si CCD	InSb	CCD/HCT	CCD/HCT	CCD/HCT	HCT	CCD/HCT	CCD / InSb

Hyperion (NASA)



LWHIS



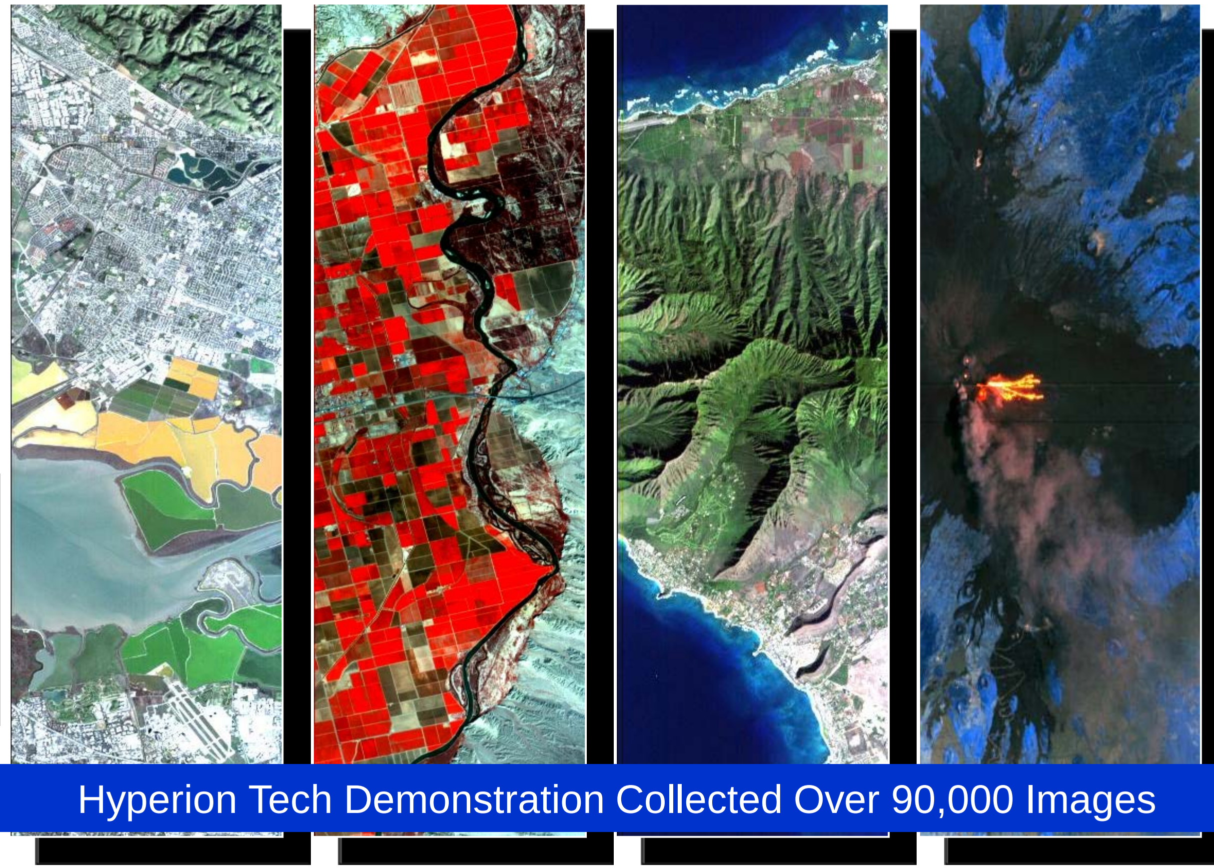
VSHCA (sub to BAE for AFRL)

HATI -2500

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

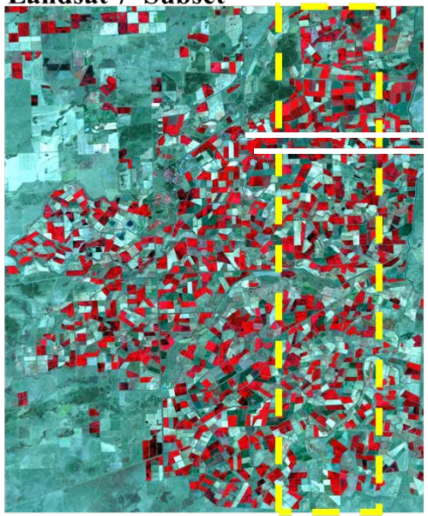
Parameter	Hyperion
Weight (Kg)	49
Volume (L x W x H, cm)	39x75x66
GSD (m)	30
Wavelength Range (nm)	400 - 2500
Spectral Resolution (nm)	10



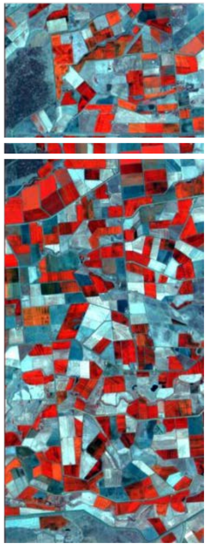
Hyperion Tech Demonstration Collected Over 90,000 Images

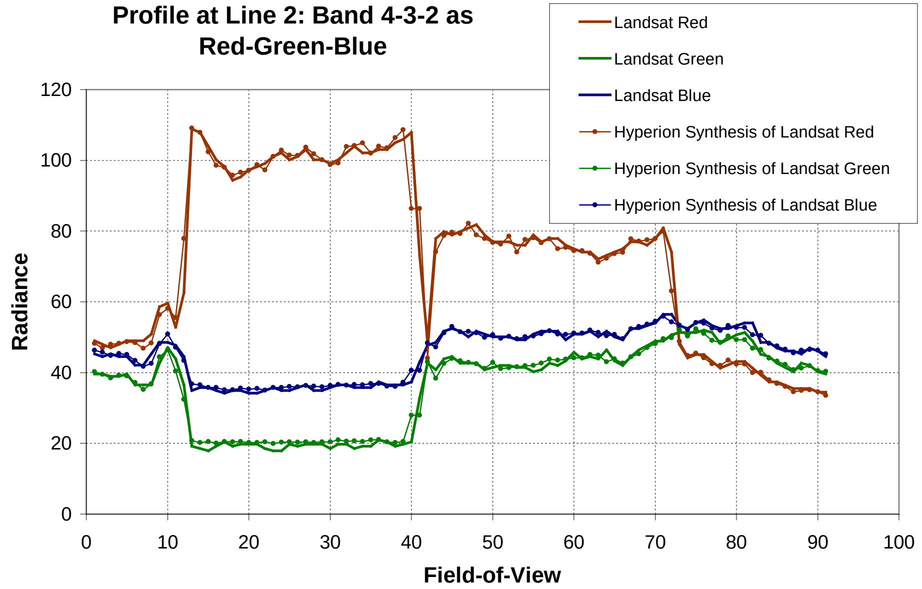
Hyperspectral Synthesis of Multispectral Bands

Landsat 7 Subset

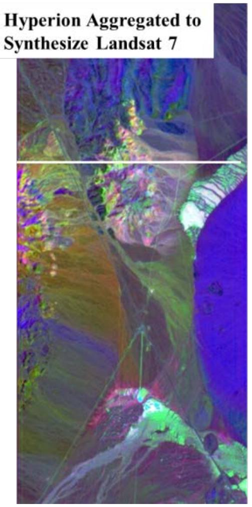


Hyperion

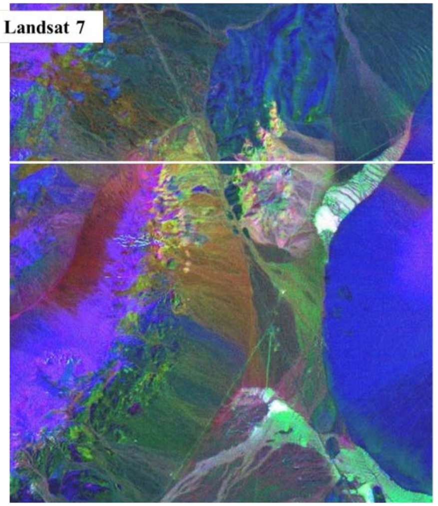


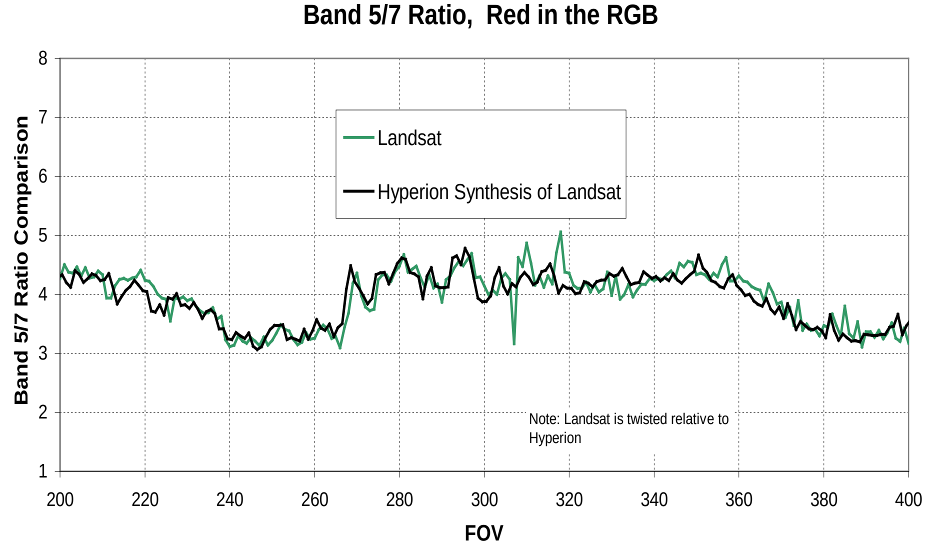


Hyperion Aggregated to Synthesize Landsat 7



Landsat 7





Photonic Spectrometer Approach

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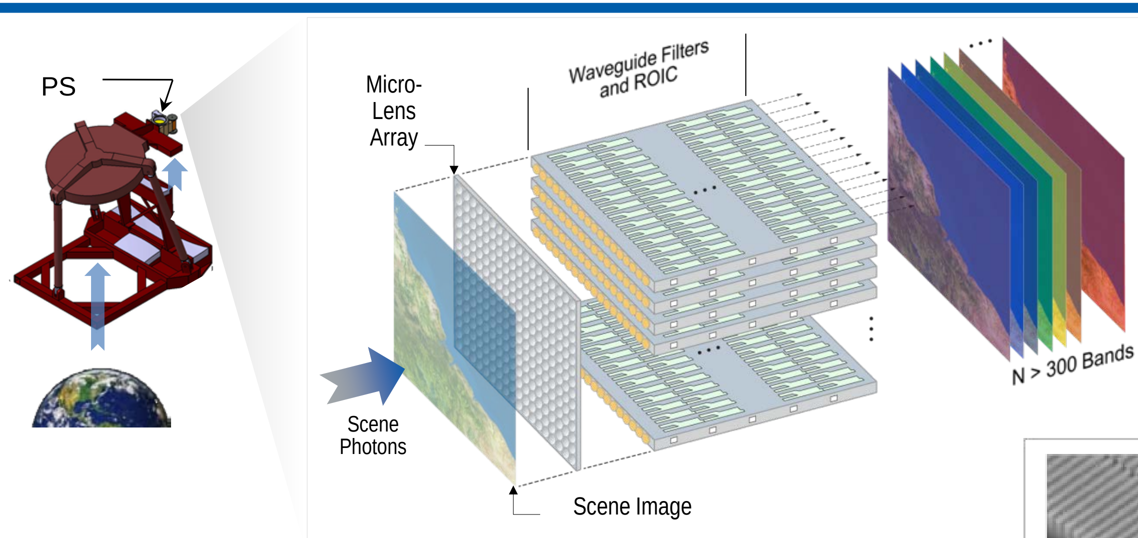
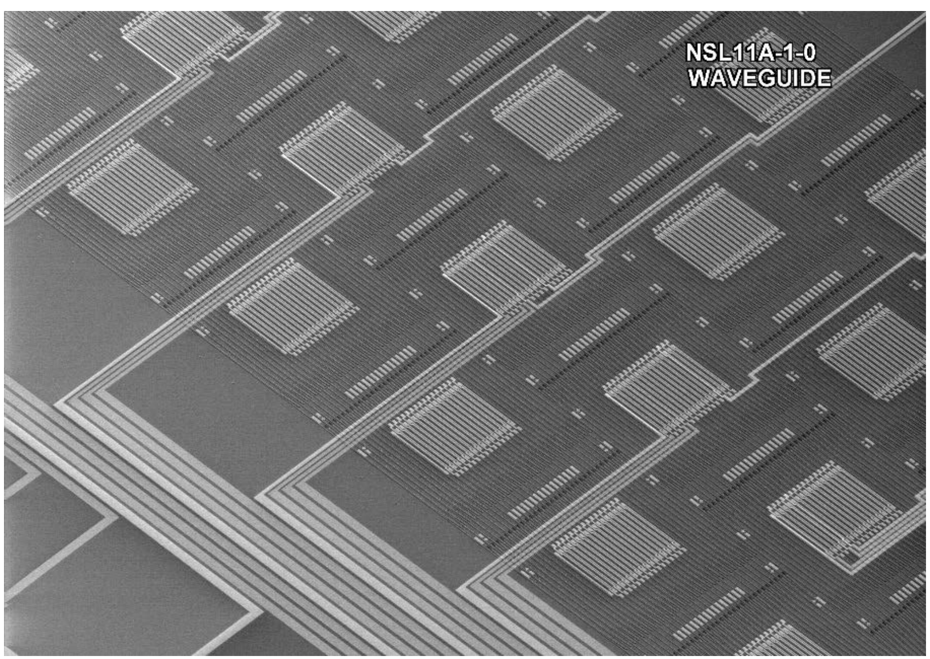
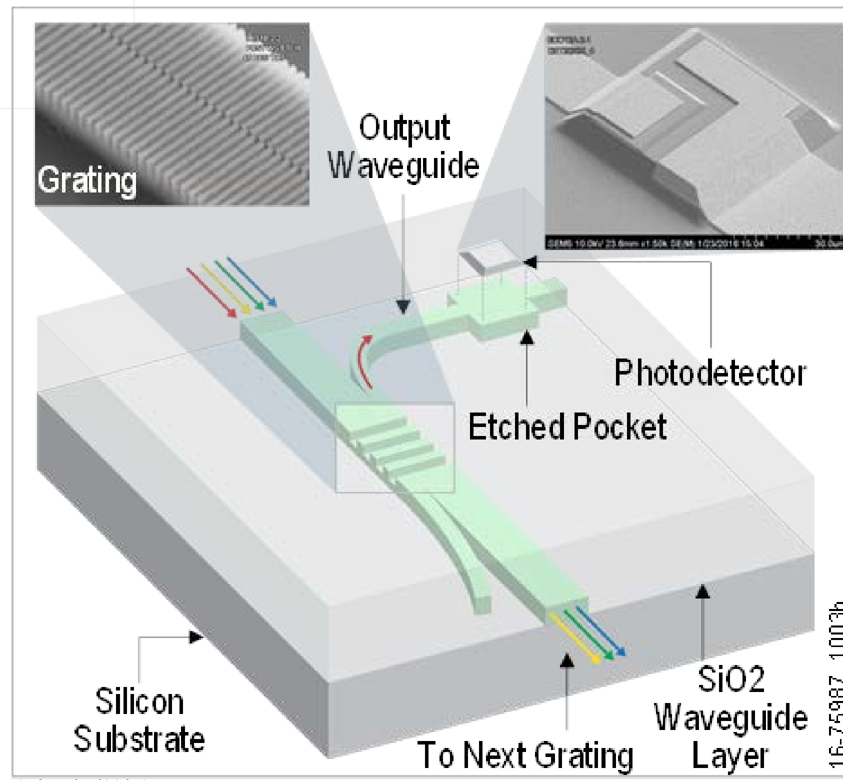


- Under the NASA ESTO SLI-T program, Northrop Grumman is building a hyperspectral sensor in which micro-patterned waveguides and photonic circuits replace traditional free-space optical components
- The use of photonics leads to ultra-compact instrument form factors

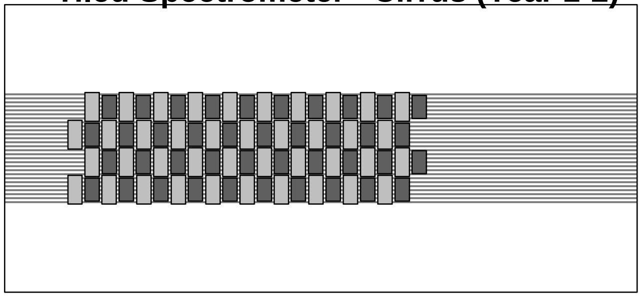




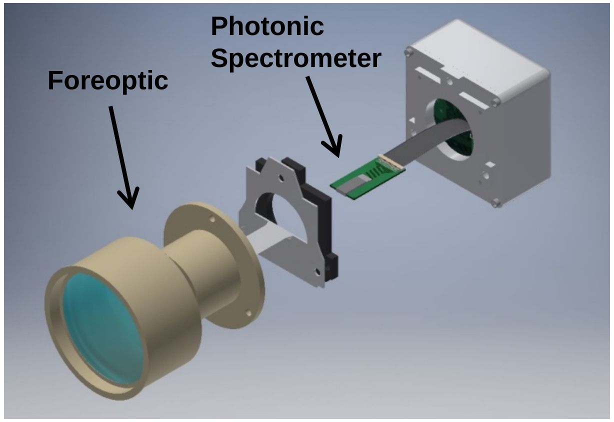
SLI-T Program

- 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

Tiled Spectrometer - Cirrus (Year 1-2)



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



Spectrometer Detector / ROIC Tiling Pattern

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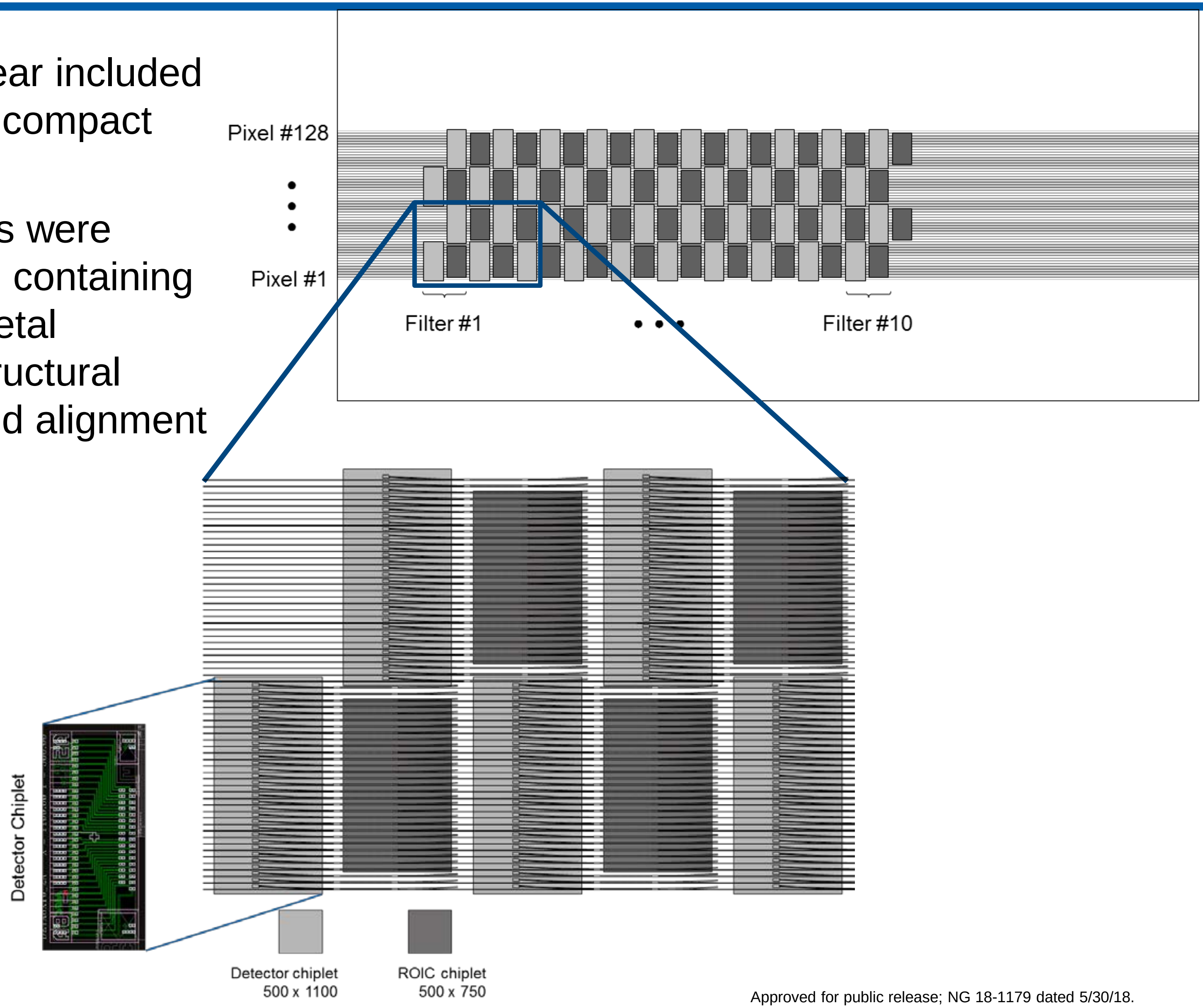
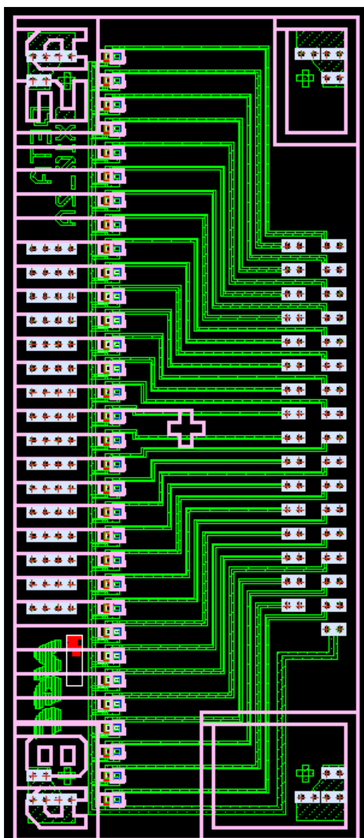
- First program year included development of compact waveguides
- Detector chiplets were designed - each containing 32 detectors, metal interconnect, structural interconnect, and alignment marks

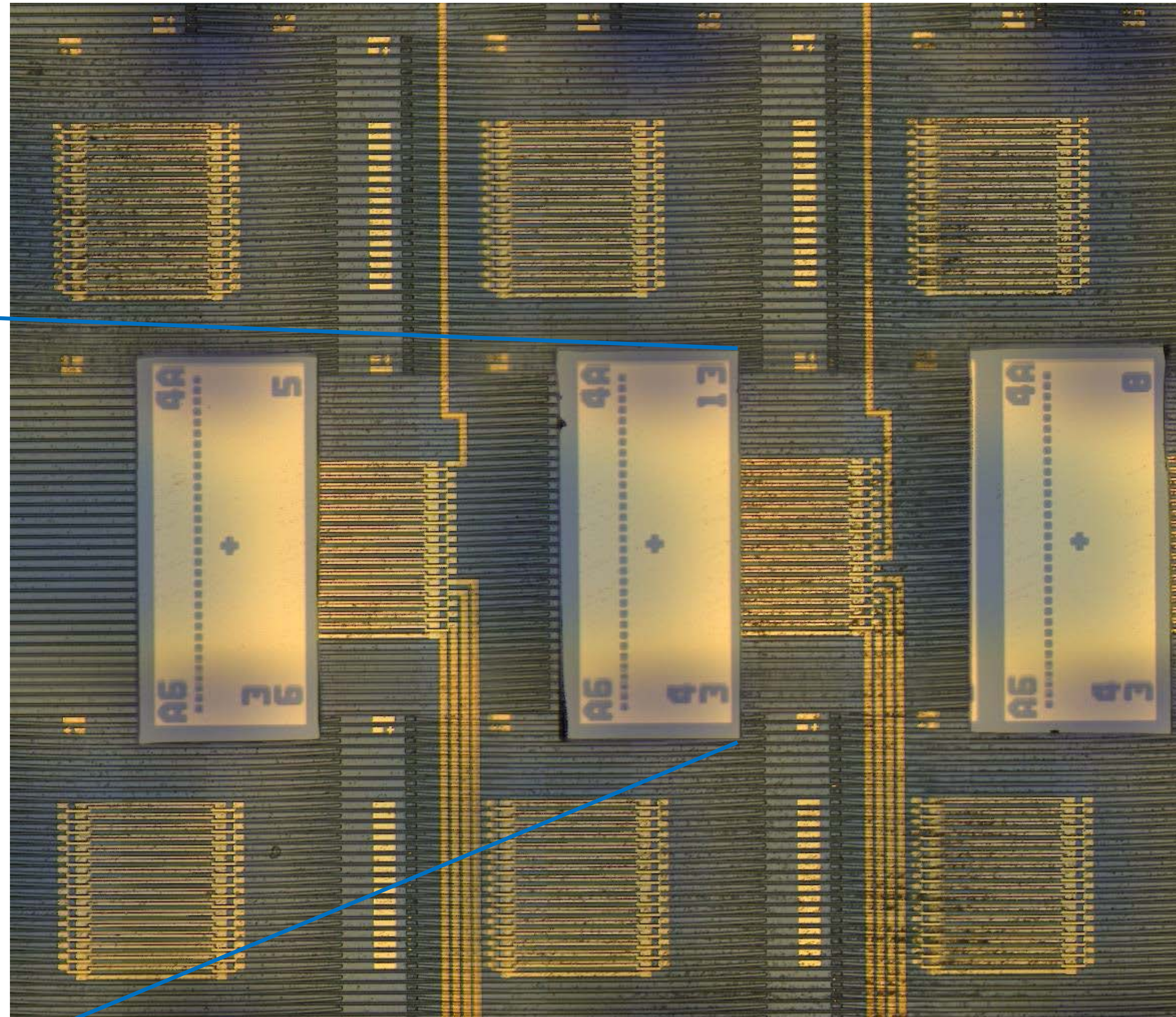


Integrated Detector Chiplets

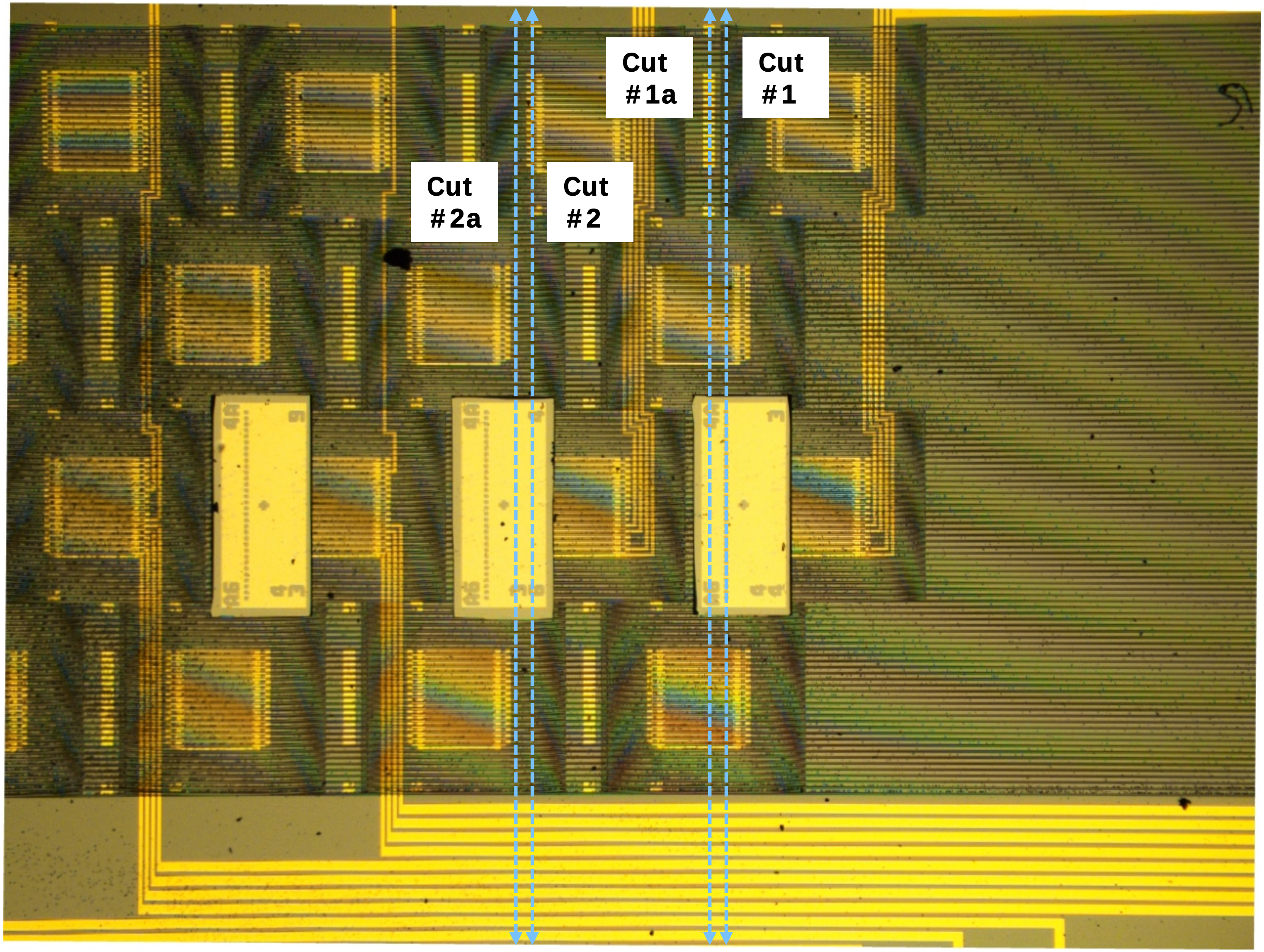
- SLI-T waveguides and detectors have been fabricated and integrated

Detector Chiplet

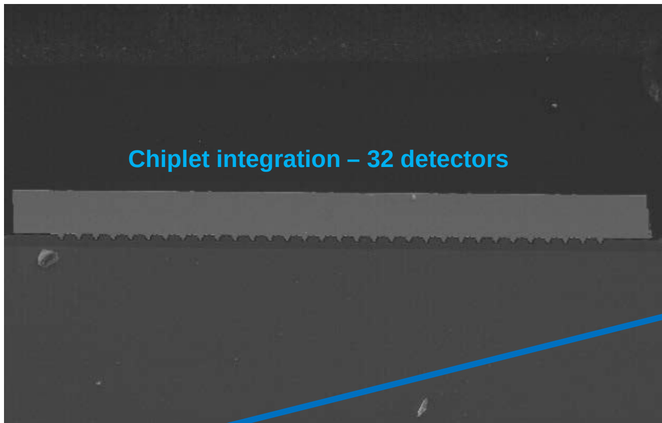


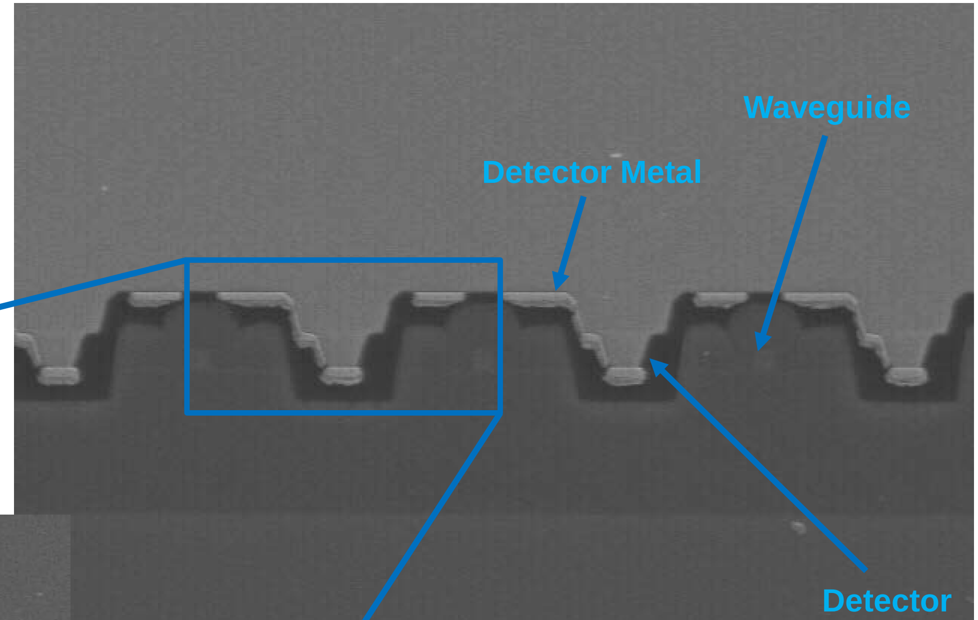


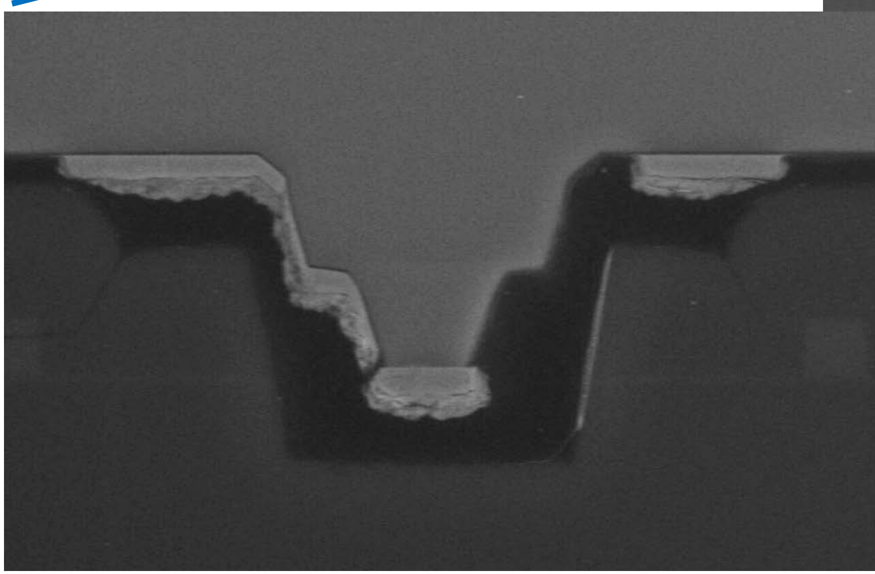
Testing: Cross Section Cuts



Cross-Sectional SEM: Cut Through Detector Pockets

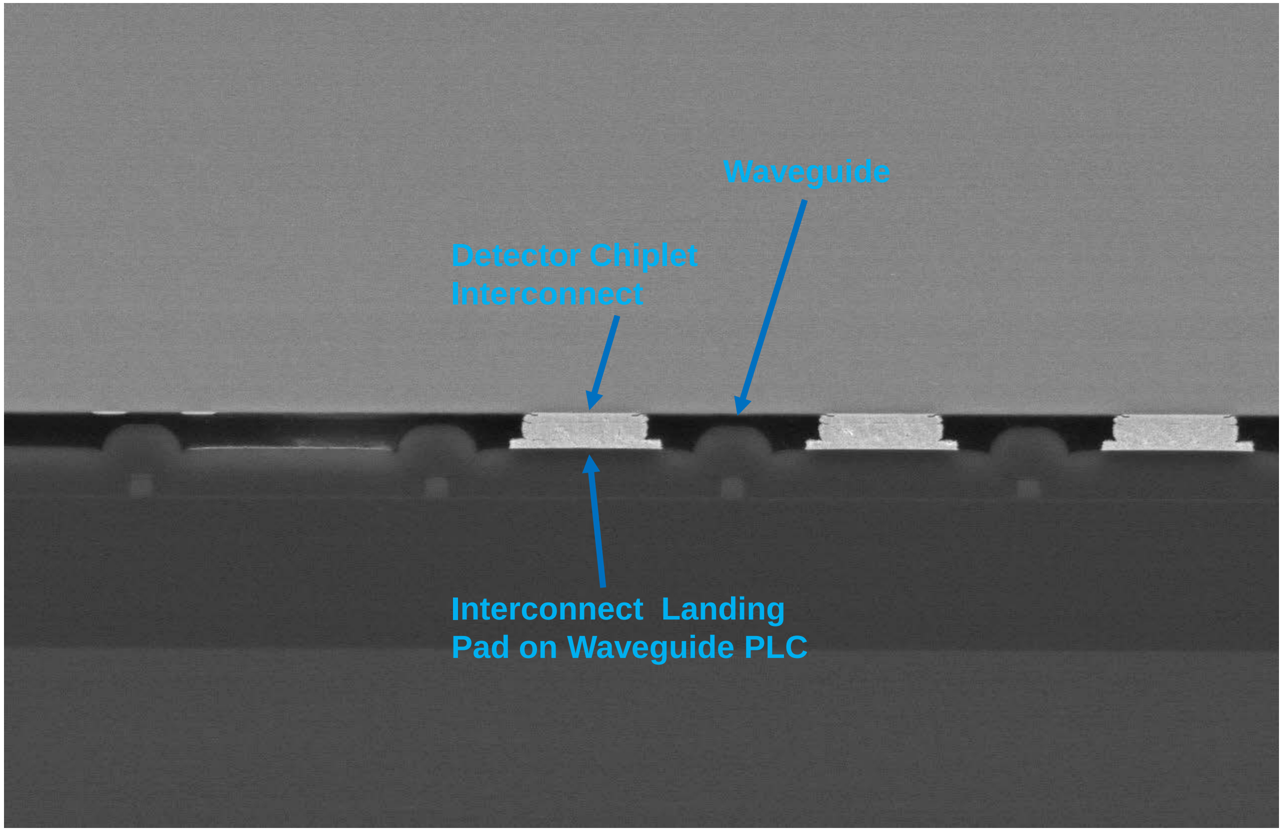






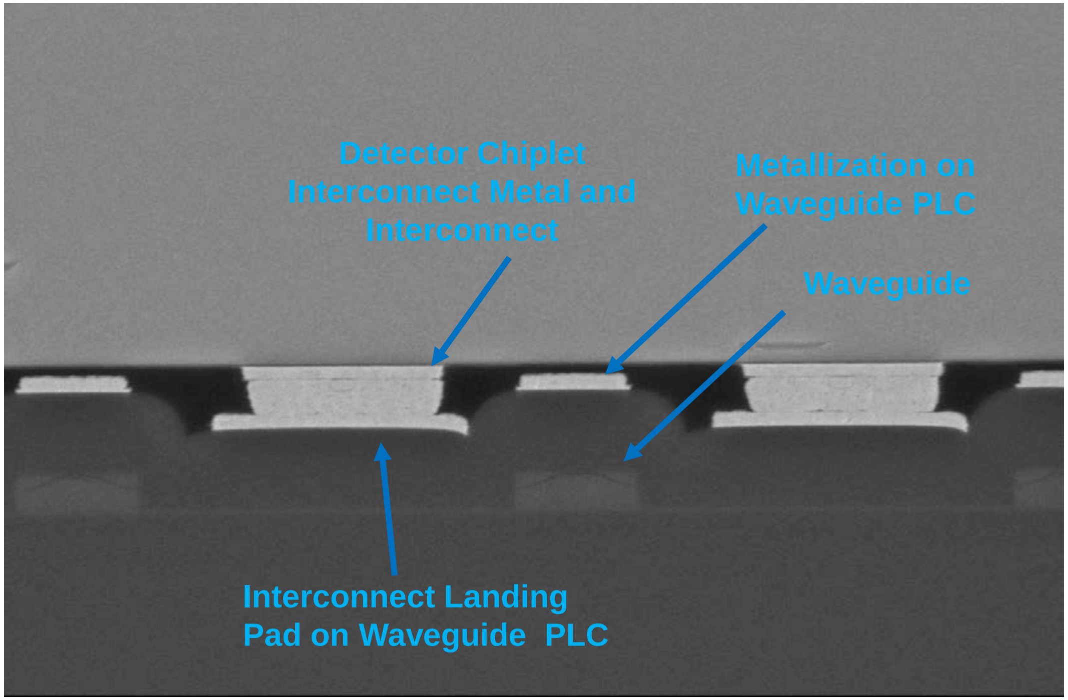
- SEMs show very good alignment and pocket positioning
- No “bottoming out” from integration

Cross-Sectional SEMs: Cut Through Structural Interconnects Between Waveguides



Demonstrates accurate interconnect alignment and bonding

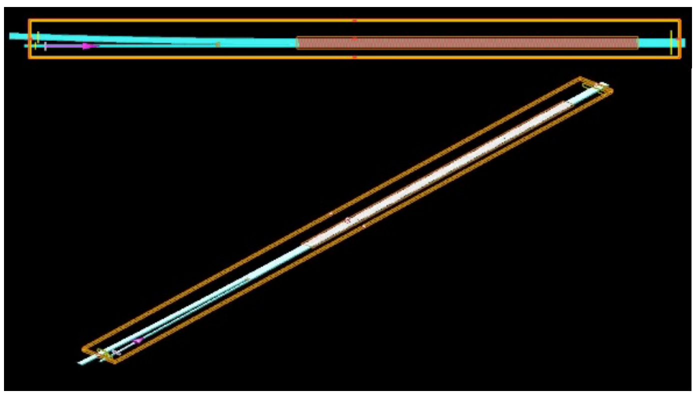
Cross-Sectional SEMs: Cut Through Electrical Interconnect and Waveguide Metallization

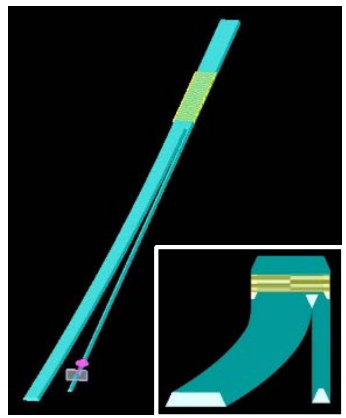


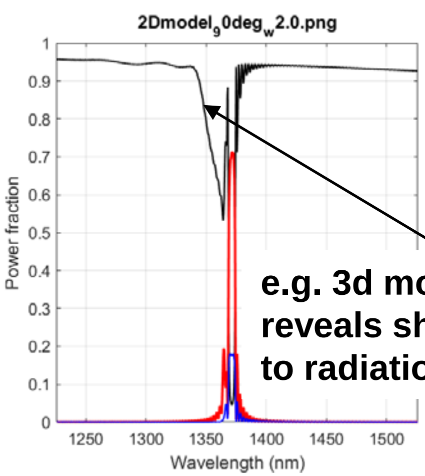
Accurate interconnect placement, alignment and bonding - shows metallization on surface of waveguide wafer

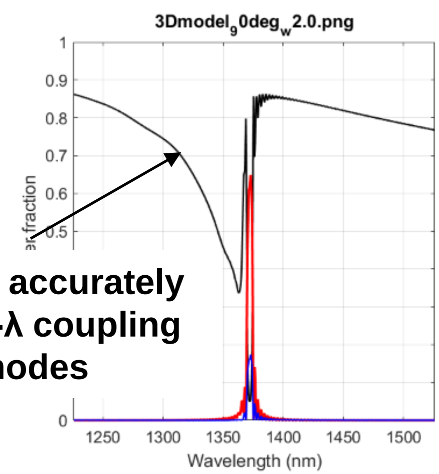
Modeling of Full 3D Waveguide Filter Structures

- 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

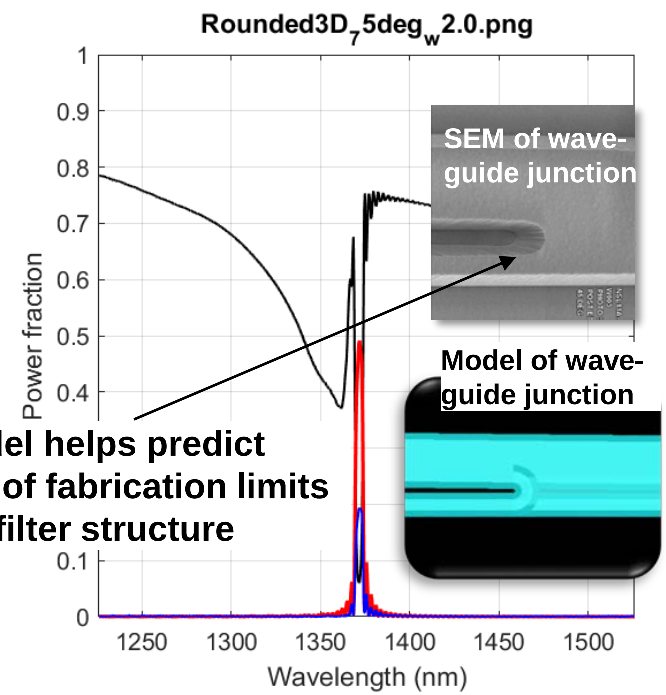








e.g. 3d model accurately reveals short-λ coupling to radiation modes



3d model helps predict impact of fabrication limits on the filter structure

System Performance Model

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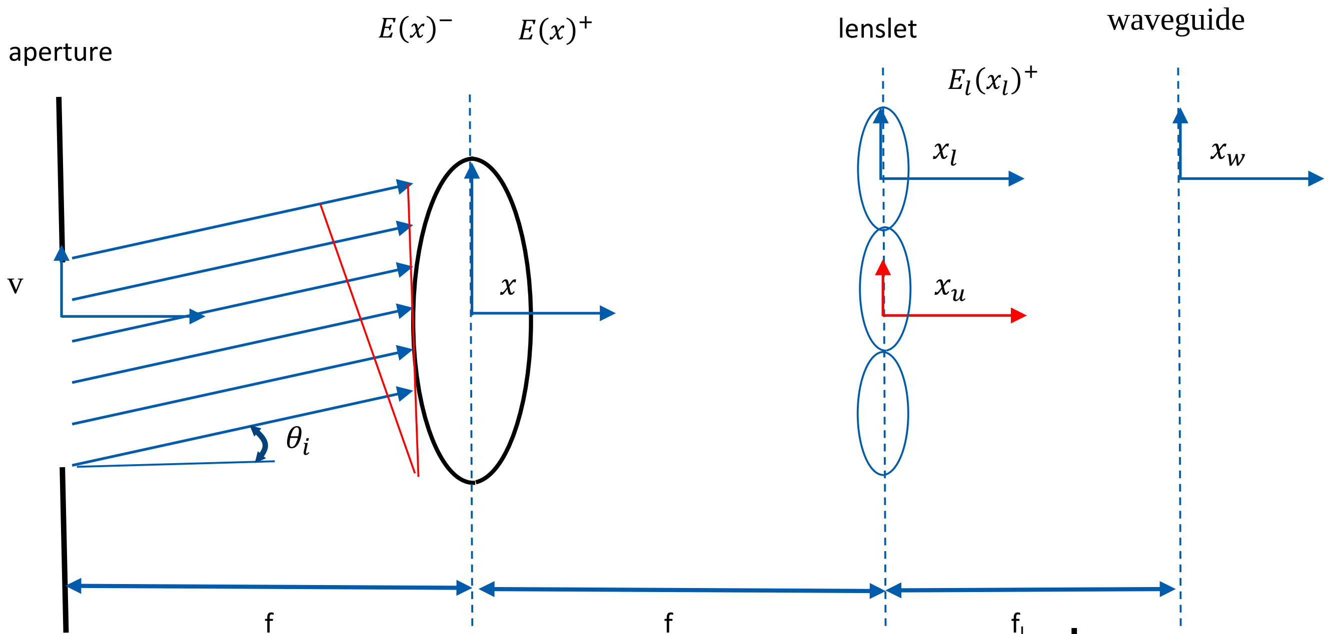
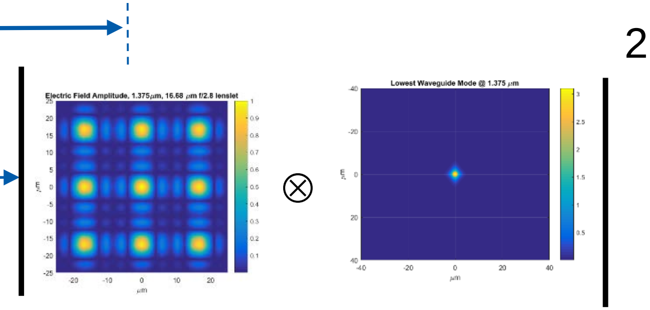
Developed system level sensor model to estimate radiometric and spatial performance



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.

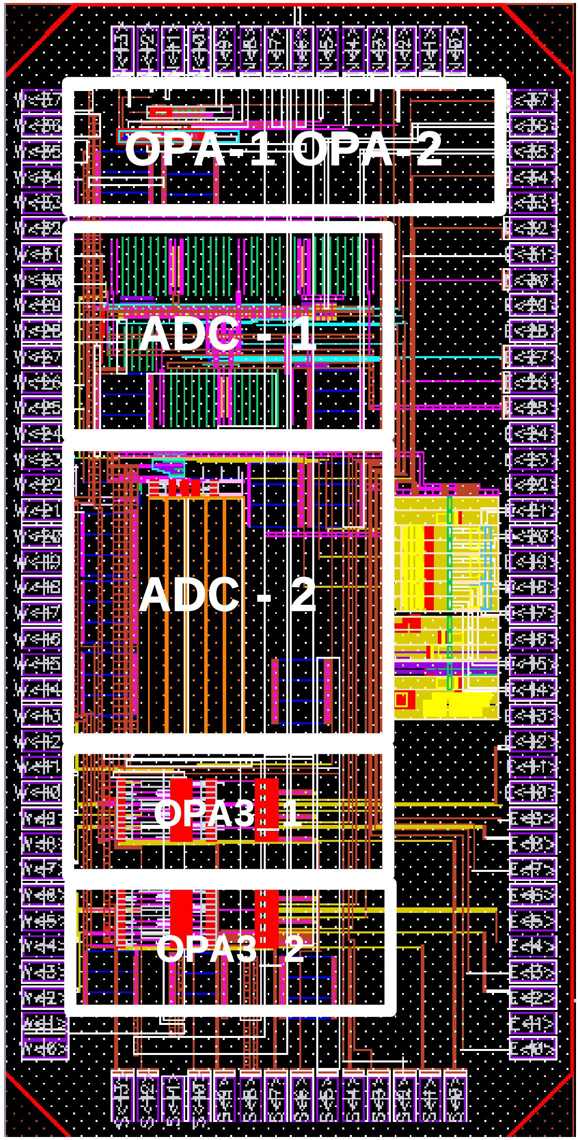
$$E(\theta_i, v) = A_0 e^{-ikv\sin(\theta_i)}$$



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

Square of normalized overlap integral is the coupling efficiency.

SLI-T ROIC



- 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

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