The Hyperspectral Microwave Photonic Instrument (HyMPI): Photonic Integrated Circuits in Space for Improved Planetary Boundary Layer sounding

Fabrizio Gambini[1,2,3], Victor Torres[1,2], Priscilla Mohammed[1,4], Edward Leong[1], David Robles[1], Michael Coon[1], Roger Banting[1,5], Jeffrey Piepmeier[1], Mark Stephen[1], Antonia Gambacorta[1]

[1]NASA Goddard Space Flight Center, [2]Univ. of Maryland Baltimore County, [3]CRESST II, [4]Morgan State University, [5]ASRC Federal Analytical Service

Motivation:

This work presents the full end-to-end of the Hyperspectral Microwave Photonic Instrument (HyMPI) which aims at developing the very first hyperspectral microwave sensor to augment thermodynamic sounding capability from space, focusing on the Earth's Planetary Boundary Layer (PBL).

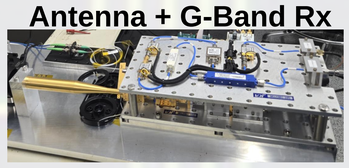
System concept:

Microwave (MW)
- Capture Earth's MW radiation
- Resilient to clouds

Photonics
- Ultra-wideband signal processing
- Minimize SWaP-C
- Tunable channels

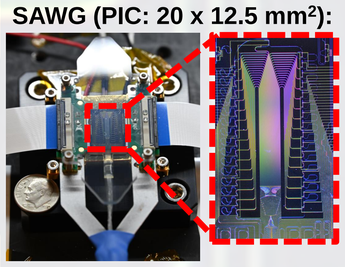
Electronics
- Hyperspectral resolution

Antenna + G-Band Rx

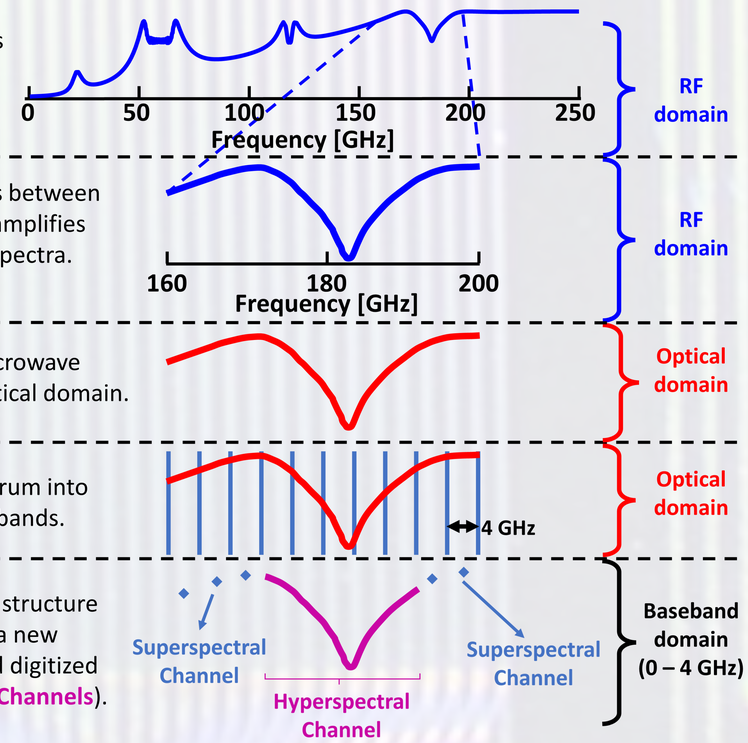


EOM:

SAWG (PIC: 20 x 12.5 mm²):



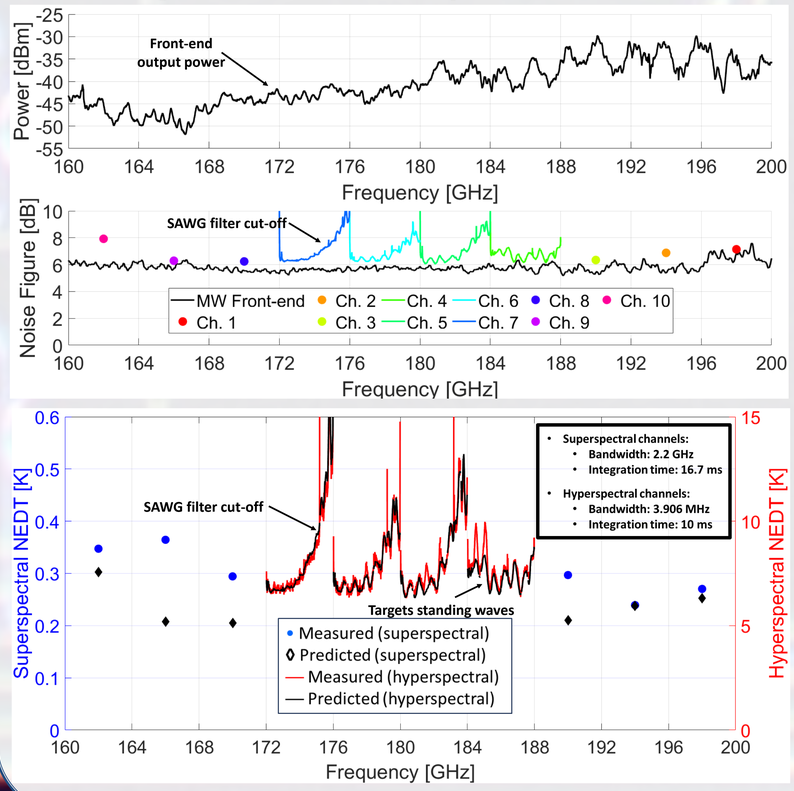
ASIC spectrometer:



Rx: receiver - EOM: electro-optical modulator - SAWG: serial arrayed waveguide grating - BPR: balanced photoreceiver - ASIC: application specific integrated circuit - PD: photodiode

- **HyMPI is based on photonic integrated circuits (PIC) to minimize size, weight and power consumption and cost (SWaP-C)**
- **HyMPI is modular. Each module provides a simultaneous 40 GHz PBL spectrum coverage**
- **HyMPI can be applied to multiple parts of the spectrum to obtain full coverage of the MW thermal domain**
- **PICs + ASICs = "PICASIC": full, contiguous, hyperspectral resolution (thousands of channel) ultra-wideband coverage**

Noise figure and noise equivalent differential temperature:

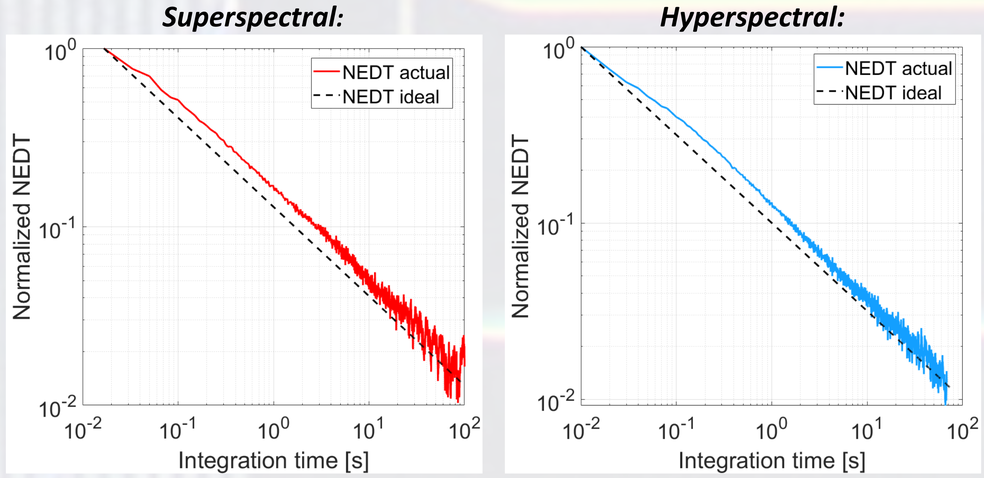


- **The Noise Equivalent Differential Temperature (NEDT) values are limited by the noise figure (NF) of the front-end**
- **The photonic link add only marginal noise**
- **HyMPI system performance demonstrated a 40 GHz frequency range with simultaneous super- and hyper-spectral resolution channels**
- **HyMPI's superspectral channels improve the performance in the Program of Records (ATMS: 0.39 K @ 3 GHz – 18 ms [1])**

[1] E. Kim, et al., "S-NPP ATMS instrument prelaunch and on-orbit performance evaluation," Journal of Geophysical Research: Atmospheres 119.9 (2014): 5653-5670.

Calibration of super- and hyperspectral- resolution channels:

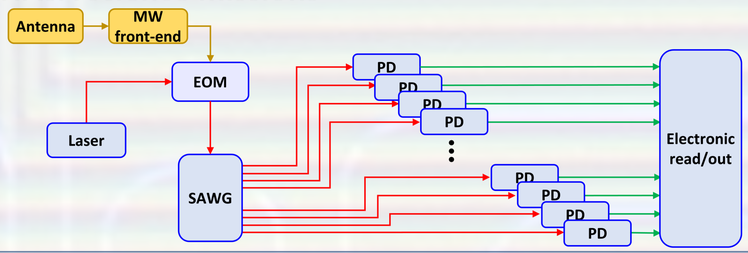
Superspectral: ***Hyperspectral:***



- **Frequent calibration reduces the impact of 1/f noise**
- **After calibration data averaged demonstrated up to 100 s**

Next step: AURORA

Space-based technology demonstration of broad-spectrum and hyperspectral microwave-photonics technology-based sounders for future NASA science missions



Conclusions:

- **We built and demonstrated the full end-to-end system performance at super- (4 GHz) and hyperspectral- (3.906 MHz) resolution of HyMPI, for Earth's PBL sounding**
- **PICs enhance the performance of the system and limit the instrument's SWaP-C without significantly affecting the noise level of the system**