National Aeronautics and Space Administration

Technology Development for Orbital Planetary Boundary Layer Humidity Sounding Radar

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Radars 2030 - Strategic Initiative Leader: Simone Tanelli

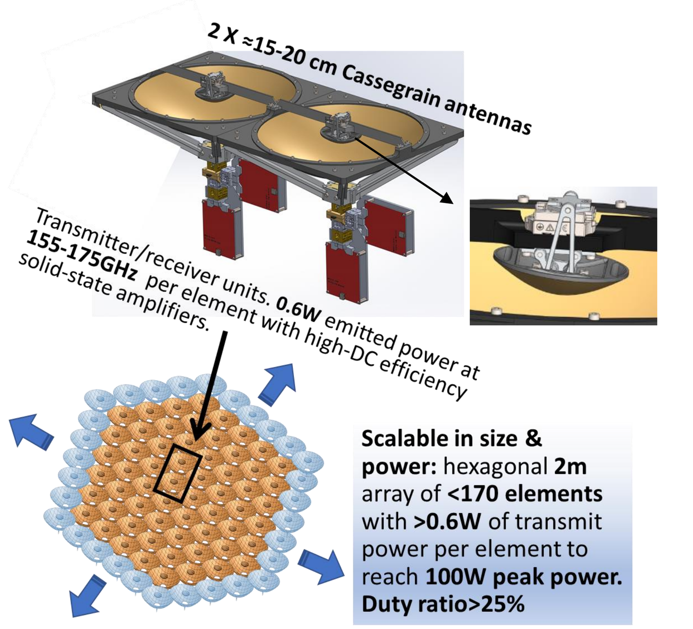
Background: ultra-high frequency radar for Earth science & security

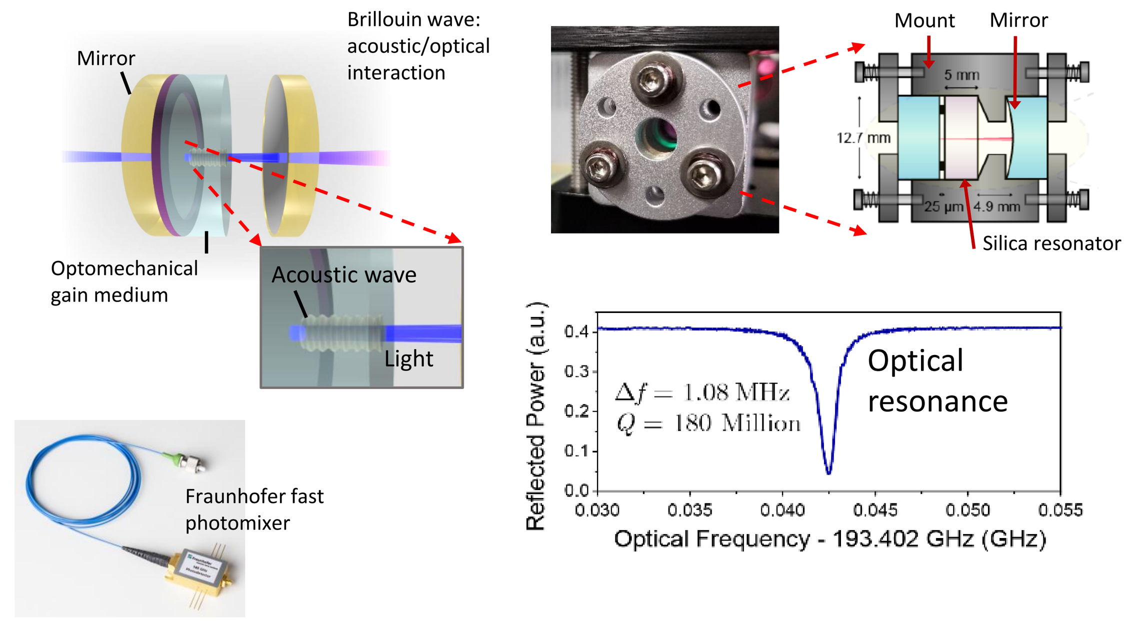
- High resolution water vapor profiles inside of clouds within the Planetary Boundary Layer (PBL) is a Targeted Observable for Incubation in the 2017 Earth Science Decadal Survey.
- JPL's 155-175 GHz Differential Absorption Radar (DAR) approach offers a novel way of retrieving humidity by measuring cloud scattering brightness varies over frequency near the 183 GHz water absorption resonance.
- To realize a spaceborne DAR system in the 2030s, great improvements in transmit power are required, along with large apertures, in order to measure scattering from clouds at orbital altitudes. Ultra-low phase noise sources above 150 GHz are also highly desirable to maximize the dynamic range of cloud detection above bright ground clutter.
- This technology is pertinent to security applications as well.

Technology Vision: spatial power-combining, RF photonics, and range-Doppler mapping

- Goal: ≥100 W transmit power with 155-175 GHz tuning, using a ~2 meter aperture diameter, and with fast beam-steering capability

  Disruptive Proposed Solution: Coherently power-combine an array of ~20-cm aperture parabolic antennas, each transmitting ~0.5 W. To achieve phase coherence, use electronic phase-shifting achieved by biasing diode frequency-multipliers which drive saturated mm-wave amplifiers. Use piezo-actuated subreflectors to rapidly steer the power-combined beam.





- Goal: Generate signals directly in G-band, without frequency-multiplication, and tunable over 155-175 GHz with <-110 dBc/Hz phase noise at 100 kHz offset.

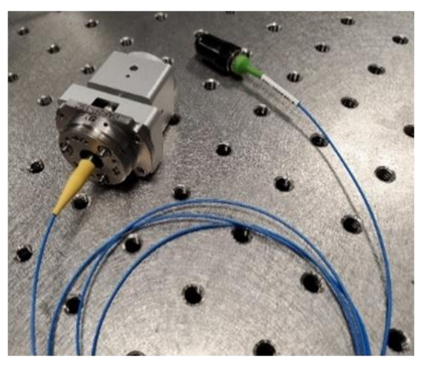
  Disruptive Proposed Solution: Use two compact, stable, and widely tunable Brillouin laser modes coupled to a fast photomixer to produce the G-band signal as a beat note.

- Goal: Use remote sensing to distinguish between different characteristics of animal vs human intruders across a defensive perimeter, and to fingerprint different types of drones.

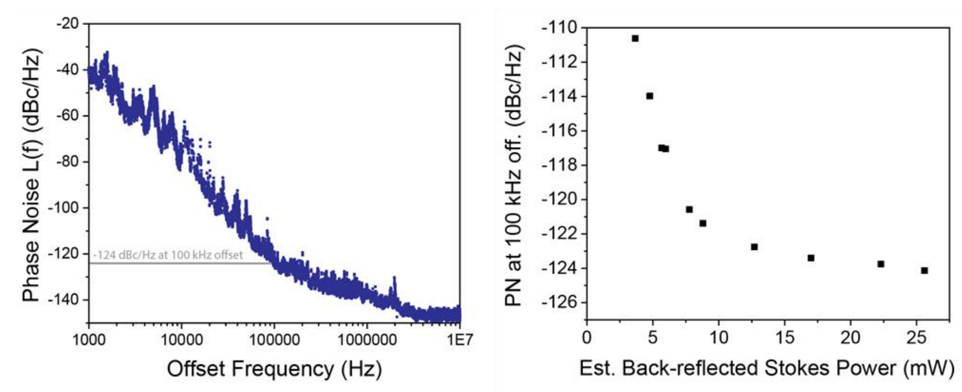
  Proposed Solution: Leverage JPL's millimeter-wave radar work to build a 240 GHz range-Doppler radar capable of medium-range detection with high sensitivity and range/spectral resolution.

Experimental Results

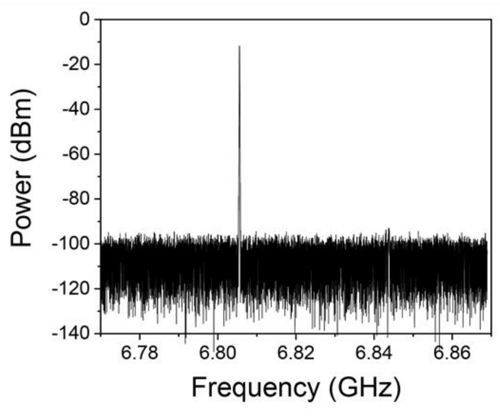
Microscale Brillouin Laser



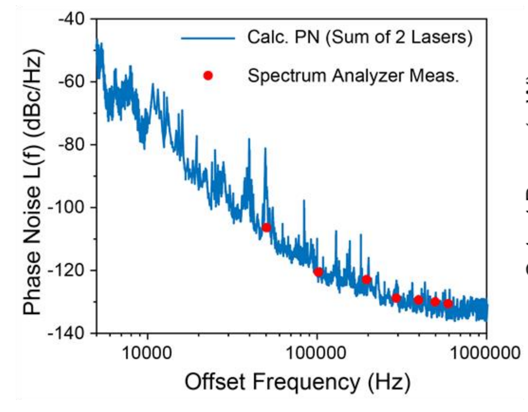
Phase noise measurements: done at laser frequency (193 THz)



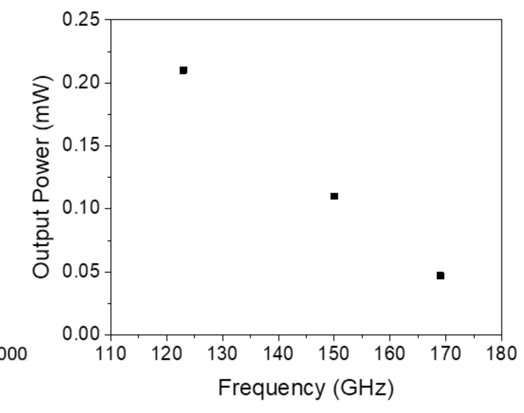
Mixing two lasers to 6.8 GHz

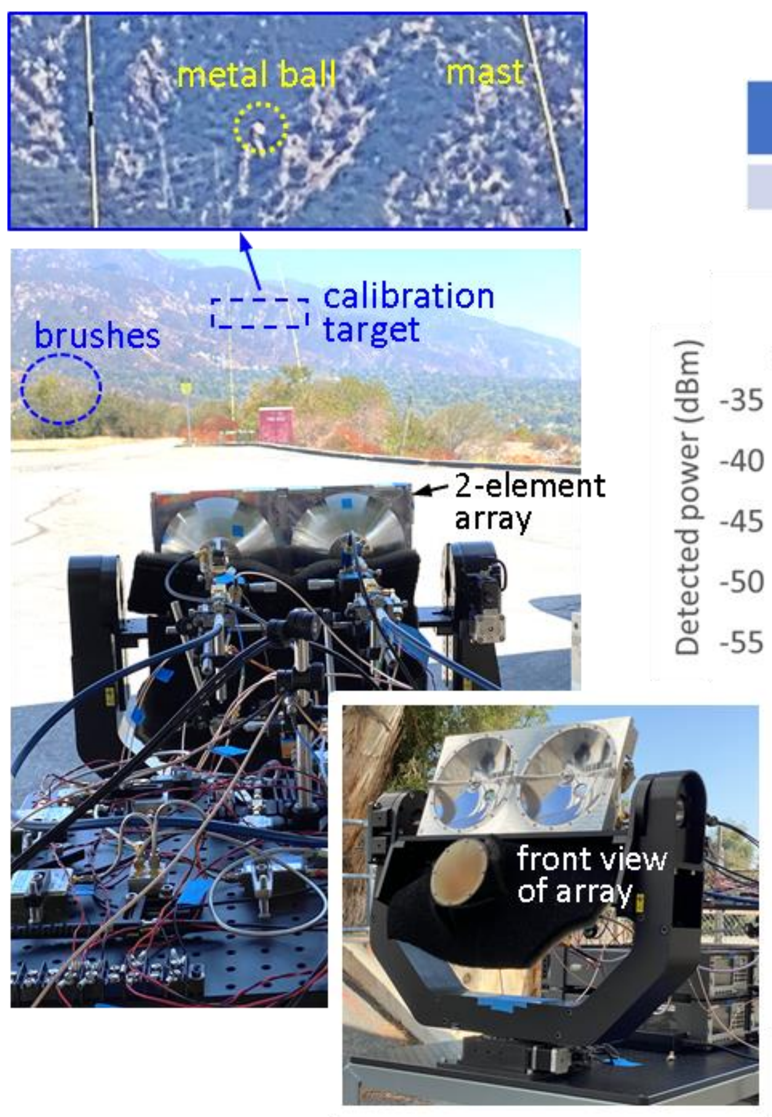


Phase noise for 6.8 GHz signal (expected to be freq. independent)



Mixing lasers to G-band

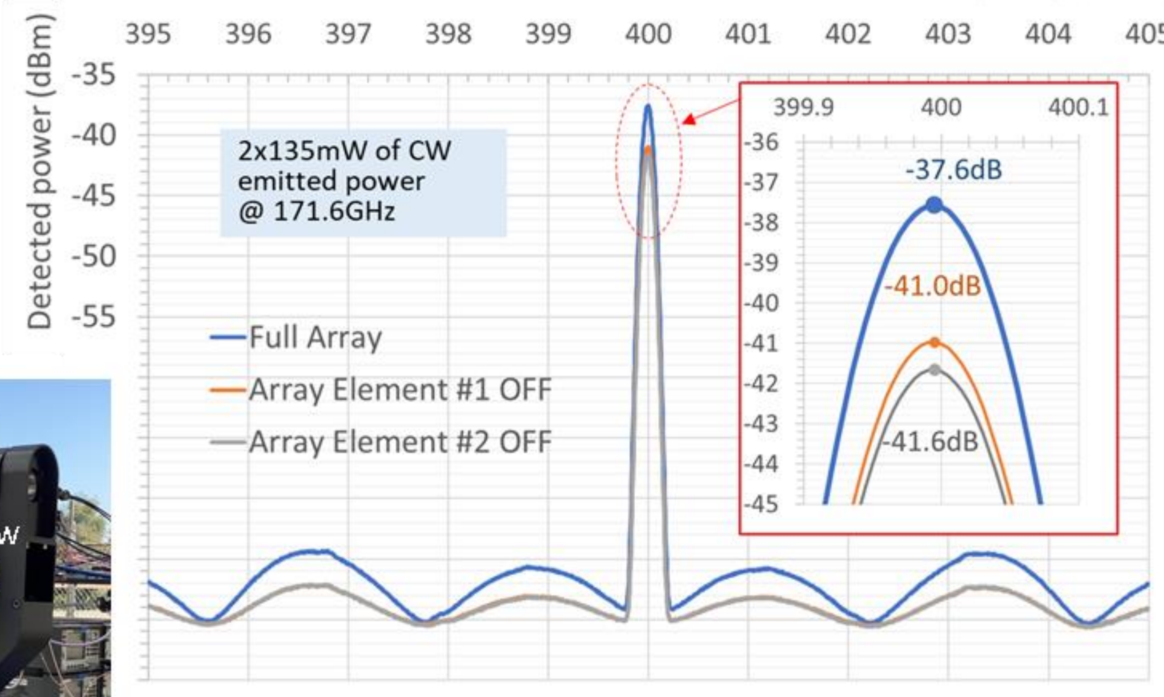


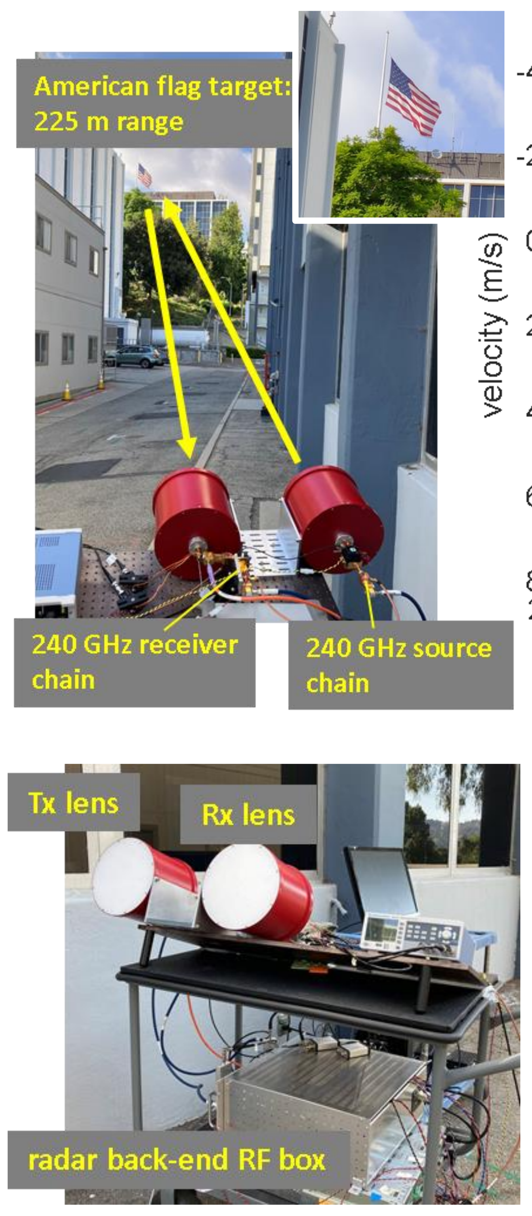


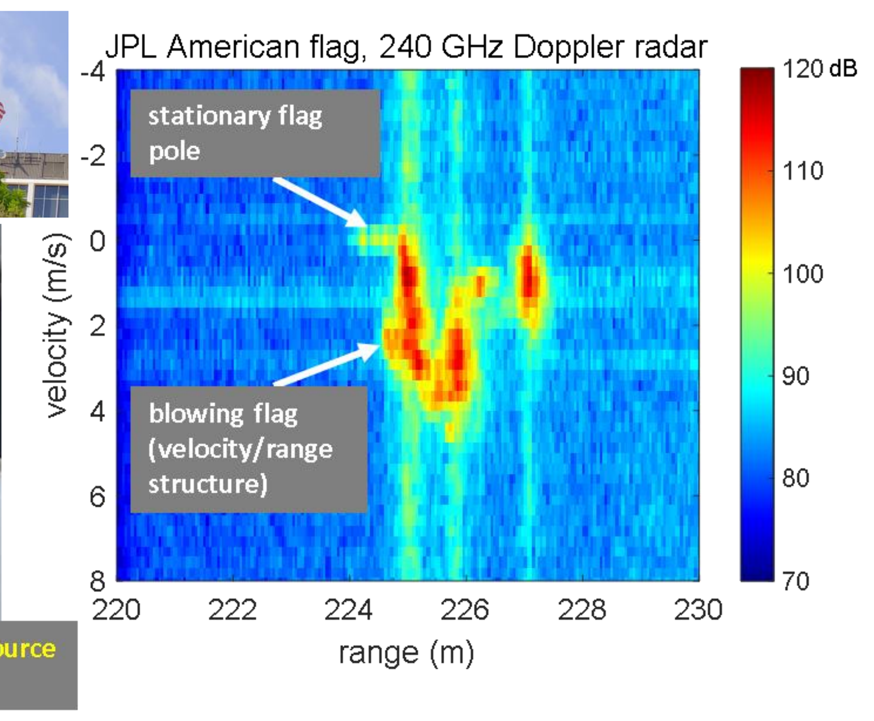
Array pointing at bushes

Full Array	Array Element #1 OFF	Array Element #2 OFF
-39.49 dBm	-42.57 dBm	-42.12 dBm

Array pointing at calibration target







240 GHz source power:	30-100 mW
Antenna directivity:	50 dBi
Receiver sensitivity:	9-12 dB NF (SSB)
FMCW chirp bandwidth:	3 GHz
Range resolution:	47 cm (typ)
Velocity resolution :	0.24 m/s (typ)
Real-time duty cycle:	25%

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Publications:

E.A Kittlaus, P.T. Rakich, K.B. Cooper "Low-noise Photonic Signal Synthesis for mm-Wave Radar," *Invited talk to be presented at the IEEE Photonics Conference*, 16 Nov. 22 in Vancouver, Canada.
Kittlaus, Eric A., Danny Eliyahu, Setareh Ganji, Skip Williams, Andrey B. Matsko, Ken B. Cooper, and Siamak Forouhar. "A low-noise photonic heterodyne synthesizer and its application to millimeter-wave radar." Nature Communications 12, no. 1 (2021).
A. Maestrini, K. Cooper, S. van Berkel, M. Lebsock, C. Lee, G. Chattopadhyay, I. Mehdi "Reflector-Based Phased Array for High Power G-band radars", to be published in the proceedings of the 32nd IEEE International Symposium on Space Terahertz Technology, Baeza, Spain, 16-20 October 2022.

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