National Aeronautics and Space Administration

Barrier Infrared Detector Digital Focal Plane Array

Principal Investigator: David Z Ting (389)
Sarath D Gunapala, William R Johnson, Arezou Khoshakhlagh (389)
Program: Strategic Initiative

Project Objective:

The goal of this project is to demonstrate digital focal plane arrays (DFPAs) using the JPL barrier infrared detector (BIRD) technology. The BIRD enables continuously adjustable cutoff wavelength ranging from the short wavelength infrared (SWIR) to the very long wavelength infrared (VLWIR), and higher operating temperature and/or sensitivity than previously attainable in cost-effective, robust III-V semiconductors. Digital FPA simplifies output electronics and reduces interference in signal chain. The availability of radiation-tolerant digital-output readout integrated circuit (ROIC) widens range of space applications. FPA based on large-well-depth digital-pixel ROIC (DPROIC) provides much higher dynamic range than a conventional FPA, leading to higher operating temperature, potentially reducing cooler size/weight/power, thereby enabling long wavelength infrared (LWIR) and VLWIR instruments for Small Satellites. We will build an integrated dewar cooler assembly (IDCA) using a DFPA and perform relevant tests to raise the TRL to meet the requirements for future flight opportunities.

FY19 Results:

We have successfully grown and tested very long wavelength infrared (VLWIR) detector material for the digital-output FPA. The spectral QE for a test detector shows a cutoff wavelength of 12.6 µm, while demonstrating good dark current characteristics. We have also developed a detector array surface passivation/encapsulation scheme for BIRD FPAs; this new process has resulted in improved stability. We have completed building the characterization setup for a digital-output readout integrated circuit (ROIC) based FPA. Using the new system we were able to successfully characterize DFPAs and acquired infrared images. We are in the process of building a hyper-spectral test setup to accommodate the testing BIRD DFPAs for hyperspectral capabilities. This is done by modifying the existing Quantum Well infrared photodetector Earth Science Testbed (QWEST) to work with BIRD DFPAs. Digital-pixel (DP) ROICs and associated FPA test setup are also being acquired. *Acknowledgement*: The contributions of Alex Soibel, Anita Fisher, Sam A. Keo, Don Rafol, Ed Luong, Cory Hill, and Brian Pepper (389) to this work are acknowledged.

Benefits to NASA and JPL (or significance of results):

The barrier infrared detector (BIRD) [U.S. Patent 8,217,480 (2012)] is a breakthrough technology in III-V semiconductor infrared detectors developed at JPL in recent years. Based on alloy or type-II superlattice infrared absorbers, BIRD can provide cutoff wavelengths ranging from 2 µm to beyond 15 µm. The mid-wavelength BIRD exhibits the same salient FPA characteristics (uniformity, operability, large-format capability, and affordability) as the market-leading InSb FPA, but (like HgCdTe) operates at much higher temperature than InSb. The long and very long wavelength BIRD FPAs have also demonstrated high operability and uniformity, but (like other photon detectors) require much lower operating temperature, which can be particularly challenging for small-satellite based infrared instrument. In an FPA based on digital pixel (DP) readout integrated circuit (ROIC), which provides a much higher effective well capacity than achievable in a conventional analog ROIC, the much longer integration times improves signal-to-noise ratio, leading to higher dynamic range, higher sensitivity, and/or higher operating temperature. The higher operating temperature advantage of the BIRD DFPA leads to reduced cryocooling system size/weight/power, thereby enabling infrared instruments for more versatile remote sensing and science data collection endeavors, including for cubesat/smallsat-class missions. For NASA Earth Science, 2017 Decadal Survey applications include: Surface Biology and Geology (hyperspectral imagery in the thermal IR), Greenhouse Gases (thermal IR sounders), and Planetary Boundary Layer (hyperspectral IR sounders). In addition, all of our current NASA projects, including CubeSat Infrared Atmospheric Sounder (CIRAS) (InVEST), VLWIR infrared focal plane arrays for Sustainable Land Imaging Technology (SLI-T) (ROSES), multiband long wavelength IR imager for studying planetary volcanism (PICASSO), VLWIR FPA for Earth Science applications (ACT), and LWIR hyperspectral thermal imager (HyTI) for SmallSat platform (InVEST), would generally benefit from the technology.

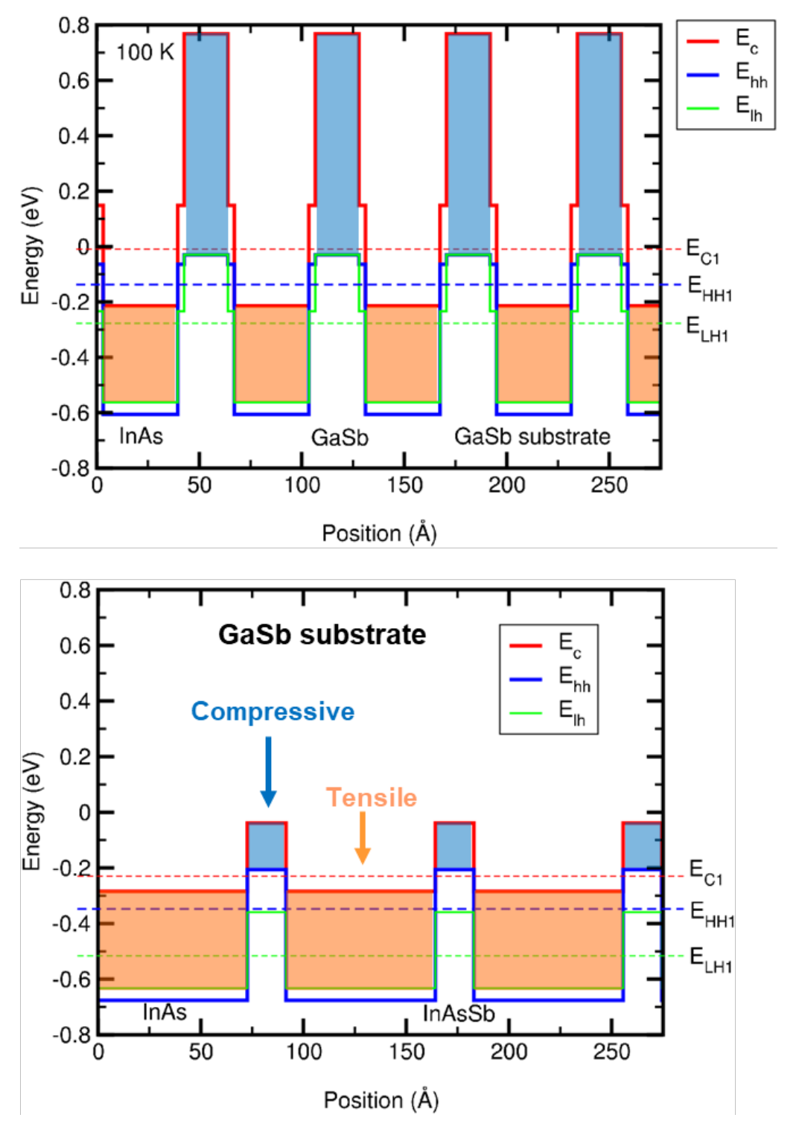

Fig. 1. Examples of type-II superlattice (T2SL) used as infrared absorbers. (Top) InA/GaSb T2SL. (Bottom) InAs/InAsSb T2SL

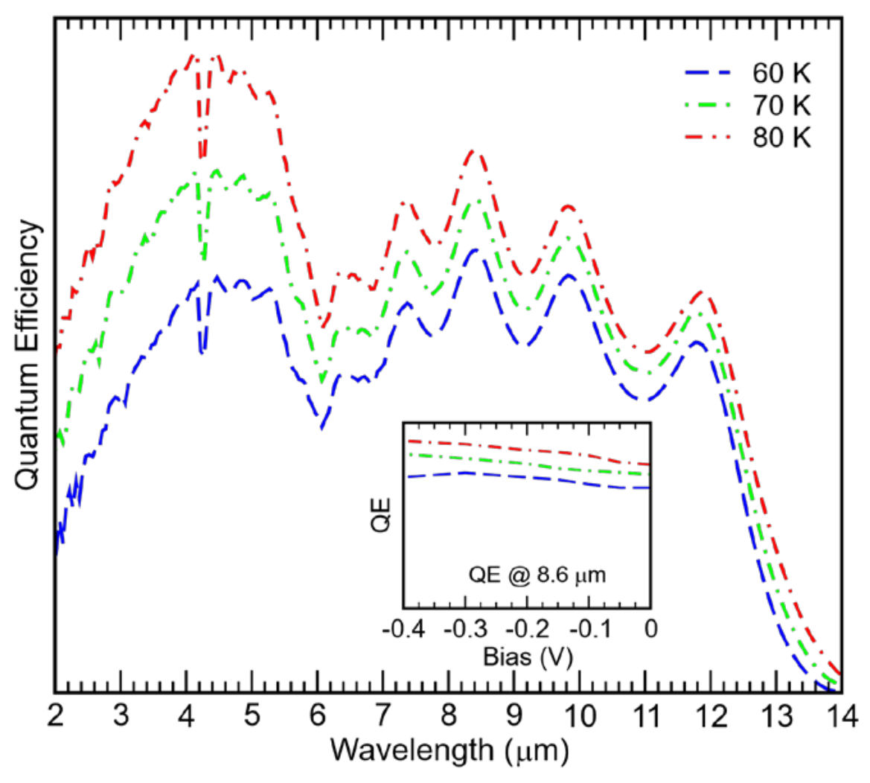

Fig. 3. Spectral quantum efficiency (QE) of a barrier infrared detector (BIRD) developed for this project. The detector incorporates a type-II superlattice absorber with a12.6 µm cutoff wavelength. The inset shows the QE at 8.6 µm as a function of applied bias.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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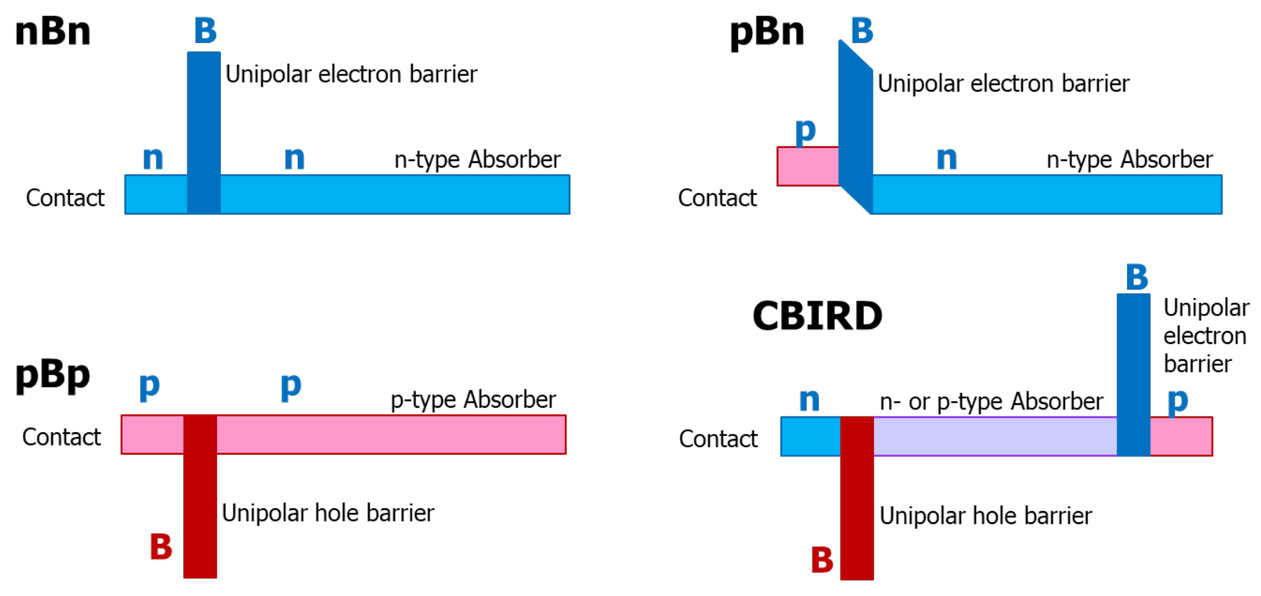

Fig. 2. Unipolar barrier infrared detector (BIRD) architecture examples. BIRD devices can incorporate type-II superlattice infrared absorbers.

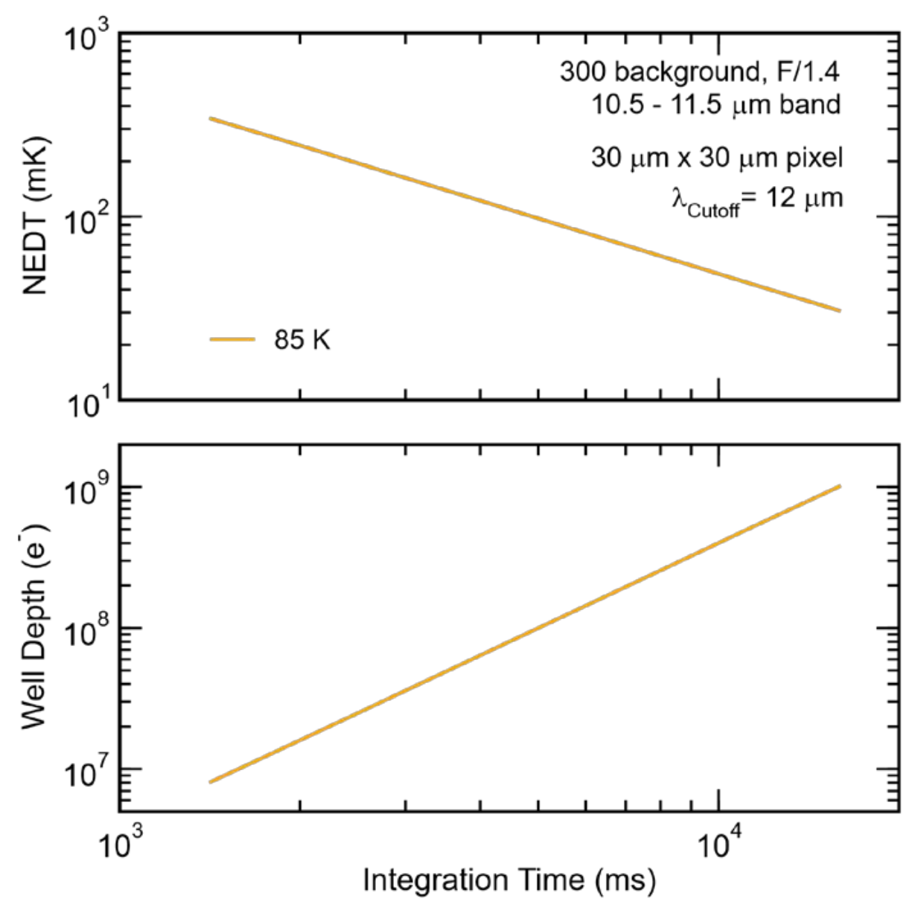

Fig. 4. NEDT (noise equivalent differential temperature) and required well depth as functions of integration time for the example of a 10.5-11.5 µm band infrared imaging application using a 12 µm cutoff wavelength IR detector. NEDT improves with longer integration time; larger well depth is needed to accommodate longer integration time.

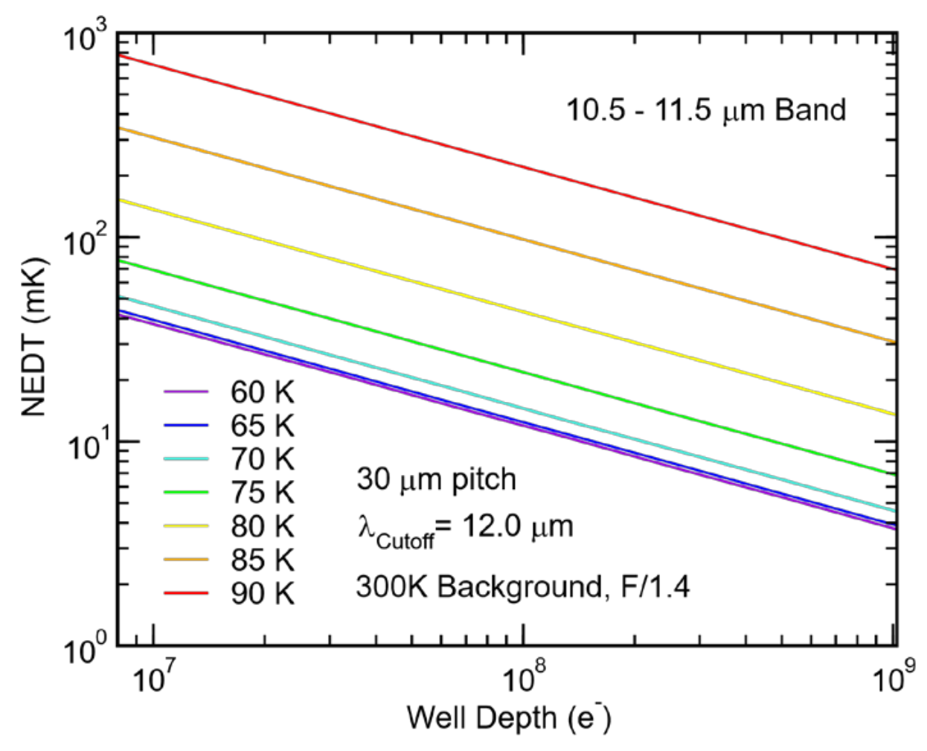

Fig. 5. NEDT at various detector operating temperatures as functions of well depth. Note NEDT improves as well depth increases. Alternatively, larger well depth leads to higher operating temperature while maintaining the desired NEDT.

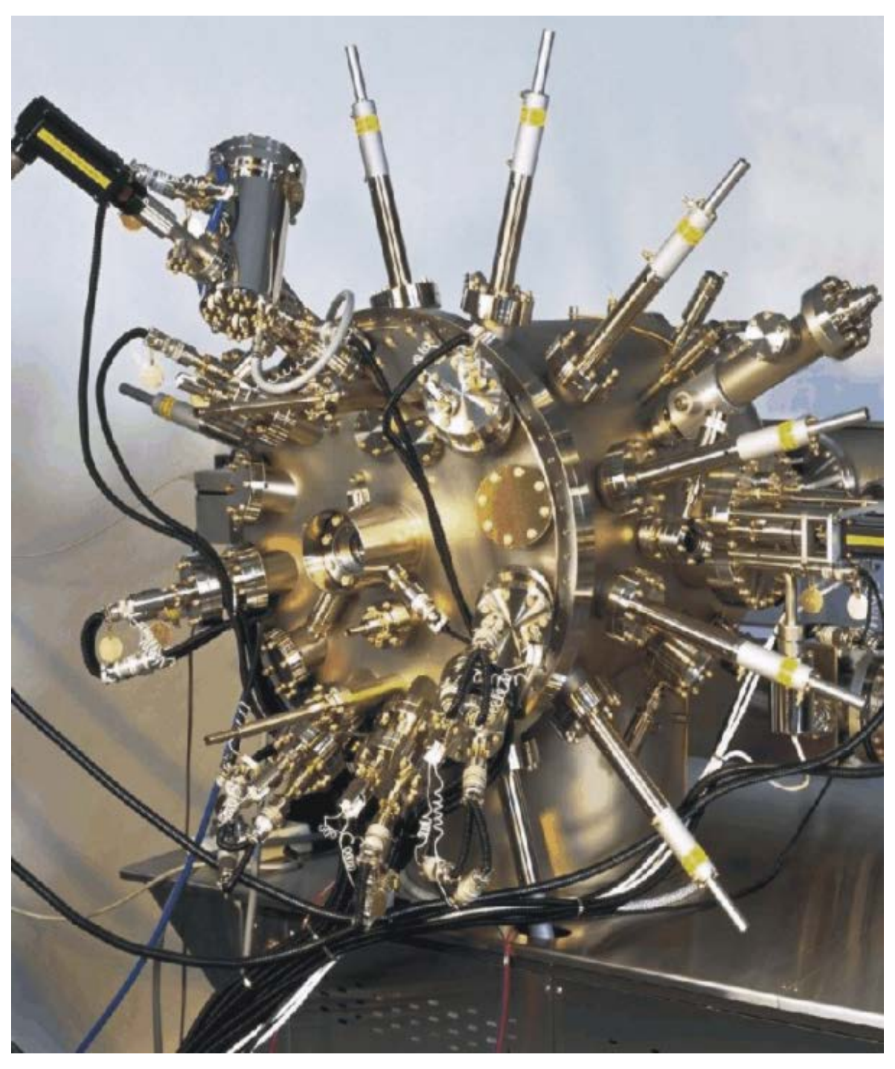

Fig. 6. Molecular beam epitaxy (MBE) machine used for growing type-II superlattice barrier infrared detector device structures.

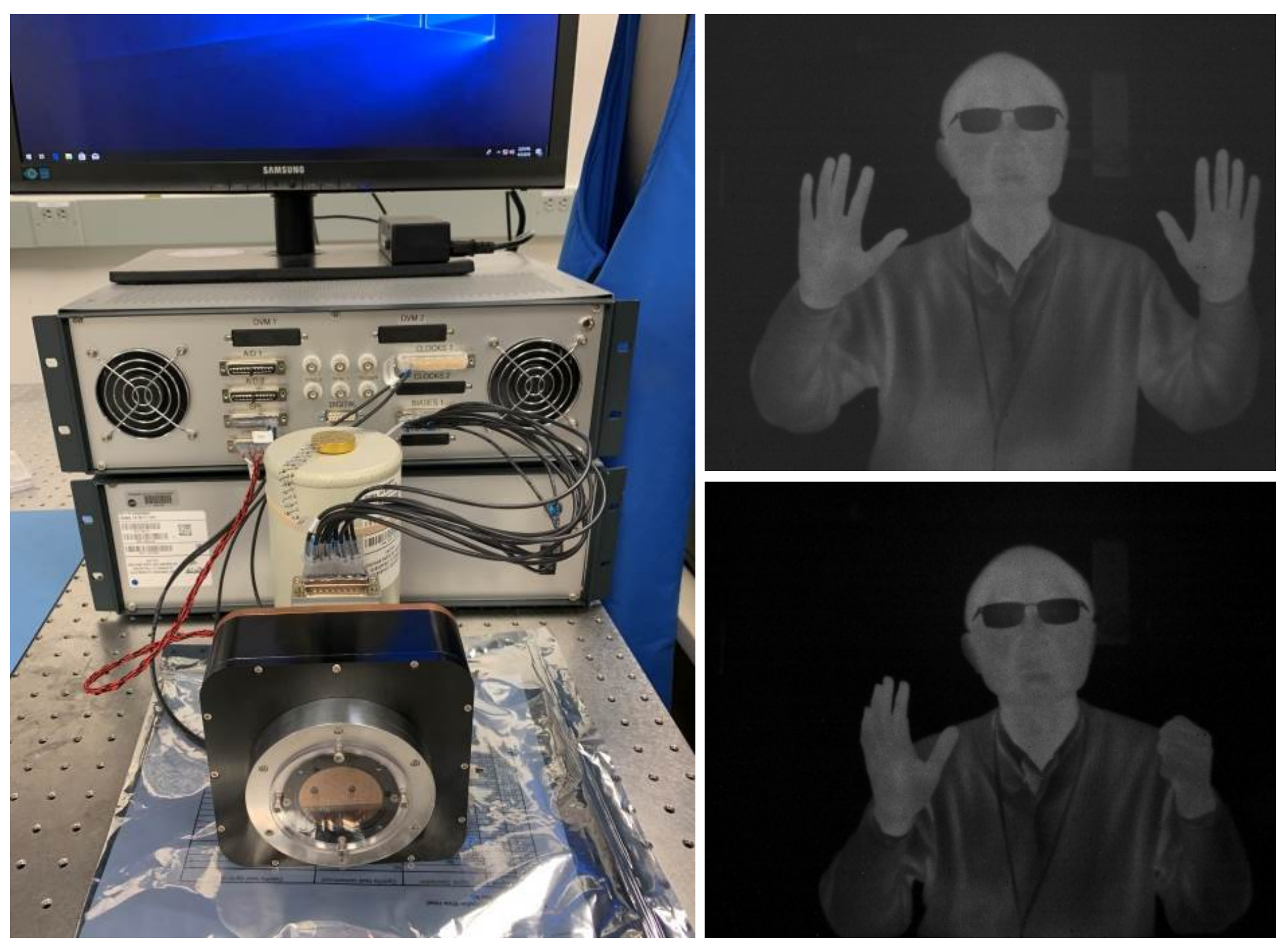

Fig. 7. (Left) Characterization setup for digital-output focal plane array (DFPA). (Right) Long wavelength infrared images taken from a DFPA using the setup.

Publications:

"Advances in III-V semiconductor infrared absorbers and detectors", David Z. Ting, Alexander Soibel, Arezou Khoshakhlagh, Sam A. Keo, Sir B. Rafol, Anita M. Fisher, Brian J. Pepper, Edward M. Luong, Cory J. Hill, Sarath D. Gunapala, Infrared Physics & Technology 97, 210-216 (2019).

"Development of InAs/InAsSb Type II Strained-Layer Superlattice Unipolar Barrier Infrared Detectors", David Z. Ting, Alexander Soibel, Arezou Khoshakhlagh, Sam A. Keo, Sir B. Rafol, Linda Höglund, Edward M. Luong, Anita M. Fisher, Cory J. Hill, Sarath D. Gunapala, Journal of Elec Materi 48(10), 6145-6151 (2019).

"The emergence of InAs/InAsSb type-II strained layer superlattice barrier infrared detectors," David Z. Ting, Alexander Soibel, Arezou Khoshakhlagh, Sam A. Keo, Sir B. Rafol, Anita M. Fisher, Cory J. Hill, Edward M. Luong, Brian J. Pepper, Sarath D. Gunapala, Proc. SPIE 11002, Infrared Technology and Applications XLV, 110020F (2019).

PI Contact Information: 4-1549, David.Z.Ting@jpl.nasa.gov

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