National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

Superconducting Integrated Filters for Kinetic-Inductance Traveling-Wave Parametric Amplifiers

Principal Investigator: Akim Babenko (386); **Co-Investigators:** Peter Day (389), Pekka Kangaslahti (386)

Background: The sky contains plenty of information about star formation, galaxy evolution and the cosmic microwave background at microwaves and millimeter waves. Superconducting KI-TWPAs have demonstrated quantum-limited noise performance across over-an-octave bandwidths [1]. Semiconductor low-noise amplifiers are necessary as subsequent amplification stages to bring the readout signal amplitudes to usable levels. The two technologies have never been integrated since KI-TWPAs require external filtering to clean the amplified signal from ancillary tones. Diplexers consist of two filters with a matched common input, each providing low-loss transmission to an output that covers a specific frequency range.

Objectives: design integrated superconducting diplexers for superconducting KI-TWPAs that cover a 5 GHz to 19 GHz frequency range and filter the ancillary (pump and idler) tones from the amplified signal **(1)**.

Approach and Results:

(i) Design the diplexers using electromagnetic computer simulation tools **(2)**. Ansys HFSS FEM and Sonnet MoM were used.

(ii) Fabricate and package the chip for measurements in a 1.4 K cryogenic probe station and in a 1 K cryocooler **(3)**. The Nb oxides prohibited repeatable electrical contact with RF probes and thus repeatable measurements. Depositing gold on top of Nb would have prevented the oxidation.

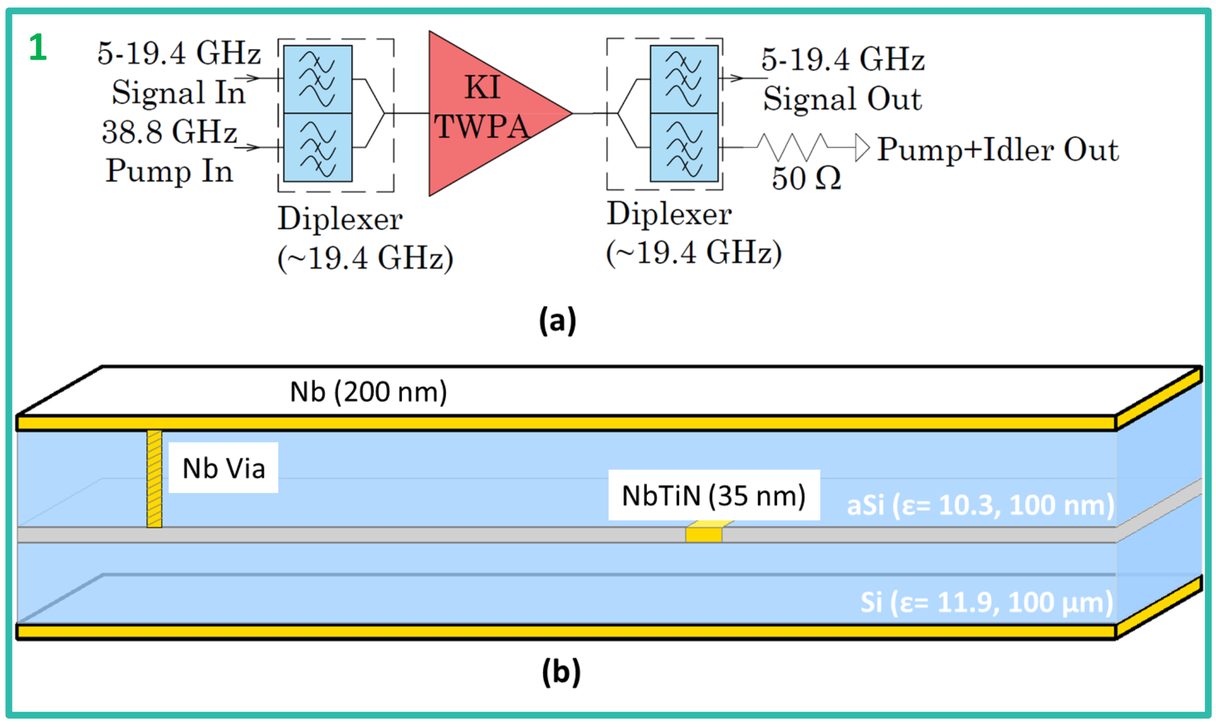
(iii) Measure S-parameters **(4)**. In (a), the "Varnish" method of chips mounting is superior at RF compared to "Rubber". The "Packaged" curve is for the chip measured in the 1 K cryocooler (low-pass only). Due to narrow 0.25 um inductors used in the low-pass filter and the 50 nm fabrication tolerance, the low-pass filters have a lower cutoff frequency than simulated, with ~2 GHz spread. (b) and (c) show respectively loss estimates for the probe station cabling and complex effective permittivity of NbTiN microstrip lines.

Significance/Benefits to JPL and NASA: The demonstrated results revealed new capabilities of the superconducting technology available at JPL that can benefit future ground- and space-based astrophysics missions that require noiseless coherent amplification – for example, PICO probe [2].

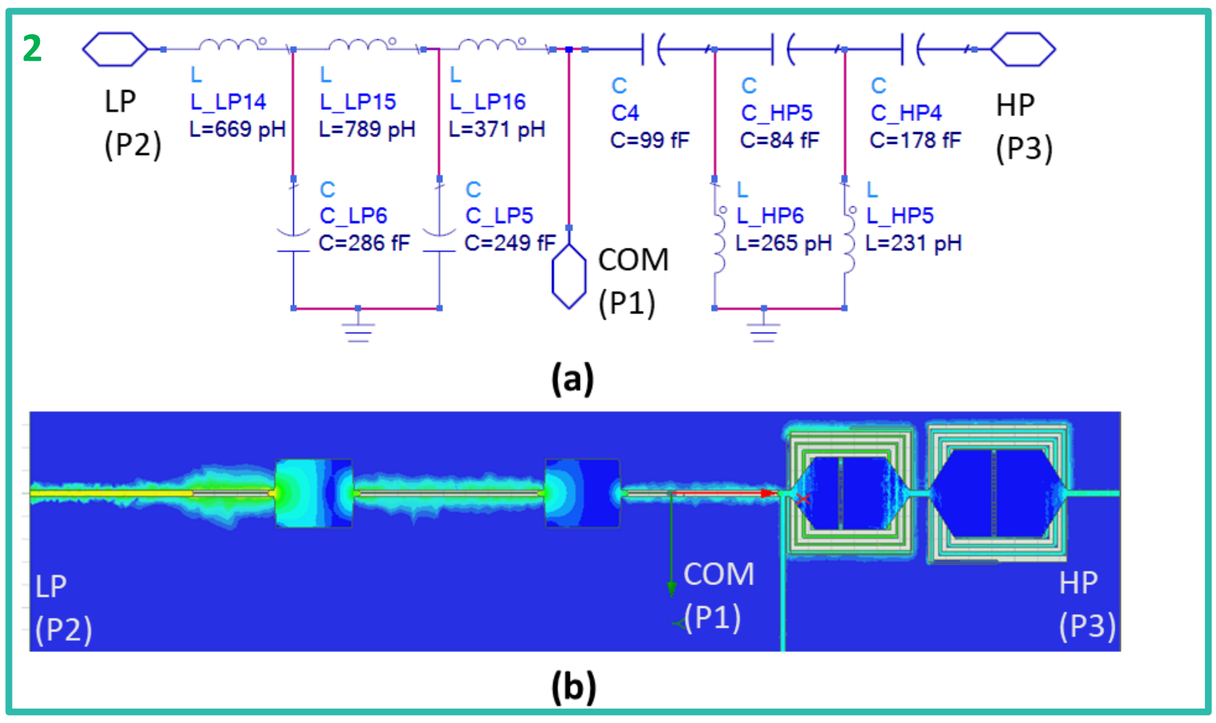
[1] Ho Eom, B., Day, P., LeDuc, H. *et al.* "A wideband, low-noise superconducting amplifier with high dynamic range." *Nature Phys* 8, 623–627 (2012). https://doi.org/10.1038/nphys2356

[2] S. Hanany et al. "PICO: Probe of Inflation and Cosmic Origins", (2019) https://doi.org/10.48550/arXiv.1902.10541

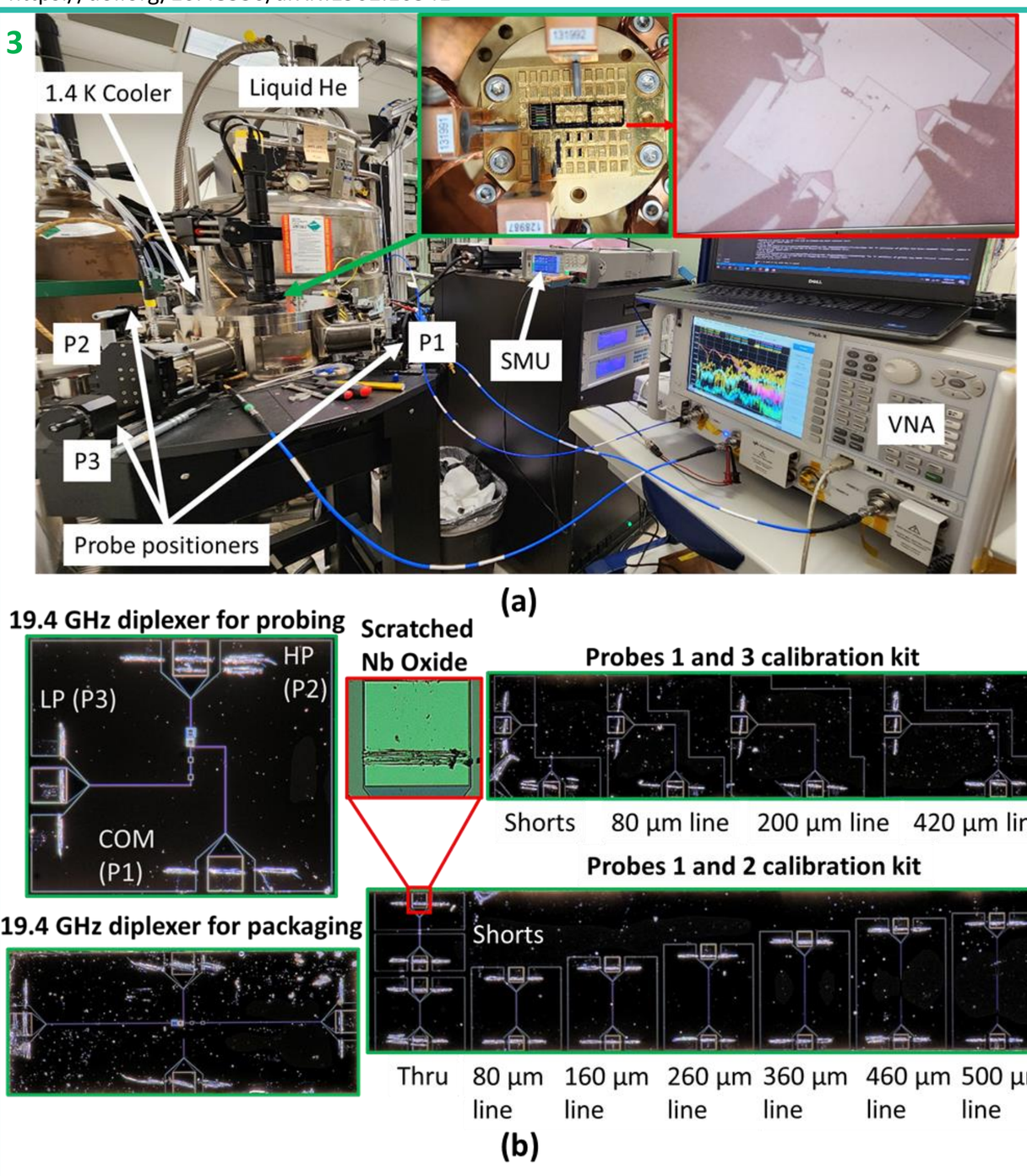
1



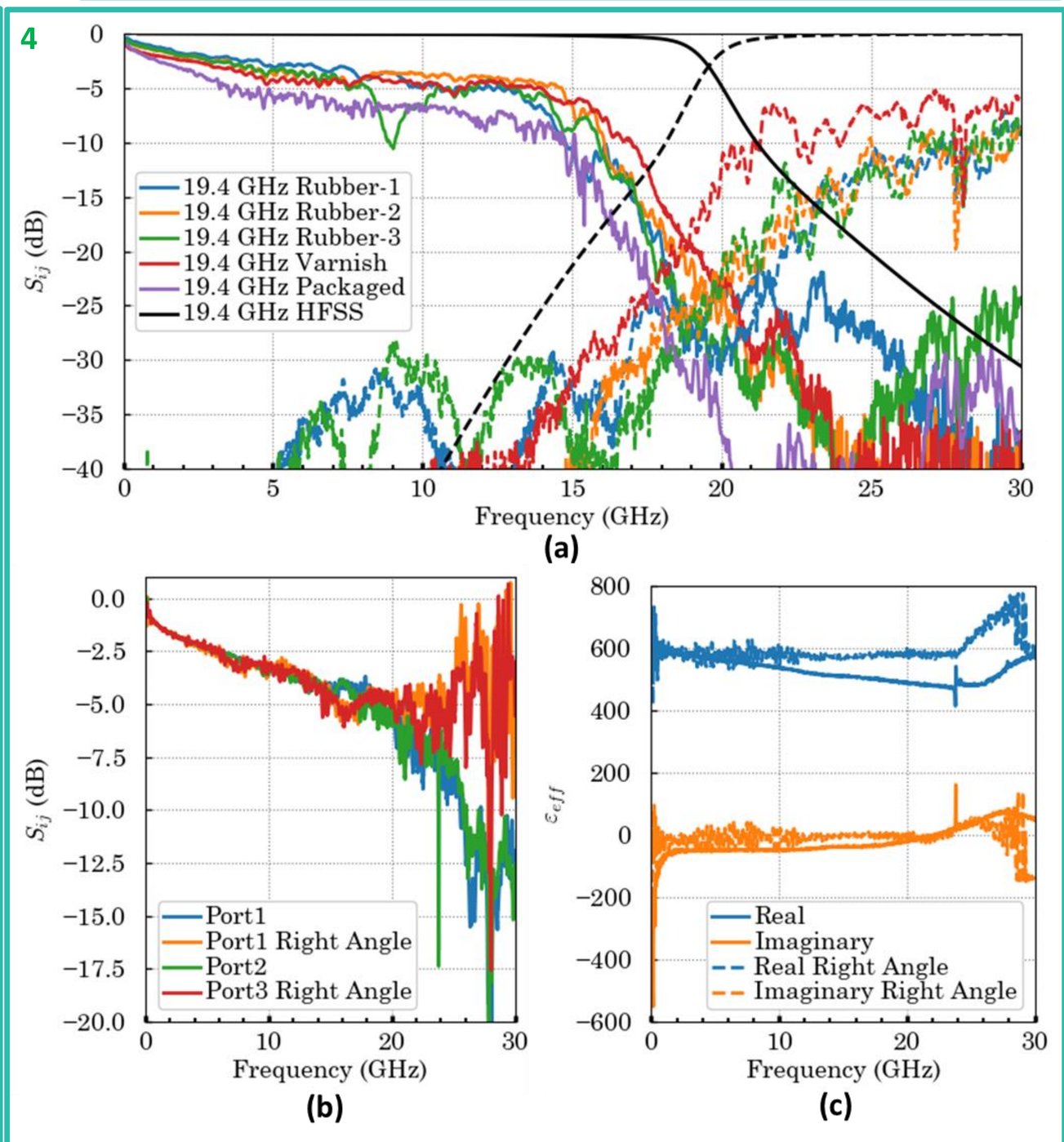
2



3



4



National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#00-0000
Poster Number: RPC#23206

To be presented at National Radio Science Meeting January 9-13, 2024 in Boulder, CO.

PI/Task Mgr. Contact Information:
akim.a.babenko@jpl.nasa.gov