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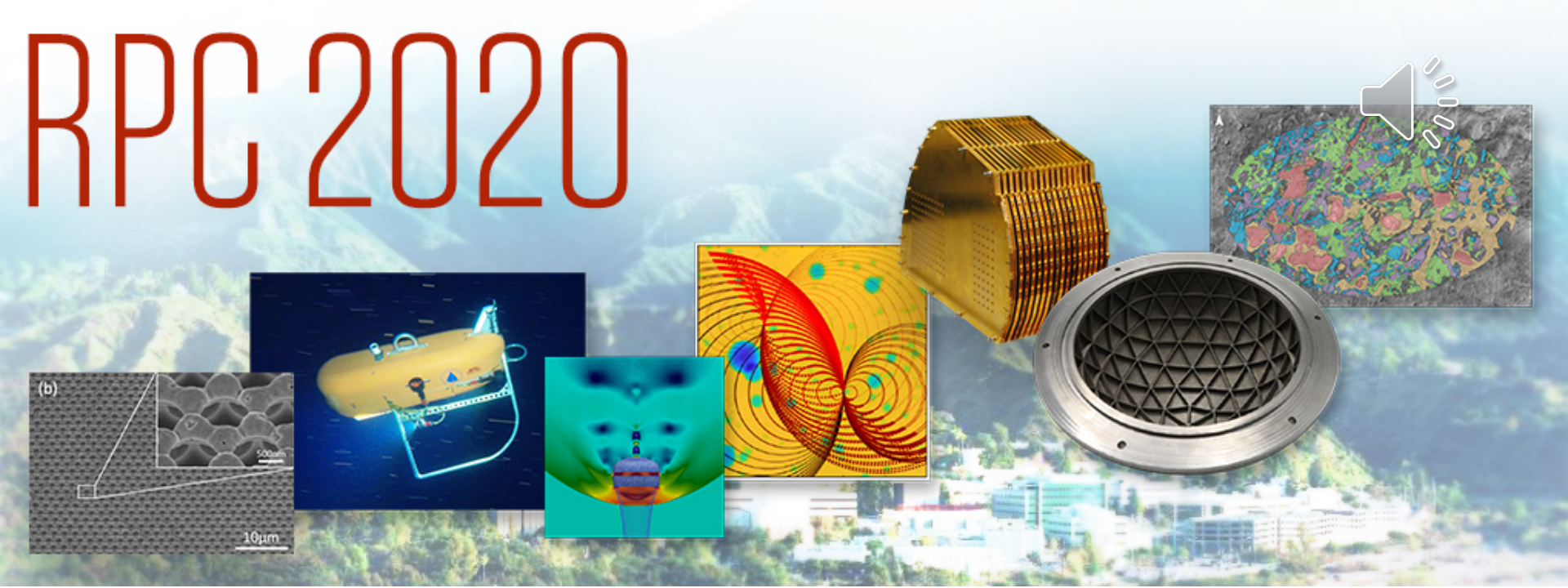

Virtual Research Presentation Conference

ASTHROS+: A 4-Pixel Ultra-Broadband 1.4-2.06 THz Receiver Channel for the ASTHROS Stratospheric Balloon Telescope

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Tutorial Introduction

Abstract

Future space THz missions will be aiming to produce the first detailed and complete census of the interstellar medium ecosystems with the aim of understanding the evolution of the ISM phases and its relationship to star formation. Current high-spectral resolution array receivers have limited RF bandwidth, which makes it extremely complex to build instruments able to capture all the key tracers of the ISM as a number of channels are needed.

The ASTHROS+ receiver aims to solve this issue by using a revolutionary and totally new concept to combine different bands in one single channel: on-chip power diplexed receivers. The proposed work will lead to a new generation of large-band submillimeter-wave heterodyne instruments that can offer a higher science return than any competing approach: HIFI , GREAT, GUSTO all-in-one.

JPL is currently building ASTHROS - Astrophysics Stratospheric Telescope for High Spectral Resolution Observations at Submillimeter-waves, a high-altitude balloon mission featuring a 2.5-m telescope. If successful, we will fly this receiver as an additional channel of ASTHROS (ASTHROS+) to increase the TRL of this new tech. and have an instrument ready that meets all the requirements for a future space missions.

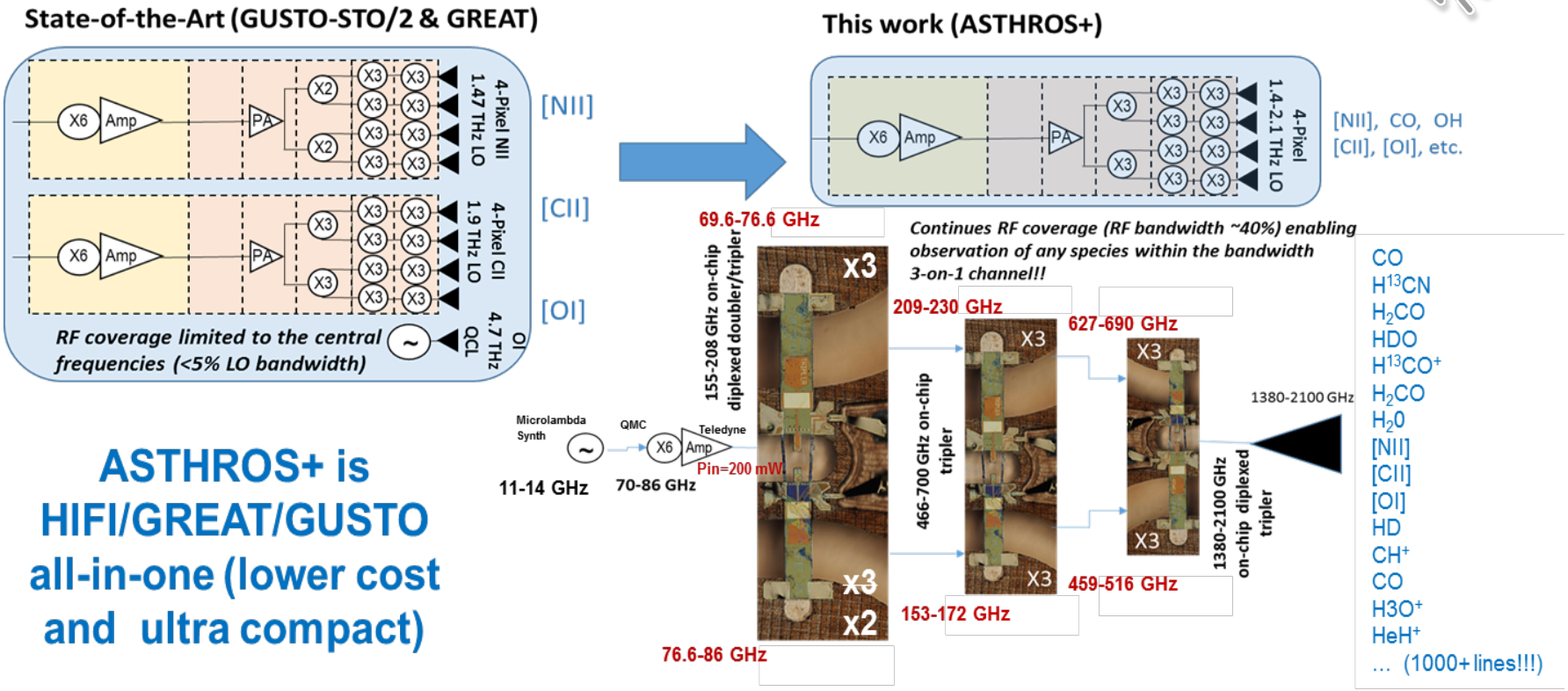
Problem Description

Far-infrared spectral lines provide a unique probe into the physical conditions of the ISM during its lifecycle. The [NII] lines at 1.5 THz and 2.7 THz, are important tracers of the ionized phase of the interstellar medium. The [CII] 1.9THz line, is a tracer of ionized gas, cold atomic gas, and diffuse molecular gas, and thus is an excellent tracer of the formation of molecular clouds, where star formation takes place. Finally, the [OI] at 2 THz is a key tracers of the dense and warm gas that has been directly affected by the radiative and mechanical feedback of newly formed massive stars. All together, these far-infrared spectral lines provide a complete picture of the life-cycle of the interstellar medium which is essential for the study of its effect on galaxy evolution. **The importance of these spectral lines have motivated several space and sub-orbital missions such as Herschel, SOFIA, and GUSTO.**

However, due to the narrow RF bandwidth of the receivers, these missions, were only able to observe subsets these lines partially and inefficiently, and thus high-spectral resolution images of the ISM in the far-infrared are only available for a handful of regions. The HIFI instrument on Herschel required 14 LOs to cover 460 GHz-1900 GHz. For the same reason, the GREAT instrument on SOFIA requires switching the LO and receiver before every flight depending on the targeted lines (only one or two channels available during any given flight).

ASTHROS+ aims to solve this issue by using a revolutionary and totally new concept to combine different bands in one single channel: on-chip power diplexed receivers. This new capability will enable ultra broadband high-spectral resolution terahertz array receivers able to efficiently generate a complete dataset that will be used to understand the life-cycle of the ISM with future sub-orbital (Balloons, SOFIA instruments) and space (SmallSats, Explorer, Probe, OST) missions.

State of the Art



ASTHROS+ is HIFI/GREAT/GUSTO all-in-one (lower cost and ultra compact)

Relevance to NASA and JPL

If the proposed work is completed successfully, we will add the ASTHROS+ channel to the JPL led ASTHROS mission (NASA APRA program), planned to fly in December 2023. **NASA strongly encourages the addition of "piggy-back" instruments/upgrades on selected balloon missions for TRL promotion of new technologies to get ready for future suborbital and space missions**. This will allow us to achieve TRL 6/7 and be ready to propose a MIDEX Space Mission by 2021 or 2023, for the MO call as a Small Sat platform with a smaller antenna, or for the next version of ASTHROS under the ASTHRO/FIR balloon facility.

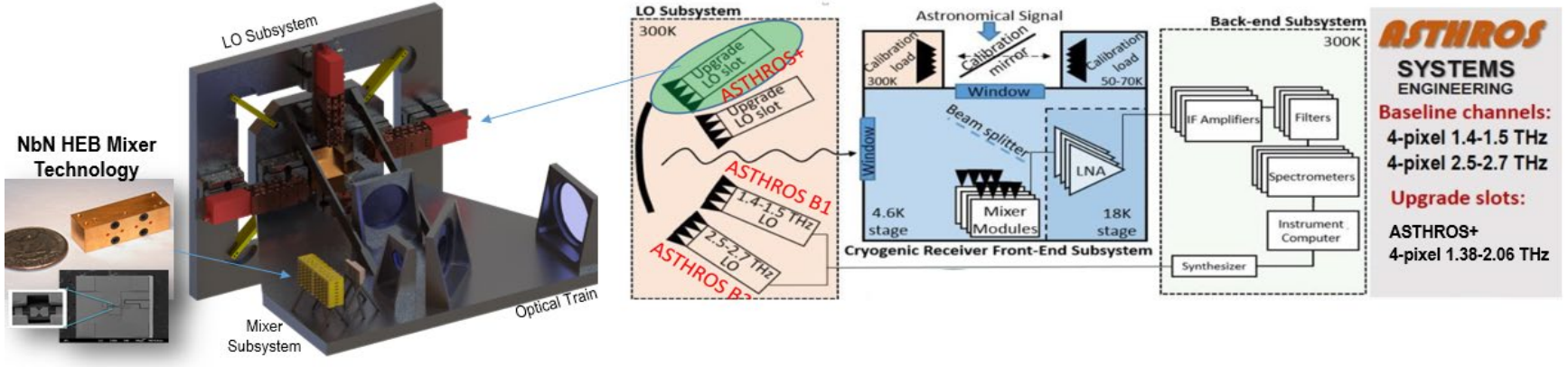
ASTHROS instrument architecture is designed to be upgradable (allowing two extra channels), and therefore, the infusion of ASTHROS+ will be very straightforward since no changes in architecture will be needed. **ASTHROS+ will turn ASTHROS into an extremely powerful platform able to *provide complete picture of the life cycle of the ISM from diffuse ionized gas to dense and warm star forming molecular gas.*** This is achieved *by* its capability to observe literally any of the key lines governing the star forming process due to the ultra-broadband tunability (see Fig. 1). Flying ASTHROS+ as part of ASTHROS will get this strategic technology ready for infusion in future suborbital (SOFIA) or space instruments (MIDEX missions, OST, Probe missions, etc).

ASTHROS+ will be the only THz heterodyne instrument able to fulfill the aggressive requirements for future missions**. A successful demonstration will guarantee JPL leadership position in the field for the next decades and the only institution with the technology to propose an ambitious mission aiming to produce the first high-spectral resolution all-sky map in the far infrared**. The aim is to (i) study spatial and velocity distribution of different gas phases, (ii) provide a complete, large statistical sample to study the properties of star forming regions, (iii) map high latitude gas and reveal the properties of gas flowing out the galactic plane, and (iv) provide insights on the effect of UV and dynamical formation from massive star regions and massive black holes accretion on ISM phases.

Methodology

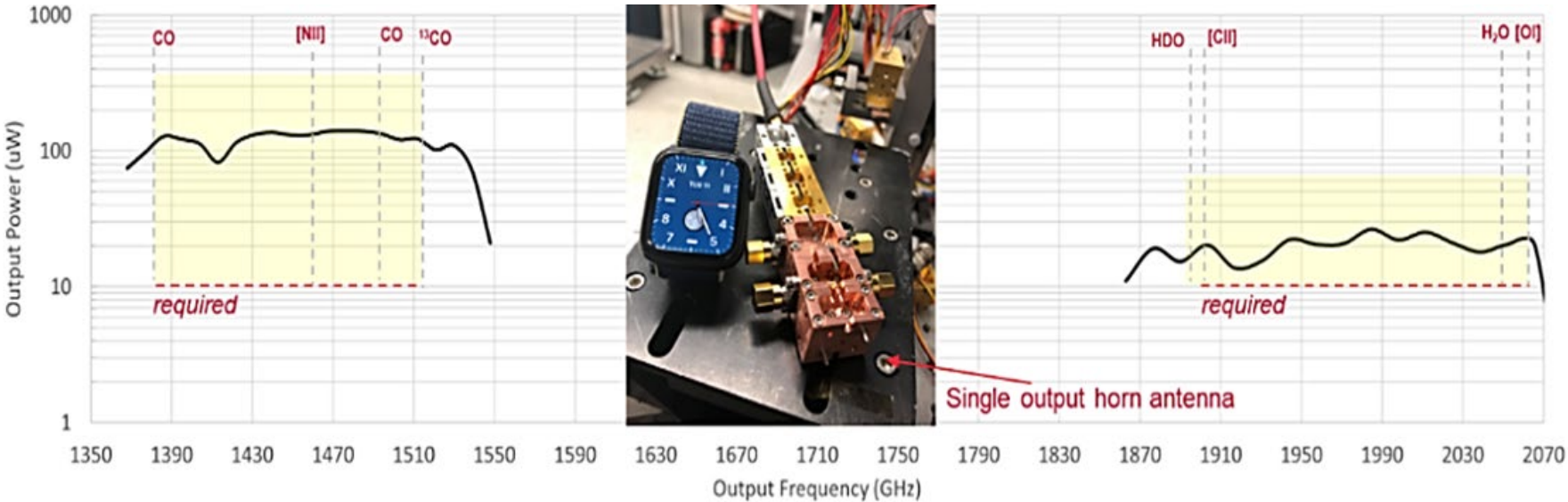
The architecture consist of the same typical heterodyne receiver scheme used for HIFI, STO-2, GREAT, etc. The methodology consists of re-designing the current state-of-the-art 4-pixel 1.9 THz heterodyne receiver (flown in STO-2) using a new concept to increase the LO bandwidth coverage up to 30-40%: 1.38-2.06 THz. The rest of the receiver remains the same, except for the HEB mixers, which requires a redesign of the probe antennas to enlarge the bandwidth.

ASTHROS+ **uses a very innovative "on-chip diplexed frequency multiplier" concept**. It consists of a single-substrate multiplier chip with half of the diodes tuned to the lower half of the target frequency band, and the other half tuned to the upper half of the band. That way a increase by a factor of two in RF bandwidth is achieved. Moreover, half of the chip can work as a doubler and the other half as a tripler. **This design was successfully fabricated and allowed us to demonstrate the ultra-broad band single-pixel LO covering the 1.39 to 2.07 THz range with only one channel.**



Results

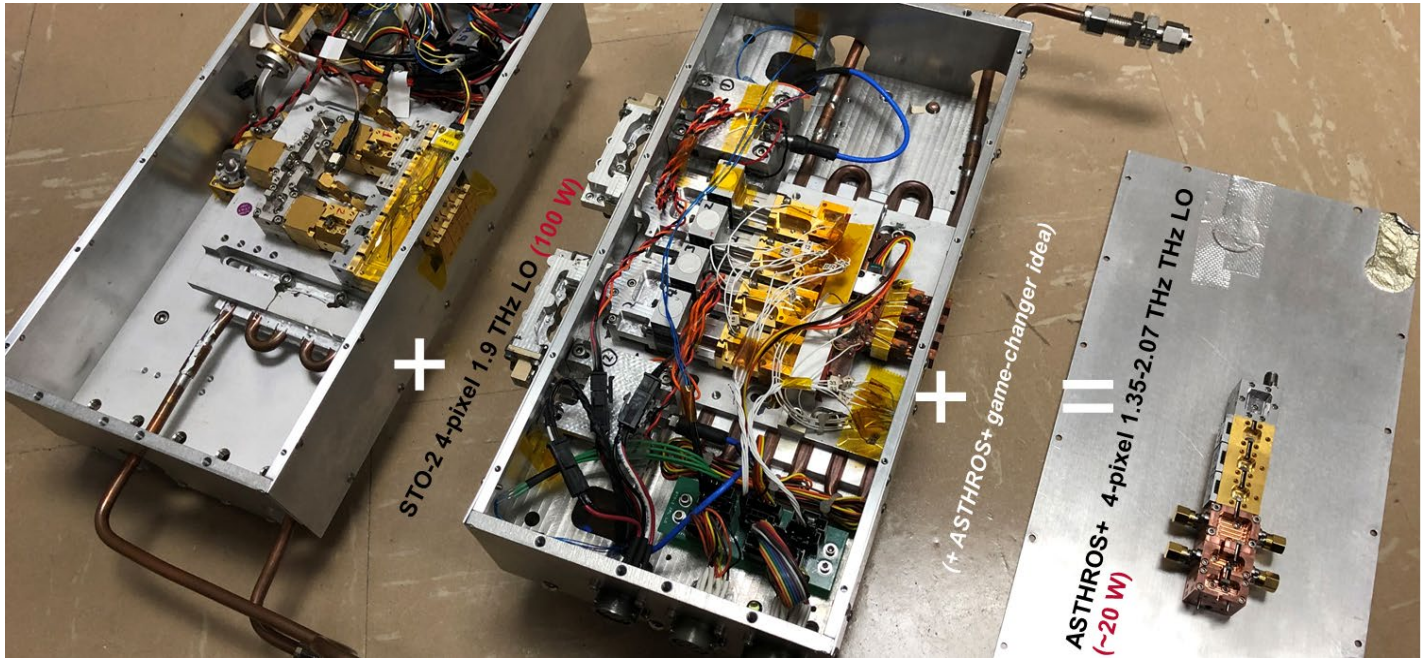
First ever on chip diplexed frequency doubler/tripler covering with a single chip tu frequency bands simultaneously. This design enabled the on-chip diplexed ultra-broadband LO source covering 1380-2070 GHz with a single frequency multiplied LO source!. **This is a game changer for high spectral resolution far infrared instruments**.



Results

Due to the RF bandwidth limitation, STO-2 required two different channels to cover the 1.5 THz and 1.9 THz bands. The ASTHROS+ source developed in this work, can cover both bands simultaneously due to the increased RF bandwidth. In addition, the ASTHROS+ source, much more efficient than the STO-2, provides one order of magnitude improvement in size, weight and power.

This is a tremendous success and a game changer for future high-spectral resolution FIR missions, and it allow us to build large array THz receivers with low power consumption and reduced complexity.



Publications and References

[1] Jose V. Siles, Choonsup Lee and Robert Lin, “On-Chip Diplexed Multi-Band Submillimeter-Wave/Terahertz Sources”, Patent pending, Serial Number: 62/931,937, CIT File Number: 8386-P, Filed: 11/7/2019.