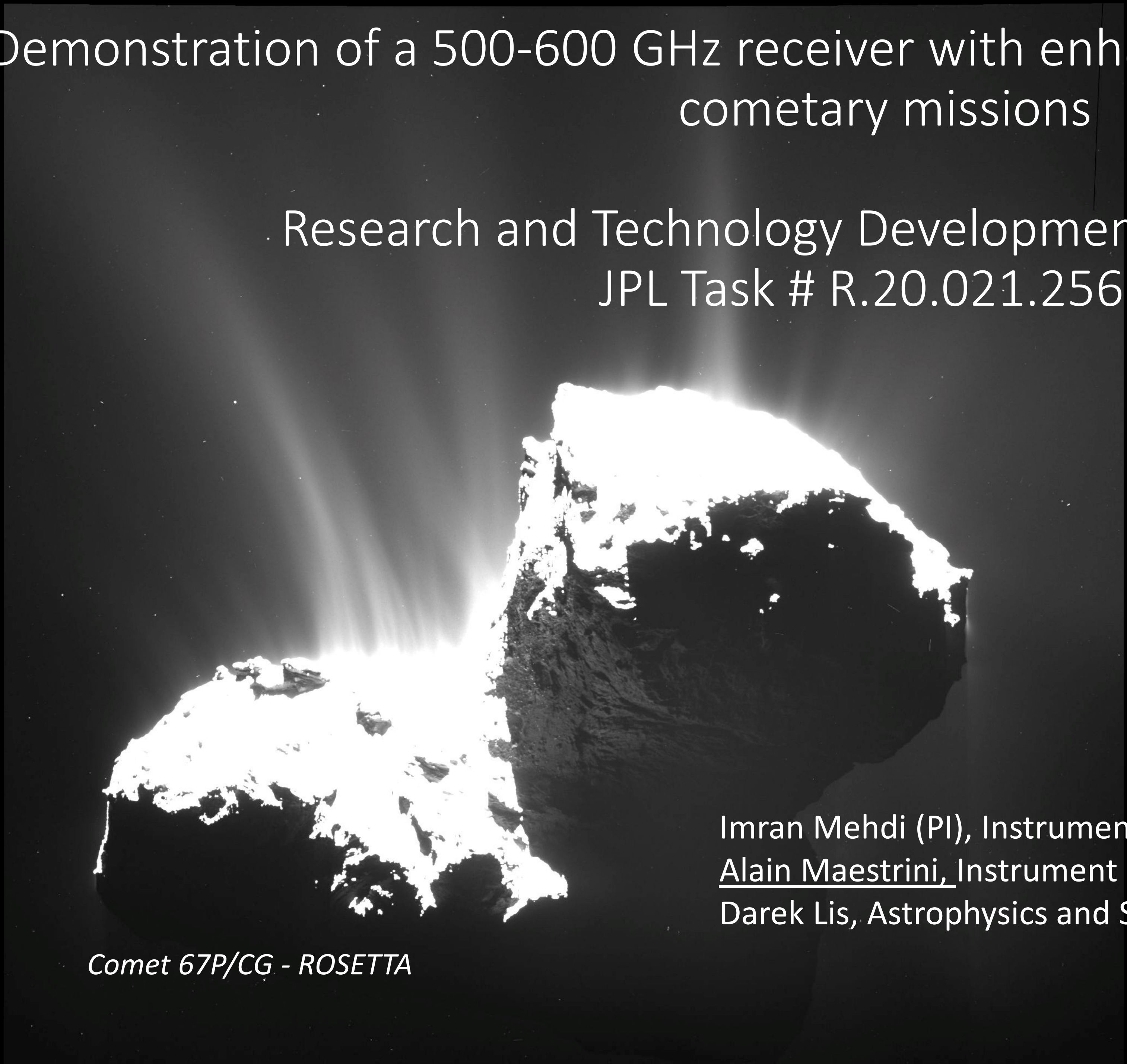
Demonstration of a 500-600 GHz receiver with enhanced sensitivity for fast flyby cometary missions

Research and Technology Development Annual Report
JPL Task # R.20.021.256



Comet 67P/CG - ROSETTA

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OBJECTIVES

The aim of this task was to prototype a thermoelectrically cooled 500-600 GHz mixer paired with an ultra-low noise intermediate frequency amplifier to demonstrate receiver sensitivities that are significantly better than current SOA, and suitable for flyby missions.

CONTEXT

- GaAs Schottky diode technology is currently the preferred technology at sub-millimeter wavelength for building low-noise, high-stability room temperature heterodyne receivers that can withstand the tough space-environment.
- For smaller platforms, mass and power is even more limited, precluding the use of active cooling and even the use of large radiators and sun screens that could enable passive cooling.

APPROACH

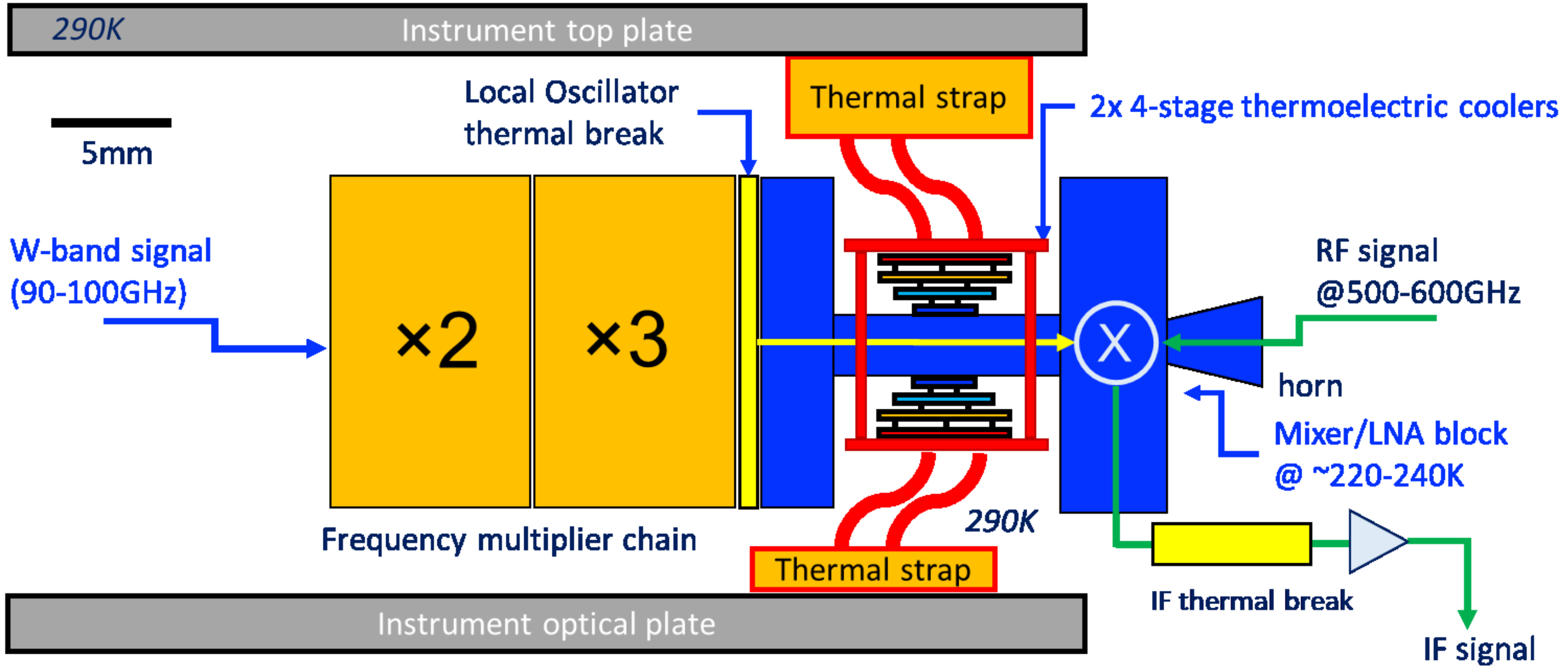
- We have proposed to build the first submillimeter-wave Schottky mixer associated with a low-power thermoelectric micro-cooler and a low-power InP based Low Noise Amplifier.

- The mixer module is thermally decoupled from the Local Oscillator module with a high-performance thermal break.

- For the IF LNA, the preferred approach was to first decouple it from the mixer before eventually integrate both elements in a same module.

Thermoelectrically-cooled 500-600GHz Schottky receiver concept

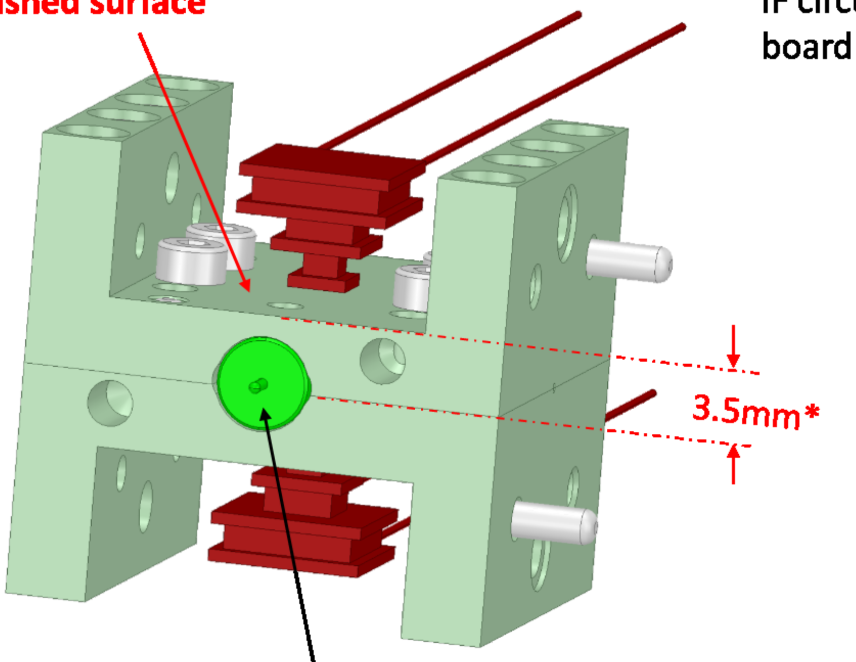
General thermal design : The mixer is decoupled from the LO and the LNA by high performance thermal break. The thermal load on the thermo-coolers is less than 50mW (in vacuum).

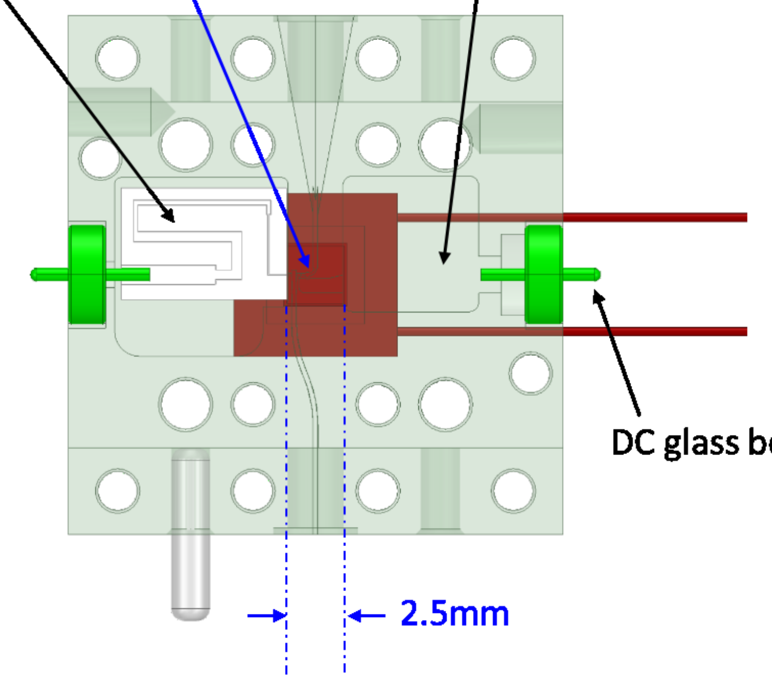


Thermoelectrically-cooled 500-600GHz Fundamental Balanced Mixer : micro-coolers implementation

Innovative mixer thermal design : two thermoelectric coolers symmetrically located on the mixer waveguide block are used.

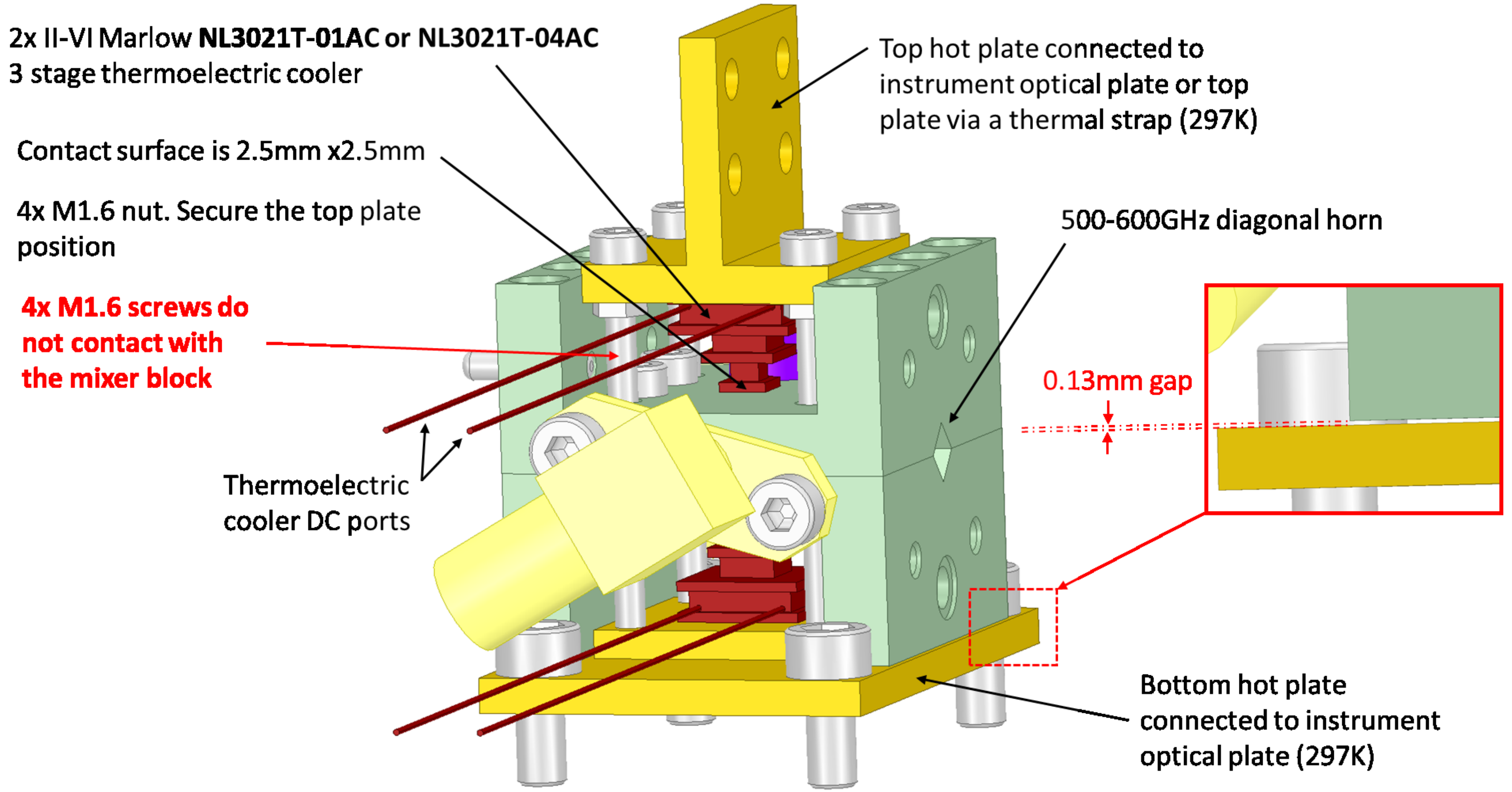
Only the cold faces of the coolers are in contact with the mixer. The distance between the cold face and the mixer chip has been reduced to only 3.5mm





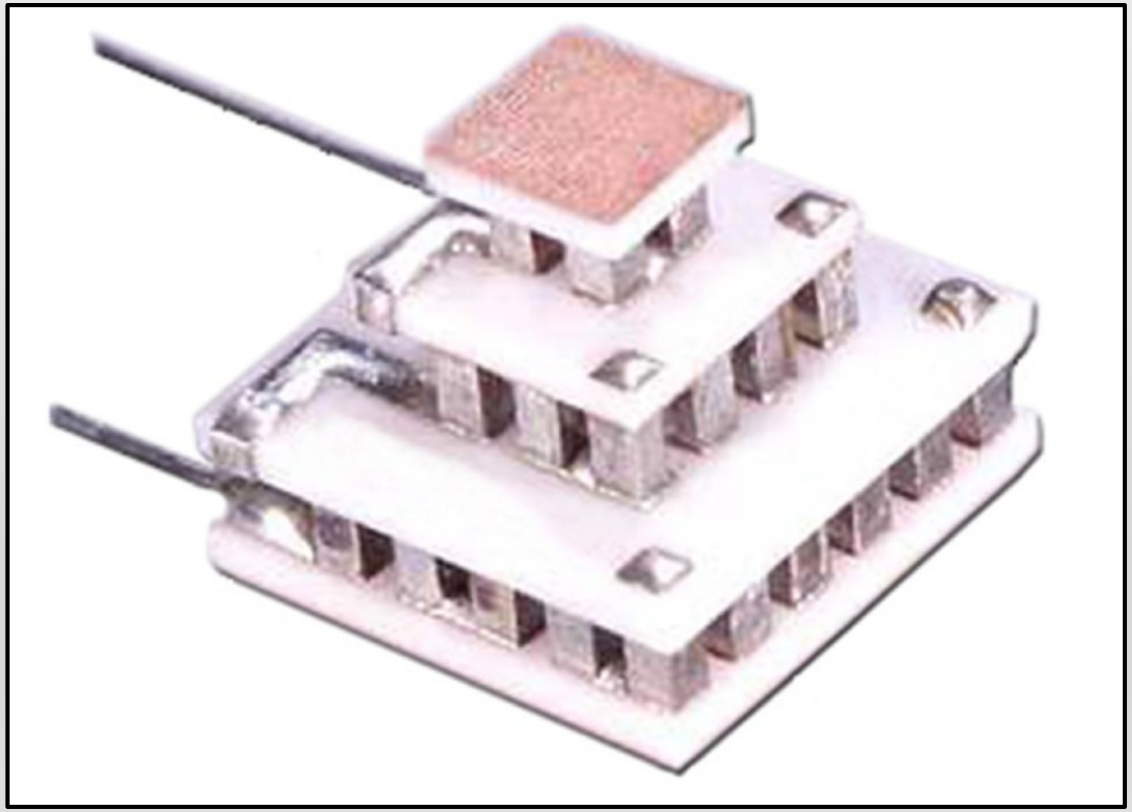
* It could possible to create a notch inside the block top/bottom parts to accommodate the cold surface of the thermoelectric cooler but the surface inside the notch needs to be perfectly flat and smooth. The preferred approach is a bigger and perfectly flat contact area.

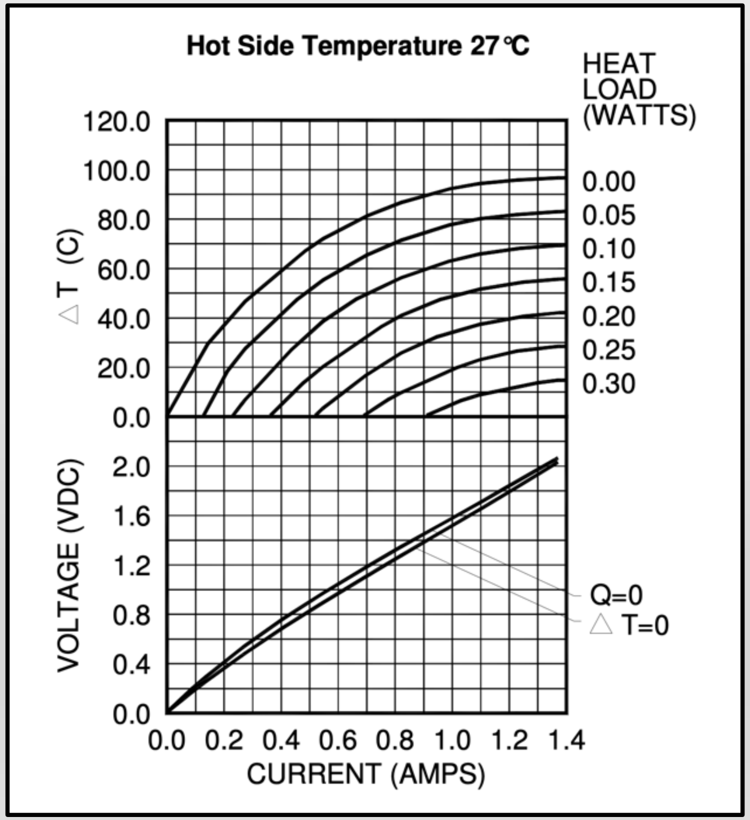
Thermoelectrically-cooled 500-600GHz Fundamental Balanced Mixer : global view



Thermo-electric cooler NL3021T-AC from II-VI Marlow Inc. selected for the 557GHz mixer block

The thermo-cooler model selected from II-VI Marlow Inc. and has a very small footprint and features 3 stages. The expected thermal load for the combined two thermoelectric coolers is 50mW maximum insuring an effective cooling of the mixer waveguide block with about 1.4W of DC power maximum for a temperature drop of 70K.





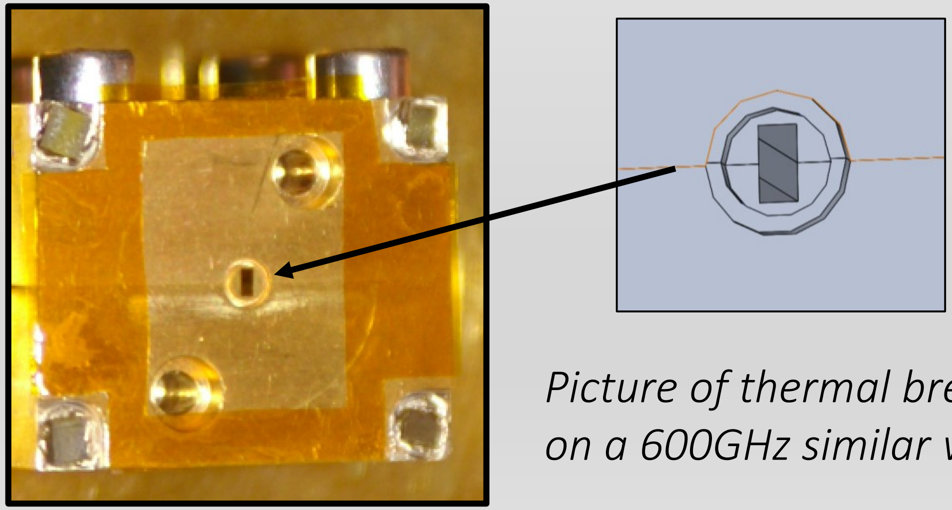
557GHz Local Oscillator port thermal break

- gap between the two waveguide blocks with a filter structure on the flange of the mixer to limit leaks of the LO signal.

- filter structure: groove machined in the waveguide LO port flange, which dimensions are optimized in a 3D EM software (HFSS). The depth of the groove is about a quarter-wavelength at the central frequency (0.135mm).

- A thin Kapton film (about 20um thick) is used to set the gap thickness between the LO unit and the mixer unit. The Kapton film is cut to decrease the contact surface and therefore the thermal conductance.

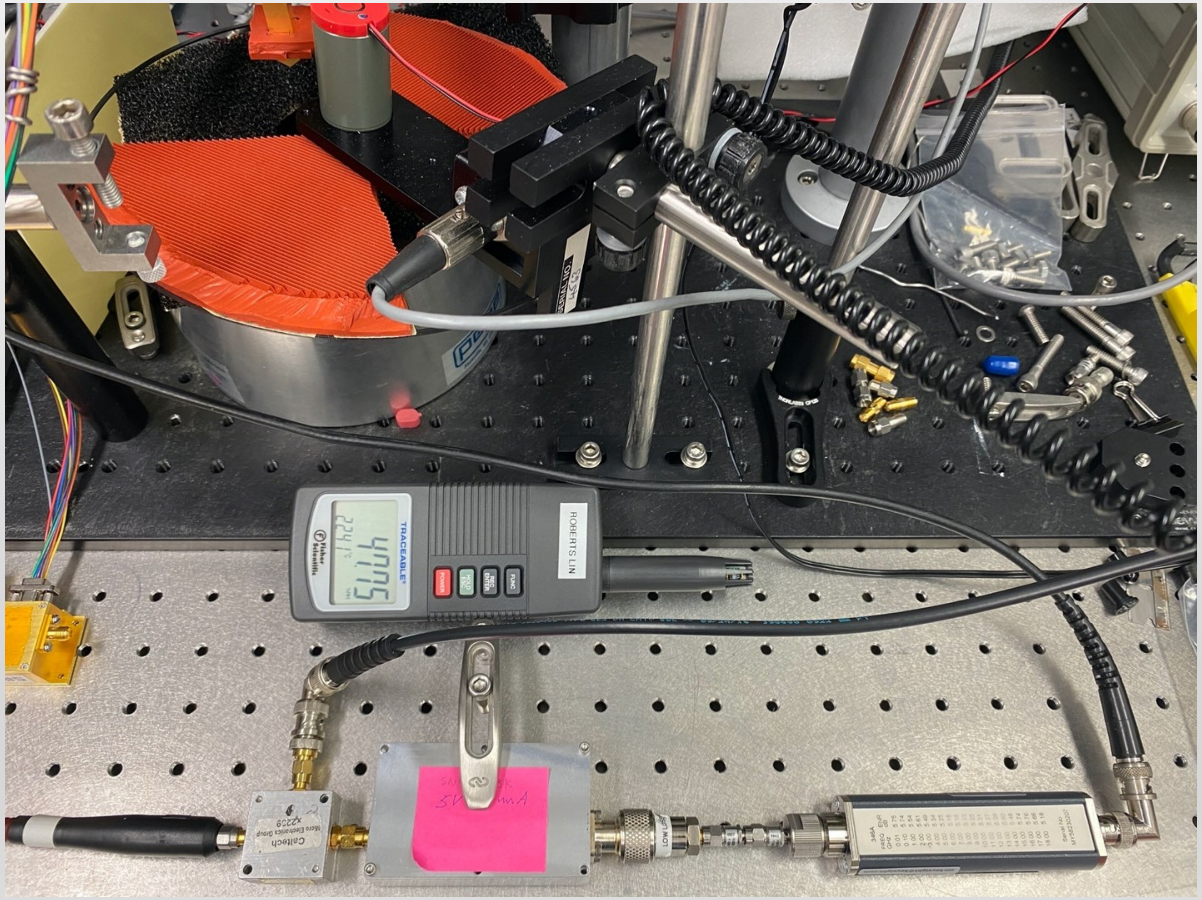
- Special screws and alignment pins will be made out of low conductivity material (Torlon 4203).



Picture of thermal break implemented on a 600GHz similar waveguide block.

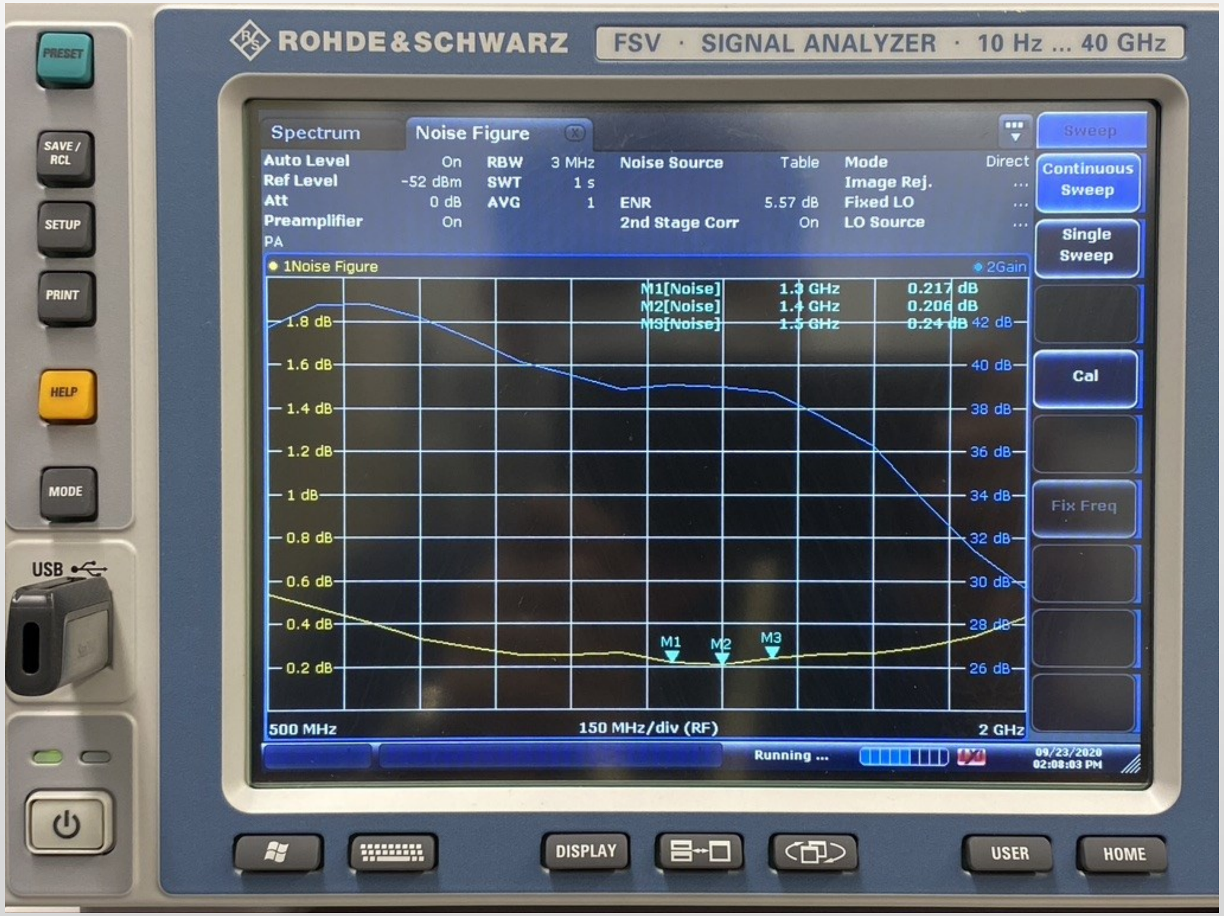
Ultra Low Noise 1.3-1.5GHz IF LNA

- Prof. Sandy Weinreb from Caltech gave us the opportunity to test one of his 1.3-1.5GHz ultra-low noise amplifier that we plan to use in the 500-600GHz receiver. The size of the amplifier is significantly larger than more standard LNAs (more than 3 times the size of the mixer block) making the integration in a mixer waveguide block not straight forward.



Test set up used to measure the gain and noise factor of Sandy Weinreb's 1.3-1.5GHz ultra-low noise amplifier.

Ultra Low Noise 1.3-1.5GHz IF LNA - measurements



Results shown on the spectrum analyzer used to measure the noise factor and gain of the amplifier.

- The noise temperature of the LNA was measured at Caltech on a well calibrated test setup suited for measuring ultra-low noise amplifiers. The measurements performed at JPL using more standard pieces of equipment gave consistent results (we found a noise temperature of 14K instead of 8K measured at CALTECH) but point out to the need to cross calibrate our test set up against the setup developed at CALTECH.
- A few 0.01dB difference in the calibration of the noise source used in our setup can explain easily the difference.

SIGNIFICANCE OF THE WORK

- An innovative thermoelectrically cooled mixer block has been fully designed and sent to fabrication.
- The compactness and weight of the thermoelectric coolers makes them very attractive to decrease and stabilize the temperature of the mixer, which noise controls the sensitivity of the whole receiver.
- All the parts needed for the assembly and the tests have been ordered.
- This work is the first step in introducing advance thermal management in THz Schottky receivers since currently the designs are made only for room temperature or passively cooled receivers that require large radiators. This will impact the design of instruments like WISPER.

FINANCIAL STATUS : $50K was funded for this task and was fully utilized