CASIMIR

Caltech Airborne Submillimeter Interstellar Medium Investigations Receiver

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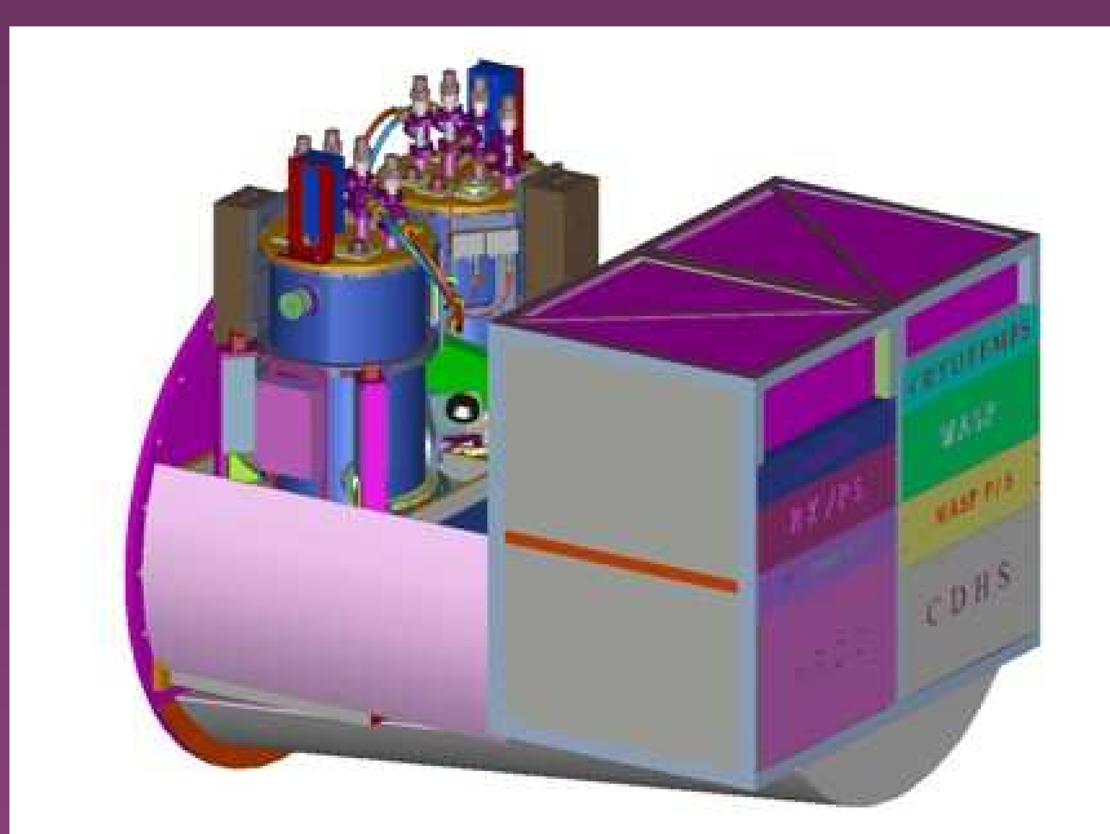
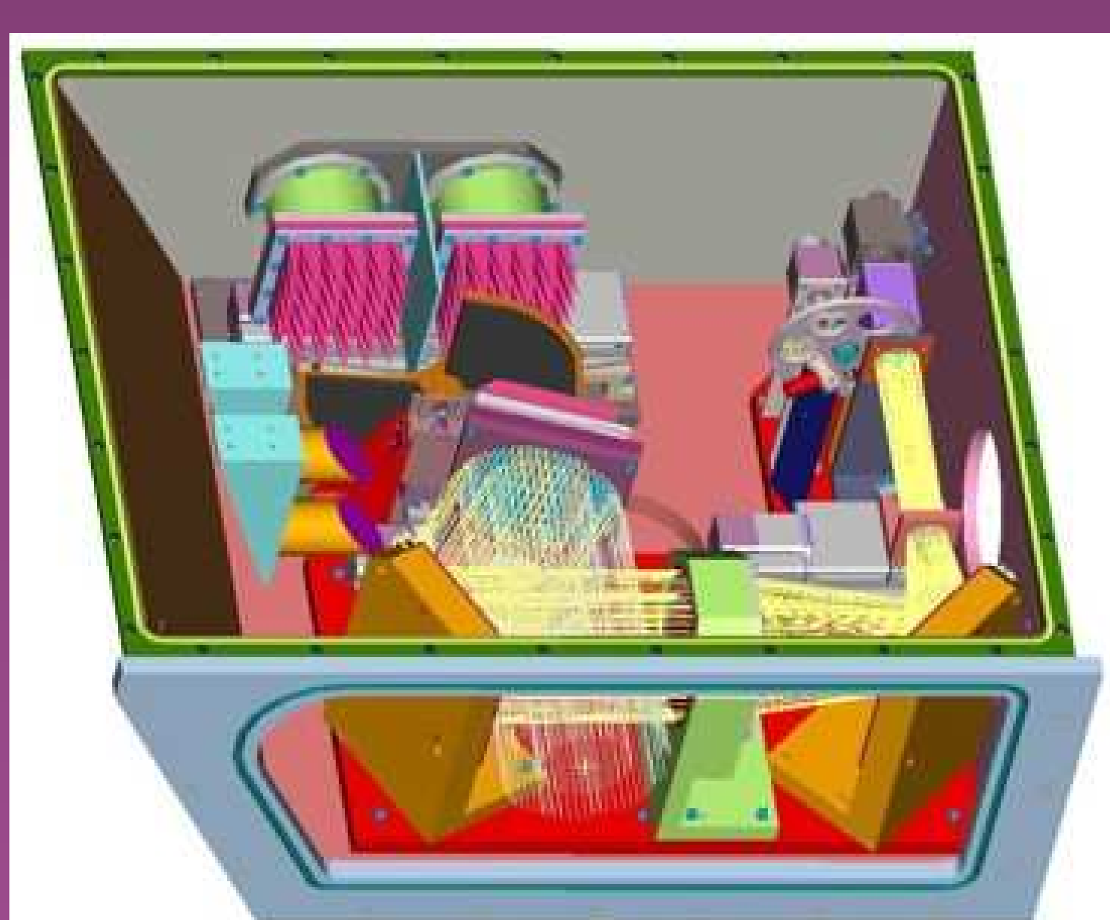
CASIMIR, the Caltech Airborne Submillimeter Interstellar Medium Investigations Receiver, is a multiband, far infrared and submillimeter, high resolution, heterodyne spectrometer under development for SOFIA. It is a first generation, PI class instrument, designed for detailed, high sensitivity observations of warm (100 K) interstellar gas, both in galactic sources, including molecular clouds, circumstellar envelopes, and protostellar cores, and in external galaxies.

CASIMIR will have unprecedented sensitivity by combining the 2.5-meter SOFIA mirror with state-of-the-art superconducting mixers. Five bands are under development: 550 GHz, 750 GHz, 1000 GHz, 1250 GHz, and 1400 GHz. Observing time is maximized by having four bands available on each flight. For example, searches for weak lines from rare species in bright sources can be carried out on the same flight with observations of abundant species in faint or distant objects. The entire instrument is about 1.5 m long, 1 m diameter, and weighs about 550 kg. CASIMIR embodies a versatile and modular design, able to incorporate future major advances in detector, LO and spectrometer technology (see below).

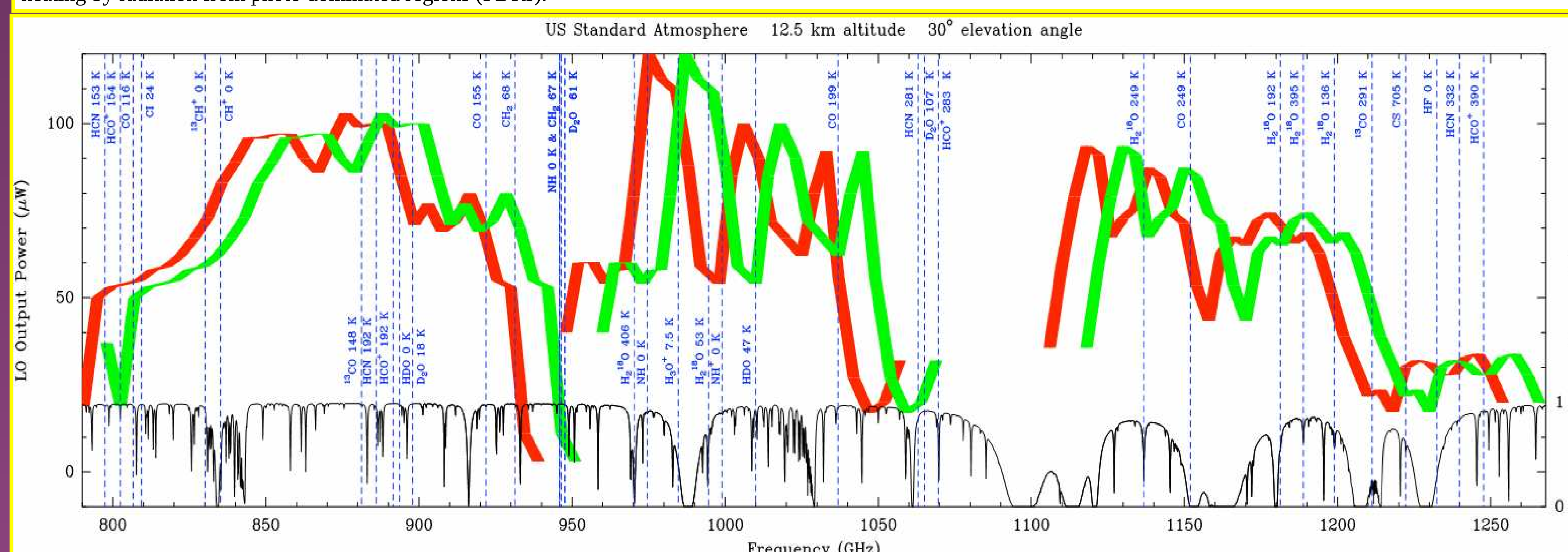


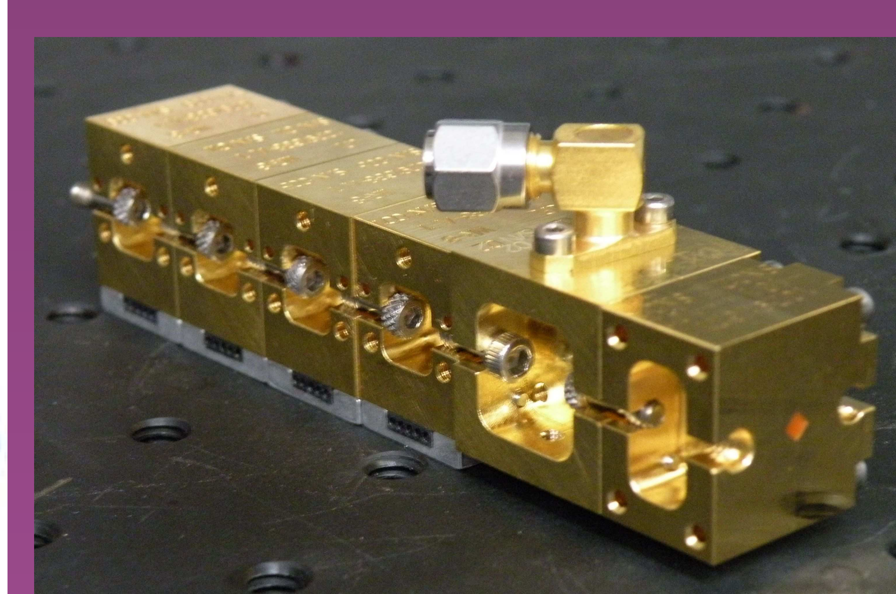


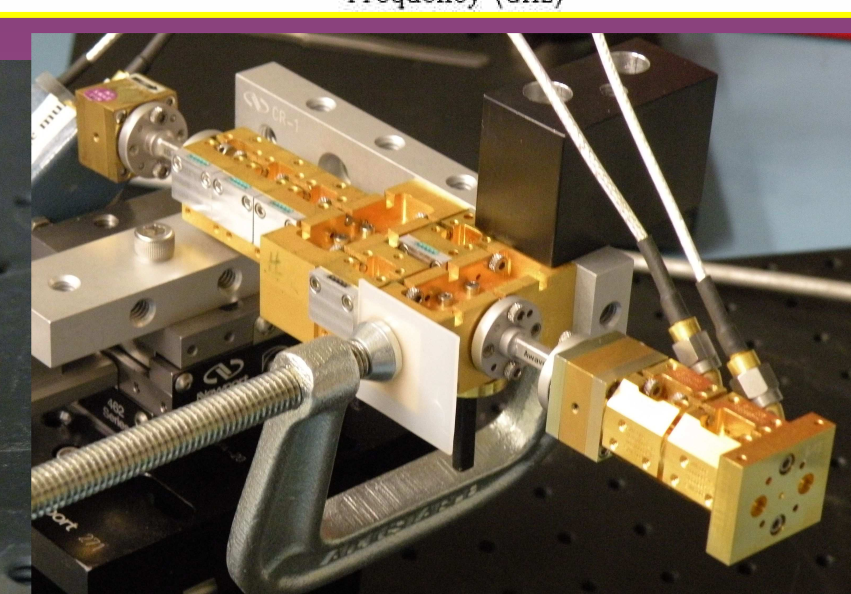
Scientific Objectives

CASIMIR will enable the study of fundamental rotational transitions of many astronomically significant hydrides and other molecules, which will provide deeper understandings of interstellar chemical associations and reactions (see chart below). This chart shows the LO output power versus sky frequency of three LO chains for the CASIMIR receivers, representing two of the five possible observing receiver bands. The output power is shown for both, upper sideband and lower sideband tuning (green and red, respectively). In addition the atmospheric transmission at 12.5 km attitude and the rest frequencies of the most important emission lines are displayed. The lines are labeled with the name of the emitting species and the energy of the lower state.

- Water vapor plays an important role in the energy balance of molecular clouds by mediating radiative heating and cooling through its rotational transitions in the far infrared and submillimeter. CASIMIR will allow the study of the abundance and distribution of interstellar water with exceptional sensitivity and spatial and spectral resolution. Even at the SOFIA operating altitude (above 12 km), there is too much terrestrial water to observe the common $H_2{}^{16}O$ isotopomer in astronomical sources. In its initial four bands, CASIMIR can detect nine rotational transitions of the rare $H_2{}^{18}O$ isotopomer, including several lines near the ground state. Only two relatively high energy transitions can be observed from the ground (i. e., CSO).
- Oxygen is the third most abundant element, yet its chemistry in interstellar clouds is poorly understood. The atmosphere is opaque to many of its key species, such as O, O_2, H_2O, H_3O^+ and OH, limiting detailed ground observations.
- The H_2D^+ ion is of particular interest, as it is the deuterated version of $H_3{}^+$, which is believed to be responsible for driving much of the chemistry of molecular clouds. Although the 372 GHz line of H_2D^+ now has been observed in several molecular clouds, the ground state line at 1371 GHz will be a better choice for studying the overall distribution of this important molecule. To date, there has been only one tentative detection of the 1371 GHz line in Orion with the KAO.
- Another transition of major importance is the 1461 GHz transition of the nitrogen ion, N^+, which traces the warm, ionized interstellar medium. COBE has shown that, apart from the 1900 GHz C^+ line, the two fine-structure N^+ lines are the brightest emitted by our Galaxy.
- The study of high *J* lines of CO, which typically trace shocked gas (studied extensively with the KAO with high-resolution, heterodyne spectroscopy), or may indicate heating by radiation from photo dominated regions (PDRs).







Local Oscillators

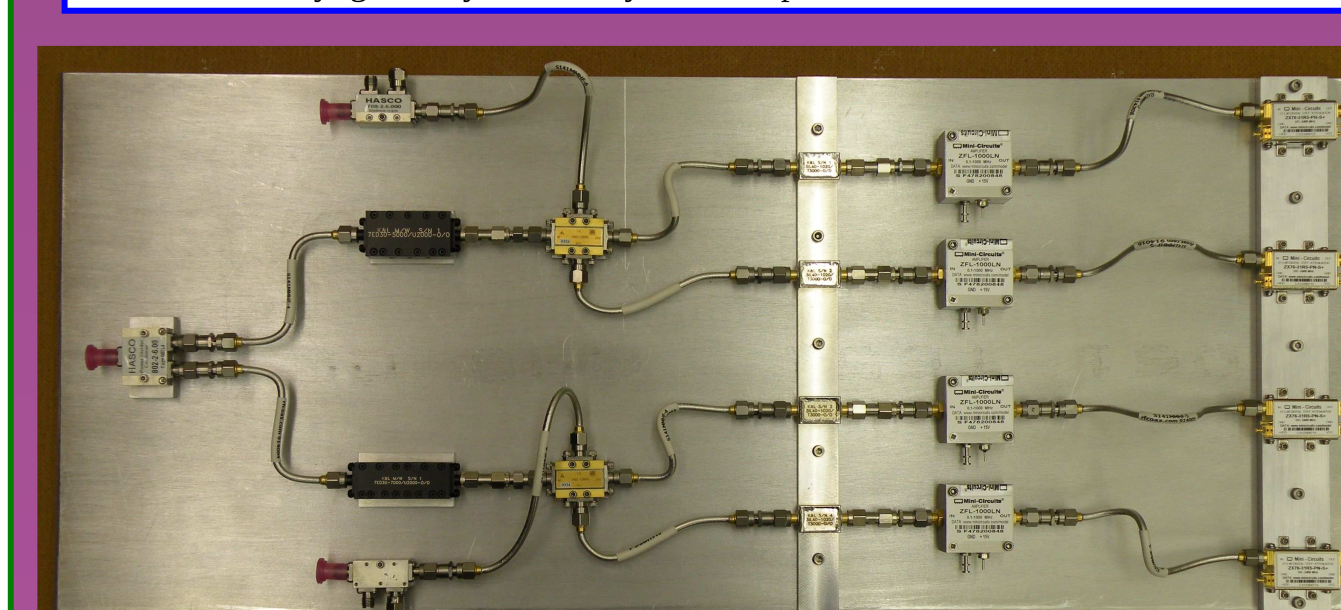
Each band uses a tunerless solid state local oscillator driven by a single, common commercial 26-40 GHz microwave frequency synthesizer. Chains of power amplifiers and frequency multipliers then generate the high frequency signals for each band. The 550 GHz and 1370 GHz (see above, right) LOs were made by Virginia Diodes; the 1000 GHz (see above, left) and 1200 GHz (see above, center) LOs were developed at JPL; the 750 GHz and 1400 GHz LO are under development. The LOs are mounted on the outside of the receivers, with the signal optically coupled to the mixers via reflecting optics, vacuum cryostat windows, and cryogenically-cooled mylar beamsplitters.

Instrument Configuration and Progress

CASIMIR contains two cryostats that each hold two mixers – thus four mixers are available on each flight. All the CASIMIR bands use advanced Superconductor-Insulator-Superconductor (SIS) mixers fabricated with Nb/AlN/NbTiN junctions in the JPL Micro Devices Lab. These planar mixers are quasi-optically coupled with twin slot antennas, and silicon hyperhemisphere lenses with Parylene antireflection coatings. Ongoing mixer developments point to DSB noise temperature improvements of 3 *hv/k* at frequencies below 1 THz, and 6 *hv/k* above 1 THz. Simulations show the present upper limit for this mixer technology is 1.6 THz.

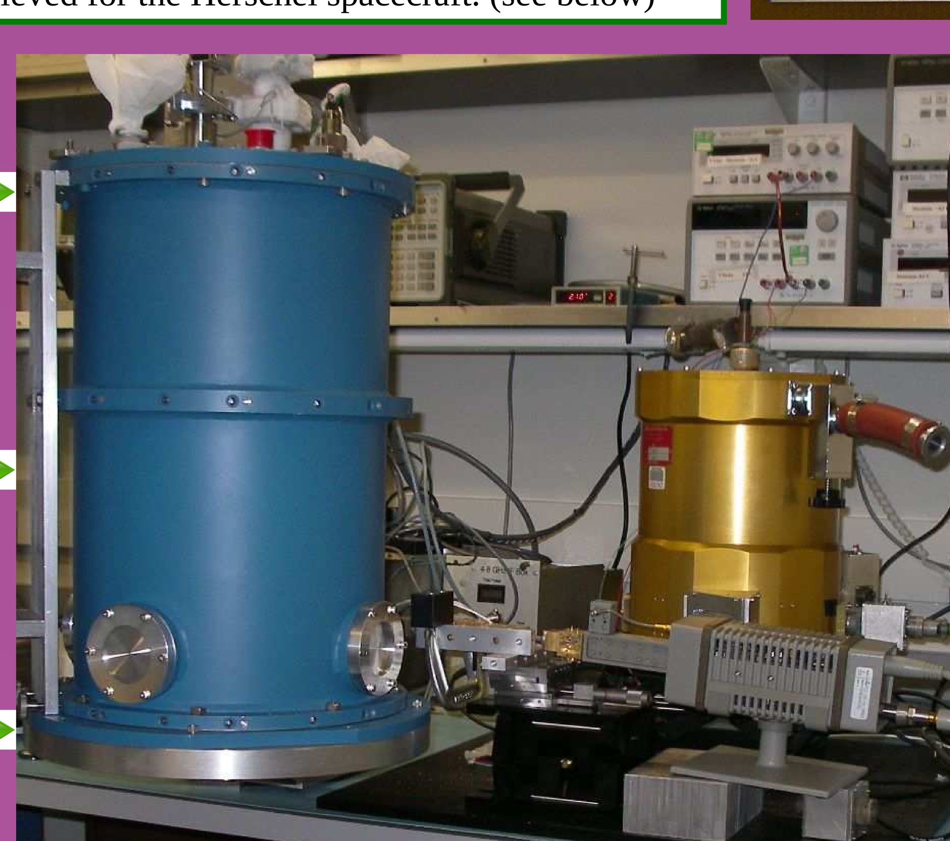
The optics box supporting the cryostats is open to the telescope cavity and contains the relay optics and calibration systems (see above). Besides the cryostat windows, all the optics are reflective and can accommodate the entire 8' telescope field of view. Bias electronics and warm IF amplifiers are mounted on the cryostats, while electronics racks contain IF processor, backend spectrometers, control electronics, and power supplies.

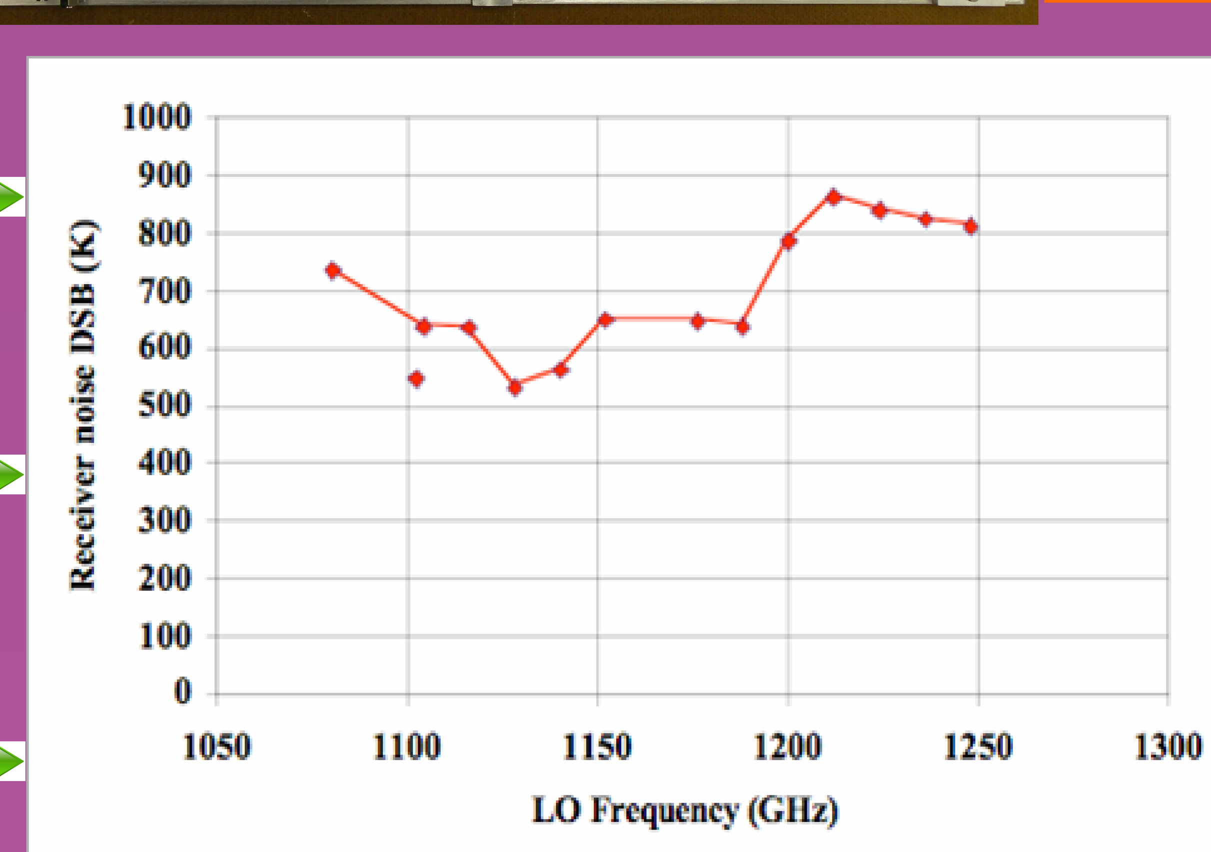
After bias wiring, the 1.2 THz mixer, cryogenic isolator, and LNA are integrated with the CASIMIR cryostat and undergoing receiver testing and debugging. Receiver performance is expected to be similar to the results achieved for the Herschel spacecraft. (see below)



Spectrometer and IF Processor

CASIMIR will have a high resolution digital FFT spectrometer developed by Omnisys. This instrument consists of two processing modules, each with two high speed samplers and an FPGA engine. The spectrometer covers the entire 4 GHz IF bandwidth, providing 8192 channels and a maximum resolution 250 kHz per channel, which corresponds to a velocity resolution of 750 m/s at 1000 GHz observing frequency. Lower resolution is possible by averaging channels. An IF processor will convert the 4-8 GHz observing bandwidth to the input frequencies required by the spectrometer (see breadboard model, left).





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http://www.submm.caltech/casimir

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