CHALMERS

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Group for Advanced Receiver Development:

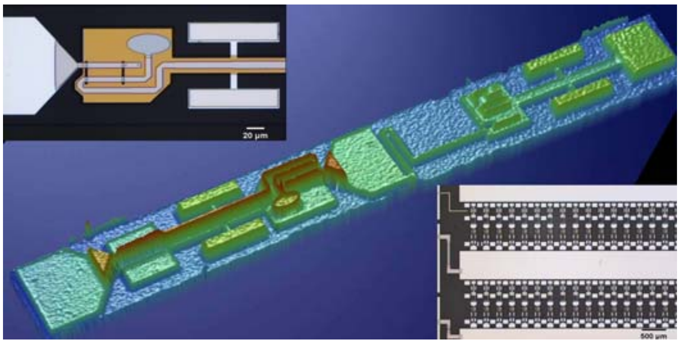
Radio Astronomy Instrumentation for MM and subMM waves and THz Frequencies

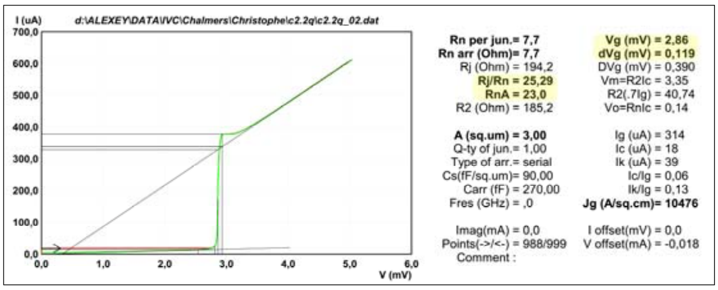
Thin Film Technology

We develop instruments for radio astronomy relying on our original designs. Our in-house thin film processing facility enables us to fabricate SIS, HEB, and the surrounding circuitries within a short turn-around time. The end result is a reliable and efficient design process from which we implement novel MM, subMM, and THz mixer receivers for radio astronomy.

SIS design rule summary

- **Junctions:**
  - R_nA -- down to 15Ω·μm²;
  - R_j/R_n ratio -- above 20;
  - junction size -- down to 3μm²;
- **Resistors:** in the range 1…50Ω/□;
- **Nb tuning circuitry:**
  - strip width -- down to 3μm;
  - strip thickness -- up to 0.4μm





Micromachined All-Copper Waveguides for SubMM Waves and THz

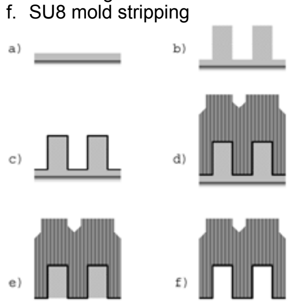
Pushing instrumentation and receiver technology above 1 THz makes waveguide technology at these frequencies necessarily important, since corrugated horns are the most efficient way to couple the antenna signal.

Maxwell's equations scale with frequency, hence the shortening of the wavelength increases the demand on surface quality (Rq< 0.1 μm @ 1.3 THz).

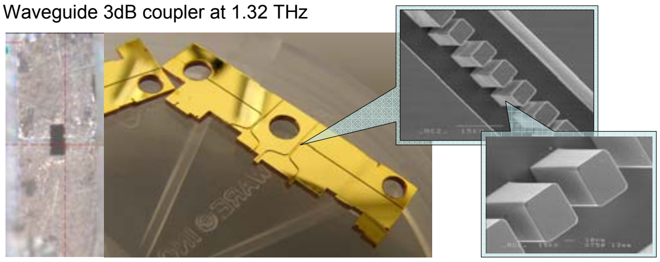
The proposed technology allows submicron resolution and photolithography accuracy of any complex structure within up to 3-layer technology.

We have successfully demonstrated this technology over a wide frequency range: 385-500 GHz, 600-750 GHz and 1.29-1.35 THz.

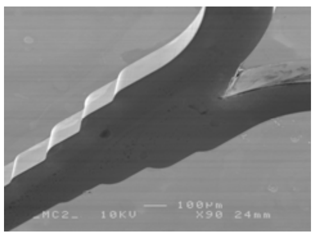
a. Release layer deposition on Si carrier wafer
b. Multi/single-layer photoresist mold patterning
c. Seed layer deposition
d. Cu electroplating
e. Releasing of Si carrier wafer
f. SU8 mold stripping



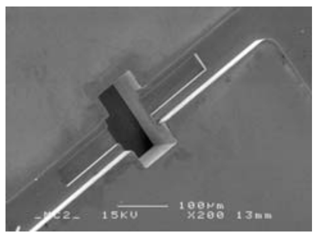
Waveguide 3dB coupler at 1.32 THz



385-500 GHz Mixer block



1.32 THz Back-piece



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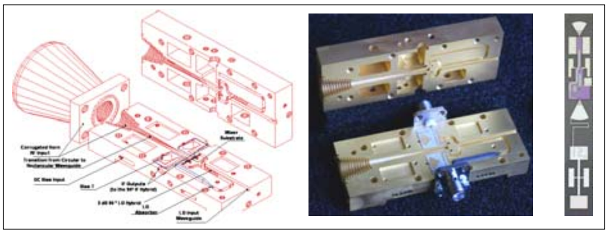
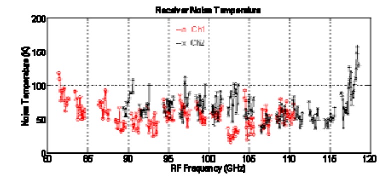
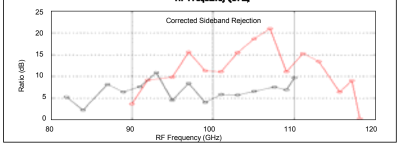
Onsala 85-115 GHz 2SB Mixer

The first 2SB mixer developed by GARD employs an integrated mixer design comprising of the LO division circuitry, two DSB SIS mixers with LO injection coupling and the resistive terminations all integrated to a single chip. The mixer uses a reversed quadrature scheme employing a 90-degree waveguide hybrid at the LO feed. A corrugated horn partially integrated within the mixer block provides an extremely compact mixer assembly.



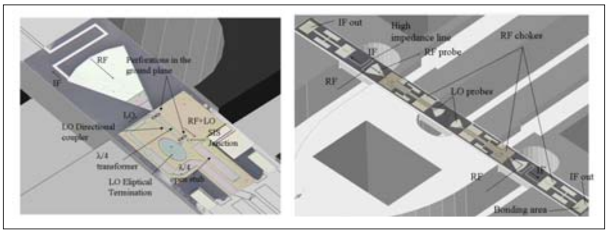


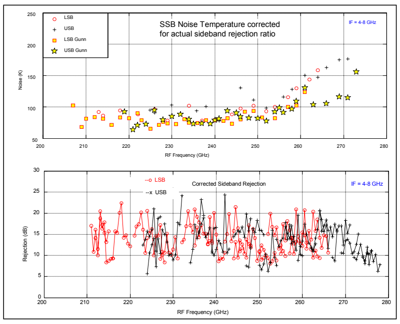


APEX-1 211-275 GHz 2SB Mixer

The APEX-1 2SB mixer has the same required specifications as the ALMA Band 6 mixer.

This mixer is original in its circuit design and is also very compact. The 2SB mixer block combines the 90-degree waveguide RF hybrid, LO division circuitry, and the mixer chip containing both DSB mixers, their tuning circuitries, and the LO injection.

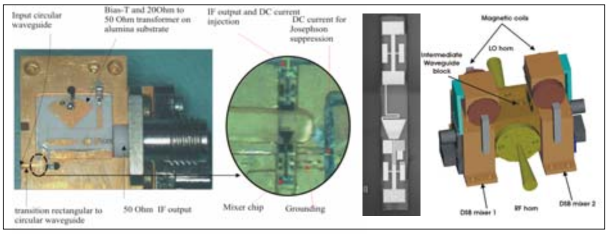


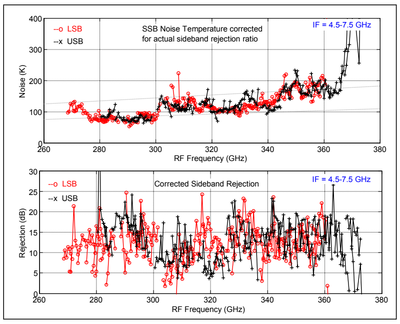


APEX-2 275-370 GHz 2SB Mixer

The APEX-2 2SB mixer has the same required specifications as the ALMA Band 7 mixer.

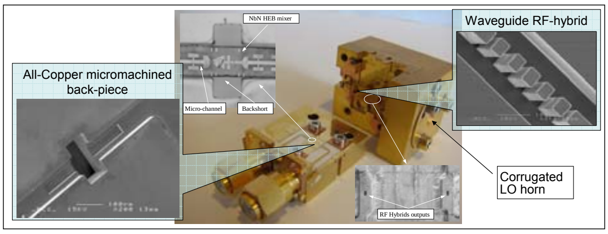
The mixer uses a modular design, similar to ALMA 2SB mixers. The mixer block houses 2 single ended DSB mixers and is joined by an intermediate split-block waveguide piece containing the LO division and injection and the 90-degree hybrid.

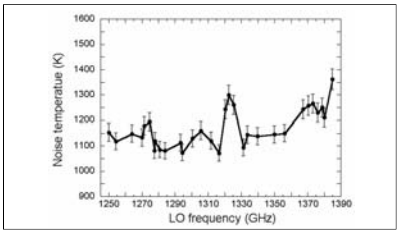




APEX-T2 1.25-1.39 THz Balanced Mixer

This mixer pioneers a balanced waveguide scheme with two NbN HEB mixers. The mixer substrates, each 1000×70×17 μm^3, are placed suspended in a micro-machined channel across a broad wall of the full-height (180x90 μm^2) waveguide. A micro-machined 3 dB quadrature waveguide hybrid provides LO injection and RF signal distribution between the two HEB mixers.





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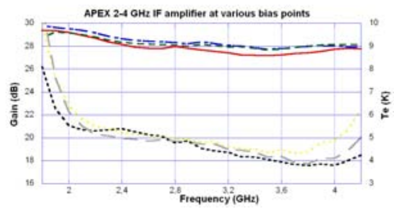
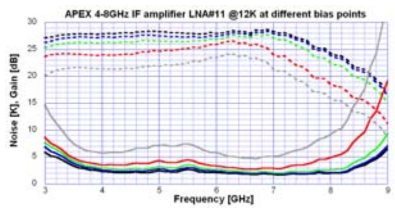
Low-Noise HEMT IF Amplifiers

GARD has developed a family of cryogenic HEMT 2- and 3 - stage amplifiers to use as the frontend (Onsala 20 m and 25 m antennas) and as IF amplifiers for SIS and HEB mixers. The amplifiers use commercial HEMT GaAs and InP transistors and provide state-of-the-art performance for their respective bands: 3.4 – 4.6 GHz, 2 – 4 GHz, 4 – 8 GHz (2- and 3-stage designs).



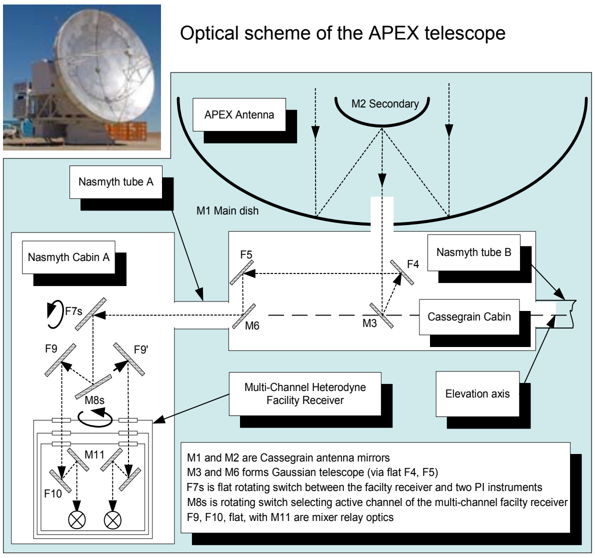
APEX 4-8 GHz IF amplifier

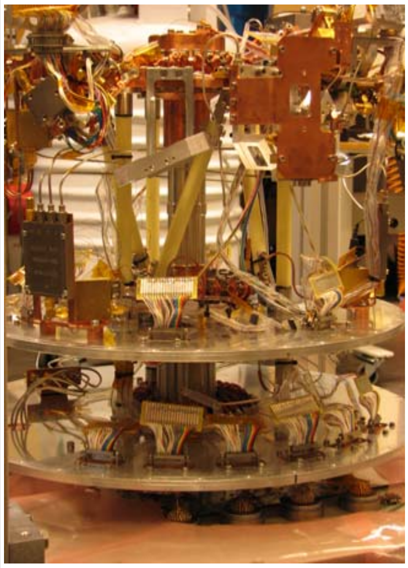


APEX Heterodyne Facility Receiver

APEX, the Atacama Pathfinder Experiment, is a collaboration between Max Planck Institut für Radioastronomie (MPIfR) with Astronomisches Institut Ruhr Universität Bochum, Onsala Space Observatory and the European Southern Observatory (ESO). The telescope was supplied by VERTEX Antennentechnik in Duisburg, Germany, and is a 12 m antenna with 15 μm rms surface accuracy operating at the Atacama Desert Llano Chajnantor, in the Chilean Andes at 5100 m altitude. The APEX heterodyne single pixel facility receiver is to be placed in the telescope Nasmyth cabin A. The receivers are coupled to the antenna via relay optics providing possibility to operate either one of the two different PI-type instruments or a 6-channel facility heterodyne receiver to cover 211 – 1500 GHz frequency range. The pictures at the right show the optical scheme of the telescope and give overview picture of the facility receiver under development in the laboratory.

Optical scheme of the APEX telescope





APEX Receiver Automated Control System

We have developed an automated control system for the APEX facility receivers. It uses National Instruments Compact FieldPoint for data acquisition and control. Digital and analog inputs and outputs are realized as rugged I/O modules. The system hardware includes SIS and HEB bias units, HEMT power supplies, cryo-temperature monitoring, deflux heaters and means for suppression of critical current SIS. The lab software for the system is developed in the LabView environment and provides automation of APEX facility receivers operation and remote control of it. The software uses Modbus commands, which is a protocol for a multidrop network based on a master/client architecture. The APEX telescope control system uses the same hardware and is interfaced via standard Ethernet while uses Linux based software GUI.

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