

Development and characterization of the superconducting integrated receiver channel of the TELIS atmospheric sounder

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Abstract

- The balloon-borne instrument TELIS (TeraHertz and submillimetre Limb Sounder) is a three-channel superconducting heterodyne spectrometer for atmospheric research use. It detects spectral emission lines of stratospheric trace gases that have their rotational transitions at THz frequencies.
- One of the channels is based on the superconducting integrated receiver (SIR) technology. We demonstrate for the first time the capabilities of the SIR technology for heterodyne spectroscopy in general, and atmospheric limb sounding in particular. This is not limited to laboratory environments but the technology is also well suited for remote operation under harsh environmental conditions as is demonstrated in two successful balloon flights in Kiruna, Sweden.
- Within a SIR the main components needed for a superconducting integrated receiver such as a superconductor-insulator-superconductor (SIS) mixer with a quasi-optical antenna, a flux-flow oscillator (FFO) as the local oscillator, and a harmonic mixer to phase lock the FFO are integrated on a single chip.
- Light weight and low power consumption combined with broadband operation and nearly quantum limited sensitivity make the SIR a perfect candidate for use in future airborne and space-borne missions.
- The noise temperature of the SIR was measured to be as low as 120 K, with an intermediate frequency band of 4–8 GHz in double-sideband operation. The spectral resolution is well below 1 MHz, confirmed by our measurements.

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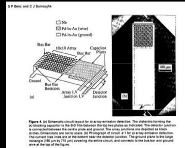
Superconducting Oscillators

Tuneable voltage controlled frequency sources, based on Josephson relation:

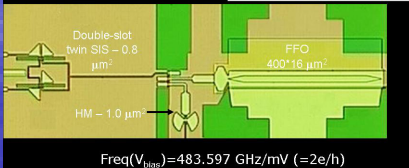
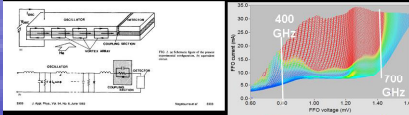
$$\text{Freq}(V_{\text{bias}}) = 483.597 \text{ GHz/mV } (=2e/h)$$

Two main types

- Arrays of Josephson junctions: 1-D, 2-D, 3-D stacks of High-Tc materials
- Flux flow oscillators: Long Josephson junctions with unidirectional flux flow motion

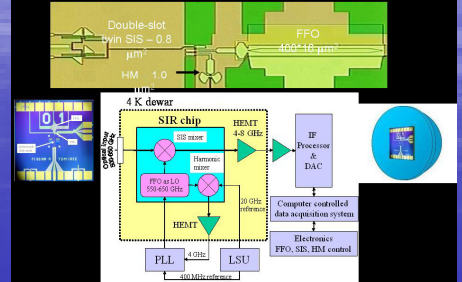


Flux-flow oscillators

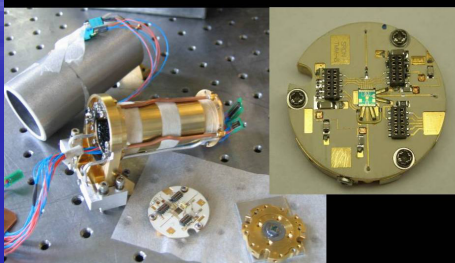


$$\text{Freq}(V_{\text{bias}}) = 483.597 \text{ GHz/mV } (=2e/h)$$

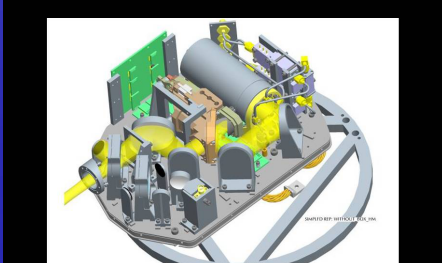
Schematics of SIR receiver: FFO phase locking



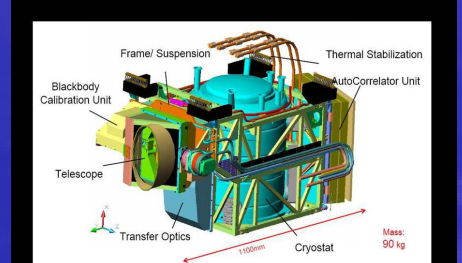
SIR Mixer Block with Shields



SIR cold channel layout: ambient temperature 4 K

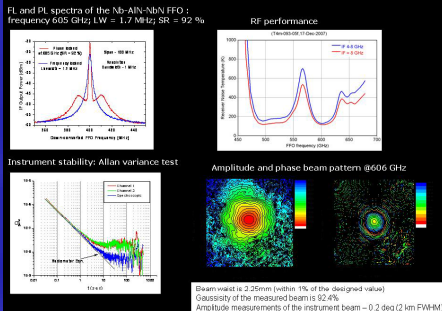


TELIS instrument



Balloon-borne mission: TELIS

- Acronym:
 - TeraHertz Limb Sounder
- Balloon instrument on board MIPAS gondola, IMK Karlsruhe
- Three independent frequency channels, cryogenic heterodyne receivers:
 - 500 GHz by RAL (UK)
 - 480–650 GHz by SRON-IRFF
 - 1.8 THz by DLR (PI-Institute)



Conclusions:

- TELIS mission objectives:
 - Scientific measurements of Earth atmosphere
 - Test bed for superconducting integrated receiver technologies
 - Validation of instrumentation for satellite missions
- Superconducting Integrated Receiver is a compact sensitive broadband spectrometer for 400–700 GHz
- The TELIS SIR was successfully installed and launched twice at Kiruna, Sweden in 2009 and 2010.
- SIR operated well with remote control over 12 hrs, until end of flights.
- Full scientific observation program succeeded with unique ClO and BrO observations.
- Continuation of TELIS and/or application in aircraft (HALO)

Working at the launch site



First flight: Teresina Brasil June 2008. No science due to thermo-mechanical problems with TELIS instrument



2010 results: BrO and ClO measurement during sunrise

