



Superconducting Integrated THz Receivers

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Abstract

A Superconducting Integrated Receiver (SIR) was proposed more than 10 years ago and has since then been developed for practical applications.

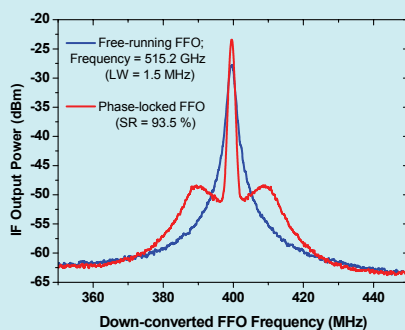
A SIR comprises on one chip (size of 4 mm × 4 mm × 0.5 mm) all elements needed for heterodyne detection: a low-noise SIS mixer with quasioptical antenna, an Flux-Flow Oscillator (FFO) acting as a Local Oscillator (LO) and a second SIS harmonic mixer (HM) for the FFO phase locking. The concept of the SIR looks very attractive for many practical applications due to its compactness and the wide tuning range of the FFO. Presently, the frequency range of most practical heterodyne receivers is limited by the tunability of the local oscillator, typically 10–15% for a solid-state multiplier chain. In the SIR the bandwidth is determined by the SIS mixer tuning structure and the matching circuitry between the SIS and the FFO. A bandwidth up to 30–40% can be achieved with a twin-junction SIS mixer design. All components of the SIR microcircuits are fabricated in a high quality Nb-AlN/NbN-Nb tri-layer on a Si substrate. The receiver chip is placed on the flat back surface of the silicon lens, forming an integrated lens-antenna. Light weight and low power consumption combined with nearly quantum limited sensitivity and a wide tuning range of the FFO make SIR a perfect candidate for many practical applications.

TELIS-SIR Main Parameters

(see report P3.1 by Gert de Lange, et al.)

#	Description	Value
1	Input frequency range	485 – 635 GHz
2	Minimum noise temperature (DSB)	120 K
3	Output IF range	4 – 8 GHz
4	Spectral resolution	< 1 MHz
5	LO frequency net	< 300 MHz
6	Dissipated power at 4.2 K stage (including IF amplifiers chain)	< 30 mW
7	Operation temperature	< 4.5 K

SIR Spectral Resolution



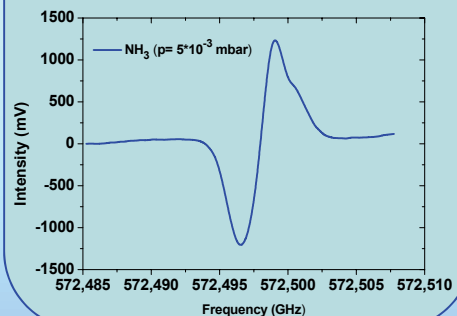
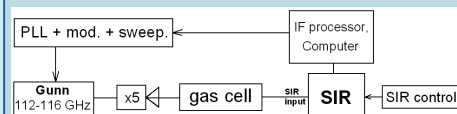
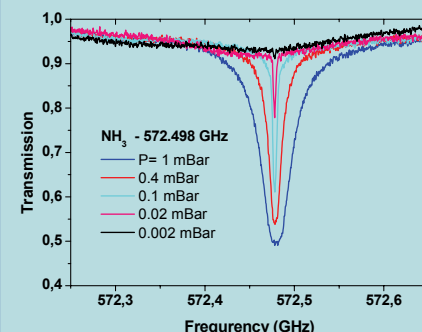
Spectra of the FFO operating at 515.2 GHz (blue curve – frequency locked; red curve – phase-locked). Linewidth (LW) = 1.5 MHz; Signal to Noise Ratio (SNR) = 36 dB; Spectral Ratio (SR) = 93.5 %. Spectra measured with RBW = 1 MHz.

Gas Spectra Detection for Medical Applications

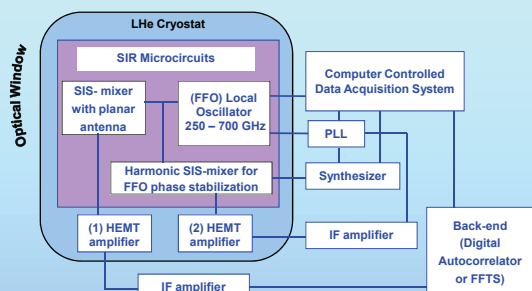
Non-invasive medical diagnostics based on analysis of exhaled air

- human exhalation contains up to 600 volatile compounds
- some of them can be used as **markers of diseases**

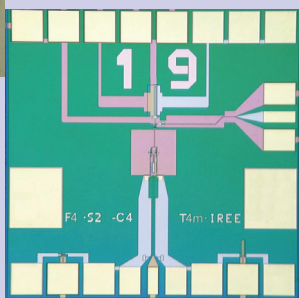
CO Blood disease, asthma, oxidative stress
 NO Diseases of respiratory tract, oncology
 NH₃ Diseases of gastro-enteric tract, liver, kidney
 CH₄ Malabsorption of hydrocarbons
 CS₂ Markers of coronary arteries diseases, schizophrenia
 H₂O₂ Radiation injury, asthma



Block Diagram of the Superconducting Integrated Receiver

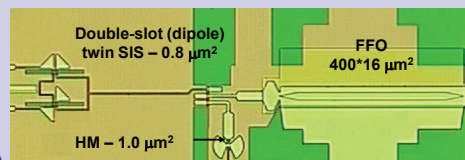


SIR Chip Design



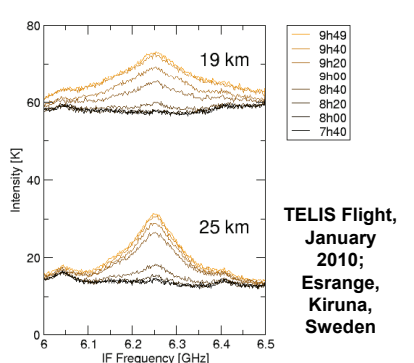
Silicon (Si);
 4 × 4 × 0.5 mm³
 Nb-AlO_x-Nb or
 Nb-AlN-NbN;
 J_C = 5 - 10 kA/cm²

Optionally:
 SIS - J_C = 8 kA/cm²;
 FFO + HM = 4 kA/cm²



Double-slot (dipole) twin SIS - 0.8 μm²
 FFO 400 × 16 μm²
 HM - 1.0 μm²

CI/O diurnal cycle



TELIS Flight,
 January
 2010;
 Esrange,
 Kiruna,
 Sweden

30-cm Portable Submillimeter Telescope (POST) Purple Mountain Observatory; Nanjing, China.

Site: Delingha of Qinghai province (altitude ~3200 m)



SIR for POST
 Frequency - 345 GHz
 Tr (DSB) < 100 K
 Spectral resolution < 1 MHz

2-stage GM type;
 cooling capacity
 - 0.1 W;

compressor - 42 kg;
 power consumption
 - 1.2 kW

Conclusion

- Concept of the **Phase-locked SIR** is developed and proven.
- Nb-AlN-NbN FFOs and SIRs have been successfully implemented.
- New generation of the SIR with PL FFO for TELIS has been developed showing a possibility to achieve all TELIS requirements:
 Frequency range 485 – 635 GHz;
 Noise temperature as low as 120 K;
 IF bandwidth 4 - 8 GHz;
 Spectral resolution better 1 MHz;
 Beam Pattern - FWHM = 3 deg, with sidelobes < - 17 dB.
- Procedure for **remote SIR operation** has been developed and experimentally proven.

- Successful TELIS flights in 2009 and 2010 (Kiruna, Sweden).
- Future space and ground-base missions are under consideration.
- SIR Technology is mature enough for both future space missions and non-invasive medical diagnostic.