Superconducting Integrated Terahertz Spectrometers

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***Abstract*— A Superconducting Integrated Receiver (SIR) comprises on one chip all elements needed for heterodyne detection. Light weight and low power consumption combined with nearly quantum limited sensitivity and a wide tuning range of the superconducting local oscillator make SIR a perfect candidate for many practical applications.**

Keywords—superconducting integrated nanostructures, terahertz receivers, oscillators and spectrometers.

I. Introduction

A Superconducting Integrated Receiver (SIR) [1] comprises on one chip 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 (see Fig. 1). The concept of the SIR looks very attractive for many practical applications due to its compactness and the wide tuning range of the FFO; a bandwidth up to 35% has been achieved with a twin-junction SIS mixer design.. 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. All components of the SIR microcircuits are fabricated in a high quality Nb based 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.

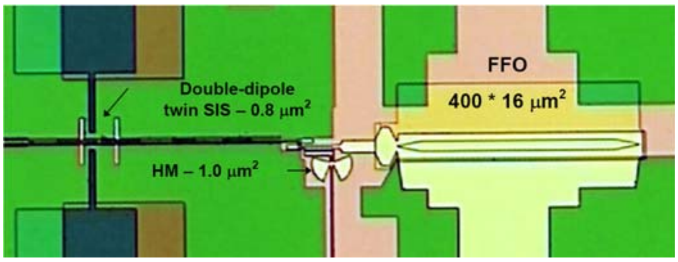

Figure 1. Central part of the SIR chip with antenna, twin SIS-mixer and harmonic mixer for FFO phase locking.

II. Results

Continuous tuning of the phase-locked local oscillator has been realized at any frequency in the range 300-750 GHz. The output power of the FFO is sufficient to pump the matched SIS mixer in a wide frequency range and can be electronically adjusted. The FFO free-running linewidth has been measured between 0.3 and 5 MHz; resulting in the spectral ratio of the phase-locked FFO above 70% over the range. As a result of receiver's optimization the DSB noise temperature was measured below 100 K that is about 4 hf/k_B; the spectral resolution is well below 1 MHz.

All these achievements enabled the development of a 450 - 650 GHz integrated receiver for the atmospheric-research instrument TELIS (TErahertz and submillimeter LImb Sounder) [2] - the balloon-borne instrument for the detection of spectral emission lines of stratospheric trace gases that have their rotational transitions at THz frequencies. Diurnal cycle of ClO has been observed; the BrO line with a level of only 0.3 K was isolated and clearly detected. Capability of the SIR for high resolution spectroscopy has been successfully proven also in a laboratory environment by gas cell measurements. The possibility to use SIR devices for the medical analysis of exhaled air has been demonstrated. Many medically relevant gases have spectral lines in the sub-terahertz range and can be detected by a SIR-based spectrometer.

Recently the SIR was successfully implemented for the first spectral measurements of THz radiation emitted from intrinsic Josephson junction stacks (BSCCO mesa) in the frequency range 585 – 735 GHz; linewidth as low as 7 MHz has been recorded in the high bias regime. The phase-locked SIR has been used for the locking of the oscillator under the test. That is the first, but very important step towards development of fully HTc phase-locked local oscillator.

New technique for fabrication of high-quality SIS tunnel junctions based on epitaxial NbN films with MgO barrier has been developed; the junctions with gap voltage Vg = 5.2 mV and quality barrier parameter Rj(2mV)/Rn > 40 have been fabricated. Such junction parameters are very promising for development of the SIRs for frequencies well above 1 THz.

Nowadays the SIR is probably the most functionally complex fully superconducting device that was already successfully implemented for practical applications. In particular the SIR is very attractive for future airborne and space-borne missions as well as for analysis of the breathed out air at medical survey and for security monitoring.

References

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