Superconducting Integrated Terahertz Spectrometer for Atmosphere Monitoring and Radio Astronomy

V.P. Koshelets, P.N. Dmitriev, A.B. Ermakov, L.V. Filippenko, A.V. Khudchenko, N.V. Kinev, O.S. Kiselev, I.L. Lapitskaya, A.S. Sobolev, M.Yu. Torgashin

Kotel'nilov Institute of Radio Engineering and Electronics, Russian Academy of Science, Mokhovaya 11, 125009, Moscow, Russia

A Superconducting Integrated Receiver (SIR) [1, 2] was proposed more than 10 years ago and has since then been developed for practical applications [3]. 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) [4] 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 [5]. 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. In particular we have developed integrated receiver for novel balloon borne instrument TELIS (TErahertz and submillimeter LImb Sounder) [6, 7]. TELIS is a collaborative European project to build a three-channel heterodyne balloon-based spectrometer for measuring a variety of the stratosphere constituents. It detects spectral emission lines of stratospheric trace gases that have their rotational transitions at THz frequencies. TELIS is designed to be a compact, lightweight instrument capable of providing broad spectral coverage, high spectral resolution and long flight duration. The TELIS instrument serves also as a test bed for many novel cryogenic technologies. The SIR for TELIS covers frequency range 450 -650 GHz. As a result of recent receiver's optimization the DSB noise temperature was measured as low as 120 K for the SIR with intermediate frequency band 4 – 8 GHz. The spectroscopic Allan stability time is about 20 seconds; required spectral resolution of about 1 MHz was confirmed by gas cell measurements. Several algorithms for remote automatic computer control of the SIR have been developed and tested. Successful results of the TELIS instrument flight on board of high-altitude balloon in March 2009 (Esrange, Kiruna, Sweden) will be presented. A possibility to implement the SIR for ground-based radio astronomy and future space missions will be discussed.

Capability of the SIR for high resolution spectroscopy has been successfully proven in a laboratory environment. Possibility to use the SIR devices for analysis of the breathed out air at medical survey will be discussed. Many of spectral lines very important for such survey and medical analysis are concentrated in the sub-terahertz range and can be detected by such spectrometer. There is also a large niche for applications of integrated spectrometers for the detection of radiation from the newly developed cryogenic Terahertz sources.

The work was supported by the projects: RFBR 09-02-00246, 09-02-12172-ofi-m, and Grant for Leading Scientific School 5408.2008.2

[1] V.P. Koshelets, S.V. Shitov, L.V. Filippenko, A.M. Baryshev, H. Golstein, T. de Graauw, W. Luinge, H. Schaeffer, H. van de Stadt "First Implementation of a Superconducting Integrated Receiver at 450 GHz"; *Appl. Phys. Lett.*, vol. 68, No. 9, pp. 1273-1275 (1996).

[2] V. P. Koshelets and S. V. Shitov, "Integrated Superconducting Receivers," *Superconductor Science and Technology*, vol. 13, pp. R53-R69 (2000).

[3] V.P. Koshelets, A.B. Ermakov, L.V. Filippenko, A.V. Khudchenko, O.S. Kiselev, A.S. Sobolev, M.Yu. Torgashin, P.A. Yagoubov, R.W.M. Hoogeveen, and W. Wild, "Iintegrated Submillimeter Receiver for TELIS", "*IEEE Trans. on Appl. Supercond.*", vol. 17, pp 336-342 (2007).

[4] T. Nagatsuma, K. Enpuku, F. Irie, and K. Yoshida 1983 *J. Appl. Phys* **54** 3302, see also Pt. II: 1984 *J. Appl. Phys.* **56** 3284; Pt. III, 1985 *J. Appl. Phys* **58** 441, Pt. IV, 1988 *J. Appl. Phys* **63** 1130

[5] M.Yu. Torgashin, V.P. Koshelets, P.N. Dmitriev, A.B. Ermakov, L.V.Filippenko, and P.A. Yagoubov, "Superconducting Integrated Receivers based on Nb-AlN-NbN circuits", *IEEE Trans. on Appl. Supercond.*, vol. 17, pp.379- 382, (2007).

[6] Pavel Yagoubov, Gert de Lange, Hans Golstein, Leo de Jong, Arno de Lange, Bart van Kuik, Ed de Vries, Johannes Dercksen, Ruud Hoogeveen, Valery Koshelets, Andrey Ermakov, and Lyudmila Filippenko, "Flight configuration of the TELIS instrument", presented at the *19th International Symposium on Space Terahertz Technology (ISSTT-08)*, Groningen, the Netherlands, April 2008, report 10-2; published in the Proceedings of the ISSTT-08, pp. 268-275.

[7] R.W.M. Hoogeveen, P.A. Yagoubov, G. de Lange, A. de Lange, V. Koshelets, M. Birk, B. Ellison, 2007 *Proceedings of SPIE* **6744** 67441U-1