1200GHz and 600GHz Schottky receivers for JUICE-SWI

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Abstract— ***The Sub-millimeter Wave Instrument (SWI) for ESA Jupiter Icy Moons Explorer (JUICE) will be the first planetary instrument to feature 1200 GHz and 600 GHz heterodyne receivers. These receivers will investigate the temperature structure, composition and dynamics of Jupiter's stratosphere and troposphere, and the exospheres and surfaces of the icy moons.***

This paper will present the ongoing work at LERMA in partnership with LPN to design, fabricate and test, at room temperature and at cryogenic temperature, a 520-630GHz and a 1080-1280GHz Schottky receivers. Both receivers rely on 132-160GHz sources provided by Radiometer Physics GmbH that deliver respectively about 30-60mW and 60-120mW. LERMA, in partnership with LPN-CNRS, has designed and fabricated the high frequency parts of the LOs as well as the sub-harmonic mixers, using a Schottky process based entirely on e-beam lithography.

LERMA 520-630GHz Schottky receiver is the most sensitive to date with a DSB receiver equivalent noise temperature in the range of 1070K-1500K at room temperature, and a DSB receiver equivalent noise temperature in the range of 620K to 885K at 134K ambient temperature. LERMA 1080-1280GHz receiver has a DSB equivalent noise temperature of ~3500-7500K across the band at room temperature.

INTRODUCTION

The Sub-millimeter Wave Instrument (SWI) onboard the European Space Agency Jupiter Icy Moons Explorer (JUICE) [1] will investigate the temperature structure, composition and dynamics of Jupiter's stratosphere and troposphere, and the exospheres and surfaces of the icy moons. SWI is a heterodyne receiver with a spectral resolution of 10^7 and a frequency accuracy of 10^{-8}. SWI will receive RF signals in two frequency bands, 530-625GHz and 1080-1275GHz respectively, with a dual-axis steerable 30cm equivalent aperture off-axis antenna. The receiver front-end is based on sub-harmonic Schottky mixers pumped by frequency multiplier-based Local Oscillators (LOs). To achieve the science goals of SWI, the sensitivity of the receivers is specified at 120K-150K ambient temperature: for the 530-625GHz and 1080-1275GHz receivers the DSB equivalent noise temperature should be respectively lower than 2000K (goal is 1500K) and 4000K (goal is 3000K). This paper will present briefly the design of both receivers with an emphasis LERMA 1080-1280GHz bias-able sub-harmonic mixer.

RECEIVER DESIGN & TECHNOLOGY

Fig. 1 gives a schematic of SWI frontend. The LOs are made with a low-phase-noise VCO-based K-band synthesizer referenced to a 100MHz ultra-stable signal followed by an E-band tripler, one or several E-band amplifiers, and two or three cascaded frequency doublers. Each sub-harmonic mixer had the same Intermediate Frequency (IF) at 3.5-8.5GHz with an external LNA. The RF signal is coupled to the mixer with an external smooth-wall feed-horn designed by H. Gibson for Radiometer Physics GmbH[1].

The last stages frequency multipliers (at 300GHz and 600GHz output frequency) and the mixers are based on Schottky devices fabricated by LERMA-Observatoire de Paris in partnership with Laboratoire de Photonique et de Nanostructures – CNRS[2]. The Schottky process is entirely based on e-beam lithography and allows for diodes of 0.2µm^2 on 2-5µm-thick GaAs membranes, with front-side beam-leads (metal membranes) [2]. The design and the fabrication of LERMA single-chip 300GHz frequency doubler and of LERMA 600GHz sub-

[1] Radiometer Physics GmbH., http://www.radiometer-physics.de
[2] LPN and Institut d'Electronique Fondamentale have merged on June 1st, 2016, and are now Centre de Nanosciences et de Nanotechnologies (C2N).

harmonic mixer have been detailed in [3]. LERMA dual-chip 300GHz doubler features a 90° hybrid 3dB coupler at the input, two identical 4-anode balanced doubler devices and a compact Y-junction at the output. This doubler is packaged in a mechanical block of only 10mm long. LERMA 600GHz doubler features two anodes in a classic configuration. The micro-electronic devices of these multipliers are fabricated on the same wafer, with a GaAs membrane thickness of 5µm and a doping level of 1E17 cm^{-3}.

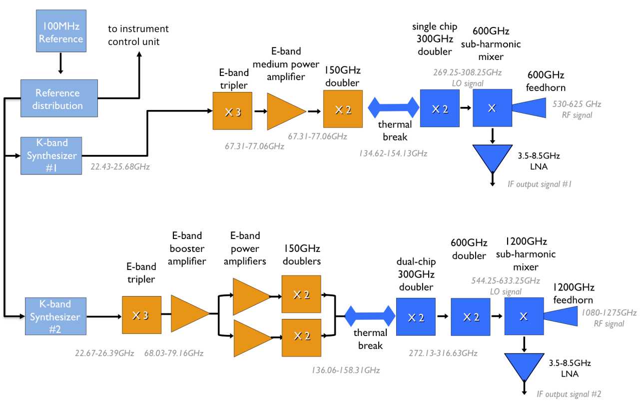

Fig. 1: schematic of SWI front-end. LERMA proposed solution for the mixers uses external feed-horns and external LNAs.

LERMA 1200GHz sub-harmonic mixer is made of a micro-electronic circuit fabricated on a 2µm thick GaAs membrane suspended in a micro-mechanical waveguide structure thanks to beam-leads (see Fig. 2). The micro-electronic circuit uses a novel configuration: it features a bias-able anti-parallel pair of Schottky diodes of 0.5fF each with a capacitor located on a T-shape mesa, which is RF grounded to the waveguide blocks thanks to lateral beam-leads attached to it (see Fig. 3).

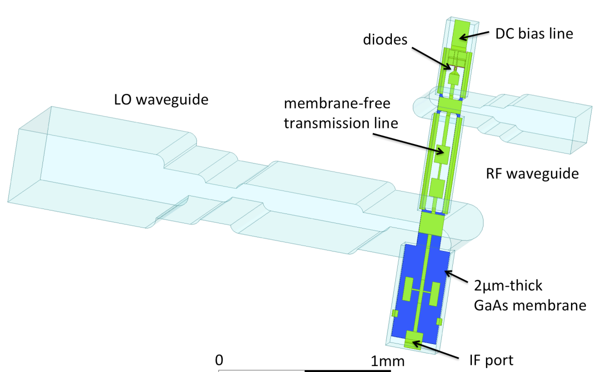

Fig. 2: 3D view of LERMA proposed 1200GHz bias-able mixer

This topology was found to provide a wideband LO and RF matching even with low levels of LO power: the mixer was designed to cover the full 1080-1280GHz band with only 1mW of available LO power. With 0.5mW of LO power the mixer can be pumped. This configuration has the additional advantage to separate the DC and the IF ports - like with the designs proposed in [4] - but with an in-line design.

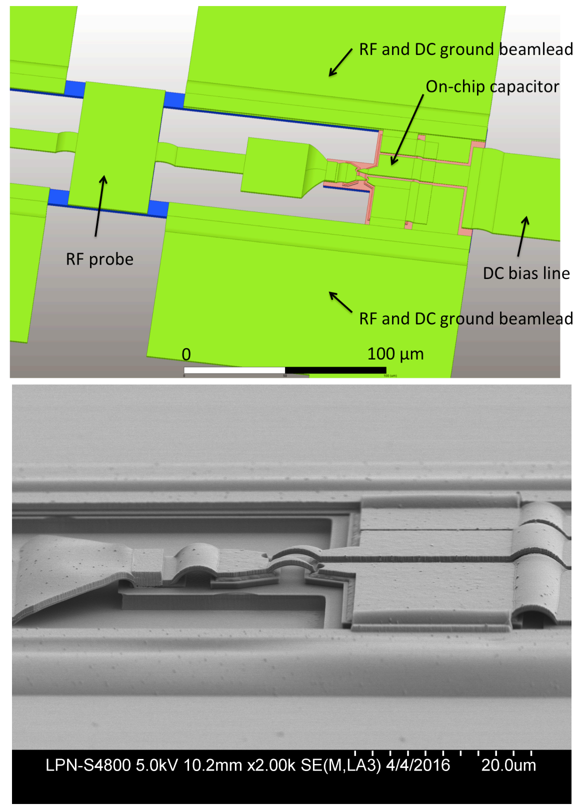

Fig. 3: 3D view (top) and SEM picture (bottom) of LERMA proposed 1200GHz bias-able mixer – detail of the diodes and bias-circuit

Preliminary measurements at room temperature in air (4.5cm air path with 60% humidity) give a DSB equivalent noise temperature of ~3500-7500K across the full 1080-1280GHz band. The 540-640GHz LO source could provide 0.5-2.0mW across the entire band at room temperature. The mixer was found to need very little LO power; it could be actually pumped with only 0.5mW at some frequency points, and we had to decrease the power provided by the LO source for most of the frequency points in order to get the best noise temperature.

CONCLUSIONS & PERSPECTIVE

LERMA 600GHz Schottky receiver is at the state of the art and could provide unprecedented sensitivity for planetary missions like JUICE. LERMA 1200GHz receiver shows good to very good noise temperature at room temperature across the full RF band of JUCE-SWI. Cooling the last stages of the receiver at 120K is expected to improve the noise performance within the specs (4000K).

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REFERENCES

[1] JUICE Jupiter Icy Moons Explorer SWI Submillimetre Wave Instrument (SWI), Science Concept Document, JUI-MPS-SWI-PL-002, 13/05/2013.

[2] L. Gatilova, J. Treuttel, F. Yang, T. Vacelet, C. Goldstein, A. Maestrini, and Y. Jin , "THz Schottky Diode MMICs for Astronomy and the Physics of the Atmosphere", proceedings of the 25th International Symposium on Space Terahertz Technology 2014, ISSTT 2014, Moscow, Russia, 27-30 April 2014

[3] J. Treuttel, L. Gatilova, A. Maestrini, D. Moro-Melgar, F. Yang, F. Tamazouzt, T. Vacelet, Y. Jin, J. Mateos, A. Feret, C. Chaumont, C. Goldstein. "A 520-620 GHz Schottky receiver front-end for Planetary Science and Remote Sensing with 1070K-1500K DSB noise temperature at Room Temperature". *IEEE Trans.Terahertz Science and Tech.,* vol. PP, no 99, p.1-8 , 2015.

[4] E. Schlecht, J.V Siles, C. Lee, R. Lin, B. Thomas, G. Chattopadhyay, I. Mehdi, "Schottky Diode Based 1.2 THz Receivers Operating at Room-Temperature and Below for Planetary Atmospheric Sounding", *IEEE Transactions on Terahertz Science and Technology*, Vol. 4, No 6, pp. 661 - 669, 2014.