Supra-THz Schottky-diode based harmonic mixers

Divya Jayasankar*(1)(2), Vladimir Drakinskiy (1), and Jan Stake (1)
(1) Terahertz and Millimetre-wave Laboratory, Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, Sweden
(2) Research Institutes of Sweden, Borås

Summary

This paper summarises the development of the 4.7-THz, ×8-harmonic, single-ended integrated Schottky diode-based harmonic mixer. The harmonic mixer utilises a sub-micron size Schottky diode fabricated with circuit elements on a suspended 2-μm-thick GaAs stripline circuit in an E-plane split-block housing. The harmonic mixer design and simulation results are presented.

1 Introduction

Terahertz (THz) heterodyne spectroscopy is a valuable tool for understanding the physics, distribution profile, and concentration of molecular and atomic gas in space [1]. Studying the chemical composition of the Earth and other planetary atmospheres can provide valuable insights into global warming and climate change. In particular, the detection of gas species such as atomic oxygen (OI) at 4.7 THz [2] and hydroxyl radical at 3.5 THz in the least explored atmospheric regions can improve the climate and weather prediction models. However, the lack of THz local oscillator (LO) sources with good frequency stability and low phase noise are one of the main drawbacks in realising THz heterodyne spectrometers. Over the past decade, quantum-cascade lasers (QCLs) have shown steady performance improvement. QCLs can provide a few mW of output power and operate in continuous-wave (CW) mode, making them an ideal candidate for space missions. However, QCLs are prone to frequency instabilities due to variations in bias current and temperature and, thus, require frequency stabilisation. Phase-locking of the QCL to a stable microwave reference oscillator using a Schottky diode-based harmonic mixer can result in a compact solution for realising high-resolution THz receivers for long lifetime space missions [3].

2 Design

Fig. 1 shows the design of 4.7-THz, ×8-harmonic mixer realised on a 2-μm-thick GaAs substrate. The incoming RF signal from the 4.7-THz QCL is coupled to the diode using a diagonal horn integrated into the RF rectangular waveguide WM-48. The

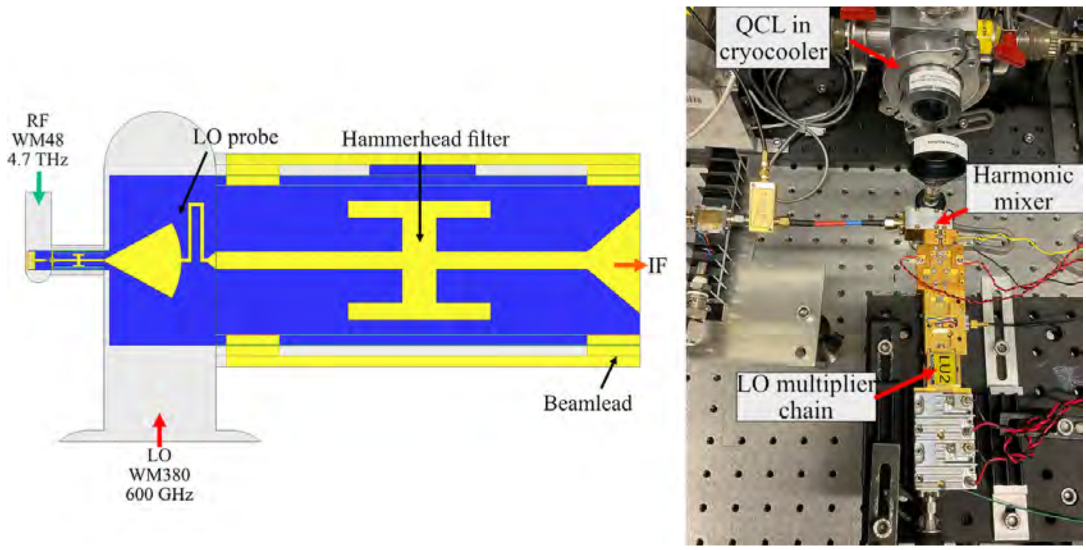

Figure 1. 4.7-THz harmonic mixer. (Left) 3D-EM model of the 4.7-THz, ×8-harmonic mixer. The GaAs circuit is suspended in an E-plane metal split-block by beamleads. (Right) Photograph showing the measurement setup in which the harmonic mixer's performance will be evaluated.

mixer is pumped by a Schottky varactor ×64-LO multiplier source. The radial LO probe was optimised to provide wide-band LO matching to the diode around 600 GHz [4].

3 Simulation results

Conversion loss plotted versus RF for LO power of 0 dBm, dc bias of −0.5 V is shown in Fig. 2. Note: loss in the substrate and low conductive mesa, conductor loss in the RF diagonal horn (≈ 2 mm), and LO access waveguide (≈ 11 mm) are not included in this ideal simulation. The fabrication of integrated mixer circuits and machining of mixer blocks is currently in progress.

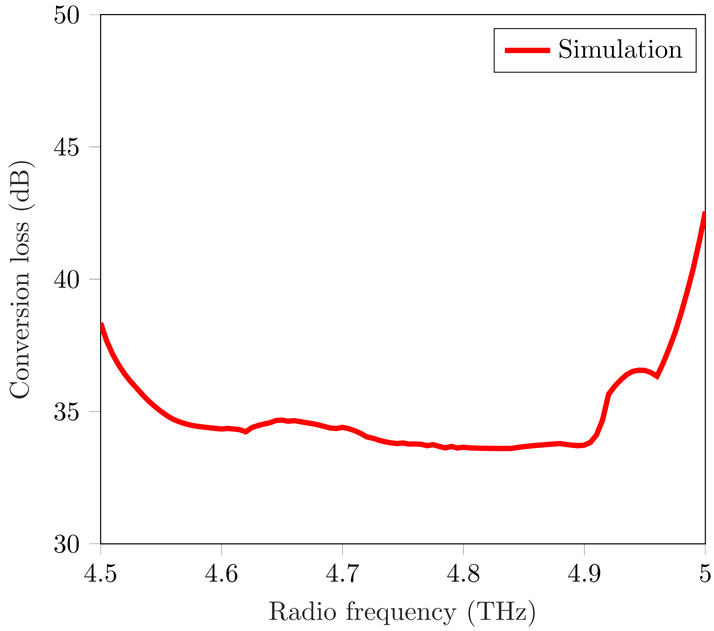

Figure 2. Simulated 4.7-THz, ×8-harmonic mixer performance.

4 Acknowledgements

The authors would like to thank Mr Mats Myremark for the high-precision machining of mixer blocks. Miss. Jayasankar's work is supported by the Swedish Foundation for strategic research (SSF) project number FID17-0040 and, in part, by the IEEE-MTTs graduate fellowship award 2022.

References

[1] D. Farrah *et al.*, "Review: far-infrared instrumentation and technological development for the next decade," *J. Astron. Telesc. Instrumen. Syst.*, vol. 5, Apr. 2019, Art. no. 020901,.

[2] H. Richter *et al.*, "Direct measurements of atomic oxygen in the mesosphere and lower thermosphere using terahertz heterodyne spectroscopy," *Commun. Earth Environment*, vol. 2, no. 1, Jan. 2021, Art. no. 19,.

[3] D. Jayasankar, V. Drakinskiy, N. Rothbart, H. Richter, X. Lu, L. Schrottke, H. T. Grahn, M. Wienold, H.-W. Hubers, P. Sobis, and J. Stake, "A 3.5-THz, 6-Harmonic, Single-Ended Schottky Diode Mixer for Frequency Stabilization of Quantum-Cascade Lasers," *IEEE Transactions on Terahertz Science and Technology*, pp. 1–1, 2021.

[4] C. Risacher *et al.*, "Waveguide-to-microstrip transition with integrated bias-T," *IEEE Microwave and Wireless Components Letters*, vol. 13, no. 7, pp. 262–264, 2003.