4.7-THz Schottky Diode Harmonic Mixer: Design, Fabrication, and Performance Optimization

Citation for the original published paper (version of record):
Jayasankar, D., Rothbart, N., Hübers, H. et al (2024). 4.7-THz Schottky Diode Harmonic Mixer: Design, Fabrication, and Performance Optimization. ISSTT 2024 - 33rd International Symposium on Space Terahertz Technology

(article starts on next page)

33rd IEEE International Symposium on Space THz Technology (ISSTT 2024) *Charlottesville, Virginia, USA*
April 7-11, 2024.

4.7-THz Schottky Diode Harmonic Mixer: Design, Fabrication, and Performance Optimization

Divya Jayasankar[1,2], Nick Rothbart[3], Heinz-Wilhelm Hübers[3,4], and Jan Stake[1]

***Abstract*—This paper focuses on the ongoing development of supra-THz harmonic mixers at Chalmers University of Technology. The planar, single-ended, ×8-harmonic mixers based on Schottky-barrier diodes were realized on a 2-μm GaAs substrate with integrated pyramidal horn. In contrast to our previous design with a diagonal horn, the new design addresses sensitivity to E-plane misalignment, which previously compromised mixer performance. The availability of THz harmonic frequency converters operating at ambient temperature is pivotal in realizing high-resolution THz heterodyne receivers.**

***Index Terms*—Harmonic mixers, Schottky diodes, Terahertz electronics**

I. Introduction

Terahertz (THz) heterodyne spectroscopy is a valuable tool for understanding the physics, distribution profile, and concentration of molecular and atomic gas in space. Identifying gas species like atomic oxygen (OI) at 4.7 THz [1] can enhance climate and weather prediction models. Quantum-cascade Lasers (QCLs) offer a few mW of output power while operating in continuous-wave (CW) mode, an optimal choice for THz heterodyne receivers. However, frequency instability arises from temperature and bias current fluctuations. Hence, frequency stabilization of QCLs is critical [2].

An efficient solution is to phase-lock the QCLs to a stable microwave source using a harmonic mixer. Danylov *et al.* [3] demonstrated phase locking of a 2.32-THz QCL using a balanced-Schottky diode ×21-harmonic mixer, which exhibited a conversion loss of about 110 dB. Later, Bulcha *et al.* [4] designed single-ended Schottky diode harmonic mixers yielding a conversion loss of 30 dB for fourth-harmonic mixing. Subsequently, Jayasankar *et al.* demonstrated single-ended planar Schottky diode ×6-harmonic mixers realized on a 2-μm GaAs substrate with 59-dB conversion loss. More recently, Reck *et al.* presented a 2.5-THz,×4-harmonic mixer with anti-parallel diodes with 26-dB conversion loss [5]. This work presents the design and fabrication of 2^{nd}-generation of THz harmonic mixer with integrated pyramidal horn.

II. Design and Fabrication

The incoming RF signal from the QCL is coupled to the diode using a pyramidal horn integrated into the RF rectangular waveguide WM-48. The mixer is pumped by a Schottky varactor ×64-LO multiplier source. The radial LO probe was optimized to provide wide-band LO matching to the diode around 600 GHz. Fig. 1 shows the integrated circuit assembled on an E-plane split-block [6].

[1]Chalmers University of Technology, SE-412 96 Gothenburg, Sweden; [2]Research Institutes of Sweden, SE-504 62, Borås, Sweden; [3]German Aerospace Center, Institute of Optical Sensor Systems, 12489 Berlin, Germany. [4]Humboldt-Universität zu Berlin, Department of Physics, 12489 Berlin, Germany.

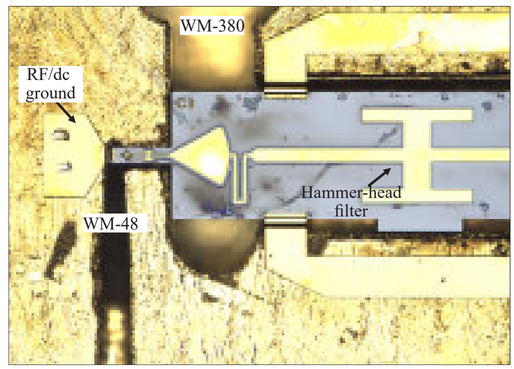

Fig. 1. Micrograph of integrated planar, single-ended 4.7-THz, ×8-harmonic Schottky diode mixer circuit assembled on an E-plane split block.

The realization of terahertz integrated circuits demands the alignment of patterns with high accuracy and precision in sub-micron order. Hence, we have developed a fabrication process entirely based on electron-beam lithography; the wafer structure can be found in [6].

III. RF characterisation

The 4.7-THz QCL is placed in a cryocooler, and a TPX lens is used to focus the incoming THz signal on the harmonic mixer. The harmonic mixers were pumped using a ×64 Schottky varactor-based multiplier source. The 200-MHz IF signal is amplified and detected using a spectrum analyzer. RF characterization is ongoing, characterization results and new measurement technique [7] will be presented at the conference.

References

[1] 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.
[2] H. Richter, N. Rothbart *et al.*, "Phase-Locking of Quantum-Cascade Lasers operating around 3.5 THz and 4.7 THz with a Schottky-Diode Harmonic Mixer," *submitted to IEEE Trans. THz Sci. Technol.* , Jan. 2024.
[3] A. Danylov *et al.*, "Phase locking of 2.324 and 2.959 terahertz quantum cascade lasers using a Schottky diode harmonic mixer," *Opt. Lett.*, 2015.
[4] B. T. Bulcha *et al.*, "Design and characterization of 1.8–3.2 THz Schottky-based harmonic mixers," *IEEE Trans. THz Sci. Technol.*, vol. 6, no. 5, pp. 737–746, Sep. 2016.
[5] T. J. Reck *et al.*, "Design of a 2.5 THz Schottky-Diode Fourth-Harmonic Mixer," *IEEE Trans. THz Sci. Technol.*, vol. 13, no. 6, pp. 580–586, 2023.
[6] D. Jayasankar *et al.*, "A 3.5-THz, ×6-Harmonic, Single-Ended Schottky Diode Mixer for Frequency Stabilization of Quantum-Cascade Lasers," *IEEE Trans. on Terahertz Science and Technology*, 2021.
[7] D. Jayasankar, T. Reck *et al.*, "A Broadband Conversion Loss Measurement Technique for Terahertz Harmonic Mixers," *submitted to IEEE Trans. THz Sci. Technol.*, 2024.