Optoelectronic Terahertz Receiver based on the Hybrid Integration of Schottky Diodes and UTC Photodiodes in a Rectangular Waveguide Block

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IMA e.V. MTT-S IEEE MICROWAVE THEORY & TECHNOLOGY SOCIETY EuMA European Microwave Association IEEE

Introduction

Terahertz heterodyne detection

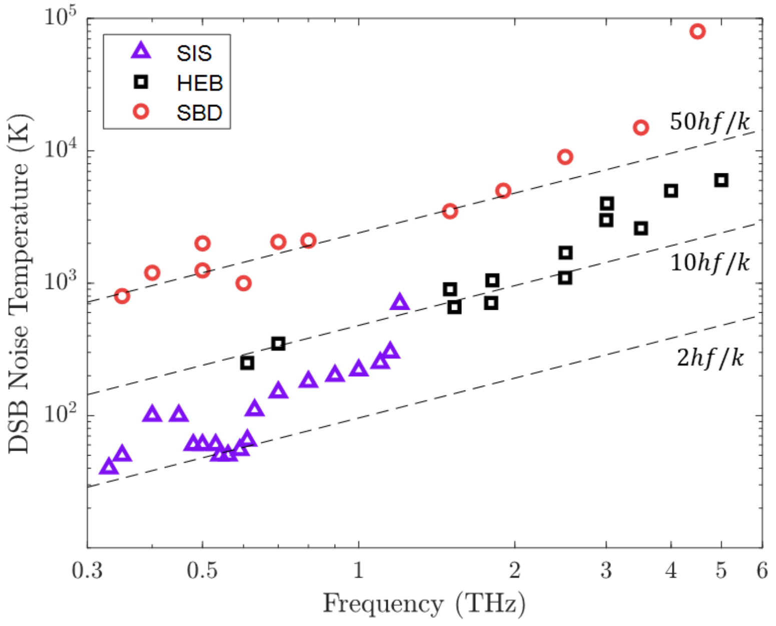
THz heterodyne receivers

Electronic

- Superconductor-Insulator-Superconductor (SIS)
- Hot electron bolometer (HEB)
- GaAs Schottky diode (SBD)

Optoelectronic

- GaAs/InGaAs photoconductor (LT-GaAs/InGaAs PC)
- Uni-travelling-carrier photodiode (UTC-PD)



Noise temperature of SIS, HEB and Schottky receivers

Introduction

Why optoelectronic terahertz receivers

Advantages of optoelectronic receivers:

- LO can be distributed over long fibre links
- Reuse of mature 1.55 um telecom technology
- High-frequency tuneability
- Potentially lower phase noise
- High LO purity

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Wireless THz link with optoelectronic transmitter and receiver

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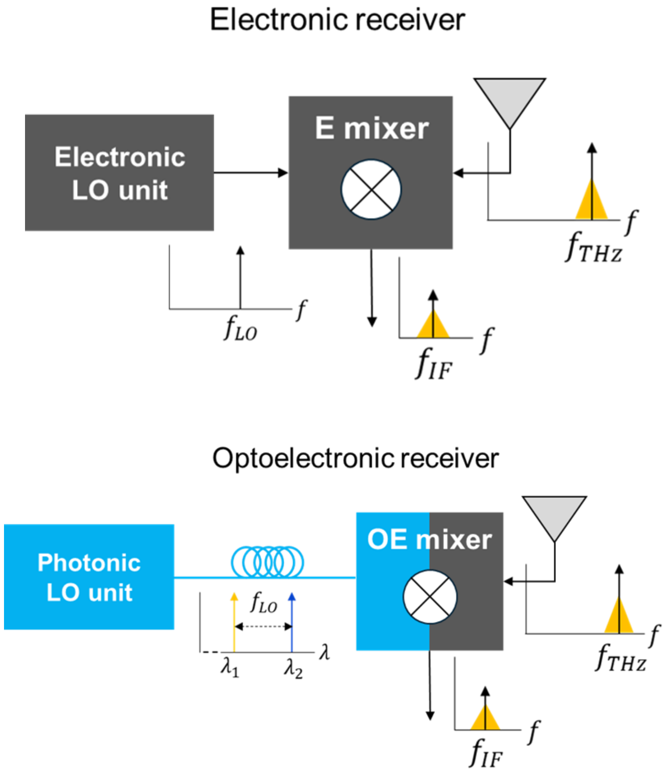


Electronic and optoelectronic mixer schematics

Introduction

Optoelectronic terahertz mixers: conversion loss

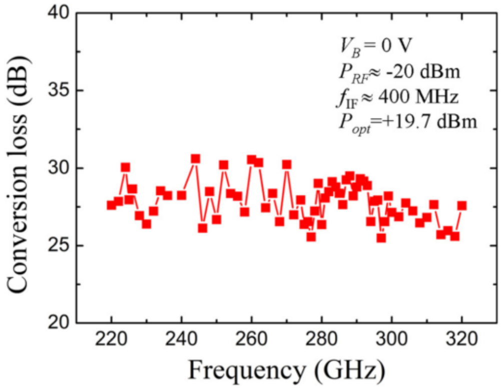


FIG. 6. Conversion loss as a function of the RF frequency in the J-band.

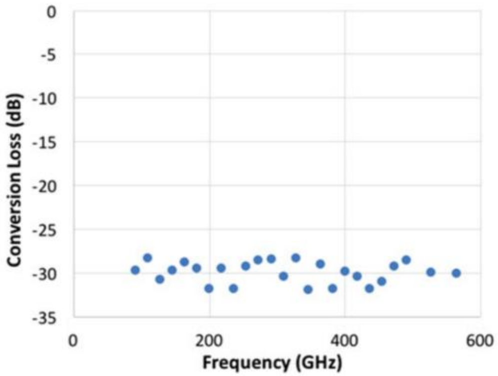


Fig. 17. Conversion loss on the UTC-PD optoelectronically pumped mixer across the detected frequency range.

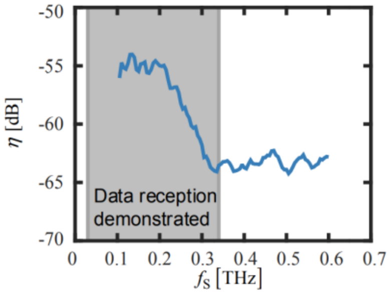
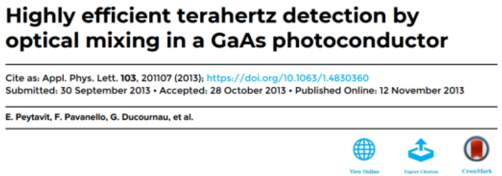


Fig. S2. Conversion efficiency of the photoconductive Rx for an optical power of $P_{LO,0} = \hat{P}_{LO,1} = 30\,\text{mW}$. The gray area marks the frequency range that is used for the data transmission experiments. The conversion efficiency for frequencies larger than 0.34 THz is reduced by 10 dB, but remains constant up to at least 0.6 THz.



Highly efficient terahertz detection by optical mixing in a GaAs photoconductor

Cite as: Appl. Phys. Lett. 103, 201107 (2013); https://doi.org/10.1063/1.4830360
Submitted: 30 September 2013 • Accepted: 28 October 2013 • Published Online: 12 November 2013

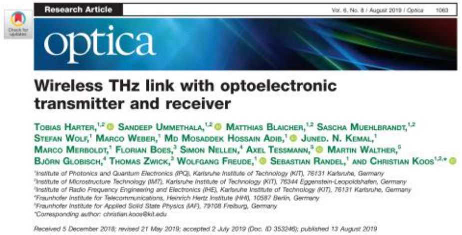
E. Peytavit, F. Pavanello, G. Ducournau, et al.

IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 24, NO. 2, MARCH/APRIL 2018 8500111

Antenna Integrated THz Uni-Traveling Carrier Photodiodes

Cyril C. Renaud, *Senior Member, IEEE*, Michele Natrella, Chris Graham, James Seddon, Frederic Van Dijk, and Alwyn J. Seeds, *Fellow, IEEE*

(Invited Paper)



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Wireless THz link with optoelectronic transmitter and receiver

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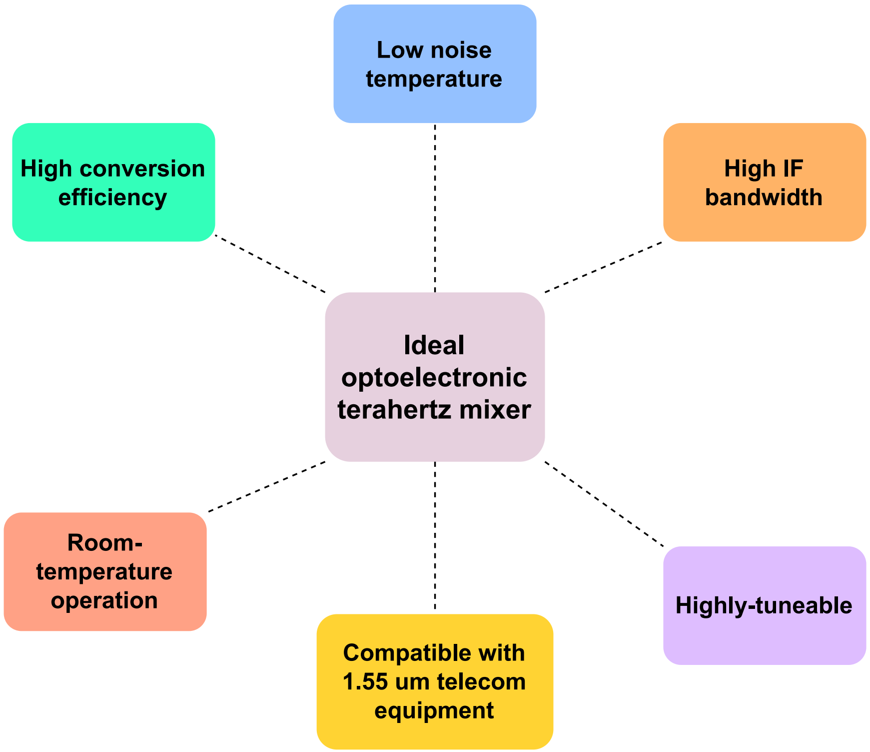
Peytavit, Emilien, et al. "Highly efficient terahertz detection by optical mixing in a GaAs photoconductor." *Applied Physics Letters* 103.20 (2013).
Renaud, Cyril C., et al. "Antenna integrated THz uni-traveling carrier photodiodes." IEEE Journal of Selected Topics in Quantum Electronics 24.2 (2017): 1-11.
Harter, Tobias, et al. "Wireless THz link with optoelectronic transmitter and receiver." Optica 6.8 (2019): 1063-1070.

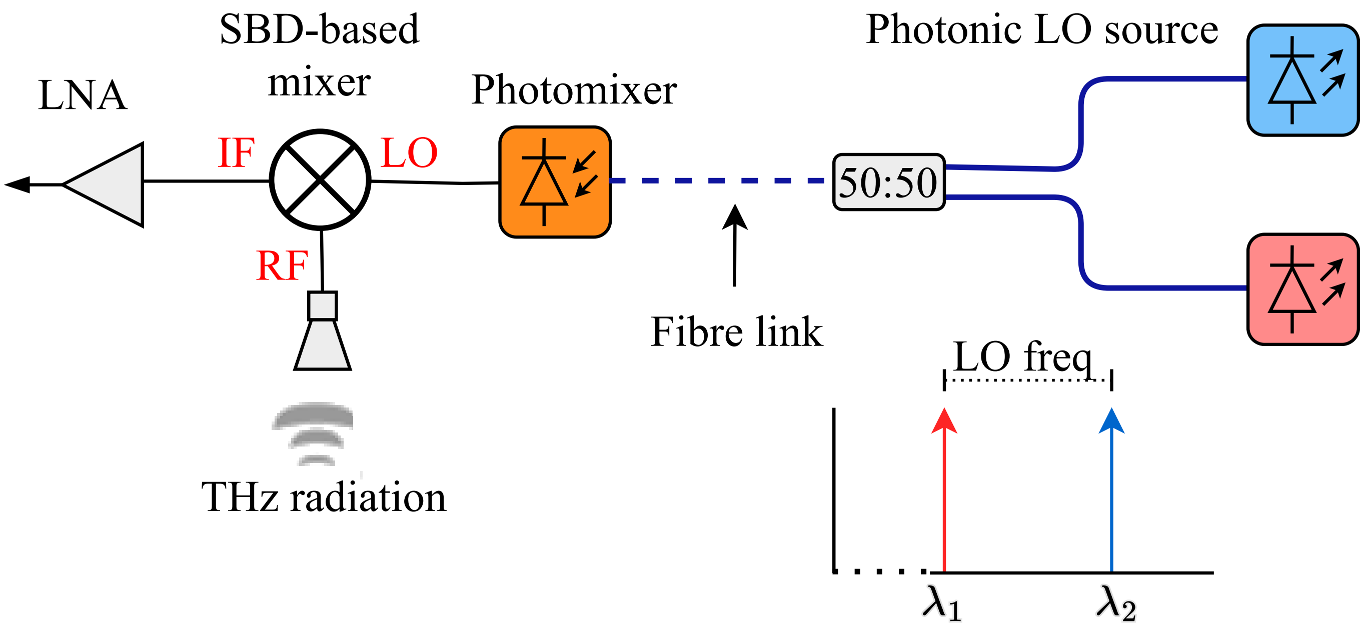
Introduction

The ideal terahertz optoelectronic mixer



Introduction

Proposed concept: photonically-driven SBD mixer



Previous work on optically-pumped SBD mixers

Research Article Vol. 30, No. 24 / 21 Nov 2022 / Optics Express 43223
Optics EXPRESS

Photonically-driven Schottky diode based 0.3 THz heterodyne receiver

IÑIGO BELIO-APAOLAZA,[1,*] JAMES SEDDON,[1] DIEGO MORO-MELGAR,[2] HANU PRIYA INDIRAN,[1] CHRIS GRAHAM,[1] KATARZYNA BALAKIER,[1] OLEG COJOCARI,[2] AND CYRIL C. RENAUD[1]
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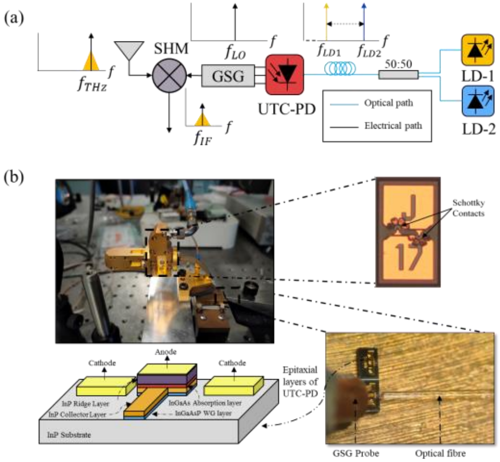
[2]ACST GmbH, Josef-Bautz-Str. 15, 63457 Hanau, Germany
*inigo.apaolaza.21@ucl.ac.uk



High-performance terahertz optoelectronic receivers enabled by monolithic integration of SBDs and UTC-PDs: modelling and design

Iñigo Belio-Apaolaza[1,*], James Seddon[1], José M. Pérez-Escudero[2,3], Iñigo Ederra[2,3], and Cyril C. Renaud[1]
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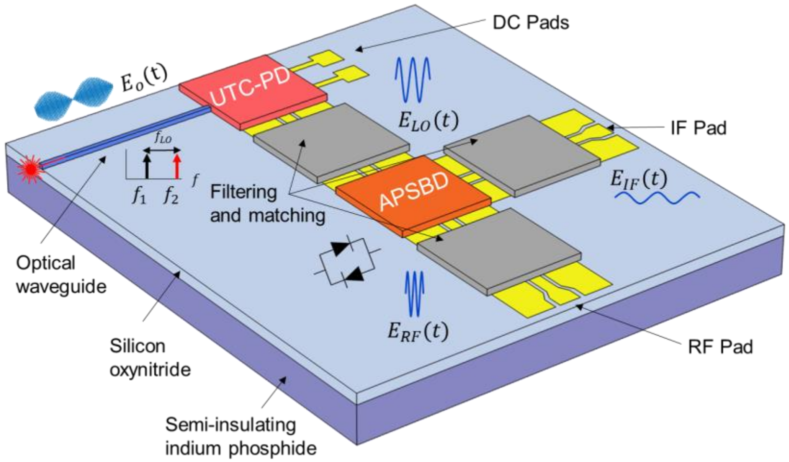
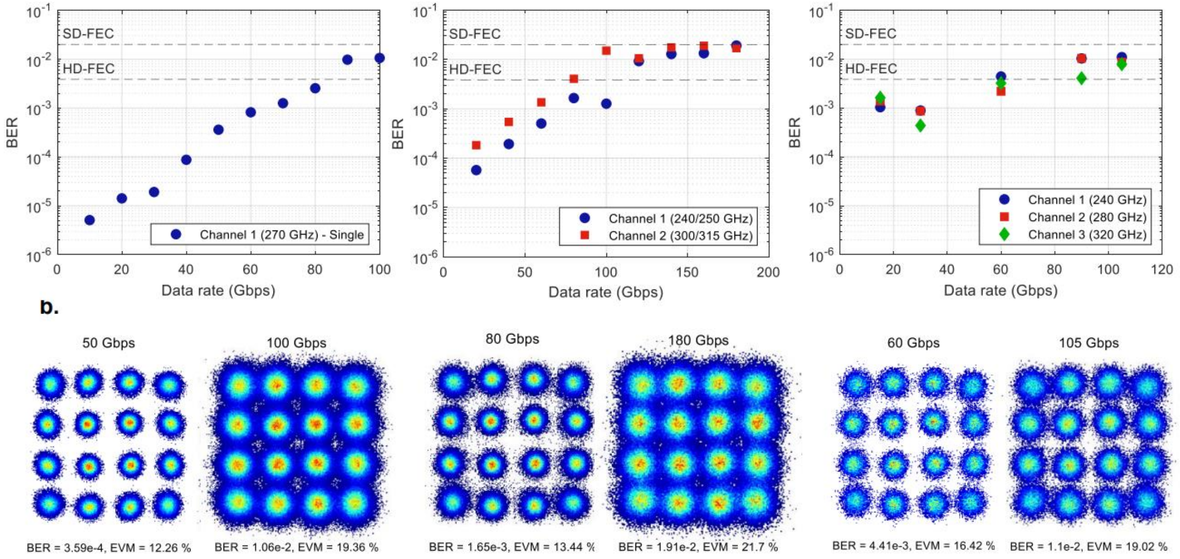


Previous work on optically-pumped SBD mixers

Low-Barrier Mixers and Photonic Local Oscillators Enabling Multi-Channel 300 GHz Communications

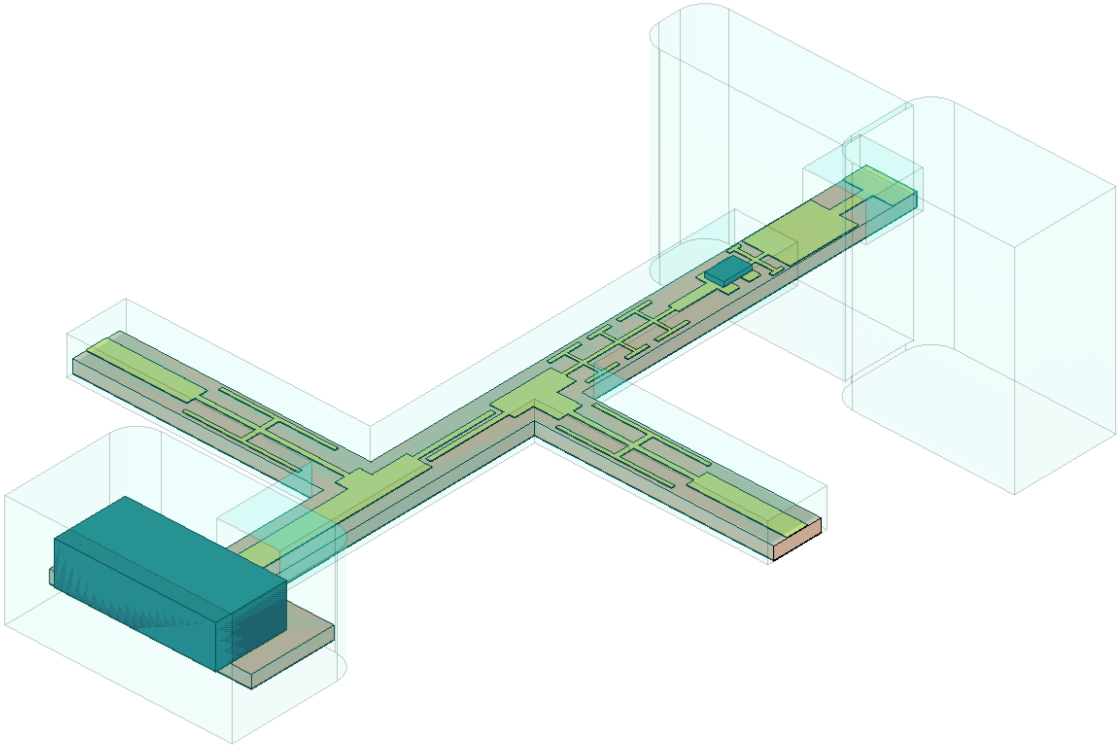
Iñigo Belio-Apaolaza, Javier Martinez-Gil, Jonas Tebart, Jose Luis Fernández Estévez, Marcel Grzeslo, Diego Moro-Melgar, Oleg Cojocari, Andreas Stöhr, *Senior Member, IEEE*, and Cyril C. Renaud, *Senior Member, IEEE*,



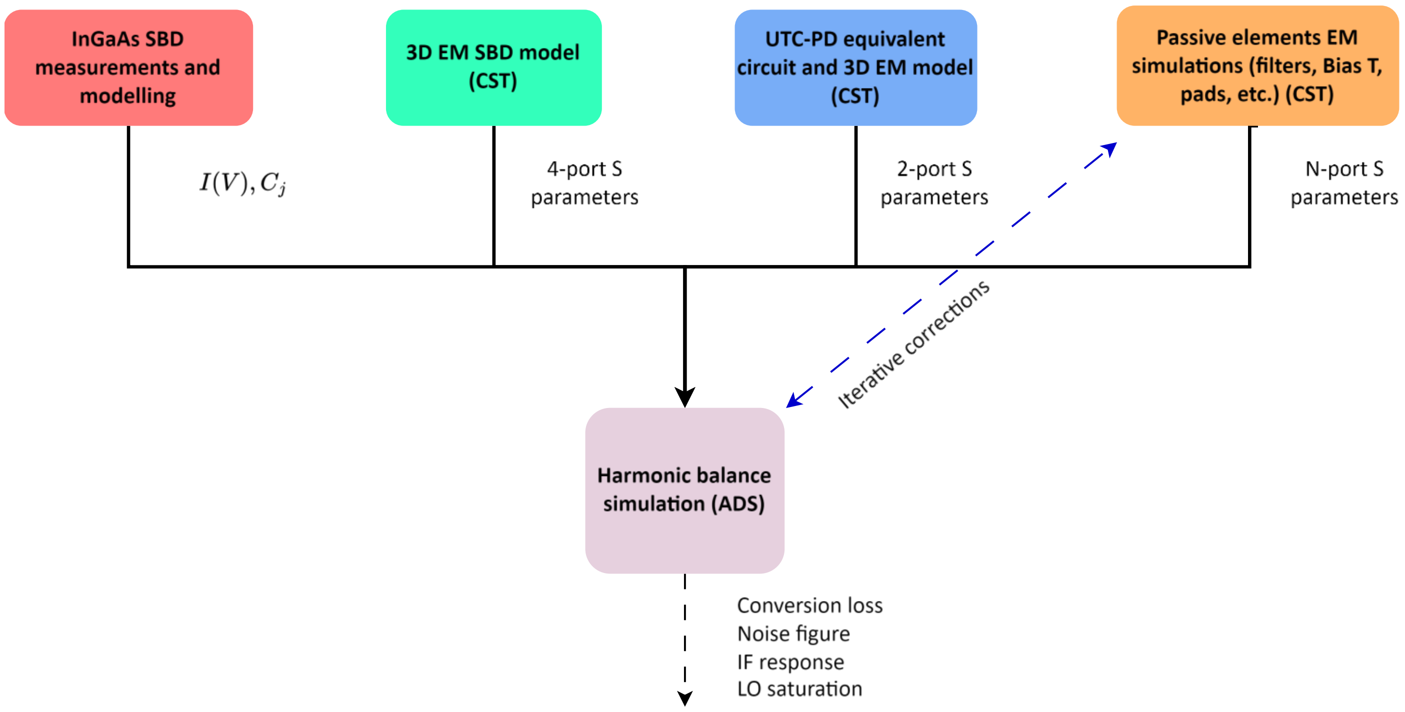
Hybrid SBD and UTC-PD mixer in WR

3D view of hybrid mixer and summary

- 300 GHz subharmonic mixer on rectangular waveguide (WR3)
- Flip-chip bonded Antiparallel InGaAs Schottky diodes
- Flip-chip bonded UTC-PD
- Mixer circuit in 50 um quartz substrate with on-chip Bias T

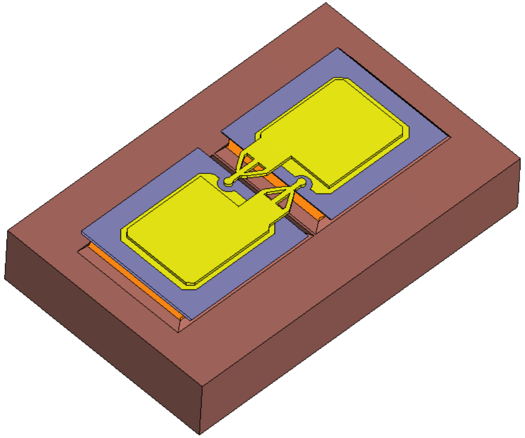


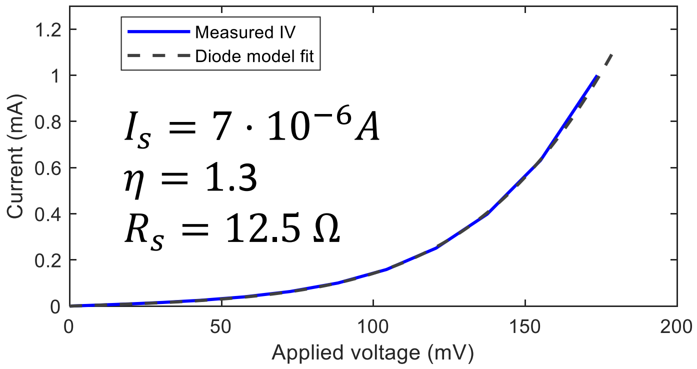
Modelling and design

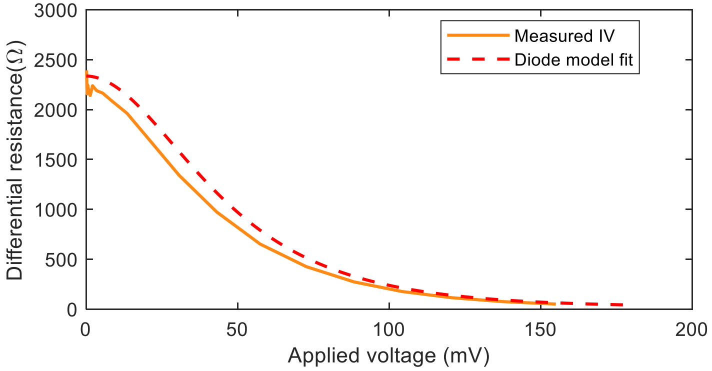


Insights on the InGaAs Schottky diodes

- Low barrier InGaAs Schottky diodes (~0.2 eV)
- Antiparallel configuration
- Junction capacitance of 0.87 fF



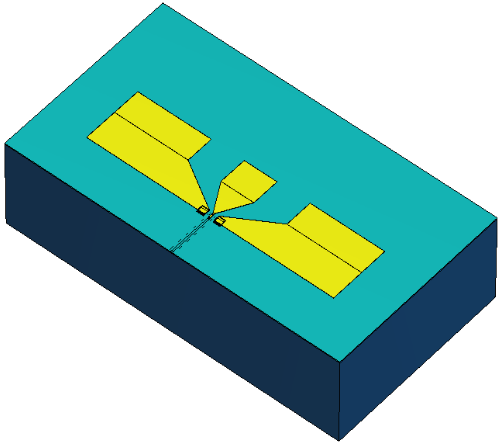


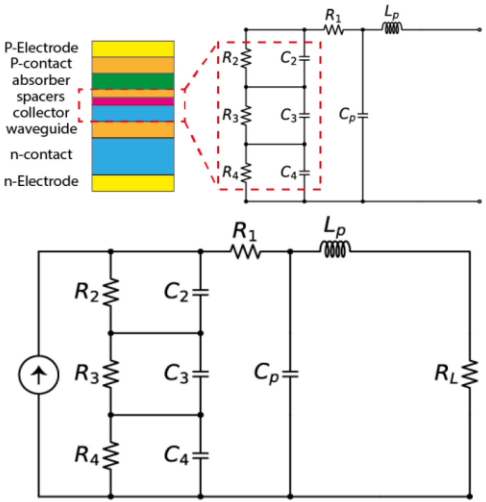


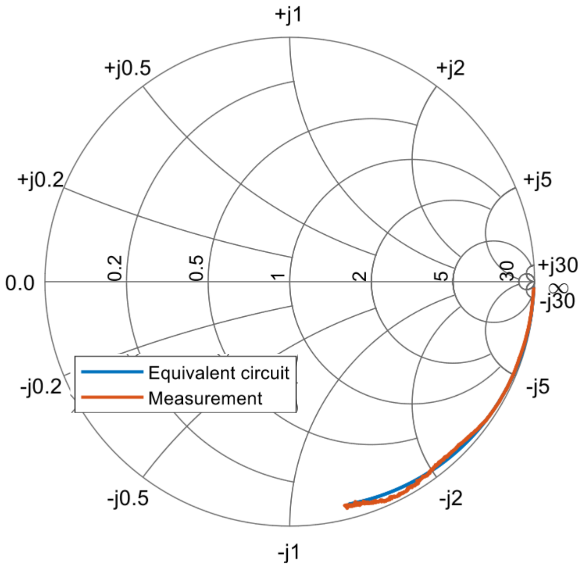
Hybrid SBD and UTC-PD mixer in WR

Insights on the UTC-PD

- Waveguide-coupled UTC-PD design
- Active area of 3x10 μm^2
- Impedance is measured and fitted to equivalent circuit

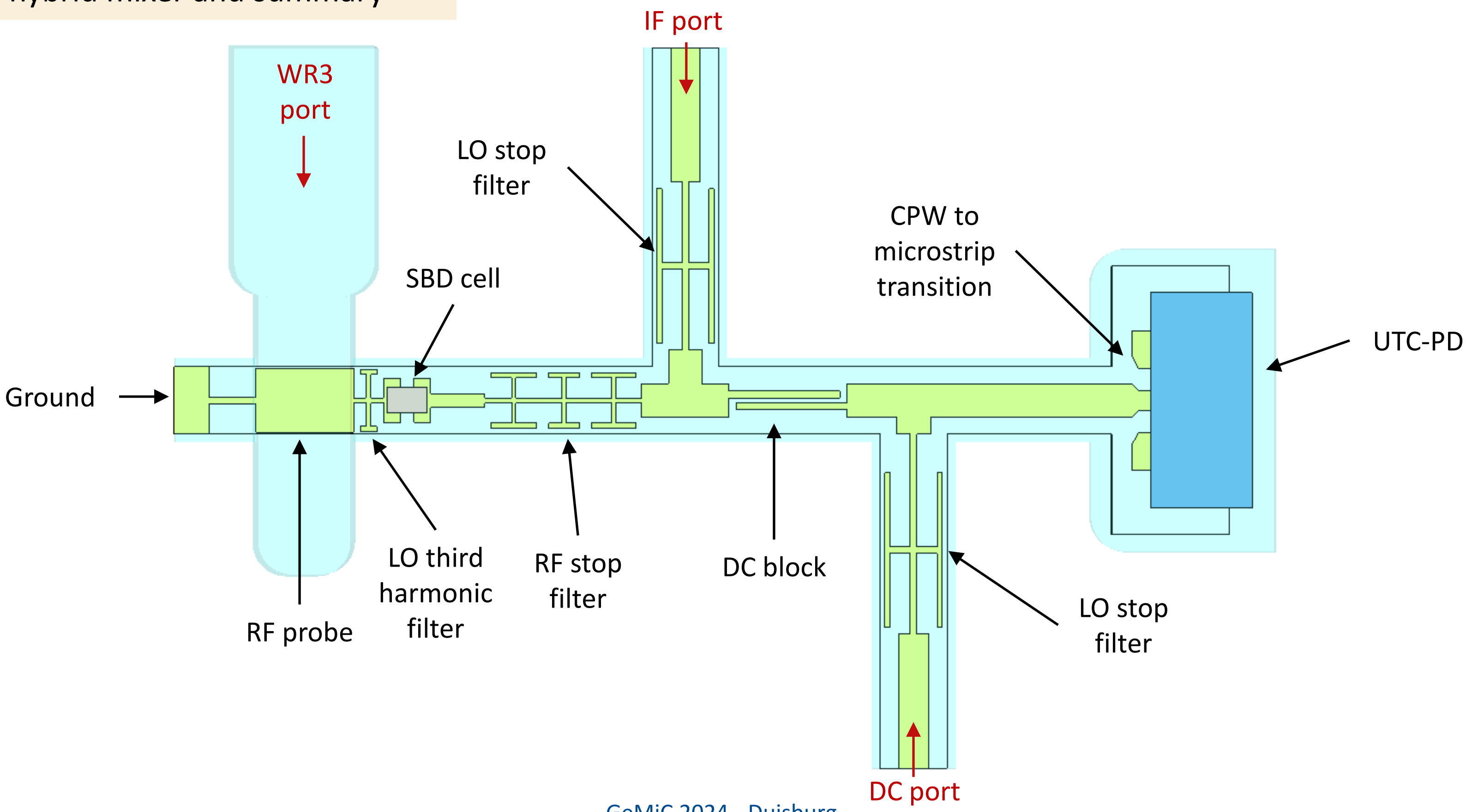






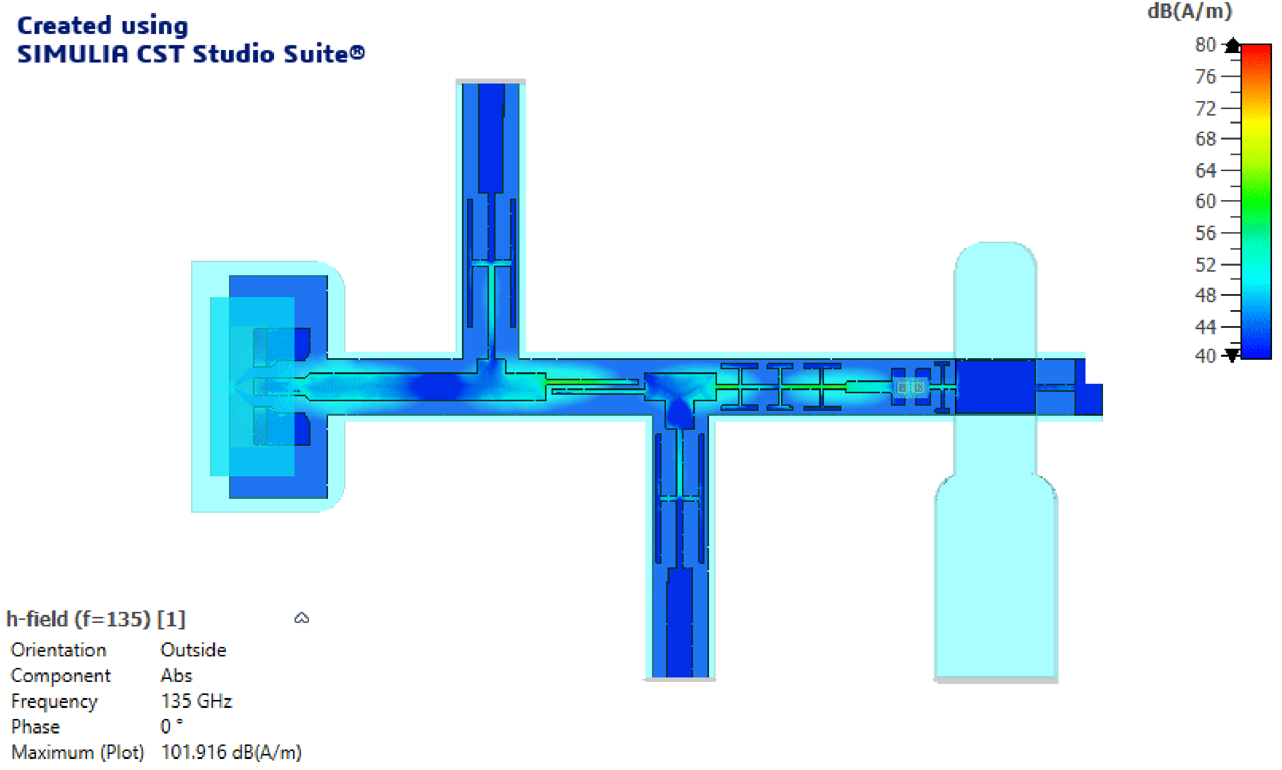
Hybrid SBD and UTC-PD mixer in WR

3D view of hybrid mixer and summary



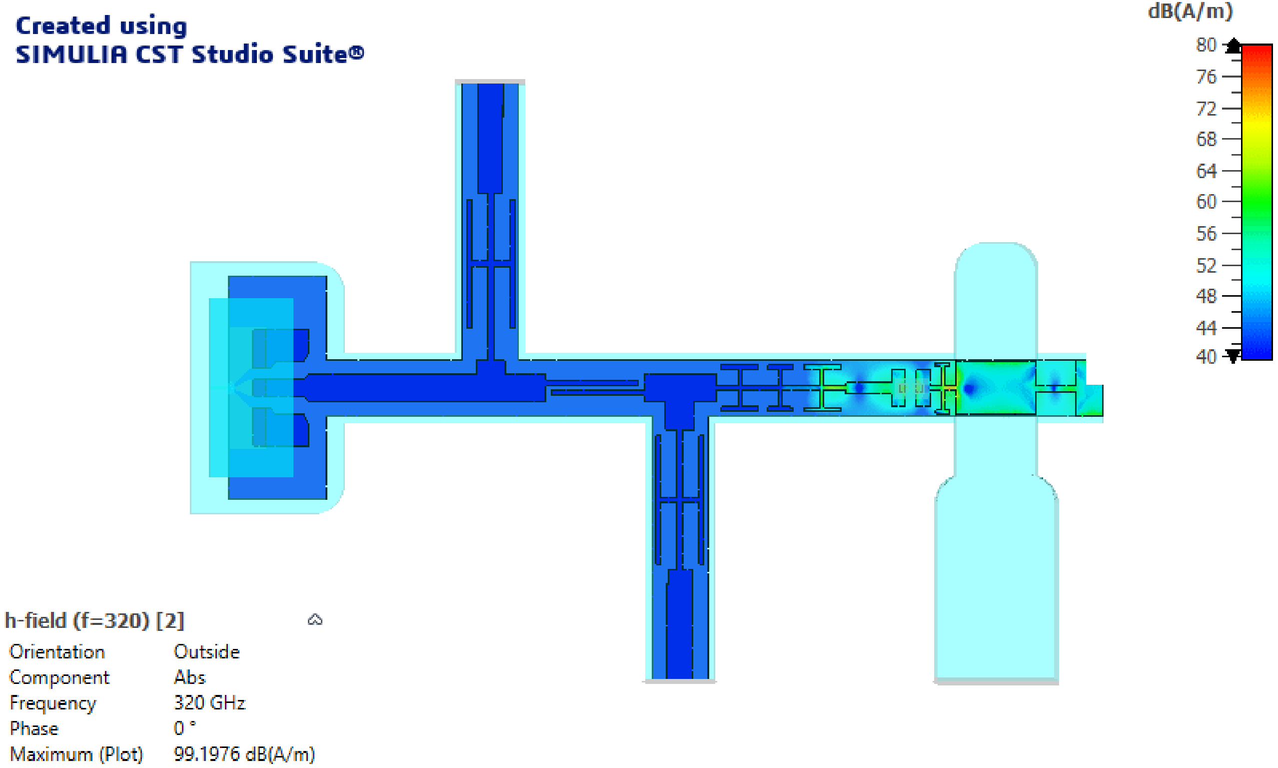
Hybrid SBD and UTC-PD mixer in WR

Simulations: LO path



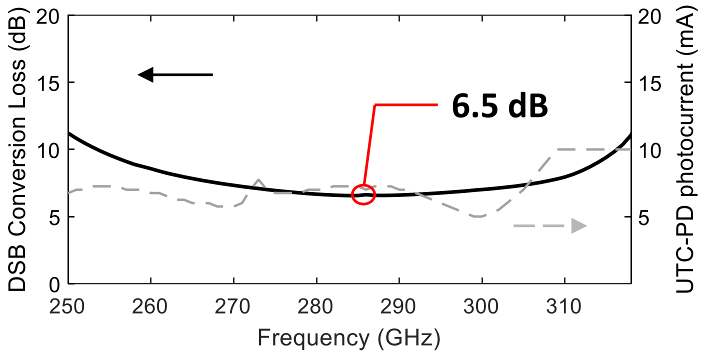
Hybrid SBD and UTC-PD mixer in WR

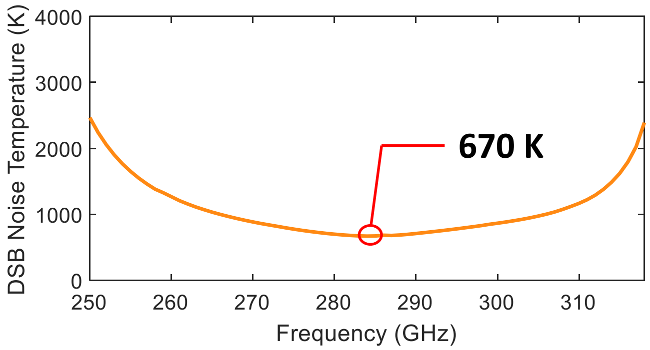
Simulations: RF path

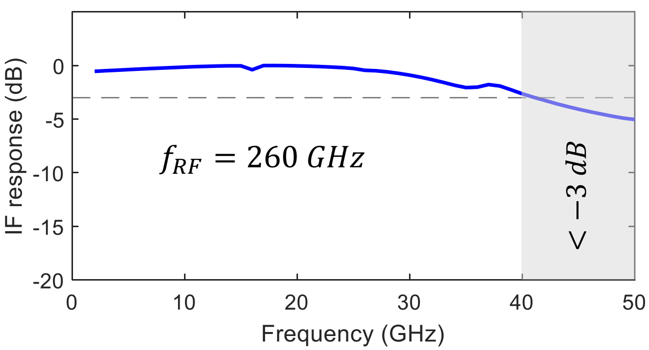


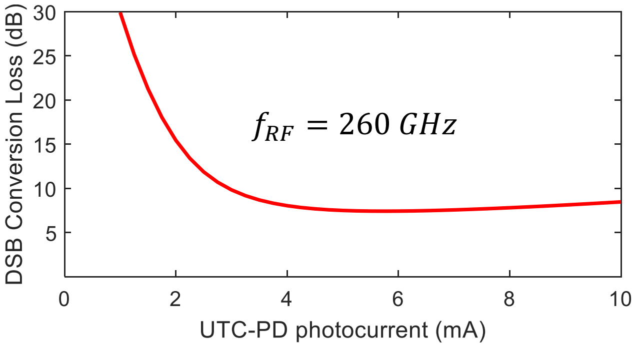
Hybrid SBD and UTC-PD mixer in WR

Simulated mixer performance









Hybrid SBD and UTC-PD mixer in WR

Final remarks

- **Hybrid receivers integrating SBDs and UTC-PDs as high-performance optoelectronic receivers.**
- **Designed 220-330 GHz rectangular waveguide mixer achieves state-of-the-art performance.**
- **Fabrication and characterization is pending.**
- **Alternative packaging solutions (quasi-optical) to be investigated.**