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JOHANNES KEPLER
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Castle of Mauterndorf,
A-5570 Mauterndorf,
Province of Salzburg, Austria
winterschool@jku.at

RF QWIPs for Characterization of mid-IR Frequency Combs

J. Hillbrand[1]*, S. Dal Cin[1], B. Schwarz[1], M. Beiser[1], A. M. Andrews[1], G. Strasser[1]

[1]*Institute for Solid State Electronics, Technische Universität Wien, Floragasse 7, 1040 Wien, Austria*

Optical frequency combs are sources of coherent light whose spectrum is comprised of numerous equidistant lines. Originally developed in the near-infrared spectral region, frequency combs have pushed high-precision spectroscopy to unprecedented limits.

Nowadays, large efforts are being made in order to bring frequency comb technology in the mid-infrared spectral region to a similar degree of maturity. A widely used method for generating mid-IR frequency combs relies on compact semiconductor lasers like the quantum cascade laser (QCL). A QCL Fabry-Pérot cavity is usually between 2 and 6 mm long resulting in a repetition frequency around 10 GHz. As a consequence, detectors with a bandwidth larger than 10 GHz are required in order to investigate locking mechanisms and noise properties of the comb.

Bandwidths exceeding 10 GHz can routinely be achieved using detectors based on intersubband transitions. In 2006, it was shown that photovoltaic quantum cascade detectors (QCD) show a relatively flat frequency response up to 4 GHz [1]. The bandwidth of the QCD was mainly limited by the cutoff properties of the circuit used to contact the detector. By defining a radio-frequency (RF) waveguide around a quantum well infrared photodetector (QWIP), it was demonstrated that this kind of detector is able to cover up to 30 GHz of bandwidth [2].

We present a scheme to connect the QWIP to a commercial RF end-launch connector using a coplanar waveguide (CPW) structure. We use a computational model determine the gap width of the CPW as a function of the center conductor width while maintaining a characteristic impedance of 50 Ohms to avoid reflections at the connector. The computational model takes the finite width of the CPW as well as the finite height of the semi-insulating InP substrate into account revealing a clearly non-linear relation between the center conductor and the gap width. Using this simulation, we are able to create a geometry that adiabatically increases the width of the CPW from the 50 µm small QWIP mesa to the almost 1 mm large connector while maintaining a characteristic impedance of 50 Ohm. The model predicts a flat frequency response up to frequencies larger than 30 GHz.

In order to the frequency response of a QWIP experimentally, we mount it in the close vicinity of the end of a commercial waveguide PCB. The connection between the center conductor and the top contact of the 200 x 200 µm QWIP is made using a wirebond whose length is kept as short as possible to reduce its parasitic inductance. The frequency response of the QWIP can then be examined by injecting an amplitude modulated RF signal into the end-launch jack connected to the waveguide PCB and sweeping the carrier frequency. The AM signal creates a rectified signal at the AM frequency due to the non-linear IV-curve of the QWIP only if the carrier frequency is below the cutoff frequency. By measuring the rectified voltage with a lock-in amplifier, we observe a cutoff frequency of almost 10 GHz.

[1] Hofstetter, D., Graf, M., Aellen, T., Faist, J., Hvozdara, L., & Blaser, S. (2006). 23 GHz operation of a room temperature photovoltaic quantum cascade detector at 5.35 µ m. *Applied physics letters*, *89*(6), 061119.

[2] Liu, H. C., Li, J., Buchanan, M., & Wasilewski, Z. R. (1996). High-frequency quantum-well infrared photodetectors measured by microwave-rectification technique. *IEEE journal of quantum electronics*, *32*(6), 1024-1028

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* Corresponding author: Johannes Hillbrand email: Johannes.hillbrand@tuwien.ac.at

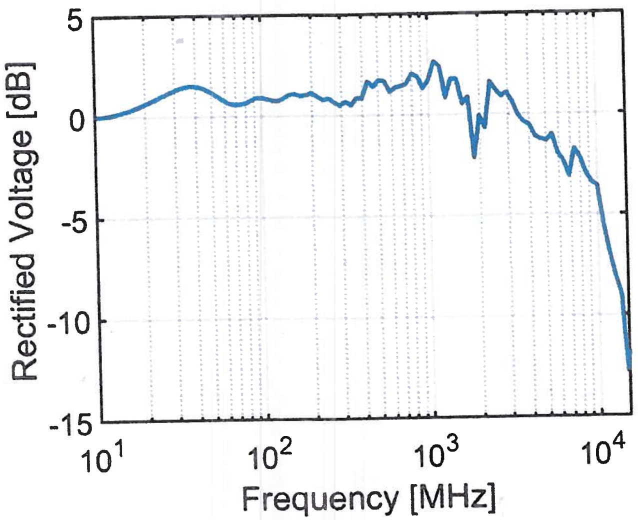

Fig. 1: Rectified Voltage as a function of the carrier frequency.