ITQW 2019

Infrared Terahertz Quantum Workshop

September 15-20, 2019

Ojai, California, USA

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Program and Abstract Catalog

15:45 **Nishant Nookala**, Sander Mann, Stephen March, Seth Bank, John Klem, Igal Brener, Andrea Alù and Mikhail Belkin
Optical power limiting from intersubband polaritonic metasurfaces

16:00-16:20 Coffee Break (Exhibition is open)

16:20-17:35 Session 17: New Intersubband Materials
Chair: Gottfried Strasser

16:20 Arnaud Jollivet, Maria Tchernycheva, Enrico Di Russo, Lorenzo Rigutti, Miguel Montes Bajo, Julen Tamayo Arrola, Adrian Hierro, Borg Vinter, Nolwenn Le Biavan, Maxime Hugues, Jean-Michel Chauveau and **Francois Julien**
Room temperature excitonic transitions induced by intersubband absorption in m-plane ZnO/ZnMgO quantum wells.

16:35 **Thomas Grange**, David Stark, Giacomo Scalari, Jérôme Faist, Luca Persichetti, Monica De Seta, Luciana Di Gaspare, Giovanni Capellini, Douglas Paul, Michele Ortolani, Stefan Birner and Michele Virgilio
Comparing III-V and group-IV terahertz quantum cascade lasers using non-equilibrium Green's functions

16:50 **Trang Nguyen**, Alexander Senichev, Brandon Dzuba, Yang Cao, Michael Manfra and Oana Malis
Non-polar strain-balanced AlGaN/InGaN superlattices for infrared optoelectronic devices

17:05 **Monica De Seta**, Michele Montanari, Chiara Ciano, Luca Persichetti, Luciana Di Gaspare, Michele Virgilio, Giovanni Capellini, Marvin Zoellner, Oliver Skibitzki, David Stark, Giacomo Scalari, Jerome Faist, Douglas J. Paul, Thomas Grange, Stefan Birner, Oussama Moutanabbir, Samik Mukherjee, Leonetta Baldassarre and Michele Ortolani
High-quality n-type Ge/SiGe multilayers for room temperature THz emission

17:20 **David Stark**, Luca Persichetti, Michele Montanari, Chiara Ciano, Luciana Di Gaspare, Monica De Seta, Marvin Zoellner, Oliver Skibitzki, Giovanni Capellini, Michele Ortolani, Leonetta Baldassarre, Michele Virgilio, Thomas Grange, Stefan Birner, Kirsty Rew, Douglas Paul, Jérôme Faist and Giacomo Scalari
Si-based n-type Quantum Cascade Structures for THz Emission

19:00-22:00 Banquet

Banquet will be held at the Ojai Valley Inn and Spa in the Hacienda Ballroom.

Award for Best Student Poster will be presented by the conference chairs along with DRS Daylight Solutions.

Friday, September 20th

09:00-10:30 Session 18: Detection
Chair: Daniel Wasserman

09:00 **David Ting**
*Type-II superlattice unipolar barrier infrared detectors **(Invited)***

09:30 **Azzurra Bigioli**, Djamal Gacemi, Daniele Palaferri, Yanko Todorov, Angela Vasanelli and Carlo Sirtori
Mixing properties of room temperature patch-antenna receivers in a mid-infrared (9 um) heterodyne system

09:45 **Changyun Yoo**, Mengchen Huang, Jonathan Kawamura, Ken West, Boris Karasik, Loren Pfeiffer and Mark Sherwin
Tunable Antenna-Coupled Intersubband Terahertz (TACIT) Mixers

10:00 **Borislav Hinkov**, Arnaud Jollivet, Hanh T. Hoang, Stefano Pirotta, Maria Tchernycheva, Raffaele Colombelli, Maxime Hugues, Nolwenn Le Biavan, Miguel Montes Bajo, Adrian Hierro, Jean-Michel Chauveau, Gottfried Strasser and Francois H. Julien
Quantum cascade detectors based on non-polar ZnO/ZnMgO quantum wells

10:15 Johannes Hillbrand, Sandro Dal Cin, Aaron Maxwell Andrews, Hermann Detz, Erich Gornik, Benedikt Schwarz and **Gottfried Strasser**
High bandwidth quantum cascade detectors

10:30-10:50 Coffee Break

Award for Best Student Presentation will be presented by the conference chairs along with DRS Daylight Solutions.

10:50-12:20 Session 19: New Physics
Chair: Mark Sherwin

10:50 **Ileana-Cristina Benea-Chelmus**, Francesca Fabiana Settembrini, Giacomo Scalari and Jerome Faist
*Electric field correlation measurements on the electromagnetic vacuum state **(Invited)***

High bandwidth quantum cascade detectors

Johannes Hillbrand[1], Sandro Dal Cin[1], Aaron Maxwell Andrews[2], Hermann Detz[2], Erich Gornik[1], Benedikt Schwarz[1], Gottfried Strasser[1,2,*]

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Short Abstract There is an increasing demand for mid-infrared detectors that allow both sensitive and high-speed detection at room temperature. Quantum cascade detectors (QCD) are a promising candidate due to their fast carrier dynamics and because they operate at zero bias. We report on high-speed QCDs connected to a coplanar microwave transmission line, which allows a 3 dB bandwidth larger than 10 GHz. A single period QCD exhibits a particularly high responsivity of more than 0.8 A/W at room temperature. It is used to investigate an interband cascade laser frequency comb.

1. Introduction

The recent years have seen a rapidly increasing interest in high-speed mid-infrared (MIR) photonics. In particular, the fields of MIR frequency combs and optical heterodyning have attracted considerable attention. Possible applications range from spectroscopy in the molecular fingerprint region to highly accurate frequency metrology and free-space telecommunication. Most techniques rely on mapping optical frequencies to the radio frequency (RF) domain by beating them on a fast detector. As a consequence, there is an increasing demand for MIR photodetectors with bandwidths large enough to detect optical beatings in the Gigahertz range.

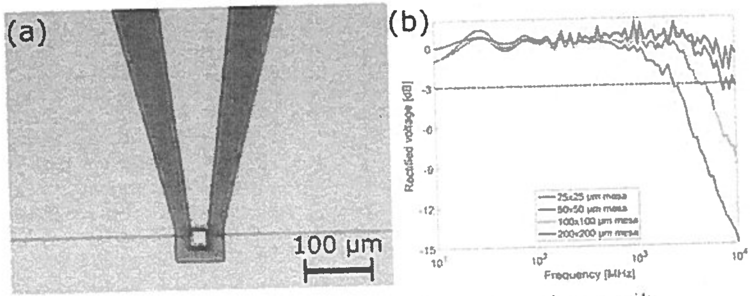

Figure 1: (a) microscope image of a 25x25 µm detector mesa connected to a coplanar waveguide. (b) frequency response of the QCD for different mesa sizes.

Quantum cascade detectors are photovoltaic intersubband detectors whose spectral response can be tailored from the mid-infrared to the Terahertz region. Due to phonon scattering and fast intersubband tunneling, their intrinsic bandwidth can be extremely high and is mostly limited by parasitic capacitance and inductance.

We report on high-speed quantum cascade detectors operating at 4.3 µm. The detector mesas are connected to a microwave coplanar transmission line (CPW) whose impedance was matched to 50 Ohms using Comsol (Fig. 1a). Transmission measurements trough the CPW reveal the influence of the different electromagnetic modes in the CPW on its frequency response. The frequency response of the correctly designed CPW remains flat within ±1 dB up to 20 GHz. Using microwave rectification, we investigate the bandwidth of the QCDs depending on the mesa size (Fig 1b). For mesa sizes smaller than 50x50 µm², the parasitic capacitance becomes small enough to enable a 3 dB bandwidth larger than 10 GHz.

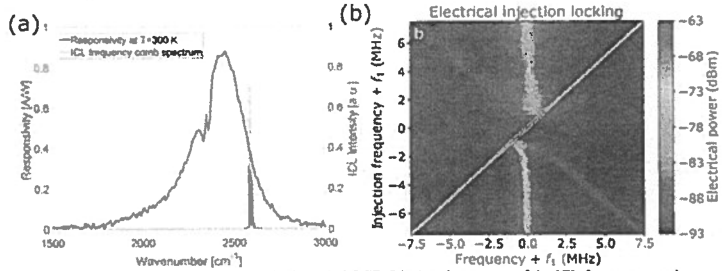

Figure 2: (a) responsivity spectrum of the single period QCD (blue) and spectrum of the ICL frequency comb (red). (b) RF beating spectrum of the ICL frequency comb observed using the single period QCD at room temperature. When the frequency of an injected signal is swept across the cavity roundtrip frequency f_1 = 11 *GHz* of the ICL, electrical injection locking can be observed.

The responsivity of QCDs scales inversely proportional to the number of periods. However, a thin active region results in lower absorption while increasing the parasitic capacitance. In order to overcome this issue, we fabricate a single stage QCD [1] as 6 µm wide and 150 µm long ridge waveguide, which is wire-bonded to a 50 Ohm transmission line. The devices show a particularly high responsivity of more than 0.8 A/W at room temperature (Fig. 1a). Both microwave rectification and an interband cascade laser (ICL) frequency comb [2] emitting around 3.8 µm are used to characterize the high-speed detection capabilities of the single period QCD. The small area of the narrow ridge allows a 3 dB bandwidth of several GHz. By shining the ICL on the QCD, it is possible to extract the beatnote of the ICL comb lines at the cavity roundtrip frequency from the detector current (Fig. 2b).

References

[1] Schwarz et al. "The limit of quantum cascade detectors: A single period device." *Applied Physics Letters* 111.6 (2017): 061107.

[2] Schwarz et al. "A monolithic frequency comb platform based on interband cascade lasers and detectors." *arXiv preprint arXiv:1812.03879* (2018).