NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

ITQW 2017

10 – 15 Sep, Singapore

14th International Conference on Intersubband Transitions in Quantum Wells

Sands Expo and
Convention Center
Singapore

CONFERENCE PROGRAM

15:30 – 16:00 Tea break

Session 12 Interband Cascade Lasers-Chair: Dan Botez

16:00 – 16:30 **Igor Vurgaftman (Naval Research Laboratory) - Invited talk**
Interband cascade lasers in the mid-IR

16:30 – 16:45 Alireza Mottaghizadeh (University Paris Diderot- Paris 7)
Ultra-fast modulation of mid infrared buried heterostructure quantum cascade lasers

16:45 – 17:00 Sukhdeep Dhillon (Laboratoire Pierre Aigrain)
Multi-THz Sideband Generation on an optical telecom carrier at room temperature using InP-based Quantum Cascade Lasers

17:00 – 17:15 Martin Holzbauer (Technische Universität Wien)
Ring Cavity interband cascade lasers

17:15 End of day four

Friday 15 September 2017

Session 13 Intersubband Devices and applications-Chair: Benjamin Williams

09:00 – 09:30 **Claire F. Gmachl /Yasin Kaya (Princeton University) - Invited talk**
II-VI and II-VI/III-V hybrid intersubband devices

09:30 – 09:45 Martin Wienold (German Aerospace Center)
Doppler-free spectroscopy with a terahertz quantum-cascade laser

09:45 – 10:00 Rolf Szedlak (Technische Universität Wien)
Commutable Monolithic QC Laser/Detector System for Remote Sensing

10:00 – 10:15 Bernhard Lendl (Technische Universität Wien)
New sensing approaches employing QCLs

10:15 – 10:45 Tea break

Session 14 Metasurfaces-Chair: Yasin Kaya

10:45 – 11:30 **Federico Capasso (Harvard University) - Plenary talk**
Metasurface

11:30 – 12:00 **Benjamin Williams (University of California Los Angeles) - Invited talk**
THz metasurface

12:00 – 12:15 Matias Katz (Technion-Israel Institute of Technology)
Vacuum-field Rabi Splitting at SWIR in Photocurrent of Quantum Cascade Infrared Photodetectors Coupled to Metamaterial Nano-antennas

12:15 – 12:30 Lorenzo Bosco (ETH Zurich)
High power surface emitting single mode Terahertz Quantum Cascade Laser

12:30 – 12:45 Moritz Wenclawiak (Technische Universität Wien)
Controlling the radiative response of plasmonic resonators in the terahertz regime

12:45 – 14:00 Lunch

14:00 – 17:00 NTU-visit

Poster Sessions

Monday 11 to Tuesday 12 September 2017 (10 am – 5 pm)

Poster Session 1

P1 **Xiaoyong He** (Shanghai Normal University)
Investigation of tunable manipulation terahertz waves based on graphene patterns

P2 **Hiroaki Yasuda** (National Institute of Information and Communications Technology)
Calculation of performance of InGaSb-based terahertz quantum cascade lasers

P3 **Wenjian Wan** (Shanghai Insititute of Microsystem and Information Technology)
Homogeneous spectral broadening of pulsed terahertz quantum cascade lasers with radio frequency modulation

P4 **Wenqi Wei** (IOP CAS)
C/L-band emission of InAs QDs monolithically grown on a CMOS compatible Ge platform

P5 **Sebastian Schoenhuber** (Technische Universität Wien)
Frequency resolved far fields of terahertz quantum cascade lasers

P6 **Jianbin Kang** (Microsystem & Terahertz Research Center)
Strain dependent intersubband transition in GaN/AlGaN single quantum well on different crystal planes

P7 **Sumit Saha** (IIT (ISM), Dhanbad)
Optical analysis of non-polar, m-plane GaN/AlGaN quantum cascade structures

P8 **Y. Zhang** (University of Tokyo)
Intersubelvel transitions in zero-dimensional nanomaterials probed by terahertz photocurrent spectroscopy

P9 **Xiaoqiong Qi** (The University of Queensland)
Dynamic modelling of coupled-cavity Terahertz Quantum Cascade lasers with optical feedback

P10 **She Han** (The University of Queensland)
Analysis of Granular Materials using a THz QCL operating as a Laser Feedback Interferometer

P11 **Yuanyuan Li** (Institute of Semiconductors, CAS)
High-power single-mode terahertz quantum cascade lasers

P12 **Holger T. Grahn** (Paul-Drude-Institut fuer Festkoerperelektronik)
Two-section, single-frequency terahertz quantum-cascade lasers with continuous frequency tuning by external illumination

P13 **Ke Wang** (Quantum Device Group, RIKEN at Sendai)
Waveguide design for GaN/AlGaN terahertz quantum cascade lasers

P14 **Moritz Wenclawiak** (Technische Universität Wien)
Efficient frequency conversion in THz metal-insulator-metal disk resonators loaded with semiconductor quantum wells

P15 **Roland Teissier** (University of Montpellier)
A comparative study of a three-well active region in double metal and single plasmon THz QCLs

P16 **Yue Zhao** (Institute of Semiconductors, CAS)

Commutable Monolithic QC Laser/Detector System for Remote Sensing

R. Szedlak[1,*], A. Harrer[1], B. Schwarz[1], M. Holzbauer[1], J. P. Waclawek[2], E. Tütüncü[3], V. Kokoric[3], J. Hayden[2], D. MacFarland[1], T. Zederbauer[1], H. Detz[4], A. M. Andrews[1], W. Schrenk[1], B. Mizaikoff[3], B. Lendl[2], and G. Strasser[1]

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Efficient light sources in the mid-infrared spectral region are desirable for numerous industrial, environmental and biochemical applications. Quantum cascade lasers (QCLs) enable tailorable emission characteristics over a broad wavelength range and at the same time provide high-performance operation. In contrast to conventional Fabry-Pérot devices, surface emitting QCLs offer the possibility of on-chip testing and 2D array integration. Furthermore, the typically large aperture produces collimated beam profiles. The versatility of these lasers allows effective implementation in different sensing setups exploiting various spectroscopic techniques.

We demonstrate the versatile applicability of ring QCLs in spectroscopic sensing systems. Such lasers consist of a circular waveguide with a second order distributed feedback (DFB) grating on top. Utilization of bi-functional quantum cascade heterostructures[1] facilitates the fabrication of wavelength-matched lasers and detectors monolithically integrated on a single chip. In combination with surface emitting and detecting cavity designs, this approach enables efficient remote sensing. We developed an innovative sensor concept consisting of two concentric bi-functional quantum cascade ring structures[2]. Both rings are capable of light emission and detection which makes mutual commutation possible and renders the distinction between laser and detector needless. In the first operation mode the inner ring acts as the detector and the outer ring is the laser. In the second operation mode the situation is reversed. The DFB grating allows to equip both rings with different emission wavelengths which increases the versatility of the device. Proof-of-principle gas sensing experiments were performed with isobutene and isobutane. The corresponding remote sensing setup is shown in Fig. 1(a).

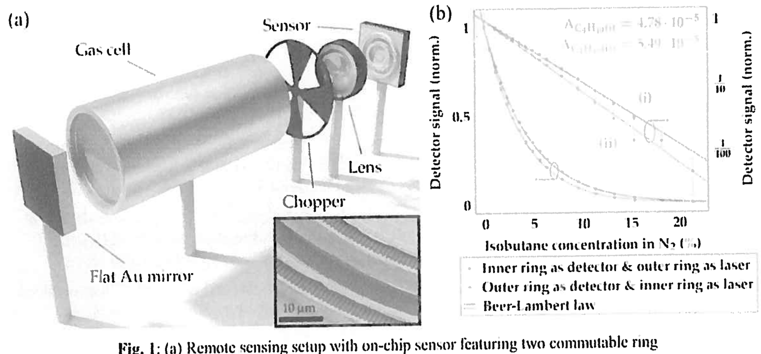

Fig. 1: (a) Remote sensing setup with on-chip sensor featuring two commutable ring QCLDs. Inset: SEM image of a segment of both rings. (b) Results of the proof-of-principle gas sensing experiment. Transmittance versus gas concentration. Source: [2]

Light is emitted from one of the rings on the sensor chip and collimated by the lens. After passing the chopper and propagating through the gas cell, the light is back-reflected by a flat gold mirror and travels along its initial path back to the sensor chip where it is detected by the other ring. The measured transmittance as a function of the gas concentration for the isobutane study is depicted in Fig. 1(b). Our data show a good agreement with the Beer-Lambert law and the experimentally determined absorbance coefficients comply with literature values. Without the utilization of temperature stabilization we reached a limit of detection of 400ppm with a 10cm long gas cell. Implementation of this concept with substrate integrated hollow waveguides (iHWGs)[3] could enable a crucial miniaturization of sensing devices. These compact gas cells require only small gas volumes and impress with high volumetric optical efficiencies. In combination with mature spectroscopic techniques, such as tunable laser spectroscopy[4], the presented on-chip sensor system could experience significant performance enhancement and pave the way for compact hand-held remote sensors. Preliminary experiments demonstrated the compatibility of ring QCLs with iHWGs as shown in Fig. 2(a).

(a) (b)

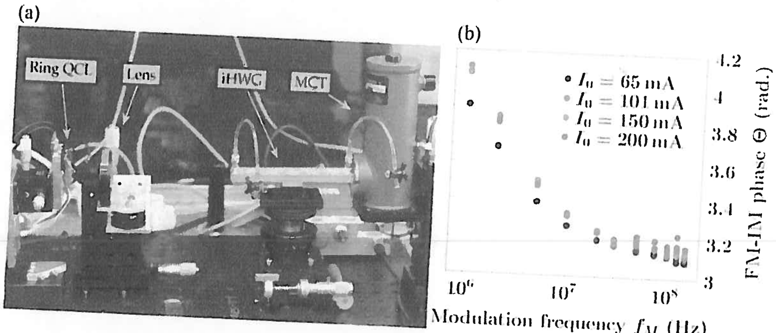

Fig. 2: (a) Setup combining ring QCLs and iHWGs. (b) Onset of thermal tuning in current modulated ring QCLs indicated by the increase of the frequency modulation (FM) – intensity modulation (IM) phase for decreasing modulation frequencies.

Furthermore, tunable laser spectroscopy with ring QCLs provides profound insights into the electronic and optical properties of these lasers and reveals the transition from electronic to thermal tuning as indicated in Fig. 2(b).

References

[1] B. Schwarz, P. Reininger, H. Detz, T. Zederbauer, A. M. Andrews, S. Kalchmair, W. Schrenk, O. Baumgartner, H. Kosina, and G. Strasser, "A bi-functional quantum cascade device for same-frequency lasing and detection," Applied Physics Letters 101, 191109 (2012).

[2] R. Szedlak, A. Harrer, B. Schwarz, M. Holzbauer, J. P. Waclawek, D. MacFarland, T. Zederbauer, H. Detz, A. M. Andrews, W. Schrenk, B. Lendl, and G. Strasser, "Remote Sensing with Commutable Monolithic Laser and Detector," ACS Photonics 3, 1794 (2016).

[3] E. Tütüncü, V. Kokoric, R. Szedlak, D. MacFarland, T. Zederbauer, H. Detz, A. M. Andrews, W. Schrenk, G. Strasser, and B. Mizaikoff, "Advanced gas sensors based on substrate-integrated hollow waveguides and dual-color ring quantum cascade lasers ," Analyst 141, 6205 (2016).

[4] M. Brandstetter, A. Genner, C. Schwarzer, E. Mujagic, G. Strasser, and B. Lendl, "Time-resolved spectral characterization of ring cavity surface emitting and ridge-type distributed feedback quantum cascade lasers by step-scan FT-IR spectroscopy ," Optics Express 22, 2656 (2014).