ITQW 2019
Infrared Terahertz Quantum Workshop
September 15-20, 2019
Ojai, California, USA

Program and Abstract Catalog
Thermoelectrically Cooled Terahertz Quantum Cascade Laser

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Short Abstract We present the first thermoelectrically (TEC) cooled terahertz quantum cascade laser (THz QCL). A high temperature 3-well THz QCL is mounted in a novel (ΔT_{TEC} = 134 K) Peltier cooler and housing. The temperature- and time-dependent laser performance, the TEC characteristics, and the duty cycle are investigated.

1. Introduction

Since the first terahertz quantum cascade laser (QCL), there has been a push toward higher-temperature devices that do not require cryogenic cooling [1]. The current T_{th} record is 159 K [1], using a 3-well Al0.5Ga0.5As/AlAs LO-phonon scheme active region for rapid depletion of the lower laser level. Progress towards new high temperature LO-phonon designs has been achieved with 2-well active regions [3] and 3-well active regions [4], both utilizing high Al-content barriers.

Thermoelectric coolers (TEC), which utilized the Peltier effect to create a temperature difference due to an applied electrical voltage, typically reach a minimum temperature around 230 K (ΔT_{TEC} = 70 K). This would require a THz QCL operating well in excess of 230 K. Multistage TECs can reach up to ΔT_{TEC} = 150 K, which makes them compatible with current state-of-the-art designs.

Here we present the first thermoelectrically cooled THz QCL, using a custom housing, laser mount, and multistage TEC. We even performed some impromptu spectroscopy with the complete device.

2. Results

A high temperature Al0.5Ga0.5As/AlAs THz QCL, design in Ref. [4], was processed into a 60x2600 μm Cu-Cu double-metal waveguide ridge. The pulsed He-cooled cryostat device performance 160–190 K is shown in Fig. 1. The output power decreases with the heat sink temperature, while the average intensity increases with the duty cycle, with the maximum limited by temperature.

The device was mounted to a custom copper mount for vertical emission on a 4-stage TEC, in a water-cooled housing. The THz QCL performance in the TEC assembly operating at the maximum ΔT_{TEC} is shown in Fig. 2, where over 4 mW of output power is measured. The pulsed power decreases with the duty cycle, while the average power actually peaks at 5%. The long-term stability is related to how quickly the entire TEC assembly can dissipate the heat generated by the THz QCL.

![Figure 1: THz quantum cascade laser mounted in a He flow cryostat. a) temperature dependent L-I-V curve. b) temperature dependent average intensity vs. duty cycle.](image1)

![Figure 2: THz quantum cascade laser mounted on a thermoelectric cooler: a) L-I-V curve at maximum ΔT_{TEC}. b) pulsed power and average power vs. duty cycle.](image2)

References


11:50  Martin A. Kaizen, Mykhaylo Semtsiv, Georgios Tsiaros, Sergii Kirkov, W. Ted Masselink, Sebastian Schoenhauer,
Benedikt Linsboecker, Hermann Deit, Werner Schenk, Karl Unterrainer, Giuffrida Strasser and Aaron Maxwell Andrews
Thermo-electrically Cooled Terahertz Quantum Cascade Laser

12:05 Lorenzo Bosco, Martin Francki, Mattias Beck, Andreas Wacker, Giacomo Scalari and Jerome Faist
Thermo-electrically cooled THz Quantum Cascade Lasers

12:20-13:30 Buffet Lunch

13:30-15:00 Session 4: THz QCL dynamics and locking
Chair: Jungho Cao

13:30 Francesco Cappelli, Luigi Consolino, Malik Nafa, Roberto Eramo, Iacopo Galli, Davide Mazzotti, Pablo Canio, Saverio
Barbalini and Paolo De Natale
Phase analysis and full phase control of chip-scale infrared frequency combs

13:45 Christian Geer Desmit, Dominik Theiner, Giacomo Scalari, Mattias Beck, Jeremy Faist, Karl Unterrainer and Juraj
Darmo
Spectrally resolved gain dynamics in THz quantum cascade lasers

14:00 Elise Uyehara, Wenda Xe, Ali Khalatpour and Qing Hu
Offset phase-locking of two THz quantum cascade lasers for high dynamic range heterodyne imaging

14:15 Valentina Pistore, Feihe Wang, Michael Riesch, Hanond Nong, Pierre-Baptiste Vigneron, Rafaele Colombelli, Olivier
Parillaud, Christian Jirauschek, Juliette Mangenev, Jerome Tignon and Sukhdeep Dhillon
Active harmonic modelocking and self-starting harmonic emission in THz QCLs

14:30 Martin Wiedl, Tasmin Alam, Xiang Li, Lutz Schrottke, Holger T. Grahn and Heinz-Wilhelm Hübbers
Light-induced frequency tuning and stabilization of terahertz quantum-cascade lasers

14:45 Yohe Sakasegawa, Shin'ichi Hayashi, Shingo Saito and Norihiro Sekine
Terahertz transmission responses of quantum cascade lasers over a wide range of incident electric field amplitude

15:00-19:00 Free Time. Enjoy the resort's pools, golf, and other amenities - or just explore the local area while the sun shines.

18:40-19:00 Coffee and Snacks

19:00-20:30 Session 5: 2D Materials
Chair: Frank Koppons

19:00 Michael Gensch
Terahertz High Harmonic Generation in Dirac Materials (Invited)

19:30 Alessandra Di Gaspare, Eva A. A. Pogna, Francesco Pisani, Osman Balci, Allison Cadore, Cinzia di Franco, Leonardo
Viti, Andrea C. Ferrari, Gaetano Scamarcio and Miriam S. Vitiello
Tunable gated graphene-on-polyimide Terahertz Modulators

19:45 and Ivan Oladyshkin
Infrared and terahertz optics and plasmonics of Weyl semimetals

20:00 Alexander McLeod
Fundamental limits to graphene plasmonics in hBN heterostructures (Invited)

Tuesday, September 17th

The sessions on Tuesday September 17 are dedicated to a Focused Workshop on Polaritons and Strong Coupling Phenomena. The
Focused Session is made up of a tutorial talk, invited talks, regular contributed talks, and several contributed talks upgraded to
"extended" status by the program during the review process.

08:30-10:25 Session 6: Polaritons 1
(Part of the Focused Workshop on Polaritons and Strong Coupling Phenomena)
Chair: Rafaele Colombelli

08:30 Alessandro Tredicucci
When light is more than a perturbation: what are intersubband polaritons? And how can we use them? (Tutorial)
Chih-Feng Wang, Terefe Habteyes, Ting Shan Luk, John Klem, Hou-Tong Chen, Oleg Miroshnyov and Ignat Brumer
Near-field Spectroscopy of Intersubband Polaritons in the Single Nanoantenna Regime (Extended)