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## **An optimized bi-functional material for integrated mid-infrared quantum cascade based sensors**

Paper 9767-49

Time: 4:40 PM - 5:00 PM

Author(s): **Andreas Harrer**, **Benedikt Schwarz**, **Peter Reininger**, **Rolf Szedlak**, **Tobias Zederbauer**, **Hermann Detz**, **Donald MacFarland**, **Aaron M. Andrews**, **Werner Schrenk**, **Gottfried Strasser**, **Technische Univ. Wien (Austria)**

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A high performance bi-functional quantum cascade laser and detector (QCLD) design is demonstrated. A revised extractor consisting of two parts and a more diagonal active transition lead to an improvement of all relevant laser and detector parameters by at least a factor of two. In pulsed operation 0.47W output power and 4.5% wall-plug efficiency was shown. A surface emitting and detecting bi-functional device consisting of a ring-QCL and a detector element is monolithically integrated. The device is fabricated from the presented material for operation at a wavelength of 6.5 $\mu$ m. We show concentration measurements of propane and butane in nitrogen in a wide concentration range.

# CONFERENCE 9767

SESSION 7 ..... TUE 4:00 PM TO 6:00 PM

## Lasers on Silicon

Session Chair: Haisheng Rong, Intel Corp. (USA)

**Road to group IV photonics** (*Invited Paper*), Detlev Grützmacher, Dan M. Bucsi, Stephan Wirths, Daniela Stange, Nils von den Driesch, Christian Schulle-Braucks, Siegfried Manti, Forschungszentrum Jülich GmbH (Germany) ..... [9767-31]

**Performance and reliability of III-V quantum-dot lasers grown directly on Si substrates**, Samuel Shultz, Stella N. Elliott, Angela D. Sobiesierski, Peter M. Smowton, Cardiff Univ. (United Kingdom); Jiang Wu, Mingchu Tang, Huiyun Liu, Univ. College London (United Kingdom); Richard Beanland, The Univ. of Warwick (United Kingdom) ..... [9767-32]

**1.55  $\mu\text{m}$  InGaAsP edge-emitting laser with a silicon hole injector**, Dong Liu, Zhenyang Xia, Zhenqiang Ma, Univ. of Wisconsin-Madison (USA); Weidong Zhou, The Univ. of Texas at Arlington (USA); Munho Kim, Sang June Cho, Univ. of Wisconsin-Madison (USA) ..... [9767-33]

**Electrically-driven 1D photonic crystal nanolaser integrated on silicon waveguides**, Guillaume Crosnier, Lab. de Photonique et de Nanostructures (France) and STMicroelectronics SA (France); Dorian Sanchez, Paul Monnier, Sophie Bouchoule, Grégoire Beaudoin, Isabelle Sagnes, Rama Raj, Fabrice Raineri, Lab. de Photonique et de Nanostructures (France) ... [9767-34]

**Photonic-crystal lasers on silicon for chip-scale optical interconnects** (*Invited Paper*), Koji Takeda, Takuro Fujii, NTT Photonics Labs. (Japan); Akihiko Shirya, Eiichi Kuramochi, Masaya Notomi, NTT Basic Research Labs. (Japan); Koichi Hasebe, Takaaki Kakitsuka, Shinji Matsuo, NTT Photonics Labs. (Japan) ..... [9767-35]

## WEDNESDAY 17 FEBRUARY

SESSION 8 ..... WED 8:20 AM TO 10:10 AM

## Interband and Quantum Cascade Lasers

Session Chair: Jerry R. Meyer, U.S. Naval Research Lab. (USA)

**Recent progress in interband cascade lasers** (*Invited Paper*), Rui Q. Yang, The Univ. of Oklahoma (USA) ..... [9767-36]

**Interband cascade laser sources in the mid-infrared for green photonics**, Johannes Koeth, Michael von Edlinger, Julian Scheuermann, Steffen Becker, nanopius GmbH (Germany); Robert Weh, Julius-Maximilians-Univ. Würzburg (Germany); Lars Nöhle, Marc O. Fischer, nanopius GmbH (Germany); Martin Kamp, Sven Höfling, Julius-Maximilians-Univ. Würzburg (Germany) ..... [9767-37]

**Step-taper active-region quantum cascade lasers for carrier-leakage suppression and high internal differential efficiency**, Jeremy D. Kirch, Chun-Chieh Chang, Colin Boyle, Luke J. Mawst, Univ. of Wisconsin-Madison (USA); Don Lindberg III, Thomas Earles, Intraband LLC (USA); Dan Botez, Univ. of Wisconsin-Madison (USA) ..... [9767-38]

**Surface-emitting quantum cascade laser with 2nd-order metal-semiconductor gratings for single-lobe emission**, Colin Boyle, Chris Sigler, Jeremy D. Kirch, Univ. of Wisconsin-Madison (USA); Don Lindberg III, Thomas Earles, Intraband LLC (USA); Dan Botez, Luke J. Mawst, Univ. of Wisconsin-Madison (USA) ..... [9767-39]

**Mid-IR coupled-cavity quantum cascade lasers**, Kamil Pierscinski, Dorota Pierscińska, Mariusz Pluska, Piotr Gutowski, Piotr Karbownik, Andrzej Czerwinski, Maciej Bugajski, Institute of Electron Technology (Poland) ..... [9767-40]

SESSION 9 ..... WED 10:40 AM TO 12:30 PM

## QCLs: Combs and Mode-Locking I

Session Chair: Sukhdeep Dhillon, Lab. Pierre Aigrain (France)

**Broadband quantum cascade laser frequency combs: physics and systems** (*Keynote Presentation*), Jérôme Faist, ETH Zürich (Switzerland) ..... [9767-41]

**Dispersion engineering of MIR QCL frequency combs**, Gustavo F. Villares, Johanna Wolf, Martin J. Süess, Dmitry Kazakov, ETH Zürich (Switzerland); Andreas Hugi, IRsweep GmbH (Switzerland); Mattias Beck, Jérôme Faist, ETH Zürich (Switzerland) ..... [9767-42]

**Single-mode to multimode transition in quantum cascade lasers caused by the dynamic Stark effect**, Tobias S. Mansuripur, Harvard Univ. (USA); Camille Vermet, Ecole Polytechnique (France); Guillaume Aoust, Harvard School of Engineering and Applied Sciences (USA) and ONERA (France); Benedikt Schwarz, Technische Univ. Wien (Austria); Yongrui Wang, Alexey A. Belyanin, Texas A&M Univ. (USA); Federico Capasso, Harvard School of Engineering and Applied Sciences (USA) ..... [9767-43]

**External cavity quantum cascade lasers operating under resonant pumping modulation** (*Invited Paper*), Dmitry G. Revin, Michael Hemingway, John W. Cockburn, The Univ. of Sheffield (United Kingdom); Yongrui Wang, Alexey A. Belyanin, Texas A&M Univ. (USA) ..... [9767-44]  
Lunch/Exhibition Break ..... Wed 12:30 pm to 2:00 pm

SESSION 10 ..... WED 2:00 PM TO 3:20 PM

## QCLs: Combs and Mode-Locking II

Session Chair: Gustavo F. Villares, ETH Zürich (Switzerland)

**Frequency comb operation of terahertz quantum-cascade lasers: fundamental aspects and practical applications** (*Invited Paper*), Martin Wienold, Humboldt-Univ. zu Berlin (Germany) and Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); Benjamin Röben, Lutz Schrottke, Holger T. Grahn, Paul-Drude-Institut für Festkörperelektronik (Germany) ..... [9767-45]

**Terahertz pulse generation from quantum cascade lasers** (*Invited Paper*), Sukhdeep S. Dhillon, Felhu Wang, Kenneth Maussang, Juliette Mangeney, Jérôme Tignon, Lab. Pierre Aigrain (France) ..... [9767-46]

**Active mode-locking in quantum cascade lasers with monolithic and external cavities**, Yongrui Wang, Alexey A. Belyanin, Texas A&M Univ. (USA) ..... [9767-47]

SESSION 11 ..... WED 3:50 PM TO 5:20 PM

## New Device Concepts

Session Chair: Andreas Wacker, Lund Univ. (Sweden)

**Superradiant emission from electronic excitations in semiconductors** (*Invited Paper*), Carlo Sirtori, Angela Vasanelli, Yanko Todorov, Simon Huppert, Thibault Laurent, Giulia Pegolotti, Univ. Paris 7-Denis Diderot (France) ..... [9767-48]

**Theoretical analysis of quantum-dot quantum cascade lasers: design considerations and current requirements**, Stephan Michael, Technische Univ. Kaiserslautern (Germany); Weng W. Chow, Sandia National Labs. (USA); Hans Christian Schneider, Technische Univ. Kaiserslautern (Germany) ..... [9767-50]

**An optimized bi-functional material for integrated mid-infrared quantum cascade based sensors**, Andreas Harrer, Benedikt Schwarz, Peter Reininger, Rolf Szedlak, Tobias Zederbauer, Hermann Detz, Donald MacFarland, Aaron M. Andrews, Werner Schrenk, Gottfried Strasser, Technische Univ. Wien (Austria) ..... [9767-49]

**Continuous-wave terahertz lasing in graphene**, Alexey A. Belyanin, Yongrui Wang, Texas A&M Univ. (USA); Mikhail Tokman, Institute of Applied Physics of the RAS (Russian Federation) ..... [9767-51]