



TeraNova Dissemination Activities

IST-511415

Period 1: 1st September 2004 – 31st August 2005

INVITED TALKS

JM Chamberlain

Between Radar and the Light Bulb: Terahertz Photonics for the 21st Century, Defence Technology Centre (MoD) Meeting, Edinburgh, September 2004

Developments in PMMW and Terahertz Imaging, European Symposium on Optics and Photonics for Defence & Security, London, October 2004.

Between Radio and Light: European Terahertz Activities in Biology, Medicine, Security and Process Monitoring: UK-Japan Nanotechnology Symposium, The University of Tokyo, Japan, March 2005

Functional Component Developments in the TeraNova Project for Terahertz Sensing & Imaging, Optro 2005, Paris, May 2005

TeraNova - European Research into Novel Terahertz Sensing and Imaging Systems, Southern Universities Research Association, Washington DC, June 2005.

The Background to Terahertz Frequency Biomedical Imaging & Sensing. International School of Solid State Physics, Erice, Sicily. 35th Workshop: Physics and Technology of THz Photonics, July 2005.

The Applicable Physics of the Terahertz Frequency Band, LOI Action Group Disruptive Technology Workshop on THz Technology, 22nd September, Edinburgh, UK.

J. Darmo

Terahertz time domain spectroscopy: technique and applications, Institut of Physics, Mountain University Leoben, Austria, 20.1.2005.

G. Davies

Squeezing more out of the electromagnetic spectrum: terahertz frequency science and technology. "Physics 2005, A Century after Einstein", Warwick UK, 10-14 April 2005

Terahertz quantum cascade lasers: realization and recent progress. Defence Technology Centre (MoD) Meeting, Edinburgh, September 2004.

Quantum Cascade Lasers, LOI Action Group Disruptive Technology Workshop on THz Technology, 22nd September, Edinburgh, UK.

S. Dhillon

THz generation and mixing in Quantum Cascade Lasers, 12th international conference on Narrow bandgap semiconductors (NGS12), Toulouse, France, June 2005.



P. Haring Bolívar

Photonic Terahertz Technology, Course at WS EuMC02 Workshop Terahertz Technology for Space and Earth Applications, 7th European Microwave Week, Amsterdam, NL, 11-15 October 2004.

THz biomolecular sensing, Seminar of the Observatoire des Micro et NanoTechnologies THz technologies: state of the art, challenges and applications, Institute Curie, Paris, F, 19 October 2004.

Integrated terahertz sensors for label-free analysis of genes, SPIE Conference Photonics West 2005, San Jose, January 22-28, 2005.

Biomolecular Sensing with Integrated THz Systems, OSA Topical Meeting on Optical Terahertz Science and Technology, Orlando, USA, March 14-16, 2005

Time-domain characterization techniques applied to THz metamaterial analysis, Workshop on Metamaterials for Microwave and Optical Technologies, San Sebastián, Spain, July 18-20, 2005.

DNA and protein diagnostics, 35th Workshop: Physics and Technology of THz Photonics, Erice, Italy, July 20 -26, 2005 (Tutorial).

THz biomolecular sensing, Biophotonics and Bioelectronics Workshop, Ottawa, Canada, 15 August 2005.

Integrated terahertz sensing arrays for label-free biomolecular sensing, 230th ACS National Meeting, in Washington, DC, Aug 28-Sept 1, 2005.

P.U. Jepsen

Chemical recognition with broadband THz spectroscopy and its applications in the defence and security sectors, DSTO workshop on Terahertz for Defence and Security, December 16-17 2005, Adelaide, Australia (presented by B. M. Fischer)

Terahertz molecular spectroscopy, Workshop on THz Photonics, July 20-26 2005, Erice, Italy

Quantitative terahertz time-domain spectroscopy and analysis in chemistry and biology, 230th ACS National Meeting, 29-31 August 2005, Washington, D.C.

M.Kemp

TeraNova - European Research into Novel Terahertz Sensing and Imaging Systems, Southern Universities Research Association, Washington DC, June 2005. [Joint with M. Chamberlain]

E. H. Linfield

Solid State Sources and Components. International School of Solid State Physics, 35th Workshop: Physics and Technology of THz Photonics Erice, Italy, July 20-26, 2005 (Tutorial).

Terahertz spectroscopy for in-process analysis. Plenary talk at the 2005 Annual Conference of the British Association for Crystal Growth, 4th-6th September 2005, Sheffield, UK.

From quantum cascade lasers to broadband sources – the development and applications of terahertz systems, Quantum Electronics and Photonics 16, 6th-9th September 2004, Glasgow, UK.

Pulsed optical approaches to THz, LOI Action Group Disruptive Technology Workshop on THz Technology, 22nd September, Edinburgh, UK.



P.C M. Planken

Terahertz near-field optics and microscopy, LEOS 2004, Puerto Rico, 7-11 November 2004

Terahertz near-field microscopy, CLEO/QELS 2005 Baltimore USA, 22-27 May 2005

Terahertz imaging, URSI 2005, Eindhoven, The Netherlands, 27 April 2005

Terahertz near-field optics and microscopy, "Physics 2005, A Century after Einstein", Warwick UK, 10-14 April 2005

A. Tredicucci

Advances in THz quantum cascade lasers: fulfilling the application potential Photonics West – Optoelectronics '05 San Jose, USA, January 22-27, 2005

THz Quantum Cascade Lasers: Developing New Operating Concepts and Advancing Application Technologies Optical Terahertz Science and Technology (OSA topical meeting) Orlando, USA, March 14-16, 2005

Quantum cascade lasers International School of Solid State Physics, 35th Workshop: Physics and Technology of THz Photonics Erice, Italy, July 20-26, 2005

K. Unterrainer

Few-cycle THz spectroscopy: A tool for spectro-imaging, Gordon Research Conference, "Chemical Sensors and Interfacial Design", The Queens' College, Oxford, Great Britain, August 28 - September 2, 2005.

Few-cycle THz spectroscopy of intersubband dynamics, 3ème Journées Terahertz, Aussois, France, 10.-13.3.2005

OTHER CONFERENCE PRESENTATIONS

Optical control processes in terahertz quantum-cascade laser waveguide, J. Darmo, K. Kröll, V. Tamousiunas, G. Fasching, K. Unterrainer, G. Strasser, M. Beck, M. Giovannini, J. Faist, CLEO/QELS 2005 Conference, May 22-27, 2005, Baltimore, Md. USA

Active photonics Structures for terahertz frequencies, Darmo, K. Kröll, G. Fasching, A. Benz, K. Unterrainer, M. Andrews, T. Roch, W. Schrenk, G. Strasser, 11th International Workshop on Applied Physics of Condensed Matter, June 15-17, 2005, Mala Lucivna, Slovakia

Optical processes in terahertz quantum-cascade laser waveguides J. Kroell, J. Darmo, G. Fasching, G. Strasser, and K. Unterrainer, International School of Solid-State Physics – 35th Workshop: Physics & Technology of THz Photonics, July 20 – 26, 2005, Erice, Italy

THz spectroscopy of semiconductor nanostructures and applications T. Müller, F. Schrey, G. Fasching, J. Darmo, J. Kröll, W. Parz, M. Andrews, T. Roch, W. Schrenk, G. Strasser, K. Unterrainer, International School of Solid State Physics - 35th Workshop: Physics and Technology of THz Photonics", Erice, Italy.

Phase matched frequency mixing between telecom wavelengths and THz radiation in a quantum cascade laser, S. S. Dhillon, C. Sirtori, S. Barbieri, A. de Rossi, M. Calligaro, H. E. Beere and D. A. Ritchie, Intersubband Transitions in Quantum Wells (ITQW) 2005, Cape Cod, USA.



Low Threshold ($I_{th} < 20\text{mA}$) Buried THz Quantum Cascade Lasers Using a Double Metal Scheme, S. S. Dhillon, C. Sirtori, J. Alton, S. Barbieri, A. de Rossi, M. Calligaro, H. E. Beere, E. H. Linfield and D. A. Ritchie, Conference on Lasers and Electro-Optics (CLEO) 2005, Baltimore, USA.

Buried waveguides in THz quantum cascade lasers based on two-dimensional surface plasmon modes, S. S. Dhillon, J. Alton, A. de Rossi, M. Calligaro, H. E. Beere, S. Barbieri, E. H. Linfield, D. A. Ritchie and C. Sirtori, OPTRO 2005, Paris, France.

Buried heterostructure 2.9 THz quantum cascade lasers operating up to 77K in continuous wave, J. Alton, S. Dhillon, S. Barbieri, H. E. Beere, E. H. Linfield, D. A. Ritchie, M. Calligaro, A. De Rossi and C. Sirtori, Photonics West 2005, San Jose, USA.

Buried waveguides in THz quantum cascade lasers based on two-dimensional surface plasmon modes, S. S. Dhillon, J. Alton, A. de Rossi, M. Calligaro, H. E. Beere, S. Barbieri, E. H. Linfield, D. A. Ritchie and C. Sirtori, Laser and Electro-Optics Society (LEOS) conference, 2004, Puerto Rico, USA.

Continuous-wave THz generation through photomixing using a dual-frequency $\text{Yb}^{3+}:\text{KGd}(\text{WO}_4)_2$ laser, R. Czarny, M. Alouini, C. Larat, S. Dhillon, M. Krakowsky, S. Bansropun, V. Ortiz, X. Marcadet, C. Sirtori, B. Gerard and D. Dolfi, 3emes journées TéraHertz, 13-16 March, 2005.

Terahertz near-field microscopy, The first Optical Terahertz Science and Technology conference Orlando USA, 14-16 March, 2005

High-speed characterization of integrated resonant THz biosensors using asynchronous optical sampling. C. Janke, M. Nagel, M. Först, and H. Kurz, Optical Terahertz Science and Technology Conference 2005, Orlando, USA (2005).

Asynchronous optical sampling for high-speed characterization of integrated THz resonator arrays. C. Janke, M. Först, M. Nagel, A. Bartels and H. Kurz, CLEO/QELS 2005 Conference, May 22-27, 2005, Baltimore, Md. USA

Cost-efficient THz-resonators for label-free detection of DNA hybridization. M. Nagel and H. Kurz, European Conferences on Biomedical Optics, June 12 – 16, 2005, Munich, Germany.

Controlling surface plasmon modes in THz quantum cascade lasers Richard Green et al MMD Meeting Genova Italy, June 22-25, 2005

Controlling surface plasmon modes in THz quantum cascade lasers Richard Green et al. 8th International Conference on Intersubband Transitions in Quantum Wells – ITQW 2005 North Falmouth, USA, September 11-16, 2005

Terahertz spectroscopy in otorhinolaryngology: investigation of native mucosa tissue samples, K. Schramm, C. Jahnke, D. Surawicz, P. Haring Bolivar, J. F. R. Ilgner, M. Westhofen, SPIE Conference Photonics West 2005, San Jose, January 22-28, 2005.

Terahertz pulse transmission of surface plasmon polaritons through semiconductor gratings, J. Gómez Rivas, M. Kuttge, P. Haring Bolivar, and H. Kurz, CLEO Europe, Munich, Germany, 12-16 Juni 2005.

Enhanced emission and detection techniques for terahertz time-domain spectroscopy, J. Kröll, J. Darmo, and K. Unterrainer, Optical Terahertz Science and Technology 2005, Orlando, USA.

Ultra-thin metallic layers studied by broadband terahertz time-domain spectroscopy, J. Kröll, J. Darmo, and K. Unterrainer, OPTRO 2005, Paris, France.

RNA spot imaging, M. Hoffmann, B. M. Fischer, H. Helm, and P. Uhd Jepsen, OSA Topical Meeting, Optical Terahertz Science and Technology, March 16-18 2005, Orlando, Florida

PUBLICATIONS

- [1] *Advances in THz quantum cascade lasers: fulfilling the application potential*, A. Tredicucci, L. Mahler, T. Losco, J. Xu, C. Mauro, R. Köhler, H. E. Beere, D. A. Ritchie, and E. H. Linfield, *Proceedings of SPIE -- Volume 5738 Novel In-Plane Semiconductor Lasers IV*, Carmen Mermelstein, David P. Bour, Editors, 146 (2005).
- [2] *Optimum resonant tunnelling injection and influence of doping density on the performance of THz bound-to-continuum cascade lasers*, J. Alton, S. Barbieri, C. Worrall, M. Houghton, H. E. Beere, and D. A. Ritchie, *Proc. SPIE Int. Soc. Opt. Eng.* 5727, 65 (2005).
- [3] *Terahertz bound-to-continuum quantum-cascade lasers based on optical-phonon scattering extraction* G. Scalari, N. Hoyler, M. Giovannini and J. Faist, *Appl. Phys. Lett.* 86, 181101 (2005).
- [4] *Buried waveguides in terahertz quantum cascade lasers based on two-dimensional surface plasmon modes*, J. Alton, S. S. Dhillon, C. Sirtori, S. Barbieri, A. de Rossi, M. Calligaro, H. E. Beere, and D. A. Ritchie, *Appl. Phys. Lett.*, 86, 071109 (2005).
- [5] *Buried heterostructure 2.9-THz quantum cascade lasers operating up to 77K in continuous wave*, J. Alton, S. S. Dhillon, C. Sirtori, S. Barbieri, A. de Rossi, M. Calligaro, H. E. Beere, and D. A. Ritchie, *Proc. SPIE Int. Soc. Opt. Eng.* 5738, 159 (2005).
- [6] *Ultra-low threshold current quantum cascade lasers based on double-metal buried strip waveguides*, S. S. Dhillon, J. Alton, S. Barbieri, C. Sirtori, A. de Rossi, M. Calligaro, H. E. Beere, and D. A. Ritchie, *Appl. Phys. Lett.*, 87, 071107 (2005).
- [7] *Time and frequency resolved THz spectroscopy of micro- and nano-systems*, J. Kröll, J. Darmo, K. Unterrainer, *Acta Physica Polonica* 107, 92-98 (2005).
- [8] *Passive Millimetre-Wave & Terahertz Imaging and Technology*, J M Chamberlain, Proceedings of SPIE Volume 5619 (SPIE, Bellingham, WA, 2004), pp1-5 [ISBN: 0277-786X]
- [9] *Generation of Terahertz Radiation in Nonlinear Waveguides*, AS Nikoghosyan, EM Laziev, RM Martrosyan, Hakhoumian, JM Chamberlain, RA Dudley and NN Zinov'ev, Conference Digest Of The 2004 Joint 29th International Conference On Infrared And Millimeter Waves And 12th International Conference On Terahertz Electronics (IEEE, New York) Editors: Thumm M, Wiesbeck W, pp 313-314, 2004 ISBN: 0-7803-8490-3
- [10] *Terahertz Transition Radiation*, A S Nikoghosyan, EM Laziev, RM Martirosyan, AA Hakhoumian, J M Chamberlain, RA Dudley & NN Zinovev, Conference Digest Of The 2004 Joint 29th International Conference On Infrared and Millimeter Waves And 12th International Conference On Terahertz Electronics (IEEE, New York) Editors: Thumm M, Wiesbeck W, pp 159-160, 2004 ISBN: 0-7803-8490-3
- [11] *THz sideband generation at telecom wavelengths in a GaAs-based quantum cascade laser*, S. S. Dhillon, C. Sirtori, A. de Rossi, M. Calligaro, H. E. Beere, S. Barbieri, E. H. Linfield, D. A. Ritchie, *Appl. Phys. Lett.*, 87, 071101 (2005).
- [12] *Continuous-wave THz generation through photomixing using a dual-frequency Yb³⁺:KGd(WO₄)₂ laser*, R. Czarny, M. Alouini, C. Larat, S. Dhillon, M. Krakowsky, S. Bansropun, V. Ortiz, C. Sirtori, B. Gerard and D. Dolfi, Proceedings of SPIE, Passive Millimeter-Wave and Terahertz Imaging and Technology, 5619, 198-207 (2004).
- [13] *Opto-electronic pulsed THz systems*, P. C. M. Planken, C. E. W. M. van Rijmenam, and R. N. Schouten, *Semicond. Sci. Techn.* 20, s121 (2005)
- [15] *Modular parallel-plate THz components for cost-efficient biosensing systems*. M. Nagel, P. Haring Bolivar and H. Kurz, *Sem. Sc. and Techn.* 20, 281-85 (2005).



- [16] *Asynchronous optical sampling for high-speed characterization of integrated resonant THz-sensors*. C. Janke, M. Först, M. Nagel, and H. Kurz, *Opt. Lett.* 30, 11, 1405-1408 (2005)
- [17] *Cost-efficient THz-resonators for label-free detection of DNA hybridization*. M. Nagel and H. Kurz, *Proc. SPIE Vol.* 5864, p. 152-160 (2005).
- [18] *Terahertz Quantum Cascade Lasers - first demonstration and novel concepts* Alessandro Tredicucci, Rüdiger [23] Köhler, Lukas Mahler, Harvey E Beere, Edmund H Linfield, and David A Ritchie *Semicond. Sci. Technol.* 20, S222 (2005)
- [19] *Frequency characterization of a terahertz quantum cascade laser* N. Beverini, G. Carelli, A. De Michele, A. Moretti, L. Mahler, A. Tredicucci, H. E. Beere, and D. A. Ritchie Submitted to *J. Phys. D*
- [20] H. Hübers, S. G. Pavlov, A. D. Semenov, R. Köhler, L. Mahler, A. Tredicucci, H. E. Beere, D. A. Ritchie, and E. H. Linfield *Terahertz quantum cascade laser as local oscillator in a heterodyne receiver* *Opt. Express* 13, 5890 (2005).
- [21] [Optimization of enhanced terahertz transmission through arrays of subwavelength apertures](#), C. Janke, J. Gómez Rivas, C. Schotsch, L. Beckmann, P. Haring Bolivar, and H. Kurz, *Phys. Rev. B* 69, 205314 (2004). [doi:10.1103/PhysRevB.69.205314](https://doi.org/10.1103/PhysRevB.69.205314)
- [22] *Time-domain measurements of surface plasmon polaritons in the terahertz frequency range*, J. Saxler, J. Gómez Rivas, C. Janke, H. P. M. Pellemans, P. Haring Bolívar, and H. Kurz, *Phys. Rev. B* 69, 155427 (2004) [doi:10.1103/PhysRevB.69.155427](https://doi.org/10.1103/PhysRevB.69.155427)
- [23] *Thermal switching of the enhanced transmission of terahertz radiation through subwavelength apertures*, J. Gómez Rivas, P. Haring Bolivar, and H. Kurz, *Opt. Lett.* 29 (14), 1680 (2004). <http://www.opticsinfobase.org/abstract.cfm?id=80572>
- [24] *Propagation of surface plasmon polaritons on semiconductor gratings*, J. Gómez Rivas, M. Kuttge, P. Haring Bolivar, H. Kurz, and J. A. Sánchez-Gil, *Phys Rev. Lett.* 93 (25), 256804 (2004). [doi:10.1103/PhysRevLett.93.256804](https://doi.org/10.1103/PhysRevLett.93.256804)
- [25] *Transmission of THz radiation through InSb gratings of subwavelength apertures*, J. Gómez Rivas, C. Janke, P. Haring Bolívar and H. Kurz, *Opt. Expr.* 13 (3), 847-859 (2005).
- [26] *Modular parallel-plate THz components for cost-efficient biosensing systems*, M. Nagel, P. Haring Bolivar and H. Kurz, *Semicond. Sc. and Techn.* 20 (7), S281-S285 (2005).
- [27] *Temperature dependence of the permittivity and loss tangent of high-permittivity materials at terahertz frequencies*, K. Berdel, J. Gómez Rivas, P. Haring Bolivar, P. de Maagt, H. Kurz, *IEEE Trans. Microw. Th. And Techn* 53 (4), 1266-1271 (2005).
- [28] *Time resolved broadband analysis of slow-light propagation and superluminal transmission of electromagnetic waves in three-dimensional photonic crystals*, J. Gómez Rivas, A. Farré Benet, J. Niehusmann, P. Haring Bolívar, and H. Kurz, *Phys. Rev. B* 71 (15), 155110 (2005)
- [29] *Terahertz science, engineering and systems—from space to earth applications*, P. de Maagt, P. Haring Bolivar and C. Mann, *Encyclopedia of RF and Microwave Engineering*, Ed. by K. Chang, pp. 5175-5194 (John Wiley & Sons, Inc., 2005) ISBN 0-471-27053-9.
- [30] *MBE growth of terahertz quantum cascade lasers*. H. E. Beere, J. C. Fowler, J. Alton, E. H. Linfield, D. A. Ritchie, R. Köhler, A. Tredicucci, G. Scalari, L. Ajili, J. Faist, and S. Barbieri. *J. Cryst. Growth* **278**, 756 (2005).



[31] High-performance operation of single-mode terahertz quantum cascade lasers with metallic gratings. Lukas Mahler, Alessandro Tredicucci, Rüdiger Köhler, Fabio Beltram, Harvey E. Beere, Edmund H. Linfield, and David A. Ritchie. *Appl. Phys. Lett.* **87**, October 24 (2005).

[31] High-performance operation of single-mode terahertz quantum cascade lasers with metallic gratings. Lukas Mahler, Alessandro Tredicucci, Rüdiger Köhler, Fabio Beltram, Harvey E. Beere, Edmund H. Linfield, and David A. Ritchie. *Appl. Phys. Lett.* **87**, October 24 (2005).

[32] *Terahertz time-domain spectroscopy and imaging of artificial RNA strands*, B. M. Fischer, M. Hoffmann, H. Helm, R. Wilk, F. Rutz, T. Kleine-Ostmann, M. Koch, and P. Uhd Jepsen, *Opt. Express* 13, 5205-5215 (2005)

[33] *Dynamic range in terahertz time-domain transmission and reflection spectroscopy*, P. Uhd Jepsen and B. M. Fischer, *Opt. Lett.* 30, 29-31 (2005)

[34] Chemical recognition in terahertz time-domain spectroscopy and imaging, B. Fischer, M. Hoffmann, H. Helm, G. Modjesch, and P. Uhd Jepsen, *Semicond. Sci. Technol.* 20, S246-S253 (2005).

PUBLIC RELATIONS

G. Davies

Publication in *The House Magazine*, Special Science Issue. This publication is circulated in the European Parliament.
Publication in *The Parliament Magazine*. This publication is circulated in the UK Parliament.

K. Unterrainer

Austrian Public Radio: ORF OE1 Dimensionen "Terahertz-Strahlung" 45 min.

P.C.M. Planken

Interview with Noorderlicht (Web-site of the science programme from VPRO radio/tv) at <http://noorderlicht.vpro.nl/artikelen/20009058/>

Interview with Dutch national newspaper Volkskrant, published July 16, 2005

TRADE FAIRS & EXHIBITIONS

Laser 2005 – include joint Femtolaser/TeraNova Booth.