



# Second Towards TeraHertz Communications Workshop

An ICT Beyond 5G Cluster Workshop

Thursday 7 March 2019 8.30 am

Albert Borschette Congress Centre (CCAB)  
Rue Froissart 36, 1040 Brussels, Belgium

The ICT Beyond 5G Cluster will host the 2nd Towards THz Communications Workshop with the support of the European Commission.

Future mobile networks and connectivity systems will require ultra-high speed and seamless performance for a huge number of connected devices and applications. Higher frequencies, and more specifically the terahertz range (0.1 THz – 10 THz) is seen as one of the promising way to address these requirements. But today, many fundamental scientific and technological challenges are still to be explored and overcome.

At the same time, allocation of the bands for THz communication is not yet done. It is thus also important to start, as early as possible, the identification of candidate bands which will be optimal from a technological point of view, while at the same time answering to the needs in the most promising and highly desirable verticals applications and use cases.

## Scope

This 2nd workshop aims at bringing together key actors currently working on, or having interest, in THz communications in order to explore future R&I plans for the period beyond 2020. The main goal of the workshop will be to have an overview of the current state of the art of the research in this area, to discuss the main challenges still to be explored, to highlight key research directions for future R&I actions and to share opinions on the foreseen frequency bands which could be good candidate to be supported by the EU in the global allocation exercise.

The workshop will be concluded by a panel session with the plenary speakers to summarise ideas and provide an input to EC for future calls.

Registration free of charge at

<https://www.eventbrite.ie/e/2nd-towards-terahertz-communication-workshop-tickets-51878969394>



WORTECS





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## Programme

- 08.40 Plenary Session: Toward THz Communications**  
*Plenary Chair Claudio Paoloni, Lancaster University, UK*  
Welcome *Claudio Paoloni, Lancaster University, UK*  
Introduction to the ICT-09-2017 Cluster *Dr. Alan Davy; Waterford Institute of Technology, Ireland*  
EC perspective on the challenges of THz communications *European Commission*  
TERAFLAG- A Catalyst for THz Communications in Europe  
*Dr.-Ing Yaning Zou; TU Dresden, Germany*  
Recent Japanese developments on THz communications  
*Prof. Tadao Nagatsuma; Osaka University, Japan*  
Terahertz wireless communications: a photonics perspective  
*Prof. Daniel Mittleman; Brown University, USA*
- 10.25 Coffee break**
- 10.55 Session 1: THz Communication Electronic and Photonic Components and Systems**  
*Session Chair Angeliki Alexiou, University of Piraeus, Greece*  
*Invited - Photonic approaches to THz communications*  
*Prof. Guillaume Ducournau; University of Lille, France*  
ULTRAWAVE – Technology for D-band Point to multipoint distribution  
*Prof. Claudio Paoloni; University of Lancaster, UK*  
DREAM – D-band Radio solution Enabling up to 100 Gbps reconfigurable Approach for Meshed beyond 5G networks  
*Dr. Vladimir Ermolov; VTT, Finland*  
TERAPOD – Terahertz-based ultra-high bandwidth wireless access networks  
*Prof. Cyril Renaud; University College London, UK*  
*Invited - THz micromachining – enabling the large-scale exploitation of the THz frequency spectrum?*  
*Prof. Joachim Oberhammer; KTH Royal Institute of Technology, Sweden*
- 12.15 Lunch**
- 13.15 Session 2: THz Communication Networks, Protocols and Architectures and User Cases**  
*Session Chair Thomas Kürner, TU Braunschweig, Germany*  
*Invited - Opening the THz-spectrum for communication for 5G and beyond*  
*Dr. Wolfgang Templ; Nokia Bell Labs, Germany*  
EPIC – Enabling Practical Wireless Tb/s Communications with Next Generation Channel Coding  
*Dr. Onur Sahin; InterDigital, UK*  
TERRANOVA – Terabit/s Wireless Connectivity by TeraHertz innovative technologies to deliver Optical Network Quality of Experience in Systems beyond 5G  
*Prof. Angeliki Alexiou; University of Piraeus, Greece*  
*Invited - Point-to-point wireless links toward to sub-millimeter wave*  
*Dr. Yinggang Li; Ericsson, Sweden*
- 14.35 Short Coffee Break**
- 14.45 Session 3: THz Communication Spectrum and Physical Layer**  
*Session Chair Onur Sahin, InterDigital, UK*  
*Invited - Standards aspects of THz communications*  
*Prof. Dr.-Ing. Thomas Kürner; TU Braunschweig, Germany*  
WORTECS – Wireless Optical/Radio Tera-bit Communications  
*Mr. Olivier Bouchet; Orange, France*  
*Invited -End user perspective on THz communication spectrum and physical layer*  
*Dr. Petr Jurčík; Deutsche Telekom, Czech Republic*
- 15.40 Wrap up coordinated by Dr Alan Davy**
- 16.10 End of the workshop**

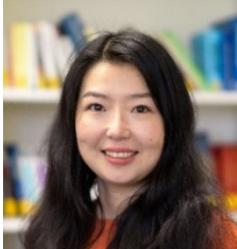


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### Plenary Speakers



#### **TERAFLAG – A Catalyst for THz Communications in Europe**

*Dr.-Ing Yaning Zou; TU Dresden, Germany*

THz frequency, i.e., 100 GHz – 10 THz, will be the next frontier of communications. For effectively bridging the very challenging THz gap and enabling a large scale of commercialisation of THz communications, it is highly important to align all the stakeholders across the whole value chain in the research planning and development. Through its FET flagship proposal, TERAFLAG initiative called out the whole Europe and attracted wide support from 30 European countries. In particular, THz communications is the topic area that has received overwhelming interests and attentions from a large number of top universities, top research institutes, SMEs and big companies across Europe. It shows that Europe has the critical mass as well as strong potential to succeed at the global stage by cultivating research excellence and industry leadership. Statistics and analysis obtained in the TERAFLAG action will provide audiences first-hand information on the current research and industry landscape in the area of THz communications.

*Yaning Zou received her M.Sc. and Ph.D. Degrees in electrical engineering from Tampere University of Technology (TUT), Finland. Currently she works as a research manager and is in charge of all EU projects as the Vodafone Chair for Mobile Communication Systems at Dresden University of Technology (TUD), Germany. Her general interests are in the design of next generation wireless communications system and the related ICT strategies and policies.*



#### **Recent Japanese developments on THz communications**

*Prof. Tadao Nagatsuma; Osaka University, Japan*

Since the first utilization of radio waves for wireless communications by G. Marconi in the early 20th century, researchers have been increasing the carrier frequency to improve data rate and channel capacity. Currently, the demand for much greater data rates of wireless technologies is growing due to the rapid advance of mobile networks and the huge data volume demanded by the internet and mobile devices. For these reasons, researchers have recently been seeking a use of terahertz (THz) waves whose frequency is over 100 GHz for ultrahigh-speed wireless links. This talk reviews the latest advances in Japanese THz communications research, and discusses future perspectives with respect to enabling photonic and electronic devices, and system applications.

*Prof. Nagatsuma received his Ph.D. degree in 1986 on the research of superconducting Josephson oscillators for millimeter and sub-millimeter-wave receivers, and then worked with NTT Laboratories for 21 years to explore mm-wave and terahertz applications, which include communications, using “room-temperature” semiconductor devices. In 2007, he joined Osaka University as a Professor, and has been continuing his terahertz research. He is a Fellow of the IEEE, a Fellow of the IEICE of Japan, and a Fellow of the Electromagnetics Academy of USA. He is currently an Associate Editor of IEEE Photonics.*



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### **Terahertz wireless communications: a photonics perspective**

*Prof. Daniel Mittleman; Brown University, USA*

The propagation of THz radiation is significantly different from that of lower frequency radiation in a number of important ways. These differences offer both challenges and opportunities for system designers. Most notably, THz signals are generally much more directional, propagating as diffracting beams rather than omnidirectional broadcasts. In this way, THz signals are more similar to laser beams than to RF wireless links. This paper will review recent developments and prospects for THz wireless communications from this photonics perspective.

*Dr. Mittleman received his B.S. in physics from the Massachusetts Institute of Technology in 1988, and his M.S. in 1990 and Ph.D. in 1994, both in physics from the University of California, Berkeley, under the direction of Dr. Charles Shank. He then joined AT&T Bell Laboratories as a post-doctoral member of the technical staff, working first for Dr. Richard Freeman on a terawatt laser system, and then for Dr. Martin Nuss on terahertz spectroscopy and imaging. Dr. Mittleman joined the ECE Department at Rice University in September 1996. In 2015, he moved to the School of Engineering at Brown University. His research interests involve the science and technology of terahertz radiation. He is a Fellow of the OSA, the APS, and the IEEE, and is a 2018 recipient of the Humboldt Research Award. He is currently serving a three-year term as Chair of the International Society for Infrared Millimeter and Terahertz Waves.*

### Invited Speakers



### **Photonic approaches to THz communications**

*Prof. Guillaume Ducournau; University of Lille, France*

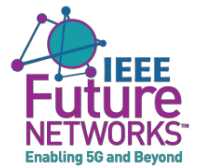
It is known that data traffic is increasing exponentially, with Internet protocol traffic expected soon to reach >100 exabytes per month. Since the fastest-growing part of data traffic is related to wireless channels, such an increase in network capacity requires much higher wireless transmission data rate links. Beyond the E-band (71-76 and 81-86 GHz) that will be rapidly saturated, the millimeter (D-band) and sub-mm range, between 275 and 400 GHz have strong potential to develop these applications. A potential solution is to use high data rate THz links using photonics-based THz emitters (UTC-PD) to down-convert optical fluxes to mm-waves.

*Prof. Ducournau obtained the Diplome d'ingénieur from ESIGELEC, Rouen, France in 2002. In 2002, he worked in Canada (Montréal) on the characterization of optical fiber Bragg gratings for core optical networks. In 2005, he obtained the PhD degree from Université de Rouen, France on fiber optic communication systems using DPSK modulation schemes. He was an Assistant Professor at the IEMN (Institute of Electronics, Microelectronics and Nanotechnology) / University of Lille 1 and Polytech'Lille Graduate School, in the THz Photonics group during 2007-2018. He is full professor since 2018. G. Ducournau is the leader of the THz wireless communications activity at IEMN using optoelectronic THz photomixers, electronic receivers, THz instrumentation and mm-wave characterization. He is author or co-author of more than 130 publications in peer reviewed international journals or conferences proceedings and holds one patent.*



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### **THz micromachining-enabling the large-scale exploitation of the THz frequency spectrum?**

*Prof. Joachim Oberhammer; KTH Royal Institute of Technology, Sweden*

Silicon micromachining is an enabling technology for building high-performance, highly-miniaturized, and volume-manufacturable THz components and systems. Waveguides are etched into silicon wafers, with feature sizes and tolerances down to micrometers, far more accurate than any other fabrication technology. KTH has developed a fabrication technology currently the world's lowest loss waveguides (0.02 dB/mm at 300 GHz), and implemented several low loss microwave components, including power combiners/splitters, couplers, and integrated matched loads and attenuators. Resonance cavities with unloaded Q-factors of 800 at 450 GHz and 1600 at 140 GHz were implemented, setting the state-of-the-art with several high complexity narrow and wideband filters in the 100-500 GHz frequency range. Wafer stacking allows for multi-level waveguide systems, and KTH has shown a turnstile-OMT working full-band at 220-330 GHz with 0.5 dB insertion loss and worst case cross-polarization of -35 dB. Several examples of very compact, high-gain (>30 dB) antennas will be shown in the 300 GHz range. Integrated MEMS actuators enable re-configurable components, and MEMS waveguide switches with >50 dB isolation and <0.6 dB insertion loss at 220 GHz will be shown, as well as switches and phase shifters in the 500-750 GHz band.

*Joachim Oberhammer has been professor in Microwave and THz Microsystems at KTH Royal Institute of Technology (Stockholm, Sweden) since 2015. He has been a post-doc at Nanyang Technological University (Singapore) and Kyoto University (Japan), as well as guest researcher at NASA-JPL (USA), Nanyang Technological University (Singapore), and Vienna University of Technology (Austria). Among others, he is recipient of an ERC-Consolidator Grant, six Best Paper Awards at IEEE conferences, a JSPS scholarship, two Swedish innovation grants and an award by the Ericsson Research Foundation. He is Associate Editor of IEEE Transactions on THz Science and Technology, and has served in the General Assembly of the European Microwave Association and in the Young Academy of Sweden.*



### **Opening the THz-spectrum for communication for 5G and beyond**

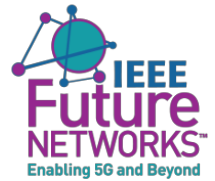
*Dr. Wolfgang Templ; Nokia Bell Labs, Germany*

Since the early 1990's our world has been subjected to a fundamental transformation into the so-called networked society. Political trends and movements as well as our private everyday lives have become widely determined by the rapid worldwide exchange of information among individuals, cybernetic systems and machines. The continuous data traffic growth together with the demand for anywhere and anytime connectivity, mainly fuelled by the demand for transmission of high definition video, result in a shortage of radio bandwidth which means "transport capacity" in the wireless communication networks. In consequence, and enabled by the impressive progress of semiconductor device technologies, future radio communication systems will utilize frequency bands in the so called "THz-spectrum", which roughly describes the range from c. 100 GHz up to several 100 GHz. This will provide an abundance of bandwidth and open entirely new perspectives for a nearly unlimited increase of data traffic. However the exploitation of THz spectral resources involves high technical challenges: propagation properties as well as environmental influences of "THz-waves" will require new radio system concepts and architectures.



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*Wolfgang Templ graduated in Physics from the University of Stuttgart in 1987. He received his Ph.D. from the University of Stuttgart working at the Max Planck Institute for Metal Physics (Stuttgart) in 1990 on the field of muon spin rotation-based investigations of spin density waves in antiferromagnetic chromium. After two years as postdoc at MPI working on nuclear methods in solid state physics at the Paul Scherrer Institute (Switzerland) and Rutherford Appleton Labs (UK) he joined Alcatel-SEL in 1992 where he worked for four years in the field of semiconductor component qualification and tests. From 1999-2005 he led the microelectronic technology group at Alcatel Research Centre which became Bell Labs Germany after the merger between Alcatel and Lucent. Until 2013 he was working at Bell Labs in the optical networking department, mainly concentrating on identification, assessment and introduction of new electronic and photonic device technologies for optical and wireless communication systems. Since 2013 he leads a Bell Labs department directed to research on wireless transceivers for 4G and 5G radio- and mmWave- infrastructure. As member of CATRENE Steering Group and acting as project reviewer he has been participating since 2001 on numerous CATRENE, FP6, FP7, H2020 and VLAIO microelectronic project reviews.*



### **Point-to-point wireless links toward to sub-millimeter wave**

*Dr. Yinggang Li; Ericsson, Sweden*

Mobile traffic growth in 5G and beyond is expected to demand huge bandwidth that is only available beyond 100 GHz in the spectrum horizon. Today, microwave backhaul technology plays a significant role in mobile transport networks and will be proven to be a viable high performance technology even in the beyond 5G era. Research and development work have now started on the longer term use of frequencies up to sub-millimetre-wave in wireless backhaul and fronthaul applications. This presentation focuses on some recent development in the D-band targeting the support of 5G evolution toward 2030, with a perspective discussion for the possibility of utilizing frequencies up to 275 GHz in fixed wireless applications.

*Dr. Li received his Ph D in 1993 in theoretical physics from Chalmers University of Technology. He was a post-doctoral fellow at Iowa State University, USA, from 1993 till 1996 when he joined the Ericsson Group in Sweden. Ever since then Dr. Li has worked in Ericsson Research and pursued hardware researches ranging from RF to microwave to millimeter-wave frequencies. His R&D experience includes circuits design, module development and sub-system building up. His current research interest is in mmW radio system targeting for point-to-point application in future mobile transport networks.*



### **Towards THz communication- Measurements, Demonstrations and Simulations**

*Prof. Dr.-Ing. Thomas Kürner; TU Braunschweig, Germany*

It has already been several years since THz communications triggered discussions and activities in standardization and regulation. In October 2017, IEEE published Std. IEEE 802.15.3d-2017 the worldwide first wireless communications standard operating in the 300 GHz frequency band. In parallel to the standardization process, activities at the ITU-R level targeting the provision of an appropriate regulatory framework at the World Radio Conference 2019 (WRC-2019) via a dedicated agenda item have taken off. The speaker has been actively involved in all these areas. This presentation will provide a brief overview on the current status of the development of THz communication systems focusing on the past and current activities at IEEE 802 and the WRC 2019 preparations.



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*Prof. Kürner received his Dipl.-Ing. degree in Electrical Engineering in 1990, and his Dr.-Ing. degree in 1993, both from University of Karlsruhe (Germany). From 1990 to 1994 he was with the Institut für Höchstfrequenztechnik und Elektronik (IHE) at the University of Karlsruhe working on wave propagation modelling, radio channel characterisation and radio network planning. From 1994-2003 he was with the radio network planning department at the headquarters of the GSM 1800 and UMTS operator E-Plus Mobilfunk GmbH & Co KG, Düsseldorf, where he was team manager radio network planning support responsible for radio network planning tools, algorithms, processes and parameters from 1999 to 2003. Since 2003 he is Full University Professor for Mobile Radio Systems at the Technische Universität Braunschweig. His working areas are indoor channel characterisation and system simulations for high-speed short-range systems including future terahertz communication system, propagation, traffic and mobility models for automatic planning and self-organization of mobile radio networks and vehicle-to-X communications. Amongst others he has actively contributed to the channel modelling document supporting the standardization of IEEE 802.11ad. Currently he is chairing the IEEE 802.15 TAG THz. He was also the chair of IEEE 802.15.3d TG 100G, which developed the worldwide first wireless communications standard operating at 300 GHz. He is also the project coordinator of the recently granted H2020-EU-Japan project ThoR ("TeraHertz end-to-end wireless systems supporting ultra high data Rate applications"). Prof. Kürner is a member of the Board of Directors of the European Association on Antennas and Propagation (EurAAP) and from 2012 to 2017 he was the founding chair of the EurAAP WG Propagation.*



### **End user perspective on THz communication spectrum and physical layer**

*Dr. Petr Jurčik; Deutsche Telekom, Czech Republic*

It has been clear for some years that existing technologies are insufficient to fulfil the demands of communications networks beyond 5G. One of the most promising candidate solutions is to develop networks which utilise the THz region of the spectrum from 300 GHz and beyond. Only a few years ago the technical challenges seemed prohibitively difficult, but recent developments in terms of technology, hardware, simulation and understanding have been dramatic. This presentation considers the potential for THz spectrum use from an end user perspective.

*Since 2010 Dr. Jurčik has worked as a Radio Network Engineering Expert with the Research and Trials team based in Prague (Czech Republic) which belongs to the Technology Architecture and Innovation department of Deutsche Telekom. His responsibilities include, among others, assessments of newly upcoming radio network technologies and system functionalities by means of theoretical analysis as well as field/lab tests and trials; searching for and evaluation of promising start-up companies and their innovative products/technologies/ideas that might be of future use within DT. He is a member of ONF.*

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# Second Towards TeraHertz Communications Workshop

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## Organising Committee



General Chairs: Claudio Paoloni, Lancaster University, UK  
Alan Davy, Waterford Institute of Technology, Ireland

Rapporteur: Bruce Napier, Vivid Components

## ICT Beyond 5G Cluster Steering Committee

Alan Davy	Waterford Institute of Technology, Ireland
Angeliki Alexiou	University of Piraeus, Greece
Bruce Napier	Vivid Components Ltd., Germany
Onur Sahin	InterDigital, UK
Mir Ghorraishi	pureLiFi, UK
Vladimir Ermolov	VTT Technical Research Centre, Finland
Claudio Paoloni	Lancaster University, UK
Thomas Kürner	TU Braunschweig, Germany

## ICT Beyond 5G Cluster

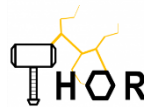
Six projects from the H2020 call ICT-09-2017 and one project from the call EU-Japan have been funded:

DREAM	<a href="http://h2020-dream.eu">h2020-dream.eu</a>
EPIC	<a href="http://epic-h2020.eu">epic-h2020.eu</a>
TERAPOD	<a href="http://terapod-project.eu">terapod-project.eu</a>
TERRANOVA	<a href="http://ict-terranova.eu">ict-terranova.eu</a>
ULTRAWAVE	<a href="http://ultrawave2020.eu">ultrawave2020.eu</a>
WORTECS	<a href="http://wortecs.eurestools.eu">wortecs.eurestools.eu</a>
ThoR	<a href="http://thorproject.eu">thorproject.eu</a>

These seven projects have agreed to form an unofficial cluster in order to try to coordinate some dissemination activities to maximise the impact of the projects.

## Acknowledgement

The ICT Beyond 5G Cluster is grateful to the European Commission for the great support of the workshop. The Cluster projects have received funding from Horizon 2020, the European Union’s Framework Programme for Research and Innovation. ThoR has also received funding from the National Institute of Information and Communications Technology in Japan (NICT).







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## Contacts

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## Venue

The workshop is held at the Albert Borschette Congress Centre (CCAB), located at 36 rue Froissart in Brussels, Belgium. The closest metro station is “Schuman” (lines 1 and 5), bus stops are Rue Froissart (22., 27 and 36) and train station is “Schuman”.

### *From Brussels Airport*

- **Bus:** Bus number 12 runs from the airport to the city centre approximately every twenty minutes. The journey will take you 30-45 minutes. Take this bus from the airport to the Schuman bus stop, located at the Schuman roundabout. From this stop, walk down rue Froissart, cross rue Belliard and continue on the right-hand side for about 300 meters. The next large building after the Clinique Leopold is the Centre Borschette Center.
- **Taxi:** A taxi from the airport will take about 15-25 minutes.
- **Train and Metro:** Trains run from the airport to Brussels Nord, Central and Midi Stations (for those staying in town) or to Bruxelles Schuman (direction Charleroi Sud or Dinant) approximately every 30 minutes, with an average journey time of 25 minutes. The minimum price of a train ticket is €8.80 and can be bought at the airport station. For more Information see: <https://www.trainline.eu/train-times/bruxelles-schuman-to-brussels-airport-zaventem>
- Note that Brussels Airport South (most notably operating RyanAir flights) is located 60km to the south of Brussels and needs to be accessed by rail or bus. More information at:
- <https://www.charleroi-airport.com/brussels-south-charleroi-airport/index.html>

### *From Brussels South Train Station (Gare du Midi/Zuidstation)*

**Metro:** The journey by metro will take you approximately 20-25 minutes. Take the metro line 2 in the direction of Simonis for 6 stops. Get off at Arts-Loi/Kunst-Wet and change to line 1A/B.

Take this metro line in the direction of either Stockel/Stokkel or Herrmann-Debroux, for 2 stops. Get off at Schuman and leave the metro station via the Justus Lipsius exit.

