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Foreword

On behalf of the founding Directors, Norbert Klein and Stepan Lucyszyn, we welcome you to the Centre for Terahertz Science and Engineering (CTSE). This is a virtual Centre, hosted by the Faculty of Engineering at Imperial College London. The Centre supports a wide range of activities across the extended terahertz (THz) spectrum, from ca. 100 GHz to 100 THz – covering the sub-terahertz (millimetre-wave), terahertz (submillimetre-wave) and ‘over the THz horizon’ (thermal infrared) bands. While the core of the Centre’s activities are within the Departments of Materials (material processing and THz metrology) and Electrical and Electronic Engineering (analytical/numerical modelling, microfabrication processing and millimetre-wave/thermal infrared metrology), there are strong collaborations with the Departments of Bioengineering, Physics and Medicine. Indeed, the inter-Faculty nature of our work highlights the scientific mission of our Centre, which complements our advanced engineering within the Faculty of Engineering.

In January 2012, a survey was carried out to see how much THz-related research was being carried out within the Faculty of Engineering. Even at that time, Imperial had a wide range of diverse THz activities:

- Analytical/numerical modelling for solutions to complex problems in electrodynamics
- Advanced contact-free material characterisation
- Exploitation of exotic materials
- Fundamental research in device physics
- Fabrication and characterization of novel components
- Exploration of novel sensor system approaches
- Systems level applications

For this reason, in February 2012, the CTSE was established to provide support and a forum for creating new interactions within Imperial. This document highlights some of the activities and achievements that have been supported over the first three years of operation. We present a dozen Case Studies, each representing a body of work with associated list of papers published in the open literature. This catalogue of activity pays testament to our diverse interests with the extended terahertz frequency range.

Currently within the UK there are many research groups working in terahertz-related fields. The philosophy adopted by the CTSE is to push the boundaries in science and technology. However, to make a tangible impact, particular emphasis is placed on creating real engineering solutions to major challenges facing society; examples include biomedical sensing (which could ultimately lead to the early detection of certain cancers from measurements of the skin or even a single droplet of blood) to enhanced security (with secure wireless communications and counterfeit detection systems).

Furthermore, the CTSE aims to address issues of creating ubiquitous applications over the extended terahertz spectrum; this requires low cost engineering solutions at all technology levels (materials, components, circuits and systems) and in supporting areas (software development, manufacturing and metrology). Finally, the CTSE aims
to expand its educational role, by teaching advanced topics in terahertz science and engineering to those working in associated areas of research and development.

In addition to pushing boundaries within academic research, the CTSE has close partnerships with industry. Examples of this include EMISENS (www.emisens.com) and Link Microtek Ltd. (www.linkmicrotek.com), for the manufacture and commercialization, respectively, of a bottle scanner for airport security. This is based on technology being developed by Prof. Klein. Moreover, we collaborate on THz technology with Rohde & Schwarz (www.rohde-schwarz.co.uk) – one of the world leading manufacturers of THz measurement equipment – and QMC Instruments (www.terahertz.co.uk) – a prominent THz components and systems manufacturer within the UK. As a direct spin-out from the CTSE, within the area of biotechnology, EVA Diagnostic (www.evadiagnostics.com) was recently founded by Dr Toby Basey-Fisher – one of Prof. Klein’s former PhD students. This company won the 2014 Oxbridge Biotech Roundtable OneStart competition.

Please do not hesitate to contact us if you wish to visit our Centre and discuss possibilities for future collaboration. Appendix 4 shows our current successful strategic associations with external organisations. The opportunities for terahertz research and development are endless and we can achieve more together.
Case Study 1: Microwave and THz Material Characterisation

Led by Dr Stephen M. Hanham (Department of Materials)
Professor Norbert Klein (Department of Materials)
Andrew Gregory, National Physical Laboratory (NPL)

The development of the terahertz region of the electromagnetic spectrum is heavily dependent on new materials that will underpin future terahertz devices and systems. Our Centre, in collaboration with NPL, has developed the capability to characterise the properties of materials over the frequency range 1 GHz to 3 THz. This large frequency range is covered using a number of different instruments and techniques that offer different levels of sensitivity and traceability.

One instrument that has been developed over the last few years is a near-field microwave microscope that allows the dielectric and conductive properties of materials to be imaged with a spatial resolution of several microns. This instrument is particularly useful for imaging thin films where the quality and consistency of films (such as graphene) can be assessed. Other instruments include the quasi-optical setups that exploit the VNA’s and the terahertz time-domain spectrometer’s ability to measure up to 500 GHz and 3 THz, respectively, to characterise materials.

Fig. 1. (a) A THz quasi-optical system designed for the characterisation of materials from 67 GHz to 500 GHz. (b) System diagram of a near-field microwave microscope designed for material measurements with micron-level spatial resolutions. (c) Simulated electric field of the near-field probe. (d) Time and frequency domain signals generated by our THz time-domain spectrometer used for measurements up to 3 THz.
Journal Papers


Conference Papers


Case Study 2: Graphene

Led by Professor Norbert Klein (Department of Materials)
Dr Olena Shaforost, Dr Stephen M. Hanham, Mohammad Adabi, Stefan Goniszewski (Department of Materials)
Dr Antonio Lombardo, Cambridge Graphene Centre
Professor Yang Hao, School of Electrical Engineering and Computer Science, Queen Mary University London

Graphene is one of the most promising new materials for the realization of low cost THz devices, which include critical components like mixers, attenuators, modulators, and detectors. As a technological basis, we have established a 4” wafer scalable process for graphene deposition, by chemical vapour deposition (CVD) as well as etching processes, to fabricate integrated graphene planar circuits on THz substrates like quartz and high resistivity silicon. Our previous work has focused on the manufacturing of high quality graphene, including optimization of the CVD and transfer processes, as well as the preparation of free-standing graphene microstructures on silicon substrates. Moreover, we have studied various microwave-to-terahertz characterization techniques for qualification of graphene for THz applications. Our future work will be directed to the practical realization of graphene THz detectors, harmonic generators and fast modulators, aiming towards low-cost THz communication and sensing systems.

Fig. 2. Free standing graphene drum and new 4” CVD kit within the Department of Materials

Journal Papers


Conference Papers

Case Study 3: THz Waveguides

Led by Dr Miguel Navarro-Cía (Department of EEE)
Dr Oleg Mitrofanov, Department of EEE, University College London
Professor James A Harrington, School of Engineering, Rutgers University, USA

The strong absorption of most media in the THz range and the strong atmospheric attenuation (especially above 1 THz) impede efficient transmission of THz waves. A way to circumvent the problem is to use propagation via hollow waveguide modes with minimal field distribution in the walls of the waveguide.

The dielectric-lined hollow metallic waveguide holds promise in this regard, because it supports a low-loss and low-dispersive hybrid HE$_{11}$ mode within a wide band. The fabrication of this waveguide for THz frequencies is not trivial, especially when they are made bendable, and the fabricated samples need to be tested.

We use near-field time-domain microscopy for measuring the samples to mitigate the characterization problems related to mode interference, pulse dispersion, large variation of the coupling coefficient and loss with frequency.

![Waveform detected on the Teflon-lined hollow metallic waveguide axis.](image)

Fig. 3. (Left) Waveform detected on the Teflon-lined hollow metallic waveguide axis. (Right) Power spectral density of the measured waveform shown on the left-hand side. The numerically-computed group delay for the TM$_{11}$-HE$_{11}$ (dotted violet) and the TM$_{12}$ modes (dotted green) are superimposed.

Journal Papers

Plasmonics is a well-established field in the visible region of the electromagnetic spectrum, where surface plasmon modes on the surface of noble metals are often used for sensing. We have shown that by adopting semiconductor materials or engineering the texture of metal surfaces, plasmonic or plasmonic-like waves can be supported on a surface at terahertz frequencies, with similar properties to their visible wavelength counterparts.

The enhancement and confinement of the electromagnetic field associated with surface plasmon wave make them ideally suited for sensing applications. We have demonstrated how these waves can be used for performing spectroscopic sensing of extremely small quantities of solids and liquids.

Fig. 4. (a) A corrugated metal surface is used to support a THz spoof plasmon, used for sensing. (b) A multi-annular metamaterial used to guide several strongly confined spoof plasmon modes. (c) Two InSb touching disks that support a localised surface plasmon resonance at terahertz frequencies.
Journal Papers


Conference Papers


Book Chapters

Case Study 5: THz Plasmonic Oscillators

Led by Dr Oleksiy Sydoruk (Department of EEE)
Professor Richard R. A. Syms and Professor Laszlo Solymar (Department of EEE)
Dr Kaushal Choonee, National Physics Laboratory (NPL)
Dr Gregory C Dyer, Sandia National Laboratories, USA

A timely problem for terahertz technology is the need for more effective sources. While existing methods of generation are being actively refined, an intensive search for alternatives is underway. Relying on rigorous solutions of Maxwell’s equations, we have been theoretically studying terahertz amplification and generation in a two-dimensional semiconductor channel supporting drifting plasmons. We have shown that transfer of power is possible from a dc current to THz plasmons. In addition, we have developed a theoretical model of passive plasmonic resonators, comprising gated and non-gated electron channels.

Fig. 5 A junction between gated and non-gated channels leads to partial plasmon reflection, which can be used to design resonators

Journal Papers

Conference Paper
1. O. Sydoruk “Is amplification of semiconductor plasmons possible despite carrier collisions and diffusion”, 38th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz 2013), Mainz, Germany, Sep. 2013
A new class of quasi-optical components can be designed with metamaterials. These components are characterized by subwavelength features that tailor their overall electromagnetic response. The new design philosophy has made possible the implementation of free-space matched diffractive optical devices without expensive and cumbersome anti-reflective coatings. Our effort is focused on developing robust metallic lenses, frequency selective surfaces and low-profile highly-directive antennas for radar and space applications.

Fig. 6. From left to right: 144 GHz epsilon-near-zero lens based on narrow rectangular waveguides operating near cut-off, THz quarter-wave plates based on the extraordinary transmission phenomenon and THz leaky-wave slit+grooves antenna

Journal Papers

6. V. Pacheco-Peña, V. Torres, M. Beruete, M. Navarro-Cía, and N. Engheta, “ε-near-zero (ENZ) graded index quasi-optical elements: steering and splitting millimeter waves,” J. Optics, vol. 16, no. 9, pp. 094009-1-7, Sep. 2014. Selected by the editors for the ‘Highlights of 2014’ collection; Fig. 4 was selected cover page of the special issue on mid-infrared and THz photonics (Invited)

Book chapter

Conference Papers

• V. Torres, V. Pacheco-Peña, B. Orazbayev, J. Teniente, M. Beruete, M. Navarro-Cía, M. Sorolla, and N. Engheta, “Epsilon-near-zero lens for beamshaping of sub-terahertz waves,” 40th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), Hong Kong, China, (Submitted)


Case Study 7: Metal Mesh Filters

Led by Dr Fangjing Hu (Department of EEE)
Dr Stepan Lucyszyn, Dr William J. Otter, Jonathan Hazell (Department of EEE)
Dr Marco Ribeiro, ISCTE-IUL, Lisbon, Portugal

For ubiquitous THz systems using low-cost components, research into scalable metal mesh filters on electrically thick substrates is being undertaken. Figure 7 shows two of these structures, the classic metal mesh filter and an improved trapped-mode design (having another complementary inner cross). These filters were realised using standard low-cost surface micromachining and measured using our turnkey TeraView 3000 terahertz time-domain spectroscopy (THz-TDS) system. The improved designs show good out-of-band rejection up to 3 THz, with narrow pass bands at the desired resonance frequencies from 0.1 to 0.5 THz. This work has led to the collaboration with Dr Marco Ribeiro from ISCTE-IUL (Lisbon, Portugal), with a €1.6k travel grant from COST Action MP1204, enabling work to design a low-cost THz stress sensor based on metal mesh structures. Other THz devices using metal mesh patterns, including modulators and absorbers, are also being investigated.

![Fig. 7. Conventional metal mesh filter (left) and trapped-mode metal mesh filter (right)](image)

Conference Papers

1. F. Hu, W. J. Otter and S. Lucyszyn, "Optically tunable THz frequency metamaterial absorber", 40th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), Hong Kong, China, August, 2015
Case Study 8: Photonic Crystals

Led by Dr William J. Otter (Department of EEE)
Dr Stepan Lucyszyn, Professor Andrew S. Holmes (department of EEE)
Dr Stephen M. Hanham, Professor Norbert Klein (Department of Materials)
Nick Ridler, National Physical Laboratory (NPL)

Photonic crystal research has focused on the design of the building blocks to create architectures for THz systems. Photonic crystals are an electromagnetic bandgap material engineered from a periodic variation in permittivity; in this case cylindrical air holes are made in high resistivity silicon (HRS) using bulk micromachining. As part of this work we have demonstrated waveguides, switches, attenuators and resonators. The resonators have shown state-of-the-art Q-factor performance, verified by traceable measurements at NPL. The use of resonators as a sensor is being investigated as part of the TERACELL project. Work to integrate the building blocks to create THz systems in ongoing to create a full photonic crystal front-end architecture.

Fig. 8. Photonic crystal filter (left) and attenuator (right)

Journal Paper

Conference Papers
Case Study 9: Biomedical Sensing
Led by Professor Norbert Klein (Department of Materials)
Dr Stephen M. Hanham, Clare Watts, Professor Molly Stevens
(Department of Materials)
Dr Stepan Lucyszyn, Dr William J. Otter, Dr Munir Ahmad (Department of EEE)
Professor Stefan Maier, Dr Paloma Arroyo Huidobro (Department of Physics)
Professor Paul D. Abel, Professor Long R. Jiao (Department of Medicine)
Dr Nadia Guerra (Department of Life Sciences)

The spectrum of electromagnetic waves from the microwaves towards visible light offers a wide variety of complementary interaction mechanism with biomatter, which enables the development of a highly differentiated methodology for fingerprint detection of cells and biomolecules in a microfluidic environment. This includes cell membrane polarisation, bulk and hydration water dynamics, single and collective vibrational mode analysis and scattering. These enable the detection of global cell properties like size, water content and granularity, but also more specific chemical information related to the molecular content.

Within the EPSRC funded project “TERACELL”, different types of microwave-to-terahertz resonator and transmission line structures have been investigated for highly sensitive liquid sensing in microfluidic systems. As a recent spin-out from these research activities, EVA Diagnostics (http://www.evadiagnostics.com/) was founded recently by a former PhD student of Prof. Klein. As the winner of the 2014 Oxbridge Biotech Roundtable OneStart competition, EVA Diagnostics is developing and commercializing electromagnetic blood analysis systems for point-of-care diagnostics.

As a long term goal for our research, we believe that the complementarity of the information revealed from different regions of the electromagnetic spectrum will provide the scientific and technological basis for a new generation of point-of-care diagnostic instruments. We are working towards the ultimate and most comprehensive health check based on sole blood analysis; including infectious diseases, early-state-cancer diagnosis and monitoring of cancer treatment as well as early state detection of diseases like Alzheimer and Parkinson.

Fig. 9. Two recent cover page journal articles published by the team: Electromagnetic anaemia detection by a microfluidics / microwave system (left) and THz liquid analysis by spoof plasmons
Journal Papers


Conference Papers


Case Study 10: THz Imaging With Strained-Si MODFET Sensors

Led by Dr Kristel Fobelets (Department of EEE)
Dr Y.M. Meziani, Dr J.E. Velázquez-Pérez, Universidad de Salamanca, Spain
Dr D. Coquillat, Dr W. Knap, CNRS-Université Montpellier 2, France

Strained-Si modulation doped field effect transistors (MODFETs) is used for non-resonant (broadband) and resonant detection of terahertz radiation. These MODFETs have a buried strained-Si channel with high electron concentration. The MODFETs are excited at room temperature by two types of terahertz sources (an electronic source based on frequency multipliers at 0.292 THz and a pulsed parametric laser at 1.5 THz). In both cases, a non-resonant response with maxima around the threshold voltage was observed. Shubnikov-de Haas and photoresponse measurements were performed simultaneously. These showed a phase-shift of $\pi/2$ in good agreement with the theory, which demonstrates that the observed response is related to the plasma waves oscillation in the channel of the MODFET. The non-resonant features were used to demonstrate the capabilities of such devices in terahertz imaging. Cooling the MODFET down to 4.2 K increases the quality factor and resonant detection was observed by using a tuneable source of terahertz radiation.

Fig. 10. Visible (left) and terahertz image (right) of a plastic box with a hidden mirror inside obtained using a strained-Si MODFET with gate length of 250 nm.

Journal Paper

Conference Papers
Case Study 11: 

Thermal Infrared ‘THz Torch’ (10-100 THz)

Led by Dr Stepan Lucyszyn (Department of EEE)
Dr Fangjing Hu, Jingye Sun, Dr William J. Otter, Rumessa Raja, Zouyiao Zou, Hanchao Lu (Department of EEE)
Dr Helen E. Brindley (Department of Physics)
Professor Anthony C. Chu (Department of Medicine)
Dr Xiaoxin Liang, Professor Yuepeng Yan, Chinese Academy of Sciences
Dr Zhengwei Wang, Sichuan Jiuzhou Electric Group Co.

The thermal infrared ‘THz Torch’ concept was first introduced by Lucyszyn et al. in 2011, for short-range secure wireless communications over a single (25 to 50 THz) channel. It fundamentally exploits engineered blackbody radiation, by partitioning thermally-generated spectral power into pre-defined frequency channels; the incoherent energy in each channel is then independently pulsed modulated. Within the past year, advances in the foundations, applications, source characterization and systems level analysis have been reported; incorporating frequency band multiplexing techniques across the 15 to 89 THz range. An up-to-date roadmap of the technology is shown in Fig. 11.

**Thermal Infrared ‘THz Torch’ Technology Roadmap**

![Thermal Infrared ‘THz Torch’ Technology Roadmap](image)

- **Low-cost Spectrometer for Early Skin Cancer Detection**

The team have recently developed a general purpose spectrometer that operates in the thermal infrared part of the electromagnetic spectrum. Instead of employing sophisticated techniques - based around coherent sources, complex filter banks and cryogenically-cooled detectors - the team exploits the ‘THz Torch’ concept that employs low-cost commercial-off-the-shelf thermodynamic components. The result is a course, but effective, transmission-mode spectrometer that has already (through practical measurements) demonstrated its ability to identify dielectric materials from a database of pre-characterized thermal infrared spectral signatures, using robust statistical techniques.
The primary objective of a new 6-month project is to re-engineer the existing low-cost spectrometer for the sole purpose of early detection of skin cancers (as illustrated in the Fig. 12); representing a totally new application for this technology. Since the thermal infrared has a relatively long wavelength it can penetrate the skin’s epidermis layer, where the complex dielectric permittivity of cancerous tissue contrasts against the background of normal skin tissue. The existing spectrometer has 16 matched pairs of band-pass filters; each filter pair providing a time-integrated spectral datum point. With 16 spectral data points, representing a course sampling of the thermal infrared (from 20 to 80 THz), the resulting signature can then be compared against a database of normal and abnormal skin tissue measurements.

Fig. 12 Proposed low-cost spectrometer for early skin cancer detection

Journal Papers

Book Chapter


Case Study 12: 
Low-loss Quasi-Optical Multiplexer (QOM) for Future Space-based Meteorological Radiometry

Led by Dr Richard J. Wylde FREng (TK Instruments)
Dr Stephen M. Hanham (Department of Materials)
Dr William J. Otter (Department of EEE)
Kevin Pike, Stuart Froud, Adam Woodcraft, TK Instruments
Professor Peter A. Ade, Professor Carole Tucker, Amber Hornsby,
School of Physics and Astronomy, Cardiff University
Lifei Jiang, Zhenchao Xie, Hongxin Xu, Shanghai Aerospace Electronic Technology Institute, CASC

A low-loss quasi-optical multiplexer (QOM) for future space-based meteorological radiometry covering nearly a decade bandwidth (from 54 GHz to 425 GHz), was developed by TK instruments. The losses in the multiplexer were measured using a novel double path $S_{11}$ VNA technique, and beam co-alignment was verified by scanning with a wideband detector using the measurement facilities within the CTSE laboratory at Imperial. The results showed that very low loss can be combined with high channel co-alignment in a compact package, suitable for surviving the launch environment.

Fig. 13. The doubled layered QOM, with Cu-coloured DCPs on the top layer with the VNA head in the top right of the picture

Conference Paper

Appendix 1: Associated Funding

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Total £4.2M
Appendix 2: Associated Resources

Department of Materials

Fabrication
Oxide, nitride and metal deposition
Combined 4” graphene – metal deposition systems

Bio-equipment
Class 2 biosafety cabinet, microfluidic equipment and cell microscope

THz Metrology
Frequency Domain:
10 MHz – 67 GHz Rohde and Schwarz VNA coaxial
70 GHz – 500 GHz Rohde and Schwarz VNA complete coverage of waveguide bands, including horn antenna pairs and complete calibration kits
Several Agilent VNAs 10 MHz-40 GHz
Quasi-optical transmission/reflection measurement setup 70 GHz – 500 GHz
Scanning near-field microscope 1 GHz -100 GHz

Time Domain:
0.06 to 4 THz TeraView TPS Spectra 3000 with remote transceivers
Department of Electrical and Electronic Engineering (EEE)

Optical and Semiconductor Devices (OSD) Group  
http://www3.imperial.ac.uk/opticalandsemidev

Fabrication
- Implantation, Diffusion  
- Oxidation, Metallisation, Electroplating  
- S/S & D/S lithography  
- RIE & DRIE, KOH  
- 3D Printing, Laser Machining

Characterisation
- Rudolph Research AutoEL®-II Automatic Ellipsometer  
- Veeco Dektak 3ST Surface Profiler  
- Atomic Force Microscope  
- LEO 1450VP Scanning Electron Beam Microscopy with EDX compositional analysis  
- Agilent 86140B and 86142B Optical Spectrum Analysers  
- Hamamatsu Photonics C2400 Near-infrared Video Camera

THz Metrology

Frequency Domain:
- 10 MHz – 110 GHz Agilent N5250A Performance Network Analyzer with RF On-wafer Probe Station  
- 75 GHz – 110 GHz WR-10 Metal-pipe Rectangular Waveguide Test Rig with Gunn Oscillators, Detectors and Horn Antennas  
- 10 THz – 30 THz Bespoke Monochromatic Grating-based Spectrometer THZ5B-BL with T-Rad Pyroelectric Detector:  
  - 100 GHz – 6.8 THz - for relative power measurements only  
  - 6.8 THz – 30 THz - corrected for sensing element absorption  
  - 30 THz – 1,200 THz - for calibrated spectrometer measurements  
- 20 THz – 80 THz Thermal Infrared ‘THz Torch’ bench  
- 23 THz – 40 THz (7.5 µm – 13 µm) FLIR E60 Thermal Infrared Video Camera
Appendix 3: Imperial’s Proactive Members

Department of Materials
Professor Norbert Klein (Director of CTSE)
Professor Neil Alford *MBE, FREng* (Head of Department)
Professor Molly M. Stevens *FREng* (Research Director for Biomedical Material Sciences in the Institute of Biomedical Engineering)
Dr Mark Oxborrow (Reader)
Dr Michelle Moram (Lecturer)
Dr Peter Petrov (Research Officer)
Dr Stephen M. Hanham (Research Associate)
Dr Olena Shaforost (Research Fellow)
Ms Clare Watts (PhD student)
Mr Mohammad Adabi (PhD student)
Mr Stefan Goniszevski (PhD student)

Department of Electrical and Electronic Engineering - Optical and Semiconductor Devices (OSD) Group
Dr Stepan Lucyszyn *FIEEE* (Director of CTSE)
Professor Laszlo Solymar *FRS* (Visiting Professor)
Professor Richard R. A. Syms *FREng* (Head of OSD Group)
Professor Andrew S. Holmes (Deputy Head of OSD Group)
Dr Kristel Fobelets (Reader)
Dr Oleksiy Sydoruk (Lecturer)
Dr Munir M. Ahmad (Research Fellow)
Dr William J. Otter (PhD graduate 2015, Research Associate)
Dr Fangjing Hu (PhD graduate 2014, Research Associate)
Dr Miguel Navarro-Cia (Junior Research Fellow)
Dr Elpida Episkopou (PhD graduate 2014)
Dr Stergios Papantonis (PhD graduate 2014, now at CST)
Dr Zhengwei Wang (1-year secondment, Sichuan Jiuzhou Electric Group Co.)
Dr Xiaoxin Liang (1-year sabbatical, Chinese Academy of Sciences)
Ms Jingye Sun (PhD student)
Mr Jonathan Hazell (PhD Student)

Department of Physics
Professor Stefan Maier (Director of the Centre for Plasmonics and Metamaterials)
Dr Helen E. Brindley (Senior Lecturer)
Dr Paloma Arroyo Huidobro (Research Associate)

Department of Life Sciences
Dr Nadia Guerra (Lecturer)

Department of Medicine (Hammersmith Hospital)
Professor Paul D. Abel (Honorary Consultant in Urology)
Professor Long R. Jiao (Consultant in Hepatobiliary and Pancreatic Surgery)
Professor Anthony C. Chu (Consultant Dermatologist)
Appendix 4: Strategic Associations
# Appendix 5: CTSE Workshops

## Inaugural Workshop (2012)
40 registered participants

The Imperial College  
Centre for Terahertz Science and Engineering (CTSE)  
Inaugural Workshop  
Friday 14th September 2012  
Room G20, Royal School of Mines  
Prince Consort Road, South Kensington Campus

<table>
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<th>Room</th>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
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<td></td>
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<td>Registration and Refreshments</td>
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<td>G20</td>
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<td>Welcome from the Directors</td>
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<td>Microwave to THz properties of proteins and cells</td>
<td>Toby Basye Fisher</td>
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<td>Plasmonics for THz science and technology</td>
<td>Prof. Stefan Mayer</td>
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<td>G20</td>
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<td>Electromagnetic properties of graphene</td>
<td>Prof. Ling Hao</td>
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<td>Refreshments</td>
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<td>Microwave to THz near field methods</td>
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<td>12:00</td>
<td>Micromachining of THz waveguide components</td>
<td>Dr. Peter Huggard</td>
</tr>
<tr>
<td>G20</td>
<td>12:20</td>
<td>Progress on the standardization of THz waveguides and interfaces</td>
<td>Nick M. Ridler</td>
</tr>
<tr>
<td>G20</td>
<td>12:40</td>
<td>100 GHz ultra high-Q photonic crystal resonators</td>
<td>William Otter</td>
</tr>
<tr>
<td>G20</td>
<td>13:00</td>
<td>Commercial EM solvers for arbitrary metal-based THz structures</td>
<td>Stergios Papanikos</td>
</tr>
<tr>
<td>G01</td>
<td>13:20-14:10</td>
<td>LUNCH DEMONSTRATION: Microwave/THz sensing for security applications</td>
<td>Prof. Norbert Klein</td>
</tr>
<tr>
<td>G20</td>
<td>14:10</td>
<td>III-nitrides and related materials for THz devices</td>
<td>Dr. Micheline Moram</td>
</tr>
<tr>
<td>G20</td>
<td>14:30</td>
<td>Use of semiconductor plasmons for THz generation</td>
<td>Dr. Oleksiy Sydoruk</td>
</tr>
<tr>
<td>G20</td>
<td>14:50</td>
<td>Cryogenics at room temperature: a solid-state maser based on molecular intersystem crossing</td>
<td>Dr. Mark Oxborrow</td>
</tr>
<tr>
<td>G20</td>
<td>15:10</td>
<td>THz imaging using strained-SI MODFETs</td>
<td>Dr. Kristel Fobelets</td>
</tr>
<tr>
<td>G01</td>
<td>15:30</td>
<td>Refreshments</td>
<td></td>
</tr>
<tr>
<td>G20</td>
<td>15:50</td>
<td>Fabrication of nano structures for rectenna devices</td>
<td>Dr. Peter Petrov</td>
</tr>
<tr>
<td>G20</td>
<td>16:10</td>
<td>THz torch technologies for 21st century applications</td>
<td>Fengjiang Hu</td>
</tr>
<tr>
<td>G20</td>
<td>16:30</td>
<td>REconfigurable Terahertz Integrated Architecture (RETINA)</td>
<td>Dr. Stepan Lucyszyn</td>
</tr>
<tr>
<td>G20</td>
<td>16:50</td>
<td>Nanoparticle based biosensing</td>
<td>Prof. Molly Stevens</td>
</tr>
<tr>
<td>G20</td>
<td>17:10-17:30</td>
<td>Q&amp;A for the Centre and Closing Remarks</td>
<td>Dr. Stepan Lucyszyn</td>
</tr>
</tbody>
</table>
Invited Workshop (2014)
63 registered participants

Centre for THz Science and Engineering Workshop 2014
Wednesday 19th November
Room 611, Electrical and Electronic Engineering, Imperial College London

05:30 Registration – Tea/Coffee
05:45 Welcome – Norbert Klein
10:00 “Fundamentals and applications of spoof surface plasmon polaritons”
    Stefan Maier – Imperial College London
10:30 “THz spectroscopy and imaging for pharmaceutical science”
    Axel Zeitler – University of Cambridge
11:00 “Studies of biological systems with high intensity terahertz radiation.”
    Peter Weigman – University of Liverpool
11:30 “Teracell: Probing the THz response of biological cells”
    Stephen Hanham – Imperial College London
11:45 Tea/Coffee Break
12:00 “Quasi-optical solutions for the emerging THz market”
    Rostyslav Dubrowska – Queen Mary, University of London
12:30 “Research and commercial applications of THz Schottky diodes”
    Byron Alderman – RAL Space
13:00 “IPHT Jena and Rohde and Schwarz collaborative projects in the field of THz”
    Torsten Mau – IPHT Jena
13:30 Buffet Lunch
14:30 “Lithographically-defined terahertz waveguides for spectroscopy, imaging, and sensing applications”
    John Cunningham – University of Leeds
15:00 “Integrated sub-wavelength aperture THz probes for imaging and spectroscopy”
    Oleg Mitrofanov – University College London
15:30 “Photonic crystal switches and attenuators”
    William Otter – Imperial College London
15:45 Tea/Coffee Break
16:00 “Identification of fibre by THz spectroscopy”
    John Molloy – National Physical Laboratory
16:30 “Secure thermal infrared communications using engineered blackbody radiation”
    Stephan Lucyszyn – Imperial College London
16:45 “Quasi-optical THz devices based on metamaterials”
    Miguel Navarro-Cía – Imperial College London
17:00 Closing Remarks – Stepan Lucyszyn

Attendance is free.
Prior registration required via email to s.brace@imperial.ac.uk
Sponsored by:

ROHDE & SCHWARZ
Appendix 6: Miscellaneous Activities

• Stepan Lucyszyn was appointed a European Microwave Lecturer (EML) for the European Microwave Association in 2013, with the lecture entitled “An Engineering Approach Towards Creating Ubiquitous THz Applications”. The EML programme is also part of the IEEE MTT-S Speaker’s Bureau. This activity has resulted in the following invited lectures:
  
  - 2015 GeMiC, Keynote, Germany
  - 2015 University College London, UK
  - 2013 ARMMS Conference, UK
  - 2013 MSMW, Plenary, Ukraine

• Stepan Lucyszyn has been a member of the Editorial Review Board since 2012 for IEEE Transactions on Terahertz Science and Technology

• Stepan Lucyszyn and William J. Otter gave invited talks on the “THz Torch Technology” and “THz Photonic Crystal Devices” at IEEE Chapter Seminar, University of Austin, Texas, September 2014

• William J. Otter gave an invited seminar on “THz Photonic Crystal Devices” at ISCTE-IUL in July 2014

• Miguel Navarro-Cia gave an invited seminar on “THz near-field time-domain spectroscopy for material and device characterization” in University of Coimbra, Portugal.

• Miguel Navarro-Cia gave a short course on “THz technology and Instrumentation” in the 9th European Conference on Antennas and Propagation, EuCAP 2015, Lisbon, Portugal.


• Miguel Navarro-Cia will give an invited seminar on “THz near-field time-domain microscopy for device characterization” at XXX Simposium Nacional de la Unión Científica Internacional de Radio, URSI 2015 - International Workshop on THz Engineering, September 2015 in Pamplona, Spain

• William J. Otter is a member of Member of IET RF and Microwave Technical and Professional Executive Committee

• The CTSE have been actively participating since 2013 in the European COST MP1204 Action “Tera-MIR Radiation: Materials, Generation, Detection and Applications"

• Stepan Lucyszyn has been on the Steering Group as a founding member since 2014 for the EPSRC Terahertz Network (TeraNet)

• The CTSE will host the TeraNet Steering Group Meeting (J un. 2015)

• The CTSE will host the TeraNet Workshop (Sep. 2015)
Appendix 7: Additional CTSE Publications

Journal Papers


Conference Papers


2. S. Papantonis, N. M. Ridler and S. Lucyszyn, “A new technique for vector network analyzer calibration verification using a single reconfigurable device”, 82nd ARFTG Conference, Columbus, USA, Nov. 2013


