Mini-Colloquium of the IEEE-EDS Distinguished Lectures Lecture Meeting

Collocated with

TeraTech 2023

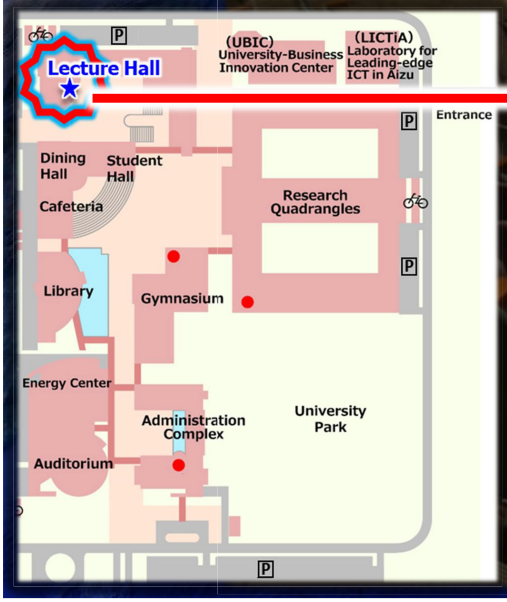
10th International Symposium on
Terahertz-Related Devices and Technologies

at Univ. Aizu, Aizuwakamatsu, Japan
Sept. 4 - 8, 2023



Venue Onsite and Online

- **University of Aizu**
  Lecture Hall 160 max.
- **Zoom online**



Technical Program Organization

- **Mini-Colloquium of IEEE-EDS DL Lectures**
  - IEEE Electron Device Society organized.
  - IEEE Distinguished Lecturers' lectures.
  - Free of charge, but need to be pre-registered.
  - https://www.ieee-jp.org/section/tokyo/chapter/ED-15/

- **TeraTech 2023**
  - 'Plenary', 'Invited', and 'Contributed' Oral talks
  - 'Poster' presentations.
  - Need to be paid and registered.
  - https://www.teratechconf.org/

Google earth

TeraTech 2023
10th International Symposium on
Terahertz-Related Devices and Technologies

Conference Time Table

Sept. 4 MON	Sept. 5 TUE	Sept. 6 WED	Sept. 7 THU	Sept. 8 FRI
	AM-1 Opening Plenary	AM-1 Mini-Colloquium	AM-1 Technical Plenary	AM-1 Technical Plenary
	AM2 Technical	AM2 Technical	AM2 Technical	AM2 Technical
	Lunch	Lunch	Lunch	Lunch
	PM1 Technical	PM1 Technical	PM1 Technical	PM1 Technical
PM2 Registration	PM2 Technical	PM2 Technical	PM2 Technical	PM2 Closing
Evening Welcome Reception			Evening Banquet	

Auditorium @ Univ. Aizu
Cafeteria @ Univ. Aizu
Aizuwakamatsu Washington Hotel

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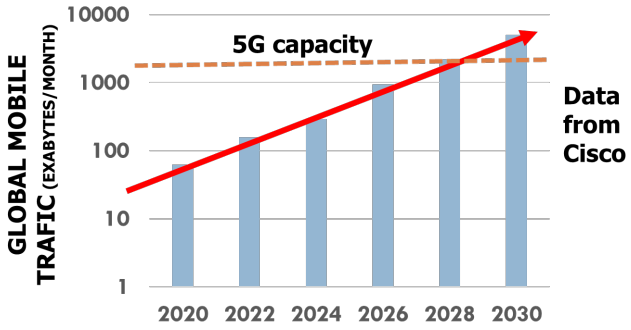
9:00am - 9:45am, Sept. 6 WED, 2023

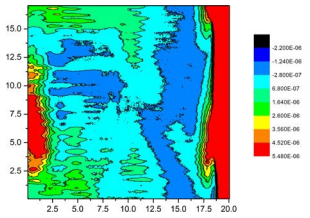
Sensing Using Terahertz Radiation

Professor Michael Shur
Dept. ECSE and Physics, Rensselaer Polytechnic Institute
Troy, NY, USA
shurm@rpi.edu

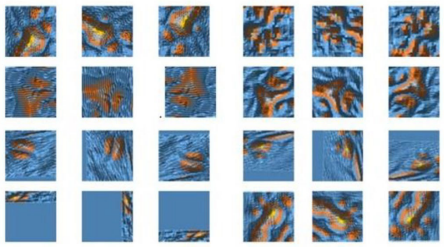
Terahertz (THz) sensing is enabling technology for 6G communication, detection of biological and chemical hazardous agents, cancer detection, monitoring of industrial processes and products, and detection of mines and explosives. THz sensors support security in buildings, airports, and other public spaces. They found important applications in radioastronomy and space research and, more recently, in Artificial Intelligence-driven THz sensing of MMICs and VLSI. Exploding demand for data transfers will require using the 300 GHz band after 2028 or even before and will make the deployment of THz sensing electronics inevitable. This lecture will discuss the new physics of THz sensing and THz sensing devices. It will also review software for THz sensing and THz sensor design, the THz sensing market, and key THz sensor companies.



The Need for 300 GHz Band



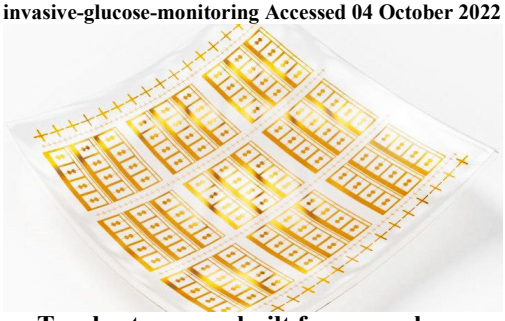
Intel I7 THz Image
M. Shur, Proc. SPIE 10639, doi: 10.1117/12.2301349



2D THz scans for training an Artificial Intelligence model to identify defective integrated circuits. From N. Akter, M. R. Siddiquee, M. Shur and N. Pala, IEEE Access, vol. 9, pp. 64499-64509, 2021, doi: 10.1109/ACCESS.2021.307542

THz Cancer Probe
https://www.news-medical.net/whitepaper/20181009/Detecting-Cancer-using-Terahertz-Pulsed-Imaging.aspx Accessed May 13, 2023

Apple developing a THz sensor for non-invasive glucose monitoring
From https://appleinsider.com/articles/21/02/11/apple-developing-new-terahertz-radiation-sensor-tech-for-non-invasive-glucose-monitoring Accessed 04 October 2022



Terahertz sensor built from graphene
From https://www.elektormagazine.com/news/terrahert accessed 10 04 2022

Michael S. Shur received MSEE Degree (with honors) from St. Petersburg Electrotechnical Institute, and PhD. and Dr. Sc. Degrees from A. F. Ioffe Institute. He is Patricia and Sheldon Roberts Professor of Solid State Electronics and Professor of Physics, Applied Physics, and Astronomy at Rensselaer Polytechnic Institute and co-founder, President and CEO of Electronics of the Future, Inc. He was also a co-founder and Vice-President of Sensor Electronics Technology, Inc. (a leading producer of deep ultraviolet LEDs) and founder of co-founder of several other startups, including Electronics of the Future, Inc. Dr. Shur is Life Fellow of IEEE, APS, ECS, and SPIE, Fellow of the National Academy of Inventors, OSA, IET, MRS, WIF, and AAAS. Dr. Shur is Distinguished Lecturer of IEEE EDS society. His awards include St. Petersburg Technical University and University of Vilnius Honorary Doctorates, Distinguished Faculty Naval Research Fellowships, William H. Wiley 1866 Distinguished Faculty Award, Rensselaer Outstanding Engineering Professor Award, Institute of Electronic Technology Achievement Medal, ECS Electronic and Photonics Award, Jefferson Science Fellowship, Recognition Award from iNEER, Tibbetts Award for Technology Commercialization, IEEE Sensors Council Technical Achievement Award, IEEE Donald Fink Best Paper Award, IEEE Kirchmayer Award, the Gold Medal of the Russian Education Ministry, van der Ziel Award, Senior Humboldt Award, Pioneer Award, RPI Engineering Research Award, Wiley Award, RPI Outstanding Faculty Award, and several Best Paper Awards. Dr. Shur was listed by the Institute of Scientific Information as Highly Cited Researcher. His h-index is 111. In 2009, the Lithuanian Academy of Sciences elected him its Foreign Member.

Terahertz plasmonic devices using graphene-based 2D materials

Professor Taiichi Otsuji
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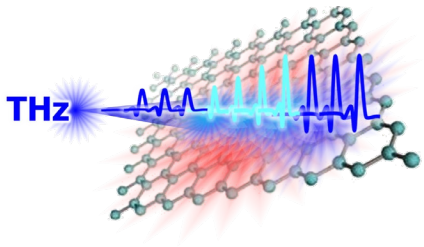
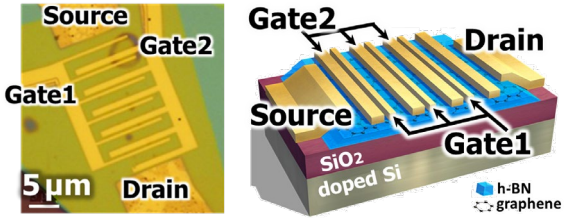
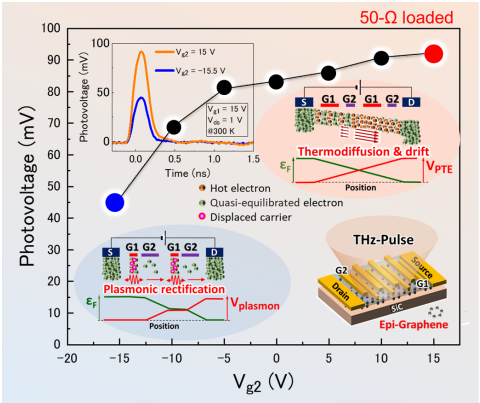
Graphene has attracted considerable attention due to its massless and gapless energy spectrum. This lecture reviews recent advances in the research of electronic and plasmonic terahertz (THz) devices utilizing graphene-based 2D materials, particularly highlighting the THz sources and detectors for use in future 6G/7G THz wireless communications systems. Carrier-injection pumping of graphene can enable negative-dynamic conductivity in the terahertz (THz) range leading to new types of THz lasers. We developed a prototype of a graphene channel laser transistor, demonstrating broadband amplified spontaneous emission from 1 to 7.6 THz and weak single-mode lasing at 5.2 THz at 100K. To increase the operating temperature and lasing radiation intensity, we introduced a physics of the current-driven instability in graphene Dirac plasmons (GDPs), succeeding in tunable resonant THz amplification with the maximal gain of 9% at room temperature. The obtained gain was far beyond the well-known landmark level of the quantum mechanical limit of 2.3% when photons directly interact with electrons without excitation of graphene plasmons. A discovery of a new instability mechanism of GDPs called Coulomb-drag instability will also be introduced. In terms of THz detection, recently we experimentally demonstrated 100-Gbit/s-class fast and sensitive THz detection in a graphene-channel transistor utilizing current-driven plasmonic and photothermoelectric rectification mechanisms. In the final part, future trends and prospects including graphene-based van der Waals heterostructures as well as active control of the parity and time-reversal symmetry are also addressed.



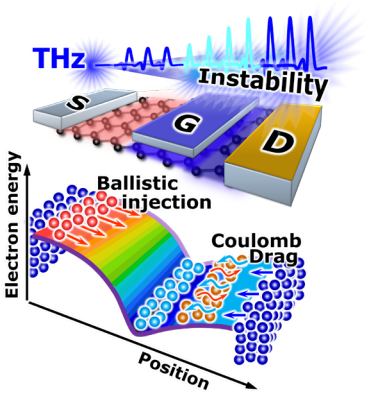
Optically pumped graphene producing THz gain.



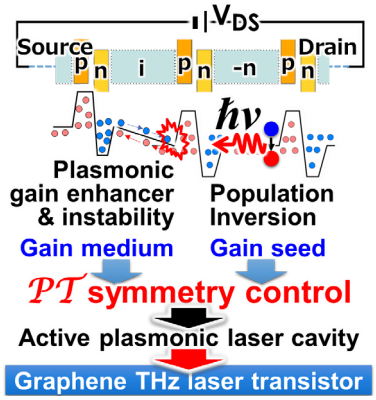
Asymmetric dual-grating gate graphene transistor.



A cutting-edge graphene THz detector.



Coulomb-drag instability of GDPs.



Active control of the PT symmetry in GDPs.

Taiichi Otsuji is a professor at the Research Institute of Electrical Communication (RIEC), Tohoku University, Sendai, Japan. He received the B.S. and M.S. degrees in electronic engineering from Kyushu Institute of Technology, Fukuoka, Japan, in 1982 and 1984, respectively, and the Dr. Eng. degree in electronic engineering from Tokyo Institute of Technology, Tokyo, Japan in 1994. From 1984 to 1999 he worked for NTT Laboratories, Kanagawa, Japan. In 1999 he joined Kyushu Institute of Technology as an associate professor, being a professor in 2002. He joined RIEC, Tohoku University, in 2005. His current research interests include terahertz electronic, photonic and plasmonic materials/devices and their applications. He has authored and co-authored 280 peer-reviewed journal papers and more than 600 conference proceedings including 240 invited presentations, and holds 11 Japanese and 7 US patents. He is the recipient of the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium in 1998, Prizes for Science and Technology in Research Category, the Commendation for Science and Technology by the MEXT, Japan, in 2019, and the 59th Achievement Award of the IEICE (Institute of Electronics, Information, and Communication Engineers), Japan, in 2022. He has served as an IEEE Electron Device Society Distinguished Lecturer since 2013. He is a Fellow of the IEEE, OPTICA (former OSA), and JSAP (Japan Society of Applied Physics), a Senior Member of the IEICE, and a member of the MRS (Materials Research Society) and SPIE (International Society for Optical Engineering).