**IEEE-EDS Japan Joint Chapter**
**IEEE-EDS Distinguished Lecture of the Electron Devices Society**

# Recent advances in 2D electronic and plasmonic terahertz devices based on graphene-based 2D materials

**Professor Taiichi Otsuji**
RIEC: Research Institute of Electrical Communication
Tohoku University, Sendai 9808577, Japan

Graphene has attracted considerable attention due to its massless and gapless energy spectrum. This lecture reviews recent advances in the research of 2D electronic and plasmonic terahertz (THz) devices based on graphene-based 2D materials, particularly highlighting the THz sources and detectors. Carrier-injection pumping of graphene can enable negative-dynamic conductivity in the terahertz (THz) range, which may lead to new types of THz lasers. The dual-gate graphene channel transistor (DG-GFET) structure serves carrier population inversion in the lateral p-i-n junctions under complementary dual-gate biased and forward drain biased conditions, promoting spontaneous incoherent THz light emission. A laser cavity structure implemented in the active gain area can transcend the incoherent light emission to the single-mode lasing. We designed and fabricated the distributed feedback (DFB) DG-GFET. A teeth-brash-shaped DG structure is introduced as the DFB cavity having the fundamental mode at 4.96 THz. Broadband rather intense (~10~100 μW) amplified spontaneous emission from 1 to 7.6 THz and weak (~0.1~1μW) single-mode lasing at 5.2 THz were observed at 100K in different samples. When the substrate-thickness dependent THz photon field distribution could not meet the maximal available gain-overlapping condition, the DFB cavity cannot work properly, resulting in broadband LED-like incoherent emission. To increase the operating temperature and lasing radiation intensity, further enhancement of the THz gain and the cavity Q factor are mandatory. Plasmonic metasurface structures promoting the super-radiance and/or instabilities as well as double-graphene-layered (DGL) van der Waals heterostructures promoting photon/plasmon-assisted resonant tunneling are promising for giant THz gain enhancement. In terms of THz detection, nonlinear nature of graphene plasmons as well as photon/plasmon assisted resonant tunneling in the DGL enable drastic enhancement of detection responsivity that can well outperform any existing room-temp. fast detectors.

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Where: Conference Room, Nano-Spin Bldg. 4F, RIEC, Tohoku University, Katahira Campus
Contact: Prof. Masaki Niwa
Email: niwa.masaki@cies.tohoku.ac.jp
Phone: +81 22 796 3408/3432

**Taiichi Otsuji** 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 Feb. 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. Since 2005 he has been a professor at the Research Institute of Electrical Communication, Tohoku University, Sendai, Japan. His current research interests include terahertz electronic, photonic, and plasmonic materials/devices and their applications. He is authored and co-authored more than 250 peer-reviewed journals. He was awarded the Outstanding Paper Award of the 1997 IEEE GaAs IC Symposium in 1998, and has been served as an IEEE Electron Device Society Distinguished Lecturer since 2013. He is a Fellow of the IEEE, a senior member of the OSA, and a member of the MRS, SPIE, JSAP, and IEICE.