

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

**Plasmon resonances in 2DEG and their applications to
high-speed electron devices**

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This lecture provides the fundamental physics of plasmon resonances in two-dimensional electron gasses (2DEGs) and their applications to high-speed electron devices. The nonlinear dynamics of the 2D plasmons including the plasmon instability and rectification effects is first presented as the operation principle to demonstrate its potentiality of sensitive detection and broadband frequency-tunable intense emission of terahertz radiation. The hydrodynamic nonlinearity of 2D plasmons can rectify the incoming electromagnetic radiation, resulting in photovoltaic detection of terahertz radiation under an asymmetric 2D plasmon cavity boundary. The Doppler-shift effect of the plasma wave velocity under an asymmetric plasmon cavity boundary and/or the spatial modulation of electron transit time in a sub-micrometer scaled 2D plasmon system with a non-uniform 2D electron density distribution can promote the plasmon instability, resulting in self-oscillation of plasmons in the terahertz regime. Second, the device structure that can provide practical detection and emission performances are addressed, which is based on a high-electron mobility transistor and incorporates the authors' original asymmetrically interdigitated dual-grating gates (DGGs). Numerical analysis reveals that in comparison with conventional symmetric DGG structure the asymmetric DGG can substantially improve the detection sensitivity as well as the instability (emissivity) by orders of magnitude. Third, excellent terahertz detection and emission performances including the record detection responsivity at 300 K with a low noise equivalent power, as well as coherent, monochromatic emission beyond 1-THz range at relatively low temperatures are experimentally demonstrated by using InAlAs/InGaAs/InP heterostructure material systems. The frequency dependence of the responsivity is in good agreement with the theory deduced from the plasmonic drag and ratchet effects. Their arrayed monolithic integration and module assembly/package issues are also discussed. Fourth, graphene-based 2D plasmons and their excellent potentialities that can outperform any existing materials/devices are addressed. Finally their applications to terahertz-imaging-based sensing as well as high-speed wireless communications are demonstrated.

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Where: Lecture Room-5, WEST Bldg.-2, 3F, Kyushu University, Ito Campus

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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.