Terahertz Light Emission and Lasing in Current-Driven Graphene-based 2D Nano- and Plasmonic-Structures

Taiichi Otsuji

Tohoku University, Japan

Abstract
Graphene has attracted considerable attention due to its massless and gapless energy spectrum of Dirac Fermions as well as strong light-matter interactions via plasmon-polaritons. This paper highlights recent advances in terahertz (THz) light emission and lasing in current-driven graphene-based 2D nanostructures. The dual-gate graphene channel transistor (DG-GFET) structure promotes 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. The GFET channel consists of a double layer (non-Bernal) epitaxial graphene, providing an intrinsic field-effect mobility exceeding 100,000 cm²/Vs. The teeth-brash-shaped DG forms the DFB cavity having the fundamental mode at 4.96 THz. THz emission from the sample was measured using a Fourier-transform spectrometer with a 4.2K-cooled Si bolometer. Broadband rather intense (~10 µW) amplified spontaneous emission from 1 to 7.6 THz and weak (~0.1 µW) single-mode lasing at 5.2 THz were observed at 100K in different samples. Present structure offers a weak gain overlapping due to poor THz photon-field confinement, resulting in a wide variation from single-mode lasing to broadband incoherent emission depending on graphene quality (carrier momentum relaxation time). Further improvements are now under way.

Conclusion & Significance: Carrier-injection pumping of graphene can enable negative-dynamic conductivity in the THz range, which may lead to a new type of THz lasers. Current-driven plasmon instabilities in dual-grating-gate GFET structures as well as plasmon-assisted resonant tunneling in gated double-graphene-layered nano-capasitor structures can promote the generation and amplification of THz waves, leading to intense, room-temperature THz lasing.

The author thanks V. Ryzhii, S.A. Boubanga-Tombet, T. Watanabe, A. Satou, D. Yadav, G. Tamamushi, M. Ryzhii, A.A. Dubinov, V.V. Popov, V. Mithin, and M.S. Shur for their contributions. This work is supported by JSPS KAKENHI #16H06361 and #18H05331, Japan.

Speaker Publications:


3. Yadav D, Boubanga-Tombet S, Watanabe T, Arnold S, Ryzhii V and Otsuji T. Terahertz wave generation and
detection in double-graphene layered van der Waals heterostructures. 2D Mater. 3 045009 (2016).


Abstract Citation:
Taiichi Otsuji., EuroSciCon Conference on Plasma Physics; Amsterdam, Netherlands- February 21-22, 2020