【Grant-in-Aid for Specially Promoted Research】
Science and Engineering (Engineering)

Title of Project：Creation of graphene terahertz lasers

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Research Area：Engineering, Mathematical and physical sciences

Keyword：Lasers, Carbon materials, Electron devices, Quantum devices, Millimeter waves

【Purpose and Background of the Research】

Terahertz (THz), situated between light-waves and radio-waves, is one of the potential resources, but had long left as an unexplored band because of the luck of microelectronic technology that can generate/detect/ manipulate the electromagnetic waves over the entire THz range. The purpose of this research is to create a new type of graphene-based THz lasers. The current-injection-type THz lasing operation will be obtained even at room temperature by electrically induced p-i-n junction in our original dual-gate graphene-channel field effect transistor (FET) structure.

Graphene is a single-layer carbon-atomic honeycomb lattice crystal in which electrons/ holes hold a linear dispersion relation with zero bandgap and zero effective mass. Since its discovery by K. Novoselov and A. Geim in 2004, graphene has made a great impact on the academic and the industrial world. We have studied the nonequilibrium carrier relaxation/ recombination dynamics in optically/electrically pumped graphene and discovered the negative-dynamic conductivity in the THz range when pumping intensity beyond the threshold. Recently, we have succeeded in observation of an amplified stimulated emission of THz radiation from optically-pumped graphene.

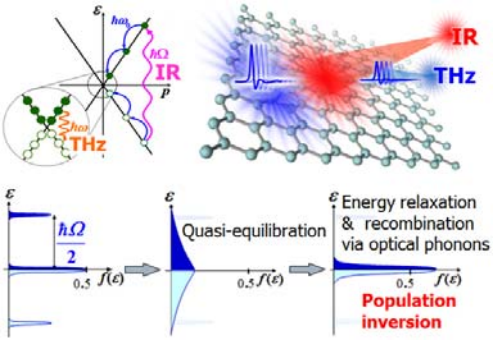

Fig. 1 Population inversion and stimulated THz emission from optically-pumped graphene.

【Research Methods】

The project will start to develop an optically-pumped graphene THz laser. We introduce a novel way to extremely gain the pumping efficiency by promoting the giant plasmon instabilities for the case of current injection-type laser realized in a dual-gate and/or dual-grating-gate FET structures. The final goal is to realize the world-first room-temperature current-injection-type THz lasing operation.

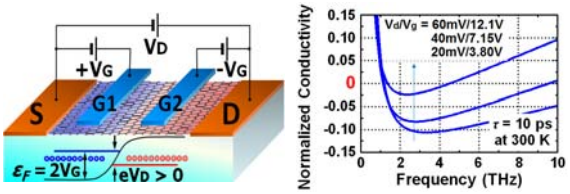

Fig. 2 Structure and simulated negative conductivity of a current-injection-type laser.

【Expected Research Achievements and Scientific Significance】

The birth of the new graphene laser theory is of extremely high scientific significance. The realization of world-first room-temperature operating integrated THz laser devices will give a tremendous impact to revolutionize industry paving the way to the future safe, secure and ubiquitous information and communication societies.

【Publications Relevant to the Project】

・V. Ryzhii, T. Otsuji, and M. Ryzhii, “Negative dynamic conductivity of graphene with optical pumping,” J. Appl. Phys. **101**, 083114 (2007).
・H. Karasawa, T. Komori, T. Watanabe, A. Satou, H. Fukidome, M. Suemitsu, V. Ryzhii, and T. Otsuji, "Observation of amplified stimulated terahertz emission from optically pumped heteroepitaxial graphene-on-silicon materials," J. Infrared Milli. Terahz. Waves, **32**, 655-665 (2011).

【Term of Project】 FY2011-2015

【Budget Allocation】 355,400 Thousand Yen

【Homepage Address and Other Contact Information】

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