2D Plasmon-Polariton Excitation in Plasmonic THz Detector with 2D Diffraction Grating Structure

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We have investigated plasmonic terahertz (THz) detectors with a diffraction grating structure, which utilize hydrodynamic nonlinearities of the two-dimensional (2D) plasmons in transistor channels for the photocurrent rectification, and demonstrated its high potentiality as on-chip, room-temperate operating, high-performance THz detectors for future 6G/7G wireless communication systems [1]. As depicted in Fig. 1(a), the one-dimensional (1D) metallic grating gates are arranged periodically in the channel length direction (*x*-direction) to enable direct coupling of 2D plasmons with incident THz waves. With the conventional 1D structure, however, only 1D oscillation of the 2D plasmons parallel to the *x*-direction is utilized in their operation. Recently, we have proposed the plasmonic THz detector with a novel 2D diffraction grating structure (Fig. 1(b)), consisting of 2D metallic nanoantennas and 1D grating gates, and have experimentally demonstrated that it can detect the polarization component of the incident THz wave parallel to the channel width direction (*y*-direction) owing to the excitation of 2D plasmons oscillating in the *y*-direction and its coupling with those oscillating in the *x*-direction [3]. This result indicates that the utilization of two-dimensionality of the 2D plasmons via the 2D diffraction structure is beneficial to improve functionalities of plasmonic THz detectors as well as their performances, although more comprehensive understanding of 2D natures of the plasmons in the 2D diffraction structure is required for it.

In this paper, we develop a simulation model for the plasmonic THz detector with the 2D diffraction grating structure for comprehensive investigation of 2D natures of the 2D plasmons, and we study the coupling of the 2D plasmon-polaritons oscillating in the *x*- and *y*-directions as one of the most fundamental properties. Our simulation model is based on 2D hydrodynamic equations self-consistently coupled with 3D Maxwell's equations (see Fig. 2 for the details). Here, we chose device parameters for an InGaAs-HEMT-based plasmonic detector (see Fig. 1), and we conducted simulations of 2D plasmon-polariton excitation in the detector by the THz wave normally incident on the detector with polarization parallel to the *y*-direction and with its frequency swept in the THz range. Figure 3 shows the frequency characteristics of the maximum absolute values of the electric field components in the channel. Among the several peaks corresponding to plasmon resonances, it is seen that the intensities of the peaks for *x*- and *y*-components at 1.9 THz are at the same level, meaning that the mode in the *y*-direction excited by the incident THz wave is strongly coupled to the mode in the *x*-direction via the 2D diffraction grating structure (see also the field distributions at 1.9 THz in Fig. 4). This result suggests that the 2D diffraction grating structure enables the coupling between the plasmon modes in *x*- and *y*-directions. This work was financially supported by JSPS KAKENHI #18K04277, Japan.

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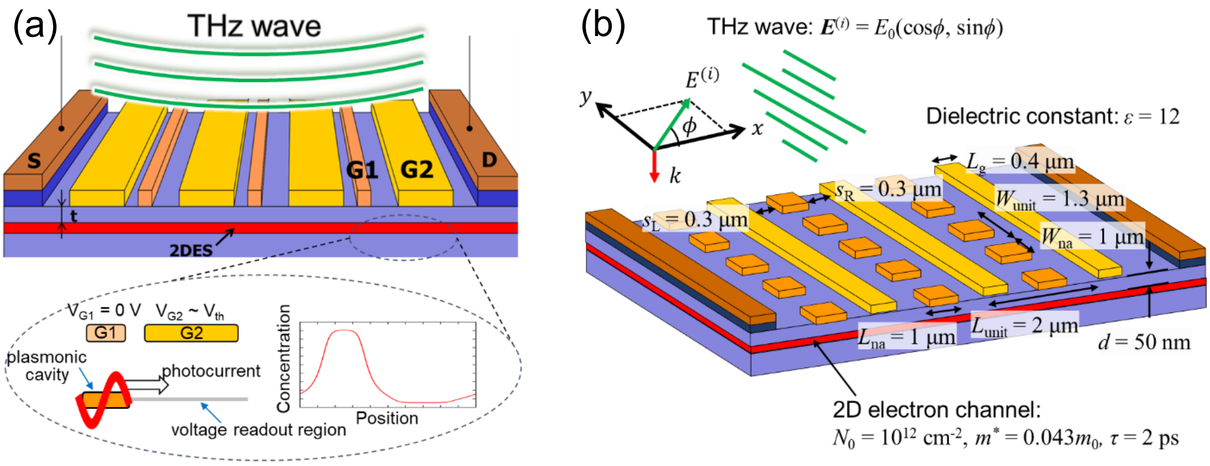

Fig.1: Schematic views of a plasmonic THz detector with the conventional 1D metallic grating gates and (b) a plasmonic THz detector with 2D metallic nano-antennas and 1D grating gates.

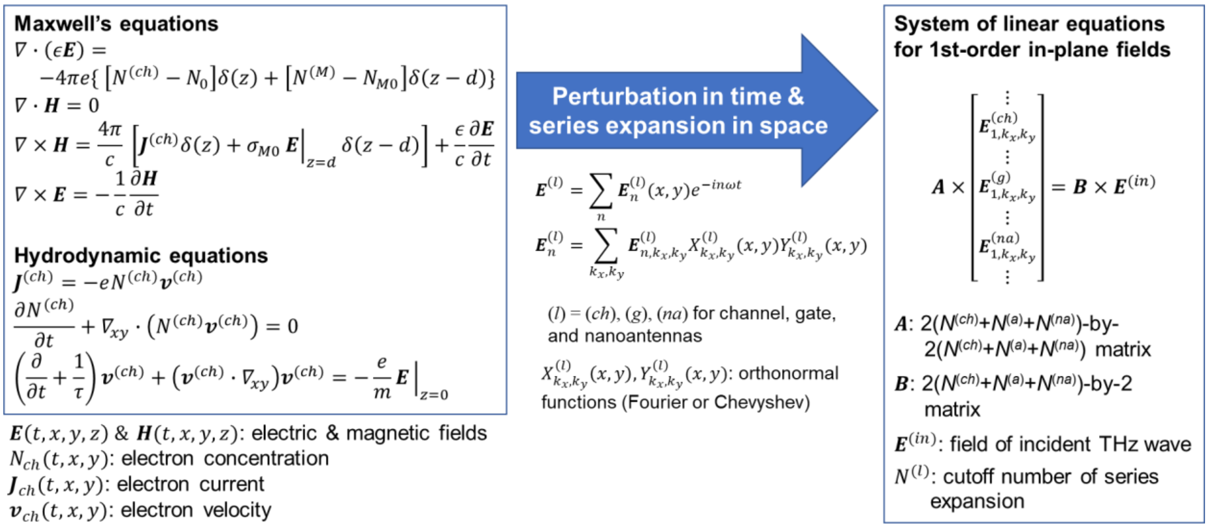

Fig.2: A simulation model developed for the plasmonic THz detector with the 2D diffraction grating structure.

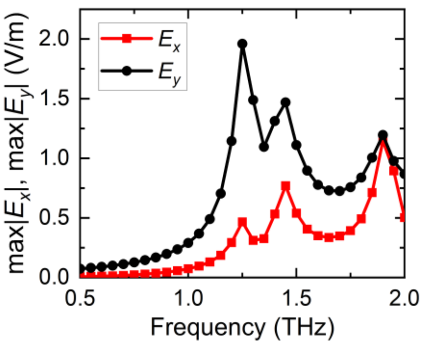

Fig.3: Frequency characteristics of the maximum absolute value of the electric field component in the channel.

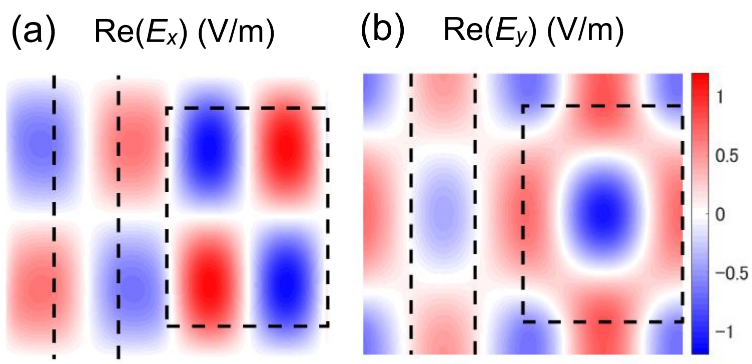

Fig.4: Electric field distribution in the channel at 1.9 THz in (a) x-direction and (b) y-direction.

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