Improving of Plasmon Controllability in Graphene by Electric or Magnetic Fields

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Tunability of graphene plasmons by external electric and magnetic fields will enable us to develop programmable plasmonic circuits and metamaterials. Beyond frequency tuning of a graphene plasmon cavity, which has been demonstrated in a variety of structures, we demonstrate active spatial control of graphene plasmons by tailoring carrier density profile. We also show almost dissipationless plasmon transport in one-dimensional edge channels formed under a magnetic field.

To control the spatial carrier density profile in graphene, we used a dual-back-gate structure consisting of a patterned ZnO film and a lightly-doped Si substrate (Fig. 1). Conductivity of the ZnO film was carefully chosen to minimize the disturbance of the electromagnetic environment. We deduced plasmon reflectivity at electronic boundaries defined by the gate biases from measured transmission spectra in the THz range. The reflectivity can be varied continuously by the carrier density difference of graphene regions on the ZnO and Si back gates [1]. We also show the imaging of plasmon reflection at a carrier density boundary by scattering-type SNOM [2].

To investigate plasmon propagation in edge channels under magnetic field, we prepared disk-shaped graphene [Fig. 2(a)]. Plasmon pulse with a time width of a few tens of pico-seconds is excited by a voltage pulse to a gate electrode and then detected as a time dependent current by an oscilloscope through another gate electrode. Under perpendicular magnetic field, the plasmon pulse goes around in a chiral one-dimensional channel along the edge of the graphene. In the quantum Hall effect regime, the dissipation is strongly suppressed and the decay length reaches 5 mm. This allows us to measure the evolution of the plasmon pulse shape by the dispersion in time domain [Fig. 2(b)] [3].

[1] N.-H. Tu et al., arXiv:1911.08672 (to be published in Communications Materials).

[2] M. Takamura et al., ACS Photon. **6**, 947 (2019). [3] N. Kumada et al., PRL **113**, 266601 (2014).

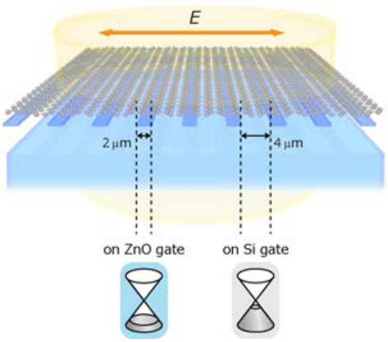

Fig. 1: Schematic representation of a graphene device with dual back gates for THz spectroscopy.

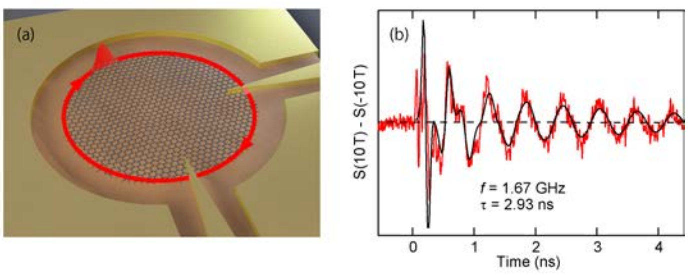

Fig. 2: (a) Schematic of a device for 50-GHz time-domain measurements. The perimeter of graphene is 1 mm. (b) Current as a function of time. Plasmon pulse is injected at $t = 0$.