Edge Magnetoplasmon in Graphene Investigated by Frequency and Time Domain Measurements

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Abstract

Chiral edge channels in a quantum Hall effect regime can be regarded as ideal one-dimensional channels, in which charge carriers are immune to backscattering. Edge magnetoplasmons (EMPs), which are collective charge excitations in the QH edge channels, can travel more than a few millimeters coherently and have a potential for the applications to plasmonic devices. One expects that graphene has advantages over conventional semiconductor two-dimensional electron systems by the lower transport loss and narrower transverse width of EMPs. However, even fundamental aspects of EMPs in graphene such as dispersion and decay are yet to be measured.

In this work, we show the velocity [1,2], the dispersion relation, and the decay time of EMPs in graphene measured by high-frequency electronic techniques with the frequency range up to 50 GHz. We fabricated a resonator of EMPs in graphene and measured the orbital motion of EMPs in either frequency or time domain. Frequency domain measurement shows resonant frequencies of the fundamental and harmonic modes of EMPs. Dispersion relation derived from the transmission spectra agrees with theory for a steep edge potential, where EMPs are confined in a narrow strip with a width less than 10 nm. The time domain measurement directly shows the time evolution of the EMP pulse, from which the EMP decay time is obtained. At low temperature (T < 10 K), the decay time is much larger than the period of the EMP modes. The EMP decay time increases with decreasing frequency, indicating that the dissipation is caused through the capacitive coupling between EMPs and the localized states induced by potential fluctuations. At higher temperature (T > 10 K), on the other hand, the decay time is no longer frequency dependent. This can be explained by finite longitudinal conductance in the interior of graphene. These pieces of information are essential for plasmonic applications and understanding high-frequency charge dynamics in graphene.

References

[1] I. Petkovic et al. Phys. Rev. Lett. **110** (2013) 016801.
[2] N. Kumada et al. Nature Commun. **4** (2013) 1363.

Figures

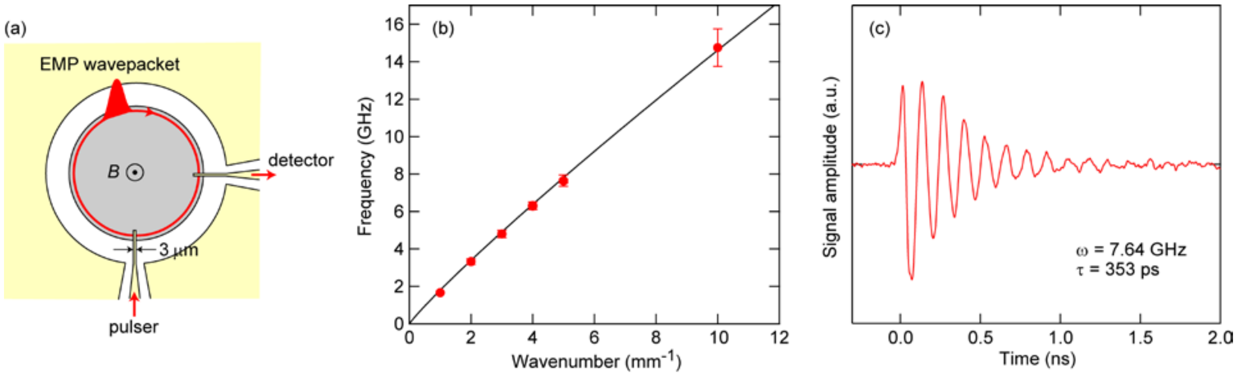

Figure caption: (a) Device structure. Graphene is circular shaped with the perimeter of 200 or 1000 μm. Two high-frequency lines to inject and detect EMPs are capacitively coupled to graphene. (b) Dispersion relation of EMPs determined by frequency domain measurement. The magnetic field is set to form the ν = 2 quantum Hall state. (c) Example of time domain measurement. Orbital motion with decay of EMPs is recorded as a function of time.