Tuning quantum non-local effects in graphene plasmonics

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Plasmons in two-dimensional (2D) electron liquids hosted by ultra-clean semiconductor and semimetal heterostructures display a long-wavelength dispersion that can be captured by essentially classical equations of motion. Upon increasing the plasmon momentum, however, the dispersion substantially departs from its classical value, becoming sensitive to *quantum* effects [1].
We here use high-quality graphene sheets encapsulated in hexagonal boron nitride and in the presence of nearby metal gates to tune the degree of quantum non-locality in the dispersion relation of graphene plasmons. For illumination frequencies in the Terahertz range, acoustic plasmons in these heterojunctions [2] have a group velocity that can be made arbitrarily close to the graphene Fermi velocity by decreasing the graphene-metal distance. In turn, this causes the emergence of large plasmon momenta and therefore a high degree of non-locality. We clearly identify *three* types of quantum effects as keys to understanding the experimental data. The first type is of single-particle nature (and captured by the celebrated Random Phase Approximation) and is related to shape deformations of the Fermi surface during a plasmon oscillation [1]. The second and third types (which are well beyond the Random Phase Approximation) are carrier-density-dependent many-body effects controlled by the *inertia* and *compressibility* of the interacting electron liquid in graphene.

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References

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