Scale-invariant quantum effects and inherited fine-structure in graphene nanonribbon plasmons

Kåre Obel Wedel
Martijn Wubs

DTU Fotonik, Ørsteds Plads 343, Lyngby, Denmark,

kaarewj@fotonik.dtu.dk

Plasmons in graphene have received great attention due to their tuneability, spatial confinement, and relative low losses[1].
Using tight-binding (TB) calculations and with insight from the solution of the Dirac equation for the ribbon geometry[2], we identify a scale-invariant departure point from the classical plasmonic energies for zigzag ribbons as indicated in Figure 1. We relate this transition point to the Fermi level's crossing of the bottom most parabolic band in the band structure and calculate its position analytically within the Dirac approximation. Additionally, we reveal the edge states of the zigzag geometry to contribute with a blue-shift of the energies in contrast with the findings for other graphene nanostructures.
From the TB calculations we extract the spatial distribution of induced charges as illustrated in Figure 2. It is found that the armchair (AC) structure shows an oscillation on every third atomic site. We show that this can also be understood from the solution of the Dirac equation.
We have also identified light-like dispersion of higher-order modes and examined the role of edge states there. Furthermore we have identified regions of the parameter space where the classical and/or Dirac approximation results agree with the TB plasmon energies.

References

[1] F. Javier García de Abajo, ACS Photonics, 1 (2014) 135-152
[2] L. Brey, H. Fertig, Physical Review B, 73 (2006) 235411

Figures

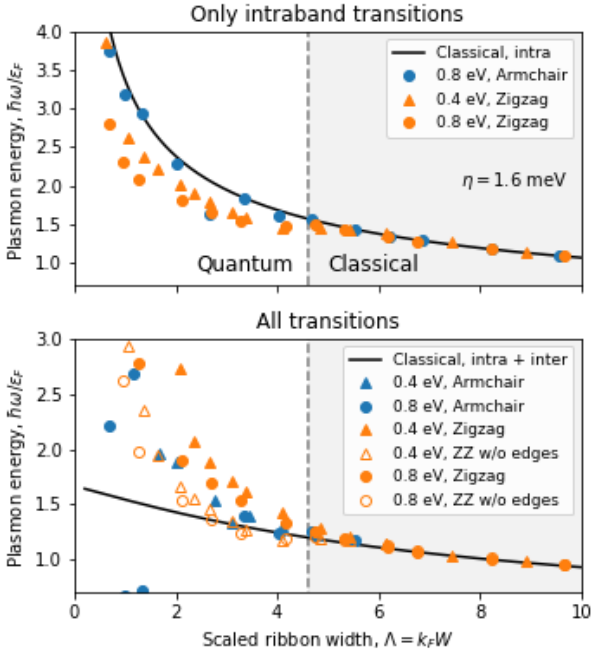

Figure 1: Plasmon energy as a function of width times Fermi wave number. The departure from classical calculations happens around $\Lambda = 4.6$.

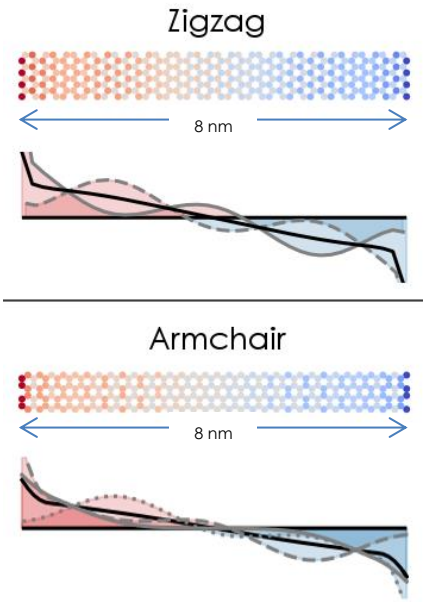

Figure 2: Induced charges for the dipole plasmon modes in 8 nm zigzag and armchair graphene ribbons. Zigzag shows oscillations between the A/B sublattice while armchair follows an every-third-atom periodicity.