Optical versus quantum trajectories in the 2D Dirac equation: Targeting high-frequency performance and noise in graphene transistors

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Due to its analogy to optic rays [1], semiclassical electron trajectories have attracted much attention in understanding/visualizing intriguing phenomena in graphene structures [2-4]. However, similarly to optic rays, such semiclassical trajectories do not properly account for wave interference, diffraction, Klein tunnelling or many-body effects. In this conference, we present quantum trajectories for time-dependent wave packets solution of the 2D Dirac equation that fully overcome the mentioned semiclassical drawbacks [5]. In particular, from the Dirac Hamiltonian, a velocity field can be found. Then, quantum (Bohmian) trajectories can be constructed (Fig. 2), which, by construction, exactly reproduce the probability presence (Fig. 1). In the figures, an example is presented where an electron impinges on a smooth n-p junction. We see that even in such simple scenarios optical trajectories (dashed lines) can provide a misleading understanding/visualization of the dynamics when compared with the mentioned exact quantum trajectories (solid lines).

In this conference we will show that relying in optical rays to understand graphene device performances or develop semi-classical simulation tools can lead to unphysical results, even at simple scenarios. On the contrary, we show that these quantum (Bohmian) trajectories are free from these drawbacks and, in addition, they are especially suited to study noise and high frequency performances of graphene devices [6,7].

Figures

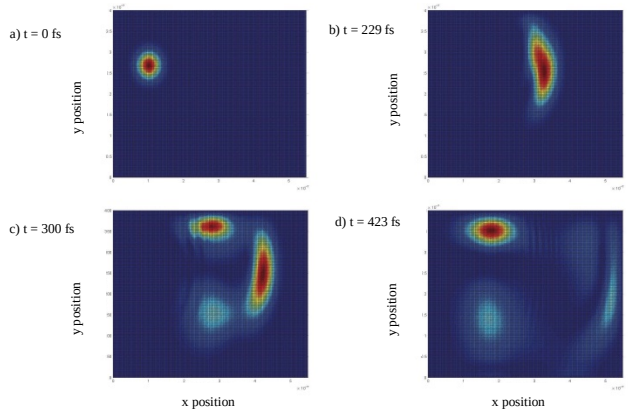

Fig. 1 Presence probability evolution of an electron wave packet impinging on a 200 nm smooth n-p junction (see inset of Fig. 2). The wave packet splits into a transmitted and a reflected component.

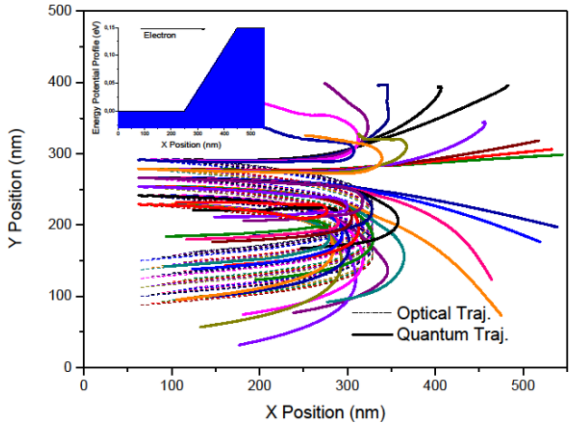

Fig. 2 Quantum (exact) and optical (approximated) trajectories in a smooth n-p junction (inset). Quantum trajectories reproduce the transmitted part of the wave packet dynamics, while optical trajectories are all reflected.

References

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