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Effect of viscosity on stopping power for a charged particle moving above two-dimensional electron gas

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The interaction of charged particles with matter is an essential issue for a variety of physical systems, in which most intriguing is perhaps stopping power and the perturbed electron gas density induced by the charged particle in the interaction process. The stopping power, i.e., the energy lost per unit path length, is a substantial quantity used to predict and understand the effects of particle radiation in the matter, ion ranges, and the energy deposited. It is a measure of the ability of a material to slow down energetic particles that travel above the 2D sheet and 3D bulk[1].

With technological development in the area of miniaturized devices and the advances in nanofabrication techniques, plasmonic materials containing fully degenerate electrons have recently received renewed attention. For accurately understanding the dynamics of a 2D quantum electron gas, the use of the quantum hydrodynamic model (QHD) is required, which was developed by solving the nonlinear Schrödinger-Possion or the Wigner-Poisson kinetic models.

In two-dimensional (2D) electron systems, the viscous flow is dominant when electron-electron collisions occur more frequently than the impurity or phonon scattering. Many experimental results confirm the theoretically predicted significance of viscous flow in mesoscopic two-dimensional electron gas. However, to the best of our knowledge, viscosity in the two-dimensional quantum electron gas (2DQEG) effect has not been considered in beam-2DQEG interactions. Thus, it is an interesting question to study the strength of the stopping power changed in the viscous 2D quantum electron gases.

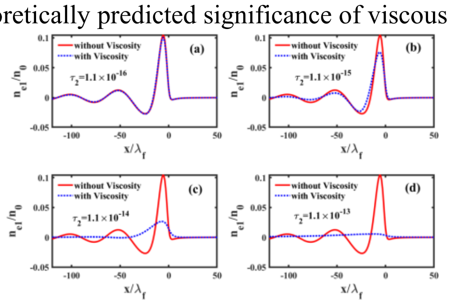

Figure 1. The perturbed electron gas density with and without viscosity

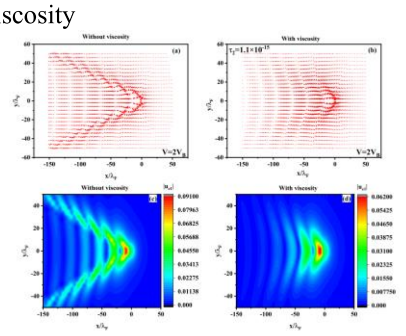

Figure 2. The spatial distribution and magnitude of the velocity vector field with and without viscosity

In this work, the main aim is to study the interaction between charged particles and 2D quantum electron gases in viscosity[2]. We propose a revised quantum hydrodynamic model for a viscous two-dimensional quantum electron based on the model obtained in Ref.[1]. Figures 1-3 illustrate the perturbed electron density, spatial distribution of the velocity vector field and stopping power versus the viscosity. The results show that viscosity affects the spatial distribution and amplitude of the velocity field. And the incident particle will suffer less energy loss due to the weakening of the dynamic electron polarization and induced electric field in 2D electron gas with the viscosity.

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References

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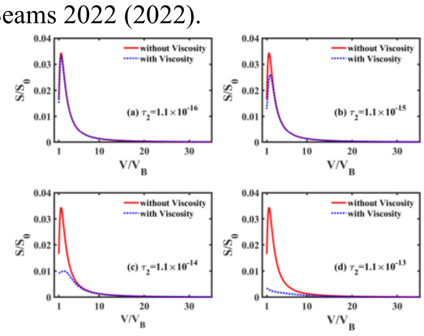

Figure 3. The stopping power S versus the moving speed with and without viscosity