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Asymmetry in the excitation of plasmons by swift particles traversing a surface at oblique incidence

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Synopsis We analyze the asymmetry found in the production of plasmons by fast charged particles entering or leaving a semi-infinite material through a planar surface. In the framework of a semiclassical dielectric formulation, we study how this effect depends on the angle of incidence.

The study of plasmon excitation is of great relevance for the characterisation of surfaces, thin films, and nanoparticles using different charged-particles spectroscopic techniques.In this work we are interested in analyzing any difference that might appear in the excitation of plasmons when a projectile enters or leaves a semi-infinite material through a planar surface, considering a variety of experimental settings. We employ the specular reflection model and the extended pseudo-medium method [1] in order to assess the energy loss rate due to plasmon excitation along the projectile's trajectory.

We consider a particle of charge Z traversing the interface between vacuum and a medium of a given dielectric function $\epsilon(\mathbf{k}, \omega)$ located in the semispace $z < 0$ with a trajectory given by $\mathbf{v}t$ (being $\mathbf{v}$ the velocity). The energy loss rate dW/dt is calculated from the time derivative of the potential induced by the incident particle, evaluated along its trajectory. We obtain two contributions corresponding to the excitation of bulk and surface plasmons. The surface term, which acts on the external particle inside as well as outside the material, remains unchanged whether the particle enters or leaves the material. The bulk term, active only when the particle is inside the material, is made up of two contributions: one comes directly from the projectile, while the other comes from the image charge [2]. Our results (figure 1) show that the energy lost by a charged projectile traversing the planar surface of a semi-infinite material is essentially different for outgoing and incoming trajectories. While for outgoing trajectories the bulk plasmon production is almost identical to that in an infinite medium, an oscillatory structure is observed when the projectile penetrates the material. These oscillations are more pronounced for near-perpendicular trajectories and fade away with increasing angles of incidence. We also notice that, far from the surface, the energy loss rate tends to a constant value independent of the angle. This has been corrected from previous calculations, where a spurious dependence with the incidence angle persisted due to an approximation in the cutoff value of the wave vector $\mathbf{k}$ [3]. Here this approximation has been avoided, and the results are valid for any angle of incidence.

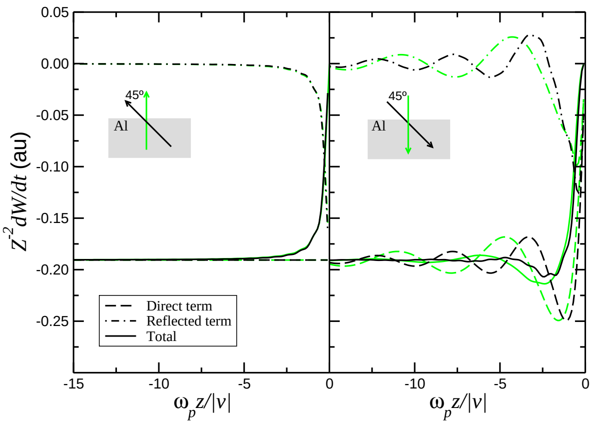

Figure 1. Bulk dW/dt for a charge leaving (left) and entering (right) a semi-infinite aluminum medium ($\omega_p = 0.55$ a.u.), in perpendicular (green) and oblique (black) trajectories. Contributions of the direct and reflected terms are included.

References

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