Interference in the plasmon field excited by a diatomic molecule on metallic cylindrical nanostructures

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Interference in the plasmon field excited by a diatomic molecule on metallic cylindrical nanostructures

S. Segui[*‡ 1], **J. L. Gervasoni**[*†‡ 2], **N. R. Arista**[*† 3]

[*] Centro Atómico Bariloche (CNEA) Av. Bustillo 9500, 8400 S. C. de Bariloche, Río Negro, Argentina.
[†] Instituto Balseiro (CNEA - UNCuyo) Av. Bustillo 9500, 8400 S. C. de Bariloche, Río Negro, Argentina.
[‡] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) Argentina.

Synopsis In this work we analyze the fluctuations of the electronic density $\Delta\rho$ and the average number of the excited plasmons, for the case of the diatomic charged molecule traveling near or passing through a metallic nanocylinder at different positions, and compare the results with the case of a single particle.

The interaction of structured projectiles with polarizable media has gained visibility in recent years due to the interest of the scientific community in the adsorption of molecules on surfaces and nanoparticles. For instance, the detection and analysis of the composition of molecules or structures adsorbed on a metallic surface can be accomplished using surface plasmon resonance techniques [1]. It is therefore desirable to have a complete description of the coupling of plasmon fields with such systems. The purpose of this communication is to study the interferences that can occur when a charged diatomic molecule interacts with the plasmon field induced in a cylindrical nanostructure, such as a wire or a tube.

Plasmons represent perturbations of the electronic charge distribution of the solid; in an infinite medium, they are spatially localized in an average distance of the order of the velocity of the incident projectile divided by the characteristic plasma frequency of the material.

In this work we use a coherent states formulation to depict the interaction of the incident particles with the plasmon field, based on the formalisms developed for cylindrical geometry [2, 3]. Within this framework, plasmon modes are considered as a set of harmonic oscillators with characteristic frequencies $\omega_\nu(k)$. The unperturbed plasmon field is described by its corresponding hamiltonian, and the temporal evolution of the plasmon field interacting with the external particles can be obtained in an exact quantum mechanical way as coherent states.

We consider the incident molecule (external charge distribution) as formed by two point particles of charge Ze, separated by a fixed distance d and traveling along a rectilinear trajectory with constant mass center velocity. With these elements, we evaluate the wake potential, the variation of electronic density and other relevant quantities for different configurations of dimers traveling in the proximity or through tubes and wires. As an example, figure 1 shows the induced charge density on the surface of a metallic wire (aluminum, with plasmon frequency $\omega_P = 0.55$ a.u.) due to the action of a diatomic Hydrogen molecule ($Z = 1$) oriented with its axis perpendicular to the velocity and travelling on an external trajectory, parallel to the wire's axis.

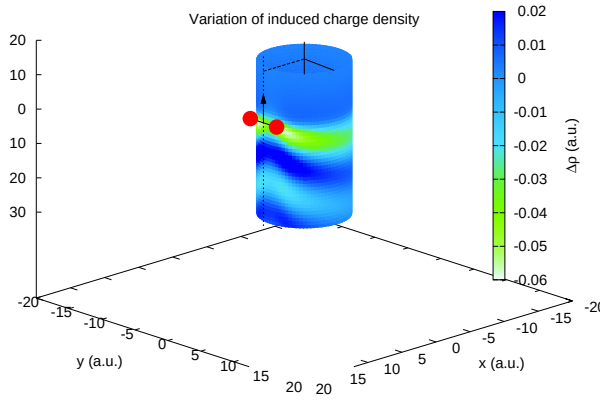

Figure 1. Variation of the induced charge density on an aluminum wire of radius $a = 5$ a.u. by a diatomic molecule with charges $Z = 1$. Velocity of the center of mass $v = 2$ a.u.; interatomic distance $d = 4$ a.u.; distance from the trajectory to the wire's axis $\rho_0 = 6$ a.u.

References

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[1] E-mail: segui@cab.cnea.gov.ar
[2] E-mail: gervason@cab.cnea.gov.ar
[3] E-mail: arista@cab.cnea.gov.ar