Surface Plasmon stimulated photoemission process at metal gratings : Theory and Experiments

A. Sadou* , M. Raynaud †, G. Duchateau* , G. Geoffroy* , P. Martin* and H. Jouin*

* Univ. Bordeaux, CNRS, CEA, CELIA, UMR 5107, F-33400 Talence, France
† CEA/DSM/IRAMIS/LSI, CNRS, Ecole Polytechnique, 91128 Palaiseau, France

Synopsis : Energy spectra related to the Surface Plasmon enhanced electron emission process at gold surfaces have been measured and calculated. Comparisons between theoretical and experimental spectra allow to obtain the amplitude of the Surface Plasmon field.

Surface Plasmon (SP) excitation by femtosecond laser pulses at metal gratings or at metallic nanoparticles has attracted considerable interest over the last decade. As SP excitation allows to concentrate and channel the incident light and also to induce a strong absorption of the laser energy, the number and the kinetic energy of the ejected electrons is drastically increased with respect to the case of a standard photoelectric effect even for modest laser intensities in the range 10^9 – 10^{11} W/cm^2 [1]. This process can lead to the generation of intense and short electron sources since the SP lifetime is of the same order as the laser pulse duration.

We have developed a model [2] in which the SP stimulated photoemission process is treated as a two steps mechanism. The first one which considers electronic transitions from the metallic conduction band towards the solid continuum due to the SP field has been initially treated by means of the perturbative quantum-mechanical approach called Jellium-Volkov (JV) [3]. This description has been recently improved through the numerical resolution of the Time Dependent Schrödinger Equation (TDSE) in one spatial dimension (the coordinate perpendicular to the surface) [3-4]. In the second step, we describe classically the motion of the freed electrons in the two components of the inhomogeneous oscillating SP field outside the metal in which they gain more or less energy depending on their initial conditions provided by the quantum calculations of the first step in terms of ejection energy, emission angle and instants of release. The enhancement factor ($\eta = E_{SP} / E_0$, with E_{SP} and E_0 the amplitudes of the SP field and of the laser one, respectively) which is the only free parameter of the model is obtained by means of comparisons between theoretical and experimental energy spectra. Experiments have been performed by focusing the laser beam (800 nm, 58 fs and intensities in the range 10^9 – 10^{10} W/cm^2) with p-polarization on a sinusoidal gold grating with 150 grooves per millimeter at an angle of incidence of 65° required for SP excitation in these conditions.

When the JV approach is used to describe the first step, calculations lead to a good agreement with experimental spectra for η values around 120 in the intensity range studied here [2] (η=135 in the case presented in Fig.1). However, this value is overestimated due to the somewhat inaccurate primary energy spectra provided by the JV method. Preliminary calculations using the TDSE resolution seem to indicate that the η factor is of the order of those calculated in [5] for continuous SP excitation (some tens).

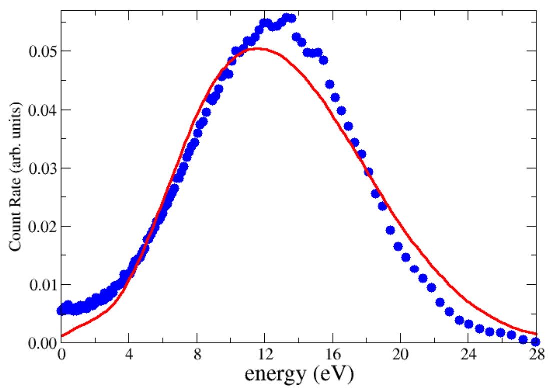

Figure 1. SP enhanced emission spectra of a gold grating as a function of electron energy for a 800 nm, 58 fs FWHM laser pulse of intensity 8.1 GW/cm^2. ● : Experiment , full line : calculation with η=135.

References

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