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CAIRO UNIVERSITY

FACULTY OF ENGINEERING

A STATISTICAL INTERPRETATION FOR ABOVE THRESHOLD IONIZATION USING A SEMICLASSICAL LASER PULSE MODEL

THESIS SUBMITTED TO

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ABSTRACT

A semiclassical model for highly intense laser pulses is introduced. Such pulses are often used to study Above Threshold Ionization which is a non-perturbative multiphoton process. Pertubation theory as well as other approximate techniques had failed to provide agreement with experiment and had constantly pointed to the importance of the modeling of the laser pulse itself. The model presented here makes use of a semiclassical photon which has a finite dimension. The pulse under consideration can be divided into elementary cells each having the same transverse size of the photon, each cell is associated with a characteristic interaction length, that shows a unique dependence on the intensity. The relation between the characteristic length and the intensity is derived from comparisons with experiments. It is shown that the characteristic length varies as the intensity to the power 0.75, independent of the experimental setup or the gas under consideration. Along the interaction length, it is shown than an atom absorbes a number of

photons that follows a Poisson's distribution, which is characterized by an average number of photons per cell. This average number corresponds to the highest peak of the spectra of the electron. The relative strength of the other peaks is statistically evaluated using the Poisson's formula. The highest peak shifts to higher energies as intensity is increased. In the mean while the model predicts that the lower energy peaks are progressively suppressed. This is a typical behaviour of above threshold ionization. Nonetheless, the peak suppression resulting from the shift of the peaks of the Poisson's distribution is quite weak. To overcome such a short coming, the ponderomotive effects should be incorporated.

In the present model, a symmetric pulse having an intensity profile with slowly rising and decaying times has been utilized to include the effect of the ponderomotive potential. Such an approach produces reasonable peak suppression, especially if compared to the energy constraint relationship derived in the Keldysh-Reiss type of solutions. The resulting spectra provide a reasonable, and to some extent, quantitative agreement with experiment.

NOMENCALTURES

h	Planck's constant
$\hbar$	$h/2\pi$
ω	Temporal angular frequency
I	Intensity
MPI	Multiphoton ionization
ATI	Above threshold ionization
$\bar{I}$	Average intensity
I_{eff}	Effective intensity
$\bar{I}_{max}$	Average maximum intensity
E_p	Pulse energy
T_p	Pulse duration
r_f	Radius of focus of the laser beam
I_s	Saturation intensity
$\psi(r)$	Wave function
$H_{5/4}$	Hankel function of order 5/4
$\underline{P}$	Momentum operator
P_o	Energy devided by C
$\underline{X}_s$	Schrödinger operator
H	Hamiltonian
$\underline{S}$	Generators of S(3,C) group
$\underline{R}$	Position operator

λ	Wave length
ΔR_a	Uncertainty in R_a
ΔR_b	Uncertainty in R_b
r_γ	Radius of the photon
r_e	Radius of the electron
α	Fine structure constant
V_p	Pulse volume
V_c	Cell volume
η	Characteristic length
C_o	Number of cells
N_o	Number of photons
$\bar{N}$	Average numer of photons per cell
V_o	Initial velocity
$V(t)$	Instanenious velocity
E_o	Amplitude of the electric field
Δ_o	Amplitude of the ponderomotive potential energy
$\underline{B}$	Magnetic induction
W_j	Correction factor at ionization energy E_j
Δ	Tha value of the ponderomotive potential energy at any position in the pulse

CONTENTS