High energy ionization by photoabsorption of a two electron atom or ion

T. Surić[1], E.G. Drukarev[2] and R.H. Pratt[3]

[1]*R. Bošković Institute, P. O. Box 1016, 10000 Zagreb, Croatia*
[2] *Petersburg Nuclear Physics Institute Gatchina, St. Petersburg 188350, Russia*
[3]*Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260, USA*

We describe within a unified nonrelativistic approach single and multiple ionization by photoabsorption at high incident photon energies ω (but still $\omega \ll m$). These processes, involving a high energy photon, can be understood in terms of singularities of the many–body Coulombic potential. These singularities, at points where any two particles (e–e and e-N) coalesce, are reflected in the singularities of the initial and final state wave functions (at these points wave functions are non–differentiable), and the singularities of the electron–radiation interaction.

The matrix elements for these radiation processes, involving these singular functions, can be understood as a generalized Fourier transform (in large electron momenta) of a function with singularities [1]. Since photoabsorption at high photon energies requires at least one large electron momentum, the analysis is equivalent to the analysis of the asymptotics of Fourier transforms [1]. The asymptotic behavior of Fourier transforms of singular functions is determined, according to Fourier transform theory [2], by the singularities of these functions.

Our discussion is general and does not depend on the choice of the form [length, velocity, acceleration etc.] of the photoionization matrix element. There is advantage in using acceleration form for high energy calculations, explained by the fact that the e–γ interaction in this form contains information (unlike in velocity or length form) on the singularities of the three body Coulombic potential. Within our unified approach we explain both (for single ionization) the persistent high energy deviations from independent particle approximation predictions [3, 4] and (for double ionization) the shake–off and quasi–free contributions [5].

We use this approach [1] here to study the high energy total cross sections for single ionization and the spectrum and total cross section for double ionization of a two–electron atom. We are able to extract the slowly converging Stobbe factor from all of the cross sections, thereby achieving fast convergence of the results at high energies. This factor depends only on the singularity (e–e or e–N) determined by the kinematics of the process and for ionization from any state is

$$S(\frac{a}{p}) = e^{-\frac{\pi a}{p}} \tag{1}$$

where p is the large electron momentum characteristic for that kinematics, and $a = mZ\alpha$ for processes (like single ionization or double ionization in the shake–off region) involving the e–N singularity, while $a = m\alpha$ for absorption involving the e–e singularity (as in quasi–free double ionization).

[1] T. Surić, E. G. Drukarev, and R. H. Pratt, to be published.

[2] M. J. Lighthill, *Introduction to Fourier Analysis and Generalised Functions,* (Cambridge University Press, Cambridge 1970.)
[3] E. W. B. Dias *et al.*, Phys. Rev. Lett. **78,** 4553 (1997). D. L. Hansen *et al.* Phys. Rev. A **60,** R2641 (1999).
[4] M. Ya Amusia, N. B. Avdonina, E. G. Drukarev, S. T. Manson, and R. H. Pratt, to be published.
[5] E. G. Drukarev, Phys. Rev. A **52,** 3910 (1995).