12-24-2009

Classical modeling of non-sequential double ionization: Recollision, time-delayed ionization, drift, and possible reattachment

Stanley L. Haan
Calvin University

Z. S. Smith
Calvin University

K. N. Shomsky
Calvin University

P. W. Plantinga
Calvin University

Journal of Physics: Conference Series

Classical modeling of non-sequential double ionization: Recollision, time-delayed ionization, drift, and possible reattachment

To cite this article: S L Haan *et al* 2009 *J. Phys.: Conf. Ser.* **194** 112002

Classical modeling of non-sequential double ionization: recollision, time-delayed ionization, drift, and possible reattachment

S L Haan[1], Z S Smith, K N Shomsky, and P W Plantinga

Department of Physics and Astronomy, Calvin College, Grand Rapids, MI 49546, USA

Synopsis We employ 3d classical ensembles to study Non-Sequential Double Ionization (NSDI) of atoms by strong laser fields at visible and infrared wavelengths. We consider in particular the wavelength dependence of final electron drift directions and the net momentum spectra parallel to the laser polarization. We find that as the wavelength is increased the spectrum transitions from a singlet to a doublet, then to a triplet, and finally back to a doublet. We also show that electrons that escape the central potential-energy well during the pulse may nonetheless be bound to the nucleus after laser turnoff.

Classical modeling of Non-Sequential Double Ionization (NSDI) has been shown to provide considerable insight into the dynamics of the recollision and ionization process [1]. In this presentation we consider how the recollision dynamics change with increasing laser wavelength, since longer wavelength implies more energetic recollisions. We consider a range of wavelengths from 483 to 2017 nm at fixed laser intensity 0.5 PW/cm^2. At 483 nm, weak recollisions can lead to a doubly excited state that decays into oppositely directed electrons [2]. At 780 or 800 nm, the most common process is recollision excitation to a singly excited state. The bound electron may boomerang [3] and escape into the backward direction (relative to recollision) at the first laser maximum after the recollision. The free electron is usually swept into the backward direction by the laser, so the electrons drift out as a correlated pair. However, depending on energy and laser phase at recollision, the free electron may be able to overcome the backward push from the laser field and drift into the forward direction [4]. Such electrons are a small part of the total at 800 nm, but become significantly more important at 1314 nm. Having the electrons thus drift in opposite directions gives rise to a central peak in the spectrum. At this long wavelength, the outer peaks are well separated and the central peak distinct, so the spectrum becomes a triplet. At still higher wavelengths there is sufficient energy at recollision to have impact ionization and *two* electrons in the forward direction. That suppresses the center peak, so that the spectrum is again a doublet.

Electrons that escape the nucleus with small drift velocity may still be in the vicinity of the nucleus at laser turnoff, and traveling slowly enough that their net energy may be negative. In other words, they may be bound to the nucleus after the pulse [5]. This classical reattachment is analogous to frustrated tunneling discussed in [6]. We show that these electrons are most likely to be the result of recollision excitation and to have escaped the central potential-energy well nearly concurrently with a field maximum. Whether a specific trajectory leads to reattachment in this nonlinear system is very sensitive to electron velocity as it escapes over the barrier. Thus a solid link to chaos theory is established.

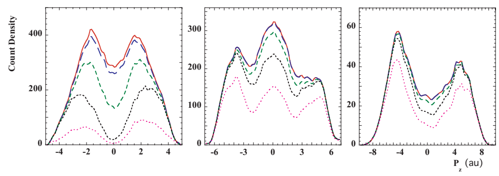

Fig. 1. Spectrum of net longitudinal momentum for I=5x10^{14} W/cm^2 and λ=800 nm (left), 1314 nm (center), and 2017 nm (right), for 5-cycle trapezoidal pulses. Maximum time delays between collision and final ionization are, from bottom to top, 0.06, 0.26, 0.50, and 2.00 cycles. Top curves show full spectra through the end of the pulse.

References

[1] See for example Haan SL, Smith ZS, and VanDyke JS 2008 *Phys. Rev. Lett.* **101** 113001 and references therein.
[2] Haan SL, Smith ZS, Shomsky KN, and Plantinga PW 2008 *J. Phys. B: At. Mol. Opt. Phys.* **41** 211002.
[3] Haan SL and Smith ZS 2007 *Phys. Rev. A* 76 053412.
[4] Haan SL, Smith ZS, Shomsky KN, and Plantinga PW 2009 submitted; arXiv:0901.2554.
[5] Shomsky KN, Smith ZS, and Haan SL 2009, submitted.
[6] Nubbemeyer T, *et al*. 2008 *Phys. Rev. Lett.* 101 233001.

[1] E-mail: haan@calvin.edu

