Photodetachment microscopy in time-dependent fields

Ilya Fabrikant[*1], **Harindranath Ambalampitiya**[*2],

*Department of Physics and Astronomy, University of Nebraska-Lincoln, Lincoln, NE 68588, USA

Synopsis The spatial and temporal interference patterns of classical electron trajectories in the photodetachment process of negative ions in a combined laser and low-frequency fields are investigated using the time dependent Green's function.

Studies of photodetachment processes in static fields [1, 2] allow observation of interference of classical electron trajectories. Recently Yang and Robicheaux [3] showed that in addition to spatial interference, one can also observe temporal interference of electron trajectories if the static field is replaced by a low-frequency THz pulse. Investigation of these processes and similar processes of photoionization of neutral atoms and molecules can give more physical insight into the well known phenomena such as the above threshold ionization and the high-order harmonic generation.

In the present paper we develop a somewhat more general approach based on the electron propagator, or the time-dependent Green's function for the electron motion in a low-frequency field. The photodetachment process is initiated by a high-frequency laser field, and the detached electrons then move towards a detector under the influence of the low-frequency field. We assume that polarizations of the high and low-frequency fields are parallel to each other, and the detector is located at a macroscopic distance away from the source in the plane perpendicular to both fields. The integral form of the Schrödinger equation for the electron outside the source can be written as

$$\psi(\mathbf{r},t) = i \int_{-\infty}^{t} dt' \int d\mathbf{r}' G(\mathbf{r},t,\mathbf{r}',t) H_s(\mathbf{r}',t') \psi(\mathbf{r}',t') \tag{1}$$

where $G(\mathbf{r},t,\mathbf{r}',t')$ is the electron propagator in the low-frequency field without the inclusion of the short-range atomic field. The perturbation $H_s(\mathbf{r}',t')$ represents the interaction of electron with the laser field which is turned on gradually at time t_0 and turned off at time t_2. For an electron in a linearly polarized field, the Green's function is well known and can be expressed as,

$$G(\mathbf{r},t,\mathbf{r}',t') = -i[2\pi i(t-t')]^{-3/2} e^{iR(\mathbf{r},t,\mathbf{r}',t')} \tag{2}$$

where R is the Hamilton's principal function along the electron trajectory. We convert first the integral equation into an integral by replacing $\psi(\mathbf{r}',t')$ in the right-hand side of Eq. (1) by the unperturbed wavefunction of the negative ion and evaluate the integral using the stationary phase method where the sta-

tionary points, t_s', correspond to the initial launching times of electrons from the source with a fixed initial energy. Divergences at the classical caustics are removed by using the uniform Airy function approximation for the integral. Our Green's function approach can easily be extended to the description of complex electron trajectories in the classically forbidden regions.
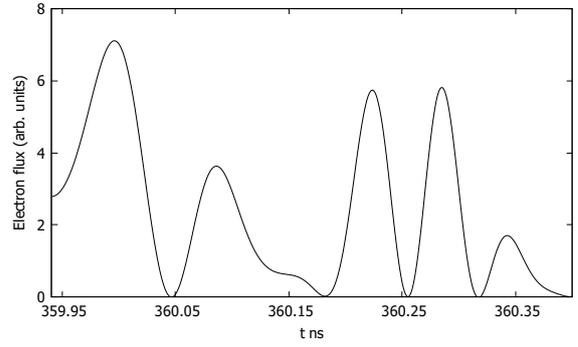

Figure 1. Sample calculation of electron flux as a function of time at the center of the detector located at the distance 0.5 m from the source. The field amplitude is 50 V/cm, and frequency 100 MHz.
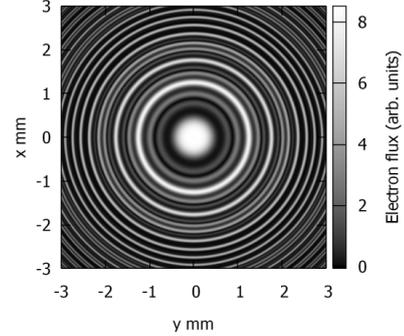

Figure 2. Spatial distribution of electron flux on the detector at laboratory time t=360 ns.

In Figs. 1 and 2 we present examples of temporal and spatial interferences in photodetachment of H^-.

References

[1] I. I Fabrikant 1980 *Sov. Phys. JETP* **52**, 1045

[2] C. Blondel *et al.* 1996 *Phys. Rev. Lett.* **77**, 3755

[3] B. C. Yang and F. Robicheaux 2015 *Phys. Rev. A* **92**, 063410

[1] E-mail: ifabrikant@unl.edu

[2] E-mail: harindranath@huskers.unl.edu