LASER INDUCED ULTRAFAST H_2^+ DYNAMIC AND ATTOSECOND GENERATION

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ABSTRACT

We examine the possibility that a H_2^+ molecular ion driven by a linearly polarized laser field can be considered as a suorce of attosecond pulses. The radiation emission is investigated taking into account the role of the internuclear distance and by changing the angle between the laser field and the molecular axis. We find that the attosecond pulses emission happen when the electron cloud is over one nucleus: on the contrary, when the electron is travelling between the two nuclei the attosecond emission do not takes place.

INTRODUCTION

Atomic and molecular systems, subjected to an intense laser pulse of frequency ω_L, emit electromagnetic radiation whose spectrum consists of odd harmonics of ω_L (up to $300\,\omega_L$). This effect is called High-order Harmonic Generation (HHG).

Highlight

The spectrum is given by the Larmor formula: $$P(\omega)=\frac{4e^2}{3c^3}\left|a_F(\omega)\right|^2$$

The acceleration is a local dynamical quantity, affected by the physical properties of the space where and when the charge is moving.

Applications

It is possible to use this emitted radiation to:

1. Observe the motion of the electron inside the atom or molecule
2. Observe the nuclear motion
3. Use the radiation as an attosecond source.

THEORETICAL MODEL

The model used to study the dynamics of the H_2^+ is a two dimensional one with fixed nuclei approximation. We numerically solve the Time-Dependent Schroedinger Equation

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t)=H_e(t)\Psi(\mathbf{r},t)$$

$$H_e(t)=-\frac{\hbar^2}{2m}\nabla^2+V(\mathbf{r})+V_L(\mathbf{r},t)$$

$$V(\mathbf{r})=-\frac{e^2}{\sqrt{A^2+\left[\mathbf{r}+\mathbf{R}/2\right]^2}}-\frac{e^2}{\sqrt{A^2+\left[\mathbf{r}-\mathbf{R}/2\right]^2}}$$

$$V_L(\mathbf{r},t)=e\,F(t)\,\mathbf{E}_L\cdot\mathbf{r}\,sin(\omega_L t)$$

$$2.62\ a_0 \le R \le 5.5\ a_0$$
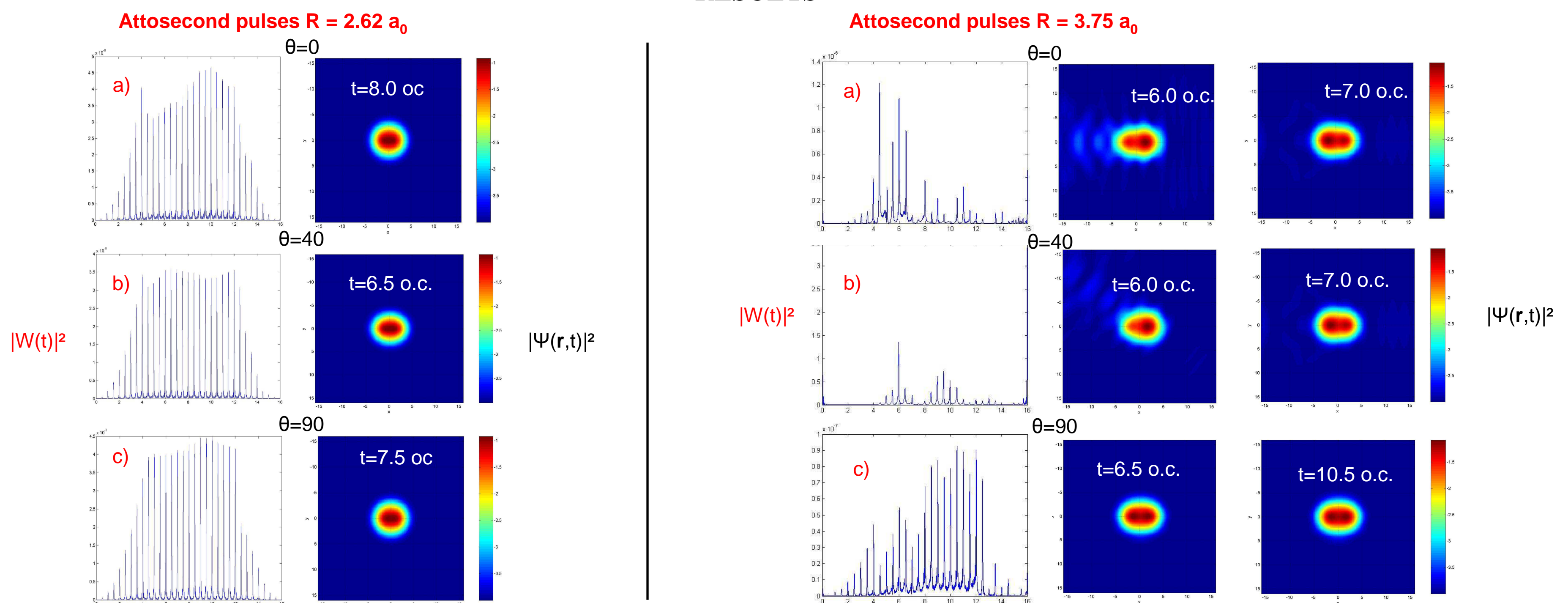
Attosecond pulse generation

The attosecond pulses (1 as = 10^{-18} s) are generated via the process of High order Harmonic Generation. We consider the attosecond generation starting from the Fourier spectrum emitted by the electron. In particular the frequencies emitted in the cut off region are taken into account. These frequencies can be filtered to generate very short pulses.

$$\left|W(t)\right|^2=\left|\int_{\omega_1}^{\omega_2}a_F(\omega)\,e^{-i\omega t}\,\mathrm{d}\omega\right|^2$$

Attosecond pulse

ω_1 and ω_2 are in the cutoff region

RESULTS

Attosecond pulses R = 2.62 a_0

$\theta=0$ — a) — t=8.0 oc

$\theta=40$ — b) — t=6.5 o.c.

$\theta=90$ — c) — t=7.5 oc

$|W(t)|^2$ $|\Psi(r,t)|^2$

Attosecond pulses R = 3.75 a_0

$\theta=0$ — a) — t=6.0 o.c. — t=7.0 o.c.

$\theta=40$ — b) — t=6.0 o.c. — t=7.0 o.c.

$\theta=90$ — c) — t=6.5 o.c. — t=10.5 o.c.

$|W(t)|^2$ $|\Psi(r,t)|^2$

Conclusions

1. when the internuclear distance is small, it is evident a train of attosecond pulses whatever the laser field orientation θ;

2. for internuclear distance greater than 3.0 a_0, the single attosecond pulse is emitted when the electron cloud is over one nucleus; attosecond emission is inhibited when the electron cloud is over both nuclei;

3. when the laser field is orthogonal to the internuclear axis, it is evident only a train of attosecond pulses whatever the internuclear distance.