Ludwig-Maximilians-Universität
München

Bachelors Thesis

The role of excited atomic states in multiphoton ionization

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March 29, 2025

Abstract

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2. Theory

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$$\partial_t u = \mathcal{H}(t)\lambda \tag{2.1}$$

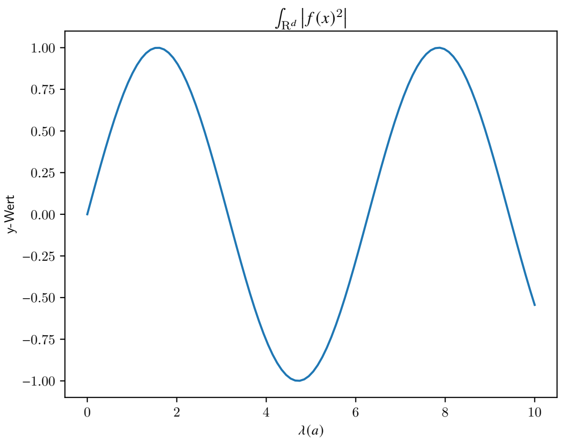

Figure 2.1: Sine function

2.1 Basic Formalism

2.1.1 schrödinger equation

Basic Definitions of schröfinger qe, light dyson series, and strong field s matrix

We want the time evolution of a quantum system in the presence of an external time dependent field in order to describe the strong field ionization later on. The time evolution of a quantum system is given by the time dependent Schrödinger equation and a general hamiltonian

$$i\hbar\frac{\partial}{\partial t}\left|\Psi(t)\right\rangle = \hat{H}(t)\left|\Psi(t)\right\rangle . \tag{2.2}$$

The formal solution depends on the time dependence of the hamiltonian and the physical setting. In the following we assume [1] (IMPORTANT) that $[\hat{H}(t), \hat{H}(t')] = 0$ so we assume some sort of quasi static approximation to the Hamiltons time evolution. The solution is then given by

$$\left|\Psi(t)\right\rangle = e^{-\frac{i}{\hbar}\int_{t_0}^{t}\hat{H}(t')dt'}\left|\Psi(t=0)\right\rangle \tag{2.3}$$

Now its time so establish a physical setting. We have Hydrogen Atom with nucleus and electron described by time indepentent Hamilton $\hat{H}_0$. The external laser Field is descirbed by an time dependent part $\hat{V}(t)$. To describe the interaction of the atom with the laser field we use in the following the dipole approximation.

2.1.2 Light-Matter Interaction

A light wave is defined by the Maxwell equations

$$\begin{aligned} \nabla\cdot\mathbf{E}(t) &= \rho \qquad & \nabla\times\mathbf{E}(t) &= -\frac{\partial\mathbf{B}(t)}{\partial t} \\ \nabla\cdot\mathbf{B}(t) &= 0 \qquad & \nabla\times\mathbf{B}(t) &= \mathbf{J} + \frac{\partial\mathbf{E}(t)}{\partial t} \end{aligned} \tag{2.4}$$

The Maxwell equations are being solved by

$$\begin{aligned} \mathbf{E}(t) &= -\nabla\varphi(t) - \frac{\partial\mathbf{A}(t)}{\partial t} \\ \mathbf{B}(t) &= \nabla\times\mathbf{A}(t) \end{aligned} \tag{2.5}$$

For these solutions we introduced the vector potential $\mathbf{A}(t)$ and the scalar potential $\varphi(t)$. These are not unique such that different choices can result in the same physical setting. In general

$$\begin{aligned} \mathbf{A}(t) &\to \mathbf{A}(t) + \nabla\chi(t) \\ \varphi(t) &\to \varphi(t) - \frac{\partial}{\partial t}\chi(t) \end{aligned} \tag{2.6}$$

also fullfil the Maxwell equations while $\chi(t)$ is an arbitrary smooth function. The arbitrarity of χ is know as gauge freedom and a direct consequenz from the Maxwell equations. Choosing a gauge (i.e a specific χ) is a matter of convenience and can be used to simplify the calculations as presentet in the following.

[1] How? Later. No physical setting bzw no approximations yet. Its better to juistify it later but have a working formalism instead of the other way around.

2.2 Strong Field Approximation

clear defintition of the strong field approximation, and the assumptions that are made.

2.3 Strong Field Ionization

Derivation of

$$\lim_{t\to\infty} |\Psi(t)\rangle = -i \int d^3p \; |\mathbf{p}\rangle \int_{-\infty}^{\infty} dt' \, e^{-\frac{i}{2}\int_{t'}^{\infty} [\mathbf{p}+\mathbf{A}(t')]^2 \, dt'} e^{iI_\mathrm{p} t'} \langle \mathbf{p} + \mathbf{A}(t') | \hat{\mathbf{d}} \cdot \mathbf{E}(t') | \Psi_0 \rangle \tag{2.7}$$

2.4 Multiphoton Ionization

Different types of Ionization, tunneling Ionization, multiphoton

3. Conclusion

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$$\partial \mathbf{A} = \mathfrak{B}$$

$$\int_{\mathbb{R}^d} |f(x)|^2 \,\mathrm{d}x = \int_{\mathbb{R}^d} |\mathcal{F} f(\xi)|^2 \,\mathrm{d}\xi \tag{3.1}$$

$$\mathrm{i}\partial_t u = \mathcal{H}(t) \, |a\rangle \, \lambda \tag{3.2}$$

for this calculation [**?**] was used

A. Appendix A

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B. Appendix B

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