Applied Mathematics and Computation 219 (2013) 8078–8094

Contents lists available at SciVerse ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

Predication of single particle quantum controlling for Yukawa interaction ☆

Quan-Fang Wang

Mechanical and Automation Engineering, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong

ARTICLE INFO

Keywords:
Quantum control
Yukawa interaction
Single particle
Variational method
Numerical experiments

ABSTRACT

In this paper, control problem is addressed for single particle (nucleon or meson) in the Yukawa interaction. Controlling the motion of interacted single particle is the purpose of the theoretical and computational issues. If external control is forcing at one single of the particles in nucleus, a computational approach is employed to find the quantum optimal solution, which transit that single particle from initial ground state to exciting one. Further, numerical demonstration is to interpret the feasibility and effectiveness for 2D case.

1. Introduction

Quantum control (coherent control, inherent control) had been laid on the centre part of physical chemistry and quantum mechanics from 1990's. The field is attracting world wide attention with its extremely changing status and rapidly developed tendency. Scientists, who is striving in the areas, had made outstanding contribution to promote the frontier field [1,4,9,12–14,27,28]. As to coherent control, inherent control for quantum system, there are iteration learning algorithm, genetic algorithm, evolutionary algorithm, and so forth methodologies (cf. [3,10,11,15]). For example, coherent control of molecular system with a sequence of ultra fast pulses can select the molecular structures, break the specific bonds and even change a reaction path. A great efforts make the success of the existing methodologies to control quantum system theoretically and experimentally.

What is the present interesting point? What perspective direction would be going in the future? Whether one can make a big breakthrough? The rising questions in here are always asked as standing at various viewpoints. Actually, the highlighted work is to control the nucleus. It is enough for us to consider that if one can steer the nuclei controlling, no matter use what kind of methods with what devices and technologies, it can be changed simplicity of a chemical reaction as well as a physical experiment. For instance, chemical reaction is taken place under appropriate conditions (pressure, temperature, time duration, etc). As a well defined reaction, it can be recorded and repeated. But no answer or incredible to the query, why it happened. In contrast, "quantum nuclei control" quite like as the role of "God", because of touching a stone, and turning it into gold. Such a wonderful thing, just like IPS 'induced pluripotent state' cell, is a dream for people in this field certainly.

Our work is to control single particle, which acting each other in the Yukawa interaction, theoretically and mathematically. Controlling of its motion and population is the goal of the work. Presently, in real laboratory experiments, external control represents ultrafast (femisecond, attosecond) laser pulse in high intensity (e.g. $>10^{19}$ W/cm^2).

The target of this article is inclusive of three points:

☆ Cite poster "Single particle quantum controlling in Yukawa interaction" [22] at European Science Foundation conference "Chemical Control with Electrons and Photons" Obergurgl, Austria, 2008.

E-mail addresses: quanfangwang@hotmail.com, qfwang@mae.cuhk.edu.hk

0096-3003/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.amc.2013.02.038

(1) Numerical approach would be considered for controlling quantum systems of single particle appeared in the Yukawa interaction (cf. [8,19,23,29]).
(2) The wave propagation would be effectively controlled by supposed shaped high intensity ultra-short laser pulse, see [17,18,24].
(3) A perspective application is to provide theoretical and computational prediction for further real laboratory experiments.

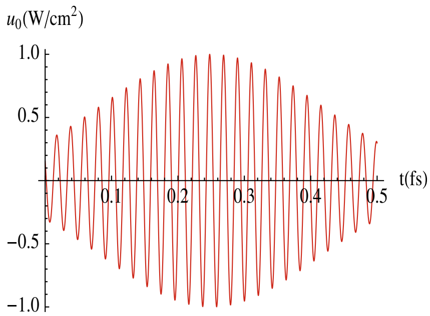

Fig. 1. Initial guess control $u_0(t), t \in [0, 0.5]$.

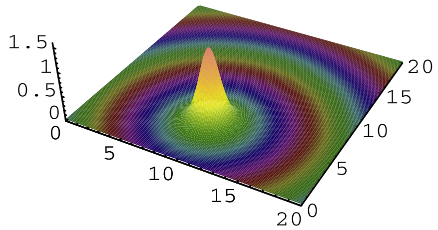

Fig. 2. Initial ground state $\psi(0, \mathbf{x})$.

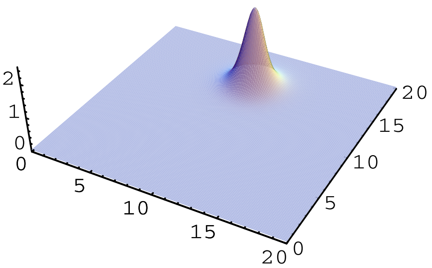

Fig. 3. Initial ground state $\phi(0, \mathbf{x})$.

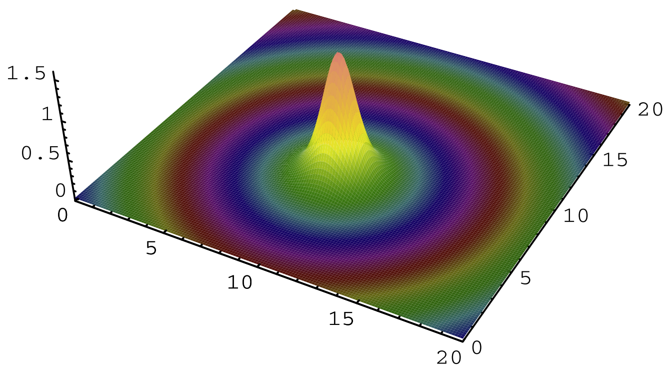

Fig. 4. Exciting state $\psi(T, \mathbf{x})$.