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RESEARCH ARTICLE

The Quantum Entanglement Dynamics Induced by Non-Linear Interaction between a Moving Nano Molecule and a Two-Mode Field with Two-Photon Transitions Using Reduced Von Neumann Entropy and Jaynes-Cummings Model for Human Cancer Cells, Tissues and Tumors Diagnosis

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Abstract

In the current study, an analytical model is presented to analyze interaction between a moving 6-Methoxy-8-[[6-Methoxy-8-[[6-Methoxy-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H Isoquinolin-7-ol and a two-mode field in the presence of two-photon transitions and in the coupling regime dependent on intensity for human cancer cells, tissues and tumors diagnosis. After identifying the initial condition of the nano molecule and the field, explicit form of state vector of the system is obtained by time evolution operator. In order to study the entanglement between two subsystems of nano molecule and field, the temporal behavior of Von Neumann entropy is evaluated as a measure of degree of entanglement for human cancer cells, tissues and tumors diagnosis.

Keywords

Quantum entanglement dynamics, Non-Linear interaction, Two-Mode field, Two-Photon transitions, Intensity-Dependent coupling, Jaynes-Cummings model, Von Neumann entropy, Human cancer cells, Tissues and tumors, Diagnosis

Introduction

Entanglement is a form of quantum superposition and is one of the major characteristics of quantum mechanics which has not similar concept in classic mechanics [1-50]. Since this quantity is used as a building block for describing structural characteristics of combined quantum systems, analyzing the characteristics of entanglement of subsystems is interested. One of the most important available physical systems that can be a suitable alternative for producing these states is nano molecule-field interaction system which describes by Jaynes-Cummings model for human cancer cells, tissues and tumors diagnosis [51-93]. The importance of the model is due to the fact that the results obtained from this fully quantum model is compatible with experimental experiences [94-117]. In the current paper, the interaction between a moving 6-Methoxy-8-[[6-Methoxy-8-[[6-Methoxy-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-ol and a two-mode field for human cancer cells, tissues and tumors diagnosis is investigated. It is assumed that nano molecule transitions are accompanied by two-photon emissions and nano molecule-field coupling is dependent on intensity for human cancer cells, tissues and tumors

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diagnosis. After finding the accurate Hamiltonian form for describing the interaction, state vector of system obtains in a fully analytical manner. Finally, quantum entanglement between nano molecule and field subsystems is evaluated using reduced Von Neumann entropy for human cancer cells, tissues and tumors diagnosis.

Despite diagnostic, preventive and therapeutic advances, the growing incidence of cancer and the high rate of mortality among patients affected by specific cancer types indicate that current clinical measures are not ideally useful in eradicating cancer. Chemoresistance and subsequent disease relapse are believed to be mainly driven by the cell-molecular heterogeneity of human cancer cells, tumors and tissues, which necessitate personalized approaches to deal with uniquely complex genetic profile of each patient's tumor. Such personalized medicinal therapies require dissection of cancer molecular profiles in order to profoundly understand the mechanisms underlying drug resistance and disease recurrence. Technological advances in comparative genome sequencing have begun to result in identification of common somatic mutations in specific cancer subtypes that potentially constitute bases for prognostic and diagnostic biomarkers and present novel therapeutic targets. These targets have to be tested in reliable platforms, so that data of drug responses obtained can be correlated with those responses elicited in origin by the parental tumor itself. Here, we studied the quantum entanglement dynamics induced by non-linear interaction between a moving Nano molecule and a two-mode field with two-photon transitions using reduced Von Neumann Entropy and Jaynes-Cummings model for human cancer cells, tissues and tumors diagnosis *in vitro* and *in vivo* and outlined the utilization of these models in drug discovery and novel therapies of cancer with prospect for developing personalized anti-cancer strategies.

Tumor heterogeneity implies that different tumor cells can carry distinct profiles of cellular morphology, gene expression, metabolism, tumor cell motility, proliferation and metastatic potentials [118-187]. Both inter-tumor and intra-tumor heterogeneity exist. Most human cancers carry intrinsic heterogeneity which is manifested in cancer histology, genomic aberrations and gene expression profile. As a result, each tumor responds to therapies in a unique manner that ultimately determines its clinical outcome. Hence, despite tremendous improvements in patient survival rates achieved in recent years, resistance to treatments drives disease recurrence in many patients and conceivably requires novel treatments to be explored [186-223]. Heterogeneity is a major problem in applying the concept of personalized medicine to design of effective diagnostic tests, identification of drug resistance mechanisms, discovery of targeted drugs and exploration of novel therapeutic strategies. In many types of cancer, heterogeneity cannot be defined by relying solely on classical histological characteristics of tumors or altered profiles of cancer cell receptors. This means that new platforms have to be created to genuinely recapitulate each human tumor and its microenvironment.

Results and Discussion

It has been shown that time evolution entropy of nano molecule or field is a measure of time evolution of entanglement between nano molecule and field so that larger entropy means more entanglement between nano molecule and field subsystems. In the current research, the reduced Von Neumann entropy approach is used. In this regard, nano molecule (field) entropy is defined based on the reduced density operator.

According to above discussion, if nano molecule and field states are pure and independent in initial time, system entropy is zero and remains constant. Therefore,

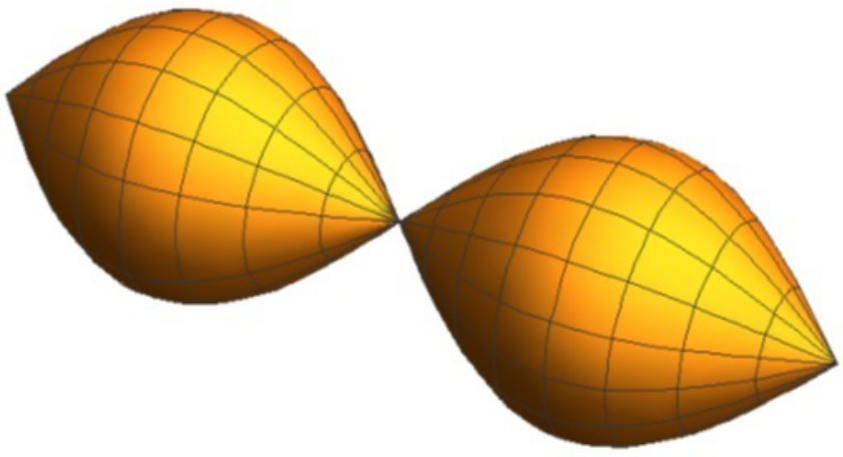

Figure 1: Interaction between 6-Methoxy-8-[[6-Methoxy-8-[[6-Methoxy-2-Methyl-1-(2-Methylpropyl)-3,4- Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-ol and a field for human cancer cells, tissues and tumors diagnosis.

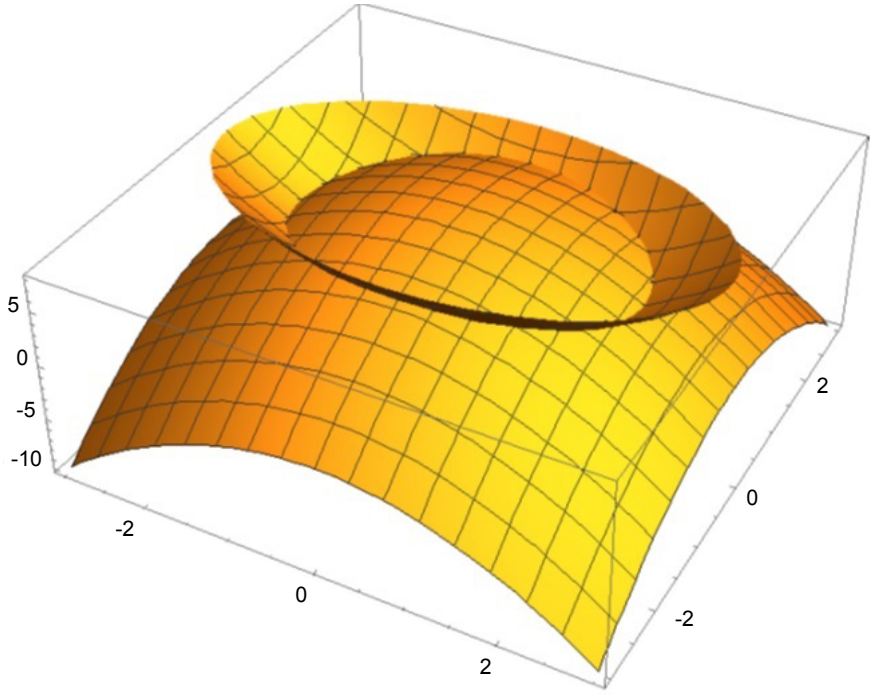

Figure 2: Time evolution of field entropy in resonance state and in constant coupling regime for human cancer cells, tissues and tumors diagnosis.

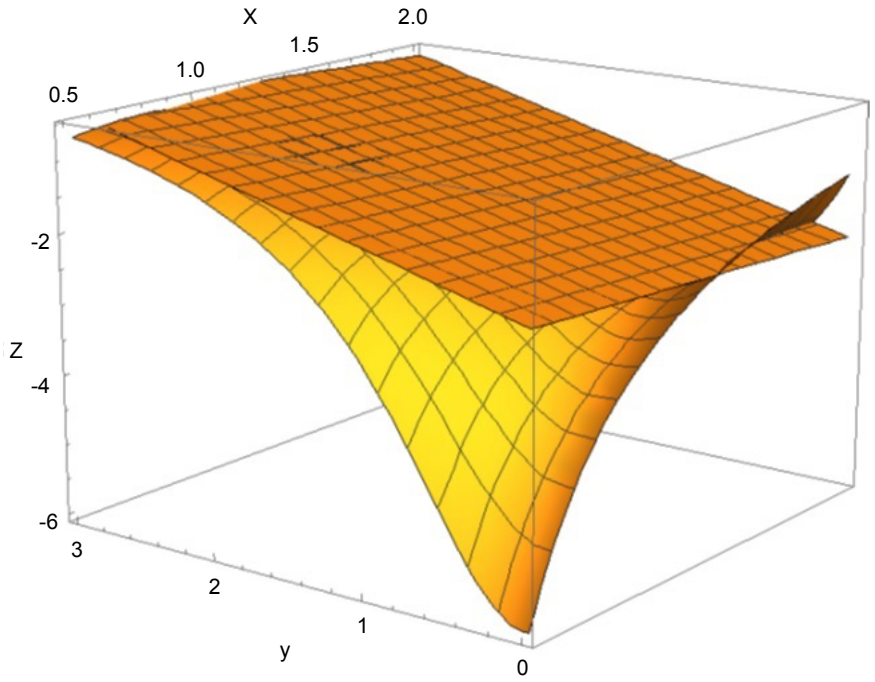

Figure 3: Time evolution of field entropy in non-resonance state and in constant coupling regime for human cancer cells, tissues and tumors diagnosis.

by independently preparing nano molecule and field states in the initial time, field entropy is equal to nano molecule entropy at $t > 0$. Hence, temporal behavior of nano molecule entropy is considered as the measure of entanglement between subsystems other than field entropy.

It is possible to determine the temporal variations of nano molecule (field) entropy which explains degree of entanglement between nano molecule and field for human cancer cells, tissues and tumors diagnosis. Moreover, if nano molecule entropy becomes zero, subsystems are separable.

Figure 1, Figure 2, Figure 3 and Figure 4 show time evolution of field entropy in terms of characteristic time for human cancer cells, tissues and tumors diagnosis. In these graphs, the effect of non-harmonic parameters, move of nano molecule and intensity-dependent coupling on entanglement between nano molecule

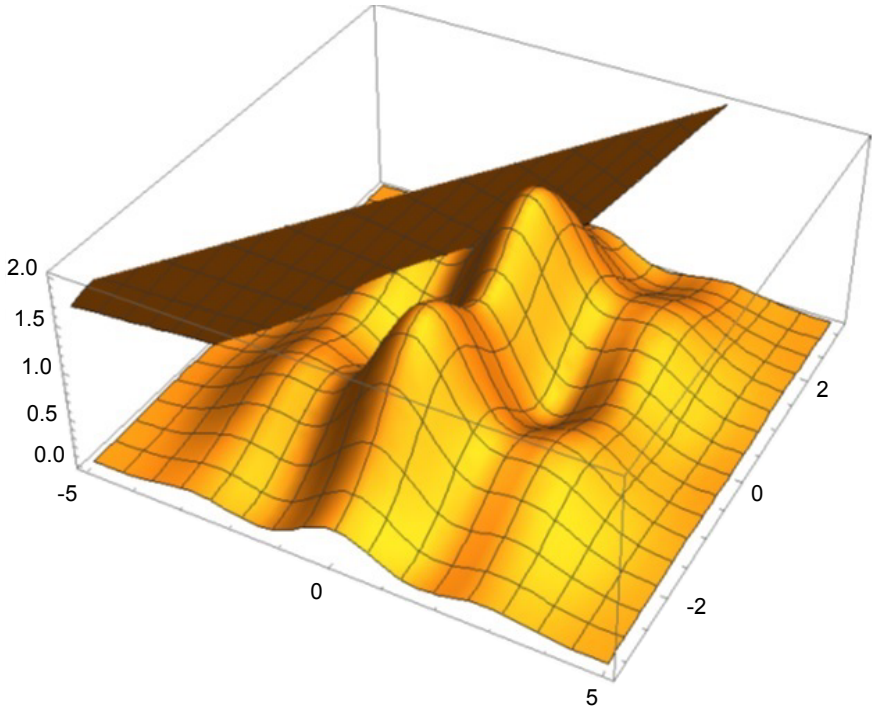

Figure 4: Time evolution of field entropy in resonance state and by intensity-dependent function for human cancer cells, tissues and tumors diagnosis.

and field for human cancer cells, tissues and tumors diagnosis are studied. Figure 2 shows that temporal behavior of field entropy is approximately constant for various nano molecule velocities. Figure 3 shows that in non-resonance state, temporal behavior of field entropy is harmonic and vibrating. Comparing Figures 2 and Figure 3, it can be said that non-harmonic parameters reduce field entropy. However, this value is considerably increased by variation of non-harmonic parameters. Figure 4, which considers intensity-dependent coupling effect, shows that this effect can increases the average degree of entanglement, in same time intervals, and maximum entanglement value for human cancer cells, tissues and tumors diagnosis.

Conclusion and Summary

In the current paper, non-linear interaction between a moving 6-Methoxy-8-[[6-Methoxy-8-[[6-Methoxy-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-yl]Oxy]-2-Methyl-1-(2-Methylpropyl)-3,4-Dihydro-1H-Isoquinolin-7-ol and a two-mode field with two-photon transitions was evaluated using generalized Jaynes-Cummings model for human cancer cells, tissues and tumors diagnosis. In the presented formulation, the nano molecule-field coupling constant depends on light intensity and nano molecule velocity for human cancer cells, tissues and tumors diagnosis. The figures obtained from numerical results were shown that non-harmonic parameters reduce the entanglement between subsystems. In resonance state, moving of nano molecule does not affects entropy while in non-resonance state, increase in mode structure parameter of field improves degree of entanglement and this parameter can be used as an adjustable parameter in entanglement between nano molecule and field for human cancer cells, tissues and tumors diagnosis. Moreover, intensity-dependent coupling can improve the maximum degree of entanglement for human cancer cells, tissues and tumors diagnosis.

However, faithful reproduction of human cancer cells, tissues and tumors reflecting their heterogeneous entity in host animals is the prime goal of cancer modeling. Then there comes the potential utility of the model for studying stages of cancer development, drug exploration and resolution of chemoresistance for better cure. The intra-tumoral heterogeneity that even results in expansion of each tumor subtype classification states that the idea of “one mouse, one patient paradigm” may need to be inevitably materialized. PDXs and the Jaynes-Cummings models have tremendous potentials in guiding therapy and quick assessment of safety and efficacy of new drugs and drug combinations, especially in those patients with deteriorating situation and so ineligible for clinical trial. When combined with cell-molecular approaches, Jaynes-Cummings model predict the outcome of the tumor more robustly and accurately. PDXs as well as GEMMs can form one arm of co-clinical trials that is sought to analyze human cancer cells, tissues and tumors more comprehensively than single trials in evaluating drug response. This is why mouse hospitals are being established in various institutions. The models also are increasingly finding their ways to molecular profiling of each tumor at genomic (or even exomic), transcriptomic and proteomic levels for personalized

solutions. PDXomics as a bioinformatics filtering tool is being employed to eliminate misreads caused by contaminated mouse xenografts. Computational, mathematical and predictive models of cancer are being vigorously developed to simulate tumor heterogeneity and meet demands for pharmacokinetic analyses in drug discovery. The ultimate integration of all these approaches will be critical for forthcoming design of patient-specific cancer therapy in personalized settings.

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