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Towards Soliton Computer Based on Solitary Wave Solution of Maxwell-Dirac equation: A Plausible Alternative to Manakov System

[1]Victor Christianto*, [2]Florentin Smarandache

Author's Affiliations: [1]Malang Institute of Agriculture (IPM), Malang, Indonesia.
E-mail: victorchristianto@gmail.com
[2]Dept. Mathematics and Sciences, University of New Mexico, Gallup – USA.
E-mail: smarand@unm.edu

***Corresponding author:** **Victor Christianto**
Malang Institute of Agriculture (IPM), Malang, Indonesia.
E-mail: victorchristianto@gmail.com

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ABSTRACT In recent years, there are a number of proposals to consider collision-based soliton computer based on certain chemical reactions, namely *Belousov-Zhabotinsky* reaction, which leads to soliton solutions of coupled Nonlinear Schroedinger equations. They are called Manakov System. But it seems to us that such a soliton computer model can also be based on solitary wave solution of Maxwell-Dirac equation, which reduces to Choquard equation. And soliton solution of Choquard equation has been investigated by many researchers, therefore it seems more profound from physics perspective. However, we consider both schemes of soliton computer are equally possible. More researches areneeded to verify our proposition

KEYWORDS Soliton computation, Manakov soliton, Choquard equation, computation

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INTRODUCTION: EARLY DEVELOPMENT OF SOLITON SCIENCE

There is little doubt that soliton technology has recently achieved close to pop science status as its proponents seek to put it to use for transporting vast amounts of information—the stuff that gives our era its name—farther and faster. It could well become one of the fundamental technologies in the current communications revolution. It was during the Industrial Revolution, however, that this phenomenon was first noticedand studied.[1]

A Scottish engineer by the name of John Scott Russell (year) had set out to create a more efficient hull design for canal boats (a 19th-century forerunner, perhaps, of current efforts to speed packets of information along fiber-optic cables). One day in August of 1834, he stood beside Union Canal near Edinburgh to observe the movement of a boat being pulled by two horses. As the rope pulling the boat snapped and the boat's movement halted, its prow dropped back down and Scott Russell saw a large mass of water, a smooth, solitary wave, gather around the prow and continue rapidly down the channel. Surprised and intrigued, he followed on horseback and noticed that the wave held its shape and only very gradually diminished in height. He lost sight of it after a mile or two but was so taken with this observation that he built a 30-foot wave tank in his back yard to study the phenomenon further. Ten years later, he reported his observations to the British Association for the Advancement of Science, calling what he had observed the "wave of translation." Scott Russell considered that day back in 1834 "the happiestday of my life", but his discovery was ignored by all but one or two people, who felt compelled to prove him wrong in the scientific literature. After all, it was common knowledge that waves could not behave in this way.[1]

Vindication came from two independent camps, both of which were attempting to explainthe movement of shallow water waves. Boussinesq's equation in 1872 and the Korteweg–de Vries (KdV) equation in 1895 proved that solitary waves were, indeed, theoretically possible. Many theoretical and experimental developments have been done since then.

By the early 1980s, however, fiber-optic technology had caught up somewhat, and LinnMollenauer, Roger Stolen, and Jim Gordon were able to observe soliton propagation in the lab. As mathematical results continued to appear, this group at Bell Labs was experimenting intensively with optical solitons, looking for ways to use them in long-distance telecommunication systems. Ironically, while their work was enthusiastically received in scientific circles, it seemed that the practical application could not be quickly realized, and they were told by the head of research, Arno Penzias, to desist.

Doggedly, they persisted until their results were so compelling that Penzias apologized and publicly praised the work. Mollenauer's group has since achieved several long- distance and speed records for optical soliton transmission.[1]

RECENT DEVELOPMENT: SOLITON COMPUTER POSSIBILITY

It is a known fact in computer industry, that the present silicon technology will not be able to keep up with the *Moore's law*. Therefore new ways of developing unconventional computing methods are being carried out in many labs.

Since 2005, some researchers from Princeton University have reported a new concept of soliton computation. As data rates in optical communication systems continue to increase, the demand for all-optical signal processing and computing devices does as well.

Examples of such devices include the nonlinear optical loop mirror, the temporal solitondragging gate, the spatial soliton deflection gate, and the TOAD, an asymmetric loop mirror. These devices avoid the bottleneck associated with optical-electrical conversion.[2] They describe physical state-restoring computation using collisions of optical solitons. Their work is part of a larger subject known as collision-based computing, sometimes called dynamical computation. Such constructions include ideal collisions of billiard balls, Conway's universal game of Life, and multidimensional excitable lattices. Early work on soliton computation involved soliton-like collisions in cellular automata, which demonstrated the ability to embed computation in automatausing particles. [2]

In an initial study, several researchers consider a Manakov system, which is essentially a system of coupled NLSE, where q1 (x, t) and q2 (x, t) are two interacting optical components, μ is a positive parameter representing the strength of the nonlinearity, and x and t are normalized space and time, respectively. The two components can be thought ofas components in two polarizations, or, as in the case of a photorefractive crystal, two uncorrelated beams. [2]

The Manakov system consists of two couple NLSWs.

$$i\frac{\partial q_1}{\partial t}+\frac{\partial^2 q_1}{\partial x^2}+2\mu(|q_1|^2+|q_2|^2)q_1=0$$

$$i\frac{\partial q_2}{\partial t}+\frac{\partial^2 q_2}{\partial x^2}+2\mu(|q_1|^2+|q_2|^2)q_2=0$$

Source: ref. [2]

From a practical standpoint, successful soliton computation requires ideal interactions and error-free propagation. In this sense, it is analogous to the construction of Fredkinand Toffoli, in which ideal, elastic collisions of billiard balls were used to achieve universal and reversible computation. In reality, noise will cause variability in solitonpropagation and collision, and fault tolerance based on logical state restoration wouldneed to be implemented in order to improve system performance. In a sense, this is ananalog rather than a digital computer. Rand et al. also reported more advanced work based on bistable configurations of Manakov solitons. [2]

More recent discussions of collision-based soliton computing still use that basic Manakov system. See [3][4].

In the next section we will discuss an alternative approach for soliton computer.

A PLAUSIBLE ALTERNATIVE: SOLITON COMPUTER BASED ON CHOQUARD EQUATION

In a recent paper, we discuss how Dirac-Maxwell equation reduces to wave equation, which can be transformed into a cellular-automaton scheme. [5] Now, it is worth to remark here that a recent paper shows that there is *travelling wave solution of (classical) Dirac-Maxwell equati*on. [6]

It should be noted that numerical results showed that Dirac-Maxwell system has definitely many families of solitary waves. Here the nonnegative integer N denotes the number of nodes of the positronic component of the solution (number of zeros of the corresponding spherically symmetric solution to the Choquard equation).

It can be shown that the nonrelativistic limit of such a solitary wave solution takes theform of Choquard equation, which can be written as follows:[6]

$$\omega\phi=-\frac{1}{2m}\Delta\phi+q^2\Delta^{-1}\left(|\phi|^2\right)\phi. \tag{1}$$

Considering that the above Choquard equations is quite similar in form with the NLSE (nonlinear Schrodinger equation), and also that Manakov system is actually a system of coupled NLSE, then we consider it plausible to consider a Manakov-Choquard system, which can be written as follows:

$$\omega\Phi_1 = -\frac{1}{2m}\Delta\Phi_2 + q^2\Delta^{-1}(|\Phi_2|^2)\Phi_1.(2)$$

$$\omega\Phi_2 = -\frac{1}{2m}\Delta\Phi_1 + q^2\Delta^{-1}(|\Phi_1|^2)\Phi_2.(3)$$

The solutions of (2) and (3) can be explored numerically with computer algebra system such as Mathematica.

As far as we know, such a coupled Manakov-Choquard system has not been proposed before forstudying soliton computation possibility.

CONCLUDING REMARKS

Considering the ever increasing demand for better computers, some researchers have considered collision-based soliton computer. And this proposal is based on Manakov system. In this paper, we consider a new concept based on travelling wave solutions of Dirac-Maxwell equations, which we call Manakov-Choquard system.

As far as we know, such a Manakov-Choquard system has not been proposed before for studying soliton computer.

We understood, that more observations and experiments are recommended to verify our propositions.

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