

# Quasi-synaptic Effect to Control the Cold Matter Transfer

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## Abstract

In this paper an electronically controlled cold atom transfer is considered. Two atom streams are guided by wires carrying the DC and RF currents. The trapping areas can touch each other under certain critical values of these currents. At the touching point the atoms are transferred from one wire to another that reminiscent the synaptic effect in the brain. The discovered effect is applicable in quantum interferometry and controlled atom transfer.

**Key Words:** cold atoms; magnetic traps; quantum registers; quantum interferometers

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## Introduction

Contemporary discussion on the role of quantum effects in the brain is rather far from the final conclusion. Any study of quantum effects which have similarity to the human brain functions is interesting and fruitful. Many new technical solutions and even principles of computations and artificial intelligence can be found on this way.

This proposed article is on the electronically controlled techniques of transferring of cold atoms from one stream to another. The cold atoms are the gaseous matter cooled up to extremely low temperatures below 1K. In these cases, the thermal movements of atoms are slow and the quantum nature of matter is brightly seen.

The most studied cold matter is composed of alkali atoms, and they are controlled by the magnetic or/and electric fields that form traps in the space. This

trapping effect is described by the effective potential and the Schrödinger equation regarding the probability density function. Under certain conditions, this cold matter can be in the Bose-Einstein condensate state when the quantum interactions are rather strong, and the atoms show the collective behavior. In this case, averaging gives a new equation describing this effect, and it is the Gross-Pitaevsky equation (Dalfovo, 1999). The behavior of Bose condensates is very rich of nonlinear phenomena, and controlling them by the electric and/or magnetic fields is a very attractive idea that probably would lead to a new type of computations, controlled spatio-time quantum processes, and even cold chemical reactions.

This proposed paper is on the one particular linear effect for cold matter governed by joint static magnetic (DC) and radio-frequency (RF) fields. The cold matter from one atom stream is pumped to another by adiabatically varied fields, and the process is reminiscent the synaptic effect in living matter.

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### Governing Potential for Joint RF/DC Excitations of Traps and Atomic Waveguides

More flexibility in the design of spatial trapping shapes provides the joint DC/RF fields. In the case of strong ones, the atoms are interacting with a large portion of the electromagnetic field quanta, and the trapped atoms are in so-called dressed state (Cohen-Tannudji, 1998). Experimentally, it has been found that the effective potential landscape depends on the RF frequency, DC and RF fields amplitudes, and the orientation of the DC and RF fields relative each other (Schumm T, 2005). In this case, several analytical formulas are derived to calculate the effective potential shapes. Thus, this joint excitation gives more flexibility to form certain potential shapes than only the DC trap feeding.

Atoms placed in a strong magnetic field have the splitted energy levels. One of them is the ground state, and the atoms in this state seek the areas with a strong potential. They can be placed at higher levels by excitation with the laser light or microwave radiation. Atoms of some higher states tend to the areas with the decreased potential. In (Kouzaev, 2007), an RF/DC Ioffe-Pritchard trap is considered allowing concentration of atoms of different quantum states in neighboring areas.

Changing the potential slow enough, these concentrated atoms can be moved from one place to another, and this is the guiding effect. Additionally, atoms from different spots can be transferred to the collision area where they can interact with each other and can be placed in the qubit state. Interacting qubits can be in the special state of a quantum cluster called entangled state, and this effect is the basic in quantum computations.

### Wire as an Open Atomic Trap and Guide

The RF/DC currents along a single wire form a cylinder like trapping area, and this is the simplest trap (Kouzaev, 2007). The minimal value of the trapping potential is zero and additional biasing by the DC or RF field is in a need to avoid the flip-flop of trapped atoms.

The atoms concentrated along the wire can be moved from one place to another

by additional forces. For this purpose, the coaxial-to-the-wire rings are used. The rings carry the RF and (or) DC currents, and the form a potential minimum at the given coordinate along the wire. Changing the currents the minimum together with the cold atom clouds can be moved from one ring to another.

### Crossed Wires and Quasi-synaptic Effect

In (Kouzaev, 2007a), it was found that perpendicularly oriented wires of the trap carrying RF and DC currents can form the merged potential minimums or these minimums can be separated from each other by a potential barrier. Later, this effect was proposed for controlled atom transfer from one wire to another (Kouzaev, 2006) and was studied in the details in (Kouzaev, 2007b).

Figure 1 shows the crossed wires when the trapping manifolds are not touching each other. The atom streams are divided by a potential barrier, and atoms can be moved along the perpendicularly placed wires independently by variation of the fields from the rings.

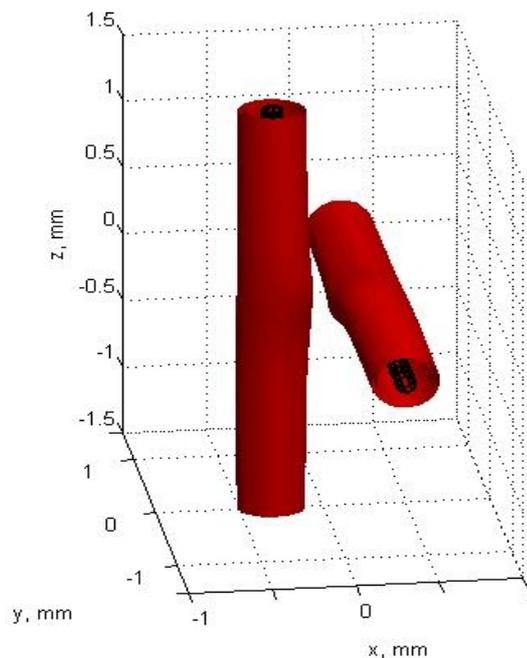


Figure 1. Isolated minimum manifolds of two crossed wires carrying DC and RF currents

Decreasing the frequency, the radii of the minimum manifolds are increased, and the trapping cylinders are touching each other (Figure 2).

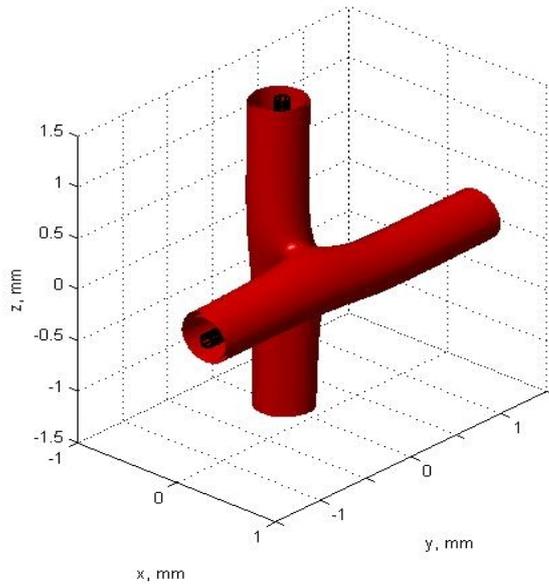


Figure 2. Merged minimum manifolds

In the ideal case, at the touching point, the effective potential manifold has a typical flower-like shape shown in Figure 3. At this point, the atoms can wander from one wire to another, and this is the quasi-synaptic effect.

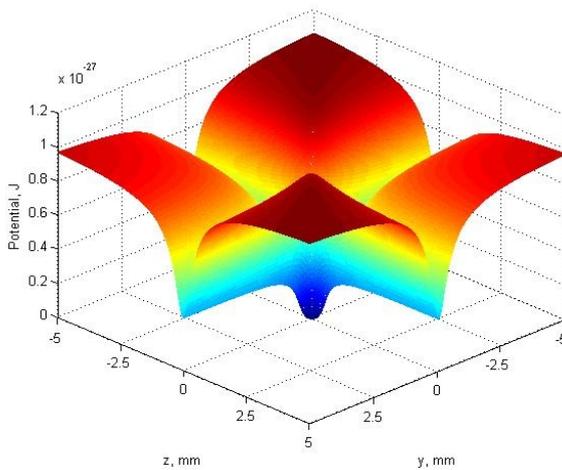


Figure 3. Potential shape at the crossing point

The atoms can be pumped from one guiding wire to another by a specially designed procedure or protocol (Kouzaev, 2006). In this case, the currents on the driving rings and guiding wires are varied according to a certain rule, and it is the following. At the first, a common minimum is formed between the donor vertical wire and horizontal acceptor wire where the atoms from the donor wire are concentrated (Figure 4).

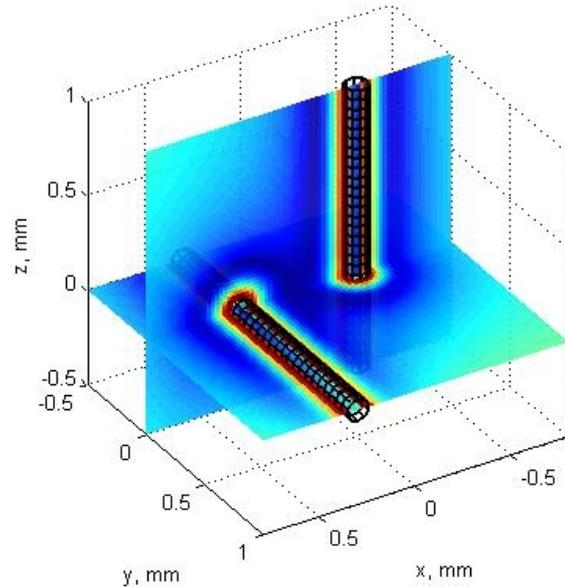


Figure 4. Common minimum between the donor vertical wire and acceptor (horizontal) one

Then, the minimums are decoupled from each other, and the atomic cloud is moved along the horizontal wire (Figure 5)

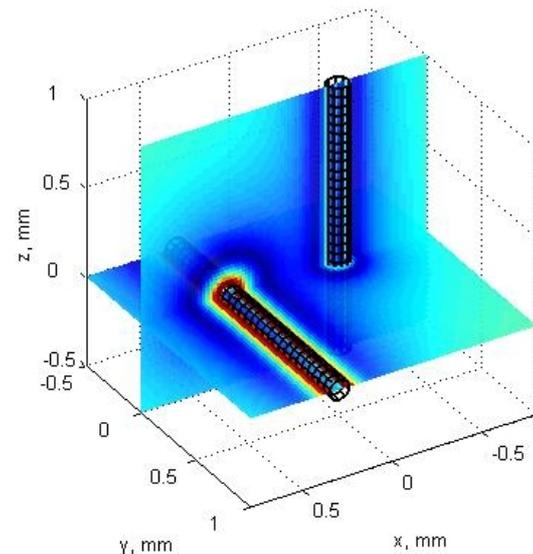


Figure 5. Separated minimums around the wires and the beginning of pumping the cold atoms around the horizontal acceptor wire

This studied transfer of cold atom matter is interesting for many applications. The first, it is prescribed delivery of atoms to the collision area. The second, it is the quantum interferometry. The third, the controlled shaping of the potential allows forming the wanted potential distributions in the 3-D space and organize the interaction of areas of cold matter or even Bose-Einstein

condensates in a prescribed manner governed by non-linear Gross-Pitaevsky equations.

### Conclusions

The quasi-synaptic effect has been considered for cold atom streams. The atoms are trapped along crossed wires. Normally, the cylindrical traps are isolated by a potential barrier. The trapping manifolds of the effective potential governing the atom movement can be touched at the cross-point, and a part of the atoms can be moved from one wire to another by the variation of the biasing and trapping currents. The found effect is interesting in quantum high-sensitive interferometry, prescribed atom transportation and shaping the trapping effective potential in the 3D space to register the cold atom clouds.

### References

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