A New Approach to Control Electron Current in Unitary Quantum Theory

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Abstract

In the Unitary Quantum Theory a probability of tunneling effects controlled by initial phase. Mathematical model created for this phenomenon use equations with oscillating charge. This effect is absent in the Ordinary Quantum Mechanics and it may be useful for creation new electronics devices.

Keywords: Unitary Quantum Theory, Tunneling effects, Electronic device, Tunneling diode, Control electron flow, Set of potential barriers, Oscillating charge.

1. Introduction

In the world literature it is written that tunnel diode was constructed by Japanese researcher L.Esaki. However, at the end of forties in Soviet popular magazine "Radio" was published a series of articles about "crystadin" constructed by Russian ham Oleg Losev. He had used a falling sector of voltage-current characteristic of point contact between steel wire and homemade crystal *FeS*. Such diode had been made from mixture of iron filings and sulfur powder heated within test-tube. The coked mass obtained was then broken to pieces from which suitable crystal was chosen. That prototype of tunnel diode was used for oscillatory tuned-circuit *Q*-factor excursion in general crystal set. Articles described the way to do it at home. One of the authors did himself being a schoolboy.

In electronics there are two principal ways to control the electron flow:

1. Control by interception, when a common vacuum electronic triode or a lock (closing device, a field controlled transistor) the amplified signal exercises control with the help of a grid over the number of the electrons passed, while the controlling element represents something like a bar (gate, valve) within the water flow.

2. This way of control involves the procedure in which electrons are slightly accelerated or slowed down with the help of amplified signal, which leads to the velocity being modulated. Then in the course of their movement in free space the faster electrons overtake the slow ones and the flow splitting or grouping into space charge clots occurs. Further on this density the modulated bunch of signals interacts with the resonator or with the system with slow wave. Such method of control is used in all super-high-frequency devices (SHF-devices): magnetrons, amplitrons, klystrons, TWT, canceratrons etc.

In this article we propose some different way to control the electron flow, using the tunnel effect. The suggestion is that it is easier to control the electron wave function phase than to use other control procedures. *In fact, it is essentially new and unknown to science, because it has not yet been established, that the tunnel effect depend on the wave function phase.*

Ordinary tunnel diode has semiconductor crystal with two potential barriers.

Interesting phenomena may be observed in the case of potential barriers series. From the pure qualitative UQT positions (Sapogin, Ryabov, 2011) it is evident that if there are two high, but quite narrow potential barriers situated at some distance one from another, then the first barrier will be penetrated by those particles only which phase is so that at the moment of the first barrier reaching the particle charge is very small. In that case the particle will pass the first barrier. The second barrier will be also is passed by the particles having in front of the barrier again the phase corresponding to the very small charge. Such a system of two or more periodic barriers results in the fact that will be cut out of the particles flow with various energies and phases a monochromatic correlated in phases flow. In cross- section of that flow there will be particles in one phase only. All this will look like the military favorable training: soldiers are marching, keeping the step and its dimension for all soldiers is strictly equal. There are rather identical considerations relative to barrier's chain within standard quantum mechanics, but from the viewpoint of that theory one can say nothing about the wave's phase and about the physical sense of phenomena observed. Let us consider in details this quite interesting situation. First clear up, how does it happen in accordance with standard Quantum Mechanics?

2. Problems in the Ordinary Quantum Mechanics.

Consider the problem of particle's passing through the system of two potential barriers described by Dirac's unit-impulse functions and situated at some distance *a* one from the other. The potential of such system is following (Fig.1):

$$U(x) = a[\delta(x) + \delta(x-a)]$$

Assume the particle's flow moving from left to the right. Let us determine the particle's energy E required for passing both barriers. The Schrodinger equation for the wave function is following:

$$-\frac{\hbar^2}{2m}\Psi'' + a[\delta(x) + \delta(x-a)]\Psi = E\Psi \qquad (1)$$

At once we can write its solution for the area 1 ($x<0$) before the barrier, where according to common approach the incident wave exists only. The solution for the area 2 ($0<x<a$) between the barriers contains both waves (right and reversed). The solution for area 3 ($x > a$) after the second barrier contains passed wave only. Therefore, we have the following solutions:

$$\Psi_1(x) = exp(ikx), \quad x < 0, \quad k = \sqrt{\frac{2mE}{\hbar^2}} > 0,$$

$$\Psi_2(x) = A\sin(kx) + B\cos(kx) \quad 0 < x < a,$$

$$\Psi_3(x) = C\exp[ik(x-a)] \quad x > a,$$

The continuity of the wave function and discontinuous character of derivative in points $x = 0, x = a$ leads to equalities:

$$\Psi'(+0) - \Psi'(-0) = \frac{2ma}{\hbar^2}\Psi(0)$$

$$\Psi(+0) = \Psi(-0)$$

Joining the wave functions and their derivatives in the points *x=0 and x=a* in standard way and taking into account the above equalities, we get the system of four algebraic equations:

$$B = 1$$

$$kA - ik = \frac{2ma}{\hbar^2}$$

$$Asin(ka)+Bcos(ka)=C$$

$$ikC-kAcos(ka)+kBsin(ka)=\frac{2maC}{\hbar^2}$$

The given system is predefined and has solution only under following condition:

$$tg(ka)+\frac{\hbar^2 k}{ma}=0\,.$$

If $k_1, k_{2,...}$ are the roots of this equation, then by using the expression for k (has been written at the beginning of this sect.), we are able to determine the energy values at which the particles penetrate (we say "tunnel") two-barrier's system:

$$E_s=\frac{\hbar^2 k_s^2}{2m}, s=1,2,...\,,$$

From solution of transcendental equation it is evident that periodic dependence in energy, while tunneling two barriers, appears due to tangent curve to be periodically crossed by straight line, emergent on some angle from the origin of coordinate system. It is obvious that barriers will be passed by the particles with de Broglie wavelength, being multiplied to *a*. That phenomenon bears a strong resemblance to processes, appearing in the cases of anti-reflecting optic lenses.

3. Problems in the Unitary Quantum Theory and new electronic devices.

We should note an interesting circumstance. If the same problem would be solved in other order that had been first to determine the portion of the particles flux penetrated (tunneled) the barrier and to consider passed portion as incident flux in respect to the second barrier, the result would be absolutely different. The multiplication of two exponents to be given by each barrier just (immediately) suppress everything. It is very difficult to understand such double game directive for an unprejudiced physician with mentality non-perverted by "quantum" logic.
There is one more amazing consideration. Let the particle has not penetrated the barrier but just going to tunnel it or to be reflected, however its "decision" depends on the second barrier distance. But how could it know what is waiting further and what is the second barrier distance? Does the second barrier exist at all? Here we can recollect the perfect words of R.Feynman: *May be the particle "sniffs out" the second barrier?* And again it is violence over logic and mind.

Similar phenomena but in more tangible and totally understandable form take place, if we analyze the solutions of the equation with oscillating charge (Sapogin, Ryabov, Boichenko, 2005, 2008; Sapogin, Ryabov, 2011).
The equations named "Equations with oscillating charge" are the important elements of our Unitary Quantum Theory (UQT). There are two forms (non-autonomous and autonomous) of these equations. For the first time, the non-autonomous equation was simply postulated in (Sapogin, 1994a, 1994b, 1996), where this equation was used for description of cold nuclear fusion process due to mutual deuteron interaction. This equation has the following form:

$$m\frac{d^2\mathbf{r}}{dt^2}=-2Q\,\mathrm{grad}\,U(\mathbf{r})\cos^2\left(\frac{mt}{2\hbar}\left(\frac{d\mathbf{r}}{dt}\right)^2-\frac{m\mathbf{r}}{\hbar}\frac{d\mathbf{r}}{dt}+\varphi_0\right),$$

where m is the mass, $\mathbf{r}$ is the radius vector, $U(\mathbf{r})$ is the external potential, φ_0 is the important parameter called "initial phase" and Q is charge of particle.

The heuristic premises to this equation were following. It was obtained (Sapogin , Boichenko, 1988, 1991) the solution of the simplified scalar integro-differential equation of UQT (Sapogin, 1979, 1980) that resulted in a periodically appearing and vanishing wave packet (identified with a particle). The integral of bilinear of such wave-packet over the whole volume turned out to be equal to the value of the dimensionless elementary electric charge with the precision up to 0.3% (Sapogin, 2011). It was easy to associate such wave-packet with simple space electric charge oscillation that has double charge amplitude, i.e. with an oscillating point charge described by a general Newton equation but taking into consideration the changes of point's characteristics within process of movement. In the essence, it is simply the next step in material point's motion theory.

It is not a new idea for ordinary mechanics. There are well known equations of I.Mestchersky for the motion of variable mass bodies and K.E.Tsiolkovsky equations for the rockets motion. To our regret, the numerical modeling is embarrassed in the case of barriers system (1) described by delta functions. That is why we have replaced (1) by the sum of two Gauss "bells":

$$U(x)=U_0\left[exp\left(-\frac{x^2}{\sigma^2}\right)+exp\left(-\frac{(x-a)^2}{\sigma^2}\right)\right]$$

The one-dimensional equation with oscillating charge, describing the particle's motion and corresponding to last potential has been solved numerically in autonomous and non-autonomous cases. As far as the results obtained are slightly different, we have shown them separately with further comparison.

3.1. An Autonomous model.

The one-dimension equation of motion has the following form:

$$m\frac{d^2x}{dt^2}-4U_0Q\left[xexp\left(-\frac{x^2}{\sigma^2}\right)+xexp\left(\frac{(x-a)^2}{\sigma^2}\right)-aexp\left(\frac{(x-a)^2}{\sigma^2}\right)\right]\frac{cos^2(\varphi)}{\sigma^2}=0\,, \quad (2)$$

where

$$\varphi=-\frac{m}{\hbar}\frac{dx}{dt}x+\varphi_0\,, \quad (3)$$

$x=x(t)$, φ_0 - the initial phase, *a*-the distance between the barriers; σ, U_0 are the width and the height of barrier respectively; *Q*, *m* are the constant part of particle's charge and mass respectively. The equation has been solved numerically by Runge-Kutta-Merson method. There the numbers of particles tunneled with respect to initial velocity and to initial phases, uniformly distributed in interval from 0 to π have been calculated.

The following starting data were used: *Q*=1, *m*=1, $\hbar=1, U_0=5$, *a*=4, $\sigma=1/8, V_0=1-3.5$. For each initial velocity value we computed variants for 101 values of initial phase (the case of $\varphi_0=\frac{\pi}{2}$ was excluded from calculations). The total number of the particles equals 20502. The results of calculations are shown in the Fig. 2, Fig. 3. The relation between numbers (percentage) of particle and the initial velocity (Fig. 2) can be well approximated by simple exponent. The distribution of particle's number in respect to the velocity after passing two barriers (Fig. 3) does show a resonance effect. From the other side, there exists particles' grouping in respect to velocity as it has been described in the beginning of that section and expected from the most general considerations. It can be seen in Fig. 3, where *x*-axis indicates particles' velocities and *y*-axis indicates the number of particles. It is curious that within velocities' intervals [1--2.27] and [3--3.25] there are no particles at all (*forbidden zones*). We will discuss it in details later.

3.2. Non-autonomous model

Non-autonomous equation has the same form (2), but with the other expression of φ:

$$\varphi=\frac{mt}{2\hbar}\left(\frac{dx}{dt}\right)^2-\frac{m}{\hbar}\frac{dx}{dt}x+\varphi_0 \quad (4)$$

The numerical integration has been made by Runge-Kutta-Merson method using following data: *Q*=1, *m*=1, $\hbar=1$, $U_0=5$, *a*=4, $\sigma=1/8$, $V_0=1.5-4$. The full number of particles N=20502. Now, as it can be seen in Fig.4, the expected resonant dependence of barrier's tunneling on the initial velocity exists. But that resonance effect is slightly suppressed because tunneling probability increases with the velocity thus compensates the drop in probability at moving away from resonance point (horizontal steps at the curve). We have plotted particles' exit velocity distribution after tunneling (Fig. 5). It is evident from the plot that forbidden zones within the area of velocity equal to 2 are outlined. Also, the particles' grouping in respect to velocities may be seen. With the help of numerical integration of the same equation we have also calculated the probability of barrier tunneling with respect to distance between the barriers *a*, to fixed initial velocity of particles, and to initial phases, uniformly distributed from 0 to π. Starting data have been following:

Q=1, m=1, $\hbar = 1$, $U_0 = 5$, a=0.25-12.5, $\sigma = 1/8$, $V_0 = 2.5$.

Total number of particles N=20502. The dependence obtained may be estimated as expected from quite general viewpoint. Really, the first barrier is to be passed by all particles which phase is so that the particle charge in front of the barrier is small. If further there is second barrier on particle's way, then it would be penetrated without any problem by particles, which have the phase, again corresponding to the small charge in front of the barrier. If the distance between the barriers has been changed, then the tunneling should periodically change. That is illustrated in Fig. 6.

In general, the character of solutions for both types of equations is similar, *there are appeared the forbidden zones*. But the most interesting fact is that both, some increasing and some decreasing, velocities in comparison with initial velocity are observed. Thus, in Fig. 3 it can be seen that there are many particles with the velocity a little bit more than initial maximum velocity, which is equal to 3.5. We can see the same phenomenon in Fig. 5, where one can find quite enough particles with the velocity more than 4 – initial maximum velocity. It is also evident that in both cases there are many particles with velocity less than the minimal initial one. In any case we will not think that some particles give up their energy to other particles and reduce their velocity and *vice versa*, what is a cause of Maxwell-Boltzmann statistical distribution. The modeling is to be made each time for one particle only (!) and *equation does not mean any interaction with the other particles*. We would like to think that additional energy of ensemble obtained, owing to fast particles, is just exactly equal to the energy has been lost by slow ones. Of course, it is pure aesthetic consideration which etymology descends from *atavistic nostalgia in conservation law*, but we have not checked this circumstance. Besides, such reasons are based on energy and momentum conservation laws that are not fulfilled for both equations (Sapogin, Ryabov, 2011).

The unitary quantum theory predicts a number of new phenomena that occur when charged particles pass through a potential barrier. A new type of semiconductor devices, based on (Sapogin, Ryabov, Boichenko, 2005, 2008; Sapogin, Ryabov, 2011) can be created. The above equation determines relationship between the particle, passing through the potential barrier, and the wave function phase. In other words, if the charge of a particle that approaches the barrier is small, then it passes the barrier quite easily. Due to this small-energy, deuterons can approach each other and interact, but this effect takes place only within a narrow phase range. This is explanation of the Cold Nuclear Fusion. But CNF impossible in the Ordinary Quantum Mechanic (Sapogin, Ryabov, 2011)!
In order to describe the particle's behavior in passing through a periodic sequence (chain) of potential barriers we shall use the most elementary potential of the kind:

$$U(x) = Ex + A\sin^2(x)$$

Then the equation for the particle's motion within such potential with superposition of weak uniform field (external operational field) will assume the following form:

$$\frac{d^2x(t)}{dt^2} = \left(E + A\sin(2x(t))\right)\cos^2\left(\frac{t}{2}\left(\frac{dx(t)}{dt}\right)^2 - x(t)\frac{dx(t)}{dt} + \phi_0\right),$$

where E is the small external operational voltage (power supply).

Assume that a certain number of charged particles with uniform phase and Maxwell velocity distribution move through a periodic chain of potential barriers, being subjected to action of external electric field. According to the UQT nearly all particles, which have passed through the barriers, have approximately equal velocities and phases (a coherent flow). It is interesting that the slow particles are accelerated while the fast ones are slightly slowed down. Consequently, the particle's phase changes too. To check this point the following problem has been set: upon a sequence of five barriers (Fig.7) a flow of particles is directed, the particles possessing various velocities (uniform distribution with respect to velocities) and various initial phases, uniform distributed in the $0..\pi$ region. In practice this problem has been solved with a mathematical program in two cycles. The first velocity-cycle has contained a phase cycle (101 phase-values have been used) in the $0..\pi$ range. The number of phase values should always be odd, as in even splitting the point $\frac{\pi}{2}$ is sure to emerge and the PC would hover for many hours until it has reach the zero because of equation's singularity in this point. The velocity range has been split into 500 intervals (stretches). Thus, the particle's motion equation has been solved by the Runge-Kutt method of the fourth order 500*101=50500 times, the procedure takes no less than a month, when using ordinary PC.

In fact, the standard Monte-Carlo procedure was applied within the two cycles. If the particle changed its velocity sign (was reflected), its behavior was considered no longer and it was excluded from the analysis. All the trajectories having been calculated, the histograms of the particles number distribution in relation to their velocity has been made, these results are given on a plot (see Fig.8). As seen from the plot (Fig.8) a lot of particles possess identical velocities and phases having passed through the 5 barriers. It is clear that such automatic phase and velocity phasing in a periodic potential sharply raises the probability for the deuterons to approach each other, which in itself serves as an additional argument to Cold Nuclear Fusion explanation (Fleischmann, 1989; Sapogin, 1983, 1994a, 1994b, 1996). Of course, in real lattice this effect is much weaker, because the problem being solved was one-dimensional. In order to solve a three-dimensional lattice model (pattern) one needs a very long time and a very powerful supercomputer. The experiments on the tunnel-effect dependence upon the wave function phase should be carried out by all means. Such a problem had never been considered in Quantum Mechanics because the wave function square module rather than the wave function itself has the physical meaning and hence the wave function phase had been excluded from the analysis. If the relationship between the particle passage through a potential barrier and the wave function phase will be proved experimentally it will serve as a crucial evidence of the UQT validity and will allow the creating of electronic devices based on the new electron-control principle.

3.3. A new electronic devices.

Let us regard the operational principle of such new device. Its schematic diagram is given in Fig.9.

This is sample semiconductor includes several equidistant potential barriers produced by introducing impurities and as it were a grid structure (for explanation only!) between the 2-nd and the 3-rd barriers. The processes that are to take place within such a device are easily predicted: all the electrons with equal phases but different energies will pass through the 1-st barrier. The electrons of de Broglie wave length, equal to distance between the two barriers divided by N (where N is an integer number), will also pass the 2-nd barrier. The energy deviation being rather small, a mono-energetic equal-phase (coherent) electron flow will be formed upon passing through the second barrier. Consequently, any change as it were of a grid potential between the 2-nd and the 3-rd barriers will cause the electron phase change at approaching the 3-rd barrier and hence the amount of electrons having passed through the third barrier will decrease.

The above-predicted results had been simulated on the same 5-barrier chain, as it were the grid being placed between the 4-th and the 5-th barriers, which did not bring about any essential changes of the situation. The resulting current behind each barrier had been summed up. In the current value calculation each particle's velocity and instant charge have been taken into consideration. In fact, for a 1-, 2-, 3-, and 5-barrier tunnel diode mathematical simulation was carried out. Each behind-barrier current's dependence upon the squared velocity of incident particles (this value being proportional to the device operational voltage) is shown on the plots in (Fig.10). It is clearly seen, that within [5--10] resulting range of volt-ampere properties there is a place with a negative resistance, and on the whole, these characteristics give a sufficiently accurate description of the tunnel diodes (Fig.10).

Further on, mathematical simulation of a new kind of the device has been made, the concept of the latter being presented in Fig.10 and its operational principle described above. To achieve this, the velocity of each electron, that having passed through the 4-th barrier, was changed by 5% as had been compared with its calculated value, the charge's instant character being taken into account. In other words, an attempt was made to imitate as it were the grid, which either accelerated or slowed down by 5% the electrons that had passed the 4-th barrier; the current that had got through the 5-th barrier was also calculated. The results are given on a summary plot (Fig.10), where two more curves representing positive and negative as it were the grid voltage, correspondingly, are shown. Of course practically control signal must be connected with 3 barrier. The simulation's outcome had surpassed our most far-reaching expectations although it looks much more complicated than was expected proceeding from the above theoretical reasoning. The simulation analysis shows that there are some voltage areas, where the gain coefficient is very high; therefore, doubtless, devising of such instruments holds very much promise.

Some strange things are also observable: the current through the 2-nd, 3-rd and 5-th barriers may be bigger than through the 1-st barrier at the certain voltage values. Any researcher can ask a legitimate question: how can it be possible within a series resistor circuit with one and the same current flowing?

The answer to this strange paradox is rather simple: the phase of all electrons, being pass through the chosen point, are such that their summed up charge varies only slightly, which leads to various current values at different points. Note, that just the same phenomenon is arranged by Nature within the so-called “Lecher wires (patterns)”. It is experimentally established that within the Lecher wires (lines) there are some points in which the voltage is equal to zero. The lines can be short circuited in these points without any change in voltage on a payload at the line’s end. Similarly, there are points, where the currents that run through the wire are equal to zero and the wire can be safely cut in these points without any damage done. Besides, the plot (Fig.10) reveals another curious phenomenon: it is seen that all curves have common intersecting points at voltage values of 1.6 and 6.4. This is a consequence of a trivial resonance effect, when the de Broglie wave length changes by 2 times. In so doing, as the phase had altered by 2π, nothing will change in the probability for the electron to pass through the barriers via these points.

There is no need to wait a long time till the velocity, modulated signal bunch, will group into clots in the free space. Therefore, such a device could apparently permit to obtain very prompt work. Probably, it would be expedient to develop this new semiconductor device on the basis of either *Ga-As* or *Al-x-Ga-x-As* super lattice devices, proposed by (Esaki L., Tsu R., 1969). It could also be achieved on the basis of common tunnel diodes or resonance-tunnel dipole transistor (M.Schur, 1990). This experiment could be carried out in institutions possessing sub-micron semiconductor technology. It is also necessary to make a super pure semiconductor device with the electron free path length, being greater than the device’s dimensions. So, the electron flow’s control devices seem to be quite possible and new electronic devices, using the phase control mechanism, can be made. The consequences of these developments are to be very far-reaching.

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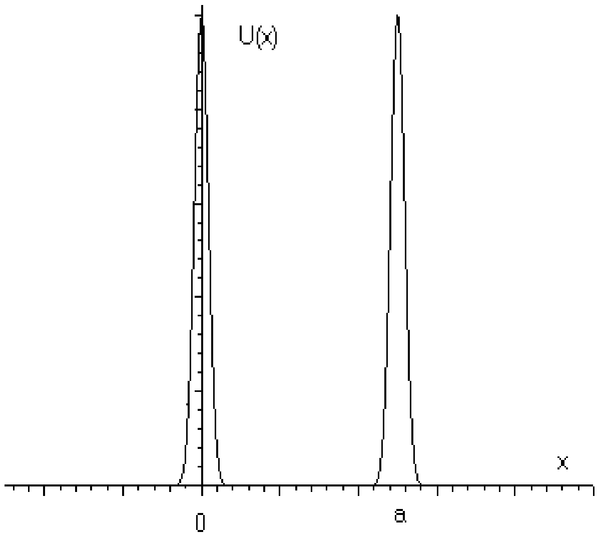

Fig.1.Potential of two-barriers system

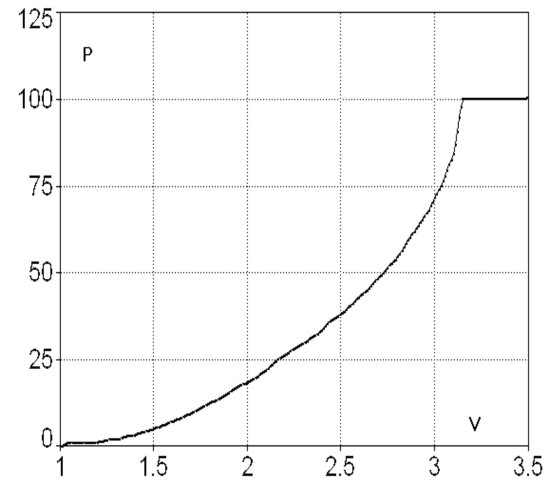

Fig.2. The number of particles (percentage *p*) passing two barriers in respect to particles velocity (autonomous equation).

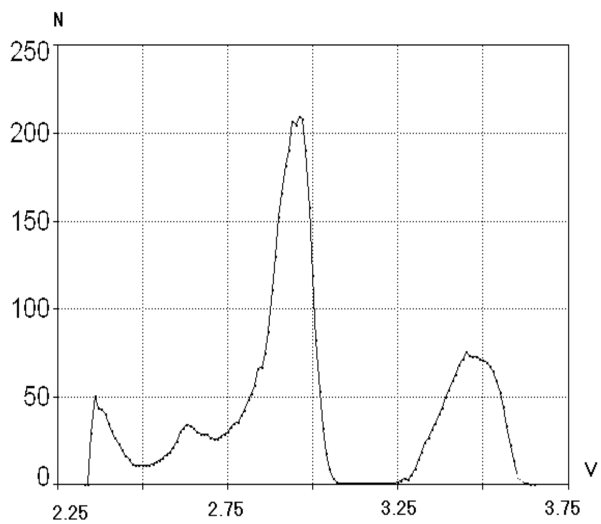

Fig.3. Distribution of particles in respect to velocity after passing two barriers (autonomous equation).

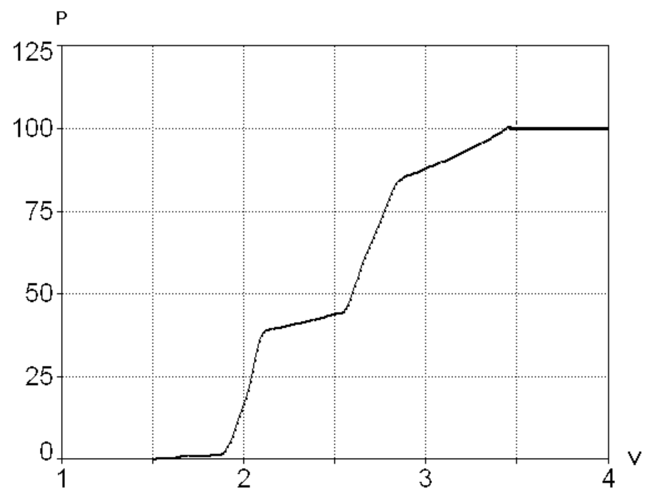

Fig.4. Probability of passing two barriers in respect to velocity of particles (non-autonomous equation).

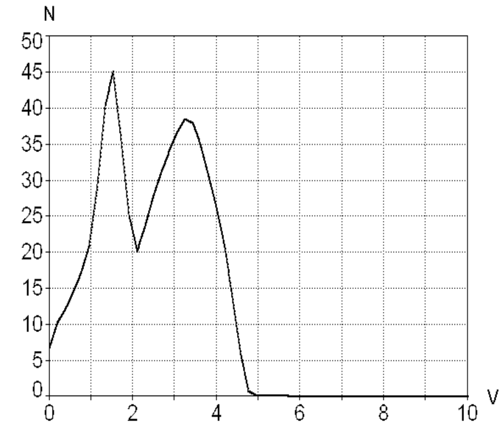

Fig.5. Distribution of particles in respect to velocities after passing two barriers (non-autonomous equation).

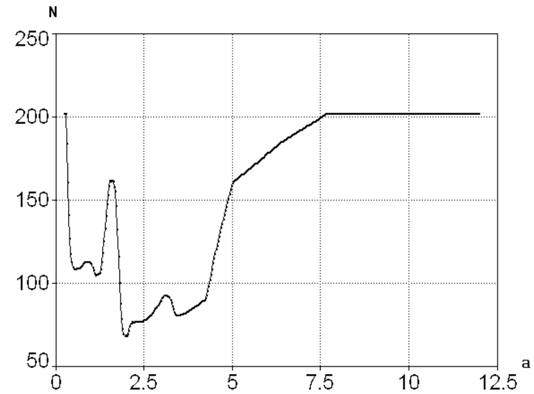

Fig.6. Number of particles passing the barriers in respect to distance between barriers (non-autonomous equation.)

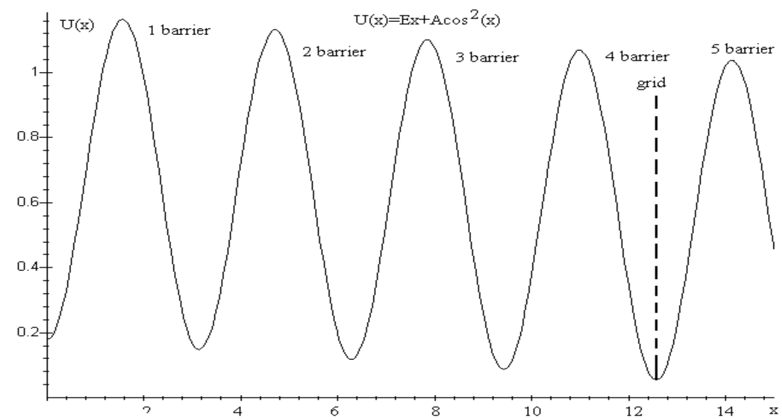

Fig.7. The Potential Barriers.

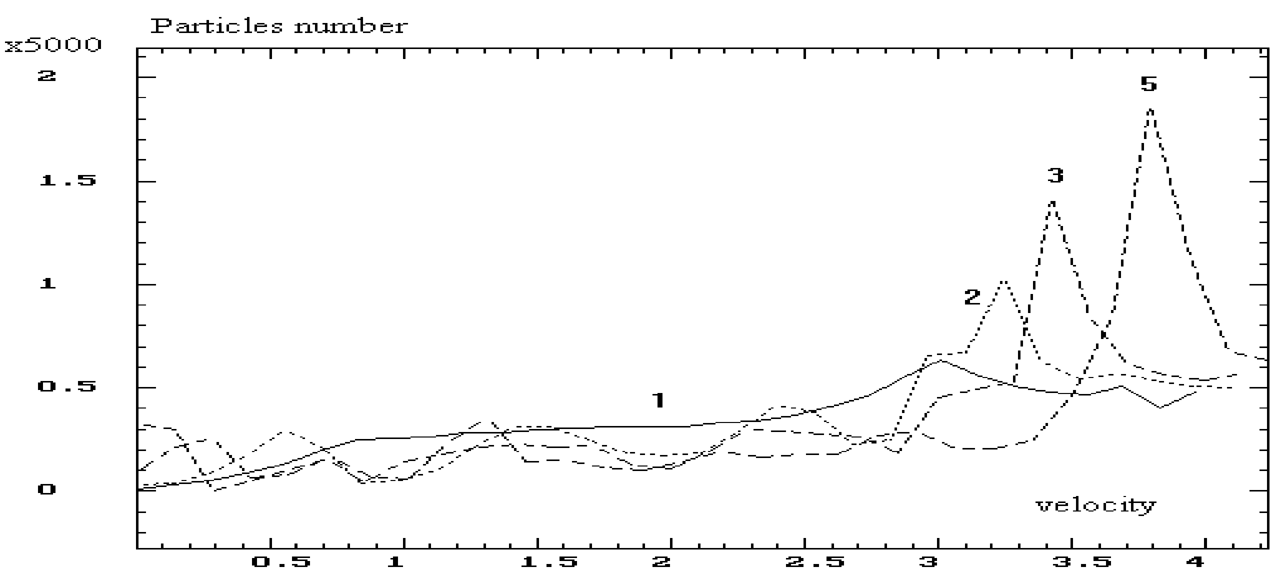

Fig.8.

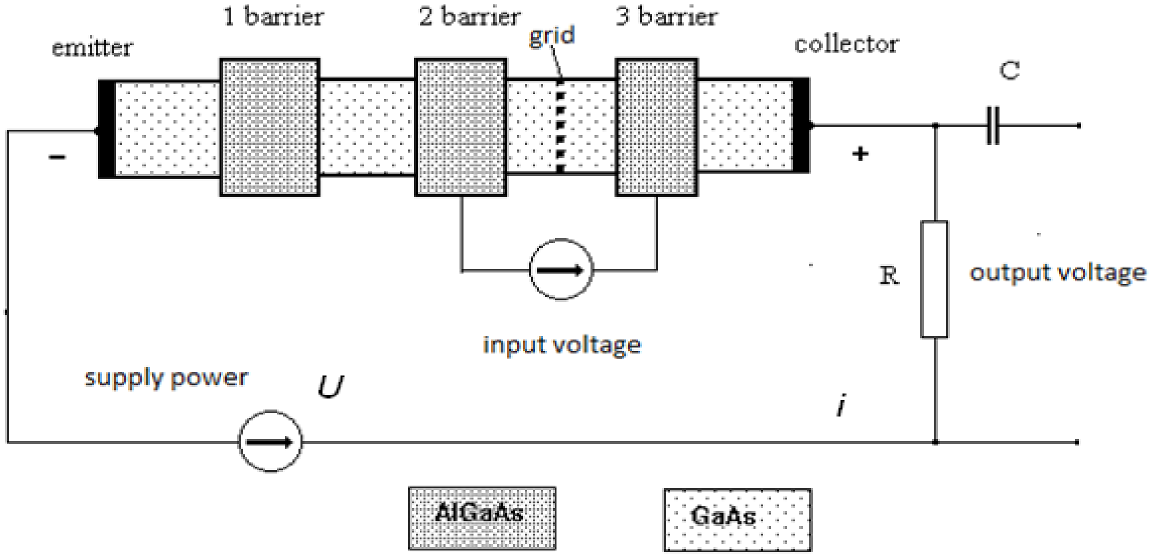
emitter
1 barrier
2 barrier
grid
3 barrier
collector
C
–
+
R
output voltage
input voltage
supply power
U
i
AlGaAs
GaAs

Fig.9.

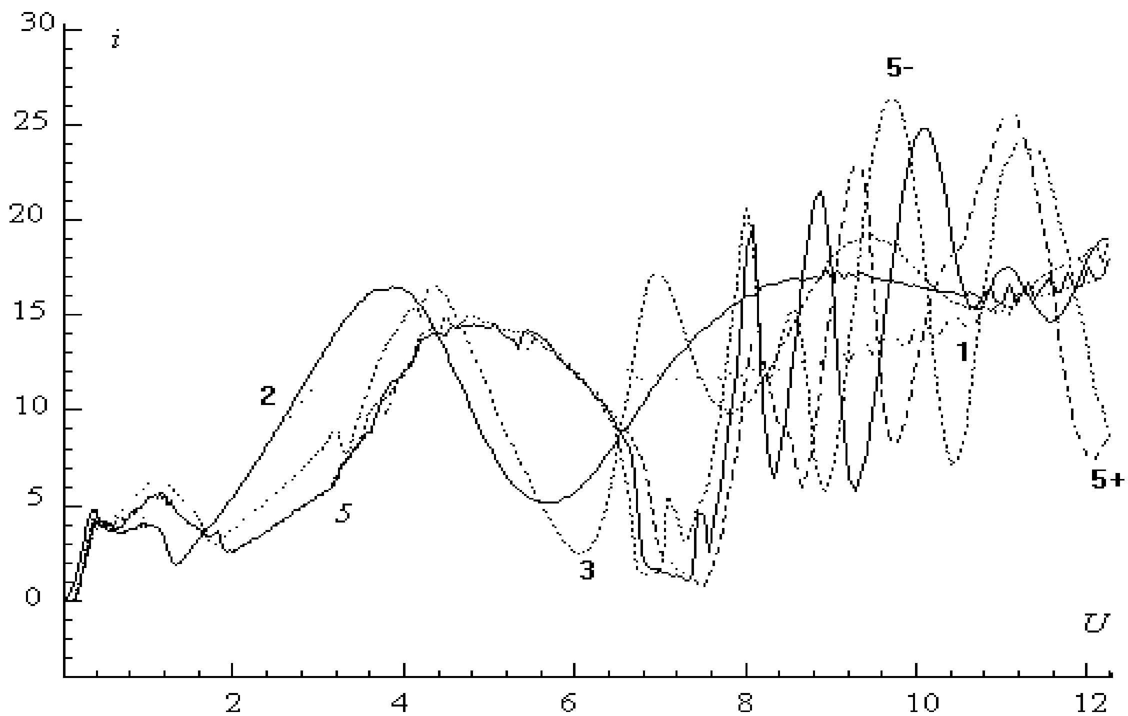
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Fig.10.