Quantum Power Source

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***Abstract*—An experimental evidence of quantum power source is considered. According to an experimental result published recently the dc voltage is observed on segment of asymmetric mesoscopic loop without any external current. It is obvious already from the experiment that it is a quantum phenomena since the value and sign of the voltage depend in a periodic way on the magnetic field with the period correspond to the flux quantum inside the loop. Although the dc power observed on single loop is weak (it does not exceed the power of thermal fluctuations $(k_BT)^2/\hbar$) enough power acceptable for real applications can be obtained since the power of the dc power source can be added. The quantum power source has optimistic perspective of wide application since it transforms heat energy into useful dc electric energy without an expense of any fuel.**

***Index Terms*— nano-structures, quantum power source, superconducting mesoscopic loops, thermal fluctuations**

I. INTRODUCTION

Progress of E-BUSINESS and E-SCIENCE is connected with miniaturization of electronic devices. Inventors and engineers endeavor to scale down devices to nanometer sizes for a wide range of technological purposes. At such small sizes some mesoscopic phenomena, different from macroscopic one are observed. Therefore small devices are not simple rescaled versions of their larger counterparts. There are fundamental limitations to miniaturization. On other hand nano-meter sizes reached now give new opportunity for the progress of e-business and e-science.

One of the fundamental limitations to miniaturization is thermal fluctuations (see for example [1], [2]). Because of fluctuations any device can not be used if the work performed during the duty cycle of it is comparable to thermal energy per degree of freedom, i.e. k_BT. Thus, chaotic energy of thermal fluctuations prevents the miniaturization. But why can not this energy be used? According to the belief predominant in the last century it is impossible because of absolute randomness of this energy. In order to use it for an useful work the random fluctuation motion should be ordered. Can it be made under equilibrium conditions? This problem is discussed already during more than century with essential benefit for science. First this problem was considered by Maxwell in 1871.

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II. MAXWELL’S DEMON AND INFORMATION THEORY

A. Maxwell’s Demon

Maxwell noted that a being that could measure the velocities of individual molecules in a gas could shunt fast molecules into one container and slow molecules into another, thereby creating a difference in temperature between the two containers, in apparent violation of the second law of thermodynamics [3]. Kelvin called this being a “demon”.

It is no coincidence that this demon appeared at the same time with the Maxwell’s kinetic theory of heat [3]. According to this theory the heat is the perpetual motion of atoms. Since absolute randomness of this motion was postulated one believed that the heat energy can be used for the performance of useful work only if it could be ordered even if partially. The partial regulating can be easy achieved under non-equilibrium conditions, for example at a temperature difference. But the task of the Maxwell's demon is to achieve the regulating under equilibrium conditions, when the total entropy might be systematically reduced, contrary to the second law of thermodynamics. Can exist the Maxwell's demon and if it can not exist then why? This problem has a long and interesting history which does not come to an end for the present.

B. Szilard’s Engine

The problem of the Maxwell's demon can be considered for a simple example of Szilard’ engine. Szilard considered in 1929 year a box that contains a single molecule, is capped at left and right ends by pistons, and is equipped with a movable partition which, when dropped, divides the box into equal left and right volumes. The molecule is maintained at temperature T by contact with the walls of the box.

A cycle of the engine goes as follows: the partition, initially raised so that the molecule is free to explore the entire box, is dropped, and the demon determines an which side the molecule is trapped. Using this information, the demon inserts the piston on the empty side of the box, raises the partition, and allow the molecule to do isothermal work as it pushes the piston back to its original position. The demon extracts work k_BT, in apparent violation of the second law.

C. Landauer’s Principle

Since the Maxwell’s demon should perform measurements and get information this problem is important not only for physics but also for the information theory [4]. In the last years it is especially popular in view of quantum computing [5].

In order to exorcize the Maxwell's demon Brillouin assumed [6] that energy should be dissipated in observing the molecule's position. This point of view is developed up to last time [7]. But the view of the demon, most popular in the last decade [5], [8]-[12], is that a demon could indeed perform useful work performing measurements and manipulating information without entropy augmentation, but must increase entropy by at least $k_B ln2$ for each bit erased. This statement is known as "Landauer's principle".

Landauer and others have found that almost any elementary information manipulation can in principle be done in a reversible manner, i.e. with no entropy cost at all [13]. Bennett made explicit the relation between this result and the Maxwell's paradox by proposing that the demon can indeed learn where the molecule is in Szilard's engine without doing any work or increasing any entropy in the environment, and so obtain useful work during one stroke of the engine. But Bennett noted that an additional step is needed to complete the engine's cycle: the demon's memory stores one bit of information - molecule on right or left. To complete the cycle, this information must be erased as the demon's memory returns to a standard state, ready for the next cycle. Bennett invoked Landauer's principle – to erase a bit of information in an environment at temperature T requires dissipation of energy > $k_B Tln2$ – and concluded that the demon does not succeed in turning heat into work.

III. In Which Case the Energy of Fluctuations Can Be Used Without Maxwell's Demon

Although first doubts about the absolute status of the Landauer's principle were published already [14], most people believe that it forbids the demon to perform useful work without entropy augmentation. The problem of the Maxwell's demon is popular up to now since most people believe in absolute randomness of any motion in equilibrium state. Heat could be easy turned into useful work in Szilard's engine without Maxwell's demon if the molecule motion is not absolutely random, if for example the molecule moves in a direction with higher probability than in opposite one. It is impossible in essence in the geometry considered by Szilard, but it is possible at a circular motion for example in the case considered by Feynman [15].

Feynman [15] (and earlier Smoluchowski [16]) considered the ratchet/pawl combination and has shown that the random molecular motion can not perform useful work. But it is obvious that the molecules could perform useful work even without ratchet and pawl at their ordered circular motion. Thus, the postulate on absolute randomness of any fluctuation motion is main obstacle for use of heat energy under equilibrium condition and we should therefore expend a fuel in order to extract useful work.

A. Postulate on Absolute Randomness in Classical and Quantum Mechanics

This postulate was used as long ago as in 19 century by Maxwell and Boltzmann in their theory of heat and was not called in question during more than century. Nobody cast doubt in particular on the belief that the average velocity of any particles equals zero under equilibrium conditions. Although this belief has an enough reliable substantiation in classical mechanics it is not correct according to quantum mechanics.

According to the classical mechanics the average velocity of any motion in equilibrium state equals zero $<v> = 0$ since if spectrum of permitted states is continuous then for any state with a velocity v a permitted state with opposite velocity $-v$ and the same probability $P(v^2)$ exists, therefore $<v> = \Sigma_{per.st.} v P(v^2) + (-v) P(v^2) \equiv 0$. But according to the quantum mechanics no all states are permitted. Therefore the average velocity of some quantum motion can be non-zero $<v> \neq 0$. Thus, according to the well known principle of the quantum mechanics the postulate of absolute randomness of any motion under equilibrium conditions can be incorrect. Moreover some enough known quantum phenomena are an experimental evidence of the non-chaotic motion with $<v> \neq 0$ in the equilibrium state.

B. Experimental Evidence of Non-Chaotic Motion in Quantum Systems Under Equilibrium Conditions

One of the examples of such motion is the persistent current observed at non-zero resistance $R > 0$ [17]. The persistent current can exist because of the quantization of the momentum circulation

$$\oint dlp = \oint dl(mv + \tfrac{q}{c}A) = m\oint dlv + \tfrac{q}{c}\Phi = n2\pi\hbar \quad (1)$$

When the magnetic flux Φ contained within a loop is not divisible by the flux quantum $\Phi_0 = 2\pi\hbar c/q$ (i.e. $\Phi \neq n\Phi_0$) and $\Phi \neq (n+0.5)\Phi_0$ the average velocity $<v> \neq 0$ since the spectrum of permitted states of velocity circulation

$$\oint dlv = \frac{2\pi\hbar}{m}(n - \frac{\Phi}{\Phi_0}) \quad (2)$$

is discrete. Therefore the persistent current $j_p = qn_q<v>$, i.e. the direct current under equilibrium conditions, was observed at numerous experiments in superconductor [18] and even in normal metal [19], [20] loops. First and most reliable experimental evidence of the persistent current at $R > 0$ is the Little-Parks experiment made first in 1962 year [21]. According to the universally recognized explanation [18] of this experiment the resistance oscillations $R(\Phi/\Phi_0)$ are observed because of the oscillations of the persistent current $I_p(\Phi/\Phi_0) = sj_p(\Phi/\Phi_0)$. The persistent current $I_p(\Phi/\Phi_0) \propto (<n> - \Phi/\Phi_0)$ is a periodical function of the magnetic flux since the thermodynamic average value $<n>$ of the quantum number n

is close to an integer number n corresponding to minimum energy, i.e. to minimum $(n - \Phi/\Phi_0)^2$. Thus, according to the Little-Parks experiment and in spite of the Ohm's law $RI = -(1/c)d\Phi/dt$ a direct screening current flows along the loop [22] at a constant magnetic flux $\Phi \neq n\Phi_0$ and $\Phi \neq (n+0.5)\Phi_0$, i.e. without Faraday's voltage $-(1/c)d\Phi/dt = 0$.

C. The Persistent Current at Non-Zero Resistance is Ordered Brownian Motion

The persistent current at non-zero resistance is the motion observed under equilibrium condition and at non-zero friction (since $R > 0$). First the motion of such type (i.e. under equilibrium condition and at non-zero friction) was observed by Brown as far back as two centuries ago. Therefore the motion of such type is called Brownian motion. Brown observed and investigated in the beginning of 19 century a random motion of small particles. This observation was very important for the history of physics.

It was realized once and for all in the beginning of the 20 century that the Brownian motion is observed in the thermodynamic equilibrium state, i.e. that it is perpetual motion. This interpretation shook the foundation of classical thermodynamics of the 19 century according to which any perpetual motion is not possible. It ought be emphasized that the Brownian motion is experimental evidence not only of the perpetual motion but also of a perpetual driving force since no motion is possible without a driving force at non-zero friction. The equation

$$m\frac{dv}{dt} + \gamma v = F_{Lan} \qquad (3)$$

proposed by Langevin for description of the Brownian motion can be used also for description of other motions at non-zero friction $\gamma \neq 0$, for example of a car.

Brownian particles moves without any fuel. Why a car can not move without a fuel if its motion is described by the same equation? Why cannot the energy of the Brownian motion be transformed into the kinetic energy of a car? According to the belief prevailing during last century it is impossible because of randomness of any Brownian motion, i.e. any motion under equilibrium conditions. Consequently, if an ordered Brownian motion, such as the persistent current at $R > 0$, is observed in violation of the postulate on absolute randomness of any motion under equilibrium conditions then we may have the hope that a car can move without any fuel as well as Brownian particles.

D. Quantum Force

Since the persistent current I_p is observed without any voltage it should be explained why this current does not slow down at non-zero resistance $R > 0$. According to [17] the persistent current is maintained in spite of the energy dissipation RI_p^2 because of reiterated switching of the loop between superconducting state with different connectivity induced by thermal fluctuations.

When the superconducting state is unclosed the velocity of superconducting pairs is zero and the momentum circulation $\oint dlp = \oint dl(mv + \frac{2e}{c}A) = m\oint dlv + \frac{2e}{c}\Phi = \frac{2e}{c}\Phi$ (see (1)). When the superconducting state is closed $\oint dlp = n2\pi\hbar$ and the velocity can not be equal zero because of the quantization if $\Phi \neq n\Phi_0 = n2\pi\hbar c/2e$. Therefore each superconducting pair accelerates and its momentum circulation changes from $(2e/c)\Phi$ to $n2\pi\hbar$ at each closing of superconducting state.

The change $(n2\pi\hbar - (2e/c)\Phi)$ of the momentum circulation can be considered as a result induced by the circulation of the Langevin force when the closing of superconducting state is induced by fluctuation. There is important difference from classical Langevin force. The time average value of the latter equals zero $\langle F_{Lan}\rangle = 0$ whereas the average value of the change of the momentum circulation during many closing of superconducting state is not equal zero at $\Phi \neq n\Phi_0$ and $\Phi \neq (n+0.5)\Phi_0$, because of discrete spectrum of closed superconducting state.

The change $(\langle n\rangle 2\pi\hbar - (2e/c)\Phi)\omega = 2\pi\hbar(\langle n\rangle - \Phi/\Phi_0)\omega$ of the momentum circulation induced by closing during a time unity may be considered as the circulation of a quantum force [17]. Although the switching of the loop between superconducting state with different connectivity induced by thermal fluctuation is random (the frequency of switching $\omega = N_{sw}/\Theta$, where N_{sw} is a number of switching during a time Θ) the quantum number n at each closing has with high probability the same integer number n corresponding to minimum energy i.e. to minimum $(n - \Phi/\Phi_0)^2$, since the energy difference between adjacent permitted states with different n is much higher than temperature. Therefore the average value $\langle n\rangle$ is close to an integer number n corresponding to minimum $(n - \Phi/\Phi_0)^2$ and the quantum force

$$\oint dlF_q = 2\pi\hbar(\langle n\rangle - \frac{\Phi}{\Phi_0})\omega \qquad (4)$$

as well as the persistent current are a periodical function of the magnetic flux Φ inside the loop.

The momentum circulation of superconducting pair changes from $(2e/c)\Phi$ to $n2\pi\hbar$ because of quantization and returns from $n2\pi\hbar$ to the initial value $(2e/c)\Phi$ because of the dissipation force F_{dis} acting in the unclosed superconducting state when $R > 0$. Its total change during a long time should equal zero. Therefore during a time unity $(\langle n\rangle 2\pi\hbar - (2e/c)\Phi)\omega + ((2e/c)\Phi - \langle n\rangle 2\pi\hbar)\omega = 2\pi\hbar(\langle n\rangle - \Phi/\Phi_0)\omega + \oint dlF_{dis} = 0$. This relation gives the total balance of force circulation $\oint dlF_q + \oint dlF_{dis} = 0$ which explains why the persistent current is observed in spite of the dissipation $F_{dis} \neq 0$. The quantum force takes the place of the Faraday's voltage and maintains the persistent current in spite of the energy dissipation RI_p^2.

E. Comparison of Persistent Current with Nyquist's Noise

The nearest classical phenomenon analogous to the persistent current at $R > 0$ is the Nyquist's (or Johnson's) noise. It is well known that any resistance at nonzero temperature is the power source of the thermally induced voltage [15]. This type of the Brownian motion was described theoretically by Nyquist and was observed by Johnson as long ago as 1928. Johnson observed a random voltage $<V^2> = 4R\, k_BT\Delta\omega$ in a frequency band $\Delta\omega$ on a resistance R at a temperature T. Nyquist has shown that this voltage is induced by thermal fluctuation. It has the same value in frequency region from zero $\omega = 0$ to the quantum limit $\omega = k_BT/\hbar$.

The observation of the persistent current at $R > 0$ as well as of the Nyquist's noise means that energy dissipation takes place: RI_p^2 in the first case and $<V^2>/R$ in the second case. Because both have power induced by fluctuations, the maximum power of the persistent current RI_p^2 [15] and to the total power of the Nyquist's noise are close to the power of thermal fluctuations $W_{fl} = (k_BT)^2/\hbar$. But there is an important difference between these two fluctuation phenomena. The power of the Nyquist's noise is "spread" $W_{Nyq} = k_BT\Delta\omega$ on frequency region from zero $\omega = 0$ to the quantum limit $\omega = k_BT/\hbar$ whereas the power of the persistent current is not zero at the zero frequency band $\omega = 0$.

It is very important difference. The persistent current can be interpreted as rectified Nyquist's noise. The Nyquist's noise is chaotic Brownian motion [15] and the persistent current at $R > 0$ is ordered Brownian motion [17]. Therefore the power of the first can not be used whereas the power of the second can be used for the performance of useful work.

IV. Nano-Scale Quantum Power Source

It is obvious that work can be easy obtained at an ordered circular motion of molecules, for example in the case considered by Feynman [15]. But how can we use the energy of the persistent current? It is doubtful that a work can be obtained at using of homogeneous, symmetric loop in which can not be a potential difference even at a non-zero current. But it is well known that a potential difference

$$V = (<\rho>_{ls} - <\rho>_l)\, l_s j \qquad (5)$$

should be observed on a segment l_s of an inhomogeneous conventional loop at a current density j along the loop induced by the Faraday's voltage $j<\rho>_l l = <E>_l l = -(1/c)d\Phi/dt$ if the average resistivity along the segment $<\rho>_{l_s} = \int_{l_s} dl\rho / l_s$ differs from the one along the loop $<\rho>_l = \oint dl\rho / l$. The relation (5) can be deduced from the Ohm' law $j\rho = E = -\nabla V - (1/c)dA/dt = -\nabla V - (1/cl)d\Phi/dt$.

A. Persistent Voltage

If the persistent current $j_p(\Phi/\Phi_0)$ is similar to the conventional current induced by the Faraday's voltage the persistent potential difference $V_p(\Phi/\Phi_0) = (<\rho>_{ls} - <\rho>_l)\, l_s\, j_p(\Phi/\Phi_0)$ should be observed without an external current on segments of a inhomogeneous loop where $<\rho>_{ls} - <\rho>_l \neq 0$ and should not observed on segments of a homogeneous one where $<\rho>_{ls} - <\rho>_l = 0$. The experimental investigations [23] corroborate this analogy.

In order to verify the analogy with a conventional loop both symmetric and asymmetric Al loops with the critical temperature $T_c \approx 1.24\ K$, diameter 2r = 1, 2 and 4 μm and a line width w = 0.2 and 0.4 μm were investigated. Because of the additional potential contacts different segments of asymmetric loops have a different resistance at $T \approx T_c$ when $\Phi \neq n\Phi_0$, whereas both segments of symmetric loops should have the same resistance if any accidental heterogeneity is absent.

In accordance with the prediction [17] and the analogy with a conventional loop (5) the voltage oscillations $V(\Phi/\Phi_0)$ proportional to the oscillations of the persistent current $j_p(\Phi/\Phi_0)$ were observed without an external current on segments of asymmetric loops and were not observed on segments of symmetric loops [23].

The analogy with a conventional loop (5) is conformed in [23] since the quantum force (4) as well as the Faraday's voltage $-(1/c)d\Phi/dt$ can not be localized in any segment of the loop in principle because of the uncertainty relation $\Delta p\Delta l > \hbar$ [17]. The velocity of superconducting pairs becomes nonzero when the momentum takes a certain value $\Delta p < p_{n+1} - p_n = 2\pi\hbar/l$, i.e. when superconducting pairs cannot be localized in any segment of the loop. The quantum force should be uniform along the loop: $\oint dlF_q = lF_q$.

Since the dc voltage $V(\Phi/\Phi_0)$ observed in [23] is proportional to the persistent current $j_p(\Phi/\Phi_0)$ it is obvious that they have the same reason. According to [17] both phenomena are explained by reiterated switching of the loop between superconducting state with different connectivity. The value of the voltage, as well as of the quantum force (see (4)), should be proportional to the average frequency of the switching $\omega = N_{sw}/\Theta$ until the frequency does not exceed a limit one corresponded to a time relaxation.

Since the dissipation force does not act on superconducting pairs and the quantum force is uniform along the loop the balance of forces acting on the pairs is $2eE + F_q = 2eV/l_s + 2\pi\hbar(<n> - \Phi/\Phi_0)\omega/l = 0$. Consequently the potential difference

$$V = \frac{\pi\hbar\omega}{e}(<n> - \frac{\Phi}{\Phi_0})\frac{l_s}{l} \qquad (6)$$

should be observed on a segment l_s remaining all time in superconducting state when other segment is switched in normal state with frequency ω. This relation between voltage and frequency resembles the Josephson one $V = \pi\hbar\omega/e$ (see for example [24]). The same voltage (6) should be observed on the segment switched in normal state since $\oint dl\nabla V \equiv 0$.

B. Persistent Power

There is an important difference between the persistent voltage and conventional potential difference observed on segment of inhomogeneous loop. The conventional current, in accordance with the Ohm's law $j\rho = E = -\nabla V - (1/c)dA/dt = -\nabla V - (1/cl)d\Phi/dt$, has the same direction with the electric field in the whole of loop whereas the persistent current is observed without the Faraday's voltage $dA/dt = (1/l)d\Phi/dt = 0$ and consequently the electric field $E = -\nabla V$ and the persistent current I_p should have opposite directions in a segment because $\oint dl\nabla V \equiv 0$. This means that according to the theory [17] and the experimental result [23] a segment of the asymmetric loop is a dc power source: $VI_p \neq 0$ when $\Phi \neq n\Phi_0$ and $\Phi \neq (n+0.5)\Phi_0$. It should be noted that already the classical Little-Parks experiment is evidence of the dc power source since the power dissipation RI_p^2 can be observed only if a power source RI_p^2 exists.

C. Direct-Current Generator

Thus, the theoretical [17] and experimental [23] investigations show that one segment of inhomogeneous mesoscopic superconducting loop is direct-current generator, the persistent power of which is induced by thermal fluctuations, and other segment is a load in which the persistent power is dissipated. This electrical circuit is like partly the fictitious one proposed by Feynman [15] for the explanation of the Nyquist's noise: in both cases the power is induced by thermal fluctuations. But on other hand there are two important differences between these two circuits: 1) The electrical circuit in [23] is not fictitious. The generator and the load are really separated because of the heterogeneousness of the loop, whereas in the Feynman's circuit they can be separated only at a temperature difference. 2) The Nyquist's noise is induced by a noise generator and the persistent voltage is induced by direct-current generator. Because of these two differences the power of the Nyquist's noise can not be used without of temperature difference and the one of the persistent voltage can be easy used.

We can easy obtain the power $W_{load} = V_p^2R_{load}/(R_{load}+R_s)^2$ on an external useful load with the resistance R_{load}. Where R_s is the resistance of the segment which is a load in the inhomogeneous loop. Already the measurement of the dc voltage in [23] is evidence of the use of the dc power. The persistent power observed on single loop does not exceed [23] and can not exceed [17], [25] the power of fluctuations $W_{fl} = (k_BT)^2/\hbar$ which is weak (for example at $T = 100$ K $(k_BT)^2/\hbar \approx 10^{-8}$ Wt).

Nevertheless we can obtain enough power acceptable for real applications since the power of the dc power source can be added. It is the third important difference of the persistent voltage from the Nyquist's noise. The power of the Nyquist's noise $W_{Nyq} = k_BT\Delta\omega$ observed on one resistance equals the one observed on N resistance whereas the power of any N dc power source can be added. The voltage $V_N = NV_p$ should be observed on a system of identical inhomogeneous loops segments of which are connected in series. The power $W_{load} = N^2V_p^2R_{load}/(R_{load}+NR_s)^2 = NV_p^2/4R_s < W_{p,N} < N(k_BT)^2/\hbar$ can be obtained on an electric device with the resistance $R_{load} = NR_s$ loaded on this system [26]. Where $W_{p,N} = NV_p^2/R_s$ is the persistent power of a system of N identical inhomogeneous loops.

D. Optimistic Perspective of Wide Application

Although only very weak power 10^{-12} Wt at T = 1.2 K was obtained [23] for the present on segment of single asymmetric Al loop with low critical temperature $T_c = 1.2$ K the quantum power source on base of a system of superconducting loops has optimistic perspective of wide application. The power of single loop can be considerably increased if we will use high-Tc superconductors (HTSC) [26], [27]. The critical temperature T_c of HTSC known now exceeds 100 K. Therefore the persistent power of single HTSC loop can mount up to 10^{-8} Wt.

A system of 10^8 HTSC loops can give the power up to 1 Wt. It is enough difficult to make such system. The persistent current and persistent voltage can be observed only in a loop with enough small diameter, which does not vastly exceed the coherence length of the superconductor. Aluminum has greatest coherence length. Therefore it was used for initial investigations of the persistent voltage in [23]. But the coherence length of all HTSC known now is very small. Therefore HTSC loops for the quantum power source should be nano-scales.

It is enough difficult to make HTSC loops with needed scales. Nevertheless modern methods of nano-technology allow to make it even now. On other hand small size has an advantage. A system of 10^8 HTSC loops with diameter 1 μm can be made an area $\approx$ 1 cm^2. The dc power of such system can reach $N(k_BT)^2/\hbar \approx 1$ Wt. The power can be increased in many times by the use of multi-layer technology. The power up to 10 kWt can be obtained in a system with volume ≈ 100 cm^3 and thickness of layers 0.01 cm.

Very high technology requires in order to make such nano-scale quantum power source and cost of its production could be enough high. Nevertheless such power source can has wide application in the future since it can give useful energy any how long time without any fuel. It can be used simultaneously as direct-current generator [28] and refrigerator [29].

V. Conflict With the Second Law of Thermodynamics

A. Carnot's Principle

The advantage of the quantum power source is conditioned by violation of the second law of thermodynamics in a superconducting loop [25]. Although many people think now that the second law was first put into words by Rudolph Clausius and William Thomson (Lord Kelvin) in 1850-51 years more erudite scientists, such as Marian Smoluchowski [16] and Richard Feynman [15] understood that Sadi Carnot discovered the second law 25 years earlier. Smoluchowski wrote in [16] about Carnot's principle which we call since Clausius time the second law of thermodynamics. The

Carnot's principle was proposed before the first law of thermodynamics was discovered [15]! Therefore it is called the second law of thermodynamics only since Clausius time.

According to the Carnot's principle the efficiency of any heat engine can not exceed Ef = $(1 - T_{min}/T_{max})$. Surrendering this principle we should expend a fuel in order to maintain the temperature difference $T_{max} - T_{min}$ in any heat engine. Violation of the Carnot's principle delivers from the necessity to expend any fuel. But most people are fully confident that it is impossible because it is well known since Carnot's time that violation of the second law means a possibility of perpetuum mobile.

The centuries-old belief in impossibility of perpetuum mobile is the reason of the emotional attitude to the second law. Arthur Eddington wrote in 1948 [30]: "*The second law of thermodynamics holds, I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations - then so much the worse for Maxwell's equations. If it is found to be contradicted by observation, well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but collapse in deepest humiliation*".

B. Statements on Violation of the Second Law Published in the Last Years

The emotional attitude to the second law played an important part in the history of physics. Because of it most physicists rejected in the 19 century the kinetic theory of heat (see [16]) proposed by Maxwell, Boltzmann and others. The blind belief in the second law was not shaken even when in the beginning of 20 century the Brownian motion was realized as most evident experimental proof of perpetual motion.

The compromise between the second law and the perpetual motion was proposed already in the 19 century by Boltzmann, Maxwell and others. According to this compromise, predominated during the 20 century, perpetual driving force exists but this force is useless because of its randomness. According to the modern interpretation, random perpetual motion does not contradict to the second law. Therefore the titles of [1] and [2] convey no quite correct the meaning of these papers in which conventional random fluctuations are considered. Only ordered perpetual motion contradicts to the second law. Therefore the postulate on randomness of any motion in the equilibrium state is so important for the preservation of the second law.

This postulate became firmly established in the beginning of 20 century and was generalized on quantum mechanics without due examination. Therefore most scientists believe in the absolute status of the second law up to now (see [31] for example) as well as in the 19 century. But this attitude begins to change in the last time. Enough many papers with challenge the second law were published in the last years [32]-[50]. More detailed Bibliography can be found at web-sites http://www.sandiego.edu/secondlaw2002/#Bibliography and http://www.ipmt-hpm.ac.ru/SecondLaw/.

C. The Persistent Current at R > 0 is Experimental Evidence of Violation of the Second Law

My interest to the problem of the second law was provoked by the experimental result obtained first in 1997 by my co-author of [51] and repeated in [23]. Beyond all question this result is experimental evidence of a dc power source. According to the explanation published first in [51] this dc power can be induced by thermal fluctuation in violation of the second law.

According to [51] and [17] the dc voltage observed in 1997 and in [23] can be induced both by thermal fluctuation and by an external electric noise but violation of the second law takes place in both cases. Moreover the consideration of this experiment allowed me to see that the persistent current at $R > 0$ observed in many works is unquestionable experimental evidence of violation of the second law. The numerous observations the power dissipation RI_p^2, i.e. I_p at $R > 0$, is evidence of a power source RI_p^2. Therefore the observation of the persistent power in [23] is not new in essence.

Many scientists state that the persistent current at $R > 0$ is not experimental evidence of violation of the second law since it is equilibrium phenomenon and therefore no work can be extracted from the persistent current. Indeed, in the equilibrium state, in which the persistent current is observed, the free energy $F = E - ST$ has minimum value and nobody can decrease a value below its minimum. But the internal energy E can be decrease without any decrease of the free energy if the entropy S decreases at the same time. Thus, this statement of defenders of the second law is turned into the statement that the second law can not be broken since it can not be broken. The observation of the persistent power in [23] is experimental evidence of work extraction from the persistent current. This result means that the total entropy might be systematically reduced, contrary to the second law of thermodynamics.

VI. Conclusion

The use of the persistent power can help to solve the fuel and energy problem in the future. But now it is not clear when the quantum power sources will begin to use really. In order to reach a real application intensive and long investigations should be made and nano-technology of HTSC should be developed. But main obstacle now is the blind belief of most people in the second law.

Six years ago I, as well as most people, was fully confident that the second law can not be broken. But an accidental experimental result forced to change my opinion. Five years ago I supposed that at least some decades will be needed in order to overcome the blind belief in the second law. But two years ago I learnt with to my great surprise that not only I challenge to the second law. The First International Conference on Quantum Limits to the Second Law, which was held July 29-31, 2002 in University of San Diego (see http://www.sandiego.edu/secondlaw2002/), and its

Proceedings, which will be published in the December by American Institute of Physics, may undermine the blind belief in the second law. The attitude to this problem changes now very quickly. Therefore I can not foretell when first application of the quantum power source will be real.

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