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Thermal Evolution Process and its Relation to Some Philosophical Problems of Physics

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Abstract- Using the technique of synchronous differential temperature measurements, we have shown, for the first time, that the process of interaction of the external electromagnetic (EM) fields with the ensemble of atoms of the homogeneous material artifact is characterized by the violations of symmetries in time and in space, by the violation of the superposition principle for the EM fields and by the hysteresis effect, even when the contribution of the thermal surface energy is made negligible. The thermal evolution process is shown to have infinite number of influence parameters, is specific for a particular observation point where it is characterized by the local time, or as defined by modern philosophers: the concepts of time and space are relational. The experiments give an experimental proof to the famous observation of Niels Bohr that in the general case, space-time description is impossible for material objects.

Keywords: evolution process, hysteresis effect, symmetry violations, synthesis.

1. Introduction

This paper will be started with the observation, which is in agreement with views on epistemology of Niels Bohr, who has re-discovered dialectics and who has "vividly realized that our proud theories are but temporary resting places of the mind on the unending road to knowledge" (Rosenfeld, 1963). In the context of our following discussion, special attention should be paid to the N. Bohr's observations that: "Physics is to be regarded not so much as the study of something a priory given, but rather as the development of methods of ordering and surveying human experience. In this respect our task must be to account for such experience in a manner independent of individual subjective judgment and therefore objective in the sense that it can be unambiguously communicated in ordinary human language.", and the other one: "Isolated material particles are abstractions, their properties being definable and observable only through their interaction with other systems". N. Bohr's point of view is very close to position of Werner Heisenberg, who discussing the Copenhagen interpretation of Quantum theory, in 1958 wrote: "Our scientific work in physics consists in asking questions about nature in the language that we possess and trying to get an answer from experiment by the means at our disposal… It is understandable that in our scientific relation to nature our own activity becomes very important when we have to deal with parts of nature into which we can penetrate only by using the most elaborate tools".

The next N. Bohr's observations are of special interest: "In physics we again and again learn that our task is not to investigate the essence of things—we do not at all know what this would mean; but to develop those concepts that allow us to speak with each other about the events of nature in a fruitful manner"; and "There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about Nature". They can help us to understand one of the most important Niels Bohr's philosophical statements, which can be even found nowadays in the University text-books (Giancoly, 2000). For example, there we find: "Perhaps the most important and influential philosopher of quantum mechanics was Bohr. He argued that a space-time description of actual atoms and electrons is not possible." The confirmation of this N. Bohr's point of view can be found in the letter of 1926 by Erwin Schrödinger to

W. Wien: “Bohr’s standpoint, that a space-time description is impossible, I reject a limine. Physics does not consist only of atomic research, science does not consist only of physics, and life does not consist only of science. The aim of atomic research is to fit our empirical knowledge concerning it into our other thinking. All of this other thinking, so far as it concerns the outer world, is active in space and time. If it cannot be fitted into space and time, then it fails in its whole aim and one does not know what purpose it really serves.”

Quite opposite to N. Bohr, were the views of R. Feynman, who wrote that “all electrons are the same, all protons are the same, all positive pions are the same; and so on” (Feynman et al., 1964). And on the next page there we read: “*Apparently it is true that the fundamental physical laws, on a microscopic and fundamental level, are completely reversible in time”*. According to R. Feynman, the laws of physics rule in Nature.

Here, it is worth noting that it was R. H. Dicke, who first pointed out that the standard theoretical treatment of spontaneous radiation by a dilute gas of molecules, in which it is considered that separate molecules radiate independently of each other, ”is wrong in principle and many of the results obtained from it are incorrect” (Dicke, 1954). In accordance with his views, the parameters of the radiation process in the system of molecules, interacting with the common EM field, critically depend on the pre-history of the system and the type of its excitation, and there is no spatial symmetry in this radiation process (Dicke, 1954).

Before short description of the results of our study, it is interesting what can be found in recently published books. B. Greene, for example, writes: “The concept of symmetry’s breaking, and its realization through the electroweak Higgs field, clearly plays a central role in particle physics and cosmology. Like the aether, a condensed Higgs field permeates space, sweeps through everything material, and as a nonremovable feature of empty space, it redefines our conception of nothigness” (Greene, 2006). Quite recently, Lee Smolin has presented the ideas of paramount importance: “There can be no absolute time that ticks on blindly whatever happens in the world. Time must be consequence of change; without alteration in the world there is no time. Philosophers say that time is relational – it is an aspect of relations, such as causality, that govern change. Similarly, space must be relational; indeed, every property of an object must be a reflection of dynamical relations between it and other things in the world” (Smolin, 2013a). He specially notes that for “complex systems, involving large numbers of atoms, we must deal with the laws of thermodynamics, which are not reversible in time” (Smolin, 2013b). And Lee Smolin makes a special emphasis that “many laws in physics are time-reversible. One is Newtonian mechanics, another is general relativity, still another is quantum mechanics” (Smolin, 2013b). And the other important observation, which is crucial for understanding the presented here experimental studies, reads:” Darwinian evolutionary biology is the prototype of thinking in time, because at its heart is the realization that natural properties, developing in time, can lead to creation of genuinely novel structures” (Smolin, 2013d).

2. Thermal Evolution Process inside Originally Homogeneous Bulk Material

The last observation of L. Smolin is in complete agreement with our studies, performed using unique Kösters interferometer (Darnedde,1992), in which very small temperature drifts, reaching the value of 1mK/hour (or 10-20 μK per minute), opened the opportunity to study the propagation of very small thermal signals in a 900mm steel gauge block. A simplified diagram of the experimental set-up is shown in Fig.1. A 900mm steel gauge block was installed inside the interferometer, and a 100 Ohm platinum resistance thermometer (PRT) was located at the center of one of the narrow side surfaces of the block. The PRT was inserted into a copper rectangular adapter, of about 90mm long and 9mm wide that covered the whole width of side surface of the gauge block. Two thermistors, also in 9mm wide copper adapters, were located on the same surface and exactly at the same distances from the corresponding surfaces of the PRT adapter, but in the opposite directions relative to the PRT. The square-wave current modulation in the PRT was realized by high-precision, automatic (Mi-T615) bridge between the two current values: 1mA and 2mA. The thermistors, connected to precision multi-meters HP-58a, realized synchronous temperature measurements at their locations that were stored in a special program. The details of the experimental set-up can be found in (Titov, Malinovsky, 2011) and the demonstration and the application of the synchronous multi-channel detection technique are presented in (Titov, Malinovsky, 2013a, b).

Before summarizing the main experimental results that were obtained using long modulation cycles (up to 2.5 hours), which opened the possibility to study the propagation of thermal signals in long gauge blocks, we are to remind the main results of the papers (Titov, Malinovsky, 2013a, b; Titov. 2015), without which the here presented studies cannot be completely understood. In (Titov, Malinovsky, 2013a, b; Titov. 2015) the thermal surface energy (TSE), which presents the oriented motion of the coupled field-particle system inside the material artifact and which arises as a result of interaction of the external EM field with the ensemble of the artifact atoms, has been experimentally demonstrated with a huge signal-to-noise ratio. The TSE is detected through the absorption in a couple of thermistors of the EM-field, emitted by the oriented motion of the field-particle system inside the artifact. The absorbed energy of the EM filed results in the increase of the conductivity of the thermistors, which can be easily detected by precision multi-meters. Using the current modulation technique in combination with the synchronous differential thermal measurements, the TSE has been shown to be linearly related to the *Poynting vector* of the external EM field, is characterized by the hysteresis effect, with the loop in a steel artifact, resembling the loop of a hard ferromagnetic material. Similar to ferromagnetic and ferroelectric materials, the process of the build-up of thermal surface energy has no symmetry in space, and is irreversible in time. The principle of superposition of EM fields is shown experimentally to be not valid in case of TSE. Thus, the nonlinear character of the interaction of the EM field with ensemble of atoms was demonstrated, using the amplitude type of measurements. In this we are in agreement with the studies of P. Kusch, who in 1954 discovered this nonlinear effect when using the spectral type of measurements (Ramsey, 1963). But the basic difference of our studies relative to P. Kusch studies is the demonstration of the hysteresis character of the interaction between the field and the ensemble of atoms, when the result of this interaction (leading to new properties of the material artifact) is accumulated gradually in time and is specific for any particular point inside the material artifact. As the thermal surface energy is detected through EM radiation and its magnitude is defined by the *vector quantity* (the Poynting vector) of the resulting external EM field, it means that all the material objects are constantly interacting with each other even in the presence of a single source of energy, radiating EM field. Consequently, as the number of interacting objects (or influence factors) is infinite and all these objects contribute to the common EM field, the thermal evolution process can be regarded as a synthesis (or self-ordering process) with the participation of the infinite number of the correlated material objects in the presence of, at least, one source, capable of generating the energy and momentum of the EM field. (The Sun -in case of experiments, performed on the Earth).

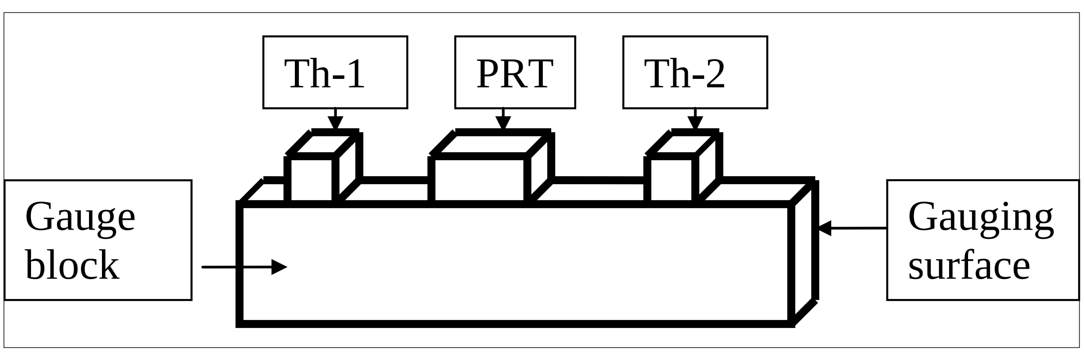

Fig. 1. Experimental set-up. A 900mm steel gauge block is installed horizontally inside the temperature stabilized interferometer. A platinum resistance thermometer (PRT) is located at the center of the side surface of the block. Two thermistors Th-1 and Th-2 are located at the same distance from the PRT. (See text for other details).

In the present study it is shown experimentally, for the first time, that the thermal evolution process occurs not only as a result of the existence of the thermal surface energy, but is observed also in the originally homogeneous material artifact under the influence of two sources of EM radiation, even when the reflections of the propagating field-particle system from the boundaries of the artifact can be neglected. The effect in the bulk material is much smaller and much more difficult to observe than in case of the TSE, when the large nonlinearity of the properties of the artifact due to the presence of its boundary makes the detection of TSE relatively easy. But the effect in the bulk material can be accumulated in space by the increase of the propagation length of the field-particle system inside the artifact, and can be detected by using synchronous differential thermal measurements. The evolution process in the bulk material, as shown experimentally, results in the hysteresis type effect, when the properties of an artifact are changing gradually in time in response to the Poynting vector of the external sources of EM radiation.

The effect of the boundaries only changes the magnitude and the form of the hysteresis loop. For example, in a steel artifact, close to the boundary, the hysteresis loop resembles the loop of a "hard" ferromagnetic material, while for the volumes inside the artifact, which are located far away from its boundaries, the loop resembles the hysteresis loop of very "soft" ferromagnetic materials.

As in case of thermal surface energy, the principle of the superposition of EM fields is not valid, and, as a result of the demonstrated nonlinearity of a material artifact in its solid state, the evolution process is accompanied by the gradual changes of the properties of the material artifact, with the generation of new properties not existing before. (Naturally, this is possible, if the artifact has been able to survive its disintegration to smaller parts at the initial stages of the interaction with the EM field. But such disintegration should be considered as the most radical change of the properties of the initially existing artifact).

As in case with the TSE, the number of influence parameters in the experiment, or the number of material objects, interacting with the artifact through the common EM field, is absolutely enormous. (As a kind of abbreviation, it can be called simply infinite). So, from the presented experimental studies it follows that all the experiments are fundamentally incomplete, and no final set of experiments is able to present all the modes of existence and manifestations of the thermal evolution process.

On the other hand, the evolution process is irreversible in time. So, it follows from (Titov, Malinovsky, 2013a, b), and this statement is in agreement with the present studies, that the modulation of the current in the PRT spoils forever the original evolution process of the artifact. (Or in accordance with the observation of L. Smolin (2013a), the artifact's environment is changed in this case). Thus, the results of the experiment do not present the properties of an "isolated" artifact, but reflect the properties of the artifact –thermometer - environment system. For example, in our experiments, to find out, even approximately, the properties of the isolated artifact, it is necessary to perform new, huge series of measurements with the decrease of the dimensions of the thermistor adapters and with the gradual decrease of the dissipated power in the thermometers. But this will result in unacceptable loss of accuracy of the following temperature measurements. So, our experiments confirm the cited quotations of N. Bohr and of W. Heisenberg, concerning the theoretical approximations in the very concept of an "isolated material object".

But the most striking experimental result deals with the fact that the process does not evolve uniformly throughout space-time (Smolin, 2013b), but its parameters are specific for a particular observation point inside the same artifact, and the dependences in time are specific for each observation point. So, it is natural that different objects, which are characterized by their own hysteresis effects, have different time scales. This confirms the point view of contemporary philosophers that space and time concepts are relational (Smolin, 2013a). The main of these properties are illustrated by figures 2-5.

In Fig.2a we present the dependence of the vector quantity **DT[1,2] (**in μK) on time that is used to characterize the difference in the values of the synchronously measured temperatures of the thermistors of the channels 1 and 2. The variation of the quantity **DT[1,2]** is induced by the increase of the modulation current in the PRT from 1mA to 2mA (Titov, Malinovsky, 2011). Its increasing value reflects the fact that the *induced energy flux* to the thermistor Th-1 is larger than the energy flux to thermistor Th-2 at the specified moment of the modulation cycle (Titov, 2015). The quantity **DT[1,2]** is, naturally, the vector quantity as it carries the information about the direction of the propagation of the energy flux. The duration of the modulation cycle in Figs. 2-4 is more than 3 hours. Here, the heating period of the modulation cycle, corresponding to the current value of 2mA in the PRT, is about 72 minutes. In these figures, the experimental points, corresponding to the heating period, are shown as dots. The cooling period of the cycle is 1.5 times longer, and it corresponds to the current of 1mA. The experimental points, representing the major part of the cooling period, are shown by rhombi, while the reference points, corresponding to the last 40 minutes of the cooling cycle, are shown as squares. The reference points of 5-6 modulation cycles are used to find 6-th order polynomial fit, and relative to this fit the variations of the quantity are obtained (Titov, Malinovsky, 2013a, b). When the PRT is located at the center of the side surface of the gauge block, and the separations of thermistors from the PRT are the same, the quantity **DT[1,2]** is, naturally, equal to zero, as a result of the homogeneity of the block material and the symmetry of the experimental set-up. But when a powerful heat source is located asymmetrically relative the interferometer, outside it, then, practically, constant energy flux can be produced inside the gauge block along its axis, which can be detected as a temperature difference **T[1,2]**, recorded by the thermistors Th-1 and Th-2. So, the curve in Fig.2a corresponds to the separations between the neighboring surfaces of the adapters of the thermistors and of the PRT equal to 270mm, and when the temperature difference between the locations of the thermistors **T[1,2]** is equal to -42.9mK. As pointed out above, this temperature difference was produced by the power-stabilized temperature source, which was located outside the enclosure of the interferometer, whose temperature was stabilized by the flux of temperature-controlled water.

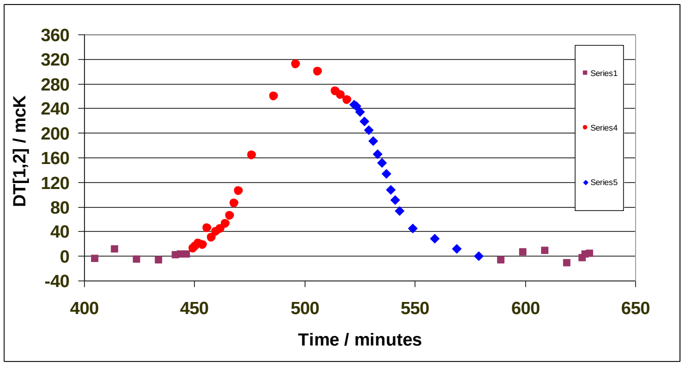

Fig. 2a. Dependence on time of the thermal evolution process, characterized by the induced temperature difference DT[1,2] in μK, obtained for the separations between the thermometers 270mm, temperature difference between the positions of the thermistors T[1,2]= -42.9mK and for current variations between 1mA and 2mA. Dots correspond for the heating period of the cycle, and rhombi to the cooling period. The experimental points, corresponding to the last 40 minutes of the cooling period of the modulation cycle are used as reference points and are shown as squares.

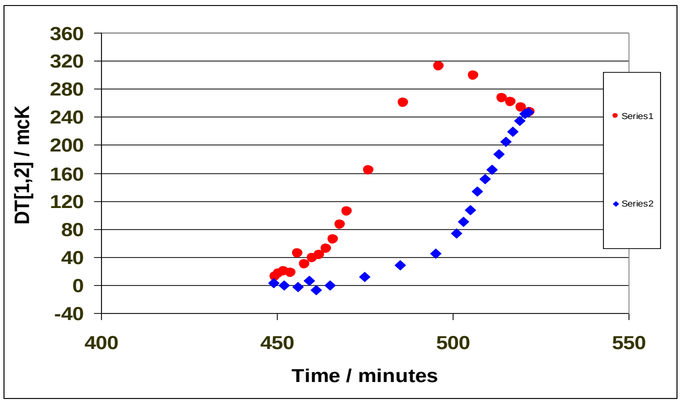

Fig. 2b. Hysteresis loop for the thermal evolution process, characterized by the induced temperature difference DT[1,2], for the separations between the thermometers 270mm, temperature difference between the positions of the

thermistors T[1,2]= -42.9mK and for current variations between 1mA and 2mA. Dots correspond for the heating period of the cycle, and rhombi to the cooling period.

The curve of Fig.2a can be also presented in a form of a hysteresis loop, using the procedure described in (Titov, 2015). The corresponding hysteresis loop is shown in Fig.2b. The forms of the curves in Figs. 2a and 2b define the amount of energy of the oriented motion of the electrons in the platinum coils that is radiated by the gauge block during the modulation cycle, then converted into heat and is removed by the flux of water from the set up, So, in agreement with Clausius - Plank formulation of the Second law of thermodynamics, the observed thermal process is definitely irreversible in time, similar to the other well-known hysteresis processes in ferroelectric and ferromagnetic materials (Titov, Malinovsky, 2013a, b).

In Fig.3 the dependence of the quantity **DT[1,2]** on time is shown for the case when the separations between the adapters of the thermometers were the same as in fig.2a (270mm), but for the temperature difference between the locations of the thermometers was changed to 12.9mK, as the result of the shift of the external heat source relative to the enclosure of the interferometer. The comparison of the dependences in Figs. 2a and 3 shows that when the energy flux produced by the auxiliary external energy source changes the direction, the induced temperature difference, described by the quantity **DT[1,2],** changes the sign! As the vector quantity **DT[1,2]** describes the temperature variations (induced by the modulation of current in the PRT) and these variations are affected by the thermal radiation of an auxiliary energy source, this means that *the principle of superposition is not valid for EM fields even for originally homogeneous bulk material, when the strong nonlinearity, associated with the boundaries of artifact, is not affecting the result of the experiment.*

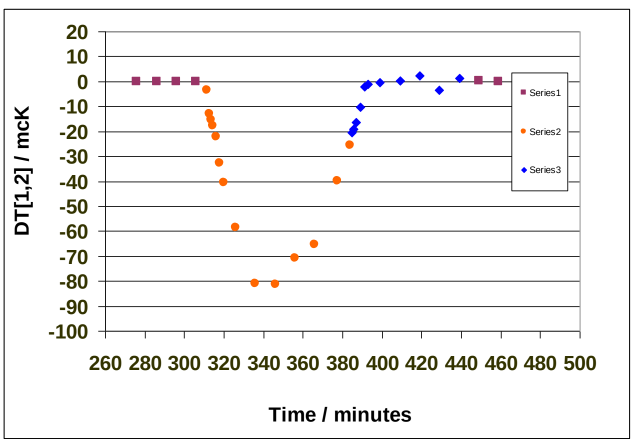

Fig. 3. Induced temperature difference DT[1,2] as a function of a current time, obtained for the separations between the thermometers 270mm, temperature difference between the positions of the thermistors T[1,2]= +12.9mK and for current variations between 1mA and 2mA.

On the other hand, the change of the sign of the quantity **DT[1,2]**, caused by the change of the direction of the energy flux in the artifact, which is produced by the auxiliary source, means that <u>in case of two sources of EM radiation the symmetry in space is lost</u>: *the originally homogeneous material acquires anisotropic properties*. A new property of the material is generated: the energy flux in the direction of the already existing current of energy, which has been installed in the bulk material of an artifact by an auxiliary source of EM radiation, is more efficiently created, than the flux in the opposite direction.

But there is another important observation, which follows from the comparison of the plots in Figs. 2a and 3. It is clearly seen that the form of the dependence on time of the evolution process is also changed with the change of the sign of the temperature difference **T[1,2]**. If we calculate the ratio of the maximum value of the quantity **DT[1,2]** to its value at the end of the heating period of the modulation cycle, then we find that for the curve in Fig.2a this ratio is 0.795, while for the curve in Fig.3 it is only 0.315. As the smaller value of the ratio is obtained for the positive value of the quantity **T[1,2]**, this gives an indication that the falling part of the curves is associated with the thermal surface energy, studied in (Titov, Malinovsky, 2013a, b).

This assumption can be checked experimentally, as the corresponding studies have been performed for several different separations between the PRT and thermistors. In Fig.4 the dependence of the evolution process on time is presented for the diminished separation value between adapters of the thermometers, which in this case was 200mm. The value of the temperature difference between the thermistors, characterized by the quantity **T[1,2]**, was also negative, as in Fig.2a, and was equal to -53.5mK. From the comparison of the plots in Figs. 2a and 4 it is clear that the falling portion of the curve in Fig.2a is significantly decreased, corresponding to the larger separation of the thermistor Th-1 from the neighboring gauging surface. The corresponding ratio for the curve in Fig.4 is increased to the value of 0.836. The last curve in this series is presented in Fig.5. The separations between the adapters of the PRT and of the thermistors were 160mm. The temperature difference **T[1,2]** was also negative and was equal to -32.6mK. The new feature of this experiment was the reduction by two times of the total duration of the modulation cycle. In this case the heating period of the cycle was about 36-37 minutes. From our studies of the velocities of the propagation of the oriented motion of the field-particle system inside the steel gauge block it follows that no measurable amount of energy can reach the position of the thermistor Th-1 after the reflection from the boundary surface. In this case the contribution of the thermal surface energy should be quite negligible (Titov, Malinovsky, 2013b). And the plot of Fig.5 gives another confirmation to our statement that the thermal surface energy arises as a result of the reflection of the wave momentum of the field-particle system from the boundary of the artifact. Indeed, the maximum value of the quantity **DT[1,2]**, describing the oriented motion of the field-particle system, is observed at the end of the heating period of the modulation cycle, and there is no suppression of the effect of the induced nonlinearity in the bulk material, by the thermal surface energy. The hysteresis loop, as it follows from the curve in Fig.5, resembles the loop of very soft ferromagnetic material.

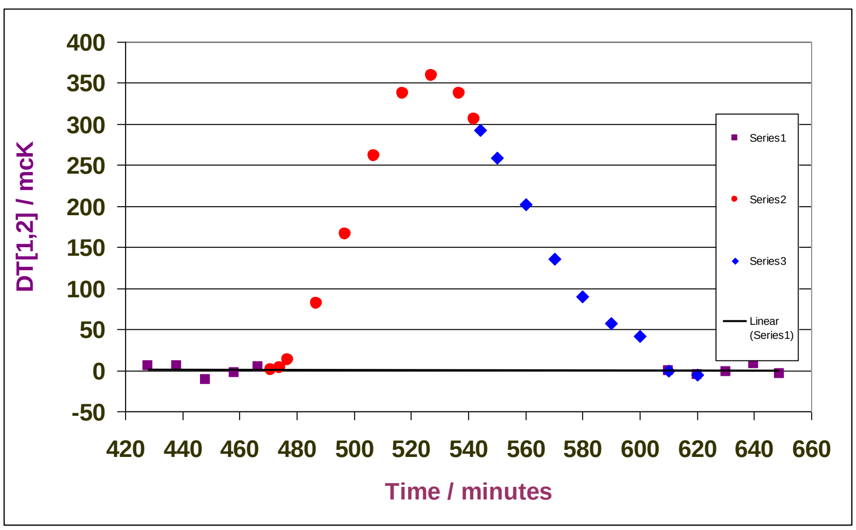

Fig. 4. Induced temperature difference DT[1,2] as a function of a current time, obtained for the separations between the thermometers 200mm, temperature difference between the positions of the thermistors T[1,2]= -59.3mK and for current variations between 1mA and 2mA.

The magnitude of the time dependence in Fig.5, which was obtained for the current variations between 1mA and 1.414mA (for doubled dissipated power in the PRT), clearly indicates that the vector quantity **DT[1,2]** is related to the Poynting vector of the EM field, produced by the source of modulation signal.

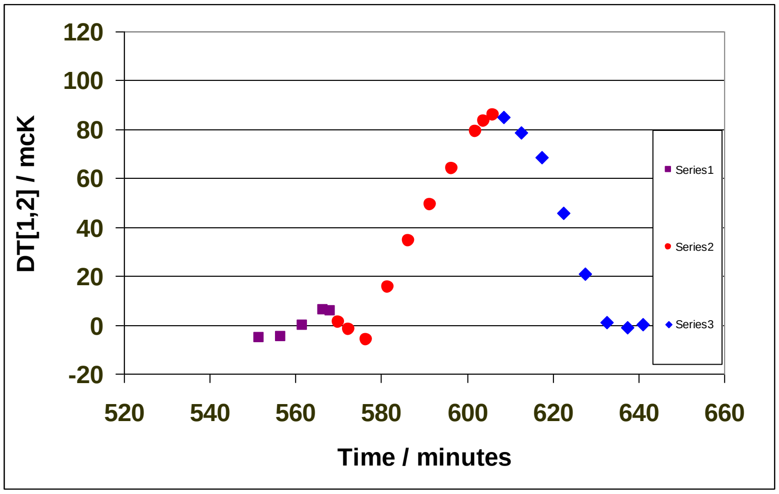

Fig.5. Induced temperature difference DT[1,2] as a function of a current time, obtained for the separations between the thermometers 160mm, temperature difference between the positions of the thermistors T[1,2]= -32.6mK and for current variations between 1mA and 1.414mA. The duration of the modulation cycle is two times shorter than the one in Figs. 2-4.

Comparison of the plots in Figs. 2-5 gives a clear experimental demonstration that for the modeling procedure with only two sources of EM radiation, the thermal evolution process is quite specific for the selected observation points and for the chosen observation moment. In the general case, the process has no symmetry in time (irreversible process) and no symmetry in space. (Just like hysteresis effects in ferromagnetic and ferroelectric materials). The number of interacting material objects, similar to the case of the thermal surface energy (Titov, Malinovsky, 2013b), is enormous, each of these material objects is characterized by its own hysteresis effect, and all these material objects are not independent, as all of them are contributing to the common EM field. It should be absolutely clear that the general description of the evolution processes in Nature, using the mathematical tools, which were developed for the description of Newtonian systems, is basically impossible, in agreement with the Niels Bohr famous prediction.

3. Conclusions

Summarizing the results of presented experimental study, we can say that the observed asymmetry in space and the irreversibility in time of the thermal evolution process are in agreement with numerous Natural sciences such as Astronomy, Biology, Geology, Paleontology and the present day experimental Physics (including radio-telescope studies). *They are in deep agreement with the Wallace-Darwin evolution theory* and with the fundamental theoretical predictions of the famous Russian physicist A. D. Sakharov about CPT asymmetry in the Universe (Sakharov, 1967, 1972). They give experimental confirmation to the dialectics of Ancient Jain philosophy in the part that *for all natural processes there is infinite number of influence parameters and modes of their manifestations*. They support experimentally the statements of the present day philosophers that the *concepts of time and space are relational*, and support the fundamental observation about *the general principle of self-organization*: "Flows of energy through open systems tend to drive them to states of higher organization" (Smolin, 2013c). These studies present experimental confirmation of *the fundamental observation of N. Bohr that the time-space description of matter is not possible in the general case*. (Similar to the more obvious examples of incapability to describe the Darwin evolution process, or the processes in the Earths atmosphere under the varying in time radiation of the Sun in terms of existing mathematical tools).

Our results give the experimental support to the whole series of theoretical papers, started by R. H. Dicke, which shows that the process of interaction of EM field with an ensemble of atoms is irreversible in time (Dicke, 1954; Stroud et al., 1972), has no spatial symmetry (Dicke, 1954), the number of influence parameters is enormous (Stroud et al., 1972), and the time evolution of the system depends on the number of atoms in the system and conditions of the initial excitation of the system (Cummings, Dorri, 1983).

References

Cummings F. W., Dorri Ali. (1983). Exact solution for spontaneous emission in the presence of N atoms, *Phys. Rev. A.*, vol. 28, pp. 2282-2288.

Darnedde H. (1992). High-precision Calibration of Long Gauge Blocks Using the Vacuum Wavelength comparator, *Metrologia*, vol. 29, pp. 349-359.

Dicke R. H. (1954). Coherence in Spontaneous Radiation Processes, *Phys. Rev.*, vol. 93, pp. 99-110.

Feynman R. P., Leighton R. B., Sands M. (1964). “The Feynman Lectures on Physics 1st edition,” Addison-Wesley, vol. 1, ch. 52, pp. 1-12.

Giancoly D. G. (2000). “Physics for Scientists and Engineers 3d edition,” Prentice Hall, 981.

Greene B. (2006). “The fabric of the cosmos: space, time and the texture of reality,” Alfred A. Knopf, New York, pp. 268.

Rosenfeld L. (1963). Niels Bohr’s contribution to epistemology, *Physics Today*, vol. 16, no. 10, pp. 47-53.

Sakharov A. D. (1967). Violation of CP Symmetry, C-Asymmetry and Baryon Asymmetry of the Universe, *JETP Lett.*, vol. 5, pp. 24-28.

Sakharov A. D. (1972). Topological structure of elementary particles and CPT asymmetry. "Problems in theoretical physics," dedicated to the memory of I.E. Tamm: Nauka, Moscow, pp. 243-247.

Smolin L. (2013). “Time reborn,” Houghton Mufflin Harcourt, Boston – New York, pp. XXV-XXVI [a]; pp. 52-53 [b]; pp. 214-219 [c]; pp. 27-29 [d].

Stroud C. R., Eberly J. H., Lama W. L., Mandel L. (1972). Superradiant Effects in Systems of Two-Level Atoms, *Phys. Rev. A*, vol. 5, no. 3, pp. 1094-1104.

Titov A., Malinovsky I. (2011). New techniques and advances in high-precision temperature measurements of material artifacts, *Can. J. of Scientific and Industrial Research*, vol. 2, no. 2, pp. 59-81.

Titov A., Malinovsky I. (2013). Experimental demonstration of thermal surface energy and its impacts, *ESJ*, vol. 9, no. 24, pp. 11-44.

Titov A., Malinovsky I. (2014). Experimental demonstration of time-irreversible, self-ordering evolution processes in macroscopic quantum systems, *Chaotic Modeling and Simulation*, vol. 1, pp. 79-93.