EXPERIMENTAL DEMONSTRATION OF THE TIME-IRREVERSIBLE THERMAL EVOLUTION PROCESS AND SOME OF ITS CONSEQUENCES

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Abstract

Using a recently developed technique of synchronous differential temperature measurements (Titov & Malinovsky 2005), the existence of the thermal surface energy (TSE) and of thermal hysteresis effect has been demonstrated in metallic gauge blocks (GB). The TSE (described here) is observed if there are inputs of energy and momentum of external electromagnetic (EM) field to material artefact and the heat source is not symmetrically located relative to the artefact surface. The TSE, linearly related to the Poynting vector of the EM field, presents the energy of the oriented motion of the coupled field-particles system inside artifacts. The TSE results in a thermal hysteresis effect, which is irreversible in time and has no symmetry in space. As the principle of superposition is shown not to be valid for EM fields in case of TSE, the hysteresis loop for the continuous sweep in time converts into a spiral, in which the form and the magnitude of the each cycle are slightly different from the ones of the adjacent cycles. In confirmation of the preceding theoretical result (Stroud *et al* 1972), the number of influence parameters in case of the field-particle system is found to be absolutely enormous, so that the thermal evolution process has, practically, infinite number of the existence and manifestation modes. Our studies present also an experimental confirmation of the basic results of the series of theoretical papers, initiated by R. H. Dicke (1954), in which the interaction of the ensemble of atoms with the electromagnetic field is analyzed.

Keywords: Temperature, hysteresis, evolution in time and space

Introduction

In recent years, important advances of temperature measurements in a standard range close to 293K were reported: the resolution of temperature measurements of ~1μK was achieved (Titov, Malinovsky & Masssone 2001); the agreement between the different water triple point (WTP) cells (which are nowadays the unit defining temperature standards) can be obtained at the level of ~3μK (Titov & Malinovsky 2005); the long term stability of temperature measurements of 9μK per year has been demonstrated (Titov & Malinovsky 2011). When these advances are combined with the multi-channel synchronous detection technique (MSDT) ((Titov & Malinovsky 2005)), in which the modulation of the input energy is performed in one of the measuring channels by changing the current in the platinum resistance thermometer (PRT) and the *induced variations of temperatures* are detected synchronously by other channels, we acquire a unique opportunity for the detailed studies of the process of heat propagation in material artefacts. Additionally, MSDT offers vast possibilities for precise studies of the non-linearity of thermal systems. Indeed, the ratio of the temperature variations of ~20mK, induced easily by a PRT, to the temperature of ~2000K (when the physical properties, including thermal, of materials change significantly) is $1*10^{-5}$, while the MSD-technique has the demonstrated precision below $1*10^{-8}$ (Titov & Malinovsky 2005). So, *there is an opportunity to check experimentally if the model assumptions of some well-established physical theories, such as Thermodynamics or Fourier thermal conductivity theory (TCT), are still in agreement with the new level of temperature measurements*.

Such studies are acquiring special importance when we recall A. Einstein's observation (1905) that "*classical thermodynamics can no longer be looked upon as applicable with precision…For the calculation of the free energy, the energy and the entropy of the boundary surface should also be considered*". In the other fundamental paper, entitled "A Theory of the Foundations of Thermodynamics", A. Einstein (1903) writes: "*Let the system be isolated, i.e., the system considered should not interact with other systems*", and further there: "*Experience shows that after a certain time an isolated system assumes a state in which no perceptible quantity of the system undergoes any further changes in time; we call this state the stationary state*". So, in accordance with A. Einstein, Thermodynamics deals only with isolated systems, and when, additionally, all the transient processes have already finished in this system. Some very important theoretical observations can be found in a popular University text-book (Sivukhin 2008b), where it is specially emphasized that the thermodynamic temperature can be regarded as a function of state, *only if it is assumed* that for quasi-static processes (that are widely used in thermodynamic theoretical analysis) the number of the influence parameters is equal to the number of the parameters, which are used for the description of the system under the thermal equilibrium conditions. D. V. Sivukhin (2008a) gave the definition of the thermal surface energy (TSE) as the energy of boundary zones, located between the macroscopic parts of the system, in which the quasi-equilibrium thermal conditions are realized. It is argued in ((Sivukhin 2008a) that the TSE is proportional to the area of the contact between the two sub-systems, and that *the internal energy of the system can be considered as additive, only when the value of the TSE is regarded as negligible*. It is also specially noted in (Sivukhin 2008a), that the thermal conductivity process presents a typical example when a relatively slow process can not be considered as a quasi-static process. This gives a clear indication that the notion of temperature in TCT (Sivukhin 2008c) cannot be associated with the thermodynamic temperature. From these sources it appears that the thermodynamic concept of temperature has to be used with great care, but, unfortunately, there is no other, more general definition of temperature in theoretical Physics.

Another important observation dealing with TCT we find in (Eckert & Drake 1972, p.46, where in the first chapters of a thick text-book it is emphasized that TCT is based on the result of a *single, one dimensional, steady-state experiment*, with the help of which the heat flux density in a material artifact is considered to be defined solely by the temperature gradient inside the artifact. So, the parameter, T, which enters the Fourier TCT, could hardly be regarded as a thermodynamic temperature. First, the presence of the temperature gradient shows that the system is not closed. Second, TCT calculates the heat transfer process, and it means that the system under consideration is not in the state of thermal equilibrium, and this is another violation of A. Einstein requirement for the applicability of thermodynamics and its concept of temperature. Evidently, only new precise experiments can help to establish the relation between the concept of thermodynamic temperature and the "experimental" temperature as a general measure of thermal energy, which has been used by mankind for centuries.

In this paper, we present the new results of the studies, reported in (Titov & Malinovsky 2013) where, for the first time, the existence of the thermal surface energy (TSE) has been demonstrated. TSE presents the energy of the oriented motion of charged particles and of the guided electromagnetic (EM) field , which is propagating inside material artifacts, accompanying a non-uniform motion of charged particles (Jackson 1999: Griffiths 1999). It is shown that TSE arises when there is an input of the thermal energy (positive or negative) to the system, and the parameters of TSE (its magnitude and the direction of its increase) are defined by the Poynting vector of the external EM field produced by a heat source. So, on one hand, we can say that TSE appears as a result of the EM field pressure (Sivukhin 2008f), or in other words, TSE is the consequence of the continuity of the EM momentum and of the equation (2.21) in (Loudon, Allen & Nelson 1997) that is written for the coupled field-particle system. On the other hand, we can also say that the TSE presents another form of the fundamental collective R. Dicke effect (1954), which is related to the interaction of EM field with an ensemble of charged particles and which has been studied in the series of papers (Stroud *et al* 1972; Wineland, Drullinger & Walls 1978; Cummings & Dorri 1982). In the particular case of the system under consideration, the collective effect corresponds to very low levels of excitation of atomic system, when as a result of the effect of trapping of EM radiation in the atomic system (Dicke 1954), the number of particles in the ensemble should become a crucial parameter in the description of interaction in the field-particle system (Stroud *et al* 1972; Cummings & Dorri 1982).

The most important results of these studies are the following. First, it is experimentally shown that TSE results in the thermal hysteresis effect, which similar to the well-known hysteresis effects in ferromagnetic (Sivukhin 2008d) and ferroelectric (Sivukhin 2008d) materials, is irreversible in time and has no symmetry in space. Second, with very high signal-to-noise ratio it is demonstrated that *the principle of superposition is not valid for TSE*, so that any two heat sources are in continuous, ever-lasting, non-linear interaction with each other through the TSE, which arises in the material artifacts under the irradiation of their surfaces by the EM radiation of the heat sources. The thermal hysteresis effect and the violation of the superposition principle for thermal fields lead to the evolution in time of thermal system, which presents a “self-ordering” process. In this evolution process, the parameters and properties of the artifact (such as the wave momentum density and the total-energy density inside artifact together with their current densities, as defined in (Loudon, Allen & Nelson 1997), as well as the mass transfer of particles, the level of stresses and deformations inside the artifact) are all under continuous changes as a result of the constantly varying in time external conditions. The key features of the thermal evolution process are that these properties of the artifact are specific for any particular point as well as for the specific time moment, and *the number of influence parameters, necessary for the description of the evolution process and TSE, is absolutely enormous under the achieved accuracy level of the experimental studies*. High-resolution measurements have demonstrated that for thermal systems (which are always open systems) neither the total energy (of the EM field and of the charged particles), nor the wave momentum can be considered as conserved quantities. By the presented experiments we show that the effects of the energy and momentum transfer from the system can be observed for the measurement time intervals of about a few minutes, only.

Experiment

The main features of our experimental set-up can be seen on the inset of Fig.1, where a 100-mm gauge block (GB) is located horizontally on three polished spheres inside a closed Dewar. The air temperature in the laboratory is precisely controlled, so that typical diurnal variations are usually within 50mK. Two temperature sensors (thermistors R6 and R3) are equipped with copper adapters, which cover the whole width (35 mm) of the GB.

Thermistors are, practically, identical and are installed parallel to the gauging surfaces of the GB (Fig.1). A 100-Ohm platinum resistance thermometer (PRT), also equipped with a copper adapter, is located exactly between the adapters of the thermistors.

We use the newly developed MSD technique (Titov & Malinovsky 2005) to measure simultaneously, with high precision the variations of temperatures in the channels that are induced by the modulation of the current in the PRT at the locations of the thermistors R6 and R3. Synchronous measurements of temperatures and of thermal velocities are realized by the program, whose print-screen for the duration of 1.4 period of the modulation cycle is presented in Fig.1. The duration of the cycle is ~140 minutes: ¼ of the cycle the PRT current is kept at the level of 5mA (heating period); for the ¾ of the cycle duration the current is 1mA (cooling period). The PRT is connected to a programmed precision bridge Mi-T615 (Canada), so that the accurate temperature measurement of the PRT is always available. Meanwhile the thermistors R6 and R3, belonging to channels 1 and 2, respectively, are connected to precision multi-meters HP-3450A, so that synchronous differential temperature measurements between the channels 1 and 2 with the resolution of 1-2μK can be achieved, as a result of high sensitivity of the thermistors relative to PRT and very fast measurement procedures of the multi-meters in comparison with the bridges. The trace in Fig.1 with a faster response time corresponds to the measured PRT resistance. The two other traces show the variations of the resistances of the thermistors with negative thermal coefficients. As a consequence of the used geometry, the system is extremely sensitive to any asymmetry in heat fluxes along the surface of the GB in the direction of the longest side of the GB, as the thermistors are calibrated to measure the temperature of the artifact surface in the close vicinity of its adapter (Titov & Malinovsky 2005). With the two cursors of the program (shown in Fig.1 as triangles), we specify the desired part of the record, and the program calculates the mean values of the temperature and of the temperature rate in each channel, using the calibration equations (temperature versus resistance) for each channel that are in advance stored in the program.

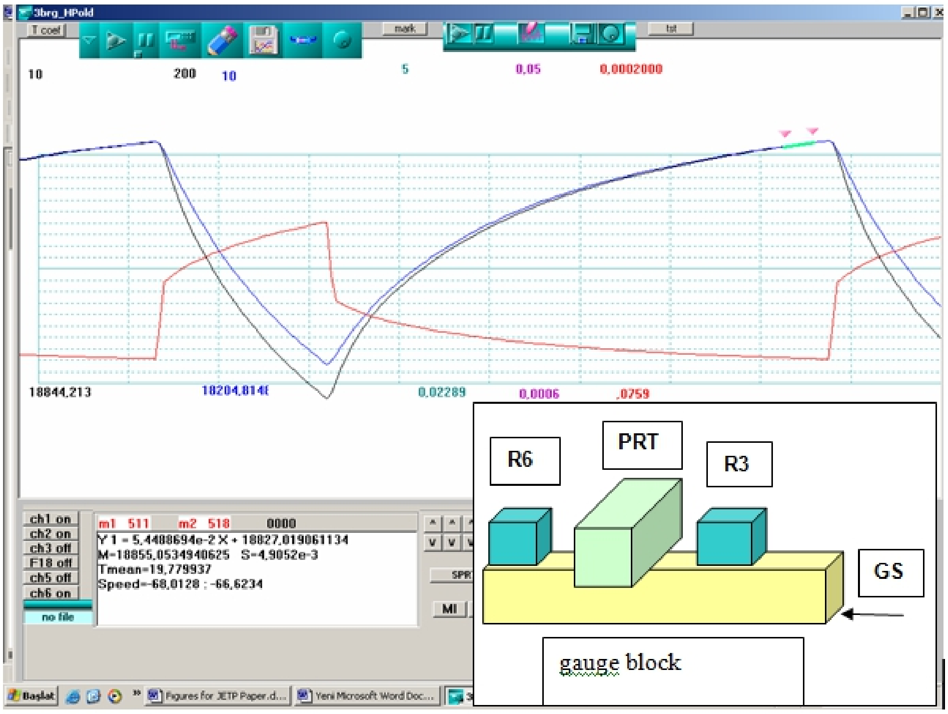

Fig.1. Simultaneous records of the resistance variations of the platinum thermometer (PRT) and of the two thermistors R6 and R3, which are located symmetrically relative to the PRT on the surface of the gauge block (see insert). During the modulation cycle, the current in the PRT is kept at the level of 5mA for ¼ of the modulation period, and it is kept at 1mA for the rest part of the period. As the sensitivities of the thermistors are equal, these records demonstrate that the induced temperature variations in the channels are different! The location of one of the gauging surfaces of the block is shown by an arrow.

In two separate windows, the program displays the initial and final moments of the measurement time interval that are defined by the position of the cursors on X-axis of the record. The larger window of the program shows the mean values of the temperature and of the temperature rate, obtained in one of the channels during the specified measurement time interval. The information about the results of the measurements in all of the channels for the sequence of the desired time intervals is written by the same program in a special file. These files contain the data of synchronous differential temperature measurements between the channels 1 and 2 as a function of time, and that information is presented separately for high and low levels of the modulation current in the PRT, so that it can be processed using the MSD technique. The plots in Figs. 2, 4, 6 present the examples of the application of the MSD technique to the data of such files. The procedure of the calibration of the PRT and thermistors is described in detail in (Titov *et al* 2005) and the application of the MSD technique is outlined in (Titov & Malinovsky 2011). Here, we note that the records of Fig.1 correspond to measurements on a steel block with 10-mm separations between the adapters of the thermistors and the adapter of the PRT.

An observation of a paramount importance can be inferred from the plots of Fig.1: though the separations of thermistors from the heat source are the same, the *induced temperature variations in the channels are different.* This means that the thermal transfer process is not symmetric in space, similar to the domain build-up processes in ferromagnetic (Sivukhin 2008d) or ferroelectric materials (Sivukhin 2008e) under the application of the external fields. This also means that the basic assumption of the Fourier TCT is in contradiction with the experimental results obtained by the variation principle, the most general and powerful in experimental Physics. Indeed, from the corresponding temperature measurement results of Fig.1 we find that for the last 30 minutes of the cooling part of the cycle at I=1mA, which is presented first in this figure, the mean temperature, recorded by the thermistor R6, was 466μK higher than the mean temperature, obtained from the thermistor R3. The mean temperature difference between the channels 1 and 2, recorded for the last 30 minutes of the cooling period, we shall denote by **T[1,2]**. For the next cycle, shown in Fig.1 and marked by two cursors, this temperature difference **T[1,2]** was ~ 469μK, so that the stability of these points was within 4μK. The points, corresponding to the last 30 minutes of the cooling part of the modulation cycle (at I=1mA), we shall call *the reference points*.

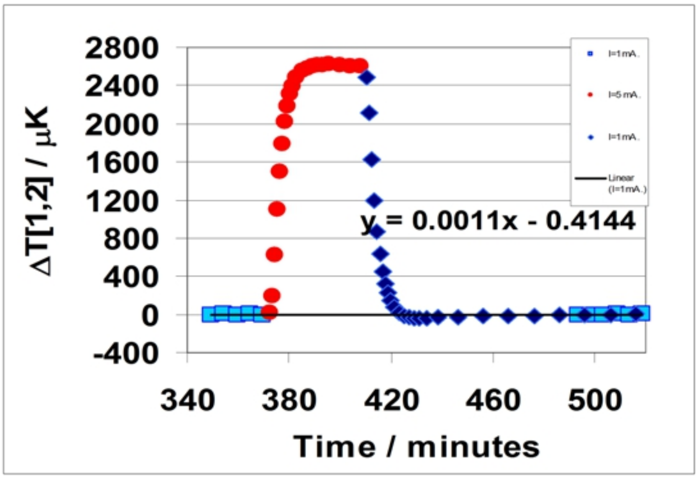

Fig.2. The dependence on time of the thermal surface energy (TSE), represented by the difference in the induced temperature variations **ΔT[1,2]**, recorded in the two thermistor channels 1 and 2 during one modulation cycle. Dots and rhombi show the experimental points, obtained during the heating and cooling periods of the modulation cycle, respectively. Squares correspond to the reference points for the two adjacent cycles, and the linear fit to these points is shown as a solid line, with the corresponding expression presented in the inset.

In Fig.2, corresponding to the experimental conditions of the records of Fig.1, these reference points are marked with rectangles, and the measurement time for the reference points was chosen 5 or 10 minutes. A linear fit, obtained for all reference points of the record of Fig.2, is shown as a solid line, which is very close to abscissa axis. The inset of Fig.2 contains the equation of this linear fit. From this equation we find that for the initial time of the record (X=350min.) the fit value is -0.02μK, while for the end of the record (X=480 min.) it gives the value of 0.11μK. So, all the values of the reference function, given by the fit equation and representing the systematic offsets, are well below ±1μK for the whole time interval of this observation. The random spread of the data points relative to this fit is also very small: a standard deviation of a single reference point relative to the linear fit is less than 3μK.

Using this fit as a reference, we can determine very precisely the difference between the simultaneous measurements of temperatures, realized by the channels 1 and 2 for the whole duration of the modulation cycle. This temperature difference, which is measured relative to the fit for the reference points, is denoted here by the quantity **ΔT[1,2]**. The experimental points of Fig.2, presented as dots, demonstrate the time dependence of the difference in the temperatures of the channels 1 and 2, when *these temperature variations are induced by the increased value of the PRT current* (I=5mA) during the heating period of the modulation cycle. The measurement time intervals are 2 and 4 minutes at the beginning and at the end of the heating period of the cycle, respectively. It follows from Fig.2 that for all data points of the heating period the quantity **ΔT[1,2]** is positive, surpassing by orders of magnitude the standard deviation for the reference points. The maximum value of the quantity **ΔT[1,2]** is equal to 2620±3μK, while the systematic offset of the reference function is within ±1μK.

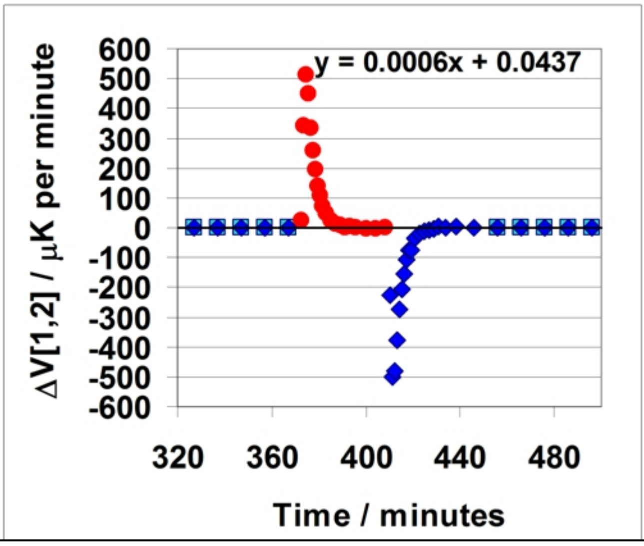

Fig.3. Variations in time of the difference between the induced temperature velocities, recorded by the channels 1 and 2, **ΔV[1,2]**, that are observed during the heating period (I=5ma) of the modulation cycle (dots) and during the cooling period (I=1mA) of the modulation cycle (rhombi). These variations are measured relative to the reference points, shown as squares. The solid line shows the linear fit to the reference points, with the corresponding equation of the fit presented in the inset.

It should be specially emphasized that the induced temperature difference **ΔT[1,2]** is a vector quantity. Its positive value indicates that the amount of thermal energy, delivered from the PRT during the heating period of the cycle to the unit volume of the material artifact in the vicinity of the thermistor R6, is larger than the corresponding amount of the thermal energy, delivered to the unit volume of the artifact in the vicinity of the thermistor R3. Thus, this experiment has given a first clear demonstration that, in spite of the fact that the thermistors are located on the surface of homogeneous artifact at the same distance from the heat source, the average flux of the thermal energy in the direction of the nearest gauging surface of the artifact is substantially higher than the average flux of energy to the bulk material away from the gauging surface, when a positive input of energy to the artifact is realized from the heat source (during the heating period) and the heat source is located closer to one of its gauging surfaces. And it should be specially noted that the larger average flux of thermal energy in the direction of the nearest gauging surface occurs when for all time intervals of the heating period, the temperature difference between the PRT and R6 was smaller than the difference between the PRT and R3, so that the projections of temperature gradients in the direction of R6 were definitely smaller than the corresponding projections of the temperature gradients in the direction of R3. So, we can infer from Figs. 1 and 2 that at the initial stages of the heat transfer process there is an additional flux of thermal energy, which cannot be related to the thermal gradients in the artifact, as it supposed in TCT.

Similar to the induced temperature difference **ΔT[1,2]**, we can introduce the induced difference in temperature velocities **ΔV[1,2]**, corresponding to the positions of thermistors R6 and R3. The dependece of **ΔV[1,2]** on time is presented in Fig.3 under the experimental conditions of Fig.2. Here, it is worth reminding that the difference in thermal velocities **ΔV[1,2]**, presented in Fig.4, is also a vector quantity. The positive value of **ΔV[1,2]** means that the thermal power, delivered to the unit volume of the artifact material, is larger in the vicinity of R6 thermistor, relative to the power, delivered to the unit volume of the artifact in the R3 vicinity. The dots in Fig.4 demonstrate the dependence on time of the difference in the induced temperature velocities, recorded by the channels 1 and 2 and obtained during the heating period of the modulation cycle. For the heating period, the quantity **ΔV[1,2]** is positive, so that the thermal power, delivered to the unit volume in the vicinity of the gauging surface, is larger than the power delivered to the unit volume, which is located symmetrically relative to the heat source but in the opposite direction, away from the nearest gauging surface. As shown in (Titov & Malinovsky 2013), the quantity **ΔV[1,2]** is defined by the difference in the total-energy fluxes arriving to the corresponding elementary voumes of the artifact through the boundary surfaces of these volumes. The comparison of the plots of Figs. 2 and 3 shows that the excessive energy flux in the direction of the boundary (gauging surface) does exist only during a short time interval of the heating period of the modulation cycle. The result of paramount importance is that the energy fluxes, propagating in a homogeneous material in opposite directions from the heat source, are not equal when the heat source is not symmetrically located on the surface of the artifact (Titov & Malinovsky 2013). When all three thermometers were moved together without changing their separations along the side surface of the gauge block the antisymmetric dependence of the quantity **ΔV[1,2]** on the displacement of the heat source relative to the center of the side surface was observed (Fig.4). The plots of Fig.4 were obtained for a 100-mm tungsten carbide (TC) gauge block. The comparison of the Figs. 3 and 4 shows that the process of the build-up of TSE is about 3 times faster than the process in the steel gauge block.

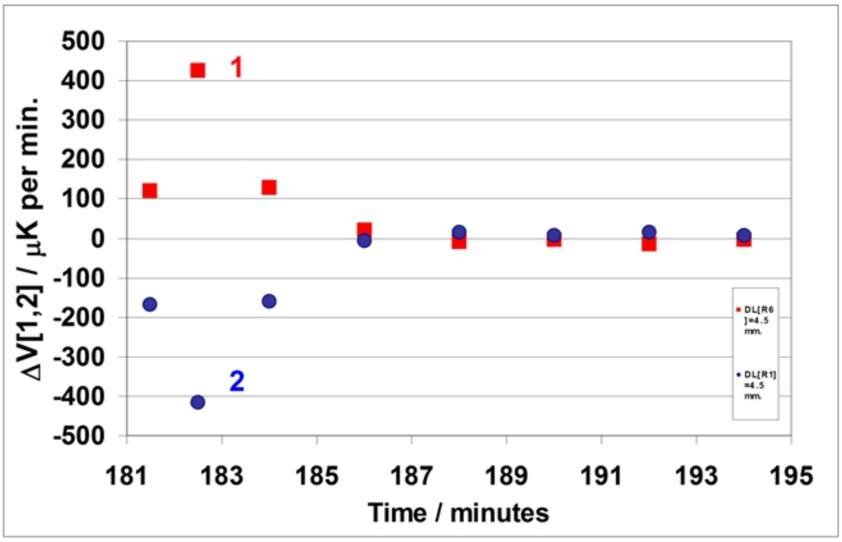

Fig.4. The dependences of the quantity **ΔV[1,2]** on the time interval, elapsed after the increase of the PRT modulation current, for two opposite cases of the thermistors positions: dependence 1 (shown by squares) corresponds to the separation of the R6 thermistor of 4.5mm from one of the gauging surfaces of the block, while the dependence 2 (shown by dots) corresponds to the case when the measuring system as a whole was shifted along the surface of the block, so that the separation of 4.5mm of the thermistor R3 from the other gauging surface was realized.

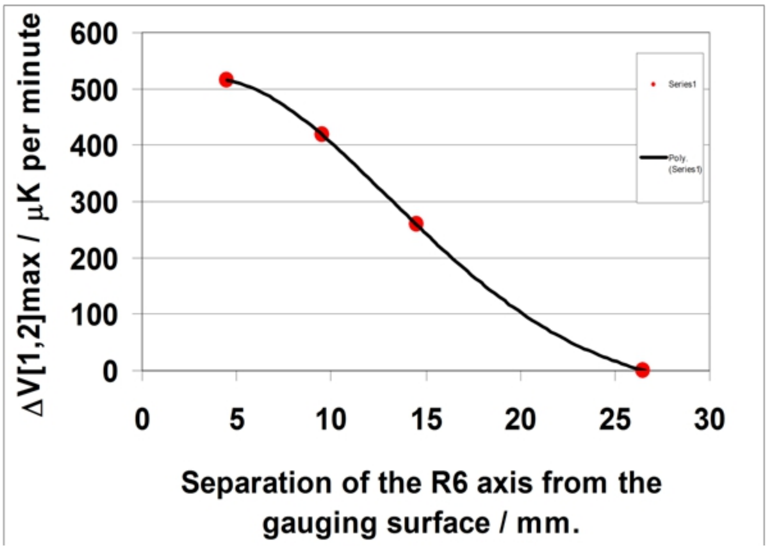

Fig.5. The dependence of the maximum value of the quantity **ΔV[1,2]** on the separation of the axis of the thermistor R6 from the nearest gauging surface. The zero value of the quantity **ΔV[1,2]** corresponds to the symmetric position of the PRT on the block surface.

The excessive energy flux, responsible for the creation of TSE (characterized by **ΔT[1,2]**), is observed in the vicinity of the boundary and falls rapidly with the increase of the distance of the temperature sensor from the gauging surface. The corresponding experimental curve for the the maximum value of the quantity **ΔV[1,2]** for the steel block is shown in Fig. 5. When described by the Gaussian curve, the dependence of Fig.5 is characterized by the mean square value of about 13.7mm. The other fundamental property of the excessive energy flux (characterized by the vector quantity **ΔV[1,2]**) is the linear dependence of its maximum value on the Poynting vector of the external EM field, created by the energy dissipation in the PRT (heat source). The corresponding dependences are presented in Fig.6 for two different positions of the thermistor R6 from the gauging surface of the steel gauge block.

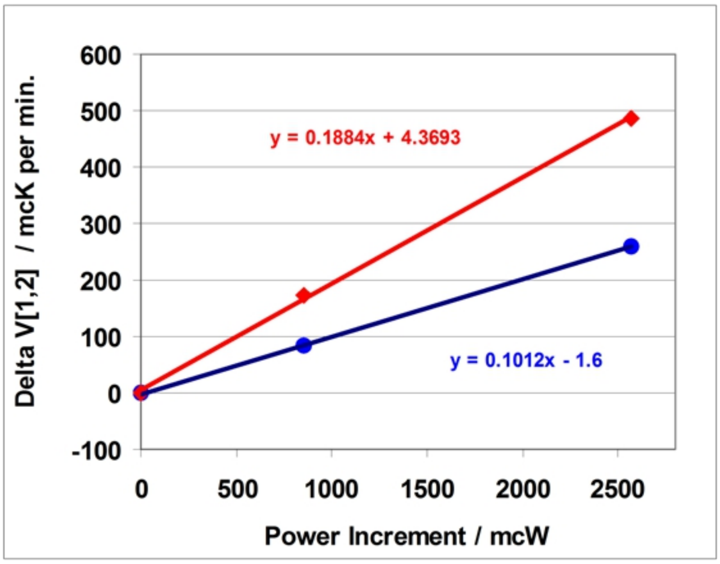

Fig.6 The effect of the PRT power increment on the quantity **ΔV1,2].** Dependences 1 and 2 correspond to the separations of the R6 axis from the nearest gauging surface of L=4.5mm (dots) and L=13.5mm (squares), respectively. The decrease of the magnitude of the energy flux with the increase of the R6 separation from the nearest gauging surface is clearly demonstrated by the dependences (1) and (2).

It is shown in (Titov & Malinovsky 2013) that the experimental curve in Fig.2 is equivalent to a hysteresis loop, and the corresponding thermal hysteresis loop is presented in Fig.7. The area, enclosed by the loop, defines the additional energy, dissipated into the environment by the gauge block and R6 adapter surfaces relative to the correspondent surfaces of the gauge block and R3 adapter (located symmetrically relative to the heat source) during one cycle of the periodic process of Fig.2. Similar to the hysteresis effect in ferroelectric materials, the thermal hysteresis process is irreversible in time, as in accordance with (Feynman, Leighton & Sands M 1964), the backward play of the record of the process, presented in Figs.2 and 6, gives the evident contradiction with the Clausius-Plank formulation of the second fundamental principle of thermodynamics (Sivukhin 2008b). So, the thermal hysteresis effect, characterized by the quantity **ΔT[1,2]**, has no symmetry in space (Fig.4) and is irreversible in time, in complete agreement with the studies of the hysteresis effects in ferromagnetic and ferroelectric materials (Sivukhin 2008d, 2008e).

The other fundamental property of the thermal hysteresis effect is that the principle of superposition is not valid for any two heat sources, affecting the temperature of the artifact. This is the consequence of the corresponding property of the thermal surface energy (Titov & Malinovsky 2013) and the general property of the nonlinearity of the ensemble of atoms, interacting with electromagnetic fields (Ramsey1963). For the case of the TSE, characterized by the quantity **ΔT[1,2]**, the effect of nonlinearity is demonstrated in Fig.8. Here, it is shown that the temperature variations, induced by the increase of the modulation current in the PRT and detected by two thermistors, located symmetrically on the artifact surface relative to the heat source, are affected by the presence of the energy flux, which is produced in advance in

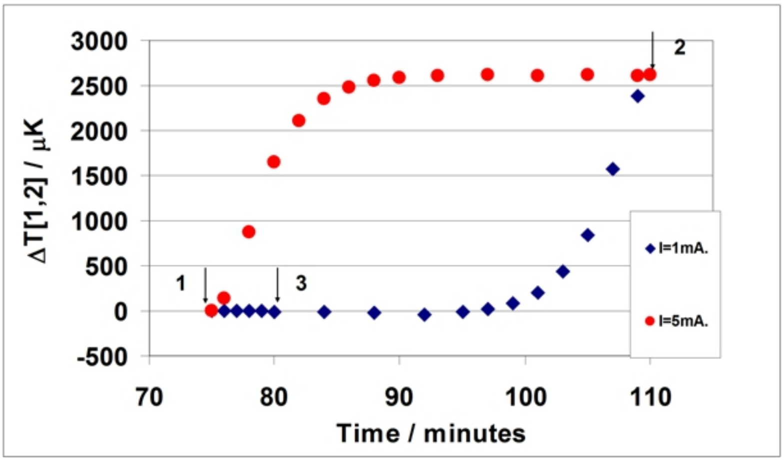

Fig.7. The thermal hysteresis loop for the quantity **ΔT[1,2]** that corresponds to the temperature records of Figs. 1 and 2. The heating period of the cycle (between the arrows 1 and 2) is shown by dots, while the cooling period of the modulation cycle (between the arrows 2, 3 and 1) is presented by rhombi.

the aretifact by an auxiliary heat source and which results in the temperature difference between the locations of the thermistors **T[1,2]** (that is measured as a mean value for the last 30 minutes of a cooling period of the modulation cycle). As it follows from Fig.8 (when the scales are chosen equal in both coordinates), the nonlinearity of the thermal system, under the conditions of the present experiment, exceeds 1% (in accordance with the linear fit presented in the figure).

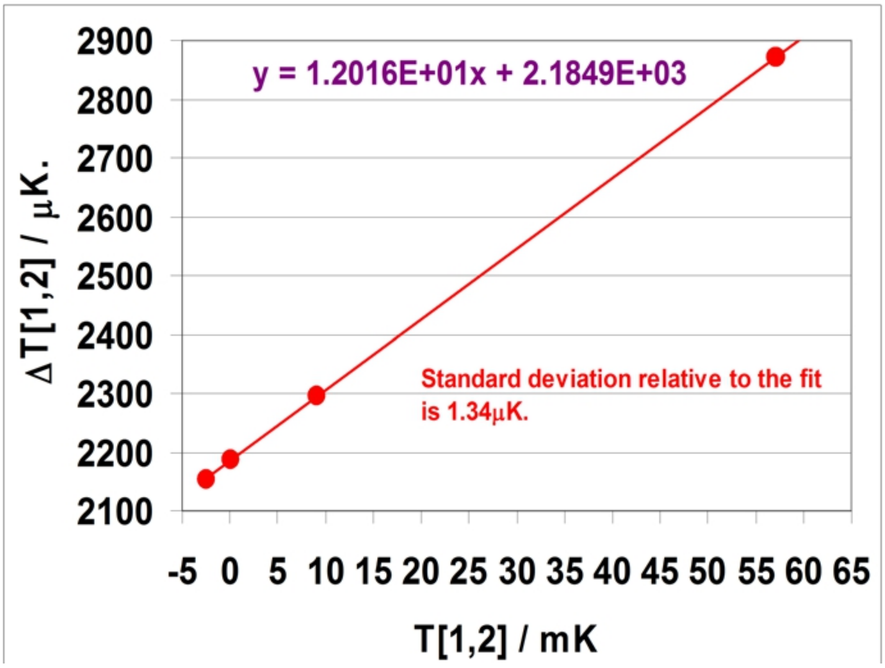

Fig.8. The dependence of the quantity **ΔT[1,2]**, measured 13 minutes after the increase of the PRT modulation current in steel gauge block, on the temperature difference **T[1,2]** between the positions of the thermistors R6 and R3.

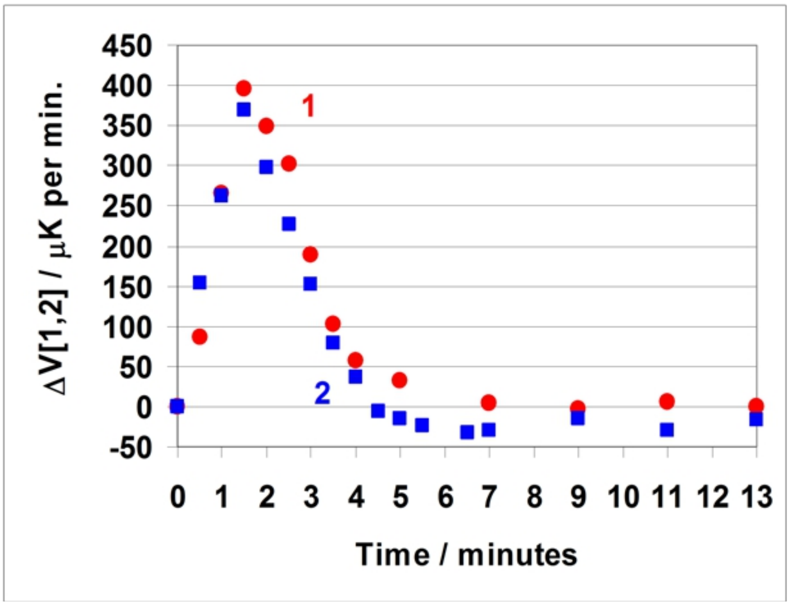

Fig.9 The dependencies of the quantity **ΔV[1,2]** on time for the first 13 minutes of the heating period that were obtained for the tungsten carbide gauge block for the temperature differences between the locations of the thermistors **T[1,2]** of -0,2mK (dependence 1; dots) and -17.2mK (dependence 2; squares). Note that the thermal evolution process is described by a complicated function of time, which is specific for the selected points inside the artifact and whose form and magnitude depend on the direction and magnitude of the constant heat flux, created in advance by an auxiliary heat source.

The nonlinearity of thermal systems in combination with the thermal hysteresis effect results in the existence of the thermal evolution process, which has no symmetry in space and is irreversible in time, naturally acquiring the properties of the thermal hysteresis effect. Under the presence of another heat source, (as a consequence of nonlinearity of the system following from Fig.8) the hysteresis loop of Fig.7 will slightly change its form and magnitude, so that the purely periodic process, presented in Fig.1, will transform into the spiral-type curve. Every next cycle of this spiral will be slightly different in magnitude and in shape from the previous cycle, as a result of constantly changing external thermal conditions. And it should be noted here that at the resolution of temperature measurement of about 1μK, which is typical for this experiment, the thermal radiation from the Sun is inevitably detected by all thermometers, in spite of temperature controlled laboratory and the additional passive thermal isolation with Dewar. So the external thermal conditions for the gauge block with attached thermometers are continuously changing in time, simply as a result of the Earths rotation relative to the Sun. Besides that, taking into account that the energy from the Sun is propagating through a turbulent atmosphere, and that the number of macroscopic parameters needed for description of turbulence is infinite (Sivukhin 2008a), we arrive at the conclusion that the thermal evolution process is characterized by the infinite number of influence parameters and has an infinite number of manifestation modes, in the general case. Clearly, the characterization and description of the thermal evolution process is becoming dramatically complicated with the increase of the accuracy of thermal measurements.

The evolution process is specific for any particular point inside the artifact (Figs. 1 and 5) and is specific for any particular time instant (Figs. 1 and 6). The effect of the external heat source on the induced difference in temperature velocities (recorded simultaneously by channels 1 and 2) is demonstrated by Fig.9. Here, the dependences 1 and 2 correspond to two independent experiments, performed under the quasi-stationary conditions for two levels of dissipated power in the auxiliary heat source, producing the desired quasi-stationary value of the temperature difference between the channels **T[1,2]**. Each data point in Fig.9 corresponds to the mean value of **ΔV[1,2]**, obtained by averaging over 4 cycles with the duration of each cycle of about 140 minutes. The uncertainty of measurement of each point is less than the dimension of the symbol of the data point in the plot. The other very important feature of this experiment is that the temperature difference **T[1,2]**, produced by the auxiliary source, by more than two orders of magnitude larger than the typical variations of the quantity **T[1,2]**, produced by the uncontrolled variations of the external thermal conditions during the modulation cycle. Thus, this experiment demonstrates that each external heat source gives the corresponding contribution to the variations of the thermal evolution process inside the artifact that is defined by the magnitude of the Poynting vector of the external EM field, produced by this source. As the number of material partners, with which any selected material artifact is in constant interaction through EM field, is always enormous, the number of the influence parameters for the thermal evolution process is always huge, resulting in a huge number of the existence and the manifestations modes of the thermal evolution process (Titov & Malinovsky 2013). This conclusion is in agreement with the fundamental result of (Stroud et al 1972), where it is shown that for the ensemble of atoms, interacting with the common EM field, among the influence parameters (defining the resultant EM field) is N radius-vectors, specifying position of each atom, and another N vectors, characterizing the orientation of each atom in space. In case of macroscopic sources of EM radiation, the number of influence parameters is even much larger, as the properties of the surfaces, structure, composition and properties of the artifact material are inevitably influencing the parameters of the radiated field. With the increase of the accuracy of measurements the number of influence parameters, which has to be taken into consideration, increases absolutely dramatically. It can be shown that the number of influence factors in all natural processes is infinite, as in the case of the thermal evolution process. This is in agreement with the fundamentals of the Ancient Indian (Jain) philosophy that the number of modes of existence and manifestations of real processes is infinite, while the cognition possibilities of human beings are quite limited. The present studies also present some experimental confirmation (Titov & Malinovsky 2013) of the basis of the classical German dialectics. In thermal measurements we have two types of energy. The first one corresponds to the oriented motion of the field-particle system that results in the mass, charge and energy transfer inside the material artifact (with inevitable change of the properties of the artifact). The other one, which can be associated with a random fluctuation process (characterized by non-measurable deformations and mass displacements in the artifact), represents the amount of energy, accumulated in a previous epoch under the influence of the huge number of influence parameters. As it follows from Fig.5 the conversion of the oriented motion into random, which occurs as result of the artifact's interaction with environment, is quite fast. In this process (which is usually called synthesis, when using the terminology of German philosophers), the excessive momentum is transferred to the environment by EM field, as the consequence of the fact that an artifact presents always an open system.

Conclusions

The basic properties of the thermal evolution process – the lack of symmetries in space and in time, taken together with the infinite number of influence parameters - are in agreement with the studies performed in different areas of Natural sciences. In astronomy, for example, the concept of the arrow of time was introduced in 1927 by Arthur Eddington, and the distinguished direction of time, according to A. Eddington,, was be determined by the study of organizations of material objects in the Universe. The regular astronomical observations of the Earth's rotation (Guinot 2011) not only demonstrate the irreversible in time character of the motion of the planet, but also indicate to the infinite number of influence factors that makes the theoretical predictions very difficult. The asymmetry in space of the properties of the thermal radiation in Universe has been established with the help of radio-telescopes (Smoot, Gorenstein & Muller 1977). In Biology, the time irreversible character of changes is known from the time of the discovery (1858) by Ch. Darwin and A. R. Wallace of “The Tendencies of Species to Form Varieties, and the Perpetuation of Varieties and Species by Natural Means of Selection”. And the examples of the asymmetry in space, known from Molecular Biology, are found even in text-books on physics (Feynman, Leighton & Sands 1964).

The thermal evolution is the simplest evolution process in which only the energy and the momentum of the EM radiation are absorbed in material object. The absorbed quantities result in the changes of the properties of the artifact and initiate the processes of wave-momentum, energy, mass and charge transfer in the material object, accompanied by the creation of stresses and deformations inside the artifact.

The presented studies give the experimental confirmation of the theoretical results of the whole series of papers dealing with the interaction of ensemble of atoms with a common EM field, including the space asymmetry (Dicke 1954), the irreversible character in time (Dicke 1954; Stroud et al 1972) and a huge number of influence parameters for the process (Stroud et al 1972).

The results of our studies are in deep agreement and present an experimental backing to the fundamentals of the Jain philosophy, which gives the clews to the interpretation of the famous observation of A. Einstein:”No amount of experimentation can ever prove me right; a single experiment can prove me wrong”, or to one of the favourite maxims of Niels Bohr that the negation of a profound truth is also a profound truth (Hans Henrik Bohr 1967).

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