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Amplification of the neutron flux transmitted through KD_2PO_4 single crystal at the ferroelectric phase transition state

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Abstract

The phenomenon of external neutron flux amplification (about 10% from total value) emitted from Cf^{252} neutron source ($I=3\cdot10^2$ n/s in 4π), than partialy moderated by use of polyethylene (Co) and transmitted through the KD_2PO_4 (DKDP) single crystal being at the ferroelectric phase transition state has been obtained. If DKDP crystal was out of the phase transition temperature interval upon the transmission of neutron flux through it, then amplification effect was not observed. The variation of excess neutron emission intensity ejected by DKDP crystal at the different detector's background level has been studied. The intensity of neutron emission (after subtraction of the background) is increased from 0.01 count/s at cosmic background level (0.01 count/s) to 0.20 count/s at 1.1 count/s background level of detector (with Cf^{252}). The dependence of count's rate of neutron events on the efficiency in DKDP crystal-detector system has been investigated too. It was determined the correlation between the value of external neutron flux transmitted through the DKDP crystal and intensity of excess neutron emission from this crystal. The non-isotropic distribution of excess neutron emission from DKDP crystals has been established. The data obtained for DKDP crystals irradiated by external neutron flux upon the ferroelectric phase transition could be the confirmation for next hypothesis: "cold fusion" neutron emission is induced by external irradiation of cold fusion objects by the cosmic background neutrons.

I. Introduction

Earlier in our works, it has been detected that on the phase transformations of the ferroelectric-paraelectric type, occurring on the transition of KD_2PO_4 single crystals through the Curie point, the generation of neutrons is observed at an intensity exceeding by 2-3 times the natural neutron background of the setup [1,2]. In these experiments, however, the reproducibility of the results even with controllable, (without defects) crystals did not exceed

90%. In most other works involving the observation of the nuclear dd-fusion reactions in nonequilibrium, deuterated solids, the reproducibility of the results was much worse [3-6]. In this connection, the question on the reality of the dd-fusion reactions in the crystalline lattice, and in particular, on the emission of neutrons, whose occurrence is considered as a direct confirmation of the $d(d,He^3)n$ reaction, remains so far open. In fact, the neutron effects in deuterated solids, in distinction from the effect of the generation of neutrons in an usual dd-reaction (in hot plasma, on accelerators, during the fission of heavy elements, etc.), exhibit a number of peculiar features that do not permit to a full extent consider them as the manifestation of the usual emission of neutrons [7,8]:

(a) the emission of neutrons is unsteady; it has the form of fluctuations, involving increases in the neutron activity of a sample for short periods of time [3-6];

(b) in most long-time experiments the signal-to-background ration did not exceed 2-3 [3-8];

(c) there is no distinctly pronounced dependence of the intensity of the emission of neutrons on the mass of the sample [2-5];

(d) and finally, what is the main feature, the absolute intensity of the "effect" (the count of neutrons with the subtraction of the background), depends on the background level and the efficiency of the neutrons detector: the lower background level leads to the lower absolute intensity of the "effect"; and the higher detector efficiency leads to the lower "effect" value [3].

The most important is the feature (d), since logically, with the hypothetically zero level of the cosmic neutron background, the intensity of neutron emission should tend to zero. In this connection, a question arises as to whether the emission of neutrons in the aforisaid experiments is a property inherent to deuterated solids that are in an essentially nonequilibrium state (the dd-fusion proper), or whether the secondary neutrons are registrated, generated by "seed" neutrons of the cosmic background, interacting with deuterium in the crystalline lattice? In such a case, the non-reproducibility of the results on the emission of neutrons (in addition to purely material-science aspects) will be connected with the non-reproducibility of the cosmic background-that is, with the probability of the appearance of a cosmic neutron in the same space region, in which the sample is found during the experiment.

For the purpose of veryfying that hypothesis, we have carried out experiments on the irradiation by an external source of the neutrons of deuterated KD_2PO_4 sample, being emitted own neutrons throughout the entire temperature range ΔT=212-222 K, corresponding to the ferroelectric transition [1,2].

2. Methods

We have utilized the DKDP single-crystal samples that had been well studied in our foregoing works. The samples in the form of plates were cut out from a single monoblock oriented in the (001) direction, having a weight of 15 g, in such a way that their cross-section be equal to 1 cm^2 with a thickness h=2 mm. The samples were placed into a brass cryostat cooled down to a temperature of 100 K, and then heated up in the linear regime at a rate of 0.1 K/s. Neutrons were detected in temperature ranges outside T_C: $T \ll T_C$ and $T \gg T_C$ (control experiments), as well as in the temperature range of 212-222 K, corresponding to the ferroelectric phase transition, in accordance with the measurements of the transition heat by the DSK-method.

The effect for DKDP samples within the temperature range of 212-222 K for 20 passes through T_C was found to amount (with the subtraction of the cosmic background) to $\Delta N=(6.0\pm1.3)\cdot10^{-3}$ count/sec, or to $\Delta I=0.56\pm0.14$ n/s, while taking into account the detector efficiency with the cosmic background $N_b=0.12\pm0.004$ count/s. The count rate of neutrons in the ranges of $T \ll T_C$ and $T \gg T_C$ during the thermocycling of the samples would also correspond to that background level. In the experiments on the external irradiation of a DKDP crystal, Cf^{252}-source of neutrons (E_{max}=2.3 MeV) [9] with an intensity of 300 n/s in 4π angle was used. The neutrons source was placed at the center of a lead capsule 4 cm in diameter (Fig.1). The changes in the background level and the detector efficiency were varied by changing the distance in the source-detector system. For the purpose of varying the detection efficiency in the crystal-detector system, the crystal-detector and the source-crystal distance were also varied. In some cases, the source (detector) was shielded by means of standard polyethylene "neutrostop" (Co) blocks, in order to diminish the background (Fig.1). In connection with a rather rapid degradation of DKDP, only 20 transitions through the T_C were made for the purpose of determining the intensity of neutron events at one detector background value, N_b, (or at one fixed source-crystal distance). Then the DKDP crystal was replaced by a new one.

3. Results

The experiments have shown that on the transmission of the neutron flux (from the Cf^{252}-source of neutrons) through the cryocell with a DKDP crystal, in the process of the ferroelectric phase transition there is observed a real enhancement of the neutron flux (depending on the efficiency of the crystal-detector system). At $N_b/N_{b.c.}=100$, that amplification of the neutron flux may amount to about 10% of the intensity of the source proper ($\Delta I_{max}=29.5\pm2.7$ n/s in 4π). In such a case, the maximum value of the absolute effect increases by about 50 times as compared with the effect magnitude observable under the conditions of the cosmic background (Fig.2, curve 2), whereas the value ΔN (without taking into account E) increases only by a factor of 20 (Fig.2, curve 1). Now, no changes of the source count rate have been recorded in the same geometry in the temperature ranges lying outside the T_C. It has also been found that the intensity of counting neutron events in the given systems strongly depends on the source-crystal distance (with one and the same value of E in the crystal-detector system). In this case, a sharp increase in ΔN is observed for the neutrons cross the DKDP crystal with the range of 0 to 10 n/transition. Then the value of ΔN is stabilized in the range of $10<n_c<80$ (Fig.3). The dependence of the ΔN on the source-crystal distance indicates on the correlation between the external flux of neutrons crossed the crystal and the intensity of the excess emission of neutrons (ΔI) from the crystal. Moreover, the form of the function ΔI (E) indicates on the nonisotropic distribution of the neutron flux, as generated by the DKDP crystal exposed to the external flux of neutrons (Fig.4). In fact, at $E=1.0\cdot10^{-3}$, the value of the excess emission of neutrons, ΔI, is rather small, since the crystal is remote at a considerable distance from the detector; and therefore, the flux of neutrons as generated by the crystal cannot make a considerable contribution to the change in the count rate of the Cf^{252}-source. Now, the values of ΔN_b at the points $E=3.3\cdot10^{-3}$ and $E=1.1\cdot10^{-2}$, prove to be approximately equal, in spite of different crystal-detector distances, what cannot be attained with the isotropic distribution of neutrons (the Cf^{252}-source itself may serve as an example). The obtained dependence of ΔI (E) can be naturally explained only in the case, where we suppose that the main flux of neutrons from the crystal is directed according to a taper perpendicular to the detector surface, but not distributed in spherical symmetry 4π-angle.

4. Discussions

The dependences of the count rates of neutron events for DKDP crystals exposed to the external neutron flux during the phase transition through the T_C confirm a hypothesis on the generation of neutrons in deuterated solids as secondary neutrons initiated by the cosmic neutron background. In fact, the absolute value of the "effect" proves to be strongly connected with the background level of the detector (Fig.2). The magnitude of the effect increases with the background level (within the range of 1 to 100), and depends in the nonlinear way on the detector efficiency (in the detector-crystal system), because of the nonisotropy of the distribution of secondary neutrons. In principle, another variant could have been suggested to explain the observed effects, which is not connected with the multiplying of background neutrons. It may be determined by the transformation of the spectrum of neutrons from the Cf^{252}-source, as a result of their moderation to energies of about kT in polyethylene walls of a measuring chamber (Fig.1). In such a case, part of neutrons emitted by the source and moderated to an energy of kT do not get into the detector, becouse it is coated by a Cd-foil. If we suppose that during the pass through the T_C the phonons of the DKDP lattice do scatter thermal neutrons as the energy of the latter increases above 0.1 eV, then such neutrons would be able to overcome the cadmium protection. However, no dependence of ΔN on the source-detector distance should be observed in the measurement geometry, since the density of the flux of thermal neutrons is constant throughout the whole volume of the measurement chamber. Therfore, that variant is not suitable for explaining the effect.

The obtained results prove that a decrease in the cosmic background would also lead to a decrease in the magnitude of the effect. They also permit one to suppose that the main portion of the emitted neutrons in the experiments on the initiation of nuclear reactions in deuterated solids is associated with the registration of the secondary neutrons generated by "seed" (background) neutrons in crystal [10].

At present, the mechanism of the generation of secondary neutrons is still far from being elucidated. In our opinion, however, one of the possible models may be related to an injection into the DKDP crystal (in the state of a phase transition), of thermal neutrons that will stay therein for a considerable length of time, $\Delta\tau \sim 10^{-4}$ 10^{-5} sec. During the time $\Delta\tau$, a thermal neutron diffusing into the crystal can obtain many times a portion of excess kinetic energy (from 5 to 10 MeV) from the multiphonon excitations [11] induced, when the elastic energy is released by the domain wall during the ferroelectric phase transition. In such a case, one neutron during the time $\Delta\tau$ can many times interact with several deuterons (n+d∫p+2n), thus generating a cascade of secondary neutrons possessing energy of several MeV. The birth of secondary neutrons will cease after the thermal neutron will have left the crystal. Let us note that short-time bursts of the emission of the neutrons of short duration will be observed in the process described, the duration being comparable to the time $\Delta\tau$ [3-6].

The nonisotropy of the distribution of neutrons emitted on the ferroelectric transition, is, in our view, associated with the crosswise polarization of the crystal-target (oriented DKDP), that leads to an azimuthal asymmetry of the differential cross-section of deuterons in the reaction of generation of secondary neutrons [9].

5.Conclusion

To understand the mechanism of the "secondary emission" of neutrons requires making further investigations, including the application of the time-distribution of neutron pulses and the monochromatic sources of neutrons with different energy values.

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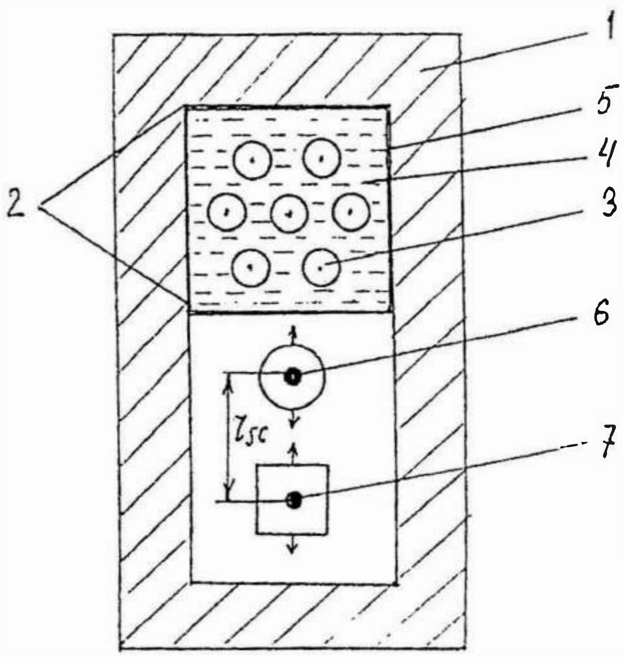

Fig.1. Schematic diagram of the experimental setup.

Key: 1. Polyethylene (Co); 2. detector; 3. counters; 4. silicone oil; 5. Cd-foil; 6. cryostat with a DKDP crystal; 7. Cf^{252}-source of neutrons.

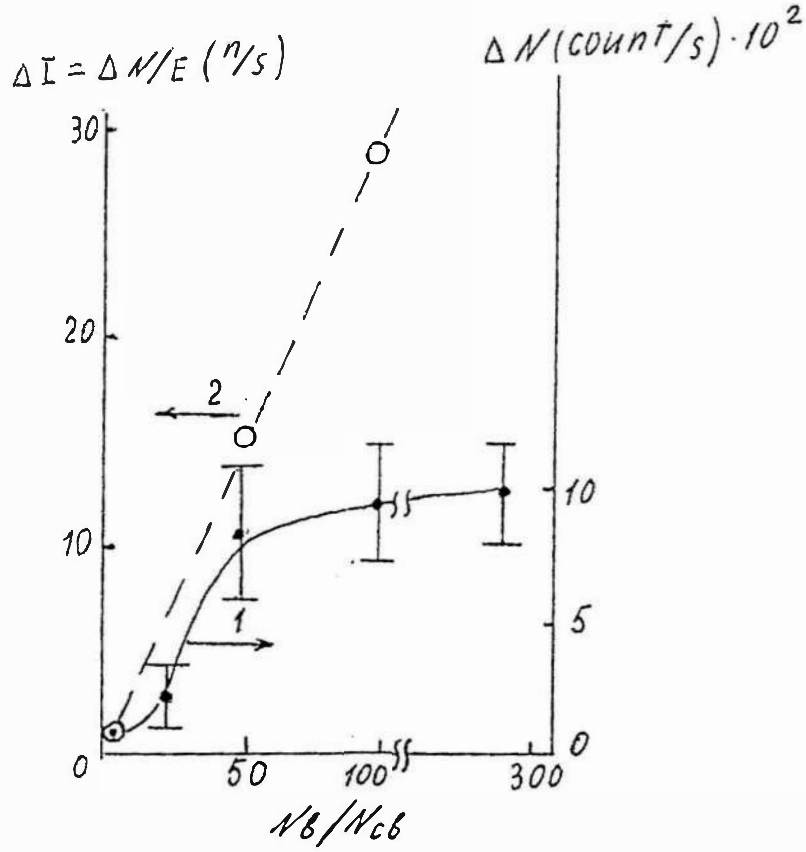

Fig.2. Dependence of the intensity of the emission of neutrons (with the subtraction of the source background) emitted by the DKDP crystal on the ferroelectric transition, on the relative value of the detector background, $N_b/N_{b.c.}$ (the source-crystal distance has been fixed, and is equal to r=6 cm) without taking into account the efficiency E in the crystal-detector system (curve 1); while taking into account E in the assumption on the 4π-distribution of neutrons (curve 2)

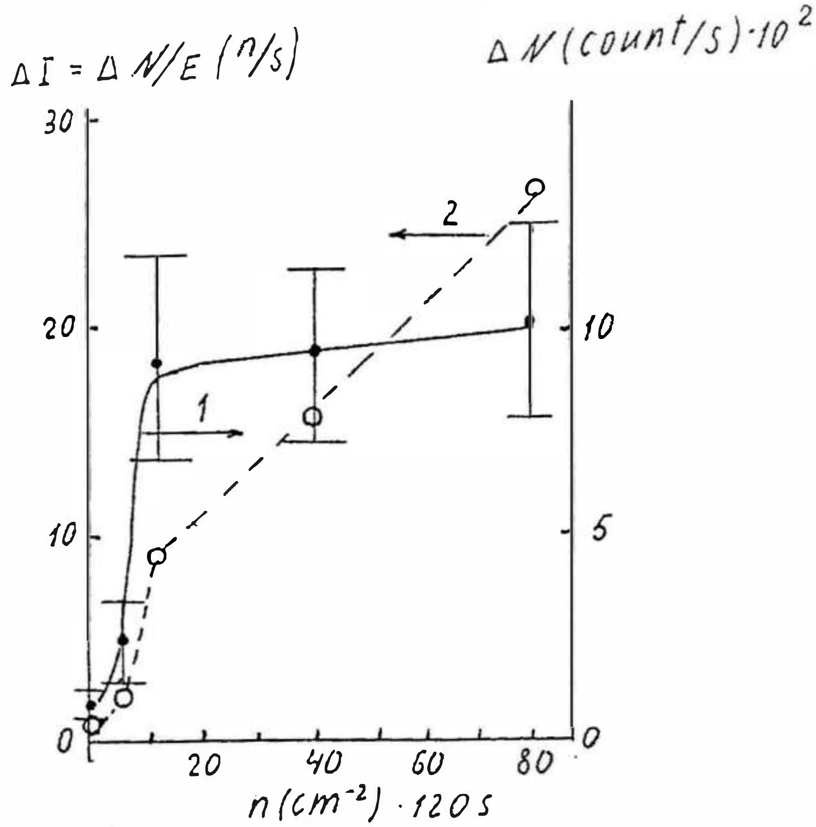

Fig.3. Dependence of intensity of neutron emission generated by DKDP-crystal (with the subtraction of the source background) on the valuem of neutron flux (n_f), that passed the crystal during the ferroelectric transition without taking into account the efficiency E in the crystal-detector system (curve 1); while taking into account E in the assumption on the 4π-distribution of neutrons (curve 2)

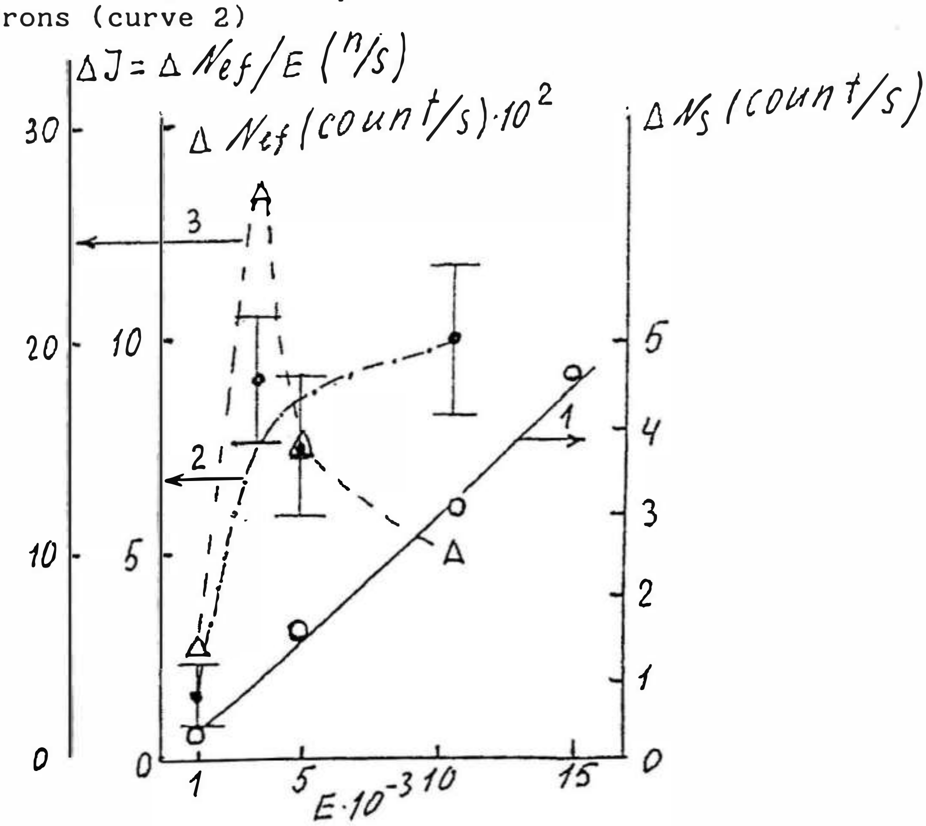

Fig.4. Dependence of the rate of counting of neutrons from the Cf^{252}-source on the efficiency in the source-detector system (curve 1); the intensity of the emission of neutrons emitted by the DKDP crystal (with the subtraction of the source background) as the function of the efficiency of detecting E in the crystal-detector system (curves 2,3).