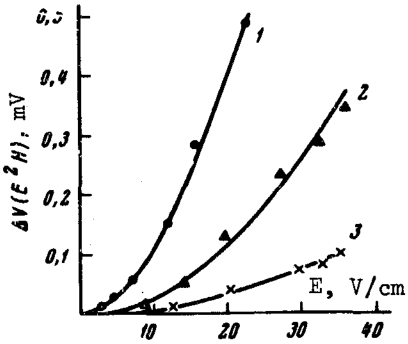

Fig. 1. Nonlinear term vs. electric field for three samples of thickness 5 (1), 3 (1) and 0.8 (3) microns. All curves were obtained with a magnetic field H = 0.35 kOe.

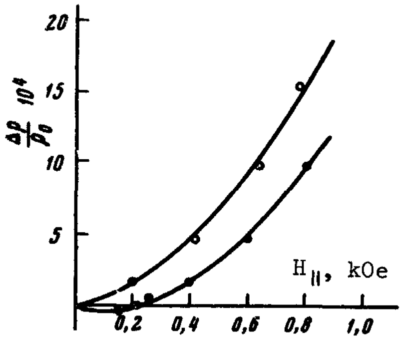

Fig. 2. Magnetoresistance vs. magnetic field for two opposite current directions. The curves correspond to a 0.08 micron sample and were plotted for E = 30 V/cm.

the film. In the investigated films, this condition is apparently satisfied as the result of the fact that one surface is free and the other is the interface between the germanium and the sapphire. It is seen from Fig. 1 that $\Delta V(E^2, H)$ decreases when the thickness changes from 5 to 0.8μ, this being in agreement with the theory [1, 3] if $d/\ell_e < 1$.

In conclusion it should be noted that the observed nonlinearity is not connected with the magnetoconcentration effect [4], which takes place in nearly-intrinsic semiconductors, since the hole concentration in the investigated films was larger by four orders of magnitude than the electron concentration.

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CONCERNING A GAS OF ULTRACOLD NEUTRONS IN A TRAP

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The possibility of storing a neutron gas in traps was first pointed out by Zel'dovich [1] and by Vladimirskii [2], but the detailed behavior os such a gas in a trap was not examined. In this paper we investigate several factors that influence the duration of the storage of a gas of ultracold neutrons (UCN) in traps, we determine the requirements imposed on the traps, and propose a method of obtained UCN directly in a trap [3]. The first to observe UCN experimentally was F. L. Shapiro and co-workers [4].

We consider first the effect UCN absorption. Assume that in a trap of volume Ω there is a "black" absorber, for example a neutron counter of area S. Then, at a coefficient of neutron reflection from the walls R = 1, we find that the number N_v of neutrons with velocity v decreases with time p in accordance with the law

$$N_v = N_{ov} = \exp\{-(\lambda + \frac{Sv}{4\Omega})\, t\}, \tag{1}$$

where λ is the free-neutron decay constant. Here

$$v \lessapprox v_{\text{lim}} \equiv \frac{\hbar}{m}\sqrt{\frac{1}{\pi} N b_{\text{coh}}}, \tag{2}$$

where N is the number of nuclei per unit volume of the trap walls, d_{coh} the coherence length of scattering, and m the neutron mass. It follows from (1) that a "black" absorber of even small area greatly decreases the lifetime of the neutrons in the trap, which does not contradict the experimental data [4]. Assuming that at the instant of accumulation (t = 0) the UCN spectrum $N_{0v} \sim v^3$ (v_{lim} is much smaller than the average thermal velocity v_T), we obtain the dependence of the ratio of the average neutron velocity v in the trap to the limiting velocity v_{lim} on $a = Sv_{\text{lim}}t/4\Omega$ (Fig. 1) [3].

When $t \to \infty$ we get $\bar{v} \to 0$; this effect is analogous to diffusion neutron cooling, if the "heat-transfer coefficient" from the moderator to the neutrons is set equal to zero.

The coefficient of reflection from the medium, R, neglecting the inelastic scattering, can be represented in the form

$$R = \left|\frac{k - k_o}{k + k_o}\right|^2, \tag{3}$$

where k_0 and k are the normal component of the wave vector in vacuum and in the medium, respectively. Confining ourselves to the case of not too strong an absorption [5], we obtain:

$$R = \frac{1 + \sqrt{\left(\frac{v_{\text{lim}}^2}{v_o^2} - 1\right)^2 + \frac{u^4}{v_o^4}} - \sqrt{2\left[\sqrt{\left(\frac{v_{\text{lim}}^2}{v_o^2} - 1\right)^2 + \frac{u^4}{v_o^4}} - \frac{v_{\text{lim}}^2}{v_o^2} + 1\right]}}{1 + \sqrt{\left(\frac{v_{\text{lim}}^2}{v_o^2} - 1\right)^2 + \frac{u^4}{v_o^4}} + \sqrt{2\left[\sqrt{\left(\frac{v_{\text{lim}}^2}{v_o^2} - 1\right)^2 + \frac{u^4}{v_o^4}} - \frac{v_{\text{lim}}^2}{v_o^2} + 1\right]}}, \tag{4}$$

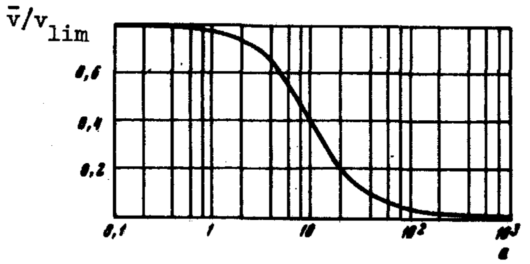

Fig. 1. $\bar{v}/v_{\text{lim}}$ vs. the parameter $a = Sv_{\text{lim}}t/4\Omega$.

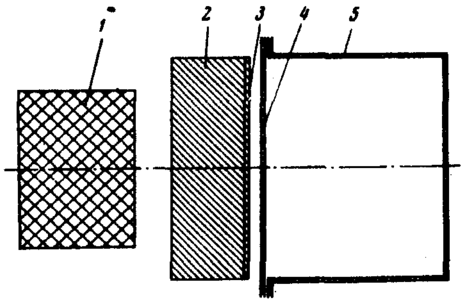

Fig. 2. Setup for the accumulation of ultracold-neutron gas: 1 -pulsed neutron source, 2 - hydrogen-containing moderator, 3 - external thin moderator layer - UCN emitter, 4 - mechanical fast shutter, 5 - UCN trap (container).

where $u = \sqrt{(\hbar/m)Nv\sigma_a(v)}$, and $\sigma_a(v)$ is the effective neutron-absorption cross section. Assuming an isotropic distribution of the velocity of the incident neutrons and using (5), we calculate the reflection coefficient $\bar{R}$ of the neutrons with total velocity v, averaged over the incidence angles:

$$\bar{R} = 1 - c\frac{v}{v_{\lim}}\frac{1}{1+\sqrt{1-(v/v_{rp})^2}}, \quad c = \frac{2u^2}{v_{\lim}^2}{}^{1)} . \qquad (5)$$

It is easy to see that the lifetimes of the neutrons should decrease as the result of absorption in the walls, by a factor

$$\sim 1 + \frac{v[1-\bar{R}(v)]S_0}{4\Omega\lambda}$$

compared with the case when $\bar{R} = 1$ (S_0 is the area of the internal surface of the trap). In a spherical copper trap (d - 20 cm) at $v_{\lim}/v = 3$, the lifetime decreases by approximately a factor of 2; in a similar trap made of Be, at $v = v_{\lim} = 6.8$ m/sec, it decreases only by approximately 4%. Consequently it is advisable to store the neutron gas in traps made of materials with small absorption (Be, C, etc.). Substances with appreciable absorption are suitable for neutron guides and mirrors (Cu, Fe, Ni, Al, Au, etc.). The absorption in the trap walls should obviously soften the neutron spectrum.

The accumulation of neutrons when the "window" of the trap is irradiated with a stationary flux of UCN should be accompanied by an appreciable leakage of the neutrons through this "window." In a trap with $\Omega = 10^5$ cm^{-3} in "window" area $S = 10^2$ cm^2, the average neutron lifetime decreases by a factor ∿ 100. In the experiment [4] they used a trap in the form of a copper tube of ∿ 10 cm diameter and 10.5 m length (internal surface ∿ 3×10^4 cm^2). The UCN emitter was a polyethylene film of area ∿ 70 cm^2, covering the end surface of this tube. The leakage of neutrons through the emitter apparently greatly reduced the observed UCN intensity (which amounted in these experiments to 0.76×10^{-2} UCN/sec at a ∿ 25% background. It is possible to eliminate the leakage by covering the "window" of the trap with a shutter reflecting the UCN. This is advantageous and easy to do when working with a pulsed "one-shot" neutron source (TRIGA [7] or IIN [8], which produce ∿ 10^{18} neutrons in a flash of 2 - 3 msec duration), or with sources operating with a frequency lower than ∿ 10 Hz. A stationary source is apparently more suitable for the formation of UCN beams with the aid of mirror-type neutron guides.

Figure 2 explains the proposed method of UCN accumulation. The neutron source 1 irradiates a hydrogen-containing moderator 2; the produced UCN flow from layer 3 of this moderator (∿ 1 mm thick) into a container 5. After this process has essentially terminated, a neutron shutter 4 operates and locks the UCN in the container 5. Its dimensions should be such that the shutter has time to operate within the time necessary for the neutrons to cover the distance from the moderator to the container wall and back.

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1) For Cu, Al, Be, and C the value of c is respectively 2.95×10^{-4}, 3.47×10^{-5}, 0.59×10^{-6}, and 0.415×10^{-6}.

Let us examine the efficiency of the method. In the flux from the moderator, the fraction of neutrons with $v \leq v_{lim}$ is $(1/2)\ (v_{lim}/u_D)^4$; at room temperature ($v_{lim} = 6.8$ m/sec) this amounts to $\sim 3 \times 10^{-11}$ [9]. If the irradiation is by fast neutrons, then a rough estimate based on the age theory yields for the probability of escape of a thermalized neutron $\varepsilon = (\exp(-B^2\tau))B^2L^2/(1 + B^2L^2)$ (τ - age of neutron, L - diffusion length; for a moderator in the form of a cube 2a on the side we have $B^2 = 3(\pi/a)^2/4$). For a hydrogen-containing moderator ($\tau = 33$ cm^2, f = 2.7 cm) we have $\varepsilon \approx 3 \times 10^{-2}$ (at a = 20 cm), i.e., the UCN generation efficiency amounts to $\sim 10^{12}$ per fast neutron falling into the moderator; cooling of the moderator to helium temperature should increase the efficiency of UCN generation by ~ 2 orders of magnitude. If the UCN emitter is made up of a series of thin moderator layers, then the UCN generation efficiency can be increased to $\sim 10^{-9}$. If reactors are used [7, 8] it is possible to accumulate up to $\sim 10^9$ UCN in one cycle. The trap with the accumulated neutron gas can be displaced at a velocity $v_{tr} \ll v_{lim}$.

Thus, the use of a multilayer emitter cooled to low temperatures should increase the UCN yield by several orders of magnitude. The use of a neutron shutter, which stops the leakage of the neutrons through the emitter, should additionally increase the neutron gas density by approximately two orders of magnitude; if the inner walls of the trap are further coated with a material that absorbs neutrons weakly (beryllium or graphite), then the lifetime of the UCN in the trap will practically be determined by the natural neutron decay.

In conclusion, the authors are grateful to Yu. A. Merkul'ev, B. V. Granatkina, and Wo Duc Bang for taking part in a discussion of the work.

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VERIFICATION OF T-INVARIANCE IN LEPTONIC RADIATIVE DECAYS OF K MESONS

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Many models have been proposed to explain CP-violation in K^0-meson decays. These models, in which the violation is connected with photon emission [1 - 4] explain "naturally" the value $\sim \alpha/\pi$ of the already known CP-odd effects and the large admixture of the $\Delta T = 3/2$ amplitude in the $K_L^0 \rightarrow 2\pi$ decay [5]. We note that it is precisely for these attempts were made to find