Portable installation for the accumulation of neutrons with a pulsed reactor

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(Submitted August 19, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 6, 387–390 (20 September 1976)

We have accumulated, for the first time, a gas of ultracold neutrons (UCN) with a one-shot pulsed reactor. The developed procedure uncovers unique possibilities both for the accumulation of a large number of ultracold neutrons and for obtaining a high-density gas of UCN.

PACS numbers: 28.20.—v, 28.40.Nw

An experimental verification of the possibility of containing UCN in closed volumes—traps—was realized in 1968 by a group headed by Shapiro.[1] The method of accumulating UCN in a trap (bottle) using a stationary reactor and subsequently transporting them to the measuring apparatus was first proposed and realized by us in[2,3]. Similar experiments were also performed by Koester and Steierl.[4] 1) At the present time research with UCN, including accumulation and containment in a trap by a neutron gas, is one of the promising trends in modern physics. It uncovers new possibilities in the study of the physics of elementary particles, nuclear physics, and solid-state physics.[4] To study inelastic scattering of UCN, which takes place in interactions with the walls of the trap, under conditions of the reactor background, it is necessary to accumulate a large number of UCN, ensuring by the same token a high volume density of the UCN. We have shown[5] that by using a pulsed reactor of the IIN type, emitting 10^{17} neutrons in a pulse lasting ~2 msec (average neutron energy 1 MeV) it is possible to accumulate an appreciable of UCN with high density.

Figure 1 shows schematically the installation for the realization of the

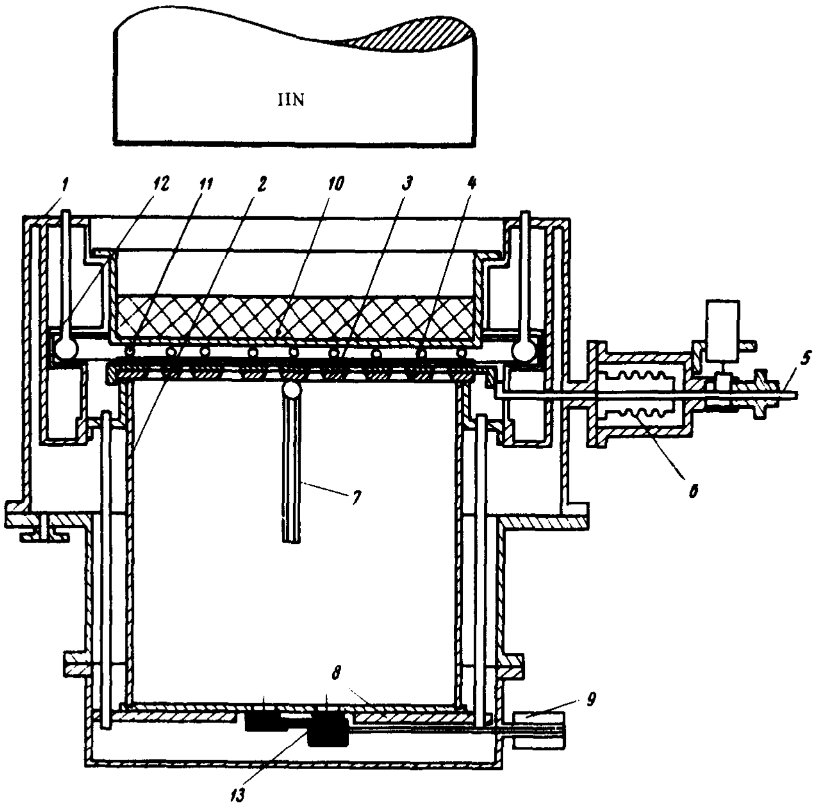

FIG. 1. Experimental setup for the accumulation of UCN: 1—housing, 2—copper trap, 3, 4—high speed shutter, 5—rod, 6—bellows unit, 7—slow shutter, 8—unit for moving the filters, 9—solenoid, 10—moderator block, 11—converter, 12-converter-cooling system, 13—detectors.

proposed method. The neutron trap 2 is an electrically-polished vessel of copper with diameter 40 cm and height 40 cm. The upper cover of the trap is a high-speed shutter 3, 4 (operating time 20 msec). To decrease the possibility of neutron leakage through the slits of the high-speed shutter, the trap is provided with a slow shutter 7 (operating time 2 sec), that covers the trap more tightly. At the bottom of the trap are two ports (2 cm in diameter), which can be covered with filters by means of a special device. Under one of these ports is located a track detector,[6] and under the other a gas scintillation detector[7] with UCN registration efficiencies 50 and 25%, respectively. The radiator in each detector is a uranium-titanium layer.[7] Both detectors are practically insensitive to β and γ rays and have low efficiency to thermal neutrons. The UCN source is a polyethylene converter 11 placed over the fast shutter. To increase the UCN generation efficiency, the converter is cooled to the boiling temperature of liquid nitrogen. The polyethylene block of the moderator 10 ensures moderation and thermalization of the neutrons emitted from the reactor.

During the time of the irradiation the installation is placed under the bottom of the reactor. After operation of the reactor and accumulation of the neutrons, the fast shutter is opened, followed by the slow one. The installation with the neutrons is transported into the measuring room with an average speed 0.3 msec, and the reactor room is closed by a shielding door to decrease the background of the delayed neutrons. The measurements begin approximately 70—80 sec after the filling of the trap. The system of detectors registers approximately 200 neutrons, of which about 60 are registered by the scintillation detector (at a delayed-neutron background ~3 neutrons). The average time of containment of the neutrons, with the detector ports open, according to the results of several runs, is 45—50 sec. Estimates show that at the start of the measurements 10^3 neutrons remain in the trap, and immediately after the accumulation the trap should contain $\sim 5\times 10^3$ neutrons, corresponding to a density ~100 neutrons/liter.

The experiments have made it possible to establish a number of possibilities for increasing both the number and density of the accumulated neutrons. These possibilities are connected mainly with an increase in the employed solid angle and cooling of the converter to lower temperatures. In the authors' opinion, when the installation is approved the number of accumulated neutrons can be increased by approximately 30 times, and the density of the accumulated neutron gas by 150 times. By shortening somewhat the time of closing of the shielding door (~ to 20 sec) it is possible to retain at the instant of registration $\sim 5\times 10^4$ neutrons, the greater part of which can be fed to the detector.

Thus, in the described experiments we have attained an accumulated neutron gas density of the same order as with a strong-flux stationary reactor. The essential difference between these experiments is the very low level of the neutron background. There are a number of possibilities for increasing the number of accumulated neutrons to $\sim 2\times 10^5$, and the density of the neutron gas to $\sim 10^4$ neutrons/liter. The indicated unique prospects of the method are of great importance for the organization of a direct experiment aimed at ascertaining the causes of the anomalously short time of containment of UCN in traps.

In conclusion, the authors are deeply grateful to N. G. Basov and D. V. Skobel'tsyn for constant interest, help, and support. The authors also thank P. A. Belyaev, V. S. Bushuev, V. V. Svezdov, and V. E. Solodilov for help with constructing the apparatus.

[1)]Academician B. M. Pontecorvo has told us that E. Fermi, with deep physical intuition, predicted long ago that in time it would become possible to accumulate neutrons in traps ("bottles") and transport them.

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