Storage of ultracold neutrons in a vessel with a magnetic "wall"

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We describe an experiment on the storage of ultracold neutrons of energy 0 to 30×10^{-9} eV in a vessel closed with the aid of a magnetic field. The results of the experiment confirm the possibility of using magnetic fields for the storage of ultracold neutrons.

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As shown in[1], neutrons of sufficiently low energy can be reflected from the energy barrier produced by a magnetic field, at any incidence angle, and this makes it possible to confine them in a bounded region of space with the aid of a field.

An experiment of this type was performed with the installation for obtaining ultracold neutrons from the SM-2 reactor.[6] The experimental setup is shown in Fig. 1. To store the ultracold neutrons we used a copper cylindrical vessel 5 with inside diameter 100 mm and length 2.4 m. An electromagnet consisting of solenoid 8 with core 9, of 100 mm diameter, and of an external steel shield 6, was placed on one end of the vessel. The solenoid with inside diameter 110 mm and length 18 cm was wound of a copper busbar of cross section 20 mm^2. At the maximum current through the winding (200 A) the field intensity on the surface of the core reached 5.3 kOe (at the center) and 6.5 kOe (at the edge).

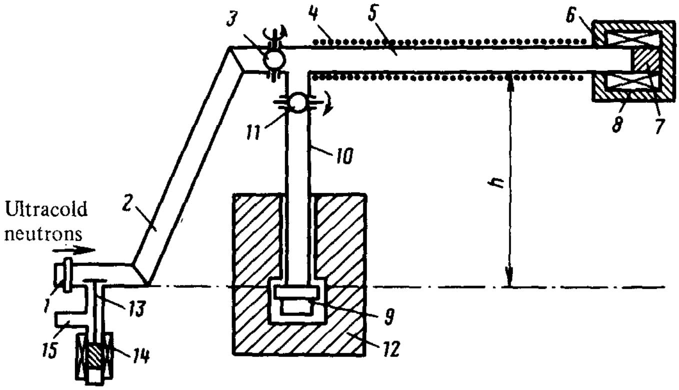

FIG. 1. Experimental setup for the storage of ultracold neutrons in a vessel with a magnetic "wall": 1—exit stub of the installation for the extraction of the ultracold neutrons, 2—inclined neutron duct, 3—entrance shutter, 4—solenoid of guiding field, 5—vessel for the storage of the ultracold neutrons, 6—shield of electromagnet, 7—electromagnet core, 8—solenoid, 9—ultracold neutron detector, 10—vertical channel, 11—detector shutter, 12—detector shield, 13—vacuum valve, 14—electromagnet of valve, 15—pumping stub.

At a distance 25 cm from the surface of the core, the intensity decreased to 50 Oe. For neutrons with spin directed along the field, the magnetic field in the region of the end face of the core produces an energy barrier

$$U = 3.2 - 3.9 \cdot 10^{-8} \text{ eV}$$

($U=\mu H$, where μ is the magnetic moment of the neutron and H is the intensity of the field). For such neutrons, the magnetic field plays the role of a "wall" of sorts, which keeps the neutrons in the vessel if their energy $E < U$. Neutrons with spin opposite to the field will be accelerated by the later and will "leak out" of the vessel.

To decrease the depolarization of the ultracold neutrons, a uniform guiding field of intensity ~50 Oe was produced in the storage volume with the aid of an additional solenoid 4.

The vessel was filled with neutrons through the exit stub 1 of the installation for the production of the ultracold neutrons, through an inclined neutron duct and through a shutter 3. The entire vessel was raised relative to the output stub to a height $h = 135$ cm. The energy of the accumulated ultracold neutrons did not exceed 3×10^{-8} eV, since the spectrum of the ultracold neutrons at the exit from the installation had an upper limit 1.62×10^{-7} eV (when raised a height $h = 1$ cm the kinetic energy of the neutron decreases by 0.98×10^{-9} eV).

To register the ultracold neutrons we used a gas-filled proportional counter 9 based on He^3, with an aluminum entrance window of area 60 cm.[2] Prior to registration in the detector, the neutrons that "leak out" of the vessel are accelerated in vertical channel 10, and acquire an energy higher than the limiting energy of the aluminum (~5×10^{-8} eV).

We investigated in the experiment the dependence of the number of neutrons stored in the volume on the storage time.

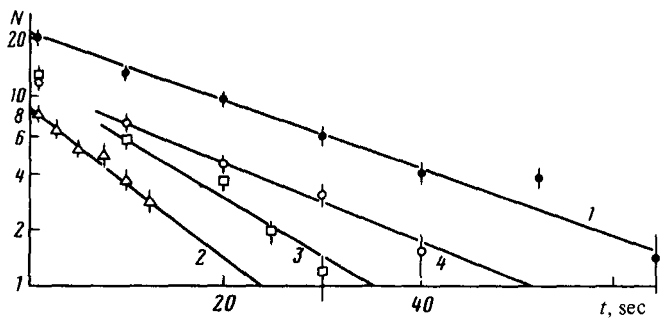

FIG. 2. Dependence of the number of ultracold neutrons remaining in the vessel on the storage time: 1—end face of core covered with copper foil, electromagnet turned off; 2—end of core covered with polyethylene, electromagnet off; 3—end covered with polyethylene, electromagnet on; 4—end covered with polyethylene, electromagnet on, solenoid of guiding field turned on.

When the electromagnet field and the leading field were turned off, and the surface of the end face of the core was covered with copper, the storage time was 25 ± 2 sec (curve 1, Fig. 2). In subsequent measurements the end of the core was covered with an ultracold-neutron absorber (polyethylene). In this case the ultracold-neutron storage time was 10.5 ± 1.5 sec and 15 ± 2 sec respectively with the electromagnet field turned off and on (curves 2 and 3, Fig. 2). The obtained short storage time indicates a noticeable depolarization of the ultracold neutrons in the volume of the vessel. A possible cause of the depolarization may be the instability of the generator feeding the electromagnet winding.

When the guiding field was turned on the depolarization decreased significantly, since the storage time increased to 22 ± 3 sec. This value coincides, within the limits of errors, with the value of the ultracold-neutron storage time in a vessel covered with copper foil.

The results of the experiment confirm the possibility, predicted in[1] of using magnetic field to store low-energy neutrons.

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