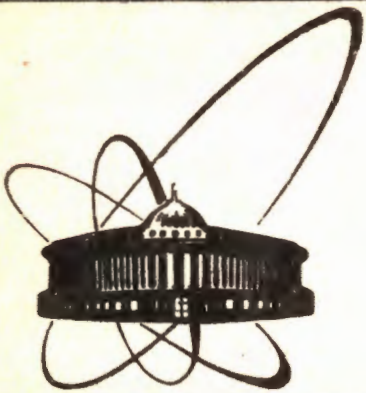

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# MOVING CONVERTER AS THE POSSIBLE TOOL FOR PRODUCING ULTRA-COLD NEUTRONS ON PULSED NEUTRON SOURCES

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Pulsed neutron sources provide extra possibilities in producing UCN's, if compared with stationary reactors. In[1] a method was proposed of UCN generation with the help of the UCN moving converter. This converter (or its jacket) material has a high boundary energy for UCN. It moves with a velocity $v_{conv} > v_{bound}$ in the time of the neutron pulse ($v_{bound}$ for beryllium is 6.8 $ms^{-1}$). As a result, the UCN's, born in the converter, pass the converter/vacuum interface practically without reflection. At the sharp stop of the converter, its surface, being a good reflector of UCN, fulfills the function of a shutter.

In this way with the use of a periodic neutron source the UCN density, stored in the near to the converter volume, could ideally approach that in the pulse.

For aperiodic neutron sources, e.g. GODIVA, TRIGA[2], or BIGR[3], having the pulse duration from fractions of a millisecond to milliseconds, a somewhat different scheme could be proposed (fig.1). The cooled to low temperatures UCN moderator-converter (1) moves fast along the vacuum tube (2) in the direction shown by the arrow, in the vicinity of the surface of the pused neutron source (3) equipped with the moderator (4) (for a water or graphite reactor this additional moderator may be not necessary). The motion of the converter is organized so that it intersects the region of maximum thermal neutron density exactly at the moment of the reactor pulse. The UCN produced in the converter

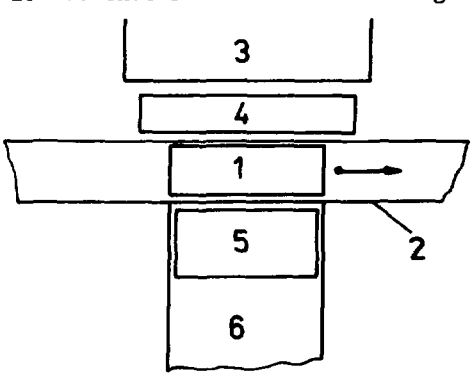


Fig.1. Schematical layout of the device: 1. Moving UCN converter-moderator. 2. Vacuum tube, the UCN converter moves along. 3. Pulsed reactor. 4. Neutron moderator. 5. Vessel for trapping the UCN "cloud". 6. Neutron guide or tube for the UCN-filled vessel dispacements.

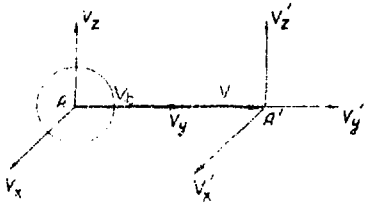


Fig.2. Volumes in the UCN velocity space, in the lab. frame, A, and in the moving frame of reference of the converter, A'. $v_b$ - the boundary velocity of UCN, v - the velocity of motion of the converter.

during the pulse, form a "cloud" at the site the converter had occupied at the moment of the reactor pulse. The UCN volumes in the velocity space in the lab.frame, A, and in the reference frame, A', of the moving converter got displaced on the value of the velocity of the converter, as shown in fig.2. The lifetime of this "cloud" in vacuum, connected with its spacial spreading is $\tau_{spr} \sim d v_{UCN}^{-1}$, where d is the size of the "cloud", $v_{UCN}$ is the mean UCN velocity. At d ~ 10 cm, $v_{UCN} \sim 5$ ms$^{-1}$, $\tau_{spr} \sim 20$ ms.

In order to "save" the UCN from "crawling" over a larger volume, a vacuum trap (5) is introduced immediatly after the reactor pulse into the region occupied by the UCN "cloud". If the trap velocity $v_{trap} > v_{bound}$, its thin enough front wall, having the boundary velocity for UCN, $v_{bound}$, is virtually transparent for them and the "cloud" gets trapped. There are two ways of the application of these "trapped" UCN. If the trap is a closed vessel, the UCN in it may be transported to any required place, e.g. as it was done in[4,7]. If the trap has no back wall, then the UCN get spread over the neutron guide (6) with their density having lowered down, however.

It is evident, that one needs to have a converter with minimum UCN losses inside it due to inelastic processes. These losses are proportional to $(v_{conv}\, \tau_{in})^{-1}$, where $\tau_{in}$ is the lifetime of UCN in the converter with respect to inelastic processes: nuclear capture and inelastic scattering on lattice vibrations.

Consider the case of the deuterated substances, $D_2O$, $CD_4$ and beryllium, freezed to low temperatures. For pure substances and sufficiently low temperatures, when inelastic scattering does not make any noticeable contribution, the UCN lifetime in the converter is determined by the capture of neutrons by nuclei: $\tau_c = (n\sigma_c v_{UCN})^{-1}$ and for the above-mentioned substances it is 150, 25 and 7 ms, respectively. Inelastic scattering decreases these values. At the pulse width $\tau_p \lesssim \tau_{in}$ and the velocity of the converter $v_{conv} \lesssim d\tau_{in}^{-1}$ the greater part of UCN leave the converter without losses (for example d ~ 10 cm, $v_{conv}$ ~ ~ 20 ms$^{-1}$).

Detailed optimization of the method requires the consideration of many parameters: the pulse width of the reactor and

the temperature of the thermal neutron spectrum, the size of the converter, which determines the time of UCN leakage from it, the velocity and the temperature of the converter, the velocity of motion of the trap, etc. Here we shall give just an estimate of the possible efficiency of this method. As in[1] we write an equation for the UCN density in the converter in the time of the reactor pulse:

$$\frac{\partial n(t, E)}{\partial t} dE = dE \int \Phi(t, E') \rho_c \sigma(E' \to E) dE' - \frac{n(t,E)}{\tau(E)} dE. \quad (1)$$

Here $n(t, E)dE$ is the UCN density in the converter in the energy range from E to E + dE at the moment t; $\Phi(t, E')dE'$, the thermal neutron flux at the moment t in the energy range from E' to E' + dE'; $\sigma(E' \to E)$, the cross section of the inelastic scattering of neutrons, having the energy E' in the converter, into the interval of energies from E to E + dE; $\rho_c$, the atomic density of the converter; $\tau(E)$, the UCN lifetime in the converter, which depends on the capture and inelastic scattering processes and the leakage.

Just to estimate the efficiency, we write the equation for the average values and the total UCN density n(t):

$$\frac{dn}{dt} = \phi(t) \Sigma_{cool} - n(t) \tau^{-1}, \quad (2)$$

where $\phi(t)$ is the integral over the thermal neutron flux spectrum; $\Sigma_{cool}$, the macroscopic cross section of UCN generation; $\tau$, the lifetime of UCN in the converter. For the sake of simplicity we assume that the pulse shape is rectangular and at $\tau \sim \tau_p$, where $\tau_p$ is the pulse width, we obtain the UCN density in the converter after the pulse:

$$n \sim \phi \Sigma_{cool} \tau. \quad (3)$$

Let us now consider the example of beryllium at 80 K. The calculation[5] performed in the Debye model for beryllium with $T_D \approx 10^3$ K allows one to find that the cross section for UCN generation in the energy range $10^{-7}$ eV induced by 400 K neutrons in 200 K beryllium is $\Sigma_{cool} \sim 10^{-10}$ $sm^{-1}$ and is little dependent on the converter's temperature. As follows from the analogous calculation[6], the UCN lifetime in beryllium at 80 K is 5 ms. At a fluence of $(1\text{-}2)\cdot 10^{15}$ n $cm^{-2}$, $\tau_p \sim 1$ ms, $\phi \sim 10^{18}$ n $cm^{-2}$ $s^{-1}$ that give $n \sim 10^5$ n $cm^{-3}$ at $\tau_p \sim 1 \div 5$ ms. With a converter, having a volume of $\sim 10^3$ $cm^3$, it appears possible

to produce ~$10^8$ UCN's per pulse. Some other converter ($CD_4$, $D_2O$) could possibly yield greater densities of UCN. However, the metallic melted beryllium is most convenient from the technological point of view. The method reported looks much attractive in the sense of the application to the experiments which require periodic filling of experimental volumes with UCN: study of neutron decay, search of the EDM of the neutron, etc.

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