The influence of low-frequency, high amplitude vibrations on UCN

C. Siemensen[a], C. Plonka-Spehr[a], D. Brose[a], N. Schneider[a]

[a] *Institute for Nuclear Chemistry, University of Mainz, Germany*

Abstract

We investigated the influence of acoustical vibrations at high amplitudes and low frequencies (as generated e.g. by vacuum pumps) on UCN reflections in a beam experiment. It turned out that this influence is not negleglibe for high-sensitivity experiments as e.g. test of the neutron charge. The loss probability for UCN per bounce is on a level of about 10 %.

So far, the influence of vibrations has been investigated with respect to UCN-storage experiments [1], at a large number of reflections of the neutrons. We recently determined the phenomena in a beam experiment. Figure 1 shows the setup which was installed in November 2011 at the ILL. The neutrons enter the vacuum chamber via an entrance guide (1), followed by a grating (2), hit a cylindrical, nickel-coated mirror (3) and are projected on two stacked detectors (5), covered by an equivalent grating as (2). As the neutrons pass through the apparatus, some of them bounce on a horizontal mirror, made of Fomblin-oil (Perfluoropolyether, PFPE). The Fomblin is filled into a basin (4). By shifting the detector, one obtains modulation curves in the UCN counting rate.

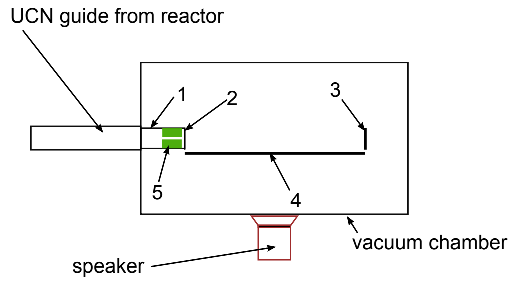

Figure 1: External exitation of vibrations with a speaker.

First, we investigated the dominating vibrations at our experimental place with an accelerometer. The main vibration has a frequency of about 73 Hz and is caused by the vacuum pumps near the experiment. We now applied acoustical vibrations of 73 Hz with a speaker mounted below the vacuum chamber (see Figure 1). We applied vibrations with amplitudes on the horizontal mirror of about 1×10^{-3} m, which is a factor of 100 larger than the vibrations produced by the pumps. In figure 2, the result of such a measurement is presented for the upper detector A. The modulation of detector A is decreased by a factor of 0.88(1), compared to the case without vibrations. The modulation of detector B is decreased by a factor of 0.93(1). Monte-Carlo simulations revealed that UCN hitting the upper detector A bounced 1.18(47) times on the horizontal mirror, and those hitting the lower detector B bounced 1.49(89) times. Thus, our experimental data could be explained by a loss probability per bounce of ≈ 10 % for detector A and ≈ 5 % for detector B.

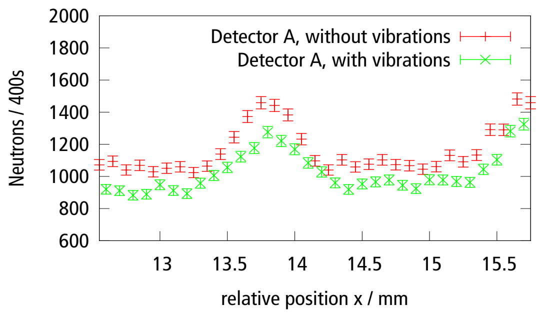

Figure 2: Measured influence of vibrations on the modulation.

In 1975, a mathematical framework was developped by V. K. Ignatovich, based on first order pertubation theory [2]. It describes the influence of vibrations on the loss probability of UCN. Within this framework, we deduced an equation describing the influence of our low-frequency vibrations on UCN:

$$\mu(\vec{k}_0) \propto \frac{k_{0\perp}^3}{u_0}(a\omega_a)^2, \tag{1}$$

where u_0 is the UCN potential of the reflecting surface, $k_{0\perp}$ is the wavenumber of the incoming neutron, perpendicular to the surface, a and ω_a is the the amplitude and the frequency of the vibrating surface. Thus, UCN must be scattered at extreme high harmonics of order 1×10^5 on the liquid PFPE surface with amplitudes of about 2×10^{-8} m to reach the above loss rates. Detector B is below detector A. Neutrons hitting detector A have more kinetic energy and therefore a higher $k_{0\perp}$. Thus, Eq. (1) explains the difference between the loss rates of A and B:
Within the simulation, the fraction $k_{0\perp}^{A}/k_{0\perp}^{B}$ was calculated to ≈1.23. Assuming that $\mu^{A}(\vec{k}_0)$ ≈10 %, one obtains $\mu^{B}(\vec{k}_0)$ ≈5 %, which is consistent with our measurement.

[1] L. Bondarenko et al., *Cooling and heating of ultracold neutrons during storage*, Physics of Atomic Nuclei 11 (2002) 65

[2] V. K. Ignatovich, *The Influence of Low-Frequency Oscillations on the Storage Time of Ultracold Neutrons*, phys. stat. sol. (b) 477 (1975) 71

Email address: `c.siemensen@uni-mainz.de` (C. Siemensen)