Experimental report

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Proposal:	**3-14-386**	**Council:**	4/2018
Title:	Observation of the UCN upscattering at the artificially generated surface acoustic waves		
Research area:	Nuclear and Particle Physics		

This proposal is a new proposal

Main proposer: **German KULIN**

Experimental team: Semen GORYUNOV
German KULIN
Alexander I FRANK
Emilio LORENZO DIAZ

Local contacts: Stephanie ROCCIA
Peter GELTENBORT
Tobias JENKE

Samples:

Instrument	Requested days	Allocated days	From	To
PF2 UCN	20	0		
PF2 EDM	0	20	05/10/2018	28/10/2018

Abstract:

The problem of neutron diffraction by a travelling wave has a rather long history. Probably, it was firstly discussed in 1975 by I.M. Frank in connection with the so-called UCN storage anomaly. Recently, this problem has been analyzed theoretically for the case of waves travelling at the surface of a liquids. However, UCN diffraction by surface waves was never observed in a direct experiment and it is necessary to meet this gap.

Travelling waves at the surface of matter arise due to periodic oscillation of atoms, which are moving up and down mainly in the direction perpendicular to the surface. For the typical amplitudes (1 nm) and frequencies (tens of MHz) of surface acoustic waves the local acceleration of the surface riches the giant value 10^(7)g. Some arguments were published that in the case of giant acceleration, the concept of an effective potential may not be valid for UCN but correct for cold and thermal neutrons.

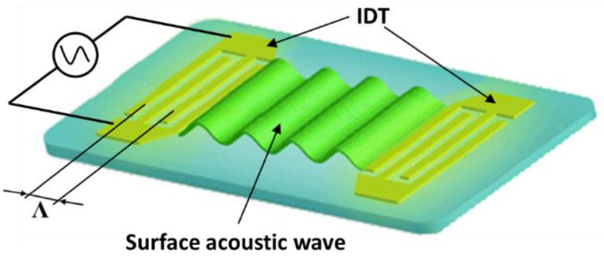
All this makes the experiment for the observation of UCN upscattering at surface acoustic waves much more important.

Observation of the UCN upscattering at the artificially generated surface acoustic waves

The possibility of neutron diffraction on surface (Rayleigh) waves was firstly noted in [1] in connection with the problem of the storage of ultracold neutrons. The diffraction of cold neutrons by traveling surface acoustic waves (SAW) excited at the surface of quartz crystal was observed in 1987 [2]. Angular distribution and diffraction orders intensities corresponds well to the theoretical prediction. Wide application of the fomblin oil for the coating of trap walls stimulated theoretical research of inelastic scattering of UCN by the waves travelling at the surface of liquids [3,4]. However, UCN diffraction by a surface waves never were observed in a direct experiment.

In October 2018, the first experiment to search for UCN upscattering due to diffraction (SAW) on a surface acoustic wave was carried out at the PF2EDM beam of the Laue-Langevin Institute. Although the theory of neutron diffraction by SAW is well known and the results of experiments with cold neutrons are in good agreement with the calculations, the physics of the interaction of UCN with ultrasonic surface waves is not entirely clear. A travelling wave at the surface of matter arises due to periodic oscillation of atoms. It is easy to estimate, that for the typical amplitude (1 nm) and frequency (tens of MHz) of SAW the local acceleration of the surface riches the giant value 10^7g. It is far from obvious that the generally accepted theory of the interaction of UCN with matter is valid under these conditions.

The surface wave was excited on the surface of the single-crystal of lithium niobate ($LiNbO_3$) when alternating voltage was applied to one of the interdigital transducers prepared on the surface of the sample by the photolithography. The signal from the second transducer was used to monitor the presence of the surface wave and to measure its amplitude. The frequency of the excited wave was f = 35 MHz. The energy transferred to the neutron $\Delta E = \hbar\omega$ at diffraction on the traveling wave should in this case be about 140 neV. The change in the energy is mainly due to a change in the component of the velocity normal to the surface of the crystal.



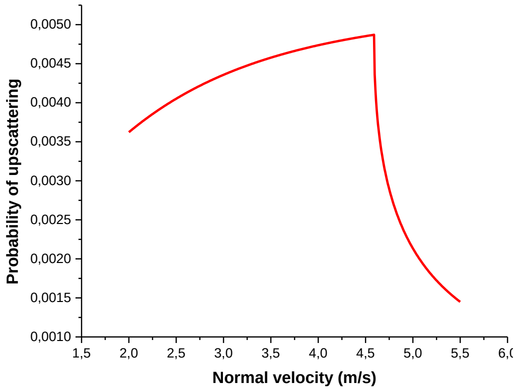


Fig.1 *Schematic view of the sample with surface acoustic wave (left) and the calculated efficiency of UCN heating on the surface wave as function of the neutron velocity component normal to the crystal surface (right).*

Neutrons were recorded by a main detector located directly above the sample. Its entrance window was covered with copper foil. Therefore, the detector was sensitive only to neutrons with an energy exceeding the boundary energy of copper, E> 170 neV. The theoretical estimation of the probability of UCN heating, obtained by integrating over the spectrum of the curve in Fig. 1 (right), is less than 0. 01. It means the success of the experiment was determined by the efficiency of suppressing the background generated by neutrons with an energy exceeding the boundary energy of copper. This background is not associated with the presence of an acoustic wave on the sample surface.

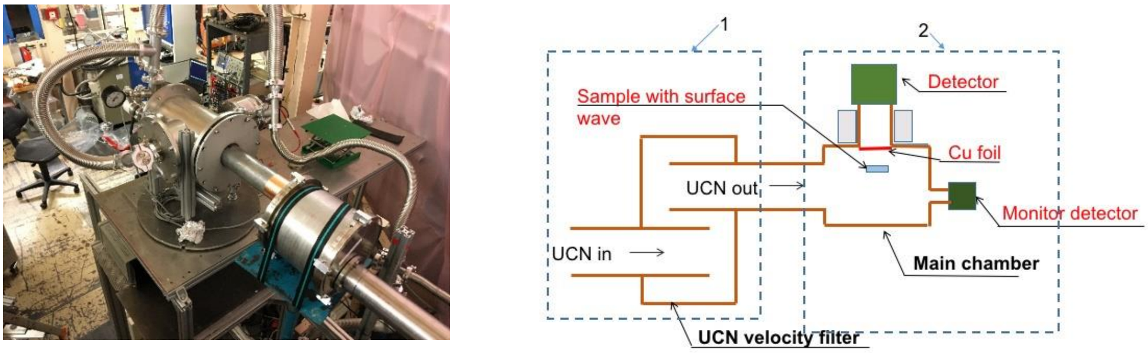


Fig.2 *View of the installation at the UCN beam PF2 EDM and the scheme of the experiment. 1 — the chamber for preliminary cleaning of the UCN spectrum, 2 — main chamber with the sample.*

To suppress this background, we used the UCN velocity filter (VF) [5] located before the entrance of the main chamber. The work for the optimization of a geometry and materials of VF as well as materials of the walls of the main chamber took a long time but as a result, we were success to suppress the background by three orders of magnitude while the count rate of useful neutrons was decreased by a factor of 10. However, even in these conditions, the background was 1000 times higher than the expected effect.

To verify the possibility to detect the upscattered neutrons we used a special mechanical device (Fig.3), which might drive up and down a nickel mirror, located in the sample position, with the frequency about 100 Hz. The transfer of energy to UCN reflected from this “kicker” due to the Doppler effect, was similar to that we should expect in the experiment with SAW. Experimental results were in good agreement with calculations.

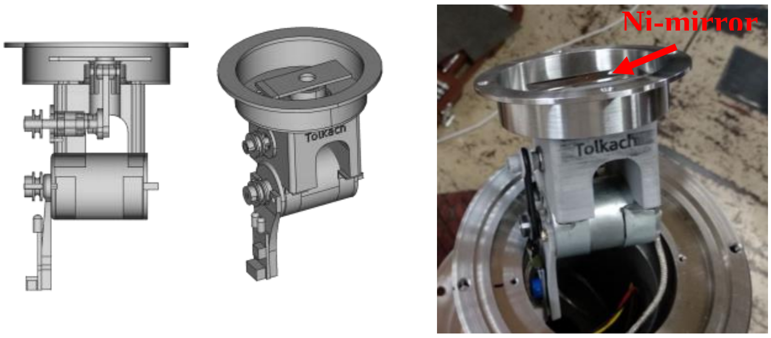


Fig.3 *UCN “kicker”. The design (on the left) and the view (on the right) of the device*

Since the work to optimize the experimental conditions and the test experiment with the mechanical “kicker” took more time than we expected the only a few hours remained for statistic collection in the main experiment. The count rate was measured as in the presence of the acoustic wave on the surface of the sample and without it. The obtained experimental heating effect, i.e. the difference two count rates, was found as -0.035 ± 0.047 cps with a theoretical expectation about 0.1 cps. While the detected effect is less than expectation it is difficult to make any conclusion concerning possible discrepancy due to the rather pure statistics. The new experiment is needed.

References

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