New spectrometer for test of equivalence principle with UCN

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Abstract

We propose a next generation experiment to test the equivalence principle for neutrons. For this purpose a new spectrometer has been build. The main modification is the measurement of a modulation phase instead of the absolute count rate. By this reason it is expected to overcome former limitations due to background fluctuations and to improve the sensitivity by one order of magnitude. First tests of the new spectrometer were performed.

In our experiment [1] the change in the energy of the ultracold neutrons falling in the Earth's gravitational field (mgH) was compensated by the quantum of energy transferred to the neutron ($h\Omega$) in the nonstationary interaction with a moving phase grating. The results of that experiment confirm the validity of the equivalence principle within $2x10^{-3}$. One of the major limitations of this experiment was a time dependence of the background count rate. Later we found [2] that the precision of the experiment of this type may be improved at least by one order of magnitude using the same UCN source.

The controlled variation of the neutron energy in a planned new experiment on verification of the weak equivalence principle will be measured by a peculiar time-of-flight method. For this purpose the neutron flux will be modulated by a chopper and the detector will measure the corresponding oscillation of the count rate. The count rate oscillation phase $\Phi = 2\pi F\tau$, where F is the frequency of the chopper, is proportional to the time of flight τ.

For these purposes a time-of-flight gravitational spectrometer with neutron interference filters has been built (fig. 1). At the end of 2010 first tests of the new spectrometer were performed. The main part of this device was the chopper-modulator of the UCN beam (fig.2). Two aluminum disks with 3 opened sectors might be rotated in opposite directions with the help of high vacuum PHYTRON stepper-motors and toothed belts. The rotation frequency and relative phase of discs rotation were controlled by a computer.

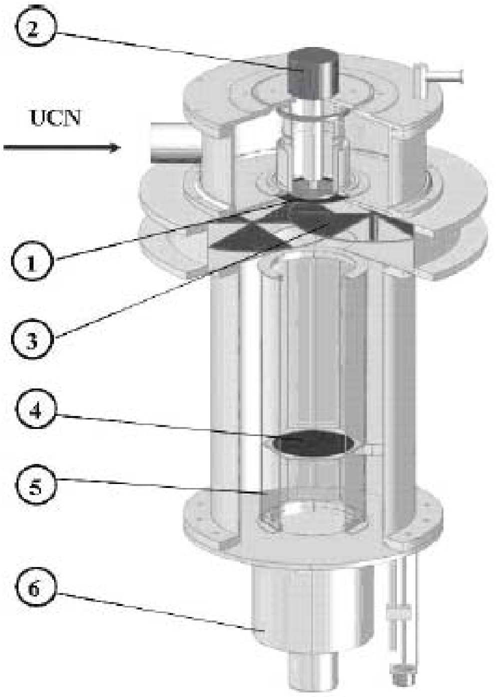

Figure 1. New spectrometer. 1 – monochromator, 2 – motor for the grating spinning, 3 – chopper-modulator, 4 – analyzer (can be moved in vertical direction), 5 – glass neutron guide, 6 – detector

Figure 2. Chopper-modulator

Two test experiments were performed. In the first one quasi-monochromatic neutron beam, prepared by transmission of UCN through Fabry – Perrot monochromator, was modulated by the chopper. The amplitude and phase of the count rate oscillation were measured for different modulation frequencies. It was found that the amplitude of count rate oscillation decreases with increasing of frequency relatively slowly (see fig.3) and modulation frequency around 100 Hz may be used in the experiment without serious loss of the contrast.

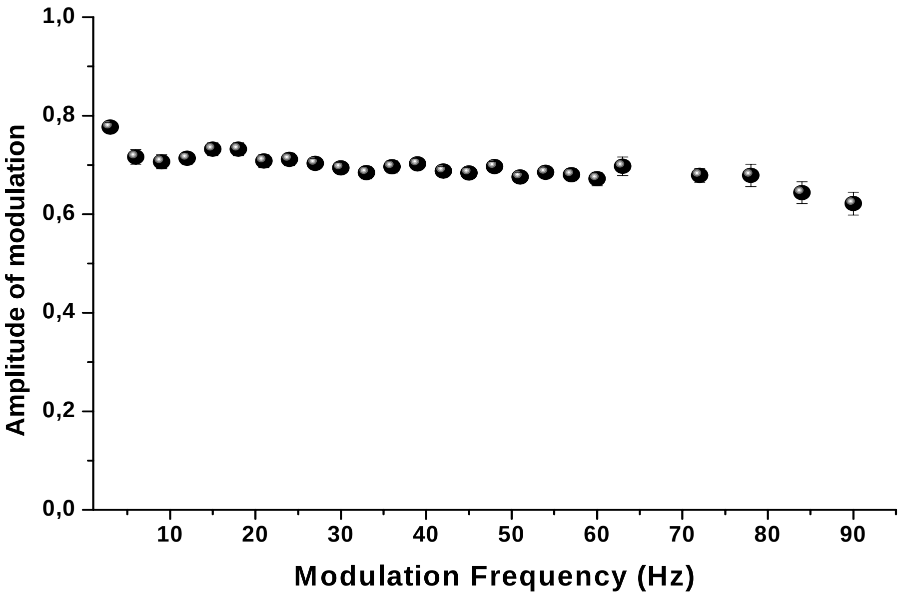

Figure 3. Amplitude of the count rate oscillation measured at different modulation frequencies

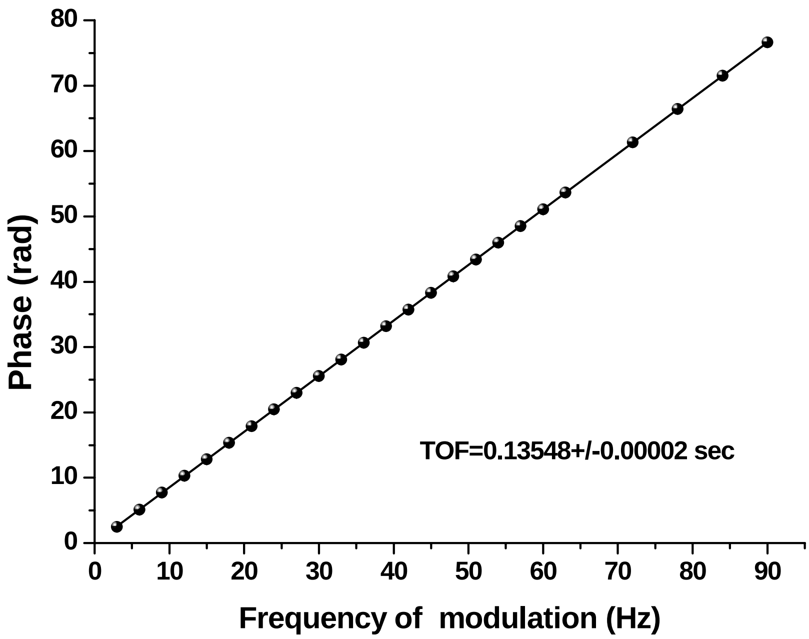

Figure 4. Phase of the count rate oscillation measured at different modulation

From the measurement of the dependence of count rate oscillation phases on frequency it was possible to obtain the value of UCN time of flight. It was found as $t = 0.13548 \pm 0.00002$sec.

The second test experiment was to measure the dependence of the count oscillation on the position of monochromator at a fixed frequency. In this experiment UCNs of a wide energy spectrum passed through modulator and only after that through Fabry – Perrot monochromator located below modulator. The position of the last one was possible to vary in height. This test experiment was important, because such experiment will be a part of experimental procedure of the planning test of the equivalence principle. Results are presented in fig. 5.

It was shown experimentally that new spectrometer with Fabry-Perrot monochromator and fast modulation of UCN flux might be used for real measurements.

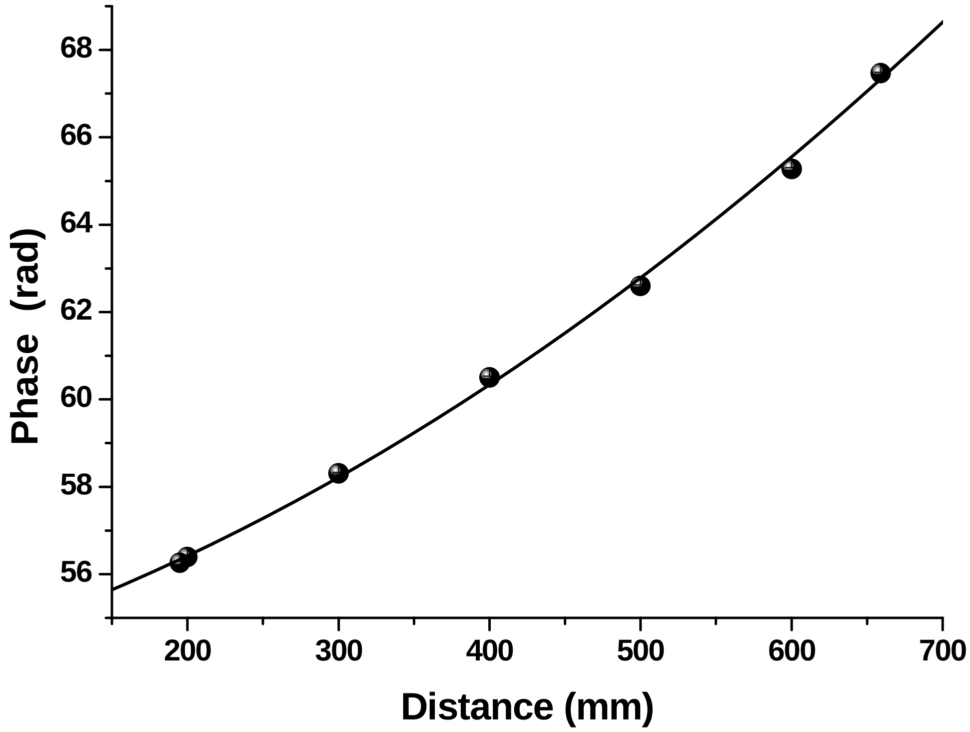

Figure 5. Phase of count rate oscillation measured at 60Hz of modulation frequency, at different position of the analyser

References

1. A.I. Frank, P. Geltenbort, M. Jentschel,et al. JETP Letters, **86,** 225 (2007)
2. A.I. Frank, P. Geltenbort, M. Jentschel et al. Nucl. Instrum. Methods **A 611**, 314 (2009)