Towards a test of the electric neutrality of the neutron

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Abstract

We continued the work on our optical device for ultracold neutrons and demonstrated the possibility to significantly improve its statistical discovery potential for external forces. The found limitation is given by the resolution of the optical elements, which is at present on a level of 0.1 mm. A reduction of the grating slits of the device to this level would yield a factor 4 in sensitivity.

The basis for our work described here are the experimental results of [1] where we revisited a former neutron optical experiment [2] to test the electric neutrality of the neutron.

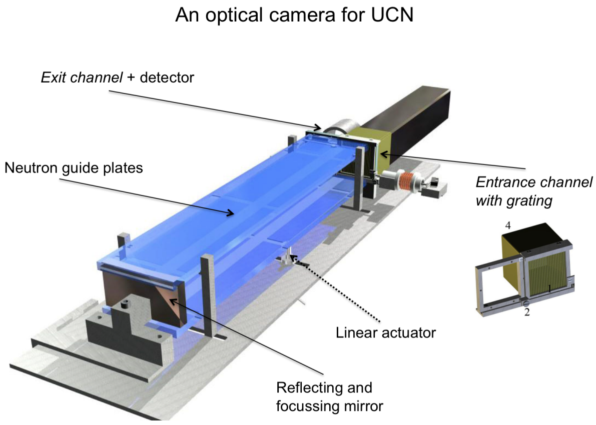

Figure 1: The experimental setup of the UCN camera.

A schematic diagram of our experiment is shown in Figure 1. A detailed description of the setup is given in [1].

The apparatus can be regarded as a camera for ultracold neutrons (UCN). It is based on the reflection of UCN from a cylindrical focusing mirror. Neutrons enter the camera through a grating composed of 40 vertical slits, 0.4 mm wide and 50 mm high, separated by 1.5 mm. The camera is made from two plane-parallel neutron guides 500 mm long and 100 mm wide (floatglass, thickness 8 mm). The UCN are reflected from a vertical cylindrical mirror with radius of curvature 500 mm and produce an image of the entrance grating at the exit grating. The exit grating together with a detector can be moved across the beam image. Thereby, a modulation of the UCN count-rate is detected.

The neutron-optical elements are aligned by light-optical means to a high precision. Figure 2 shows the obtained modulation of a measurement with UCN taken at PF2, ILL, Grenoble in 2010. The detected signal can be fitted with the response function $f(x)$ which is the convolution of one triangular function t (the convolution of two rectangular slits, entrance and exit grating) and one gaussian g of width $\tilde{w}$:

$$f(x) = (t \otimes g)(x) = \int_{-\infty}^{\infty} t(y) g(x-y)\, dy. \quad (1)$$

The width $\tilde{w}$ of the gaussian describes the resolution of the optical system. From the fit of $f(x)$ to the modulation data,

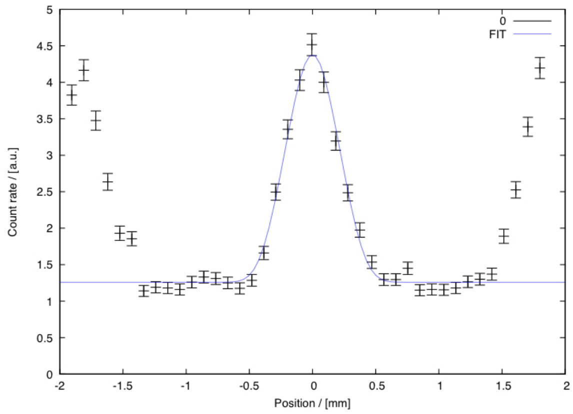

Figure 2: Obtained modulation curve.

a value $\tilde{w} = 0.11(1)$ mm is derived. The full width of $f(x)$ is $2\,\tilde{w} = 0.41(1)$ mm.

We conclude that the influence of imperfections of the optical elements can be described empirically by a gaussian of width 0.1 mm. This width is significantly smaller than the width of the grating slits (0.4 mm).

The sensitity of the experimental method in order to detect forces perpendicular to the main UCN flight trajectory (as from a neutron charge in a strong electric field) scales with:

$$\delta a = \frac{4}{t^2} \sqrt{\frac{2\,N}{\tau}} \cdot \left(\frac{dN}{dx}\right)^{-1}. \quad (2)$$

Herein a denotes the acceleration, N is the count-rate and $\frac{dN}{dx}$ the gradient on the steep slope of the modulation. t^2 denotes the quadratic transit time of the UCN and τ is the overall measuring time. The analysis shows that the grating slits can be reduced to 0.1 mm (at present 0.4 mm). This will enhance the sensitvity on $\delta\, a$ by a factor of 4.

[1] C. Plonka-Spehr et al., DOI: 10.1016/-j.nima.2010.02.110
[2] Y. Borisov et al., Zh. Tekh. Fiz. 58 (1988) 951

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