Investigation of a Sitall glass ceramic as UCN storage material

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Abstract

We investigated a new storage material for ultracold neutrons called Sitall. The storage properties of this glass ceramic were measured at the UCN source of the reactor TRIGA Mainz. A storage time of (160 ± 2) s was found. Further material properties of this material are outlined.

The storage of ultracold neutrons (UCN) in material bottles can be described by an effective potential $U_{\mathrm{F}} = V - \imath W$, where V describes the reflectivity potential which depends on the atomic density N_i and on the coherent scattering length b_i of the material composition:

$$V = \frac{2\pi\hbar^2}{m_{\mathrm{n}}} \cdot \sum_i N_i\, b_i. \tag{1}$$

In general, the number of storable UCN in a material bottle scales with $V^{3/2}$. The so-called storage time $\tau_{\mathrm{stor.}}$ describes the loss of UCN in the material bottle during the storage process. These losses are mainly due to absorption on the walls and depend on the ratio of $\frac{V}{W}$. Herein, W is the imaginary part of (1) which depends on the absorption cross sections of the material composition.

Certain experiments like the search for a permanent electric dipole moment of the neutron (nEDM) require in addition a high electrical resistivity, non-magnetic properties and a high vacuum compatibility of the material in order to enhance the sensitivity of the measurement technique.

Y. Borisov has suggested to use Sitall as a material for UCN storage cell in an EDM experiment. Test of Sitall samples at PNPI have shown high specific volume electroresistance exceeding $10^{16}\,\Omega\,$cm and the possibility to achieve electric field strength of 32 kV/cm. For investigations of the UCN storage properties, a Sitall storage chamber has been developed and made together with PNPI in RTIOMS (Russia). The chemical composition of the Sitall ceramic was measured by X-ray fluorecence analysis (RFA), X-ray diffracometry (XRD) and neutron activation analysis (NAA) in Mainz: 60% SiO_2, 20% Al_2O_3, 20% MgO_2.

The storage time of a Sitall cell (Volume 20 liters) was measured in a one-day experiment at the UCN source C of the reactor TRIGA Mainz. The experimental setup is shown in fig. 1. UCN are produced in the solid D_2 converter (11) of the source and transported via a switch (7), driven by an actuator rod (8) towards the Sitall bottle (2) placed in a vacuum chamber (1). The UCN production rate of the source was monitored by a detector (10). After a variable time UCN were stored in the Sitall, the shutter plate (3) of the cell was opened by the actuator (6) and the remaining UCN were counted in the detector (9).

Prior to the installation inside the vacuum chamber, the Sitall was cleaned in an ultrasonic bath. After installation, the Sitall was heated from above (4) and exposed to a helium discharge cleaning. Details about the cleaning process, the experiment and the analysis are described in [1].

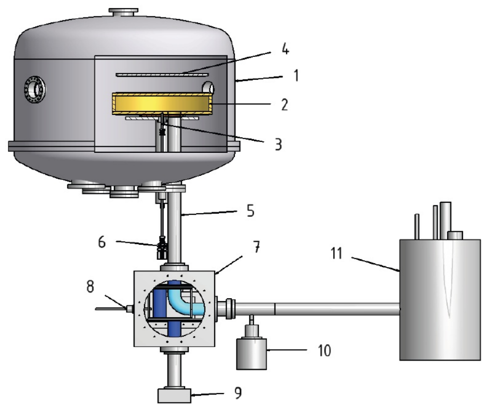

Figure 1: Draft of the experimental setup, not at scale.

Figure 2 shows the detected number of UCN (normalized to the monitor detector) after different holding times in the Sitall cell. The derived storage time from the fit is $\tau_{\mathrm{stor.}} = (160 \pm 2)$ s. With respect to its electrical properties, Sitall might be a well-suited material for storage experiments like the search for an electric dipole moment of the neutron.

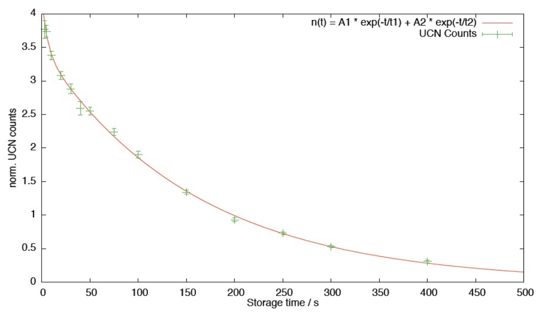

Figure 2: Storage data and exponential fit of $\tau_{\mathrm{stor.}}$ with $\chi^2_{\mathrm{red.}} = 0.9$.

[1] C. Düsing, Diploma thesis, Mainz, 2010

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