Possibility to Decrease the Losses of Ultracold Neutrons in Material Traps Covered by Liquid Helium

P.D. Grigoriev[1,2], A.M. Dyugaev[1], A.V. Sadovnikov[3], V.D. Kochev[2]

[1]*L.D. Landau Institute for Theoretical Physics, 142432, Chernogolovka, Russia*
[2]*National University of Science and Technology "MISiS", 119049, Moscow, Russia*
[3]*Lomonosov Moscow State University, 119991, Russia*

We propose a method to increase both the neutron storage time and the precision of its lifetime measurements by at least tenfold [1,2]. The storage of ultracold neutrons (UCN) in material traps now provides the most accurate measurements of neutron lifetime and is used in many other experiments. The precision of these measurements is limited by the interaction of UCN with the trap walls. We show that covering trap walls with liquid helium may strongly decrease the UCN losses from material traps. 4He does not absorb neutrons at all. Superfluid He covers the trap walls as a thin film, ≈10 nm thick, due to the van der Waals attraction. However, this He film on a flat wall is too thin to protect the UCN from their absorption inside a trap material. By combining the van der Waals attraction with capillary effects we show that surface roughness may increase the thickness of this film much beyond the neutron penetration depth, ≈33nm. It is demonstrated that triangular roughness is more efficient than rectangular for the reduction of the rate of loss of ultracold neutrons [2]. Triangular roughness is more easily implemented technically, as such diffraction gratings are fabricated industrially. Thus, not only the bottom but also a rough side wall of UCN trap holds the required amount of ^{4}He by the capillary effects. To increases the thickness of liquid He on the very edges of rough side walls and to cover the entire UCN trap surface by sufficiently thick helium films we also propose to apply an electric voltage to these rough side walls of UCN traps. This completely protects UCN from being absorbed inside the trap walls. We estimate the required electric field and voltage for several possible designs of UCN traps. This improvement may give rise to a new generation of ultracold neutron traps with very long storage time. Using liquid He for UCN storage requires low temperature, $T<0.5$ K, to avoid neutron interaction with He vapor, while the neutron losses due to the interaction with surface waves are small and can be accounted for using their linear temperature dependence [4].

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References

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