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Monte Carlo Simulation of the Extraction System for Very Cold Neutrons Using a Nanodiamond Reflector

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Intense fluxes of very cold neutrons (VCN) with the velocities between 20 and about 200 m/s are of great interest for a variety of applications both in fundamental research and neutron scattering. However, the absence of efficient VCN reflectors was one of the most significant problems for developing the intense VCN sources. The reflectors allow neutrons to be extracted from the source, focused and delivered to experimental facilities. The promising solution to the issue of VCN reflectors is Detonation Nanodiamonds (DND). In a series of works [1–4] it was experimentally shown that DND powders can be used as an effective diffuse reflector of VCN, providing even the possibility to store the VCN in a closed trap.

The latest experiment also demonstrates capability to extract and enhance a VCN flux using a DND reflector 5. The DND reflector has the shape of a thick-walled cylindrical tube closed at one end with a thick disk. The source is a VCN beam passing through a hole in the sidewall of the reflector and falling on its bottom. As a result of multiple reflections from the bottom and side walls of the cylindrical cavity formed by the reflector, VCN can escape through the open end of the cavity. Compared with a similar isotropic source without a DND reflector, the gain factor in the total VCN flux through the open end of the cavity is between ~14 and ~33 for neutrons with velocities of ~92 and ~45 m/s, respectively. The corresponding enhancement of a VCN flux extracted directionally using the DND reflector is about 10 times. It is itself a noticeable increase of the VCN flux delivered to experiments. Moreover, these results will make it possible to attract more attention to the development of the full-scale VCN sources and to expand the scope of VCN applications.

Nevertheless, the setup of the experiment discussed above does not allow us to obtain such basic characteristics of the DND reflector as the albedo (the diffuse reflection probability at all incidence angles of neutrons), losses of VCN, and others. It is only possible to calculate these characteristics via the full Monte Carlo simulation of the experiment. In this work, we present the results of the corresponding simulation. It includes the reproducing of the installation geometry, as well as the implementing the process of the VCN propagation inside a material of the DND reflector. Simultaneously, it is the first extensive test of the model of VCN interaction with DND powders for describing a complex experiment. The albedo, VCN extraction probability, and angular distribution of the extracted neutrons are the main simulation results obtained using Wolfram Mathematica. The application for Geant4 is being developed. Its features and first results compared to Mathematica will be discussed. The developed software and the model can be used for evaluating the performance and optimal parameters of the real sources and extraction systems of VCN. In turn, this will help to identify a list of scientific problems that could be solved using these VCN sources.

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