CONFINED PROPAGATION OF SLOW NEUTRONS USING NANOTUBES

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Abstract.

Neutron guides allow for the confined propagation of slow neutrons (cold, thermal, epithermal...) for various applications. We summarize previous researches regarding the neutron guides experimentally implemented thus far, with transverse sizes ranging from several centimeters (cm) [1], [2], [3] down to mm and microns (μm) [4], [5]. Various analysis of those neutron guides based on a classical geometrical-optics-like description of the neutrons (namely, in terms of rays and their multiple internal reflections by the internal walls of the guide) are physically correct, provided that the transverse size of the guide be adequately large. Based upon an analogy with the confined propagation of light along thin dielectric waveguides (optical fibres), in which the wave nature of the former plays a crucial role, the confined propagation of thermal neutrons along suitable waveguides of small cross section has been proposed [6], [7]. The transverse dimensions of the latter waveguides should be smaller, by some orders of magnitude, than those of the above neutron guides, so that the neutron would be described by quantum mechanical waves, at least in principle. The relevance of quantum effects in the experiments reported in [4], [5] has been stressed in [8] (where reference to further work on the subject has also been given).

In recent times, carbon nanotubes (CNT) [9], [10] have become physical systems of increasing importance. Leaving aside many other reasons which have generated interest on them, they could constitute one natural possibility for waveguides with transverse dimensions at scales below the μm down to nanometers. Motivated primarily by the latter observation, we shall investigate here the possible confined propagation of slow neutrons along CNT, behaving as waveguides having lengths ranging from tens to a few hundred μm. As a second motivation, we remind that the possibility of focusing, at the nm scale, other radiations (specifically, X-rays) has attracted interest recently [11].

We treat single wall and multiwall CNT (SWCNT and MWCNT, respectively) and both possible descriptions for the neutron: the classical one (with rays) and the quantum-mechanical one (with waves and propagation modes). We estimate various possible losses in the intensity of a beam of slow neutrons propagating confined along the CNT: nuclear absorption and diffuse scattering, bending losses, tunnelling effects across the walls of the CNT towards the surrounding medium... From those estimates,

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it appears that the confined propagation of slow neutron beams may be possible in MWCNT, while SWCNT would be an unfavourable possibility. Due to the smallness of the transverse cross section, the number of confined neutrons transmitted along the MWCNT would be rather small (as a very rough order-of-magnitude estimate, about one neutron per hour across the whole transverse cross section, for an incoming flux outside the MWCNT about 10^{14} $neutrons/cm^2 \times sec$). A proper description of that confined propagation would require Quantum Mechanics. Then, the MWCNT would support a rather reduced number of propagation modes for the slow neutrons. The possible interest of the confined propagation of slow neutrons at the nanoscale is discussed very briefly. We consider the possibility of the latter phenomenon in other possible NT different from CNT, very succinctly.

1. References

[1] J. Crist and T. Springer. Nukleonik, **4** (1962) 23.
[2] H. Maier-Leibnitz and T. Springer. J. Nuclear Energy, A/B **17** (1963) 217.
[3] Jacrot B., 1970. Proc. Symp. Instrumentation for Neutron Inelastic Scattering Research (Vienna 1969) IAEA, Vienna, Austria.
[4] M. A. Kumakhov and V. A. Sharov 1992. Nature, **357** (1992) 390.
[5] H. Chen, R. G. Downing, D. F. R. Mildner, W. M. Gibson, M. A. Kumakhov, I. Yu. Ponomarev, and M. V. Gubarev. Nature, **357** (1992) 391.
[6] R. F. Alvarez-Estrada and M. L. Calvo. J. Phys. D: Appl. Phys. **17** (1984) 475.
[7] M. L. Calvo and R. F. Alvarez-Estrada. J. Phys. D: Appl. Phys., **19** (1986) 957.
[8] B. Rohwedder. Phys. Rev. A, **65** (2002) 043619.
[9] P. M. Ajayan and T. W. Ebbesen. Rep. on Prog. in Phys. **60** (1997) 1025.
[10] H. Dai, J. Kong, C. Zhou, N. Franklin, T. Tombler, A. Cassell, S. Fan and M. Chapline. J. Phys. Chem., **B1999** 103, 11246.
[11] C. Bergemann, H. Keymeulen and J. F. van der Veen, Phys. Rev. Let., **91** (2003) 204801-1.