Group Delay Time in Neutron Optics and Neutron Wave Reflection Time

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Using the example of the reflection of a neutron pulse (wave packet) from two - and three-layer planar structures, it was previously shown that the formation of the reflected pulse occurs with a certain time delay relative to the incident pulse [1]. This is obviously due to the fact that some time is spent on the penetration of the wave into the medium and its exit back, which is the physical reason for the well-known Goos–Hänchen effect. In the first approximation, this delay is determined by the so-called group delay time (GDT) [2,3], equal to the energy derivative of the phase from the amplitude reflection coefficient.

The report considers a simpler case, namely the reflection of neutrons from a semi-infinite homogeneous medium. As is known, the amplitude of the mirror reflection and the distribution of the field (or wave function) in the medium are described by the exact Fresnel formulas. With their help, it is easy to obtain expressions for the amplitude of reflection, the structure of the field and the depth of penetration of radiation into the medium, but they do not give any answer about the thickness of the near-surface layer in which the reflected wave is formed.

The report discusses the relationship between GDT and the depth of the formation of a neutron wave mirrored from a semi-infinite homogeneous medium. Calculations show that in the region below the threshold of total external reflection (TER), this depth of formation is exactly equal to the depth of penetration of an exponentially decaying wave. However, in the region above the threshold TER, where the penetration depth of radiation increases significantly, both the GDT and the depth of reflected wave formation obtained on the basis of this value, on the contrary, decrease. For a weakly absorbing medium, the estimate of the depth of formation of the reflected wave obtained in this way leads to a non-physical result consisting in a subnanometer depth of this layer.

Attempts to determine the relationship between the depth of reflection formation and GDT in the region above the TER threshold lead to contradictions. In particular, this applies to the results obtained, on the one hand, on the basis of the first Born approximation, and on the other hand, on the basis of calculations of the reflection time of wave packets using the Green function.

In conclusion, the probable reasons for this discrepancy are briefly discussed, as well as possible experimental approaches to measuring the reflection time of a neutron wave.

References

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