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Radiation of a twisted neutron in the presence of a dispersion medium

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Free particles carrying orbital angular momentum (OAM) are called twisted particles. The wave function of such particles has a characteristic phase $e^{il\varphi}$, where l is the OAM projection onto the axis along the particle motion and φ is the azimuth angle of a point of a wave packet in the cylindrical system of coordinates. The twisted neutrons have been obtained relatively recently, in 2015 [1], by using a phasophobic plate. The methods for obtaining and detecting twisted neutrons are being actively developed [2,3]. The reason for this is the potential applications of such states. They are able to excite forbidden transitions in nuclei that can be employed in nuclear physics. Another promising application of such neutrons is the neutron diffraction. Due to the OAM the twisted neutrons have a higher resolution and sensitivity to magnetic properties of matter. The processes involving neutrons with nonzero OAM can be used to study the internal structure of the neutron itself.

The available papers on twisted neutron scattering [4,5] and radiation [6,7] show that the features arising in these processes cannot be reduced to quantum effects previously known for plane neutrons. For example, new corrections in radiation proportional to $\frac{(|l|+1)\sigma_\perp^2}{m^2}$, where $\sigma_\perp$ is transverse size of wave packet, are typical for the processes with twisted particles [6]. As were noted in [6,7], these and other corrections can be larger by an order of magnitude than the classical contribution.

We have studied the Cherenkov and transition radiations produced when a neutron twisted wave packet traverses a medium translationaryt invariant in the plane perpendicular to the incidence direction. We showed that the quantum effects associated with the neutron OAM and the cross section of the neutron wave packet have the same structure as found in [6]. We have derived the estimates for the number of emitted photons and the energy loss due to radiation. We discuss the possibility of observing the generated radiation and how to use it to determine the shape of the wave packet. The result obtained can be generalized to the case of N-particle wave packets using the results of [6,7].

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