Analysis Anomalous Doppler Effect from quantum theory to classical dynamic theory

Introduction:

The Anomalous Doppler Effect (ADE), in which the observed frequency shift behaves contrary to the conventional Doppler Effect under specific conditions, was first theoretically predicted by Soviet physicist Vitaly L. Ginzburg1. This phenomenon occurs when a moving system system’s velocity exceeds the phase velocity of light in the medium, it transfers its kinetic energy to its internal energy while emitting radiation. A notable example, discussed by Frank in his 1958 Nobel lecture2, demonstrates that radiation emission does not result from atomic transitions from a higher (excited) state to a lower state, as is typical, but rather occurs inversely—from a lower state to a higher state—where the energy is supplied by the system’s translational kinetic energy. This intriguing theoretical prediction has attracted significant attention and has motivated extensive research.

In 1967, Artsimovich3 observed discrepancies in tokamak experiments: measurements of electron temperature derived from diamagnetic signals stronger than derived from electrical conductivity measurement. This anomaly, unrecognized at the time, may represent the first experimental observation of ADE. It was not until 1968 that B. B. Kadomtsev4   identified the cause as ADE, wherein electrons’ parallel velocities scatter to circular velocities under resonant ADE conditions. This process amplifies the diamagnetic effect beyond contributions from thermal motion alone. After that, more and more experiment about ADE are observed in experiment such as the electron beam scattering in magnetic field vacuum tube5, and even in tokamak discharge many phenomena related to ADE are reported in previous\*\*\*.

The physics of the Anomalous Doppler Effect (ADE) was previously briefly explained based on the quantum analysis provided by Frank and Ginzburg\*\*, followed by a quasilinear analysis given by B. In this paper, building on Ginzburg’s quantum analysis and incorporating angular momentum conservation, we present a more detailed analysis of ADE, offering further insights into the relationship between ADE and wave polarization. Additionally, we demonstrate numerical simulations based on classical dynamical equations. The energy transfer ratio from kinetic energy to the internal system is derived from both quantum theory and numerical simulations, with results showing strong agreement. This work enhances our understanding of the complex wave-particle interaction phenomenon from a quantum perspective, providing a clearer physical interpretation.

Quantum analysis of ADE

In this work, we provide an analysis based on the conservation of angular momentum and combined with the quantum analysis given by V.L. Ginzburg[\*], I. Tamm[\*], Nezlin[\*], and I.M. Frank [\*].Here we analysis the radiation from the electron moving in medium. when a charged particle moves through a medium at a speed greater than the phase velocity of light in that medium, it induces polarization in the surrounding molecules. As these molecules return to their equilibrium state, they emit electromagnetic radiation. The constructive interference of these emissions produces the characteristic Cherenkov radiation, forming a cone-shaped wavefront as shown in fig.1. The direction of Cherenkov radiation is constrained to the Cherenkov radiation angle ,where c′ is the speed of light in the medium and v is the velocity of the charged particles.

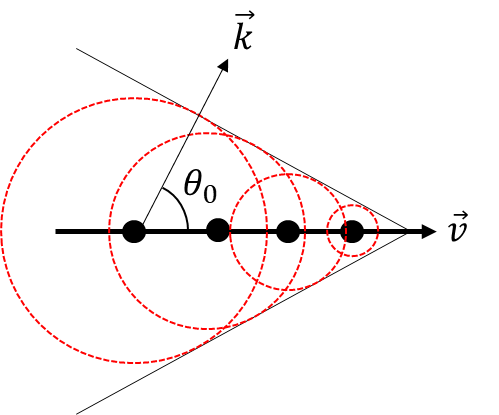


Figure . Schematic diagram of Cherenkov Radiation. The black points stand for the snapshot of the electron at different time, the read dash circle refers to the current radiation surface from the previous electron.

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