

Anti-Larmor precession, negative reflection and refraction, multi-reflection and multi-refraction in thin films with perpendicular magnetic anisotropy.

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We present a theoretical and numerical investigation of the role of perpendicular magnetic anisotropy (PMA) in shaping spin-wave (SW) dynamics under low magnetic fields in thin and ultrathin magnetic films. PMA introduces an in-plane torque that counteracts exchange, dipolar, and Zeeman contributions, fundamentally modifying SW dispersion and inducing a local minimum that, under specific conditions, becomes the lowest frequency across all geometric configurations. This results in a sombrero-shaped dispersion in ultrathin films and a cowboy-hat-like shape in thicker films, where dipolar interactions dominate. Using isofrequency contour (IFC) analysis, we demonstrate that these PMA-induced dispersion shapes enable nontrivial wave phenomena unprecedented in uniform media: bireflection and negative reflection in ultrathin films, and trireflection in thicker films—where a single incident beam splits into three reflected components, two with negative angles. Most remarkably, we predict and demonstrate tri-refraction, where one incident beam generates three refracted beams with two exhibiting negative refraction angles. We further show anti-Larmor precession of magnetization near the dispersion minimum in thicker films, arising from the interplay between PMA-induced and dipolar torques. Systematic simulations across diverse material systems—metallic films, ferrimagnetic garnets, hybrid structures, and multilayers—confirm the universal nature of these phenomena in any PMA system supporting stripe domain transitions. These results open new opportunities to explore wave phenomena beyond magnonics.

