The Magneto-Acoustic Interaction in Ferromagnetic Materials Induced by Einstein-De Haas Effect

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The interaction between magnetization and acoustic waves have received intensive attention because of their potential in prospective applications [1,2]. However, up to now, the magneto-acoustic interaction has only been studied on the basis of magnetostriction. Here, we theoretically study the generation of acoustic waves under the Einstein-de Haas effect. This effect refers to a phenomenon of mechanical rotation caused by the change of magnetization, in which the lost magnetic angular momentum is converted into mechanical angular momentum [3,4].

We develop a dynamic phase field model for magneto-acoustic interaction by combining the Einstein-de Haas effect and generalized elastodynamics equation with Landau-Lifshitz-Gilbert equation. Different from the traditional magnetoelastic coupling of magnetization and strain, the coupling between the body couple and the change rate of magnetization, i.e., Einstein-de Haas effect, is employed in the present model. We show by this model that the vortex under the action of local magnetic field gets flipped over at around 20 ps, which can realize great magnetization change rate in an ultra-short time. It creates a large mechanical angular momentum to induce a body couple at the vortex core and excites a high-frequency acoustic wave based on the Einstein-de Haas effect as shown in Figure 1. Furthermore, we find that the displacement amplitude of the acoustic wave is highly relevant to the gyromagnetic ratio. The smaller the gyromagnetic ratio is, the larger the displacement amplitude is. Moreover, the coupling of acoustic wave and spin wave is realized in ferromagnetic materials, which not only provides a new mechanism for dynamic magnetoelastic coupling but also sheds new insights into the magneto-acoustic interaction.

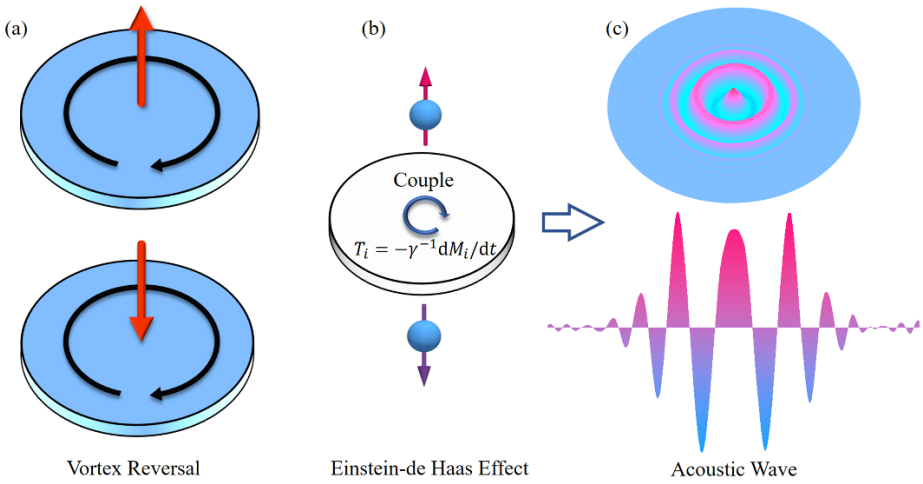

Figure 1: (a) Schematic illustration of the magnetization reversal at the vortex core in a ferromagnetic disk. (b) A body couple T_i generated at the vortex core by the magnetization reversal due to the Einstein-de Haas effect. (c) The rapid appearance of the body couple at the vortex core induces high-frequency acoustic waves in the ferromagnetic disk.

References

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