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Time-Domain Analysis of Antiferromagnetic Spin Dynamics and Electromagnetic Wave Interaction

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Antiferromagnets(AFM), recently attracting attention, have small angular momentum and can operate at high speeds because their magnetization is canceled out by paired magnetization vectors. This property makes them suitable for compact oscillators that operate at room temperature and pressure, which are expected to be used in next-generation communications[1-4]. However, experimental research into these materials, especially considering the effects of electromagnetic fields on AFM, is costly and time-consuming. Therefore, numerical simulations are essential for efficiently analyzing their properties.

In this study, we conduct multi-physics simulations to analyze the interaction between the magnetization precession of AFM and electromagnetic fields[5]. To investigate the electromagnetic wave behavior, we employ the finite-difference time-domain(FDTD) method, which discretizes Maxwell's equations in both time and space. Magnetization precession of AFM is described using two coupled Landau-Lifshitz-Gilbert-Slonczewski(LLGS) equations[1], which are solved using a 4th-order Runge-Kutta method for higher accuracy. The analysis space is set as a free space, and AFM is modeled as a thin NiO film on a platinum substrate. The magnetization precession of AFM is driven by injecting a spin-polarized current. The interaction between electromagnetic fields and AFM is modeled by incorporating the magnetic fields, which is calculated from Maxwell’s equations, into the effective fields used in the LLGS equation. Conversely, the magnetization vector obtained from the LLGS equation is used to compute the magnetic fields in Maxwell’s equations. This approach enables precise characterization of the coupling between spin dynamics and electromagnetic fields. By analyzing the effect of electromagnetic waves on AFM and the electromagnetic fields generated by magnetization precession of AFM, we validate the effectiveness of the proposed method through comparisons with the conventional method.

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