Localized Magnon States in Fe/nGd/Fe Atomic Sandwiches

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In this work, we study the magnon states localized in Fe/nGd/Fe atomic sandwiches. These systems consist of *n* atomic planes of Gadolinium inserted between two semi-infinite Iron materials, with Gd thicknesses of *n* = 3, 5, or 7 atomic layers. At such ultrathin scales, localized magnonic states are dominated by interfacial effects, and the strong contrast between the Fe–Fe, Gd–Gd, and Fe–Gd exchange interactions creates interfacial potentials that able to confine the spin-wave modes.

To determine the localized magnon states in these sandwich systems, we employ the Heisenberg Hamiltonian, taking into account the exchange integrals between the different atomic species as reported in the literature, namely Fe–Fe, Gd–Gd [1], and Fe–Gd. The resulting spin-wave equations are solved using the wave-function matching method [2-4], which ensures the continuity of both the magnon wave functions and their discrete derivatives at each Fe/Gd interface. This approach allows us to analytically connect the spin-precession equations of the atoms in Gd region to those in the two iron regions. Consequently, the natural frequencies and the corresponding mode profiles associated with the localized magnon states can be determined and identified.

Our analysis reveals the coexistence of three distinct types of magnon states: Interfacial modes at low frequencies, dominated by the Fe/Gd exchange coupling, Confined modes within the Gd spacer at higher frequencies, arising from the weak intralayer Gd exchange and Hybrid (or dispersive) modes, which exhibit a stronger sensitivity to the geometric configuration of the multilayer and typically appear near the band edges. The degree of localization is strongly frequency-dependent: low-frequency excitations predominantly yield interfacial states, whereas higher frequencies activate volumetric (Gd-confined) modes. As the Gd thickness increases, additional states emerge in the band diagram.

These findings demonstrate that the location, symmetry, and resonance frequency of the magnon states can be precisely engineered, and that is crucial for the development of advanced nanoscale spin-wave devices, magnonic filters, and magnon-based information-processing architectures.

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