Calculation of Intrinsic Damping in Half Metals

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**Motivation**
Understanding of damping in magnetic systems has been quite limited for many years and has therefore been treated mostly phenomenologically. Recent technological requirements such as those associated with increased magnetic recording speeds, the need for low noise read sensors and the possible advent of spintronic devices based on spin-torque phenomena make it imperative that we improve our understanding of magnetic damping for the relevant materials.

**Landau Lifshitz Gilbert equation:** describes the relaxation of the magnetization

\[
\frac{d\mathbf{M}}{dt} = -\gamma [\mathbf{M} \times \mathbf{H}_{\text{eff}}] + \frac{\lambda}{\gamma M_s^2} \frac{d\mathbf{M}}{dt} \quad \text{for } \mathbf{H}_{\text{eff}} \text{ effective field, } M_s \text{ saturation magnetization, } 
\gamma > 0 \text{ gyromagnetic ratio, } 
\lambda = \alpha \gamma M_s \text{ Landau Lifshitz damping rate, } 
\alpha \text{ dimensionless Gilbert damping parameter.}
\]

**Kamberský’s torque correlation model:**
Damping in terms of the spin orbit torque correlation function:

\[
\lambda = \frac{\mu_0 a^2 h^2 \pi^2 / 2}{\hbar \Omega_{at}} \left\langle \sum_{m,n} |\Gamma_{mk,nk}|^2 W_{mk,nk} \right\rangle_k
\]

\[n, m \text{ band indices, } k \text{ electron wavevector, } \langle \cdot \rangle_k \text{ average over first Brillouin zone,} \]

\[|\Gamma_{mk,nk}|^2 = |\langle m, k | [\sigma^- \mathcal{H}_{SOC}] | n, k \rangle|^2 \]

describes torque between spin & orbital moments during precession

Spectral overlap:

\[W_{mk,nk}(k) = \frac{1}{\pi} \int dE \left( -\frac{\partial f(E)}{\partial E} \right) \langle D(E_{mk}) \rangle \langle D(E_{nk}) \rangle \]

**Damping in half-metals:**
Half-metals Co$_2$MnSi and Co$_2$MnGe

**Averaged spectral density of states:**

\[
\langle D(E_{mk}) \rangle = \frac{1}{\pi (E - E_{mk})^2 + \delta_{mk}^2}
\]

\[f(E) \text{ Fermi function, } \tau_{mk} \text{ Bloch state lifetime, } 
\delta_{mk} = \frac{\hbar}{2\tau_{mk}} \text{ Bloch level width.} \]

**Damping calculations:**
- Band structures from first principle calculations including spin orbit coupling (VASP)
- Fitting procedure to obtain an extended Hückel tight binding model (EHTB) including spin orbit coupling: \( \mathcal{H} = \mathcal{H}_0 + \eta \tilde{L} \cdot \tilde{S} \)
- Use tight binding model with Kambersky’s torque correlation model to calculate damping
- Advantage: analytical expression for the matrix element \( |\Gamma_{mk,nk}|^2 \)

**Result:**
- extremely low damping rate due to missing spin down channel
- analysis of damping contributions within first Brillouin zone

**Intraband contributions**
**Interband contributions**

| Total          | Co$_2$MnGe: 3.2MHz | Co$_2$MnSi: 1.1MHz |