Magnetic circular dichroism and the orbital magnetization of ferromagnets

IVO SOUZA, University of California and LBNL, Berkeley, DAVID VANDERBILT, Rutgers University — The spontaneous magnetization of ferromagnets has both spin and orbital contributions, \( \mathbf{M} = \mathbf{M}_{\text{spin}} + \mathbf{M}_{\text{orb}} \), which can be separated out via gyromagnetic measurements. Recently\(^1\) it was found that, when expressed as a bulk property of the Bloch electrons, the orbital magnetization itself consists of two terms, \( \mathbf{M}_{\text{orb}} = \tilde{\mathbf{M}}_{\text{LC}} + \tilde{\mathbf{M}}_{\text{IC}} \), which can be loosely interpreted as the localized and itinerant contributions, respectively. Interestingly, \( \tilde{\mathbf{M}}_{\text{LC}} \) and \( \tilde{\mathbf{M}}_{\text{IC}} \) are separately gauge-invariant, which raises the possibility that they may be independently measurable. We show that indeed they are related to the magnetic circular dichroism (MCD) spectrum by a subtle sum rule. MCD, the difference in absorption between left- and right-circularly-polarized light, is given by \( \sigma^{(2)}(2,\alpha\beta)(\omega) \), the absorptive part of the antisymmetric conductivity. We derive the following sum rule for the interband contribution:

\[
\int_{0}^{\infty} \tilde{\sigma}^{(2)}(\omega) d\omega = \frac{2\pi e c}{\hbar}(\tilde{\mathbf{M}}_{\text{LC}} - \tilde{\mathbf{M}}_{\text{IC}}),
\]

where \( \tilde{\sigma}^{(2)}(\omega) \) is a pseudo-vector. Hence, by combining the results of gyromagnetic and magneto-optical experiments, \( \tilde{\mathbf{M}}_{\text{LC}} \) and \( \tilde{\mathbf{M}}_{\text{IC}} \) can in principle be measured independently.


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