# Ultrafast Entropy Production in THz-excited (Anti-)Ferromagnetic Systems

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**INTRODUCTION:** Advancing experimental techniques for THz laser excitations and subsequent time-resolved relaxation observations spark interest in a consistent thermodynamic description. As Caprini et al. have shown in their work on “Ultrafast entropy production in pump-probe experiments” [1], it is possible to derive the entropy production in laser-driven quantum materials based on quantum stochastic thermodynamic theories. We develop this paradigm on the example of magnons, i.e., spin excitations in magnetic materials, which opens new perspectives on ultrafast magnetization processes.

**METHODS:** The ultrafast processes of magnons, like demagnetization, are expected to produce entropy and contribute to the heating of the sample. According to the fluctuation-dissipation theorem (FDT) of thermodynamics, damped excitation of magnons leads to dissipation of energy into degrees of freedom, which are usually unspecified. Due to FDT, fluctuations (stochastic noise) also have to be present, and they depend on the same parameters as the dissipation. However, fluctuation dissipation is typically discussed close to equilibrium. With the help of path-integral formalism, the entropy production is calculated for ferromagnetic as well as anti-ferromagnetic systems far from equilibrium.

**RESULTS:** Magnons have a non-vanishing entropy production in laser-excited systems and therefore contribute to the heating of the sample. The exact contribution depends strongly on the considered dissipation channels and laser frequency.

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**REFERENCES:** [1] Caprini, L., Löwen, H., & Geilhufe, R. M. (2023). Ultrafast entropy production in pump-probe experiments. arXiv preprint arXiv:2302.02716.