



杭州电子科技大学
HANGZHOU DIANZI UNIVERSITY

Beamer Theme for Hangzhou Dianzi University Based on L^AT_EX3

SAN Chi Nan (C668668E0)

Supervised by Prof. YIP Tsz Ching

March 7, 2025 / Xiasha Campus





杭州电子科技大学
HANGZHOU DIANZI UNIVERSITY

Research Methods



Landau-Lifshitz-Gilbert Equation

Landau-Lifshitz-Gilbert (LLG) equation describes the microkinetics of magnetization in ferromagnetic materials. It combines the Landau-Lifshitz (LL) equation and the Gilbert damping term α , which is used to simulate and understand the micro-magnetic dynamics phenomena such as the motion of magnetic domain walls and magnetization reversal.

$$\frac{d\mathbf{m}}{dt} = -\gamma \mathbf{m} \times \mathbf{H}_{\text{eff}} - \alpha \mathbf{m} \times \frac{d\mathbf{m}}{dt} \quad (1.1)$$

To process the term $\alpha \mathbf{m} \times d\mathbf{m}/dt$, we left multiply the LLG equation by \mathbf{m} and use the identity $\mathbf{m} \cdot d\mathbf{m}/dt = 0$ to generate LL equation.

$$\frac{d\mathbf{m}}{dt} = -\frac{\gamma}{1 + \alpha^2} \mathbf{m} \times \mathbf{H} - \frac{\gamma\alpha}{1 + \alpha^2} \mathbf{m} \times \mathbf{m} \times \mathbf{H} \quad (1.2)$$

The LLG equation is more convenient for numerical calculation, while the LL equation can introduce the dissipation term more physically.

Applications

Magnetic Memory

Magnetic memory is a type of non-volatile memory that uses magnetic fields to store data. It is a type of computer memory that does not require power to maintain the information stored in the memory.

Magnetic Logic

Magnetic logic is a type of logic gate that uses magnetic fields to perform logical operations. It is a promising technology for future computing systems.

Magnetic Sensor

Magnetic sensors are devices that detect magnetic fields. They are used in a wide range of applications, including automotive, industrial, and consumer electronics.

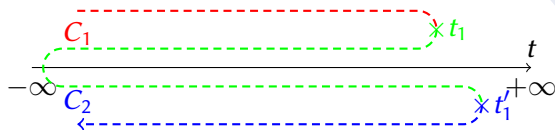
Lorem[1], Ipsum[2], dummy[3], text[4–12]

The NEGF Method

The Nonequilibrium Green Function (NEGF) method can be used to study the quantum transport properties of nanoscale devices, such as quantum dots, nanowires, and molecular junctions. The four important Green's functions in the NEGF method are

$$\begin{cases}
 G^r = -i\theta(t - t')\langle\{a_i(t), a_j^\dagger(t')\}\rangle & \text{Retarded Green's function} \\
 G^a = i\theta(t' - t)\langle\{a_i(t), a_j^\dagger(t')\}\rangle & \text{Ahead Green's function} \\
 G^< = i\langle\{a_j^\dagger(t'), a_i(t)\}\rangle & \text{Lesser Green's function} \\
 G^> = -i\langle\{a_j^\dagger(t'), a_i(t)\}\rangle & \text{Greater Green's function}
 \end{cases} \quad (1.3)$$

And sometimes we need multiply anchors on the contour of time.



Bibliography I

- [1] Fuming Xu et al. “Unified framework of the microscopic Landau-Lifshitz-Gilbert equation and its application to skyrmion dynamics”. In: *Physical Review B* 108.14 (2023), p. 144409.
- [2] Liming Wang et al. “Electrical switchable room-temperature magnetic skyrmions in multiferroic MXene”. In: *Physical Review B* 108.5 (2023), p. 054440.
- [3] Hartmut Haug, Antti-Pekka Jauho, et al. *Quantum kinetics in transport and optics of semiconductors*. Vol. 2. Springer, 2008.
- [4] Ze-quan Wang et al. “Switching intrinsic magnetic skyrmions with controllable magnetic anisotropy in van der Waals multiferroic heterostructures”. In: *Nano Letters* 24.14 (2024), pp. 4117–4123.
- [5] Kaushalya Jhuria et al. “Spin-orbit torque switching of a ferromagnet with picosecond electrical pulses”. In: *Nature Electronics* 3.11 (2020), pp. 680–686.

Bibliography II

- [6] Thomas L Gilbert. “A phenomenological theory of damping in ferromagnetic materials”. In: *IEEE transactions on magnetics* 40.6 (2004), pp. 3443–3449.
- [7] Jørn Fors et al. “Magnetization noise in magnetoelectronic nanostructures”. In: *Physical review letters* 95.1 (2005), p. 016601.
- [8] AL Chudnovskiy, J Swiebodzinski, and A Kamenev. “Spin-torque shot noise in magnetic tunnel junctions”. In: *Physical review letters* 101.6 (2008), p. 066601.
- [9] Jørn Fors et al. “Noise and dissipation in magnetoelectronic nanostructures”. In: *Physical Review B—Condensed Matter and Materials Physics* 79.21 (2009), p. 214407.
- [10] J Swiebodzinski et al. “Spin torque dynamics with noise in magnetic nanosystems”. In: *Physical Review B—Condensed Matter and Materials Physics* 82.14 (2010), p. 144404.

Bibliography III

- [11] Arne Brataas, Yaroslav Tserkovnyak, and Gerrit EW Bauer. “Scattering theory of Gilbert damping”. In: *Physical review letters* 101.3 (2008), p. 037207.
- [12] Arne Brataas, Yaroslav Tserkovnyak, and Gerrit EW Bauer. “Magnetization dissipation in ferromagnets from scattering theory”. In: *Physical Review B—Condensed Matter and Materials Physics* 84.5 (2011), p. 054416.

