

- Date & Time : **Monday 1st JUNE 2026 14:00-15:30**
- Venue : Common Room, Information Science Bldg. 4F



Prof. Thierry Valet

Visiting Professor,
AIMR & CSIS, Tohoku University
Founder and CEO, MPhysX OÜ

“Gauge Invariant Quantum Kinetic Theory of Multiband Electron Systems Applications to Spintronics and Orbitronics”

In recent works [1, 2], we extended **gauge invariant quantum kinetic theory** [3] to fully capture quantum-geometric effects in N-band electron systems. After a concise overview of our formalism, I will demonstrate its practical power through selected applications in **spintronics** and **orbitronics**. First, I will present calculations showing how **quantum geometry and disorder jointly determine spin-orbit torques** in two dimensional systems, exposing the limitation of commonly used approaches [4]. I will then turn to orbitronics [5], offering a new perspective on the orbital Hall effect and uncovering **a new gradient effect which induces out of equilibrium spin and orbital coherences** [6]. The latter points to a common, possibly dominant, contributing origin for recent observations of orbital edge accumulation [7] and current induced torques in multilayers with light metals [8]. I will conclude by outlining how our approach provides the theoretical foundation for next generation numerical simulation tools that can bridge microscopic material modeling and mesoscopic device modeling.

[1] T. Valet and R. Raimondi, Semiclassical kinetic theory for systems with non-trivial quantum geometry and the expectation value of physical quantities, *EPL*, **143**, 26004 (2023)

[2] T. Valet and R. Raimondi, Quantum kinetic theory of the linear response for weakly disordered multiband systems, *Phys. Rev. B*, **111**, L041118 (2025)

[3] S. Onoda, N. Sugimoto and N. Nagaosa, Gauge Covariant Formulation of the Wigner Representation through Deformation Quantization: Application to Keldysh Formalism with an Electromagnetic Field, *Prog. Theor. Phys.*, **117** (3), 415 (2007)

[4] D. G. Ovalle, A. Pezo and A. Manchon, Spin-orbit torque for field-free switching in C3v crystals, *Phys. Rev. B*, **107**, 094422 (2023)

[5] D. Go, D. Jo, H.-W. Lee, M. Klaui and Y. Mokrousov, Orbitronics: Orbital currents in solids, *EPL*, **135**, 37001 (2021)

[6] T. Valet, H. Jaffrès, V. Cros and R. Raimondi, Quantum Kinetic Anatomy of Electron Angular Momenta Edge Accumulation, *Phys. Rev. Lett.*, **135**, 256301 (2025)

[7] I. Lyalin, S. Alikhah, M. Berritta, P. M. Oppeneer, and R. K. Kawakami, Magneto-Optical Detection of the Orbital Hall Effect in Chromium, *Phys. Rev. Lett.*, **131**, 156702 (2023)

[8] R. Gupta et al., Harnessing orbital Hall effect in spin-orbit torque MRAM, *Nature Comm.* **16**, **130** (2025)