Condensed Matter Physics Laboratory（2021）
Chief Scientist: Gen Tatara (D.Sci.)

(0) Research field

Physics

Keywords: Spintronics, Condensed matter theory, spin transport, magnetism

(1) Long-term goal of laboratory and research background

Our objective is to explore novel spin-related effects with extremely high efficiency in condensed matters based on microscopic field theories. Our studies are expected to contribute to development of spintronics, a technology using spin as well as charge of electrons, and to realization of ultrafast and high-density information technology with low energy consumption. Our particular present interest is in a strong quantum relativistic effect in solids, which is applicable to very strong magnets and efficient conversion between spin and electric information.

(2) Current research activities (FY2021) and plan (until Mar. 2025)

Hydrodynamic theory of electron and spin transport in disordered metal

Electron and spin transports in metals were theoretically studied from a hydrodynamic viewpoint by calculating momentum flux density as a linear response to an applied electric field. Dissipative (ohmic) fluid regime was considered. Various transport effects were found and new physical pictures were presented.

• A bulk angular momentum generation by an electric field in chiral (Weyl) system was predicted by calculation of momentum flux density

• Spin motive force (voltage generation) by magnetization-vorticity coupling in anomalous Hall system was derived. Non-conservative force was found besides conventional conservative force.

• Hydrodynamic theory of anomalous Hall and spin-polarized electron system was discussed to be elegantly described by introducing a toroidal moment $\boldsymbol{M}\times\boldsymbol{E}$ or $\boldsymbol{s}\times\boldsymbol{E}$, where $\boldsymbol{E}$ is the applied electric field, $\boldsymbol{M}$ and $\boldsymbol{s}$ are magnetization and electron spin, respectively.

• The spin Hall effect is argued from the viewpoint of a spin-vorticity coupling. The theory is free from the fundamental problem of ambiguity of spin current definition, which is unavoidable in the conventional spin current scenario. Spin-electric current response is studied in the finite q-regime, and broad response in the q space was found.

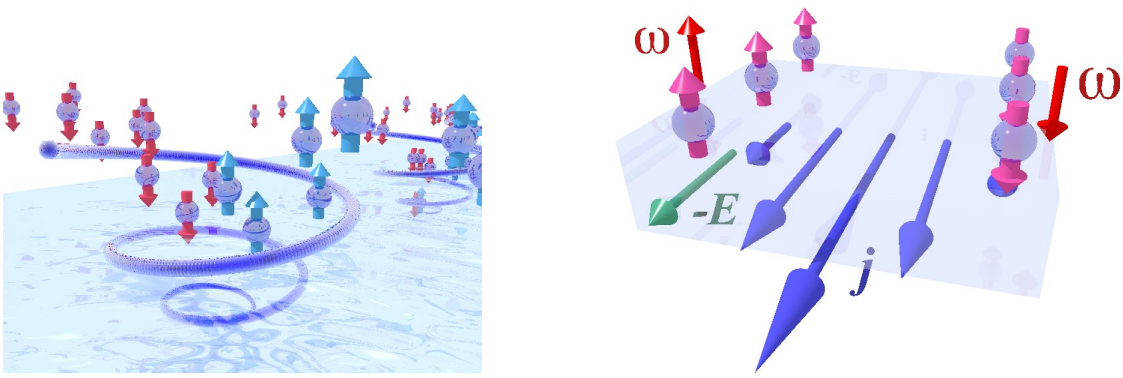

Figure caption: Left: Vorticity of electron generates spin and spin current as a result of spin-vorticity coupling. Right: When an electric current is applied to metals, vorticity emerges near the edges, generating the edge spin density as a result of spin-vorticity coupling. This is an alternative interpretation of spin Hall effect.

Future plan, 1) We will extend the present analysis to include photons (light), magnons, etc.

(3) Members

(Chief Scientist)
Gen Tatara

(Postdoctral Researcher)
Hiroshi Funaki

(Assistant)
Kazue Akiyama

(4) Representative research achievements up to 5 FY2021

1. H. Funaki & G. Tatara, " Hydrodynamic theory of chiral angular momentum generation in metals", Phys. Rev. Res., 3, 023160 (2021).
2. H. Funaki, R. Toshio, & G. Tatara, "Vorticity-induced anomalous Hall effect in an electron fluid", Phys. Rev. Res., 3, 033075 (2021).
3. G. Tatara, " Hydrodynamic theory of vorticity-induced spin transport", Phys. Rev. B, 104, 184414 (2021).
4. Tatara, G., "Spin Hall Response at Finite Wave Vector in Ferromagnets", J. Phys. Soc. Japan, 91, 034705(2022).
5. Tatara, G., Nonlocality of Electrically-Induced Spin Accumulation in Chiral Metals, Phys. Soc. Japan, **91**, 073701(4) (2022).

Laboratory Homepage
https://www.riken.jp/research/labs/chief/condens_matter_phys/index.html
http://spinphys.riken.jp/sptrt/index.html