量子物理学・ナノサイエンス第 394 回セミナー

Ultrafast switching of order parameters at the frequency of optical phonons

講師　：　Dr. Carl S. Davies

HFML-FELIX, Radboud University, the Netherlands

日程　：　7 月 22 日（月）14:00－

場所　：　南 5 号館 5 階 503CD 大会議室

概　要

All-optical switching of magnetization represents a fascinating area of condensed matter physics with significant technological potential [1]. Here, we explore how magnetization can be manipulated by narrowband infrared optical pulses tailored to match the eigenfrequencies of optical phonon modes. We find that an ultrafast excitation with frequency matching that of the longitudinal optical phonon modes in magnetic iron-garnet films switches magnetization in to a peculiar quadrupolar domain pattern [2]. We similarly find that this type of excitation is capable of switching magnetization in antiferromagnetic iron borate [3], with the domain pattern comprising a distribution of circulating magnetization at the center with tapered domains extending outwards along a certain axis. This pattern is very distinct to that found in iron garnets, but a similar qualitative description can account for this domain pattern that forms at the frequency where the crystal's permittivity goes close to zero [4]-[5]. Alternatively, we show that it is also possible to switch the magnetization of a heterostructure by driving at resonance circularly-polarized transverse optical phonons in the underlying paramagnetic substrate. We explain this helicity-dependent behavior in terms of the ultrafast Barnett effect, whereby the angular momentum of the optical phonons creates a transient magnetization that drives the reversal [6]. Our results suggest that lattice vibrations may represent a universally applicable lever for exercising ultrafast control over different order parameters found in magnetic and ferroelectric systems.

[1] C.S. Davies *et al*, J. Magn. Magn. Mater. **563**, 169851 (2022).
[2] A. Stupakiewicz *et al*, Nat. Physics **17**, 489 (2021).
[3] T. Janssen *et al*, Phys. Rev. B **108**, L140405 (2023).
[4] M. Kwaaitaal *et al*, Nat. Photonics **18**, 569 (2024).
[5] C. S. Davies & A. Kirilyuk, npj Spintronics **2**, 20 2024
[6] C. S. Davies *et al*, Nature **628**, 540 (2024).

連絡教員　　山田　貴大（内線 2454）