

Summaries of Papers for FELIX Internship 2026

Stan Daniels

Radboud University Nijmegen

FELIX Laboratory

(Dated: December 1, 2025)

I. KIRILYUK 2010 ULTRAFAST OPTICAL MANIPULATION OF MAGNETIC ORDER

[1]

II. GIDDING 2023 DYNAMIC SELF-ORGANISATION AND PATTERN FORMATION BY MAGNON-POLARONS

In this article [2], it is shown that some peculiar patterns arise when a sample is hit by a pump pulse to change its magnetic order.

Realy precise switching of magnetic order(spins) is important for low energy cost data storage. The abstract states that it is a known fact that when a sample is hit by a ultra short pump pulse the resulting magenitization is chaotic. This would be due to internal instabilities in the sample. However it turns out that the bahavior of the magnetic reagion is not necceraly chaotic at all, some patterns will arise in these cases. It is also well understood that a spatially-localised perturbation creates propagating waves with wave vectors determined by the profile of the excitation.

I now wonder what could be the cause of these peculier paterns and how they might be used in the future. I also still don't know what magnon-polarons are.

III. KWAAITAAL 2024 EPSILON-NEAR-ZERO REGIME ENABLES PERMANENT ULTRAFAST ALL-OPTICAL REVERSAL OF FERROELECTRIC POLARIZATION

In this article [3], it is shown that ultrafast excitation under epsilon-near-zero (ENZ) conditions can permanently reverse ferroelectric polarization between stable states.

ENZ materials have a dielectric constant $\epsilon \approx 0$ whch enhances light-matter interactions. This article shows that in ENZ conditions it is possible to achieve permanent all optical switching of an order parameter. This means that only light is used to achieve a switching of an order parameter, the order parameter in this article is the ferroelectric polarization. After switching from one order to the other the polarization remains stable and thus permanent.

IV. DAVIES 2024 PHONONIC SWITCHING OF MAGNETIZATION BY THE ULTRAFAST BARNETT EFFECT

In this article [4], it is shown that spontanious magnetization can be achieved using the ultrafast Barnett effect.

This is done through the resonant excitation of circularly polarized optical phonons in a paramagnetic substrate. The Barnett effect describes how an inertial body with zero net magnetic momentum can aquire magnetization when mechanically spinning. When the substrate is circularly polarized it generates a magnetic field that can permanently and selectively change the magnetization of the upper layer. This effect only happens when the laser frequnicy is in resonance with the phononmodiof the substrate.

V. STUPAKIEWICZ 2021 ULTRAFAST PHONONIC SWITCHING OF MAGNETIZATION

In this article [5], it is shown that certain patterns arise when we magnetize a sample using a laser.

The patterns rotates as the polarization direction of the laser rotates. The collective excitation modes (like magnons and phonons) define the energy range that determines all the important and intriguing thermodynamic and macroscopic properties of solids, such as electric, magnetic or crystallographic order, and the superconducting transition temperature. Control of the crystal structure of materials is the core aim of the field of straintonics. For the experiment they used an accumulation of pump pulses to not damage the sample but still get results. The multi pulse approach seems to only have the effect of a slight growth of the domains. The best magnetic switching occurs at wavelengths of $\lambda = 14\mu m$ which also shows a big phonon response. It seems tha the LO phonon are more responsible for the magnetic switching than the TO phonons, but i don't know what they mean, further investigation required.

In the future, ultrafast modification of the crystal field environment, and thus of magnetocrystalline anisotropy, may become the most universal way to manipulate magnetization. Magneto-elastic interactions are present in all materials and thus can be used everywhere, for example in antiferromagnets.

VI. BEAUREPAIRE 1996 ULTRAFAST SPIN DYNAMICS IN FERROMAGNETIC NICKEL

In this article [6], the relaxation processes of electrons and spins systems following the absorption of femtosecond optical pulses in ferromagnetic nickel have been studied. They have used pump probe techniques and have shown that the magnetization drops rapidly after just a few pico-seconds.

They talk about the kerr effect, I should investigate what it is exactly. The magneto optical kerr effect is known as MOKE. The aim of this paper is to study both electronic and spin dynamics after excitation of a Ni film with 60 fs pulses. The delays between pump and probe are achieved using a modified Michelson interferometer (should learn what this is). The signals are recorded using a boxcar and a lock-in synchronous detection. The information about the spin dynamics is contained in the time evolution of the hysteresis loops recorded for each time delay δt . hysteresis loop basically means that the output depends on the history of the input.

This work basically showed that using optical and magneto-optical techniques can be used to measure extremely fast events. The experiment showed that for the first few picoseconds the dynamics of spin and electron temperatures are different.

VII. KIMEL 2005 NON-THERMAL OPTICAL CONTROL OF MAGNETIZATION IN FERROMAGNETIC SEMICONDUCTORS

[7]

VIII. BIGOT 2009 COHERENT ULTRAFAST MAGNETISM INDUCED BY FEMTOSECOND LASER PULSES

[8]

IX. FORST 2011 NONLINEAR PHONONICS AS AN ULTRAFAST ROUTE TO LATTICE CONTROL

[9]

X. NOVA 2017 AN EFFECTIVE MAGNETIC FIELD FROM OPTICALLY DRIVEN LATTICE VIBRATIONS

[10]

XI. MAGNETISM: FROM FUNDAMENTALS TO NANOSCALE DYNAMICS

[11]

XII. INTRODUCTION TO SOLID STATE PHYSICS

[12]

XIII. NONLINEAR OPTICS

[13]

XIV. MAGNETIC DOMAINS: THE ANALYSIS OF MAGNETIC MICROSTRUCTURES

[14]

XV. QUANTUM OPTICS

[15]

XVI. KIMEL 2019 NONTHERMAL OPTICAL CONTROL OF MAGNETISM AND ULTRAFAST SPINTRONICS

[16]

XVII. MISHRA 2021 PLASMON-ENHANCED ULTRAFAST DEMAGNETIZATION IN MAGNETOPHOTONIC NANOSTRUCTURES

[17]

XVIII. SAVOINI 2018 TRACING THE ULTRAFAST MAGNETIC RESPONSE WITH RESONANT X-RAY DIFFRACTION

[18]

XIX. SCHUBERT 2017 SUB-CYCLE CONTROL OF TERAHERTZ HIGH-HARMONIC GENERATION BY DYNAMICAL BLOCH OSCILLATIONS

[19]

XX. KALASHNIKOVA 2018 ULTRAFAST LATTICE CONTROL OF MAGNETIC ANISOTROPY IN ORTHOFERRITES

[20]

XXI. HENIGHAN 2016 GENERATION MECHANISM OF THZ-FREQUENCY COHERENT ACOUSTIC PHONONS IN FE BY ULTRAFAST OPTICAL EXCITATION

[21]

XXII. MISHRA 2020 ULTRAFAST DEMAGNETIZATION AND SPIN TRANSPORT IN CO/PT MULTILAYERS

[22]

XXIII. CIUCIULKAITE 2021 COHERENT CONTROL OF OPTICAL PHONONS IN IRON GARNET FILMS

[23]

XXIV. MISHRA 2019 DYNAMIC REGIMES OF MULTI-SHOT ALL-OPTICAL SWITCHING IN FERRIMAGNETIC ALLOYS

[24]

XXV. SAVOINI 2020 SPIN-LATTICE RELAXATION AT ULTRAFAST TIMESCALES INVESTIGATED VIA RESONANT X-RAY SCATTERING

[25]

XXVI. MICROMAGNETIC STUDIES OF LASER-INDUCED MAGNETIZATION DYNAMICS IN FEPT-C FILMS

In this article [26], they have simulated laser-induced magnetization dynamics using a hybrid Monte Carlo micromagnetic method. The results show that the magnetization dynamics includes an ultrafast demagnetization, a slower magnetization recovery, and a long-timescale magnetization reversal or the continuing recovery, depending on the magnitude of laser fluence and the external magnetic field.

They have only studied linearly polarized light, but the experimental and simulated results closely match. This shows that hybrid Monte carlo micromagnetic simulations are a good way to go about simulating these kinds of effects. They have used time-resolved magneto-optical Kerr effect (TR-MOKE) to derive the spin temperature profile directly. In the TR-MOKE measurement, a pump pulse excites the sample, and then the reflected probe beam is split into two orthogonal polarized components, denoted by signal A and signal B. The difference between their intensities, IA -IB, is due to the rotation of plane of polarization, which is induced by the magneto-optical Kerr effect.

XXVII. MICROMAGNETIC MODELING OF ALL OPTICAL SWITCHING OF FERROMAGNETIC THIN FILMS: THE ROLE OF INVERSE FARADAY EFFECT AND MAGNETIC CIRCULAR DICHROISM

[27]

XXVIII. ALL-OPTICAL SPIN SWITCHING PROBABILITY IN [TB/CO] MULTILAYERS

[28]

XXIX. MICROMAGNETICS AT FINITE TEMPERATURE

This article [29], shows the development of hybrid Monte carlo (HMC) micromagnetic simulations. The HMC micromagnetics is a self-consistent method for the magnetic studies at finite temperature.

-
- [1] A. Kirilyuk, A. V. Kimel, and T. Rasing, Physics Reports **488**, 117 (2010).
 - [2] M. Gidding, T. Janssen, C. S. Davies, *et al.*, Nature Communications **14**, 2208 (2023).

- [3] M. Kwaaitaal, D. G. Lourens, C. S. Davies, *et al.*, Nature Photonics **18**, 569 (2024).
- [4] C. S. Davies, F. Fennema, A. Tsukamoto, *et al.*, Nature **628**, 540 (2024).

- [5] A. Stupakiewicz, C. S. Davies, K. Szerenos, *et al.*, Nature Physics **17**, 489 (2021).
- [6] E. Beaurepaire, J.-C. Merle, A. Daunois, *et al.*, Physical Review Letters **76**, 4250 (1996).
- [7] A. V. Kimel, A. Kirilyuk, P. A. Usachev, *et al.*, Nature **435**, 655 (2005).
- [8] J.-Y. Bigot, M. Vomir, and E. Beaurepaire, Nature Physics **5**, 515 (2009).
- [9] M. Först, C. Manzoni, S. Kaiser, *et al.*, Nature Physics **7**, 854 (2011).
- [10] T. F. Nova, A. S. Disa, M. Fechner, *et al.*, Science **364**, 1075 (2017).
- [11] J. Stöhr and H. C. Siegmann, *Magnetism: From Fundamentals to Nanoscale Dynamics* (Springer, 2006).
- [12] C. Kittel, *Introduction to Solid State Physics*, 8th ed. (Wiley, 2005).
- [13] R. W. Boyd, *Nonlinear Optics*, 3rd ed. (Academic Press, 2008).
- [14] A. Hubert and R. Schäfer, *Magnetic Domains: The Analysis of Magnetic Microstructures* (Springer, 1998).
- [15] M. O. Scully and M. S. Zubairy, *Quantum Optics* (Cambridge University Press, 1997).
- [16] A. V. Kimel, A. Kirilyuk, and T. Rasing, Laser Photonics Reviews **13**, 1900120 (2019).
- [17] K. Mishra, A. Ciuciulaite, R. M. Rowan-Robinson, *et al.*, ACS Photonics **8**, 2043 (2021).
- [18] M. Savoini, I. Radu, D. C. Nutting, *et al.*, Physical Review B **98**, 014409 (2018).
- [19] O. Schubert, M. Hohenleutner, F. Langer, *et al.*, Nature Photonics **12**, 604 (2017).
- [20] A. M. Kalashnikova, M. Kozina, A. V. Kimel, *et al.*, Physical Review B **97**, 184403 (2018).
- [21] T. Henighan, M. Trigo, O. Shpyrko, *et al.*, Physical Review B **93**, 220301 (2016).
- [22] K. Mishra, C. S. Davies, B. Koene, *et al.*, Physical Review B **102**, 174415 (2020).
- [23] A. Ciuciulaite, A. Frej, C. S. Davies, *et al.*, Physical Review B **104**, 104437 (2021).
- [24] K. Mishra, A. V. Kimel, A. Kirilyuk, *et al.*, Applied Physics Letters **115**, 232404 (2019).
- [25] M. Savoini, I. Radu, A. V. Kimel, *et al.*, Structural Dynamics **7**, 064301 (2020).
- [26] J. Miao, J. Wang, R. Mandal, *et al.*, IEEE Transactions on Magnetics **54**, 1 (2018).
- [27] V. Raposo, R. Guedas, F. García-Sánchez, *et al.*, Applied Sciences **10**, 1307 (2020).
- [28] L. Avilés-Félix, L. Farcis, Z. Jin, *et al.*, Scientific Reports **11**, 6576 (2021).
- [29] D. Wei, J. Song, and C. Liu, IEEE Transactions on Magnetics **52**, 1 (2016).