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Strain modulation of altermagnets

A. Scientific context of the project (max. 2,5 pages)

Context

Altermagnetism represents a newly-discovered magnetic order which lays halfway between antiferromagnetism and ferromagnetism, combining antiparallel spin configuration and zero net magnetisation as the former, and the presence of magnetic signatures (such as the anomalous Hall effect) of the latter. This combination of properties makes altermagnets promising for spintronics application by combining the advantages of both orders. Altermagnetism existence was experimentally observed in MnTe[1], CrSb[2], and FeS[3].

Since the origin of altermagnetism lies in lattice symmetry[4], it is expected that altermagnets will be strongly influenced by its alterations, as it was observed in CrSb[5]. Therefore, symmetry alteration by an external parameter, is expected to affect the altermagnetic properties. Among external parameters, **strain is a powerful tool, able to modify the electronic band structure** (energy gap, band splitting) **or the magnetic anisotropy**, with **direct impact on the magnetic properties and the spin configuration**. Recently, a strain-induced transition between antiferromagnet to altermagnet was theoretically predicted in ReO_2[6], and indirectly observed in FeS[7]. This makes strain an ideal "knob" to control future altermagnetic devices.

However, to exploit strain engineering, it is necessary to understand its effects on the electronic and magnetic properties of altermagnets. In this project the PhD student will perform strain-dependent x-ray diffraction (XRD) and Raman spectroscopy to calibrate the applied strain, static magneto-optics Kerr effect (MOKE) measurements to probe the Néel vector [8], and ultrafast pump-probe spectroscopy to track phonon and magnetic dynamics under controlled deformation[9].
This approach allows to measure the dynamics of magnetic properties, which is essential to **assess the potential of these materials in high-speed, field-free spintronics architectures**.

Scientific approach

Axis 1: Material design and strain modulation

The first axis consists in the growth of altermagnetic samples by chemical vapour transport (CVT) [10]. CVT allows the growth of large bulk single crystal samples which are well-suited for macroscopic strain modulation, and optical measurement. The CVT technique is well mastered by the DEMARE team at IMPMC [10]. The work will start with the student growing prototypical altermagnets MnTe, CrSb, and FeS and they will study the effect of strain on the magnetic and structural properties. To apply and modulate the strain they will use a piezo-electric actuator, as already used in other materials[11]. Raman and XRD measurements will be performed at the INSP and IMPMC platforms and will allow for an effective strain calibration. Magnetic measurements (SQUID, MOKE) will be performed at INSP. Epitaxial altermagnet MnTe will also be available from existing collaborators at City College New York. **In this axis the student will grow altermagnetic samples and will identify how strain can control their static properties.**

Axis 2: Dynamical properties

The second axis will focus on understanding the dynamical response of altermagnets.
Ultrafast pump-probe spectroscopy consist in using two subsequent femtosecond laser pulses to excite the electronic system and drive the magnetic order (the pump) and study the subsequent dynamics with a second, weaker pulse (the probe). The magnetic dynamics identifies the signatures of magnetic order, and provides its recovery timescale. Currently there is limited understanding on the dynamical behaviour of altermagnets.

In addition, ultrafast lasers can launch coherent excitations such as acoustic and optical phonons, or spin excitations, as already observed in MnTe[9]. Coherent vibrational excitations provide information on the strength of electron-phonon interaction, lattice distortion and strain propagation, all key parameters to control altermagnetism through structural parameters and strain. Coherent magnetic excitations can measure quantities such as the magnetic anisotropy and spin-lattice relaxation times, which have historically been used to characterise magnetic materials for applications such as spintronics. **In this axis the student will develop the skills and will perform the measurements of the electronic and magnetic dynamics of unstrained altermagnetic samples**

This part of the project will benefit from the ultrafast experiments developed at the PHOCOS group (INSP), including time-resolved Kerr rotation, differential absorption and circular dichroism (allowing for femtosecond or picosecond resolution, variable temperature and magnetic field).

Axis 3: Dynamics under strain

The final axis aims to combine the two previous approaches by performing dynamical measurements on strained altermagnets. By exploiting the thorough characterisation of axis 1 and the response baseline obtained in axis 2, as well as the skills and knowledge acquired in both axes, the student will attempt to measure the dynamical response of strained samples. In particular, any changes in coherent vibrational excitations will act as an in-situ measurement of strain. By measuring the timescale of magnetisation recovery as well as frequency and damping of magnetic excitations with varying strain (while correlating them with the measurements of axis 1) **the effect of strain on magnetic properties will be ascertained**. This will pave the way for strain control of altermagnetism

Risks and mitigation

Samples: MnTe are already available via a well-established collaboration (IRP CNRS-CCNY) and the DEMARE team has all the equipment to grow MnTe, CrSb, FeS crystals as well as large experience in CVT growth [8] The set-ups are available via IMPMC and INSP platforms (XRD, Raman spectroscopy, SQUID, ultrafast spectroscopy).
For strain control there are several options (piezoelectric, mechanic, uniaxial, 3-point bending stage) which have already been applied to some altermagnets[7] and implemented in time-resolved spectroscopy measurements[12].
The third axis proposes a complex experiment. In the lab, there is already a cryostat, which can host a magnetic field, that has large space and multi-axis control system to align complicated and bulky sample holders, and allow for variable temperature (4-300K).

Adequacy to the IMAT call

The projects fits very well into the axis “Fundamental challenges in materials science” of the IMAT, by combining material synthesis, strain engineering, and advanced time-resolved characterisation techniques to achieve functional control of magnetic properties in emerging materials. The focus on strain engineering with the aim to establish the link between structural and magnetic properties is very adapted to the objectives of IMAT.

Bibliography

[1]J.Krempaský, *et. al*, Nature, **626**, 517-522 (2024) [2]G. Yang, *et. al*, Nat. Comm., **16**, 1442 (2025) [3] R. Takagi, *et. al*, Nat. Mater., **24**, 63-68 (2024) [4]L. Šmejkal, *et. al*, Phys. Rev. X, **12**, 031042 (2022) [5]Z. Zhou, *et. al*, Nature, **638**, 645-650 (2025) [6]A. Chakraborty, *et. al*, Phys. Rev. B, **109**, 14421 (2024) [7]W. Yao, *et. al*, ArXiv:2602.14790 (2026) [8]L. Han, *et. al*, Sci. Adv., **10**, 0479 (2024) [9]I. Gray, *et. al*, Appl. Phys. Lett., **125**, 21404 (2024) [10]H. Yang, *et. al*, Phys. Rev. B, **111**, 24115 (2025) [11]H.M.G.A. Tholen, *et. al*, Phys. Rev. B, **94**, 245301 (2016) [12]V. Sih, *et. al*, Phys. Rev. B, **73**, 241316 (2006)

Skills and coherence of the team:

The supervisor team is composed by: Maurizio Monti (INSP) and Yannick Klein (IMPMC).
Maurizio Monti, Maître de conférences in the PHOCOS team at INSP. He has extensive expertise in femtosecond laser spectroscopy, including complex technique development, and in the study of the dynamics of complex materials, such as manganites and magnetic materials. Supervision: 50%
Yannick Klein, Maître de conférences (HDR) in the DEMARE team at IMPMC. He has extensive experience on the growth and characterisation of correlated, magnetic, and functional materials. Supervision: 50%
The project requires simultaneous control of material properties and ultrafast dynamics, neither can succeed independently.

Research plan with provisional calendar (max. 0,5 page)

Year	Months	Activities	Milestones
Year 1	0-6	Growth training. Sample growth and characterisation	One dataset on an unstrained altermagnetic sample
		Basic time-resolved spectroscopy training on reference samples	
		Attendance to a school on topological materials or magnetism	
	7-12	Development of a sample holder for applying strain	
		Perform time-resolved spectroscopy on one unstrained sample (with and without magnetic field and temperature dependence)	
Year 2	13-18	Analysis and interpretation of dynamical data, identification of coherent excitations	Comprehensive dataset of the strain dependence of the static properties
		Sample characterisation under strain for calibration	
	19-24	Static MOKE on strained samples	
		Perform non-magnetic time-resolved spectroscopy on strained sample	
Year 3	25-30	Explore the effect of strain on the room-temperature magnetic dynamics	Time-resolved dataset on a strained sample
		Data analysis and interpretation of the strain-induced effects on the dynamics	
	31-36	Finalization and thesis writing	