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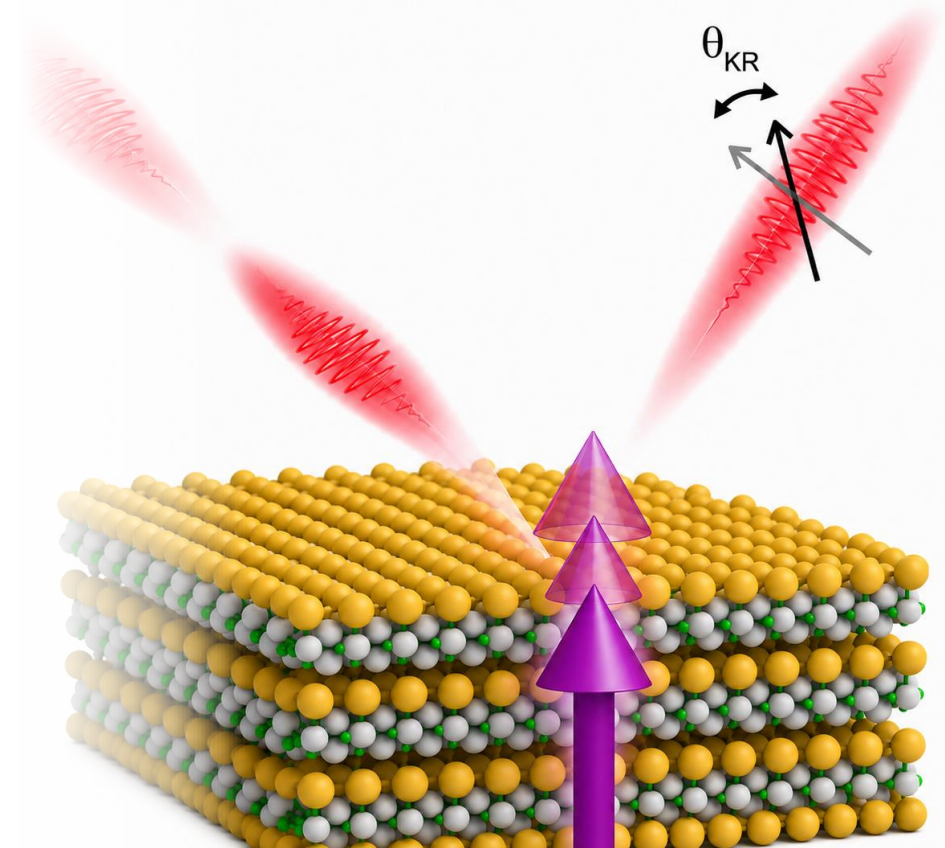
www.rug.nl/optospintronics

Controlling magnetisation of van der Waals magnets through optics, electronics and substrate engineering

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University of Cambridge, UK

University of Groningen, NL



OptoSpintronics of Quantum Materials



Freddie
Hendriks



Rafael
Rojas



Roberto
Lo Conte



www.rug.nl/optospintronics



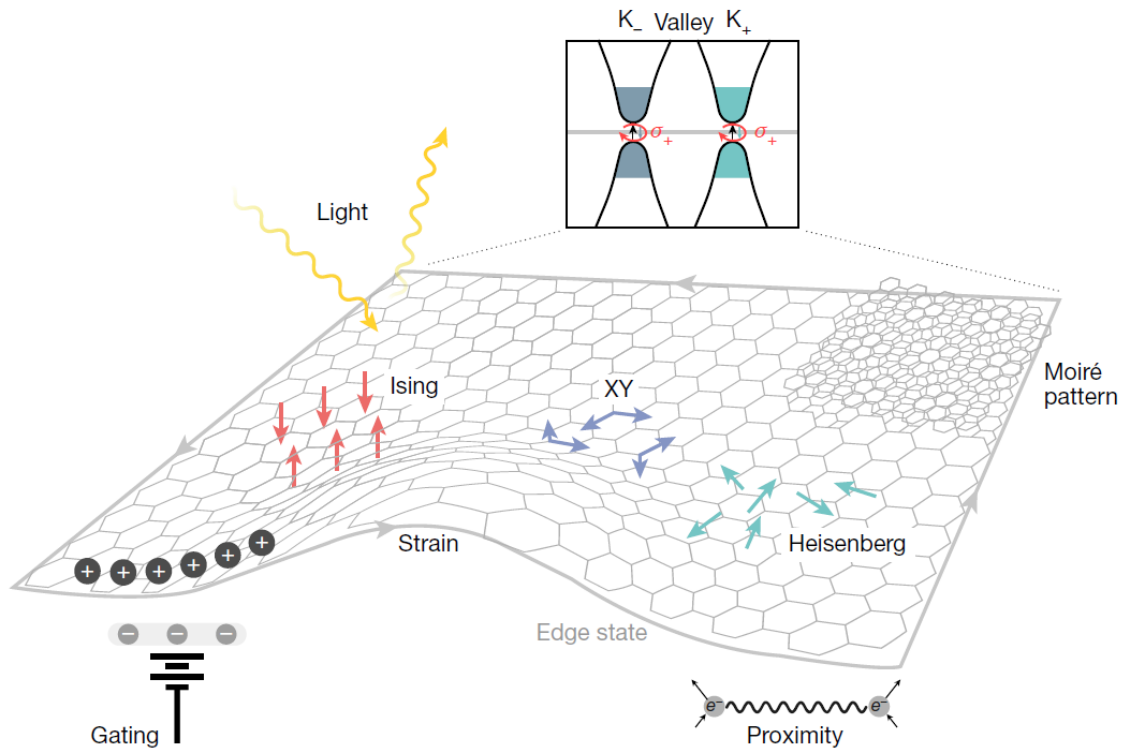
Malte
Roesner



Sasha
Rudenko



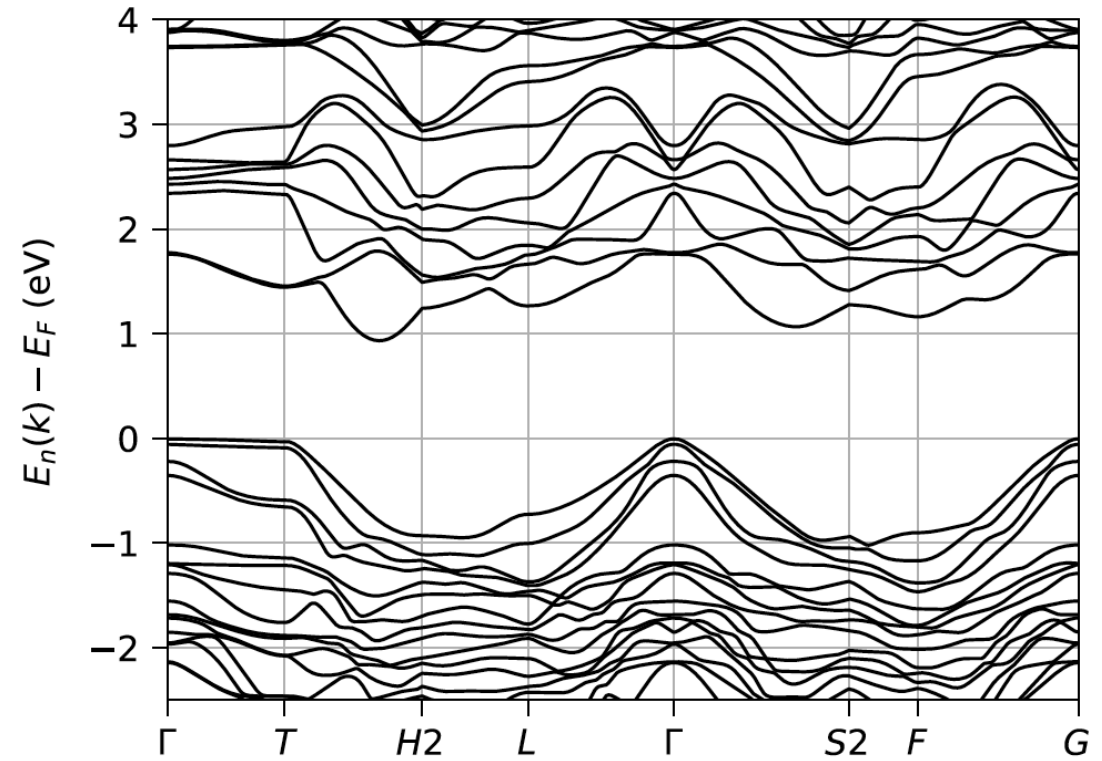
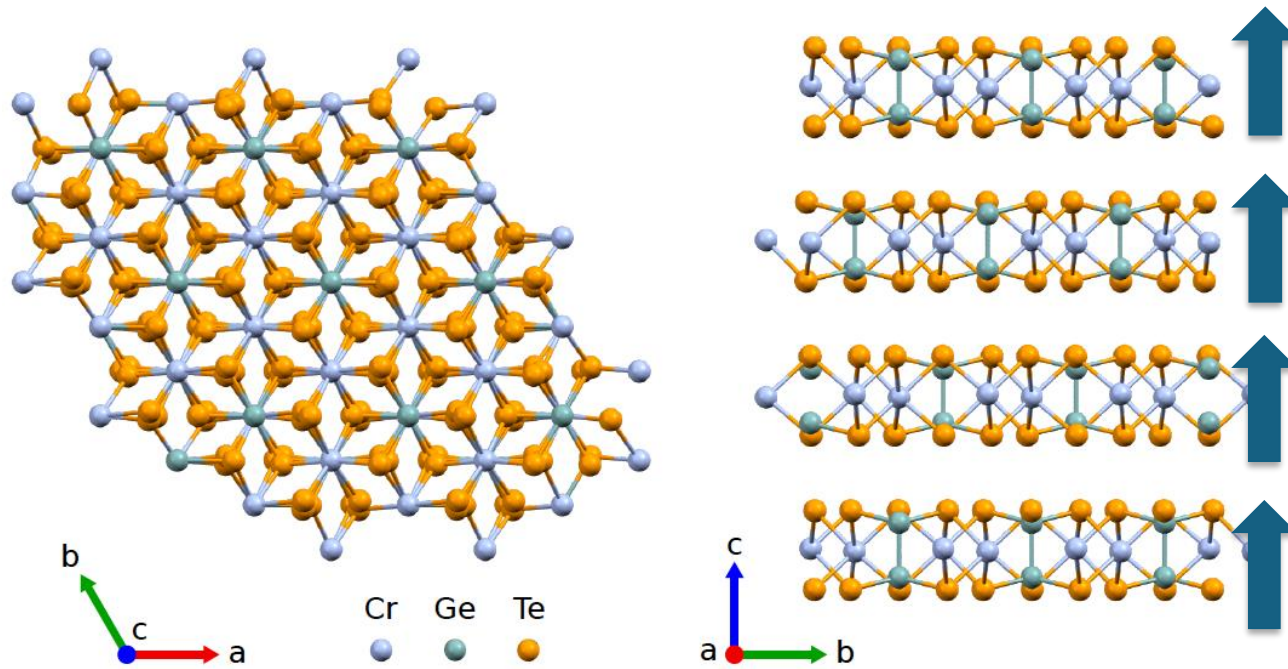
Magnetism in Two-Dimensions



- External (electric) tunability of magnetic ordering
- High quality down to atomically-thin layers
- Strong light-matter interaction
- Attractive to theoreticians
(simple systems)
- Combination with other materials

Many nice reviews (*but particularly ours!*):

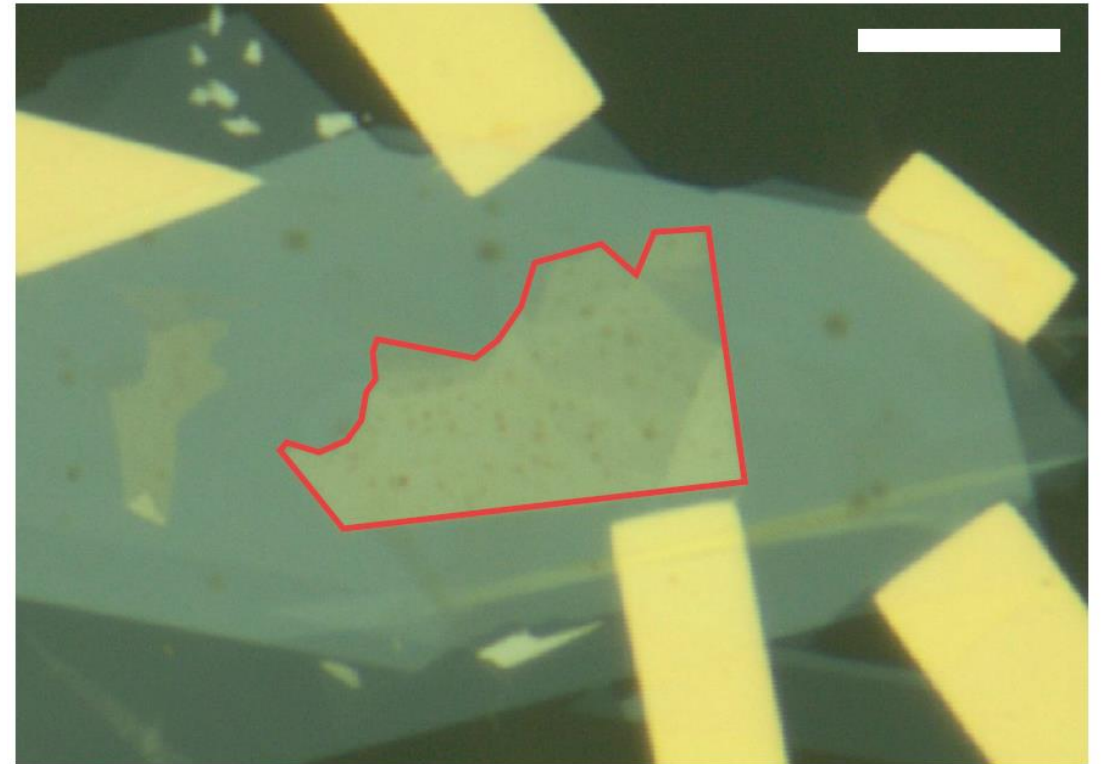
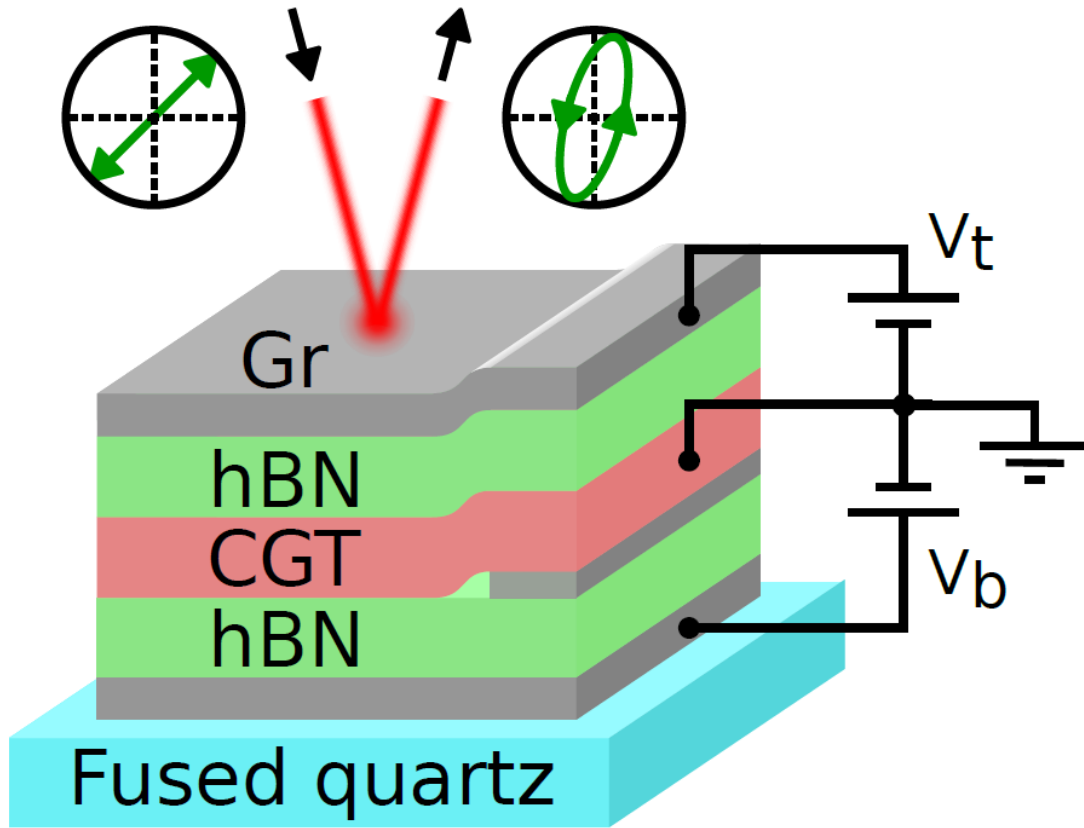
“Roadmap on Quantum Magnetic Materials”
Grubisic-Cabo, Guimaraes, et al.
2D Materials **12**, 031501 (2025)



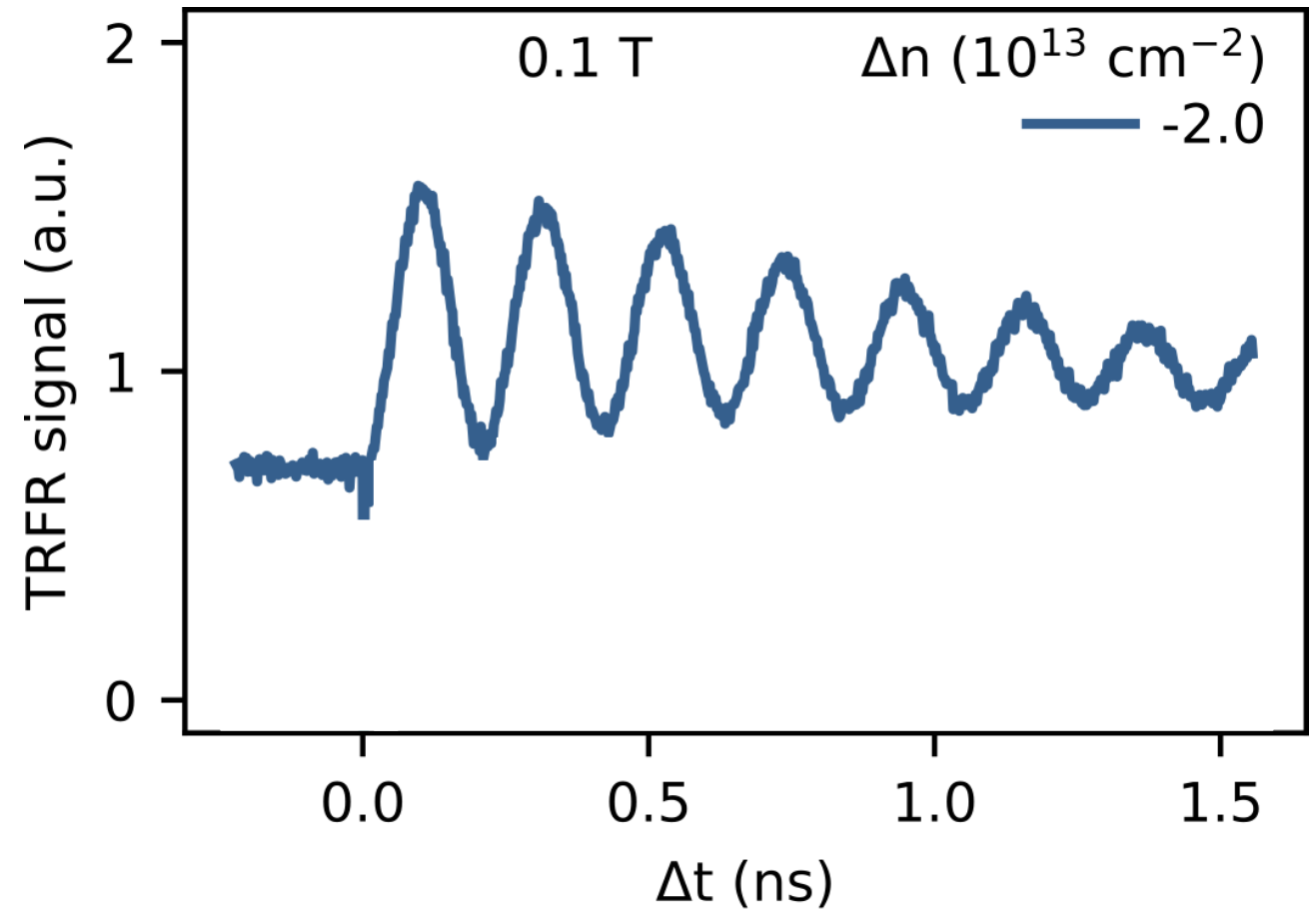
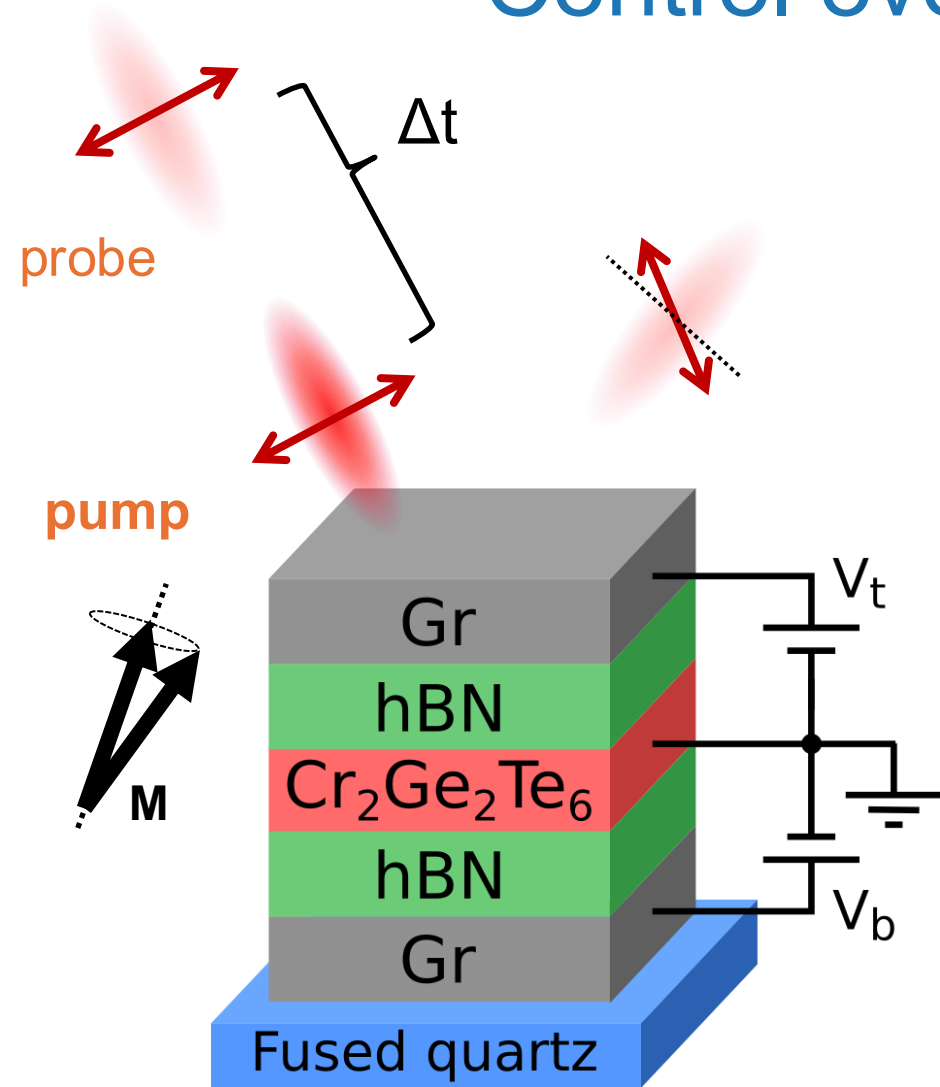
Ferromagnetic semiconductor

$T_C \sim 68$ K

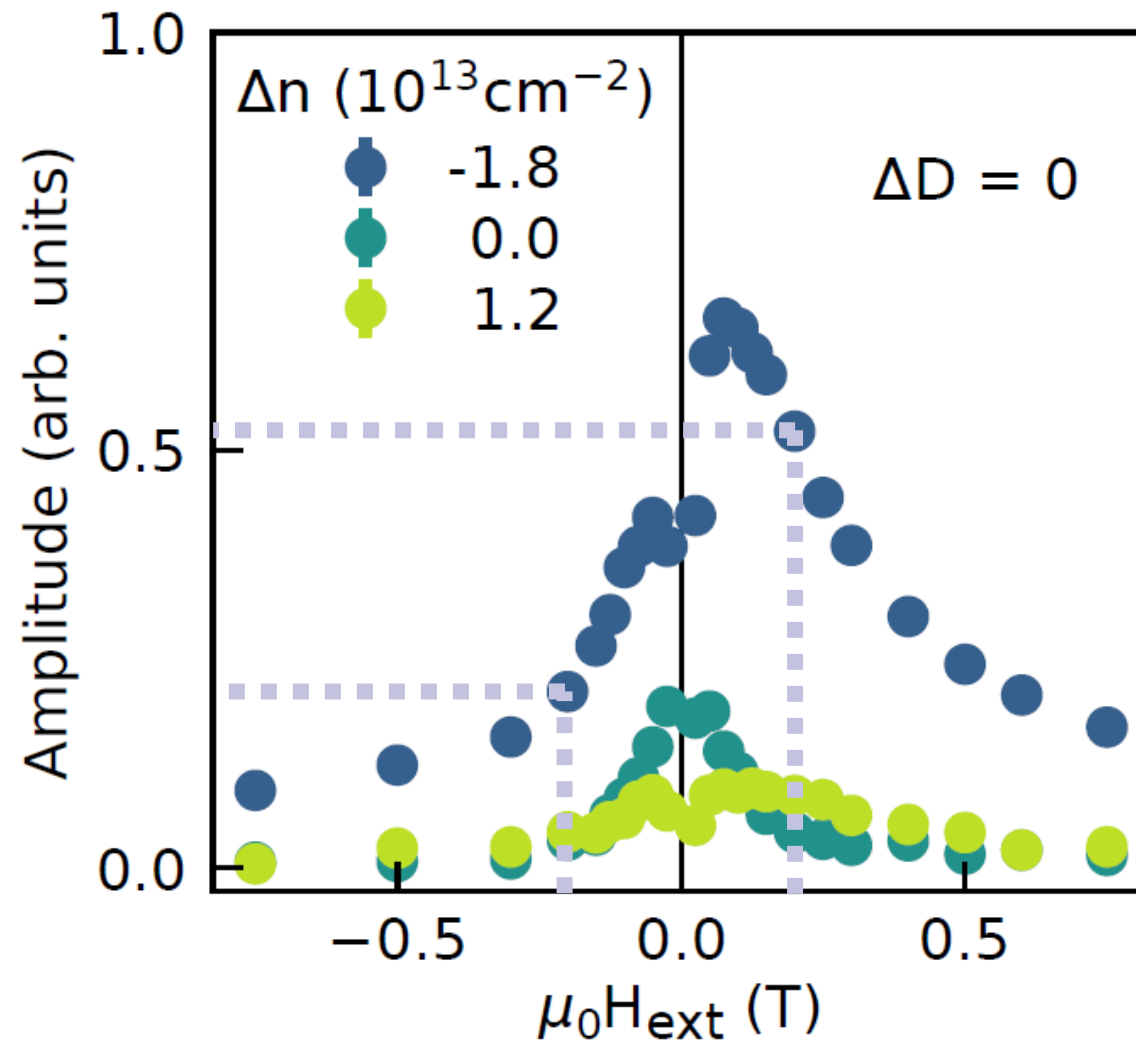
A Tiny Sandwich



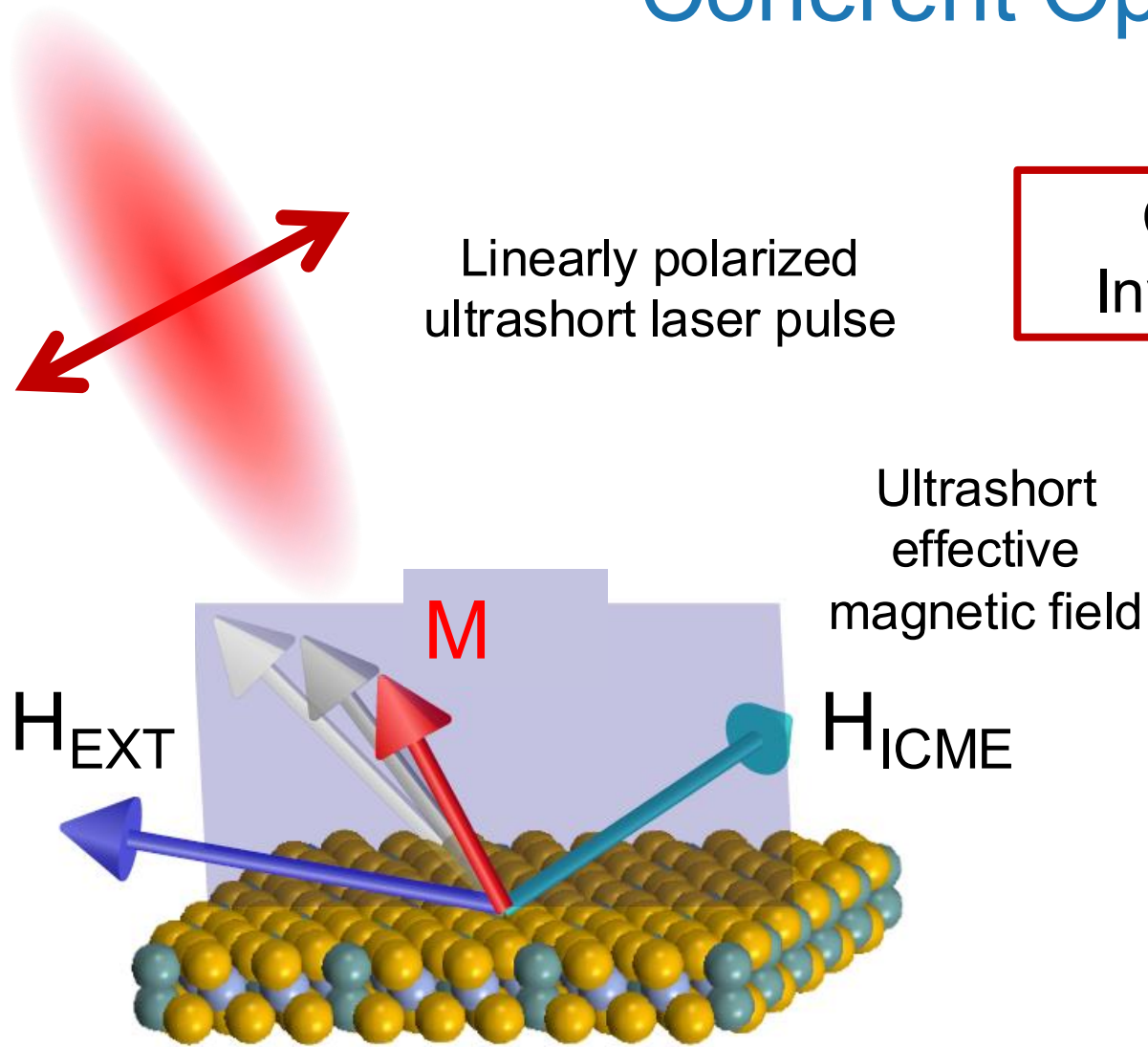
Control over Magnetisation Dynamics



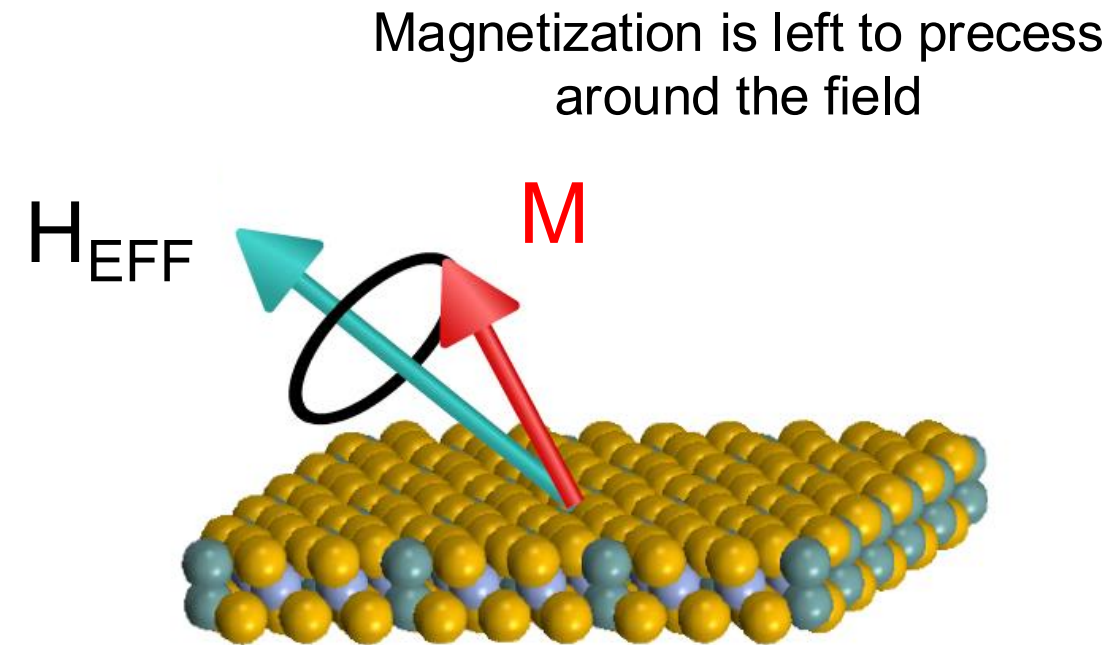
Amplitude of Precession



Coherent Opto-Magnetics



Coherent Opto-Magnetics:
Inverse Cotton-Mouton Effect



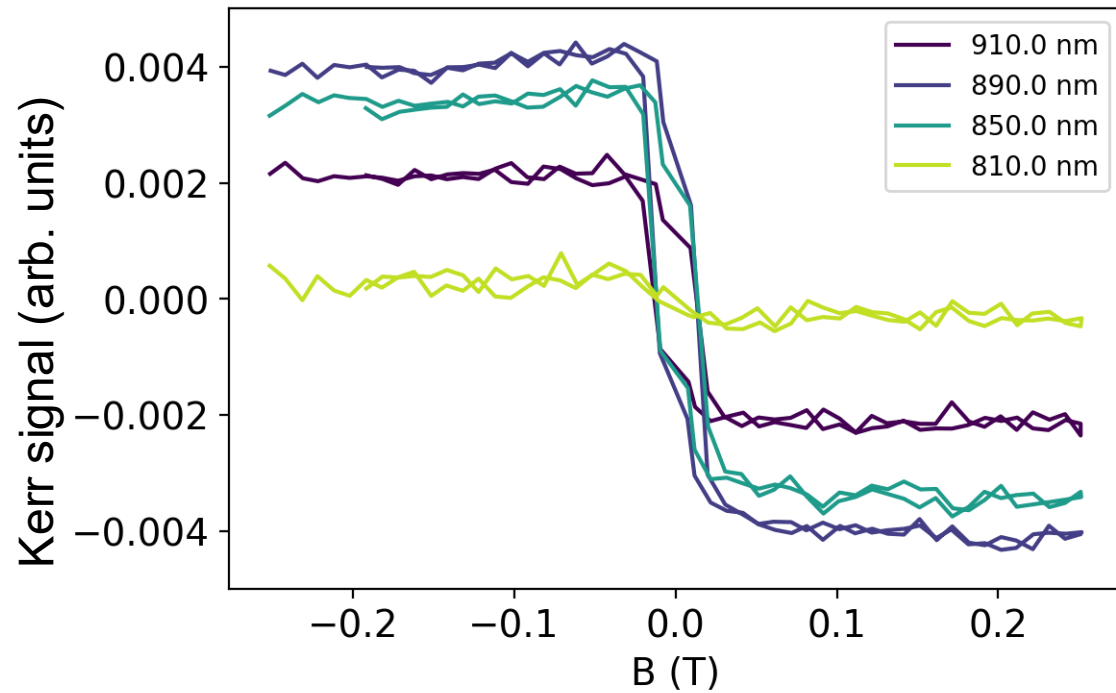
Opto-Magnetics

- Induces large torques on the magnetisation
- Works at ultrashort (fs) timescales
- Nonthermal effects for magnetisation manipulation

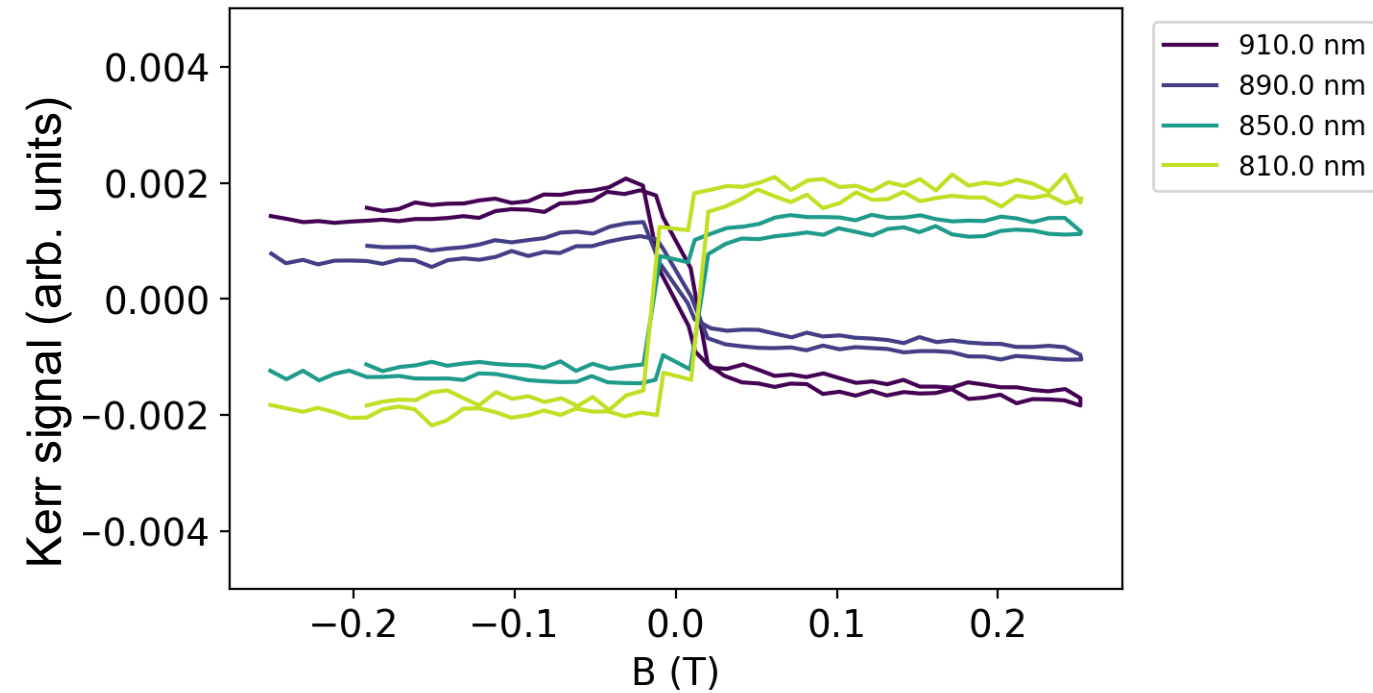
Where does it come from?

Magneto-Optic Spectrum

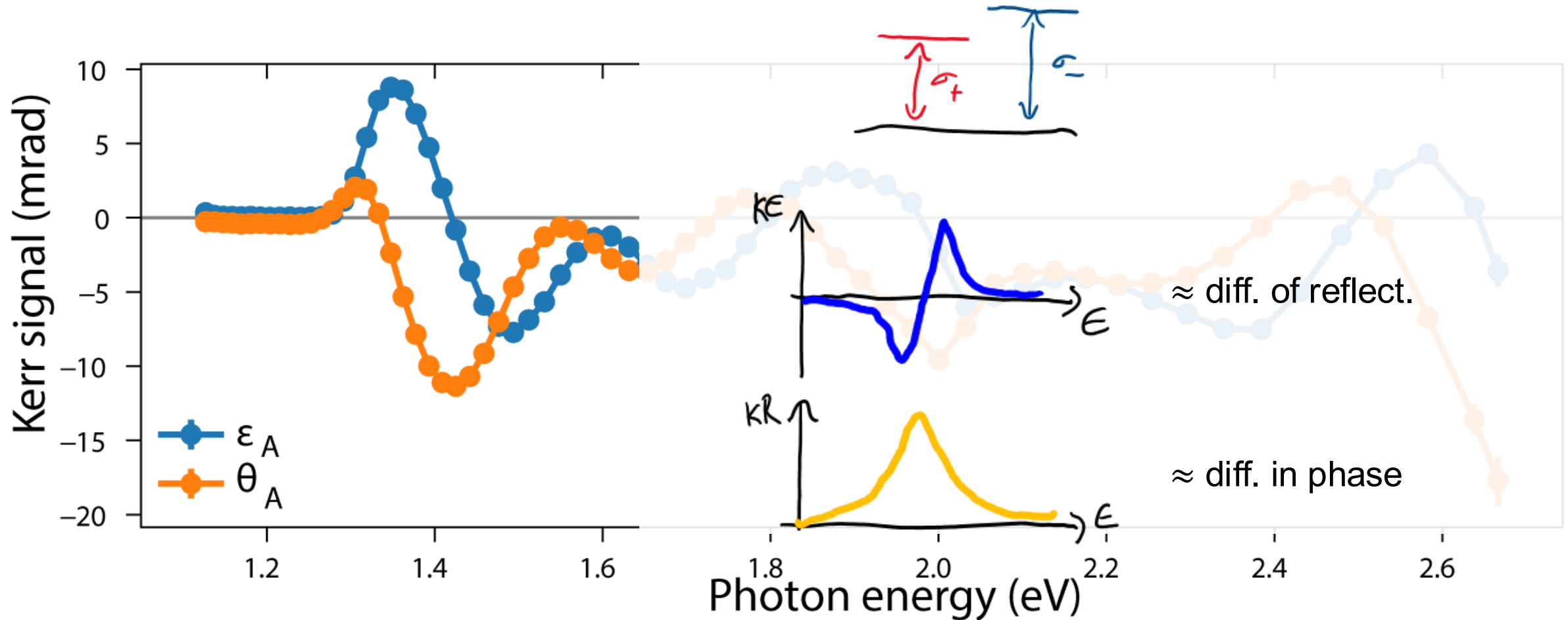
Ellipticity



Rotation



Magneto-Optic Spectrum

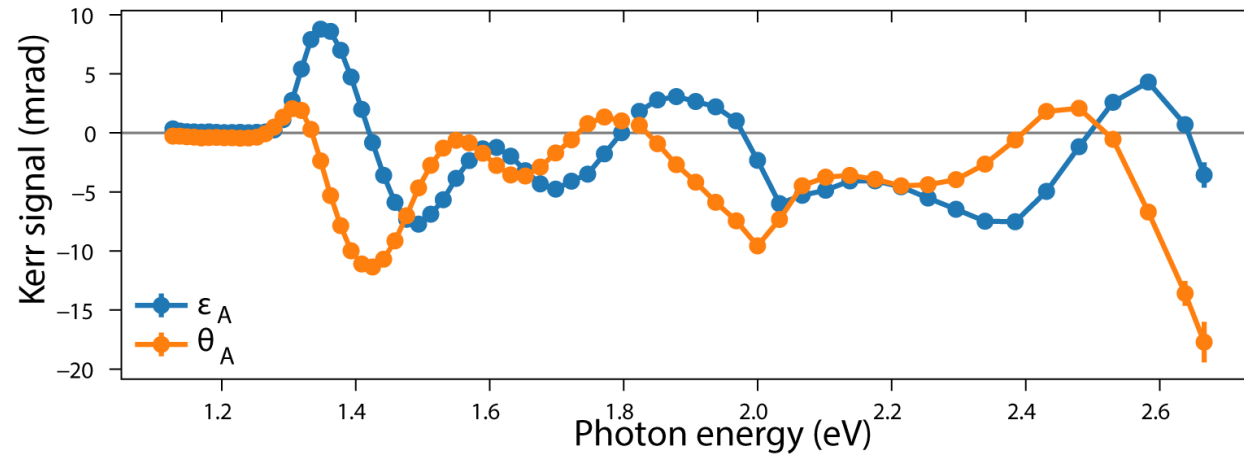


Hendriks, ..., MHDG,
Phys. Rev. Mat. **10** L011001 (2026)

~10x higher than conventional materials
with 10x lower absorption coefficients

Excitonic Effects in Magneto-Optics

Experiment



Sasha Rudenko



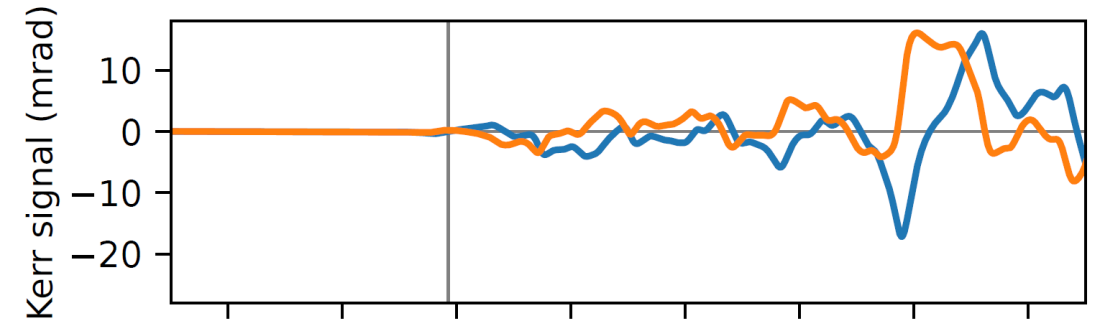
Malte Roesner



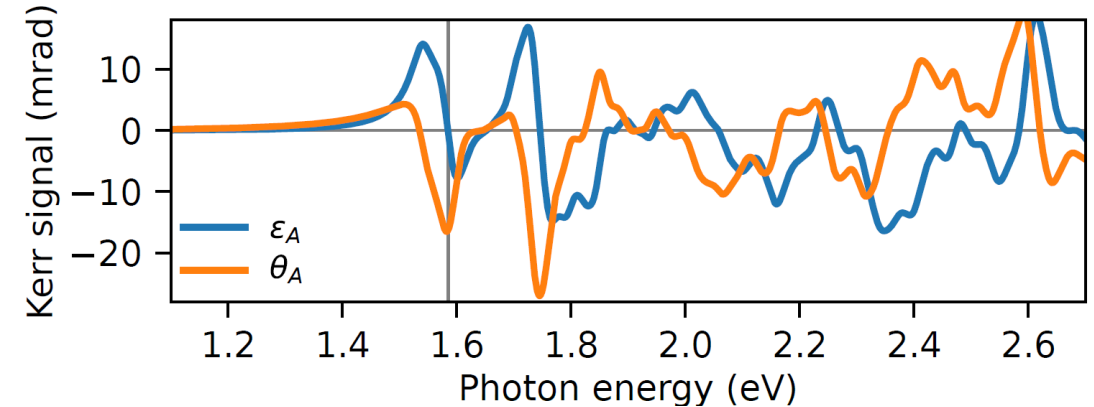
Hendriks, ..., MHDG,
Phys. Rev. Mat. **10** L011001 (2026)

Theory

Without excitonic contributions

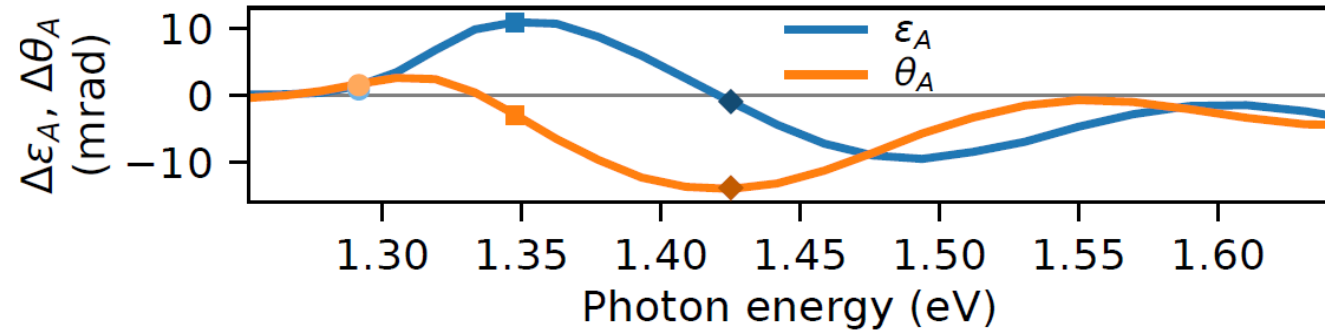
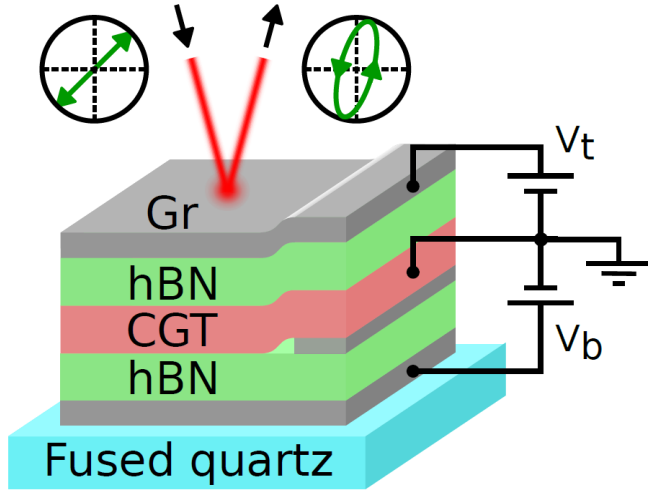


With excitonic contributions



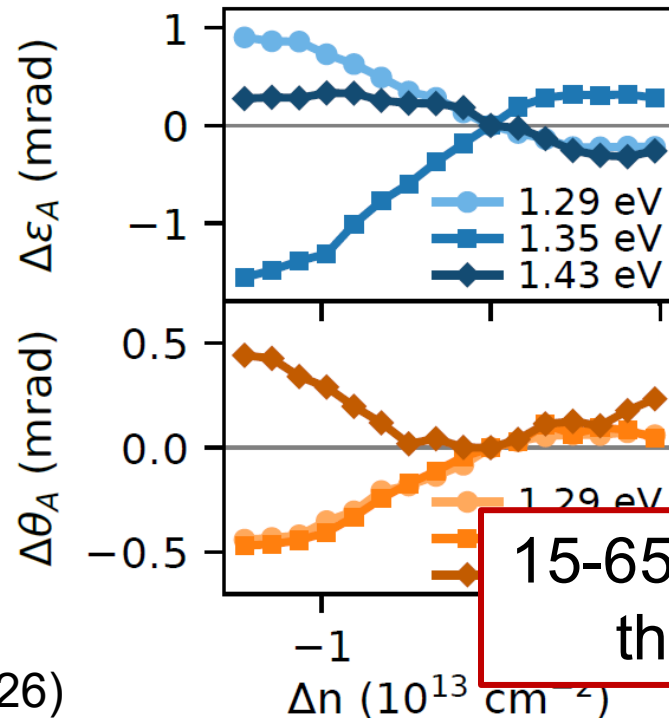
DFT + TD-Hartree-Fock

Electric Control over Magneto-Optic Strength

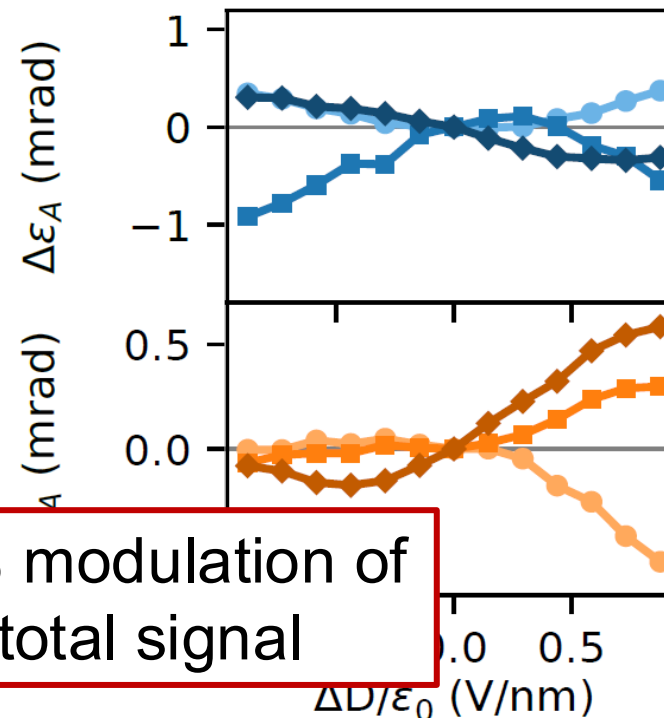


Changes of magneto-optic efficiency with

Carrier
Density

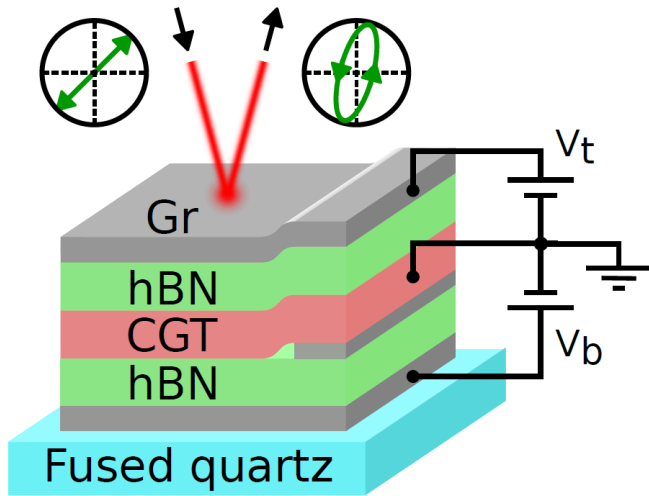


Displacement
Field

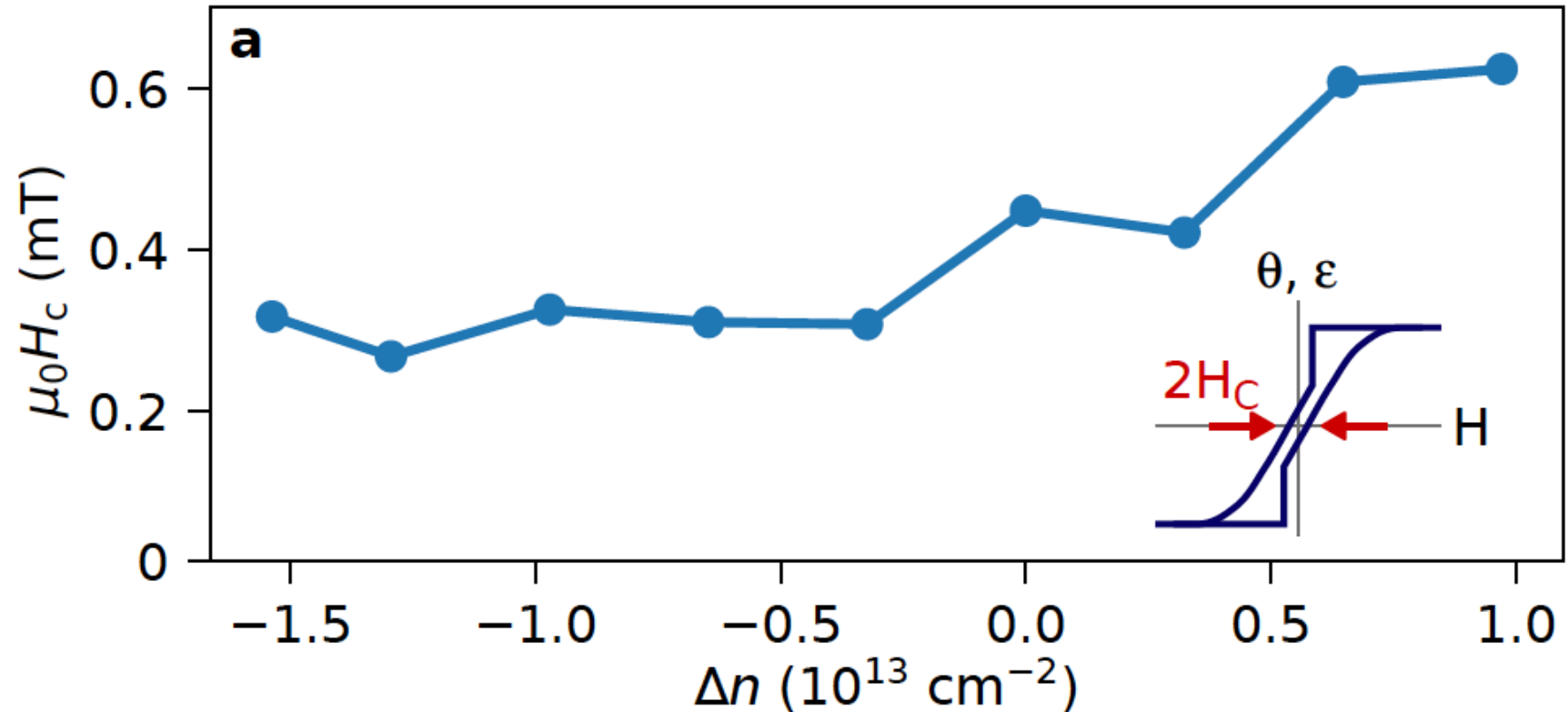


15-65% modulation of
the total signal

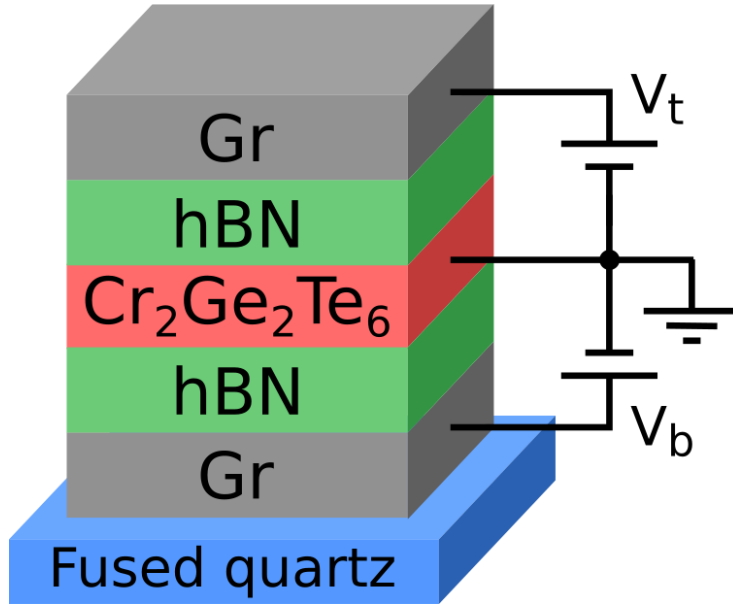
Electric Control over Coercive Fields



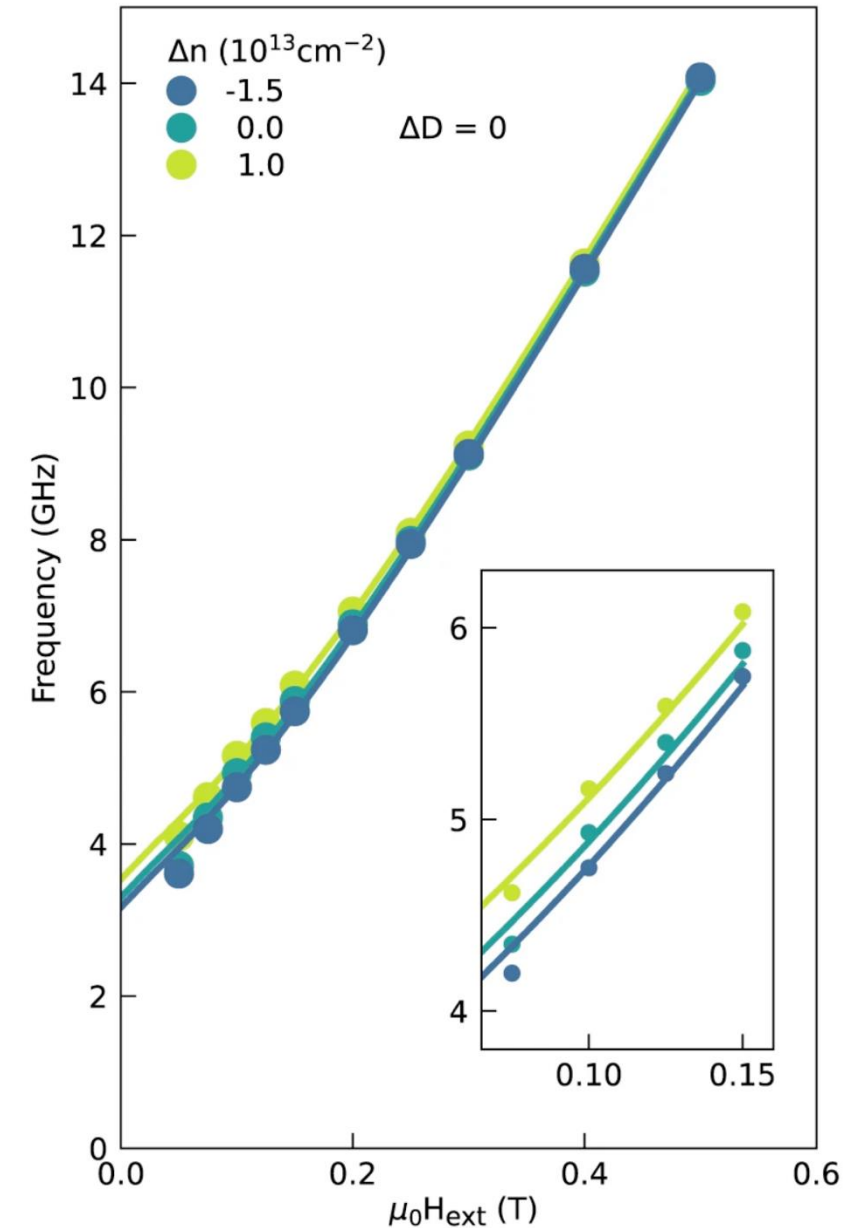
Control over
coercivity



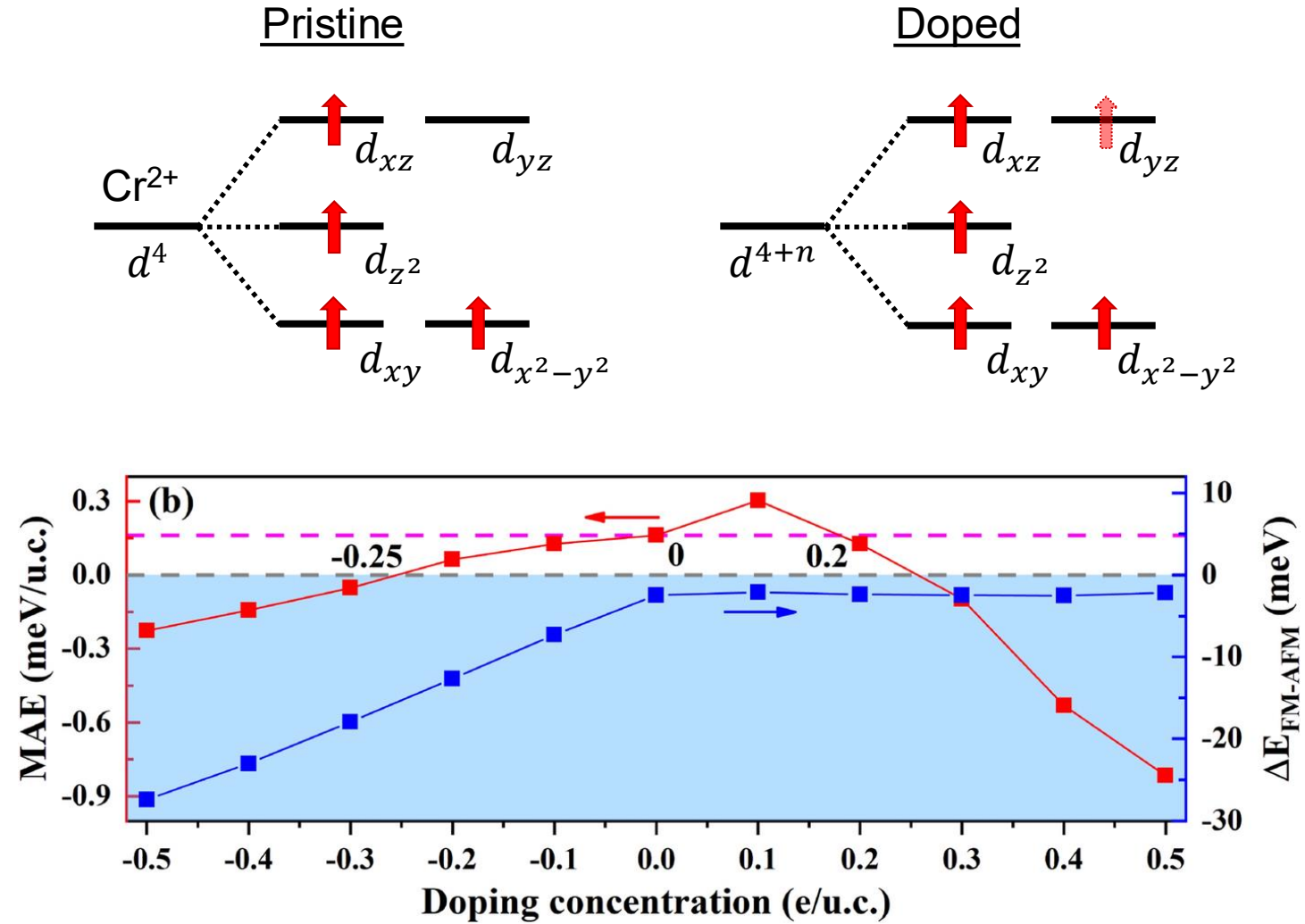
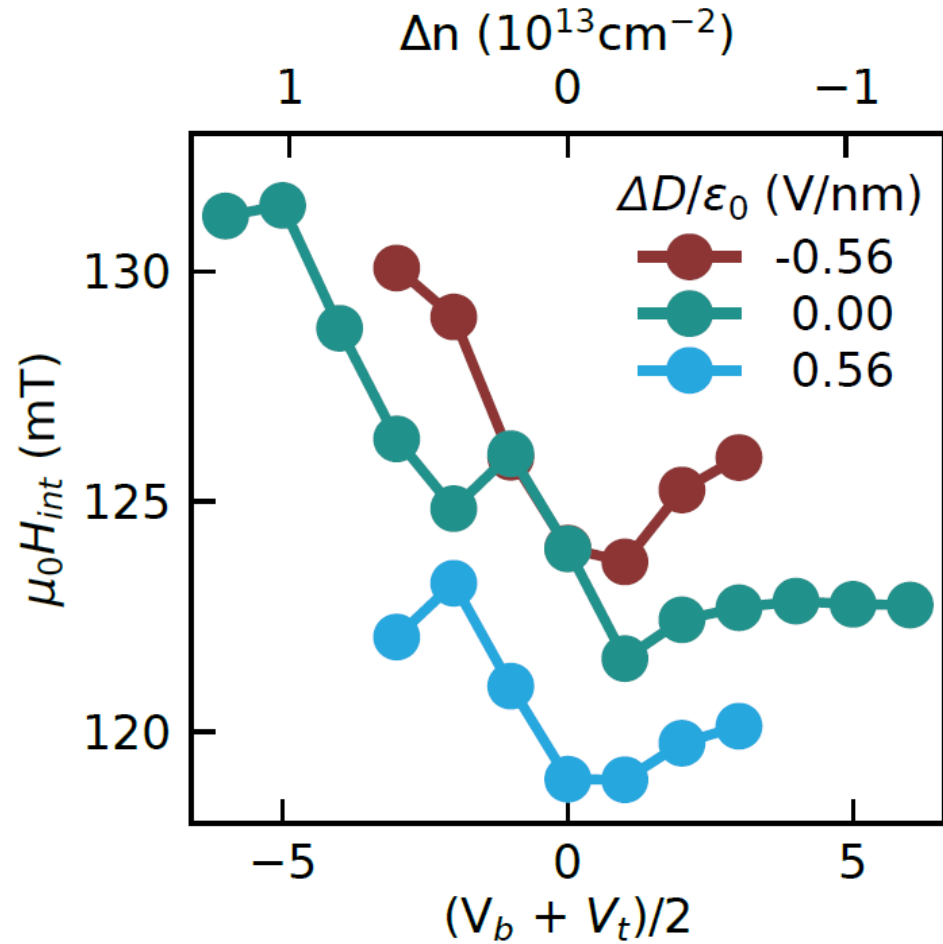
Electric Control over Magnetisation Dynamics



Electric control over
magnetization dynamics



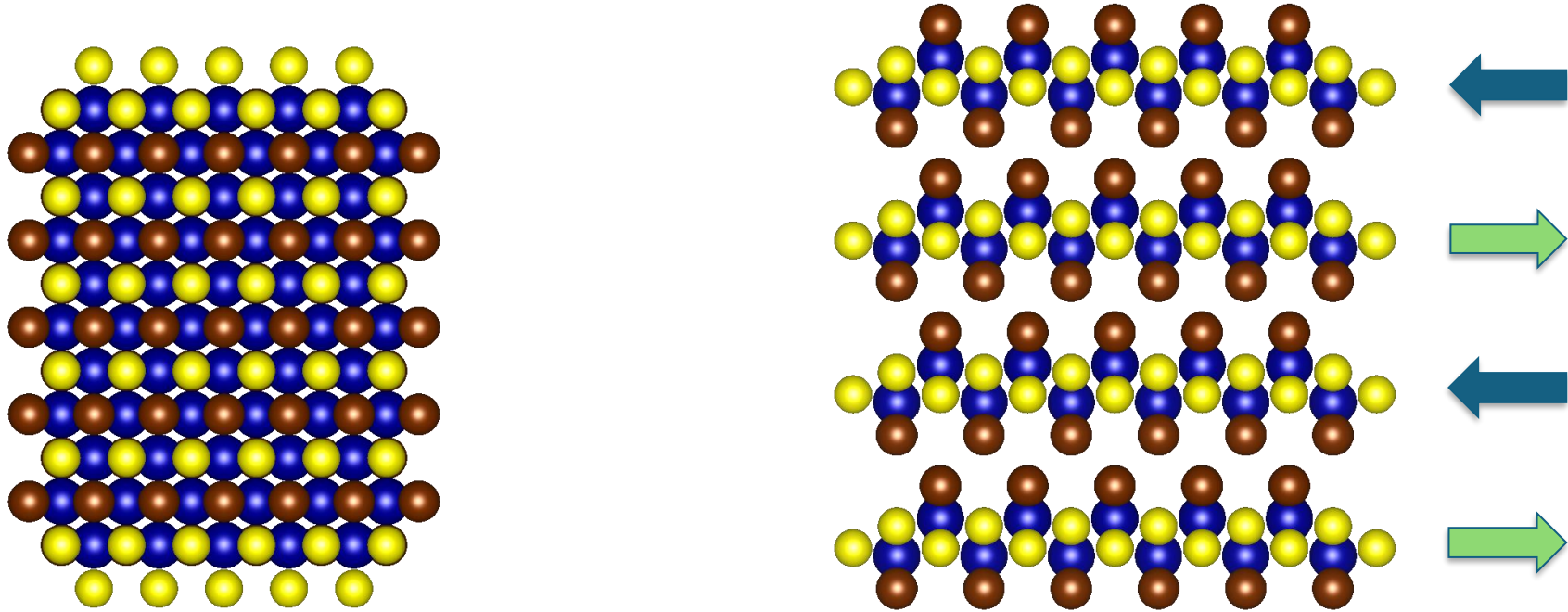
Orbital Contributions to Anisotropy



Hendriks, ..., MHDG, *Nature Comm.* **15**, 1298 (2024).

Ren, et al., *Sci. Rep.* **11**, 2744 (2021)

CrSBr – Layered (A-type) AFM



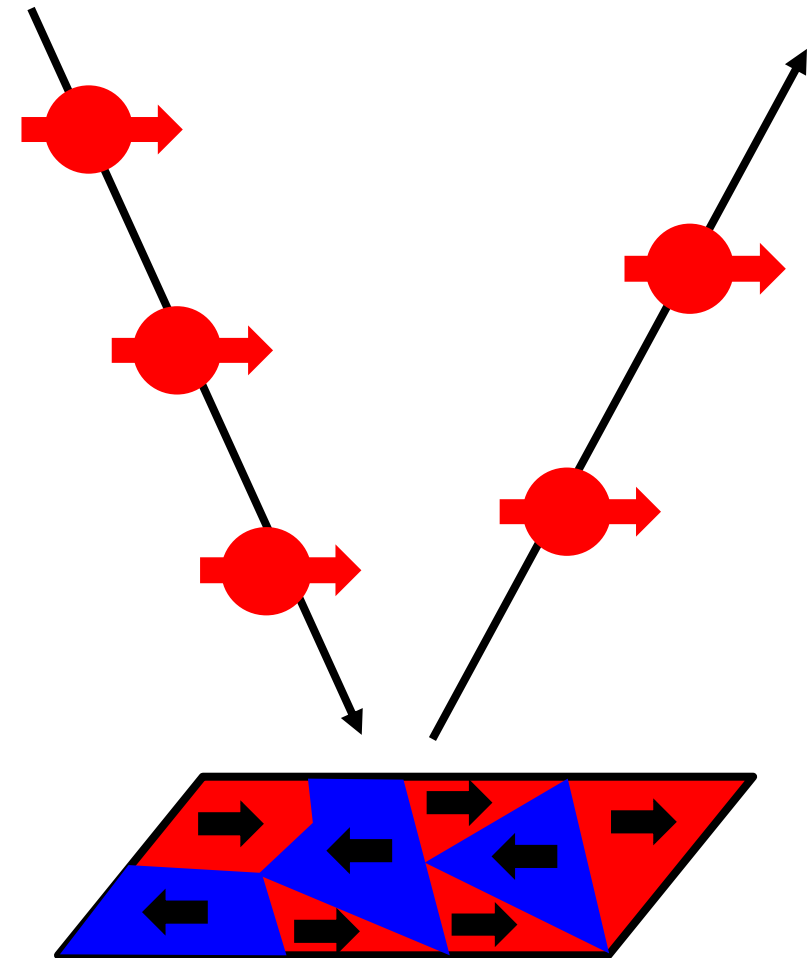
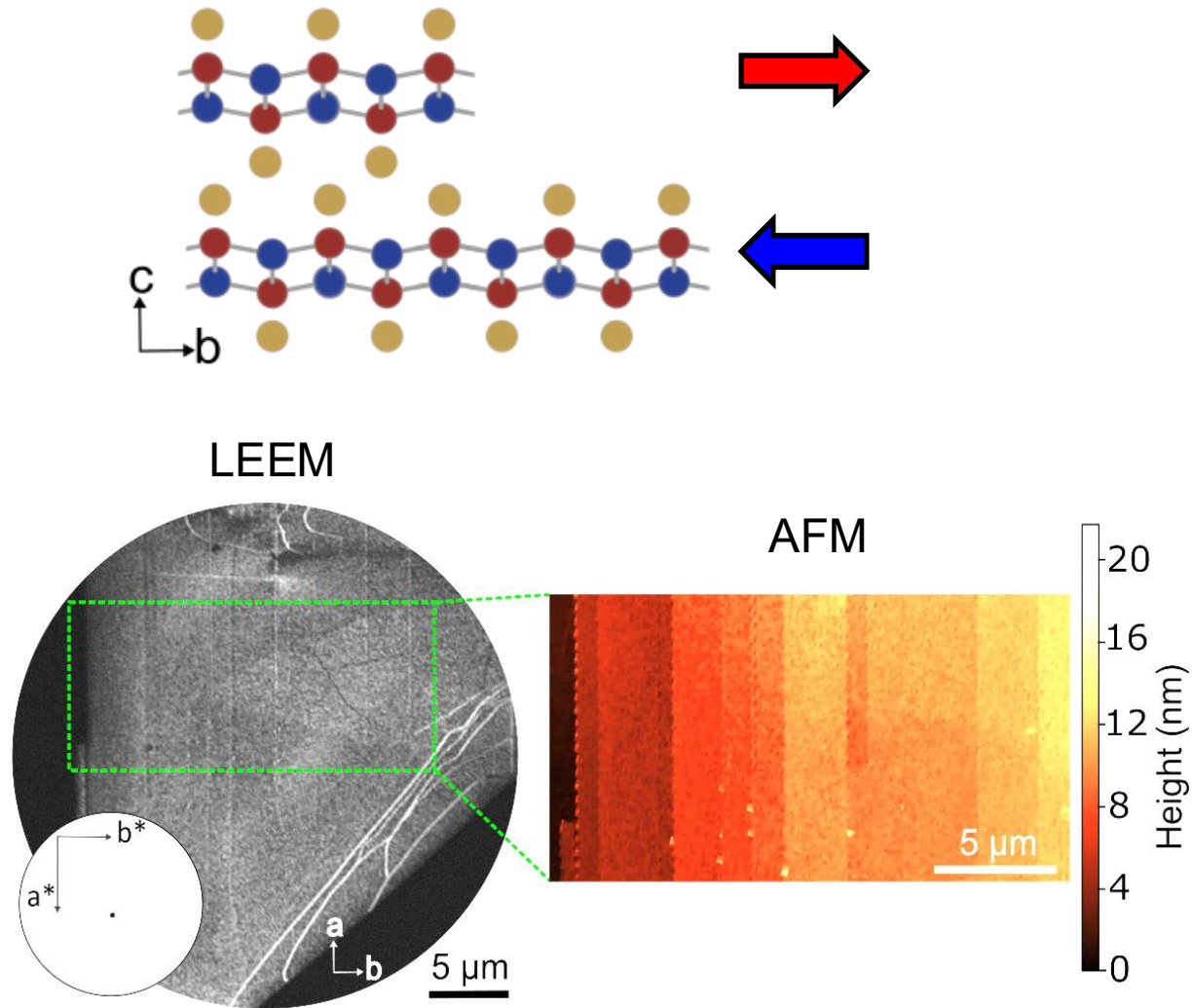
Antiferromagnetic semiconductor

$$T_N = 132 \text{ K}$$

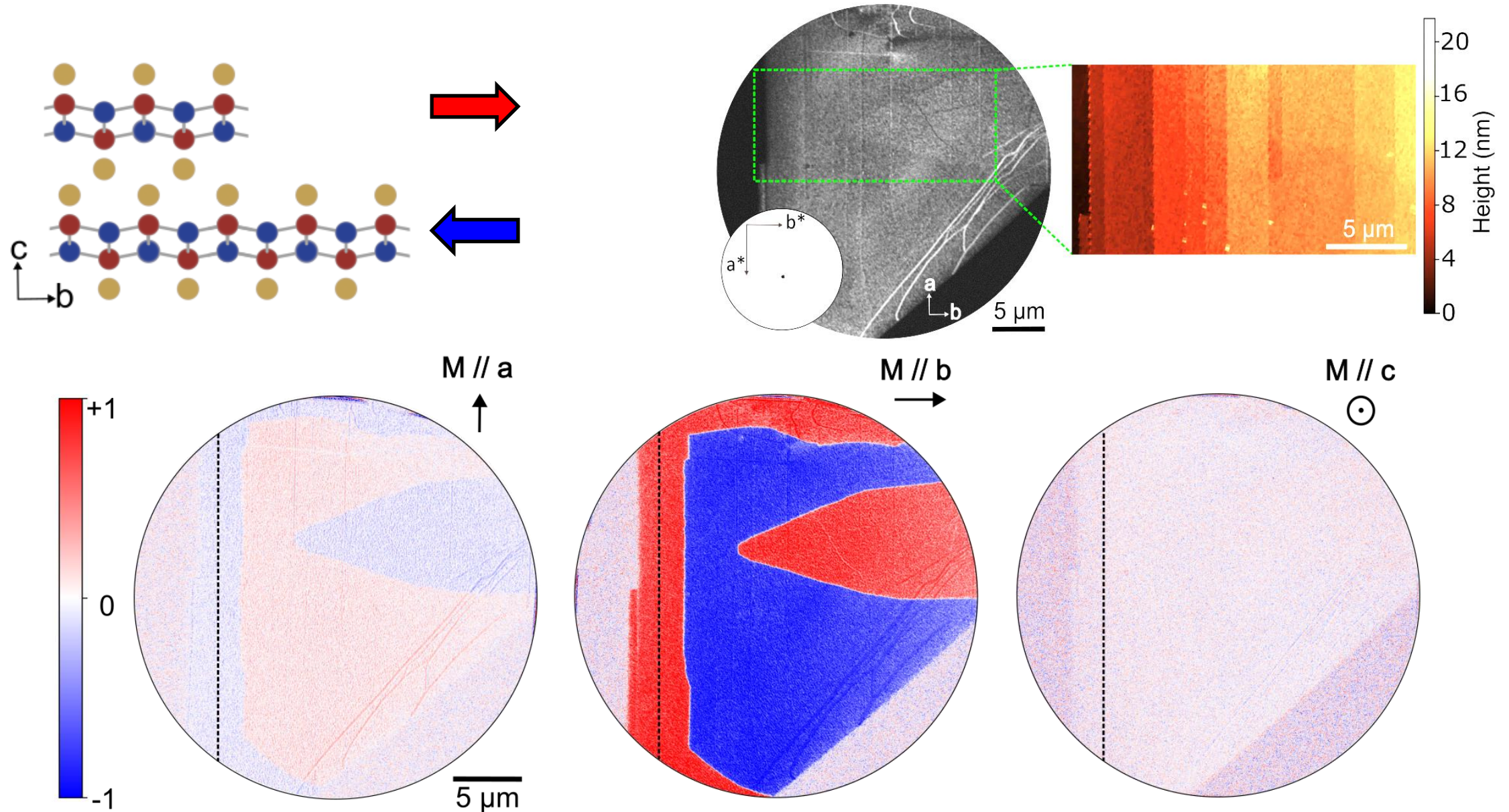
Spin-Polarised LEEM – SPLEEM



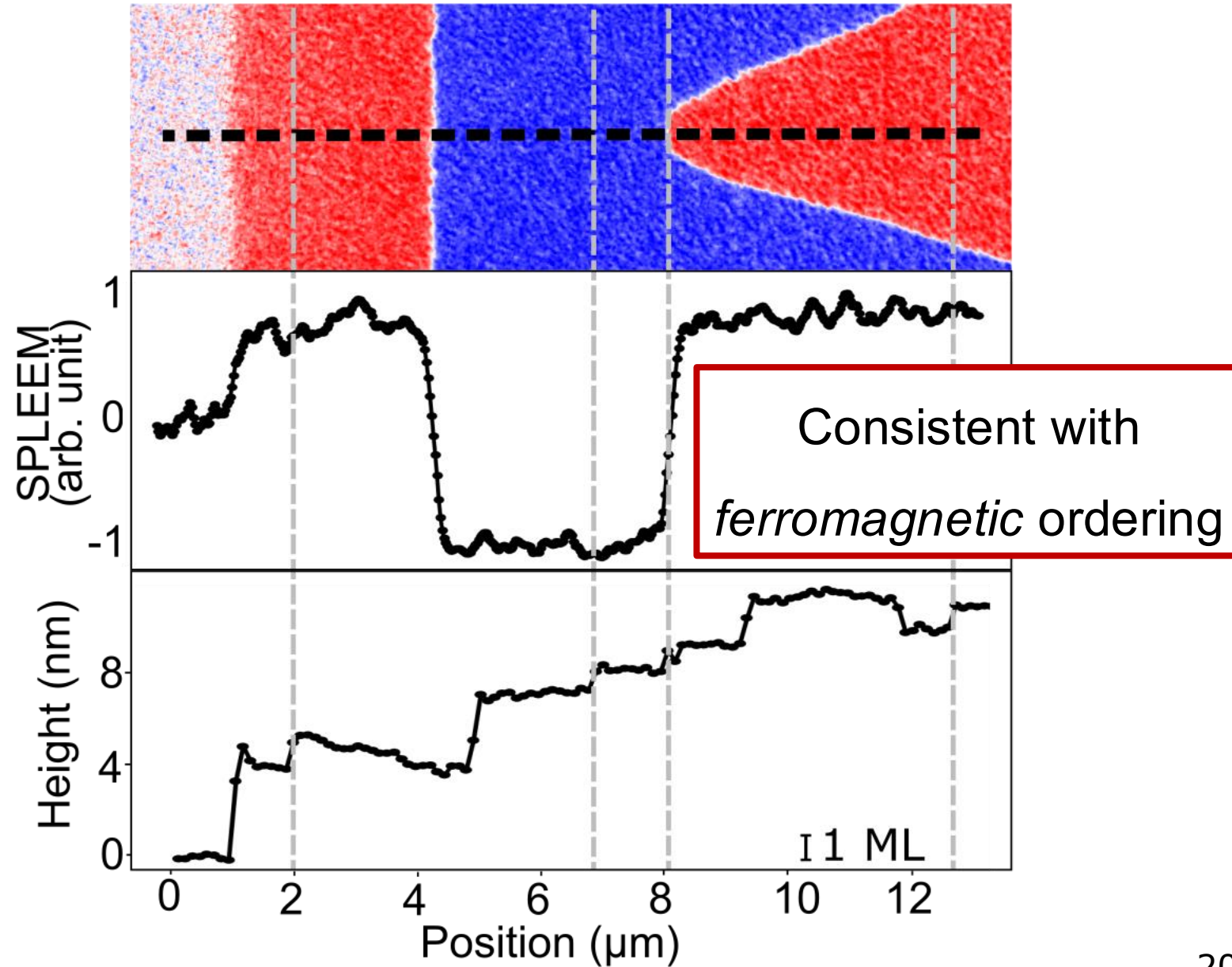
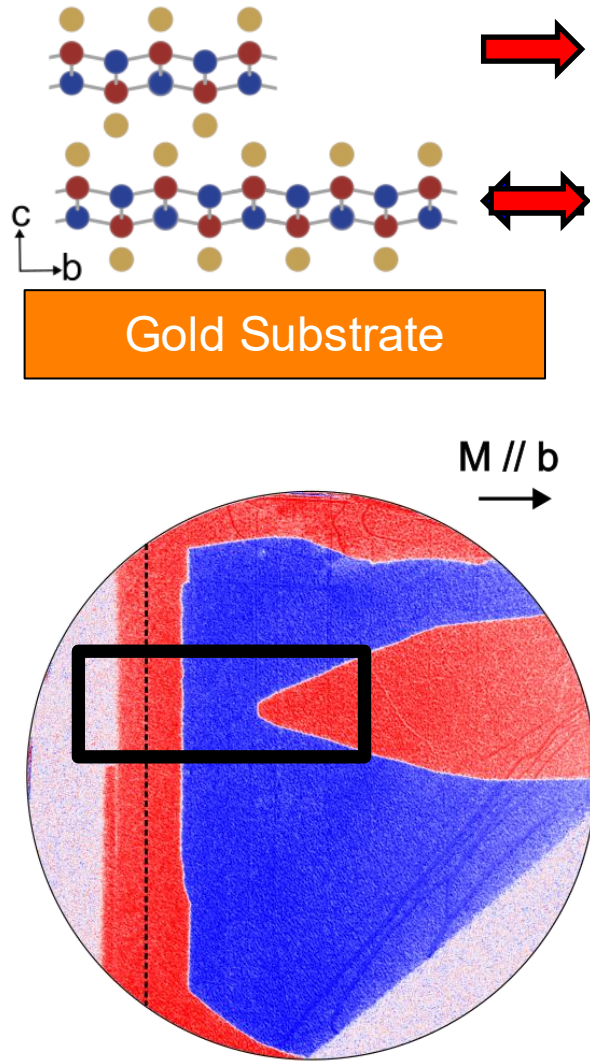
Roberto
Lo Conte



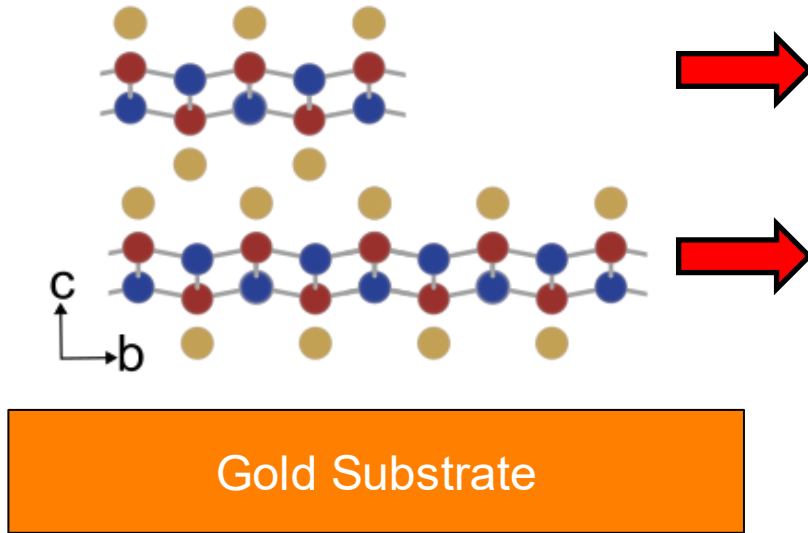
Imaging Magnetic Domains



Substrate Engineering of CSB Magnetisation



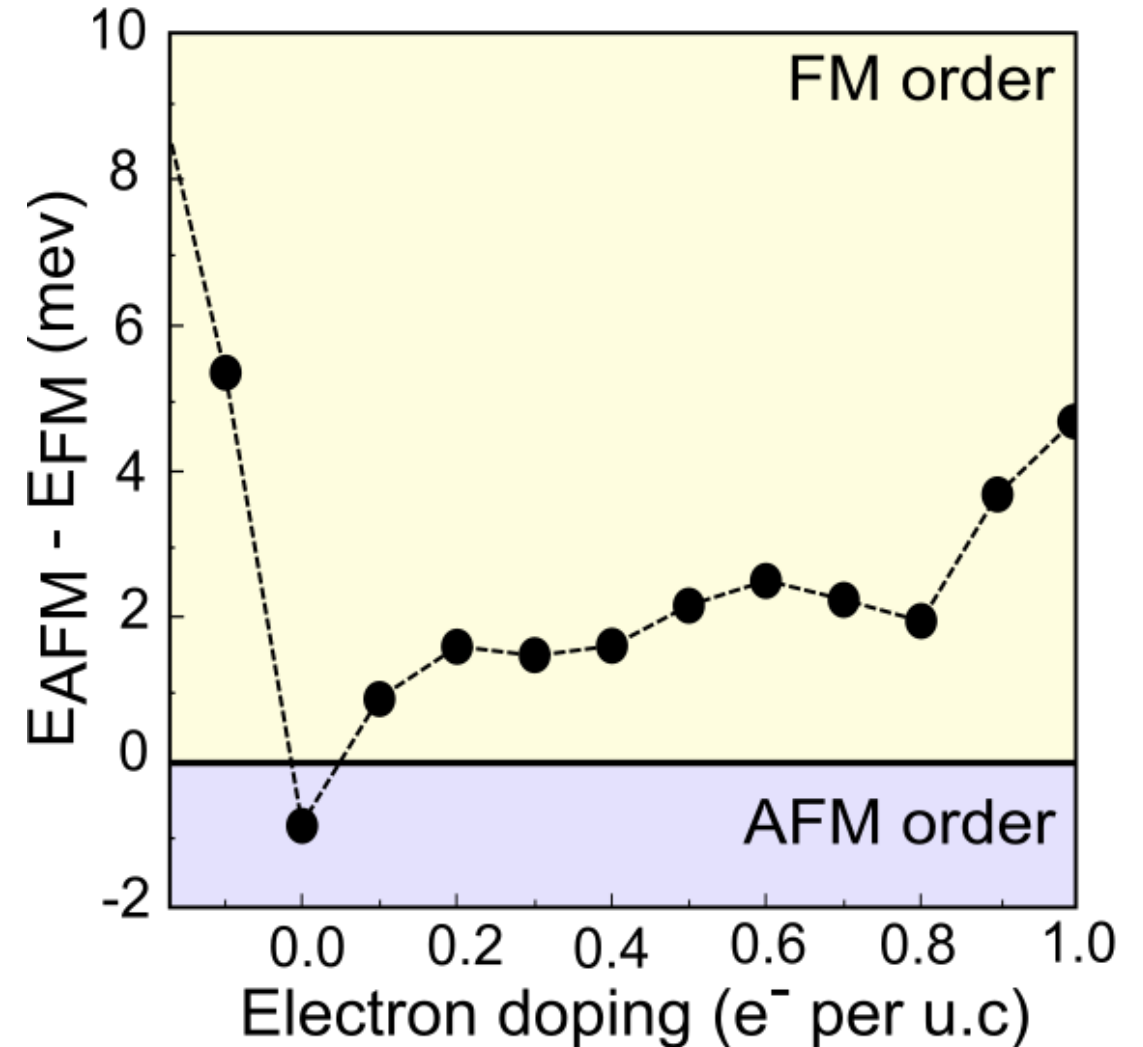
AFM to FM Through Doping



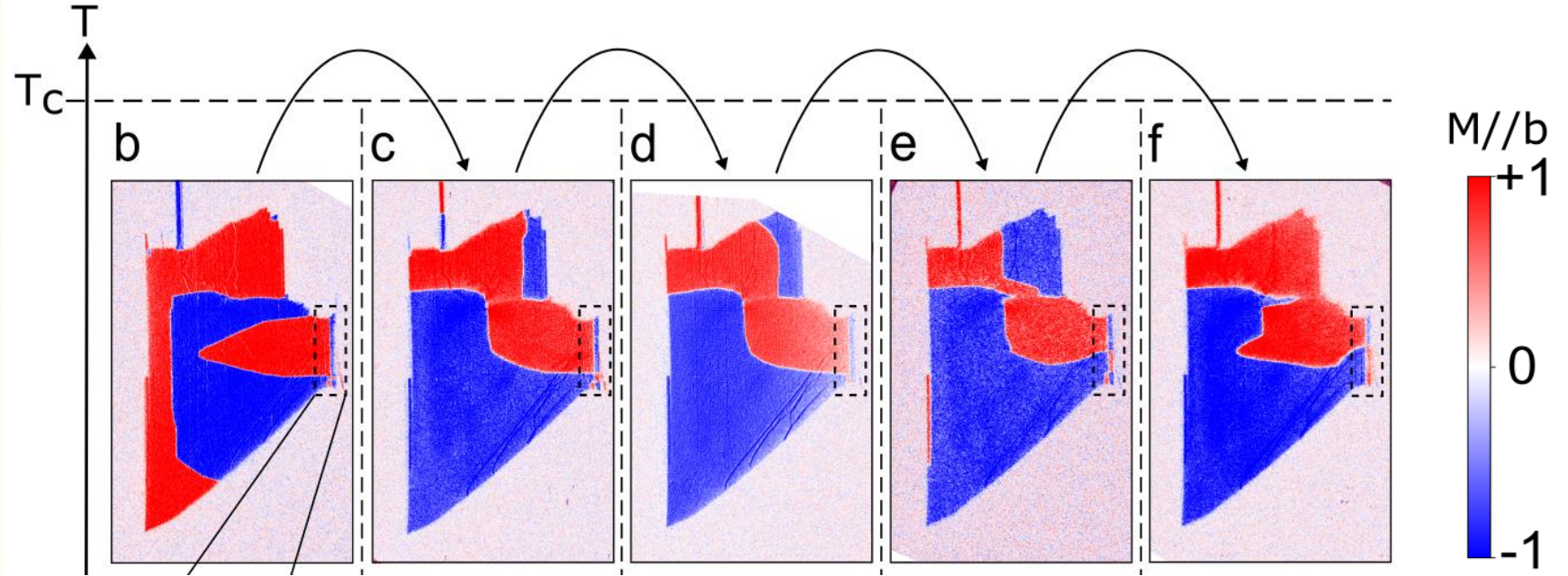
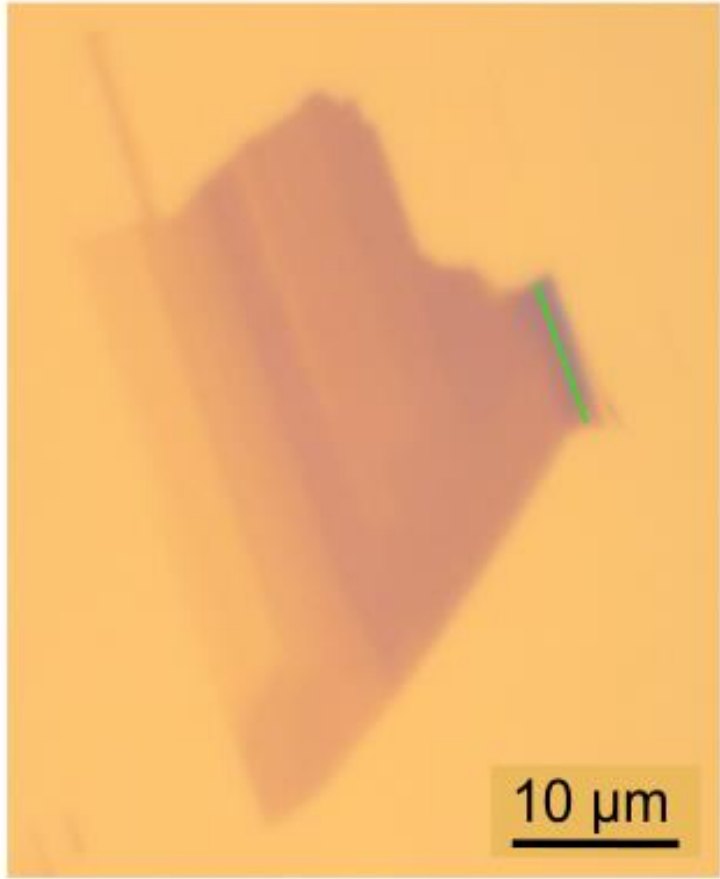
0.1 e⁻ per u.c.

$\sim 10^{19} \text{ cm}^{-3}$

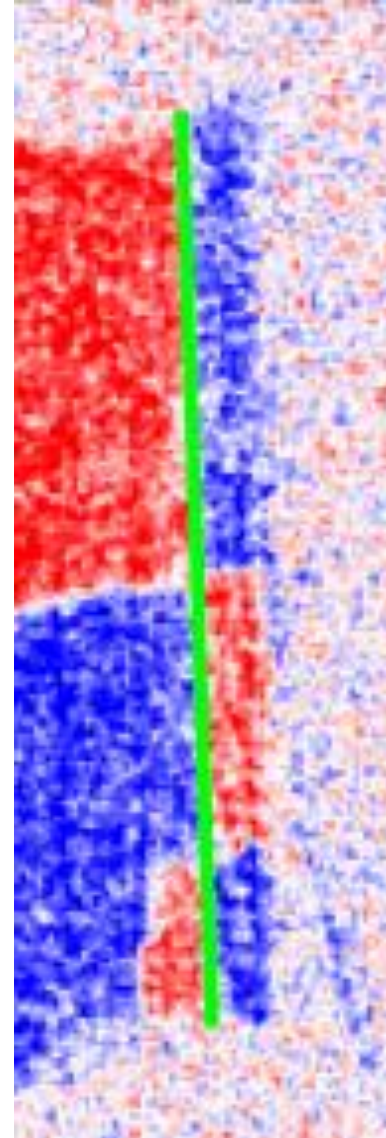
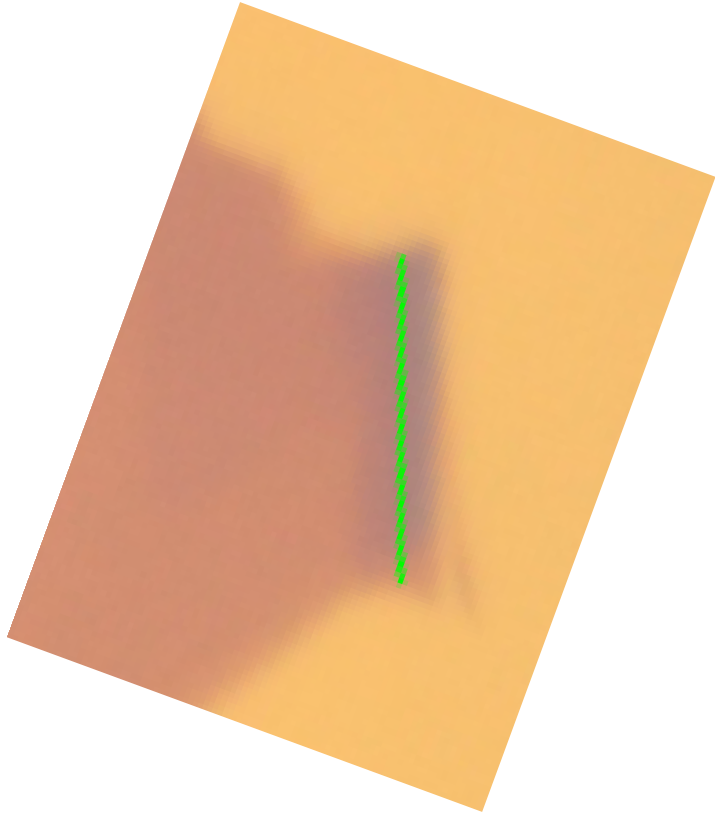
$\sim 10^{13} \text{ cm}^{-2}$



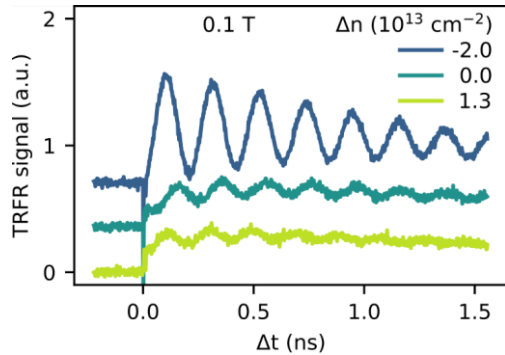
Temperature Cycling



AFM Recovered for Thicker Regions



Controlling Magnetism in vdW Materials



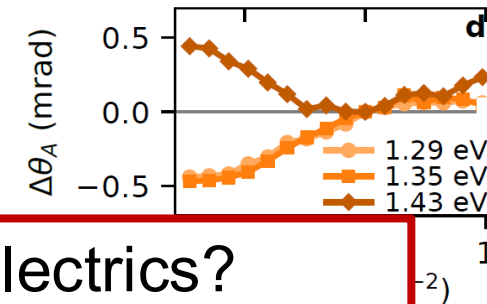
Gate-controlled opto-magnetics and magnetization dynamics in CGT

Nature Comm. **15**, 1298 (2024).

Light

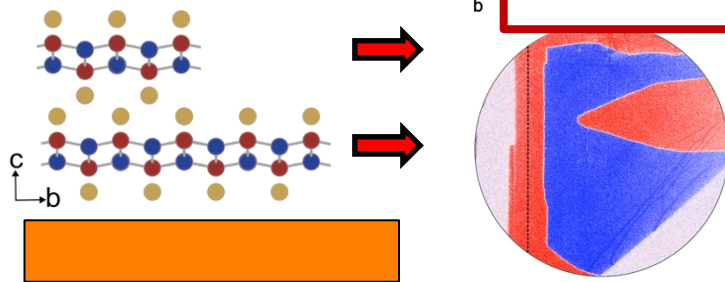
Gate-control of magneto-optics and excitons in CGT

Phys. Rev. Mat. **10**, L011001 (2026)



Voltage

Combination with 2D Ferroelectrics?
Ferrons + Magnons in 2D



FM ordering through substrate engineering

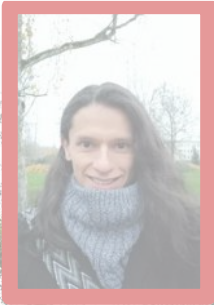
Arxiv: 2604.09794 (2026)

Substrate

OptoSpintronics of Quantum Materials



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Hendriks



Rafael
Rojas



Roberto
Lo Conte



www.rug.nl/optospintronics



Malte
Roesner



Sasha
Rudenko

