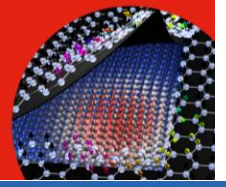
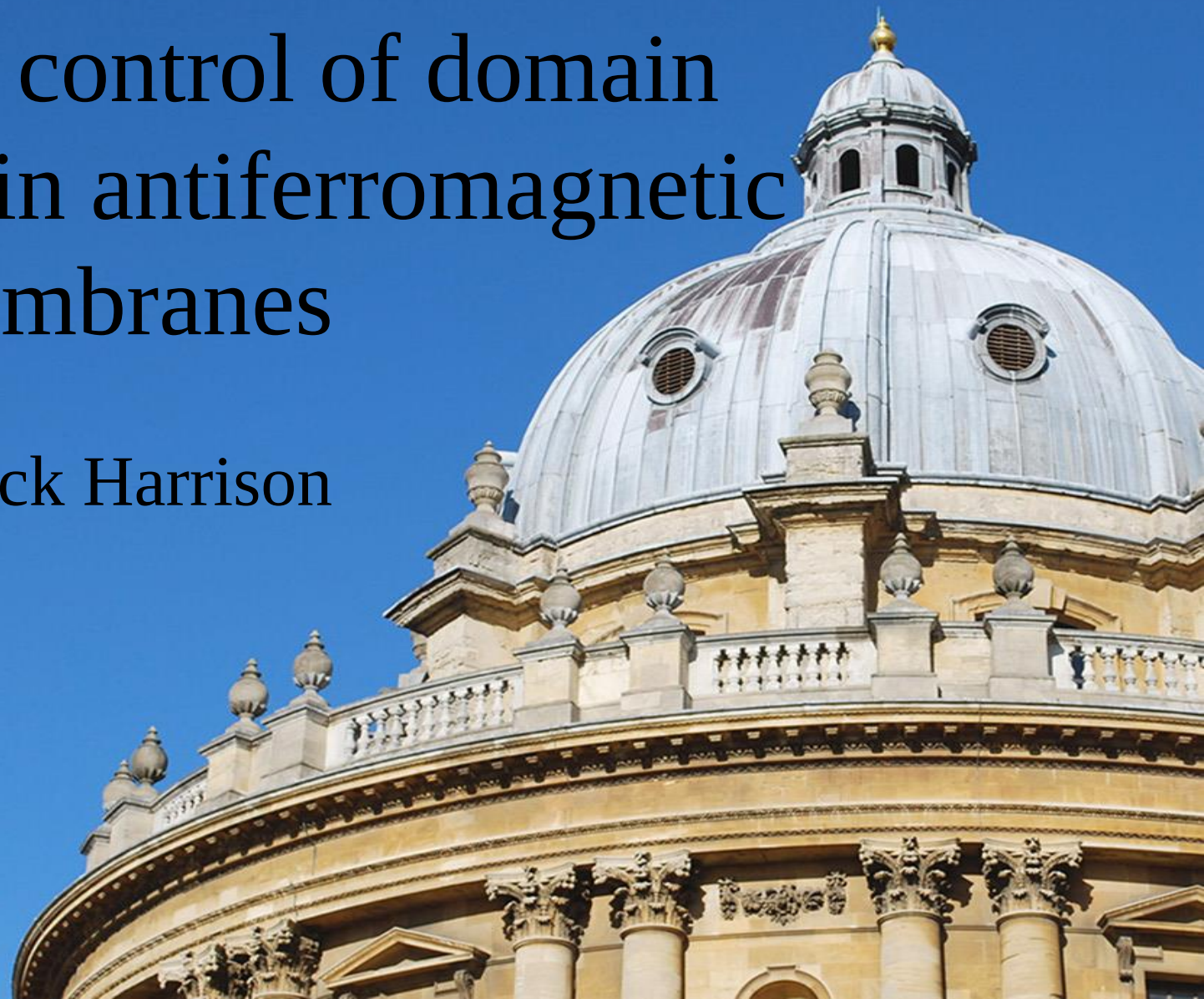
Magnetism 2023
3–4 April 2023
University of Manchester, UK

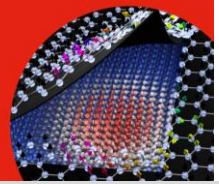


UNIVERSITY OF OXFORD

In-situ strain control of domain morphologies in antiferromagnetic membranes

Jack Harrison





Overview

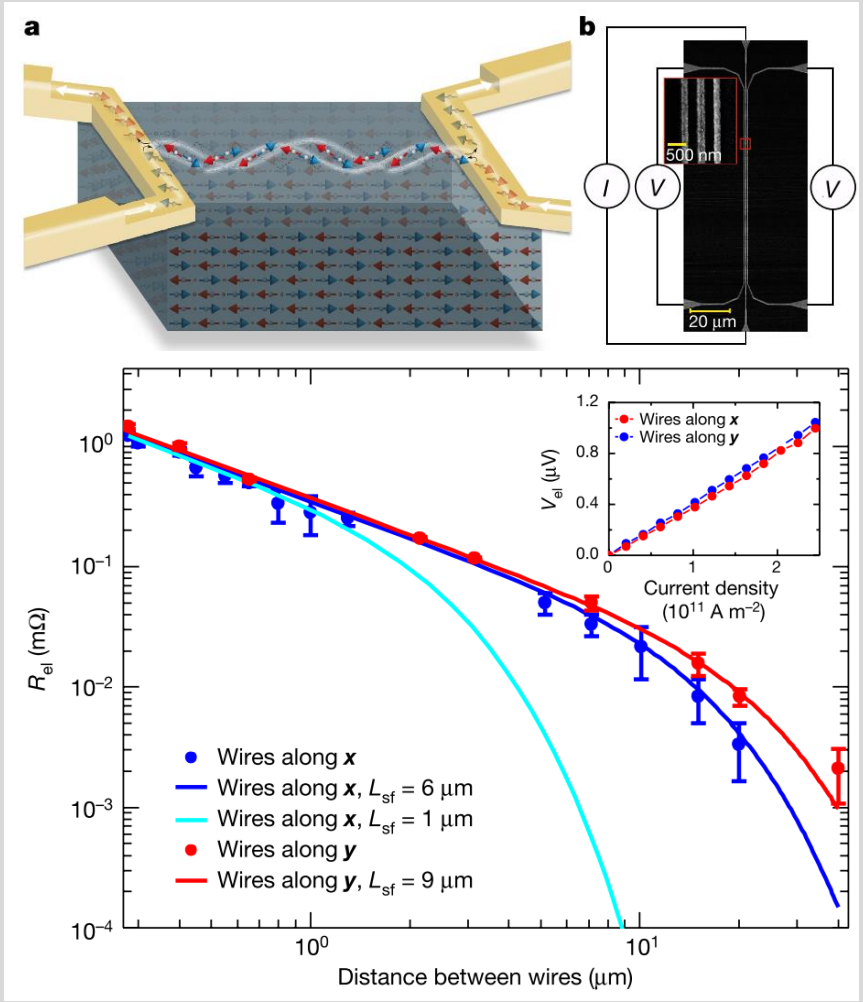
- Introduction to antiferromagnetic α-Fe_2O_3
- Preparation of lifted crystal membranes
- Scanning transmission x-ray microscopy imaging
- Strain modulated AFM domains across bends in lifted membranes
- Systematic strain control of AFM domains

Magnetism 2023
3–4 April 2023
University of Manchester, UK

Introduction to α-Fe_2O_3

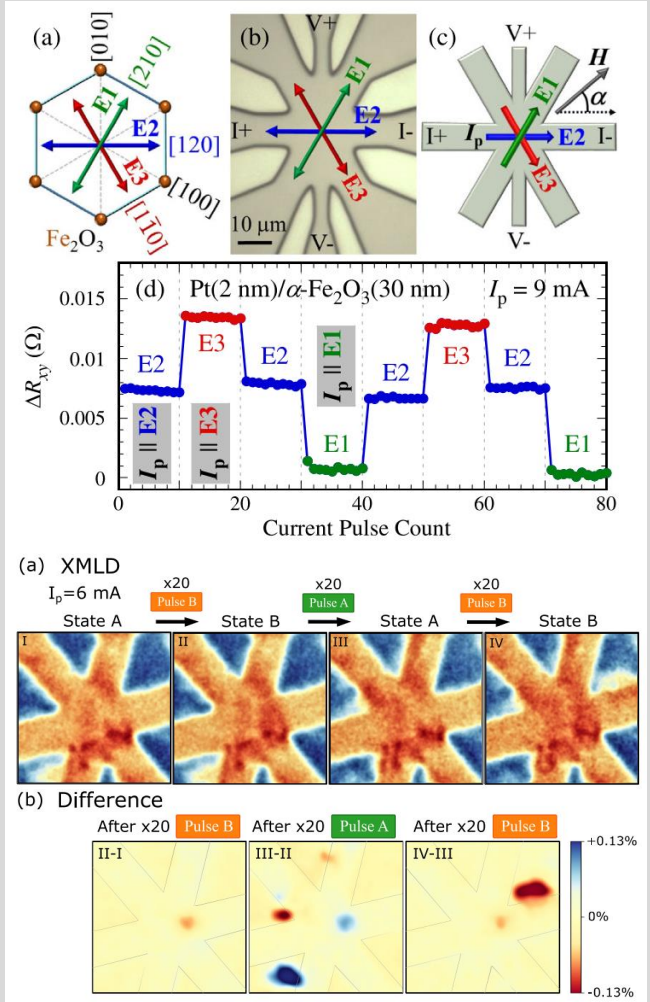
UNIVERSITY OF OXFORD

Relatively long spin diffusion length



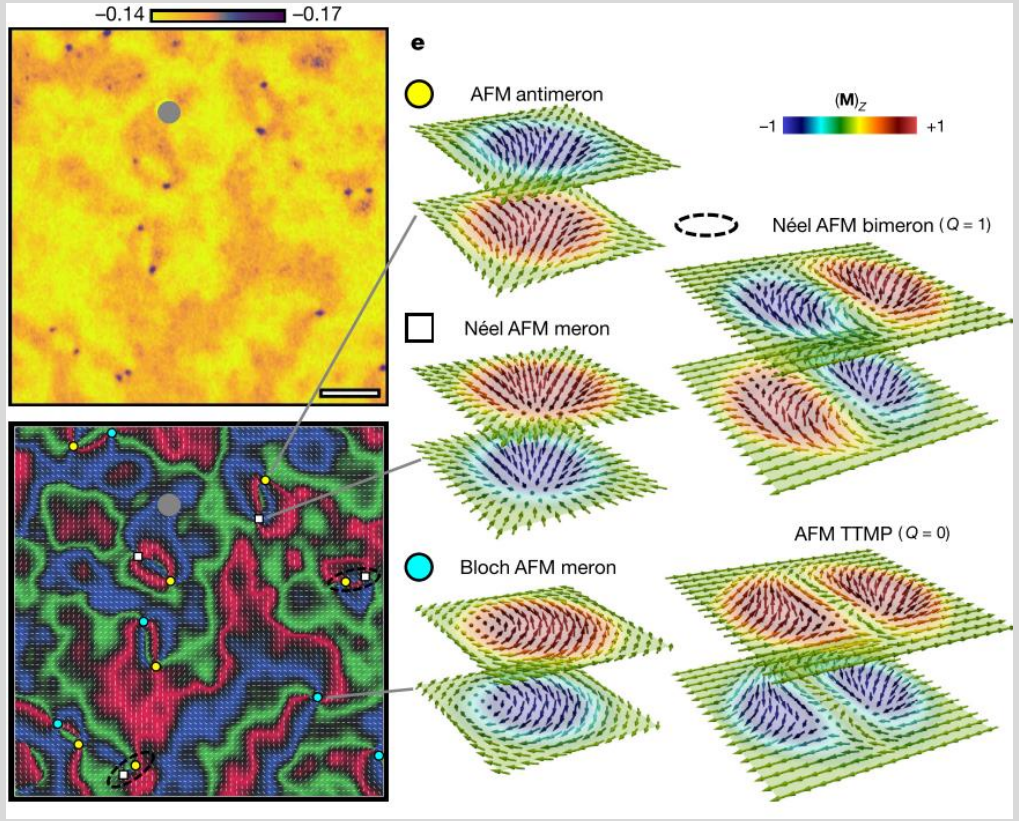
R. Lebrun, et. al., *Nature* **561** (2018), pp. 222–225.
R. Lebrun, et. al., *Nat. Comms.* **11** (2020), p. 6332.

Spin-torque switchable domains



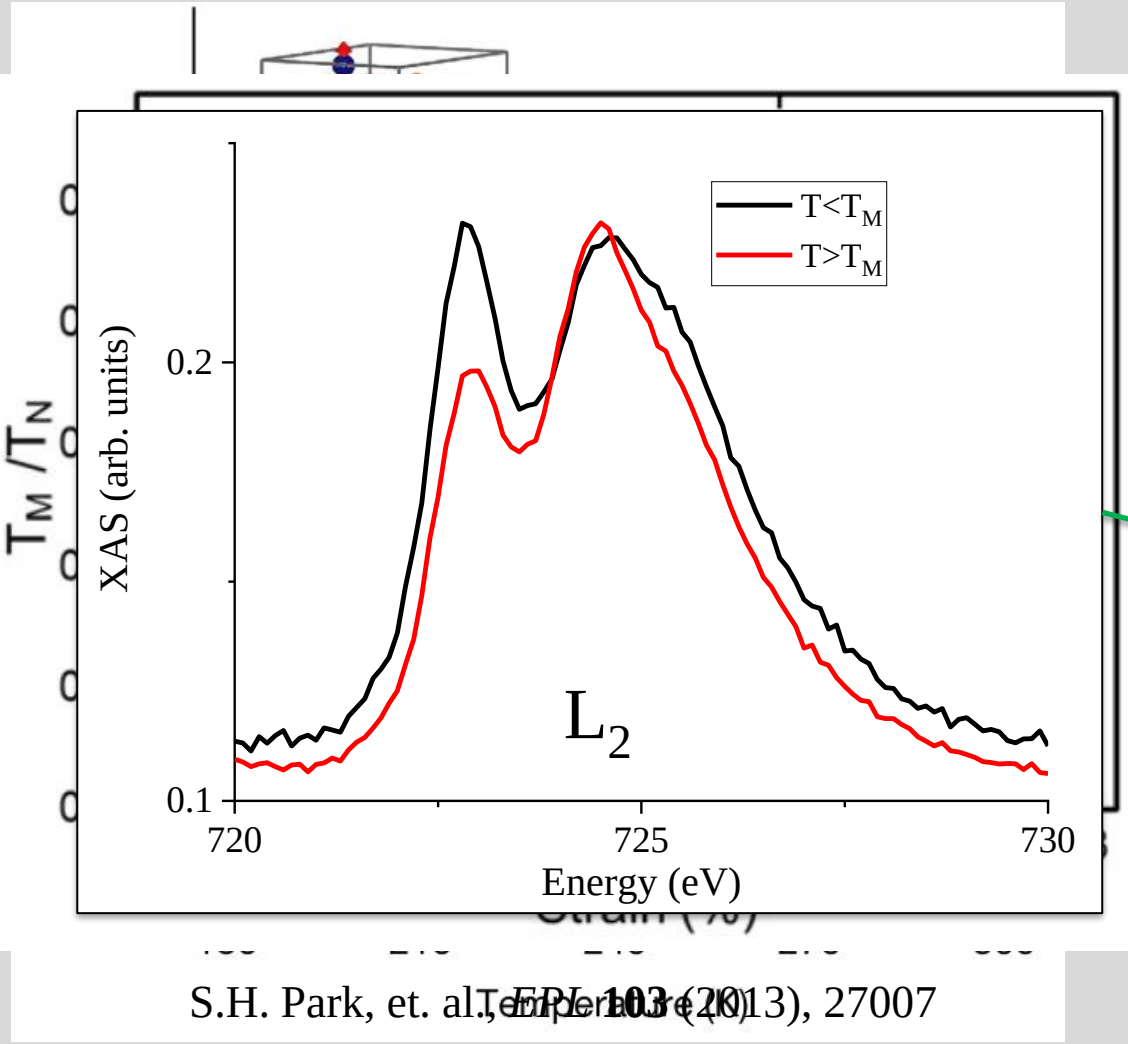
Y. Cheng, et. al., *Phys. Rev. Lett* **124** (2020), 027202
E. Cogulu, et. al., *Phys. Rev. B* ***103*** (2021), L100405

Hosts antiferromagnetic topological textures

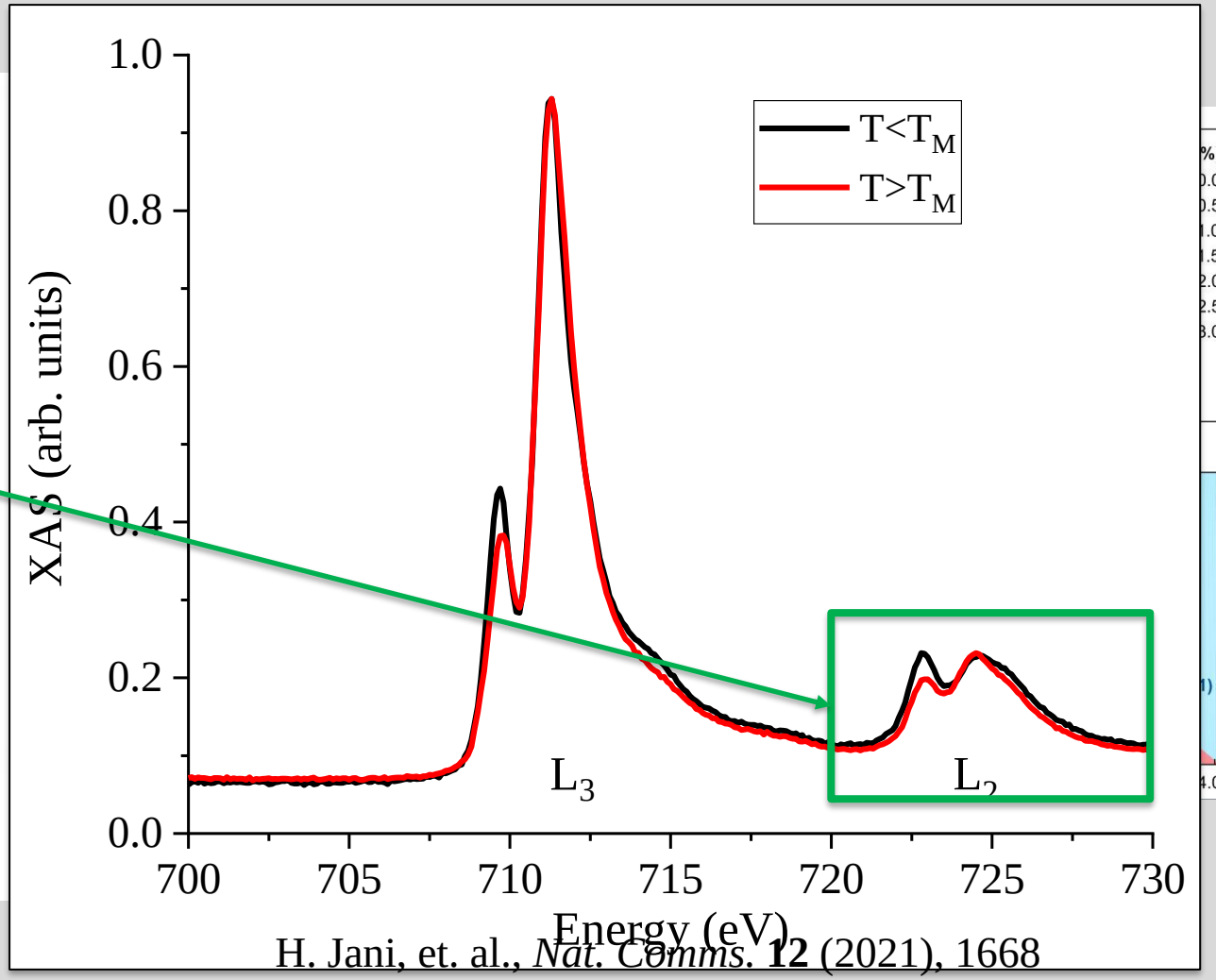


F. Chmiel et. al., *Nat. Mater.* **17** (2018), pp. 581–585.
H. Jani et al., *Nature* **590** (2021), pp. 4–79.
H. Jani, J. Harrison, et. al., preprint *arXiv:2303.03217* (2023).

The Morin Transition



S.H. Park, et. al., *EPL* **103** (2013), 27007

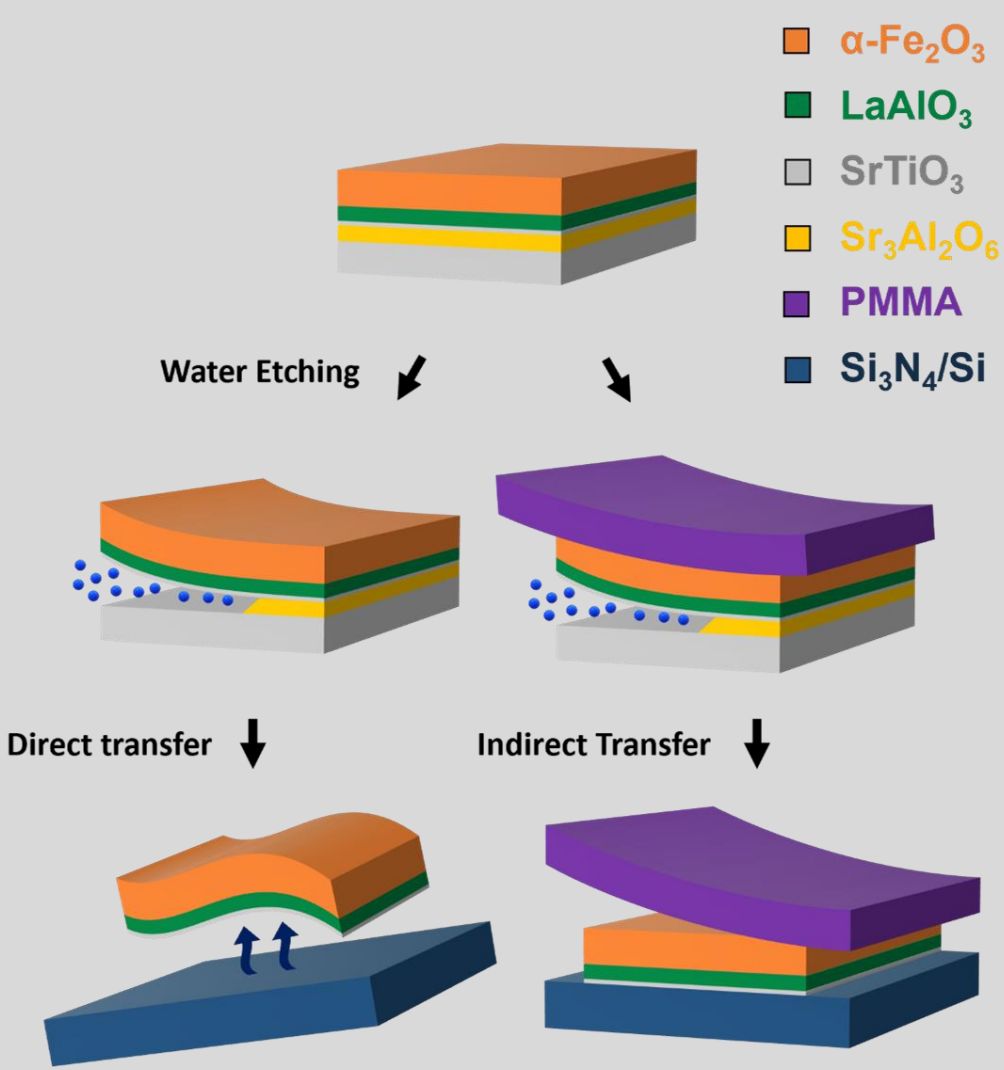


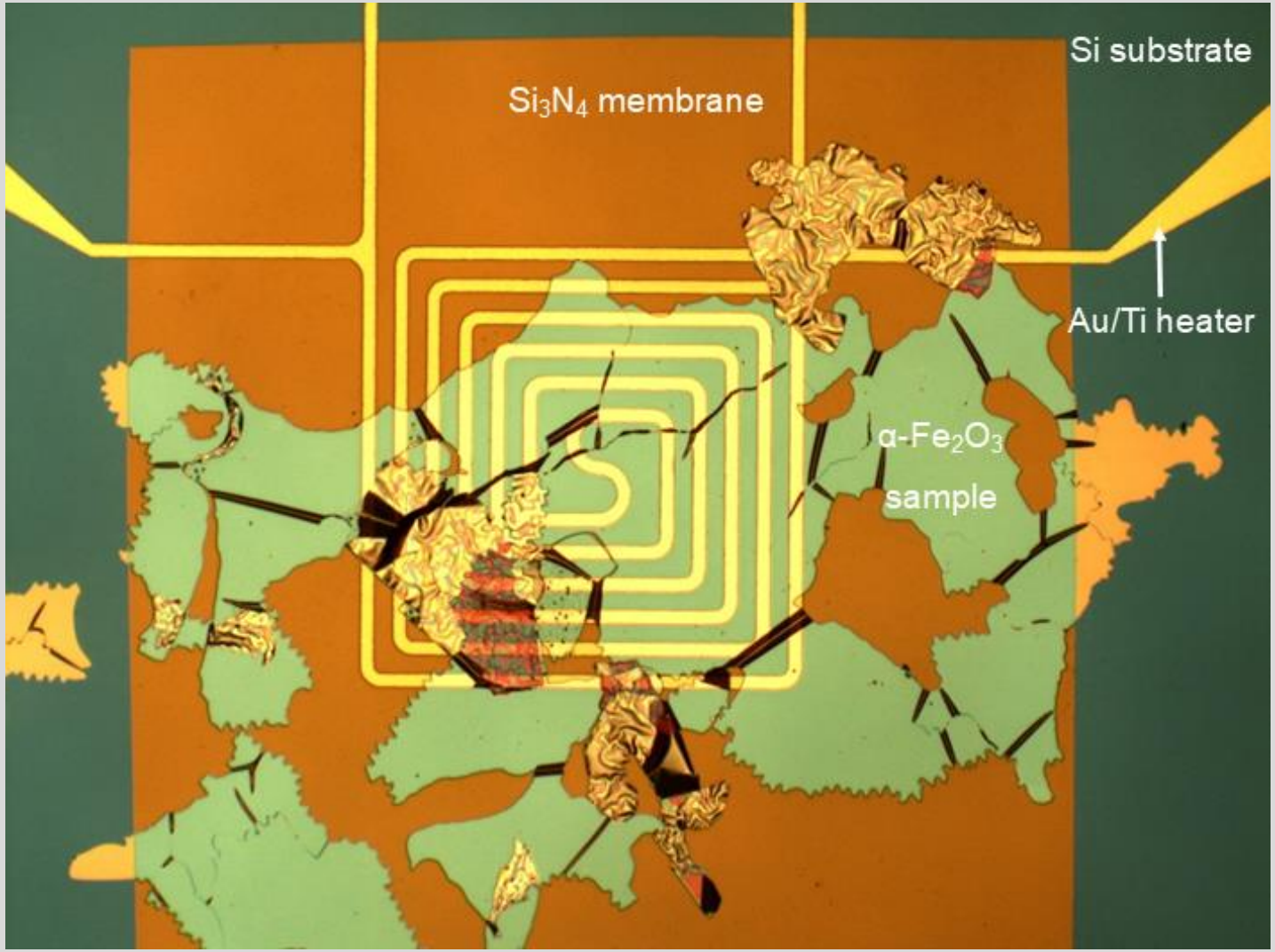
H. Jani, et. al., *Nat. Comms.* **12** (2021), 1668

F. J Morin. *Phys. Rev.* **78** (1950), pp. 819–820.
H. Jani et al., *Nature* **590** (2021), pp. 4–79.

P. Kuiper et. al., *Phys. Rev. Lett.* **70** (1993), 1549-1552

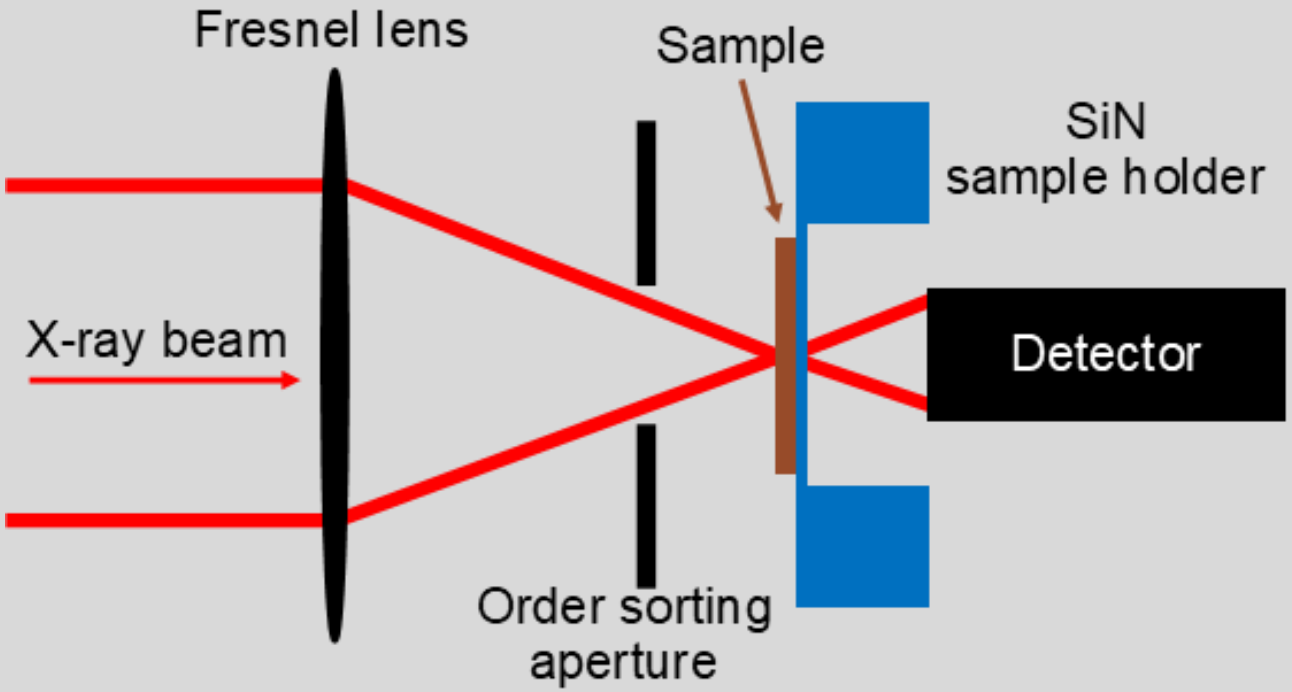
Lifted AFM membranes



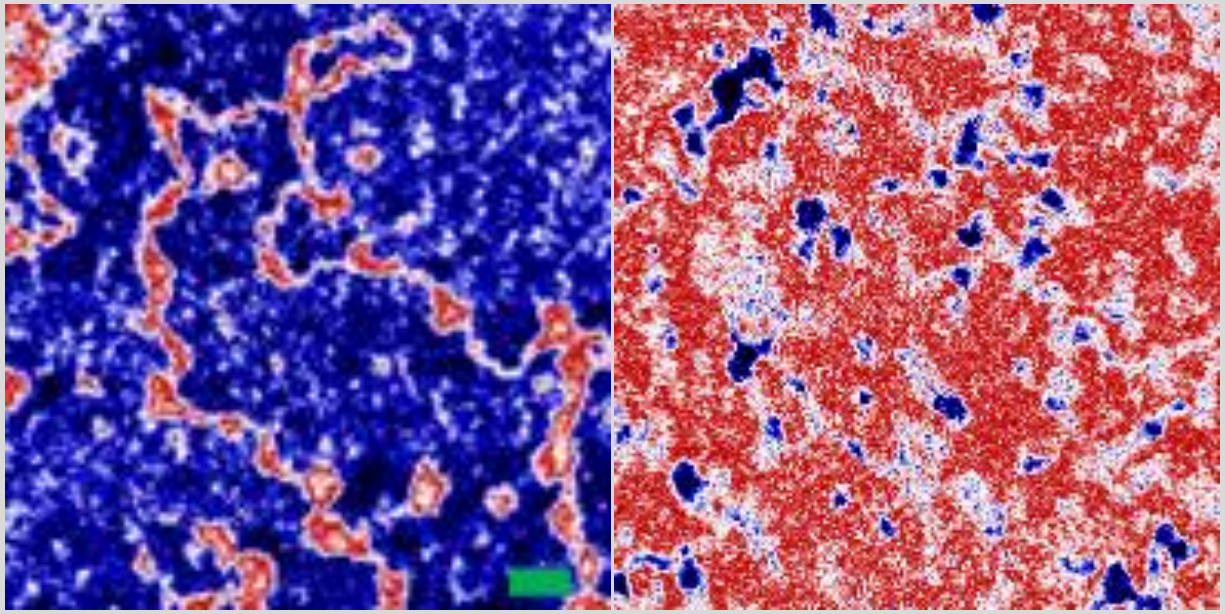


H. Jani, J. Harrison, et. al., preprint *arXiv:2303.03217* (2023).

Scanning Transmission X-ray Microscopy

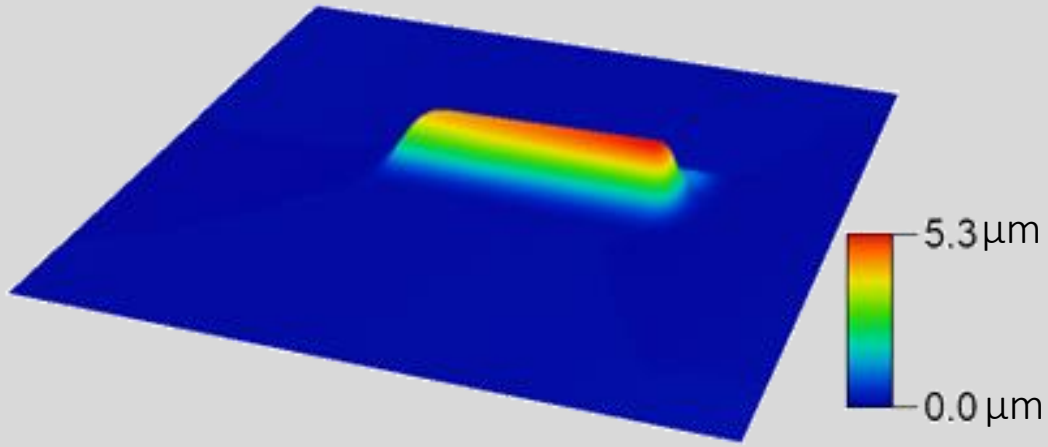


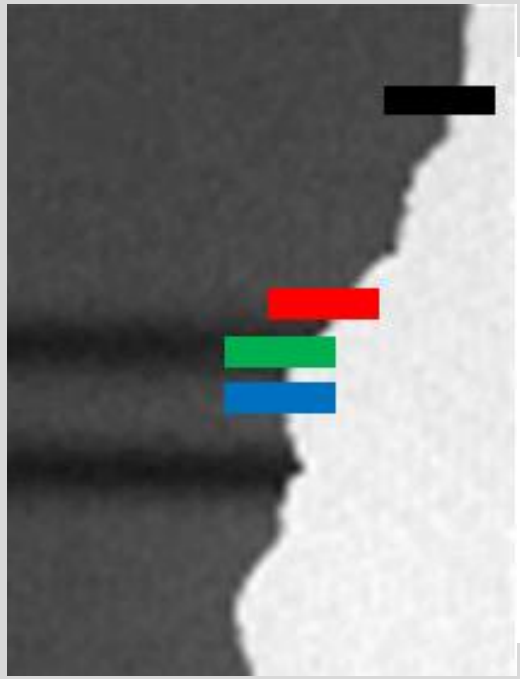
Blue: out-of-plane contrast, Neel vector along c-axis
Red/White: in-plane contrast, Neel vector in a-b plane

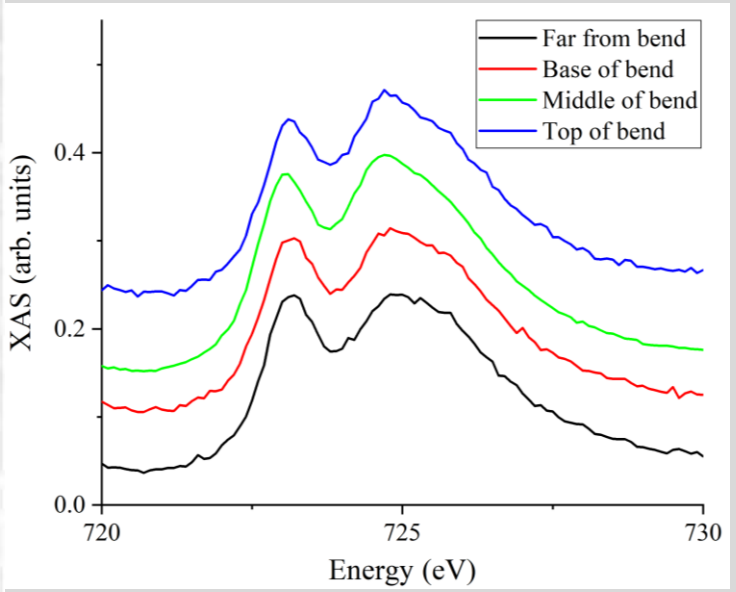


$T<T_M$ $T>T_M$

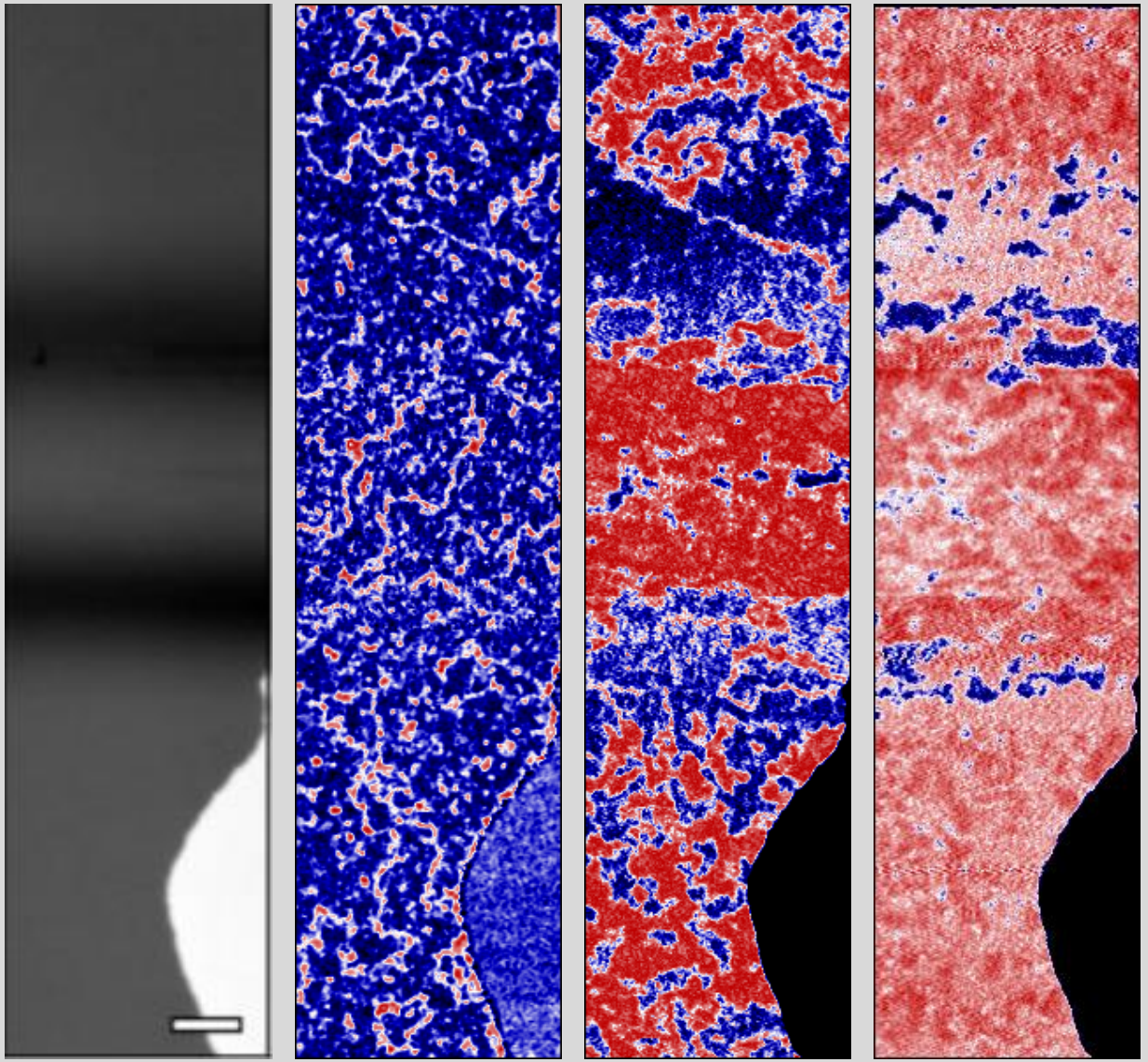
AFM domains across a bend



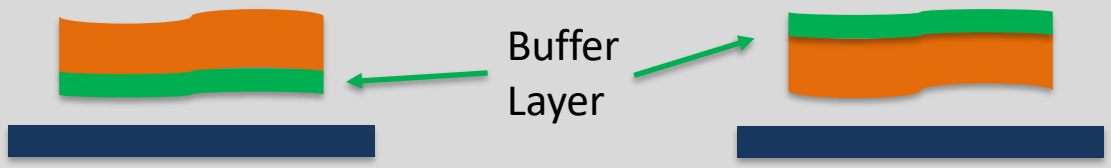


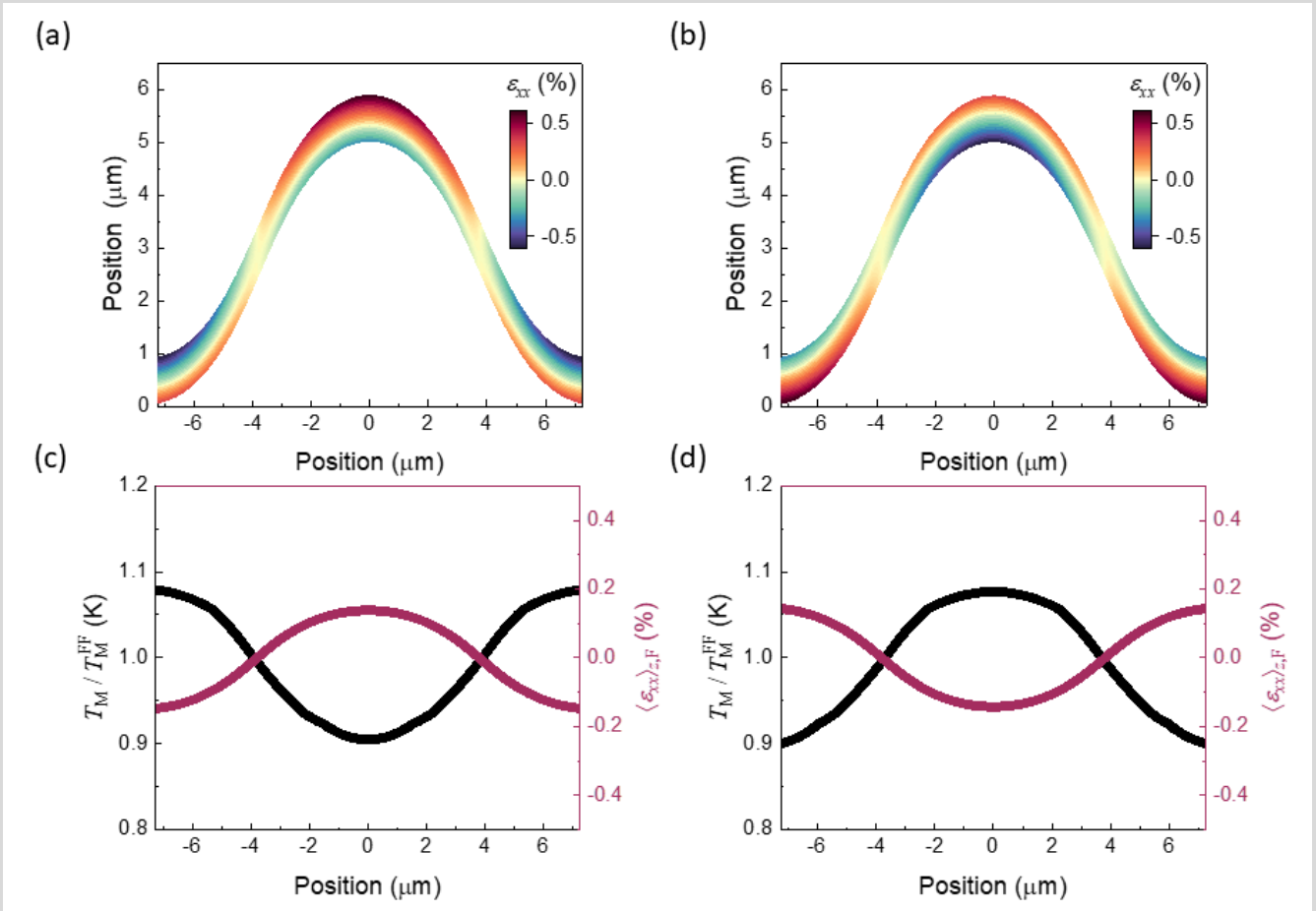


$T<T_M$ $T\approx T_M$ $T>T_M$

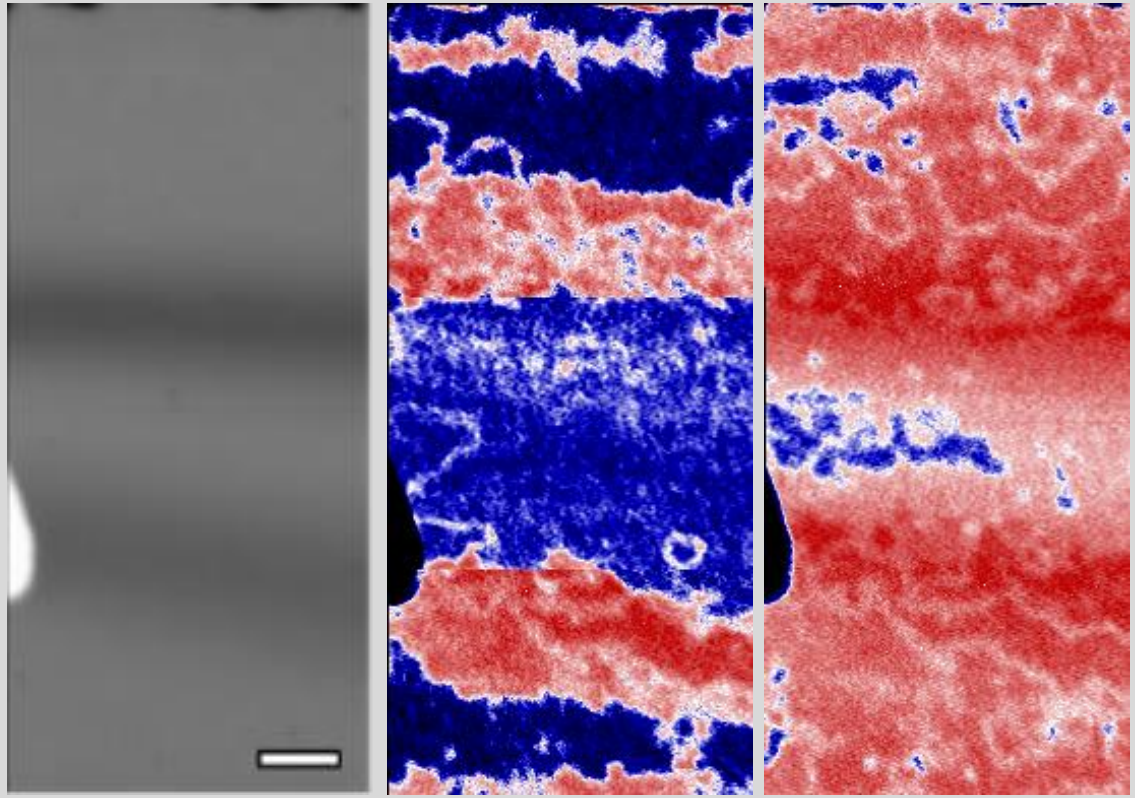


Mechanical model of strain

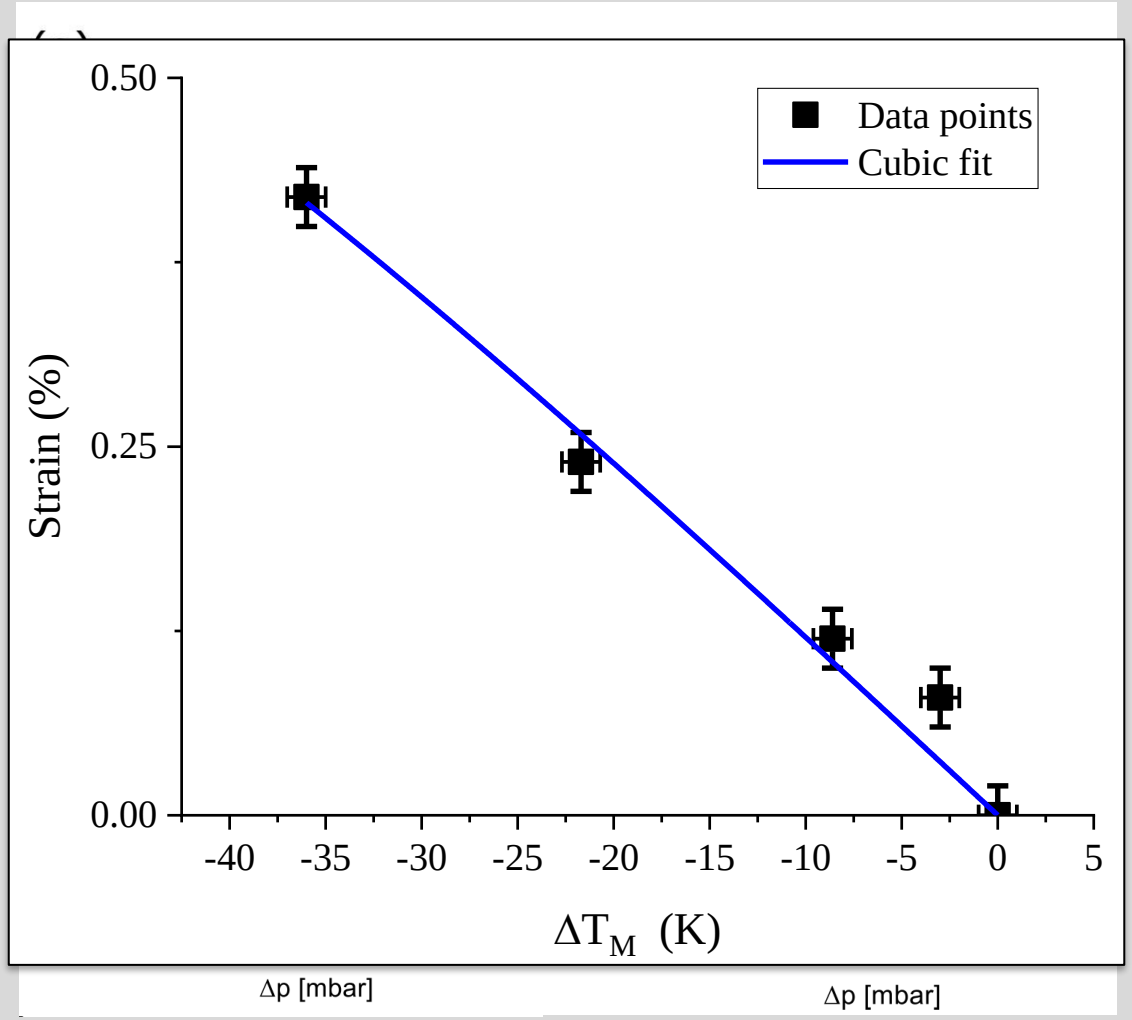


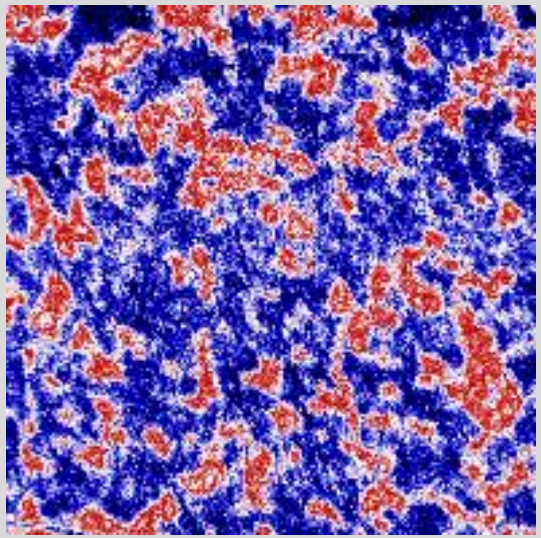


$T \approx T_M$ $T > T_M$

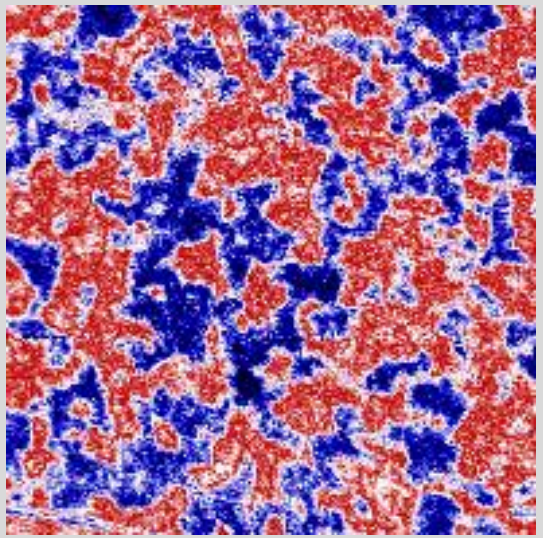


Systematic strain control

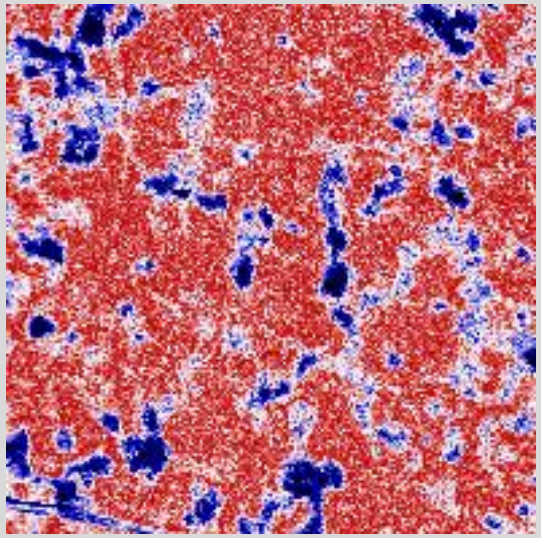




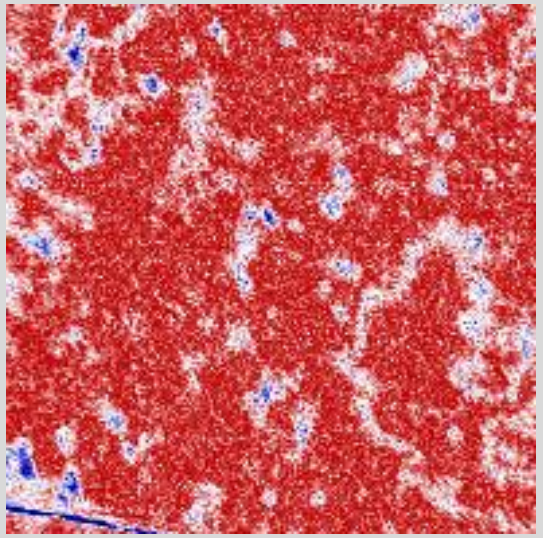
33ºC, 0 mbar



33ºC, 100 mbar

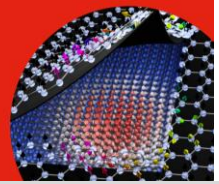


33ºC, 150 mbar



33ºC, 200 mbar

S. Finizio, et. al., *Rev. Sci. Instrum* **87** (2016), 123703
S. Finizio, et. al., *Phys. Rev. B* ***96*** (2017), 054438



Conclusions

- Novel lifted crystal membranes allow for transmission-based experiments with in-situ perturbations.
- Serendipitously formed bends lead to spatial modulation of Morin transition.
- Mechanical model shows membrane strain is the cause of this modulation.
- Systematic strain control of transition temperature demonstrated.

Acknowledgements

UNIVERSITY OF OXFORD

University of Oxford

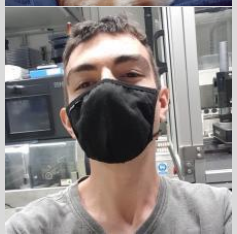
Prof. Paolo Radaelli

Dr. Hariom Jani

Paul Zeng

Jheng-Cyuan Lin

Charlie Godfrey

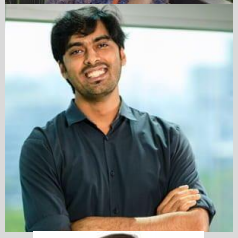


National University of Singapore

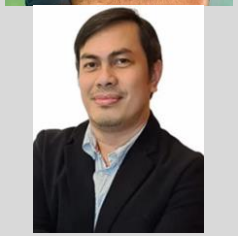
Junxiong Hu

Sonu Hooda

Saurav Prakash

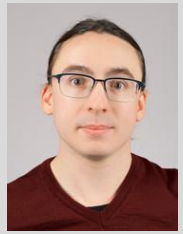


Prof. Ariando



Paul Scherrer Institute

Dr. Simone Finizio



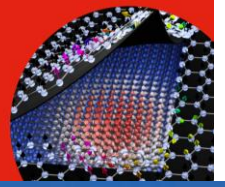
Dr. Jörg Raabe

With thanks to EPSRC for funding my DPhil through DTP scheme

UKRI Engineering and Physical Sciences Research Council

PAUL SCHERRER INSTITUT PSI

Part of this work was performed at the PolLux (X07DA) beamline of the Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland. PolLux endstation was financed by the German Bundesministerium für Bildung und Forschung (BMBF) under contracts 05K16WED and 05K19WE2.



Thank you for listening!

I would be happy to answer any questions you may have.

Contact: jack.harrison@physics.ox.ac.uk