Non-Volatile Voltage Control of Magnetization in magnetostrictive epitaxial FeGa

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The University of Nottingham

Outline

Existing magnetisation Control

Our work : strain control of magnetisation

The way ahead

Introduction

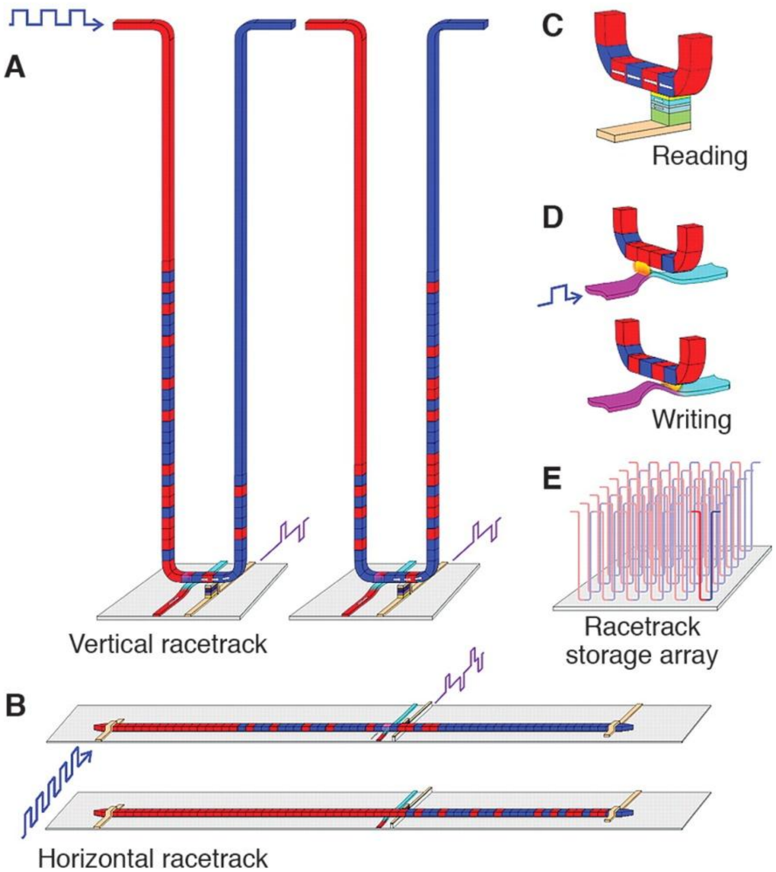
Control of magnetisation is important in many data storage and logic devices.

Techniques involving magnetic fields or electrical currents have limitations.

We use strain to demonstrate non-volatile control of magnetisation in highly magnetostrictive epitaxial FeGa.

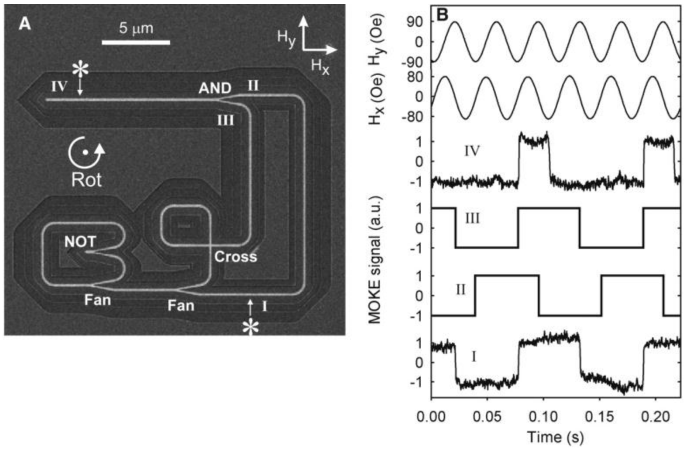
Magnetisation Control

Racetrack memory

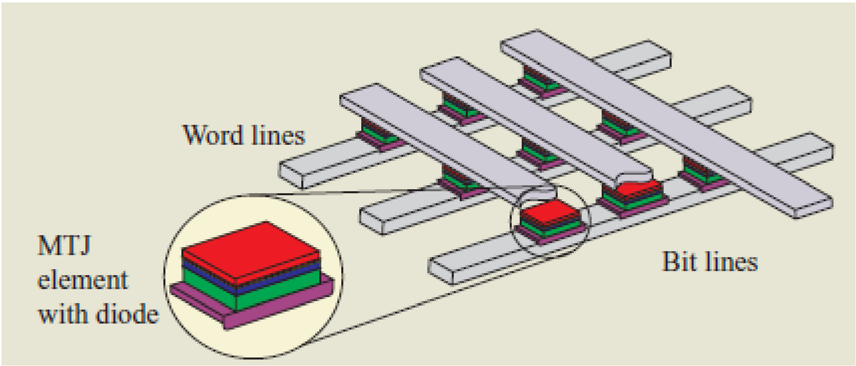


S S P Parkin et al. Science 2008;320:190-194

Domain wall logic



D A Allwood et al. Science 2005;309:1688-1692



MRAM

Gallagher, W.J. and Parkin, S.S.P. IBM J. Res. & Dev. 1, 5 (2006).

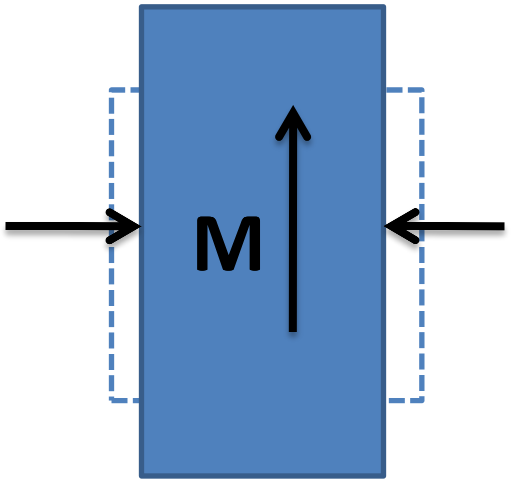
Existing Techniques

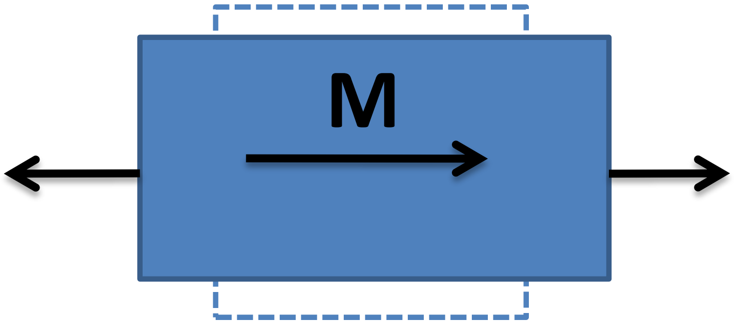
Electrical currents have problems with energy dissipation.

Magnetic fields can also have additional problems due to stray fields.

Control of magnetisation by strain

Compressive strain





Tensile strain

Piezoelectric transducers - electric fields into strain

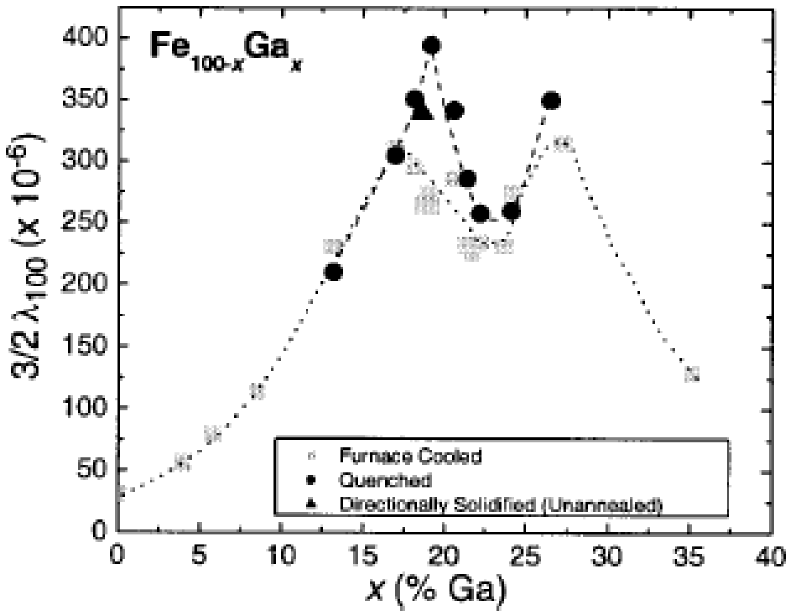
Our work

Voltage-controlled, **non-volatile switching of magnetisation** at room temperature in the absence of magnetic fields.

We exploit the large magnetostriction and biaxial magnetocrystalline anisotropy in epitaxial FeGa

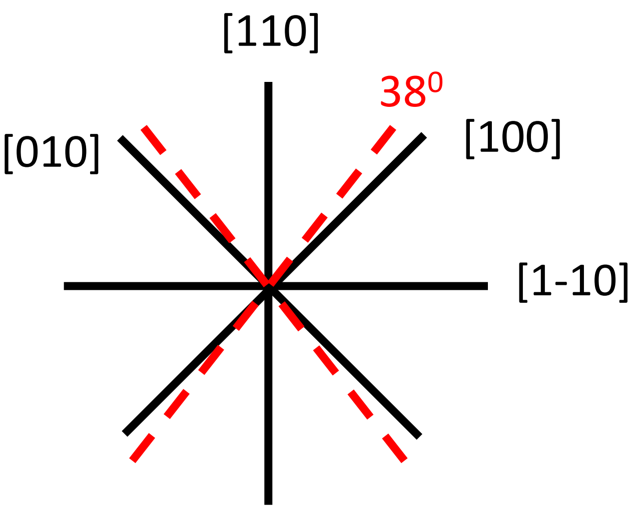
Why use FeGa 'Galfenol'?

Large Magnetostriction



Clark et al., JAP 93, 8621 (2003)
Quench cooled bulk samples

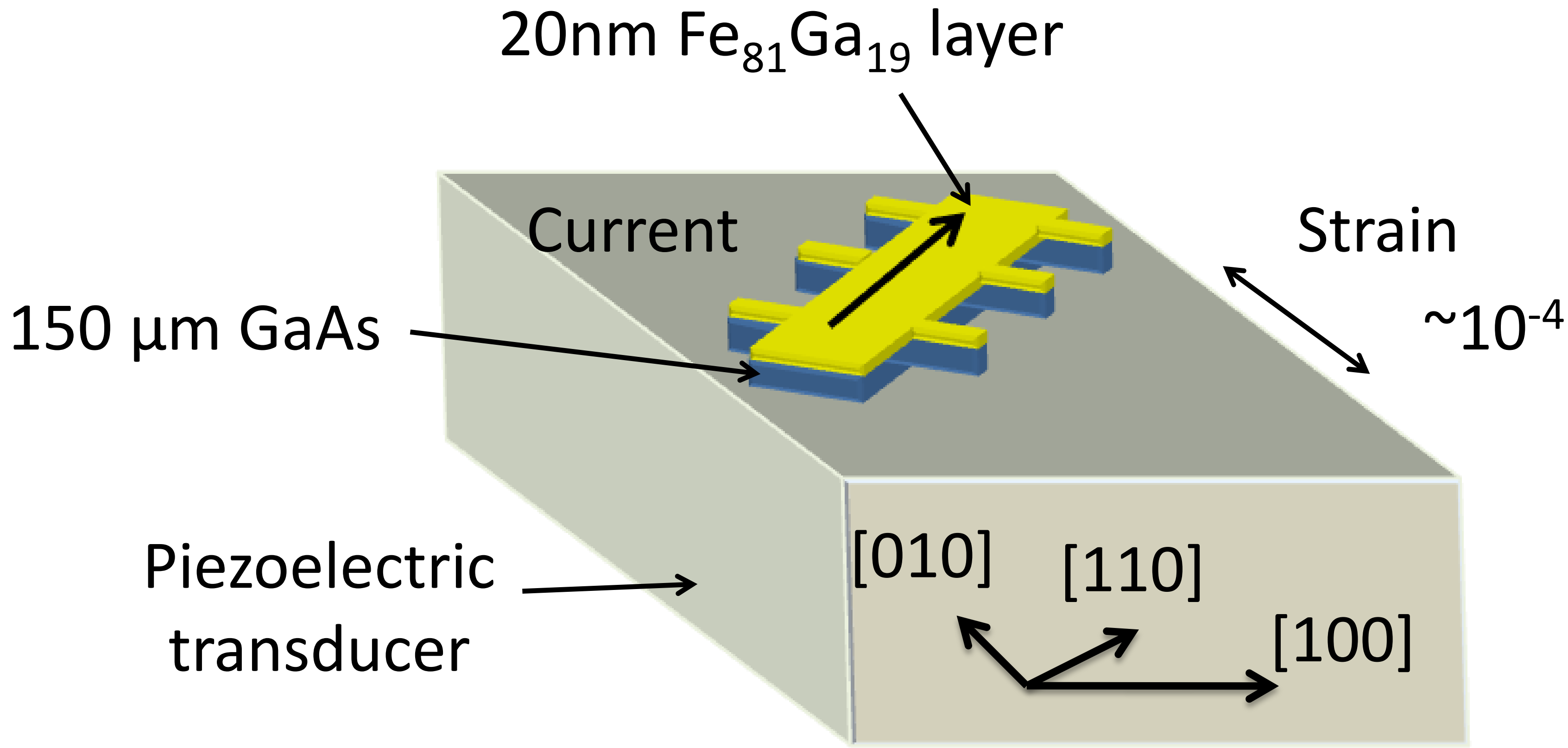
Strong biaxial magnetocrystalline anisotropy



Superconducting quantum interference device (SQUID) magnetometry

Our device

Strain is voltage-controlled via a piezo-electric transducer.



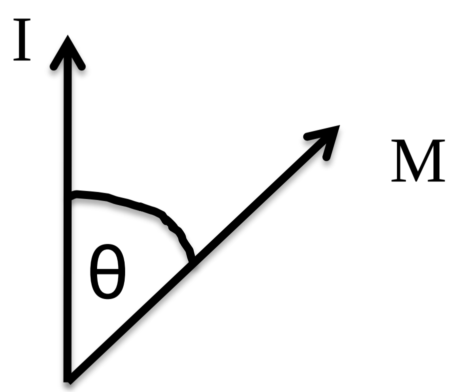
Operating voltage range: -40V to +60V.

Crystal axes

Magnetotransport

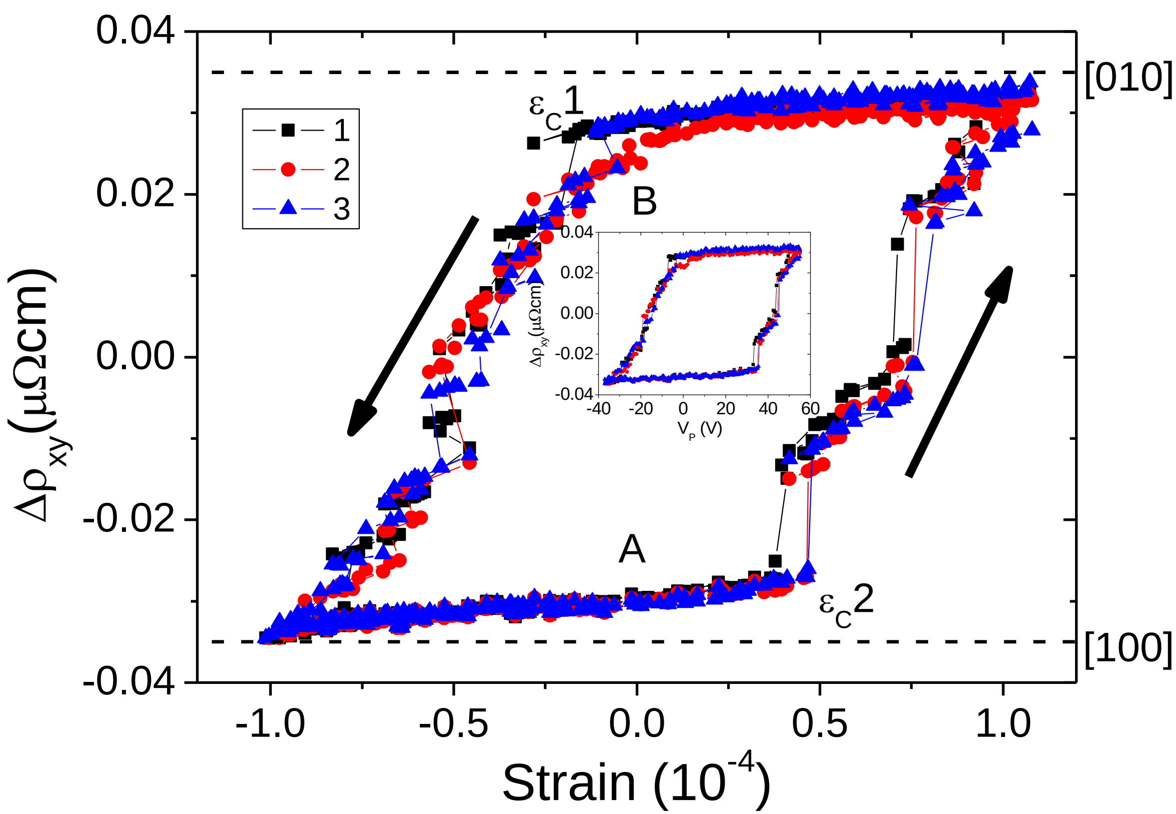
The magnetisation direction is detected by measuring the transverse anisotropic magnetoresistance (AMR)

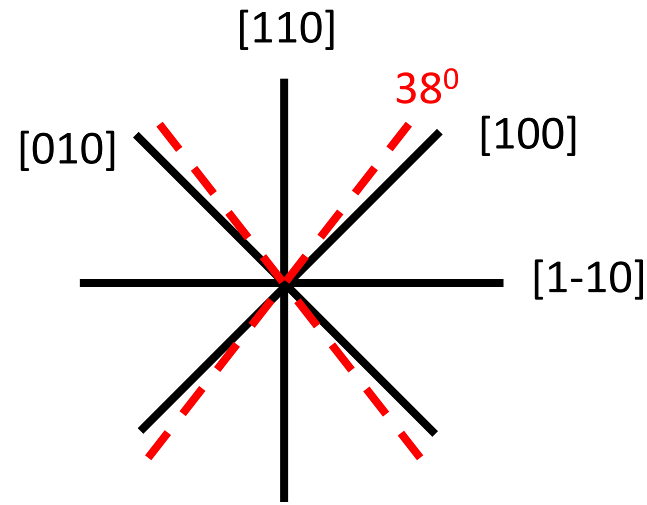
$$\rho_{xy} = \Delta\rho \sin 2\theta$$



where θ is the angle between the magnetisation and the current direction

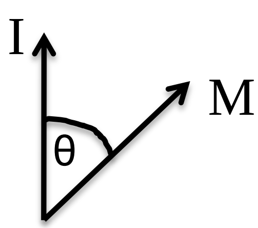
Non-volatile switching





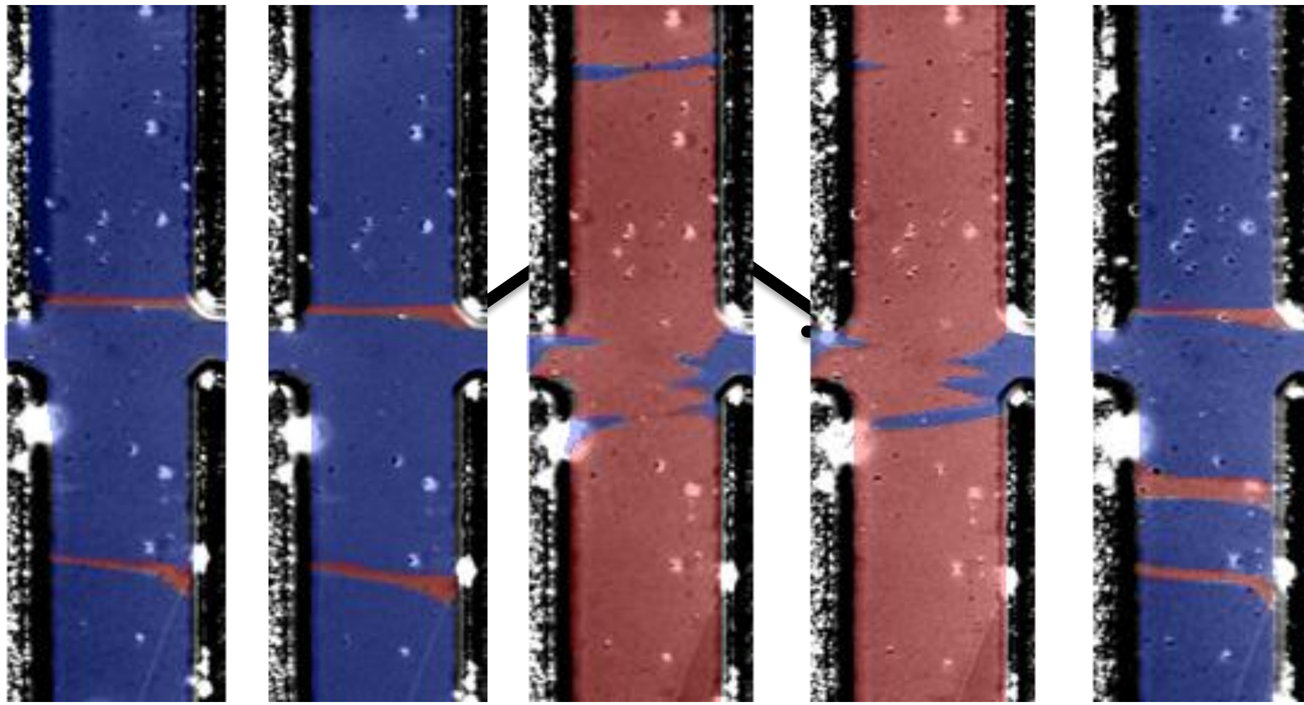
Switch between '[100]' and '[010]'

$$\rho_{xy} = \Delta\rho \sin 2\theta$$



MOKE images

ε = (10^{-5}) -8.0 0.0 +10.8 0.0 -8.0



50µm

Magnetisation direction

Two stable states at zero strain

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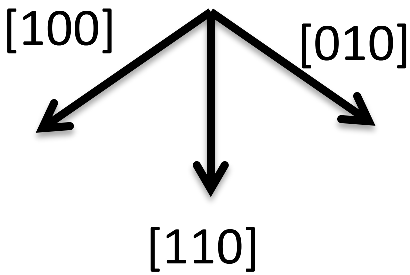
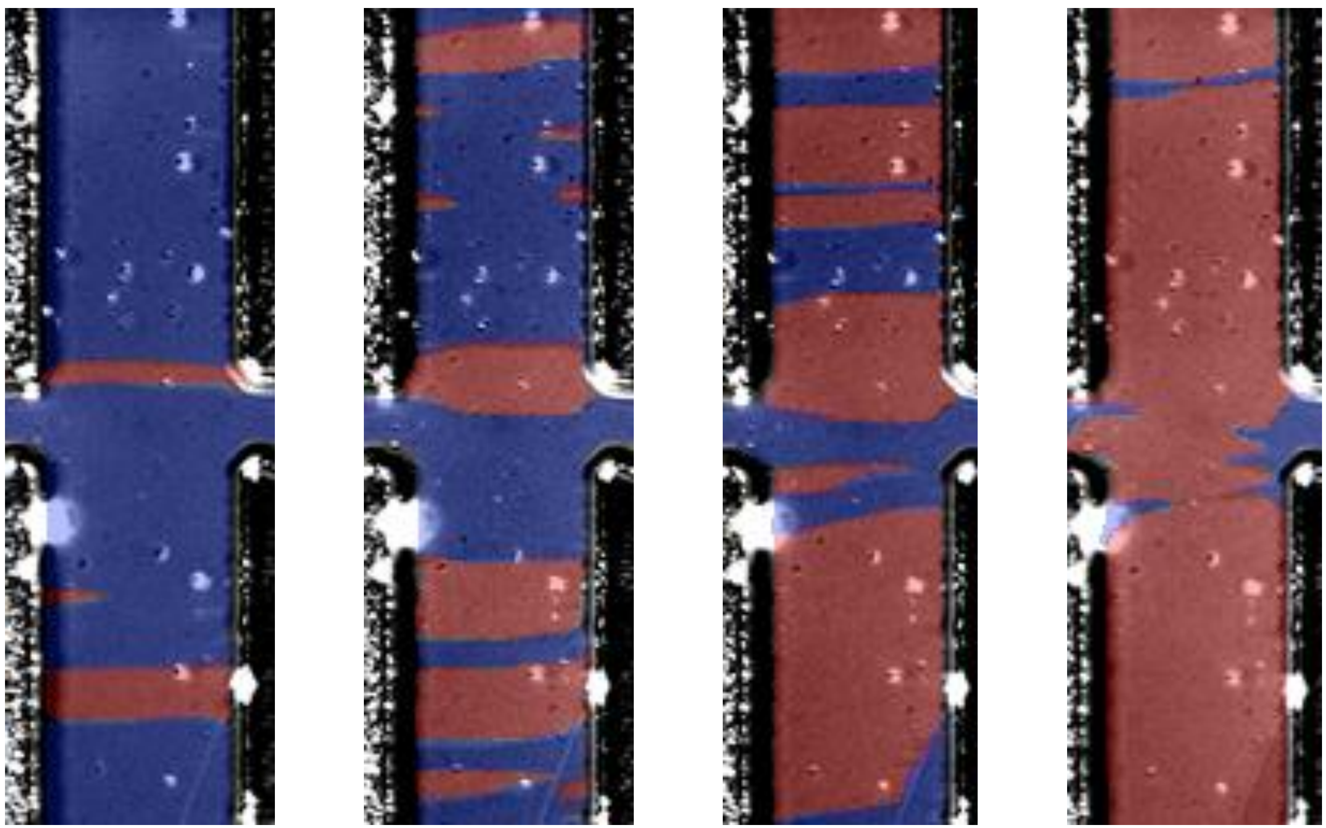
Domain Wall Motion



Magnetisation reversal via domain wall motion

Increasing strain



50µm

Device Considerations

Switching speeds

- Precessional frequency ~ GHz (switching times ~<1ns)
- DW motion: 100nm/ns

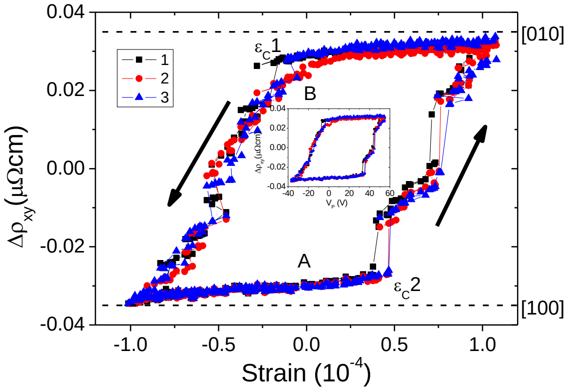
Low power consumption

- ~10mW/cm^2*

* Roy, K et al. APL **99**, 063108 (2011)

Summary

Strain-controlled magnetisation switching



Domain wall motion