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STOKES POLARIMETRY AND MAGNETO OPTICAL PROPERTIES OF NANOSTRUCTURED MATERIALS



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沈铁汉

University of
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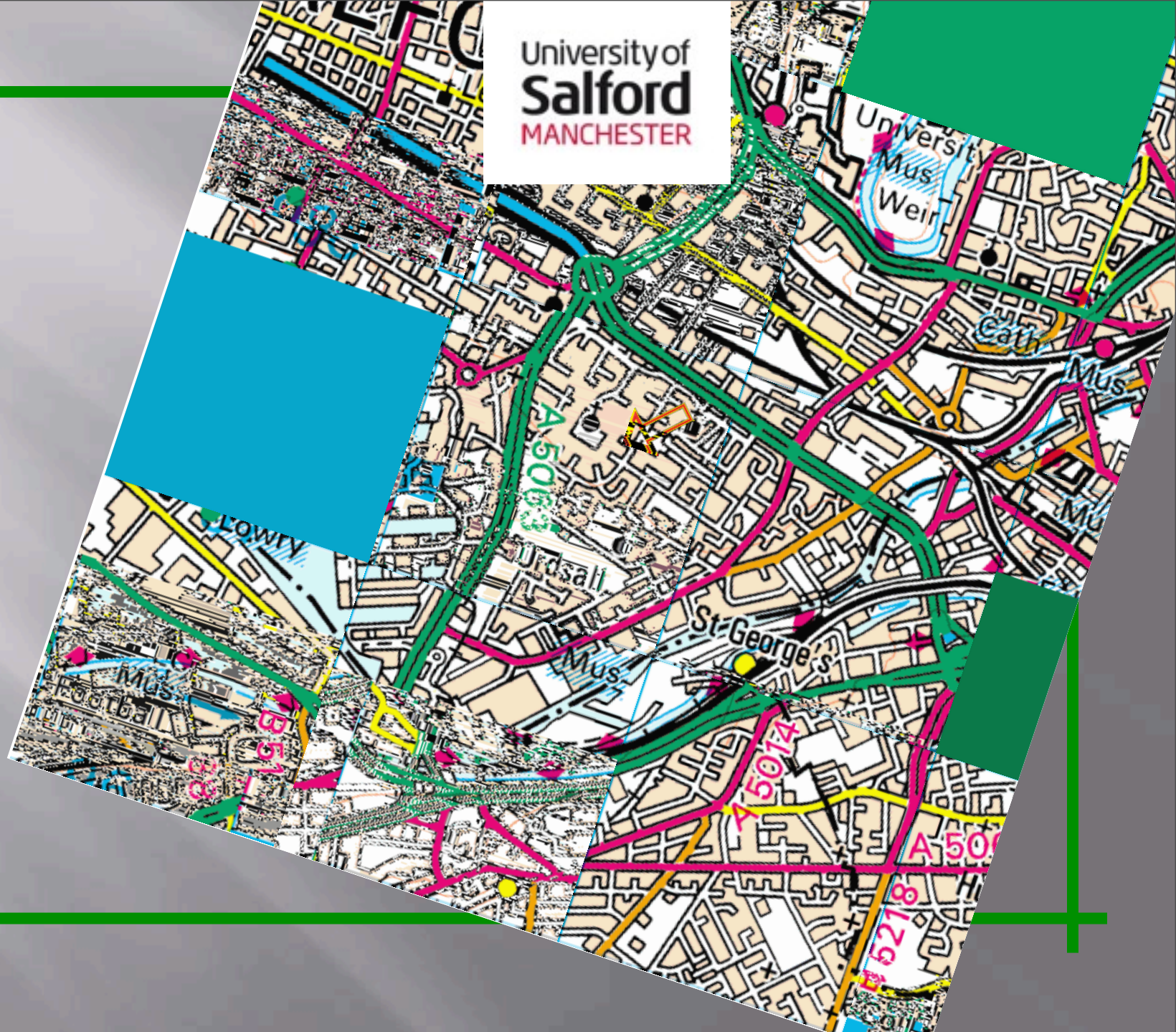
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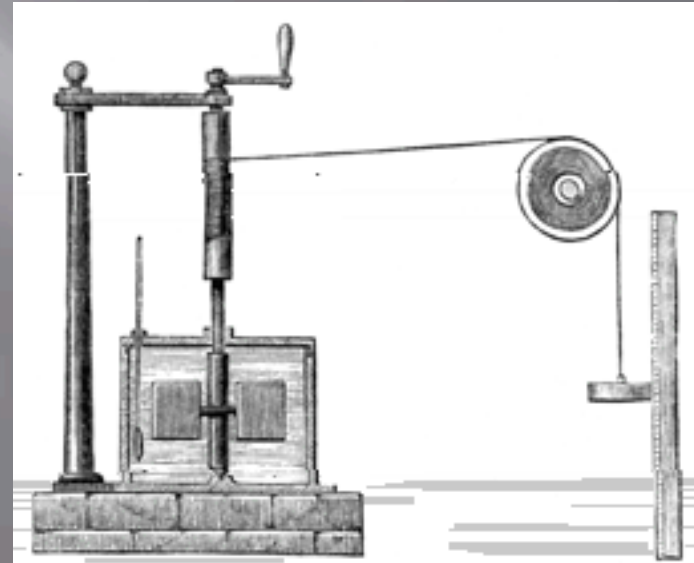


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Joule's contribution to Physics includes:

Heating of a current carrying conductor (Joule heating).
The mechanical equivalent of heat.
Joule-Thomson effect.

The physics laboratory
is name after the great
Salfordian physicist.

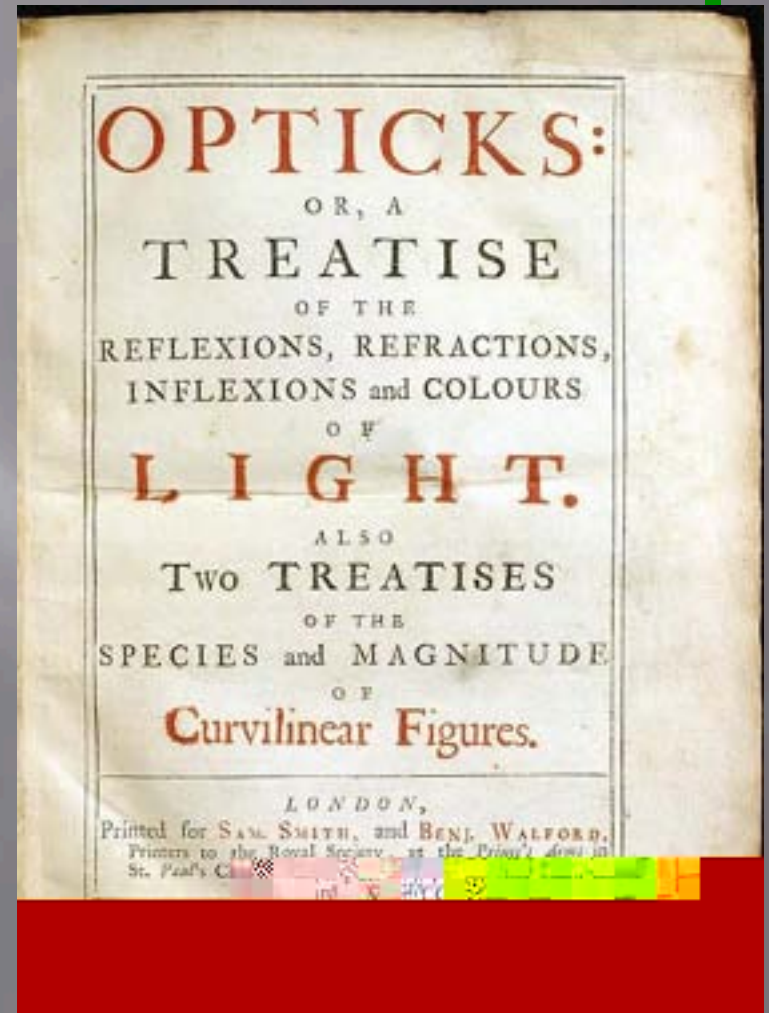


DETERMINATION OF THE STATE OF POLARISATION OF LIGHT

- e ea e e f S e
a a e e



Newton– Opticks: Question 26



the polarisation states of light



polarisation and the handedness of life?



Modern exploration of the polarisation characteristics of light has wide-ranging applications

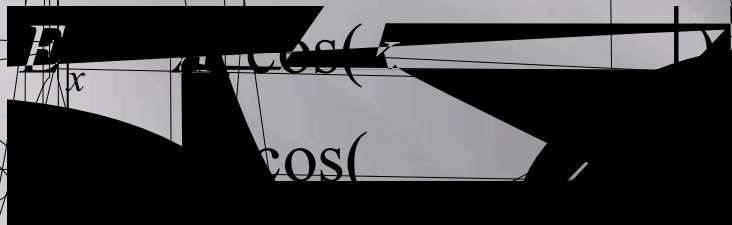


examples of polarisation analysis in the life sciences



Polarisation and Stokes parameters





The Stokes parameters



$$\begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & \cos 2\alpha & \sin 2\alpha & 0 \\ \cos 2\alpha & 1 & 0 & 0 \\ \sin 2\alpha & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

ent... th

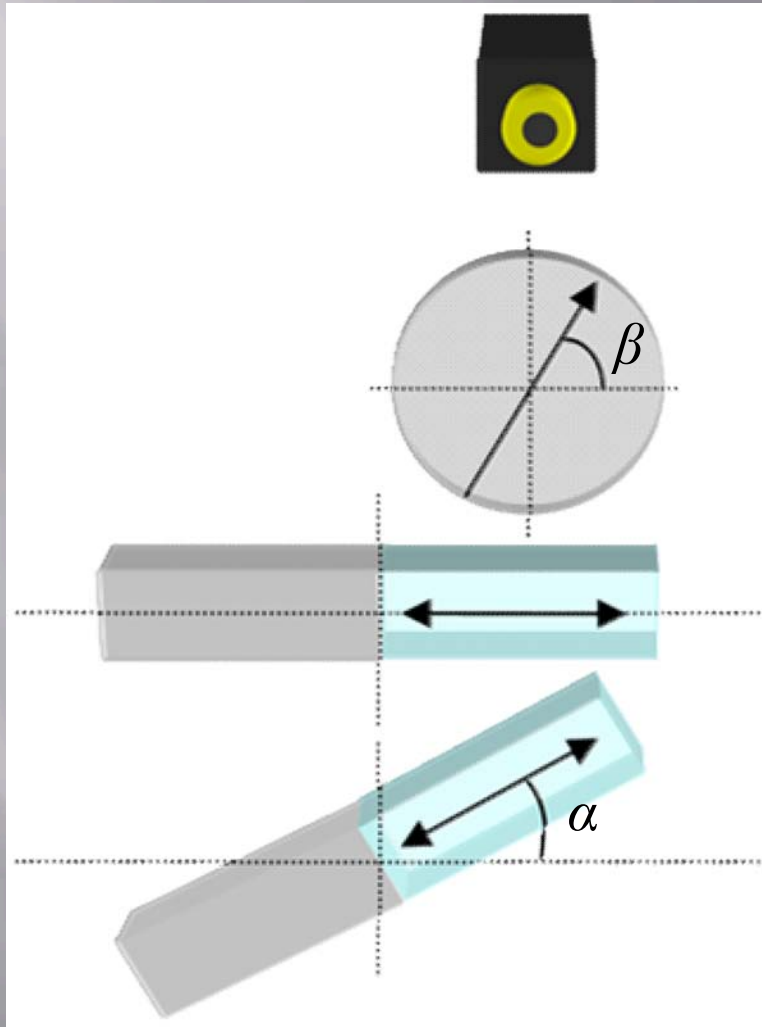
9.

9.

9.

Phase modulation technique





A dual photoelastic modulator (PEM) polarimeter showing the 1st PEM, the 2nd PEM, a polarisation analyser and a photodetector.



α

2 ____

2 ____

2 ____

—

—

—





β

$$M_3 = \frac{1}{2} \begin{pmatrix} 1 & \cos 2\beta & \sin 2\beta & 0 \\ \cos 2\beta & \cos^2 2\beta & \cos 2\beta \sin 2\beta & 0 \\ \sin 2\beta & \cos 2\beta \sin 2\beta & \sin^2 2\beta & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

$$\begin{pmatrix} I' \\ Q' \\ U' \\ V' \end{pmatrix} = M_3 M_2 M_1 \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$



— — 2 —

— 1

— 2 —

— 2

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1 2

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1

2



Dual PEM based method–the basic expansion

$$I' = \left(I + \frac{Q}{\alpha} \right) \text{IUY} (\alpha \text{IUY} (\beta + \frac{U}{\alpha} \text{YOT} * \alpha \text{IUY} (\beta \text{YOT} (\alpha \text{IUY} (\beta \text{EQYOT} (\alpha -U \text{IUY} (\alpha \text{FJ}_{\&} \delta_{\&} \text{YOT} (\alpha \text{YOT} (\beta \text{EQIUY} (\alpha +U \text{YOT} (\alpha \text{FJ}_{\&} \delta_{\&} - \text{IUY} (\alpha \text{YOT} (\beta \text{EQYOT} (\alpha -U \text{IUY} (\alpha \text{FJ}_{\&} \delta_{\&} J_{\&} \delta_{\&} + \alpha \text{YOT} (\alpha \text{YOT} (\beta \text{E}' - J_{\&} \delta_{\&} \text{FEQIUY} (\alpha +U \text{YOT} (\alpha \text{F} + U \text{YOT} (\beta J_{\&} \delta_{\&} b \sum_n J_n \delta_{\&} \text{IUY} n \Omega_{\&} t + \text{EYOT} (\alpha \text{IUY} (\beta - \text{IUY} (\alpha \text{YOT} (\beta J_{\&} \delta_{\&} \text{FEQYOT} (\alpha -U \text{IUY} (\alpha \text{F} \sum_n J_n \delta_{\&} \text{IUY} n \Omega_{\&} t \mp \text{YOT} (\beta \text{EQYOT} (\alpha -U \text{IUY} (\alpha \text{F} \sum_m \sum_{m_{\&}} J_m \delta_{\&} J_{m_{\&}} \delta_{\&} \text{IUYE} m \Omega_{\&} \pm m_{\&} \Omega_{\&} t \text{F} - \text{IUY} (\alpha \text{YOT} (\beta \text{EQYOT} (\alpha -U \text{IUY} (\alpha \text{F} \sum_n \sum_{n_{\&}} J_n \delta_{\&} J_{n_{\&}} \delta_{\&} \text{IUYE} n \Omega_{\&} \pm n_{\&} \Omega_{\&} t \text{F} + V \text{YOT} (\beta J_{\&} \delta_{\&} \sum_m J_m \delta_{\&} \text{YOT} m \Omega_{\&} t + V [\text{IUY} (\alpha \text{YOT} (\beta J_{\&} \delta_{\&} - \text{YOT} (\alpha \text{IUY} (\beta \sum_m J_m \delta_{\&} \text{YOT} m \Omega_{\&} t + V \text{IUY} (\alpha \text{YOT} (\beta \sum_m \sum_n J_m \delta_{\&} J_n \delta_{\&} \text{YOTE} m \Omega_{\&} \pm n \Omega_{\&} t \text{F} \pm V \text{YOT} (\beta \sum_n \sum_m J_n \delta_{\&} J_m \delta_{\&} \text{YOTE} n \Omega_{\&} \pm m \Omega_{\&} t \text{F} \end{array} \right. \quad \begin{array}{l} 1-3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \end{array}$$



TABLE I. Frequencies of angular variables to determine the Stokes parameters for different cases.

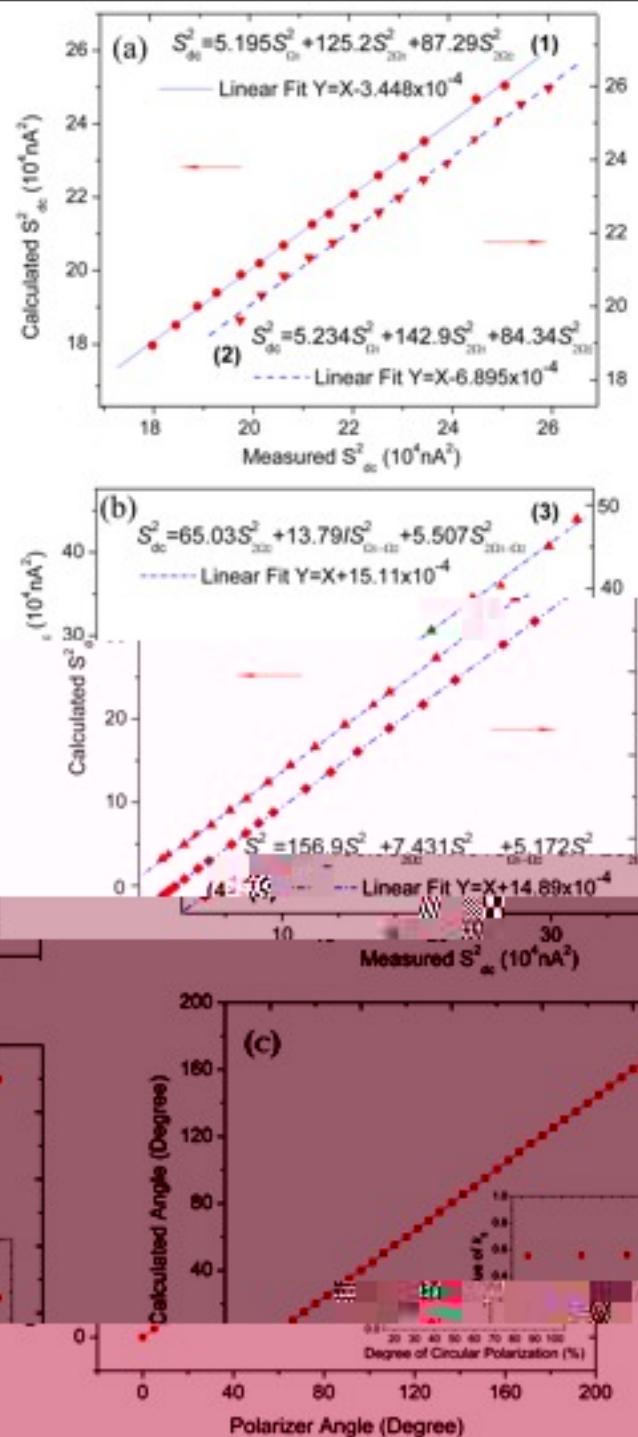
Case	Condition	I	Q	U	V
I	$\alpha=45^\circ$, β =arbitrary [$\sin(2\beta) \neq 0$]	dc	$2\Omega_1 [\cos(2\beta) \neq 0]$ or $\Omega_1 \pm \Omega_2$	$2\Omega_2$	$\Omega_1 [\cos(2\beta) \neq 0]$ or $2\Omega_1 \pm \Omega_2$
II	$\beta=45^\circ$, α =arbitrary [$\sin(2\alpha) \neq 0$]	dc	$2\Omega_2$ and $2\Omega_1 \pm 2\Omega_2 [\cos(2\alpha) \neq 0]$ or $2\Omega_2$ and $\Omega_1 \pm \Omega_2$		$\Omega_1 \pm 2\Omega_2 [\cos(2\alpha) \neq 0]$ or $2\Omega_1 \pm \Omega_2$

TABLE II. Frequencies of signals, re.  determine the Stokes parameters in special cases where both angular variables are specified.

Case	α (deg)	β (deg)	I	Q	U	V
a	45	22.5	dc	$2\Omega_1$	$2\Omega_2$	Ω_1
b	45	45	dc	$\Omega_1 \pm \Omega_2$	$2\Omega_2$	$2\Omega_1 \pm \Omega_2$
c	22.5	45	dc	$2\Omega_2$ and $2\Omega_1 \pm 2\Omega_2$		$2\Omega_1 \pm \Omega_2$

calibration

$$I^2 = Q^2 + U^2 + V^2$$



calibration matrix

$$I_{dc} = c \cdot I + c_{(} Q + c_{)} U$$

$$I_{QU^{+}} = c_{*} Q + c_{+} U$$

$$I_{QU^{(}} = c_{,} Q + c_{-} U$$

$$I_V = c_{\cdot} V$$

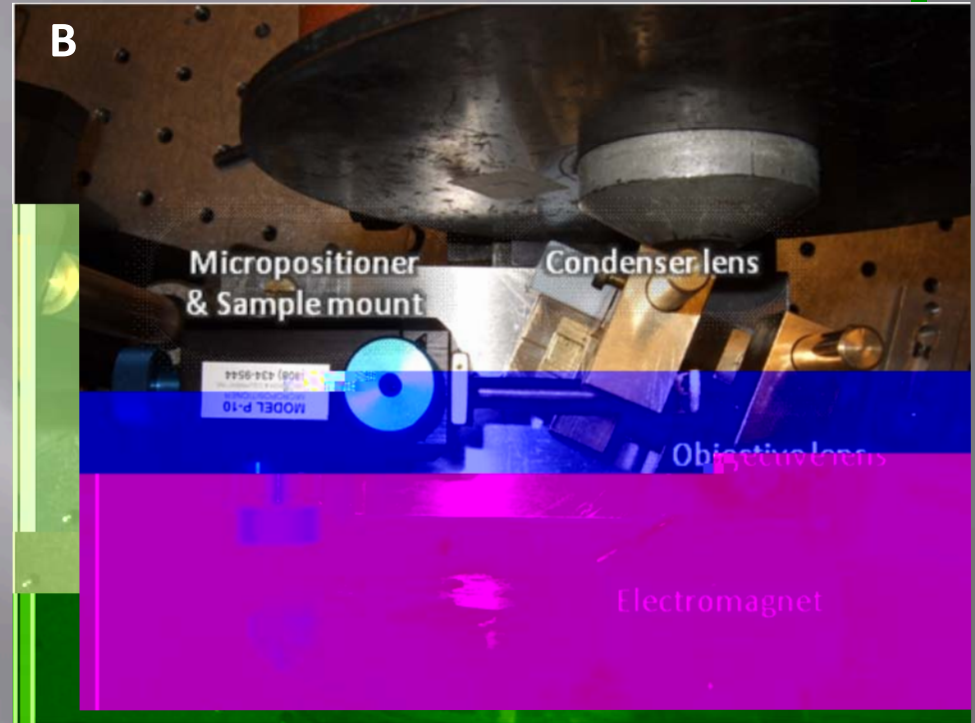
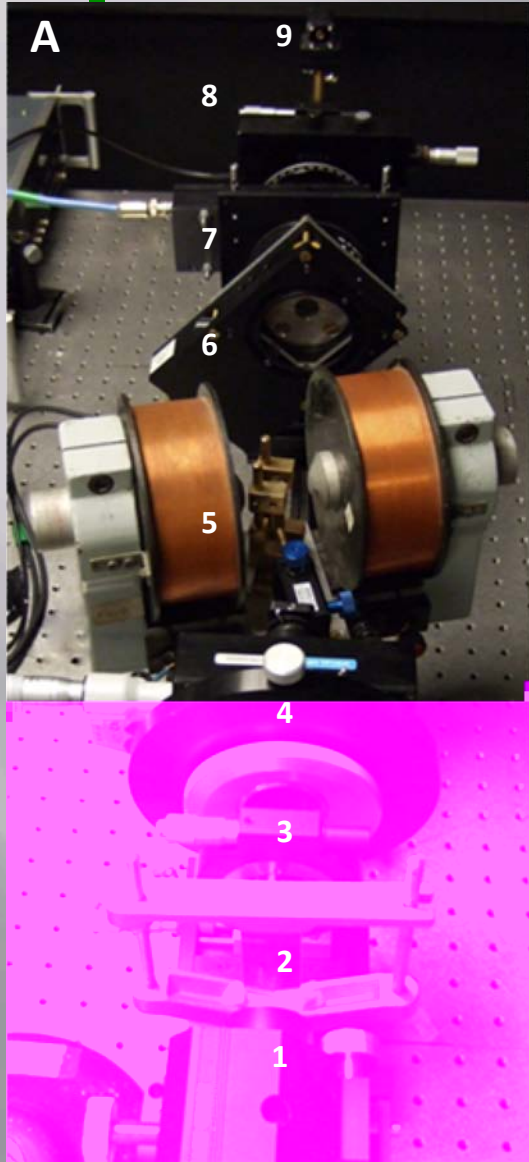


calibration matrix

$$\begin{pmatrix} \cdot \\ \cdot \\ \cdot \end{pmatrix} = \begin{pmatrix} \cdot \\ \cdot \\ \cdot \end{pmatrix}$$

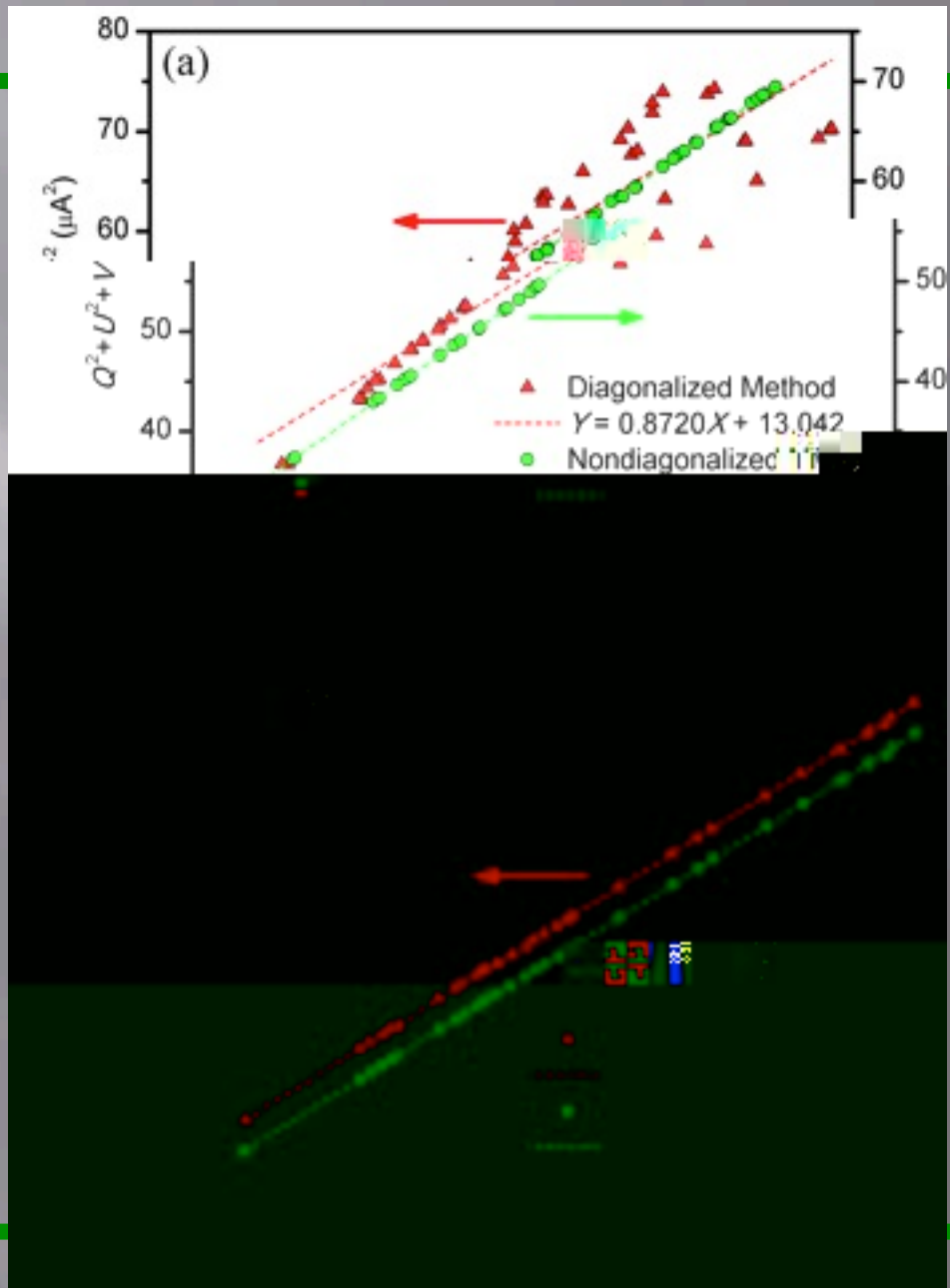
A practical magneto optical Stokes polarimeter

A practical magneto optical Stokes polarimeter



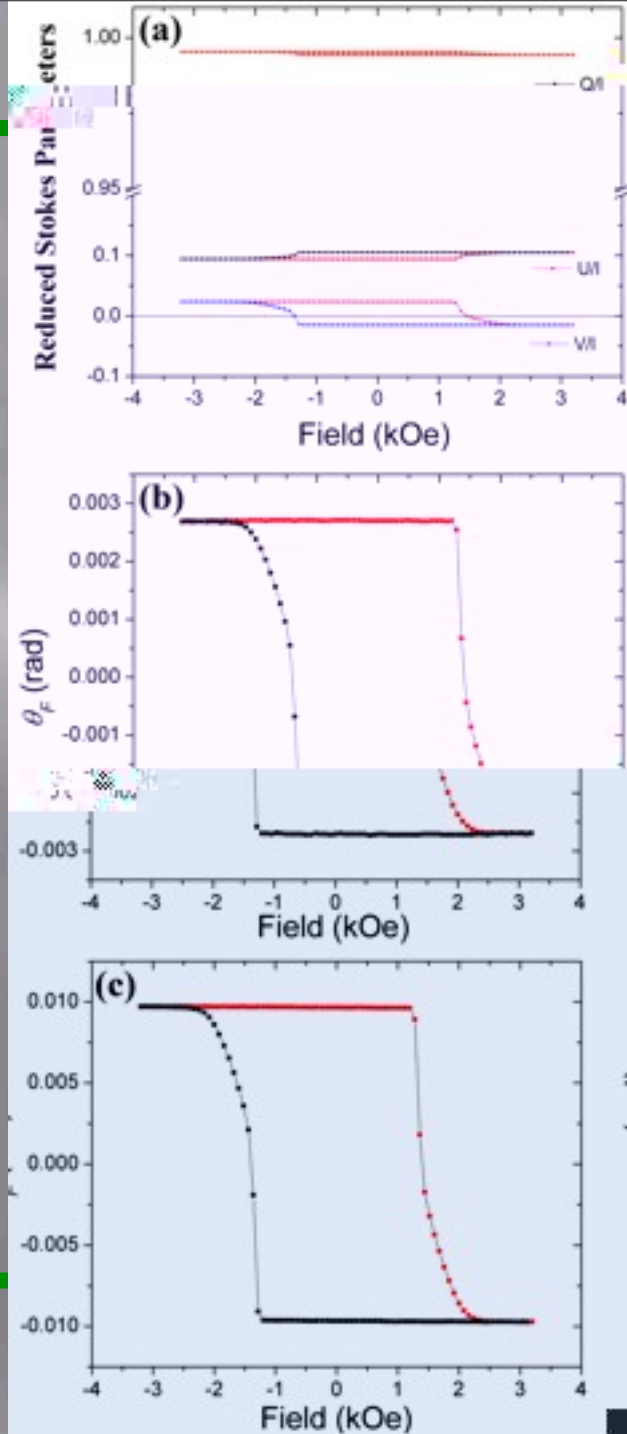
Robustness

Guan et al.
Appl. Opt. (2010)



Example

-Faraday effect in CoPt multilayers



NANOSTRUCTURED MATERIALS

-A d f e a e
ca c a ac e c



the motivations of our own work



NANOSTRUCTURED MATERIALS

-A study of the magneto optical characteristics of anodic aluminium oxide (AAO)



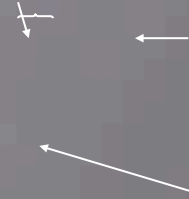
Preparation and characterisation of anodic aluminium oxide (AAO) and the nanowire arrays

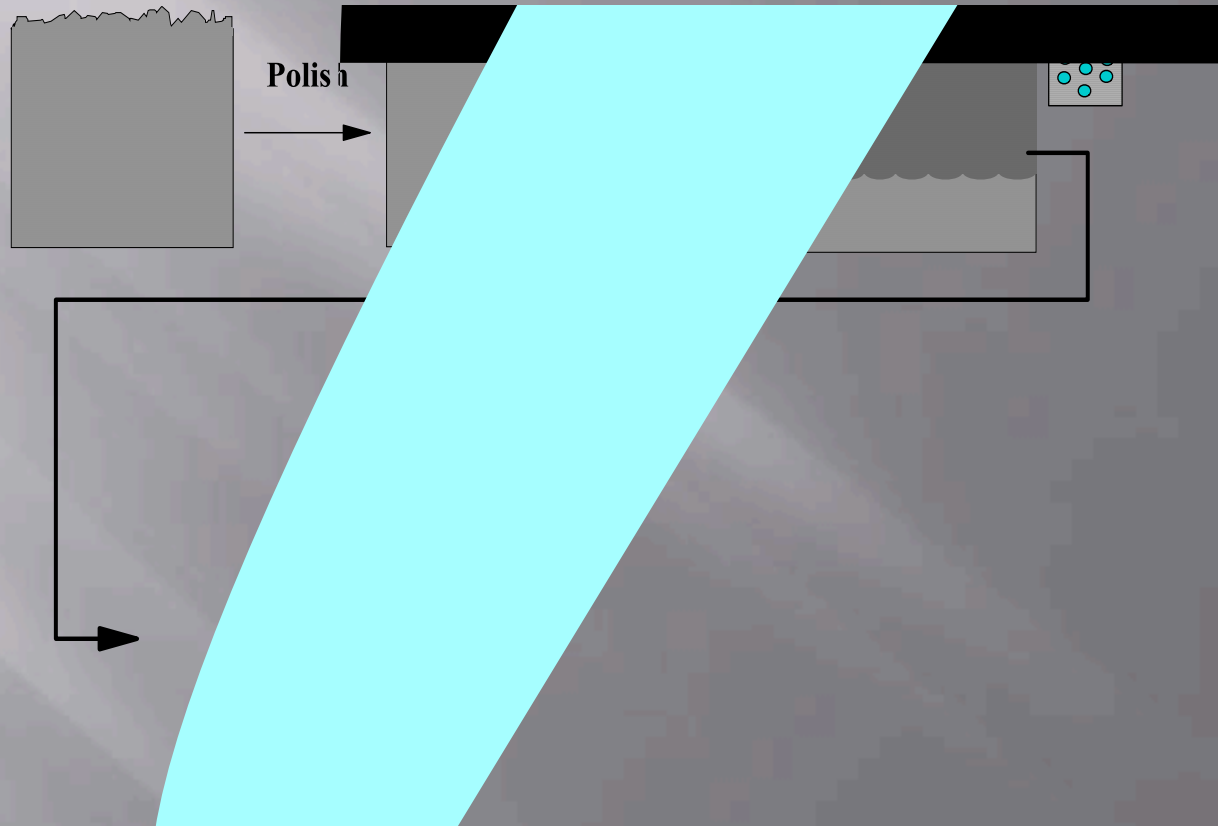
Magneto-optical properties of Fe nanowire arrays

Magneto-optical properties of Co nanowire arrays

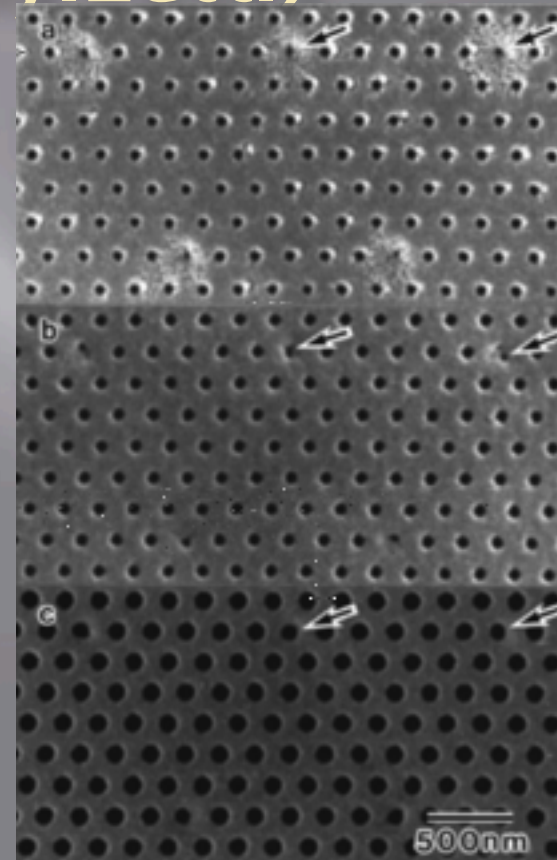
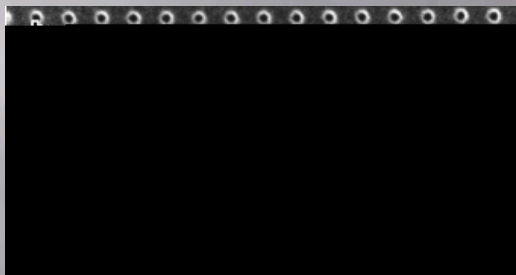
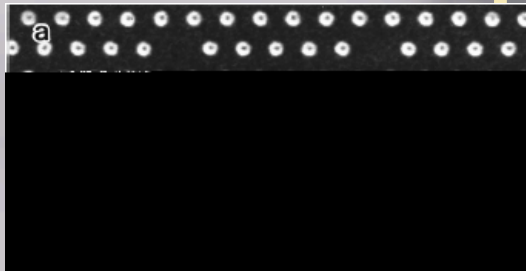


AAO Template method-sample preparation





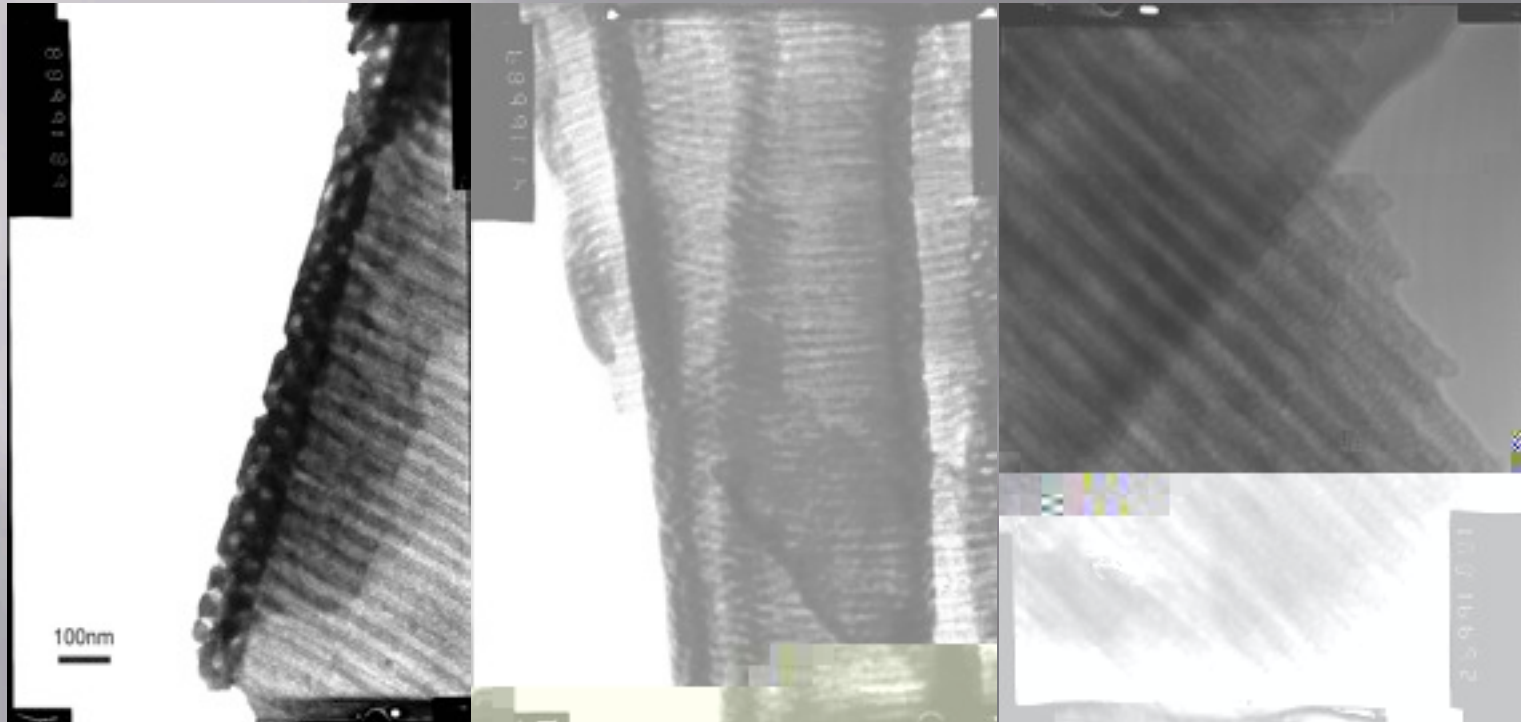
Self-organised growth/self repair of defect structure (Masuda, et al, App.Phy.Lett.)

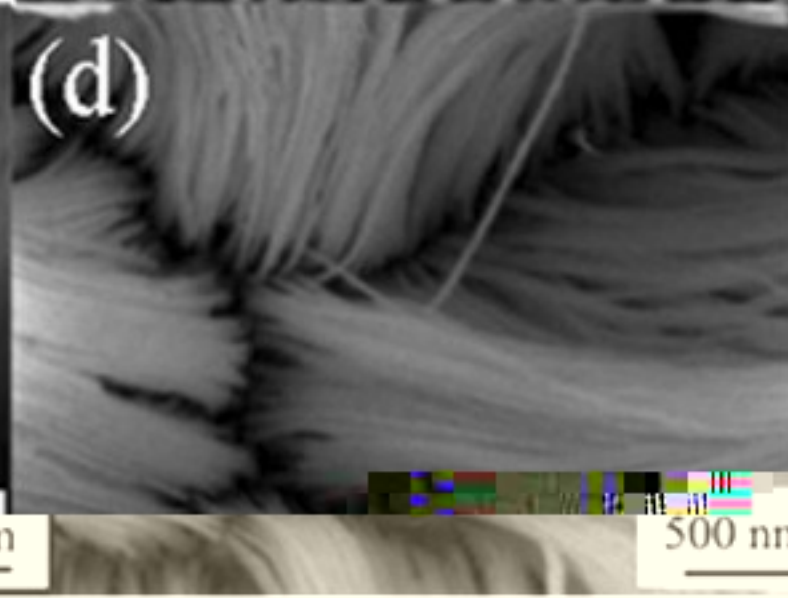
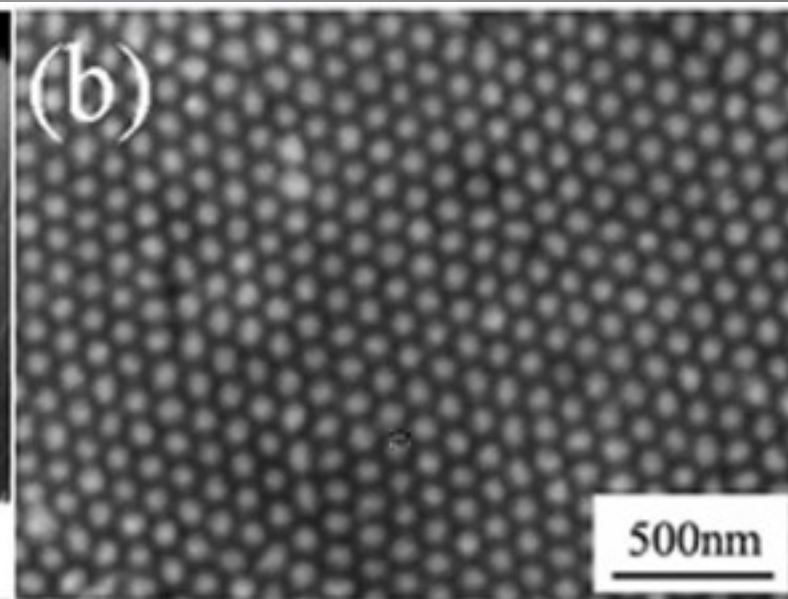
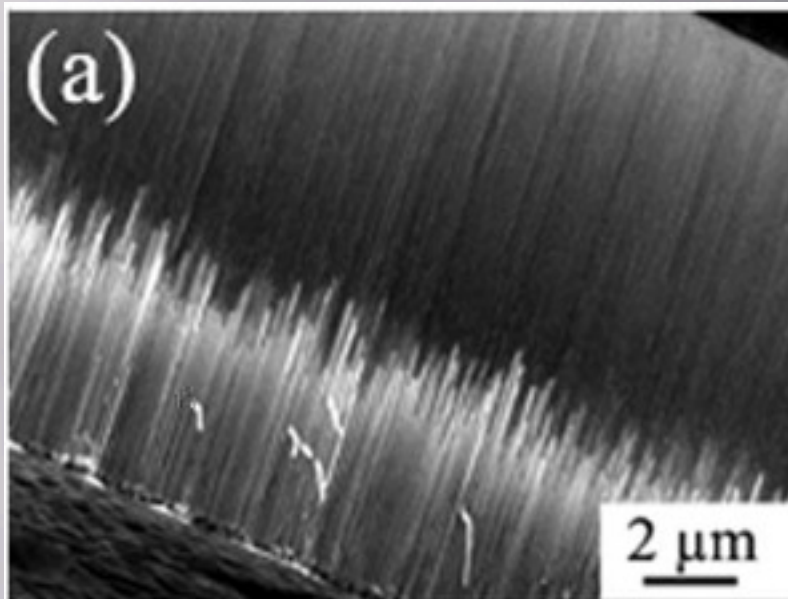




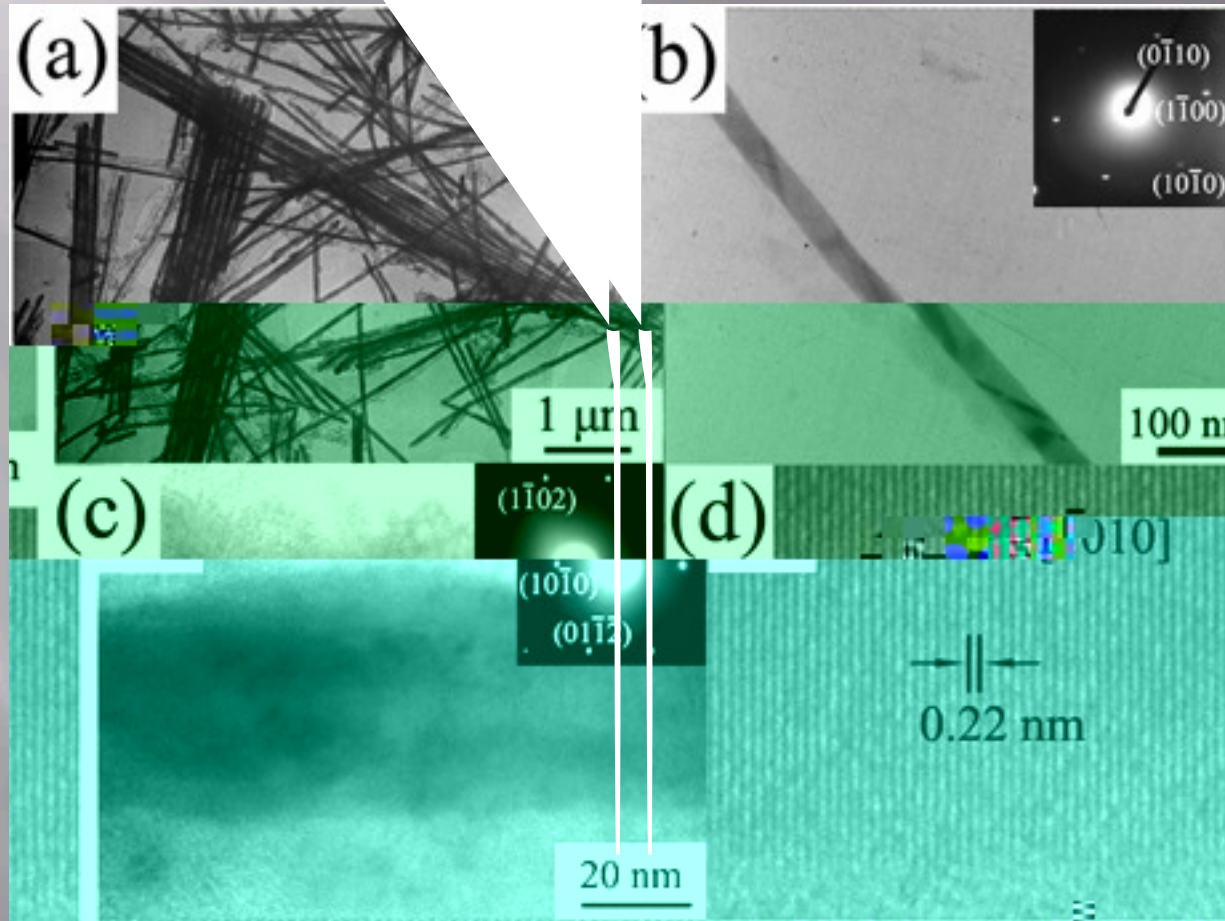
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Characterisation– TEM Images of Fe–nanowire embedded in AAO template

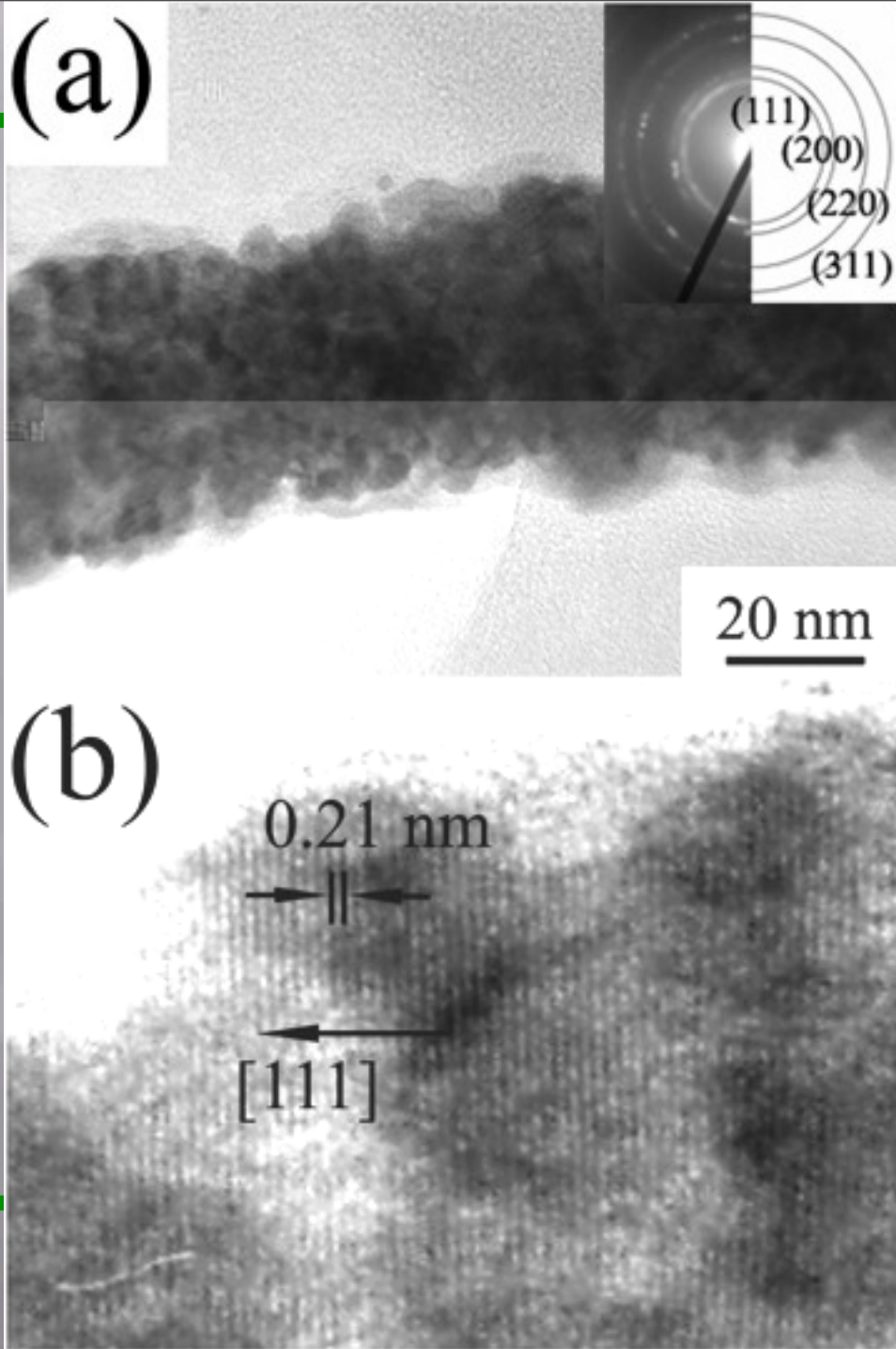


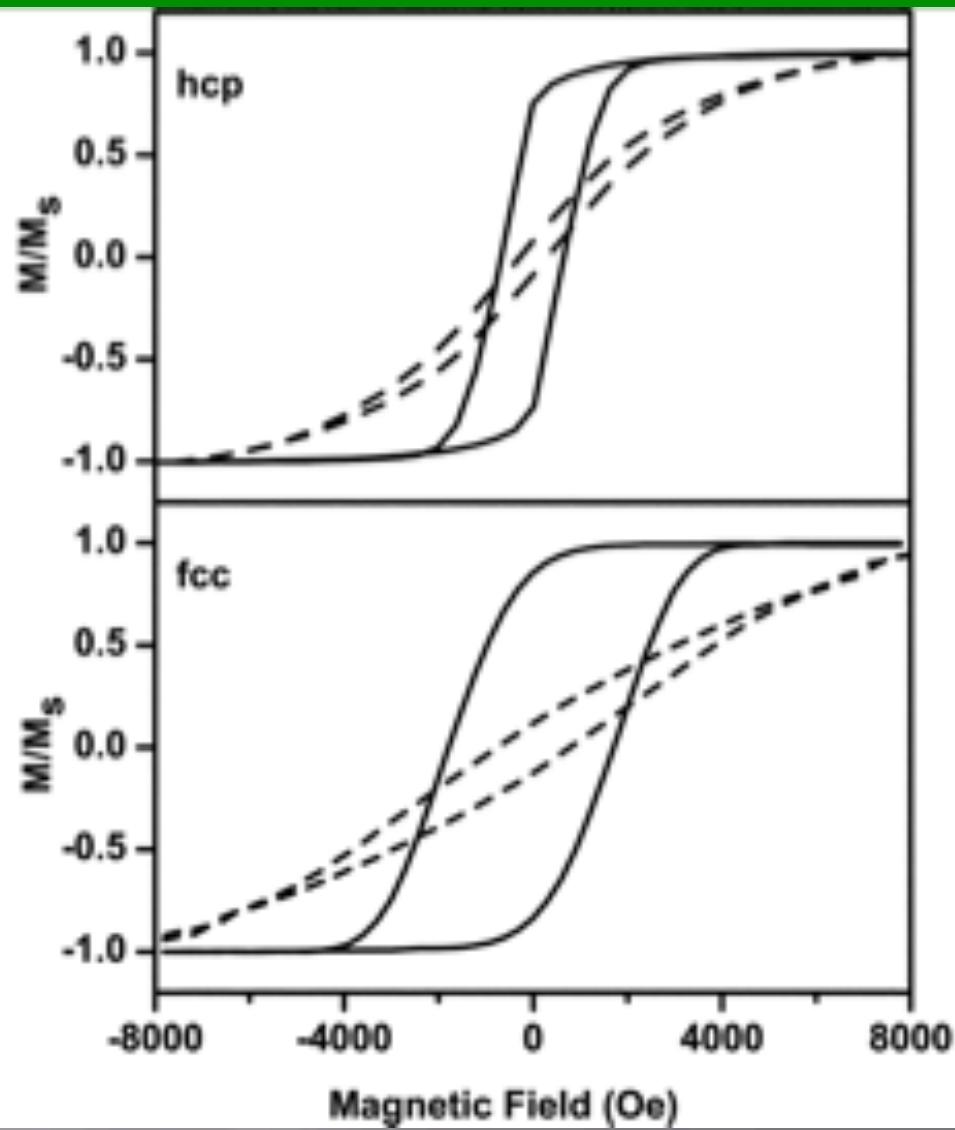


hcp Co



Fcc Co





-0.5

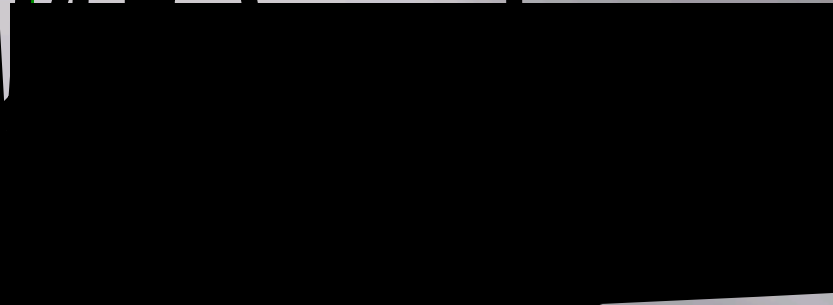
-1.0



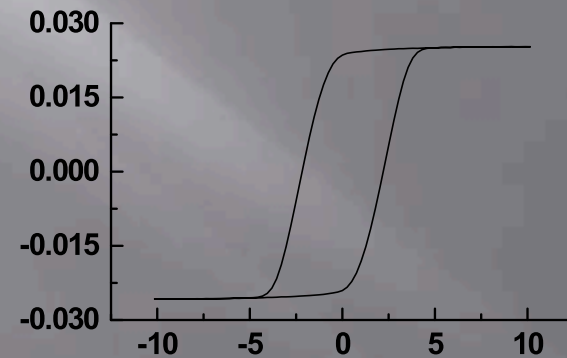
Characterisation –

Magnetic properties of nano-wire arrays in AAO

(1/5/10)

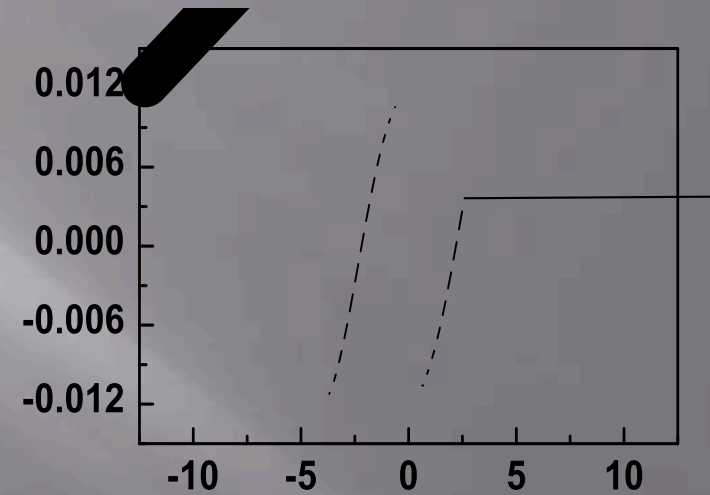


Results– MO properties of Fe nanowire array in AAO matrix

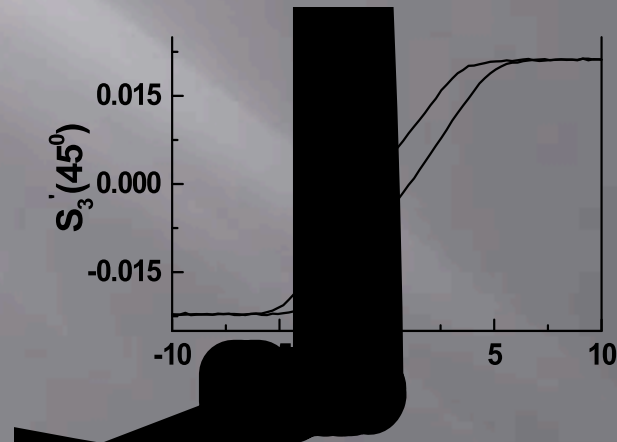


Results–

MO properties of Fe nanowire array in AAO matrix



Results– MO properties of Fe nanowire array in AAO matrix



Results–

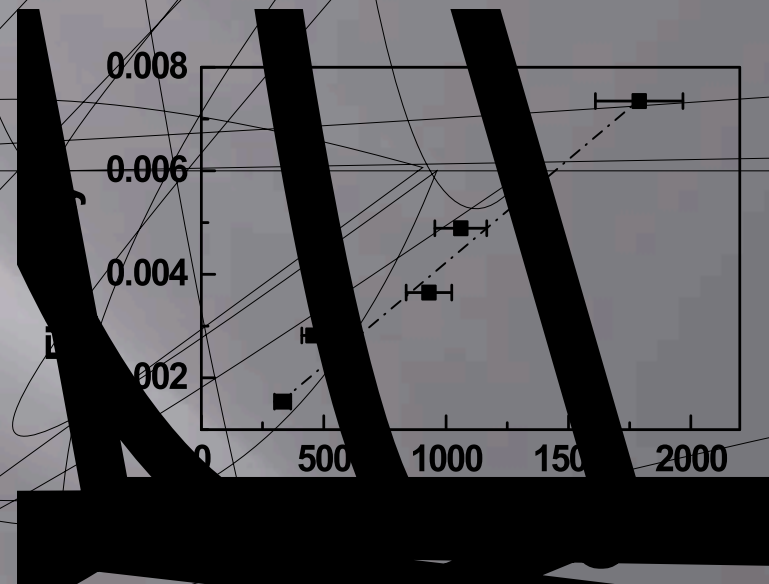
MO properties of Fe nanowire array in AAO matrix

-10 -5 0 5



Results–

MO properties of Fe nanowire array in AAO matrix

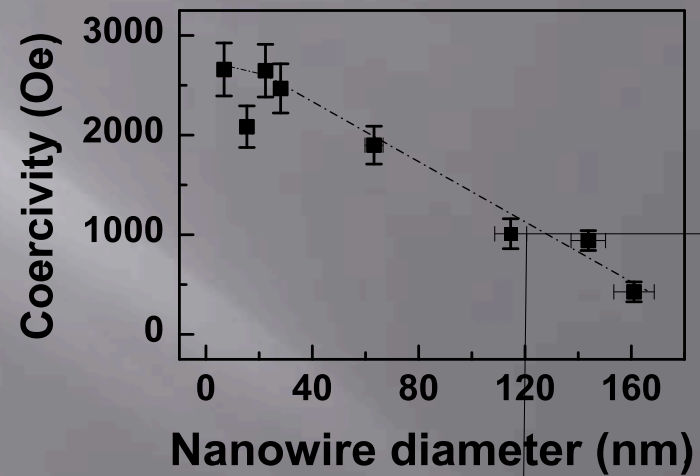


Results–

MO properties of Fe nanowire array in AAO matrix

0

0 40 80 120 160



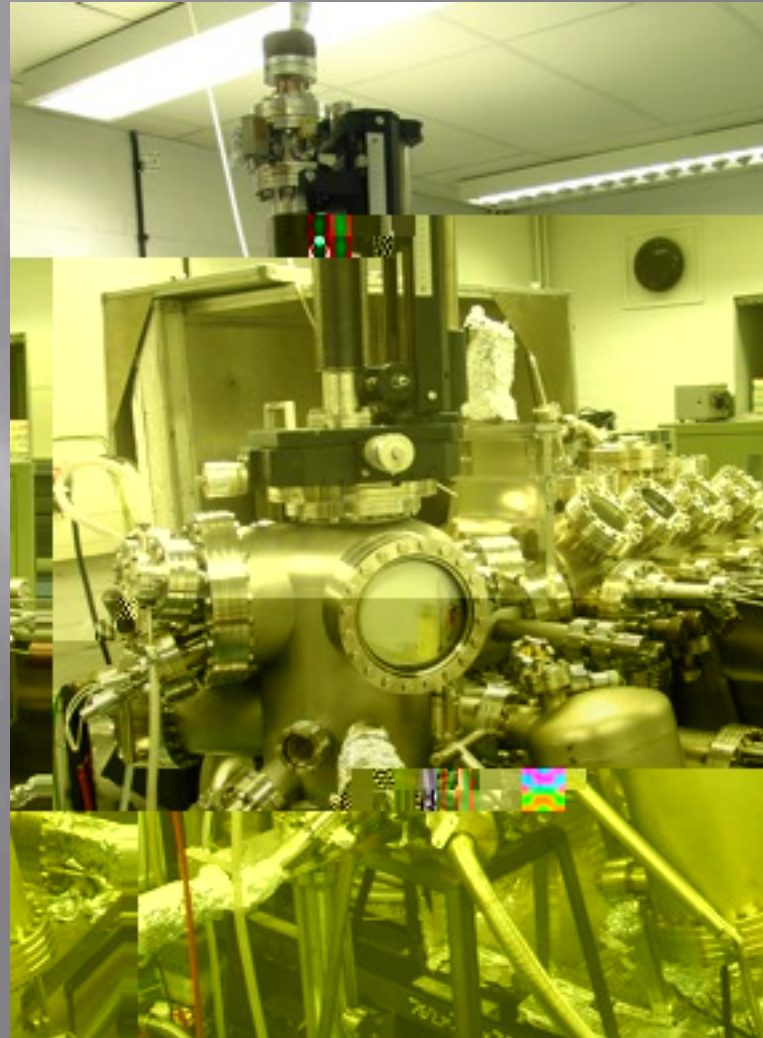


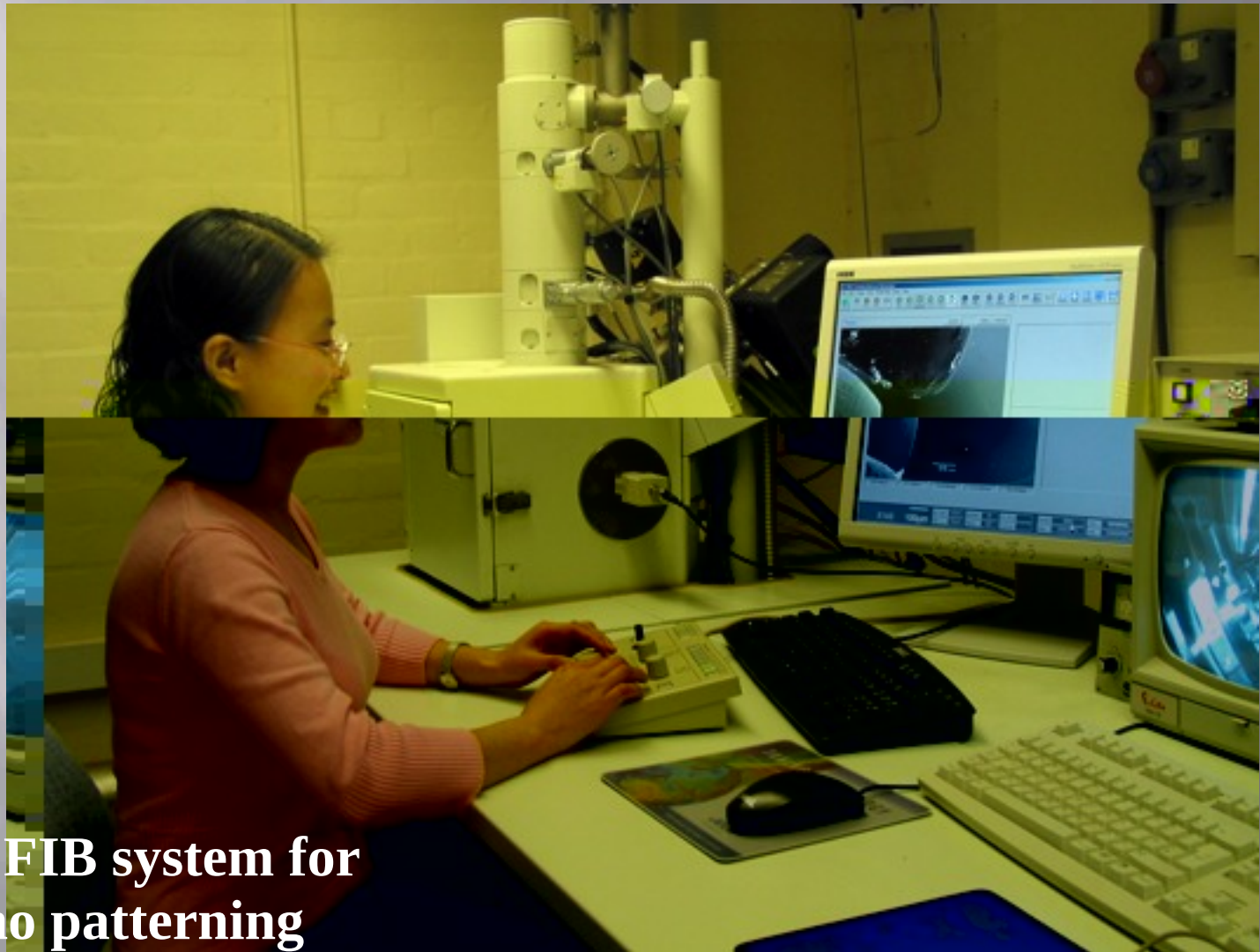
key experimental observations



Sample preparation:
–thin film

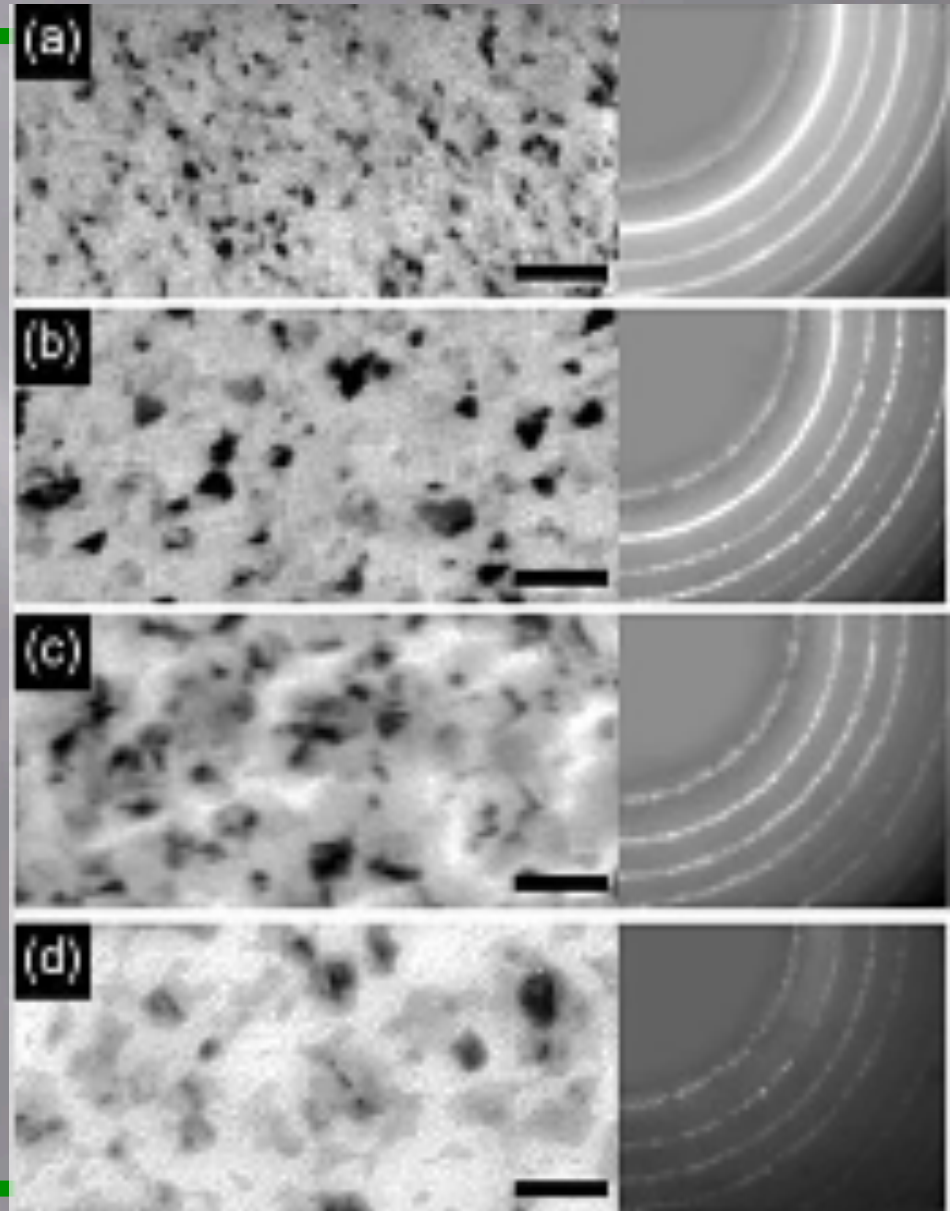
UHV e-beam
deposition



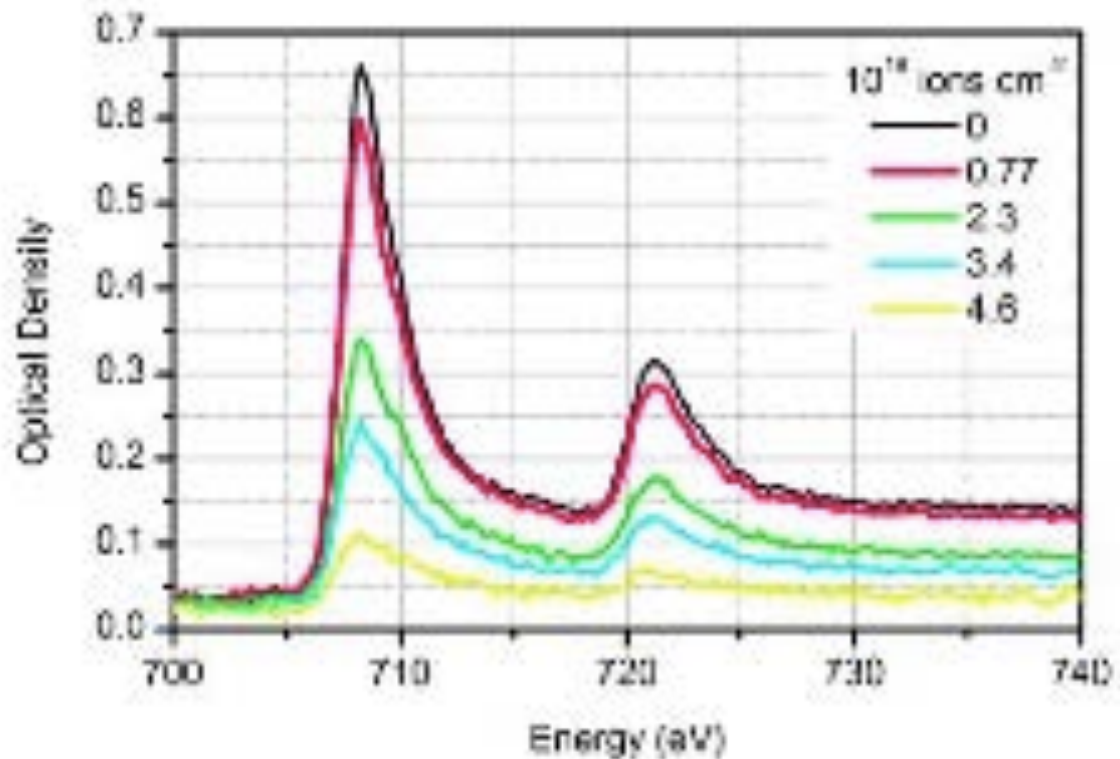


 An FIB system for
nano patterning

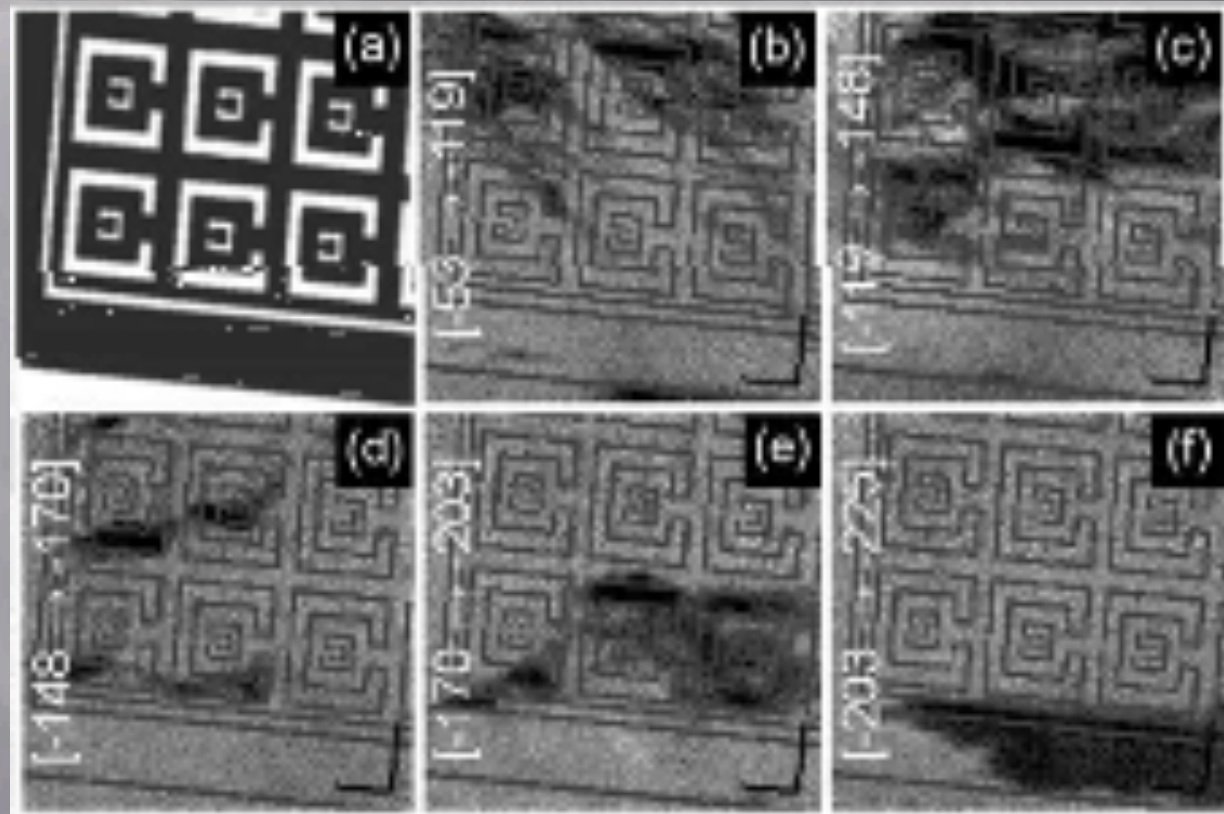
TEM images and SAED patterns for the as-grown Fe (a) and the Fe-Ga irradiated with (b) 7.7×10^{15} , (c) 2.3×10^{16} and (d) 3.4×10^{16} ions cm^{-2} . The scale bars represent 100 nm.



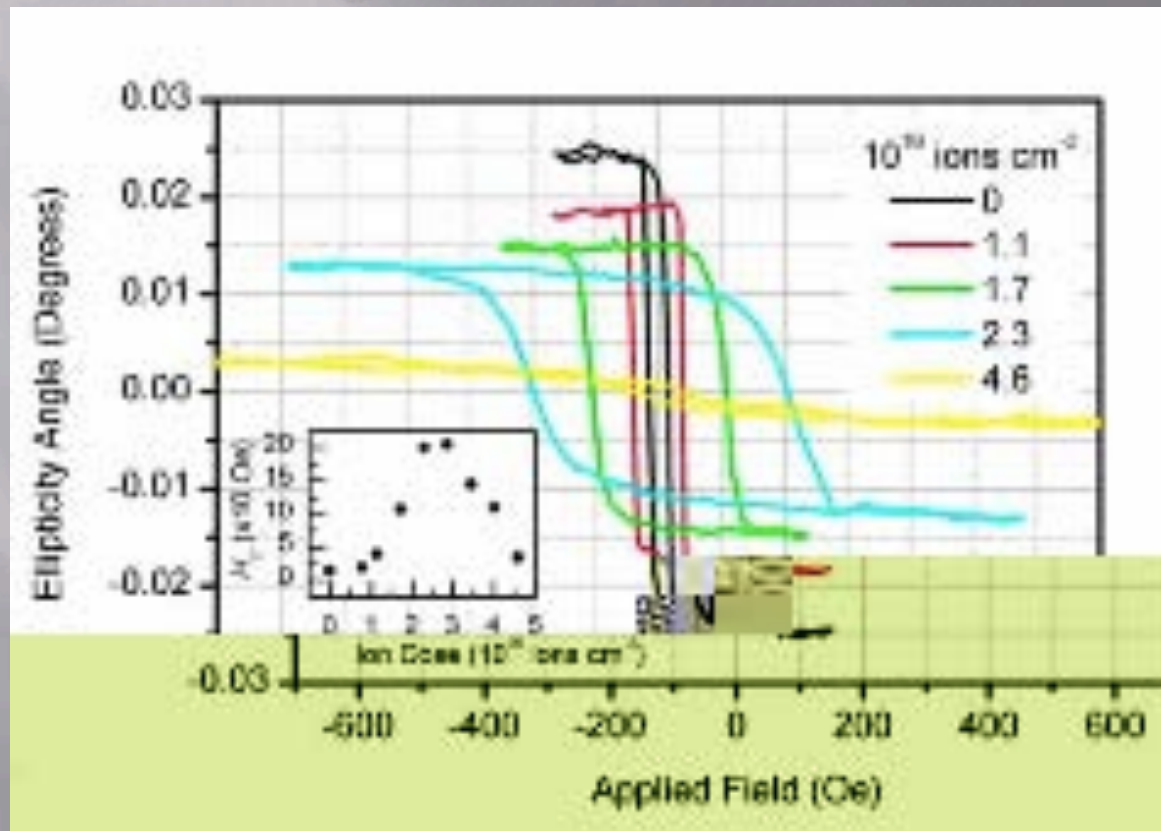
XAS showing the Fe L_{2,3} absorption peaks at 721 and 708 eV respectively for the as-grown and irradiated film.



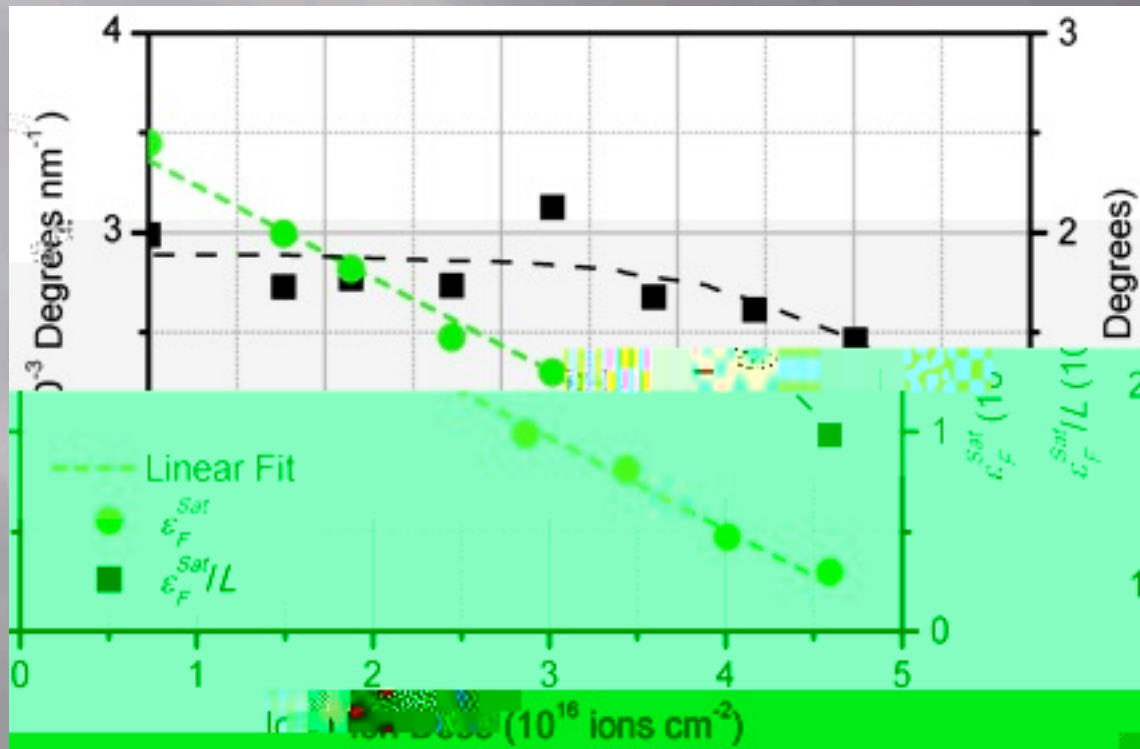
A composite Fe and Fe-Ga pattern. The pattern design is shown in (a), where the dark areas represent the Ga irradiation. XMCD images of the magnetisation reversal sequence are shown in (b)–(f), with an overlay of the pattern design as a guide. The images only show the areas of the film that switch between two successive field steps, which are given along the left side of the images.



Magnetic hysteresis loops measured using Selective Area Stokes Polarimetry (SASP) show the variation in ellipticity angle of the transmitted light with applied field. The inset plots the coercivity of the film vs. ion dose.

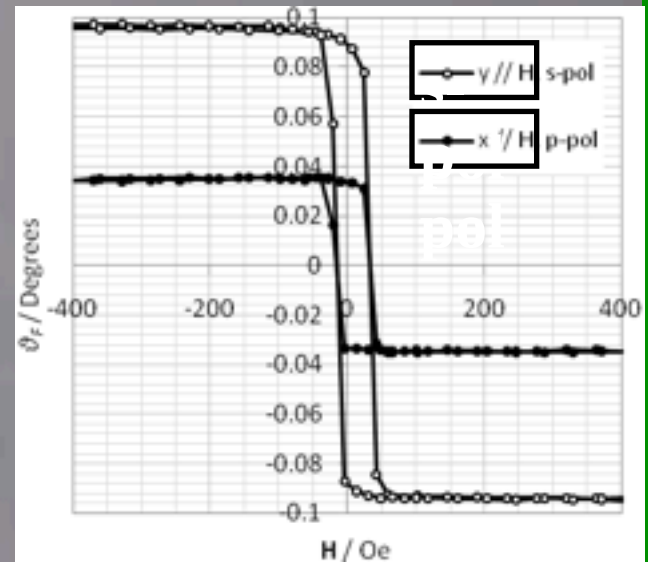


The ellipticity angle of light transmitted through the magnetically saturated Fe and Fe-Ga is inversely proportional to the ion dose due to reducing film thickness. The magnetic circular dichroism is independent of ion dose until the film becomes discontinuous at doses above 3×10^{16} ions cm^{-2} . This is illustrated by the black dashed line, which is a guide to the eye only.

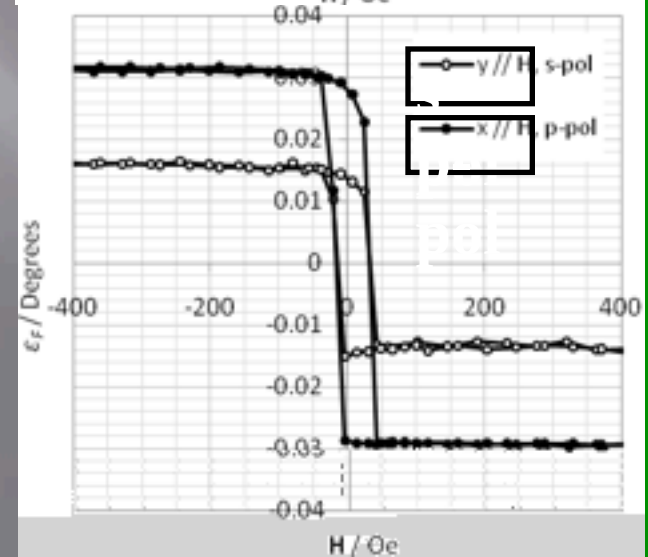


Magnetic hysteresis behaviour of an Fe thin film obtained using the SASP technique. Predominantly s- and p-polarised light was incident at an angle of approximately 63° with the magnetic field applied in the plane of incidence. The Faraday rotation induced by the film is shown in (a) and the ellipticity angle in (b).

(a)



(b)



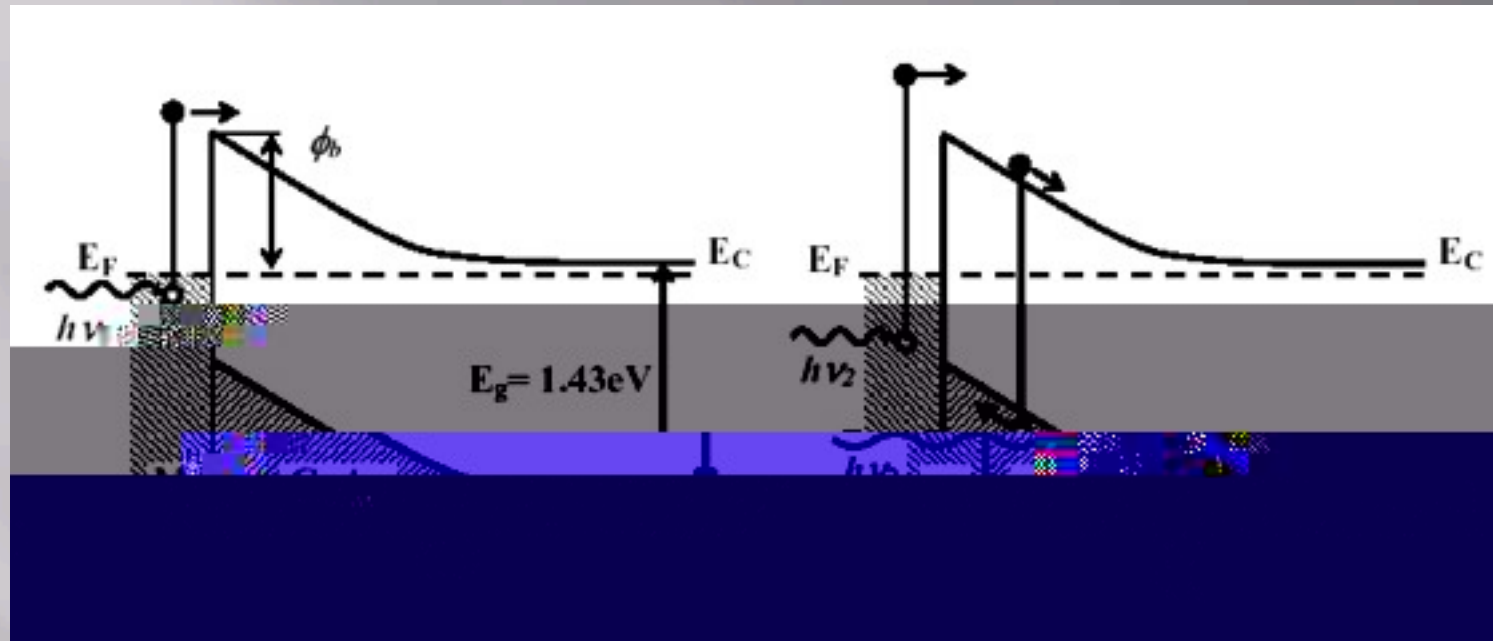
SEM images of the chess-board-style patterns etched into an Fe film using an FIB. The dimensions of the Fe (bright) and etched (dark) elements are (a) $0.725\ \mu\text{m} \times 0.725\ \mu\text{m}$ (a), (b) $0.725\ \mu\text{m} \times 2.9\ \mu\text{m}$ and (c) $0.725\ \mu\text{m} \times 5.8\ \mu\text{m}$.



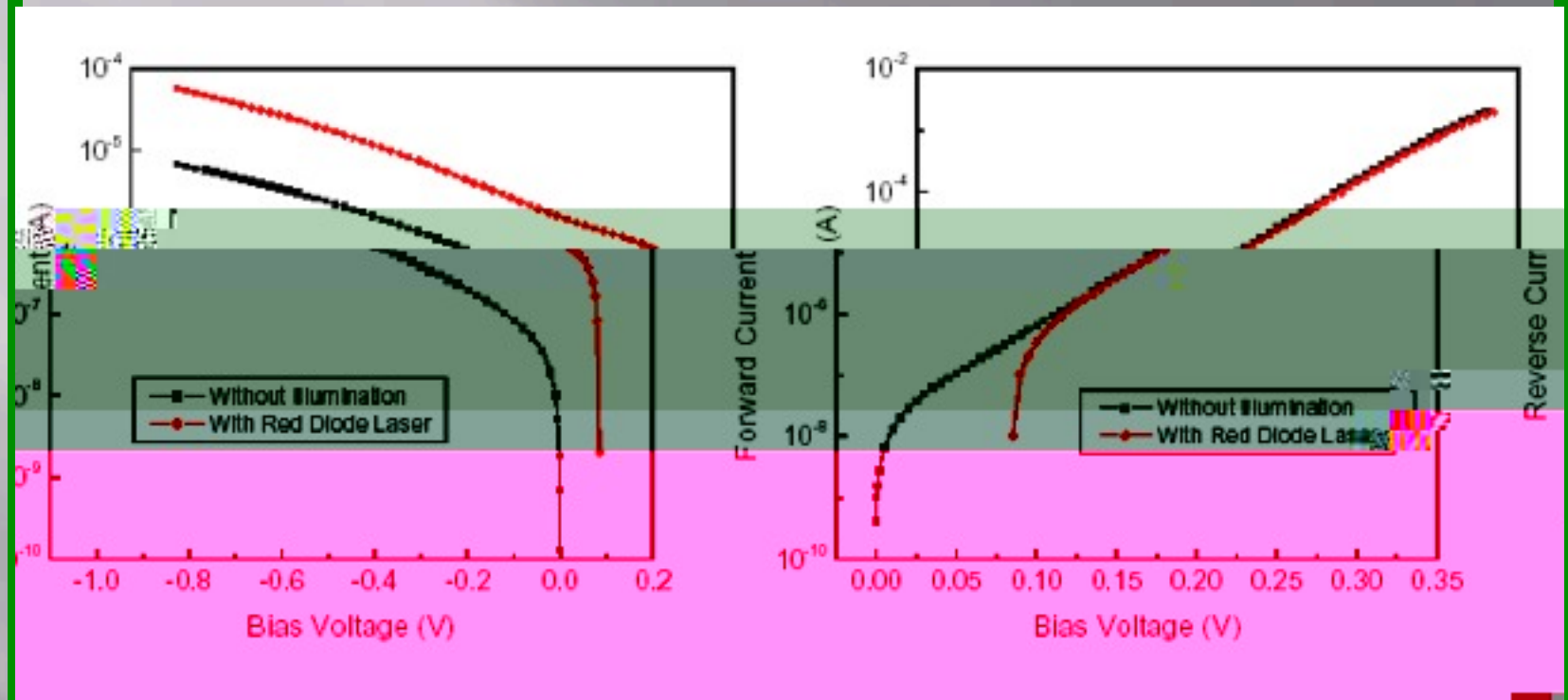
DETERMINATION OF THE MAGNETIC ASYMMETRY IN PHOTOCURRENTS

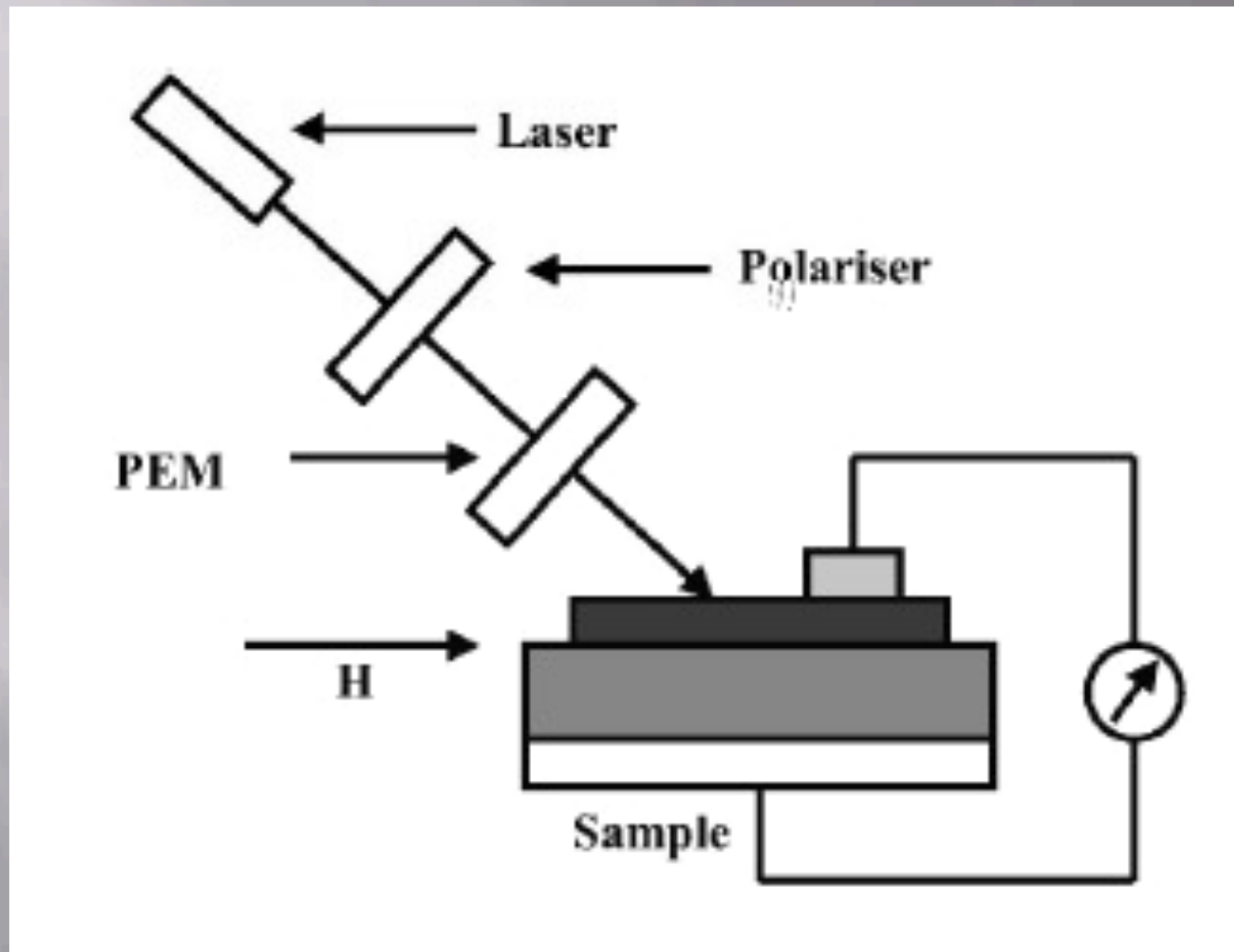
ac e Fe/GaA a d N /
GaA e face





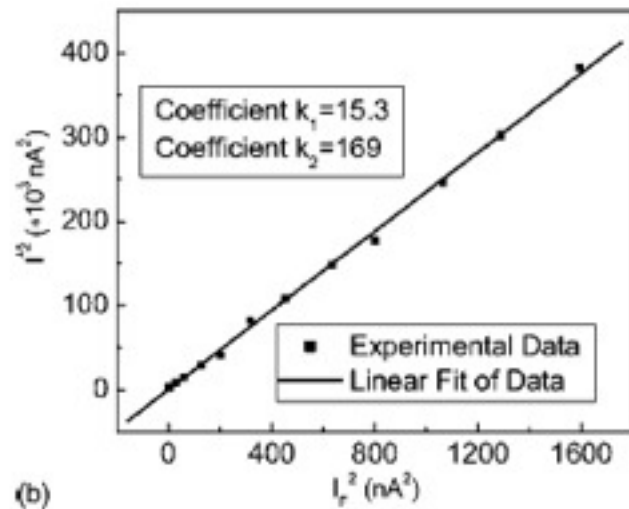
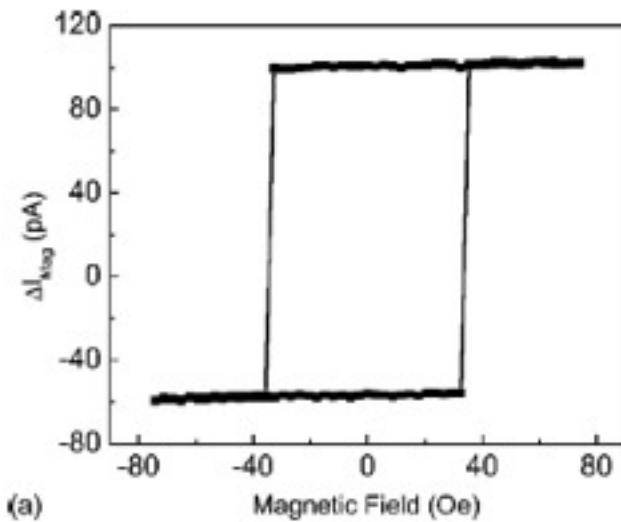
I-C characteristics

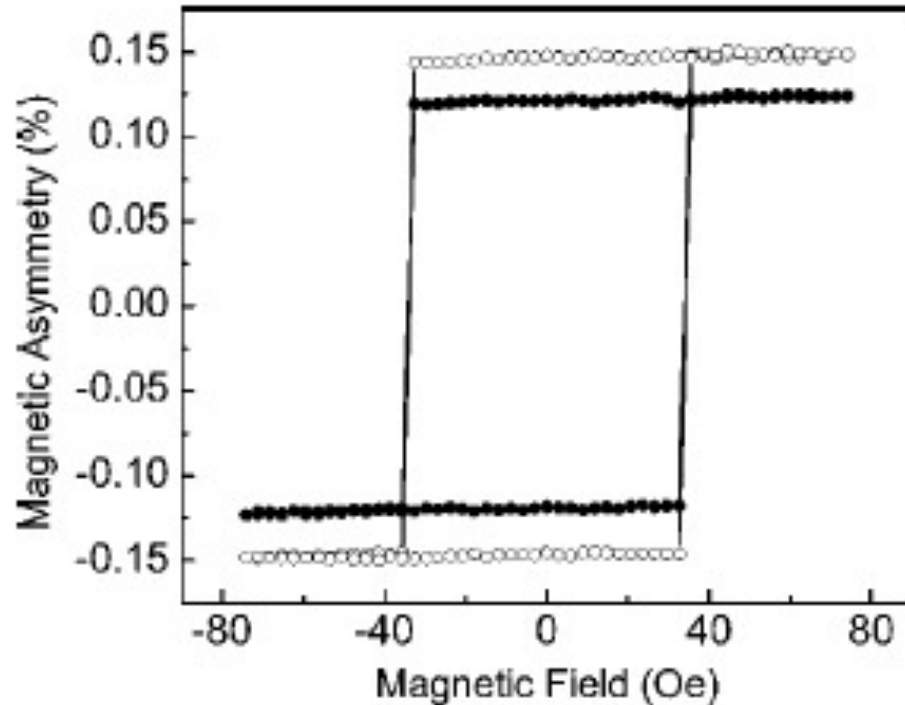




$$I_{\text{Photo}}^2 = k_2^2(I_{2F,Q}^2 + I_{2F,U}^2) + k_1^2 I_F^2.$$

$$A = k_1 \frac{\Delta I_{\text{Mag}}}{I_{\text{Photo}}}.$$





The magnetic asymmetry for Fe(12 nm) /GaAs at 45° incidence. The magnetic field was in the plane of incidence and along the magnetic easy axis of the sample. The filled circles are for the measurements using a red diode laser ($\lambda = 670$ nm, $\nu = 1.85$ eV), and the open circles using an infrared laser ($\lambda = 1064$ nm, $\nu = 1.17$ eV).



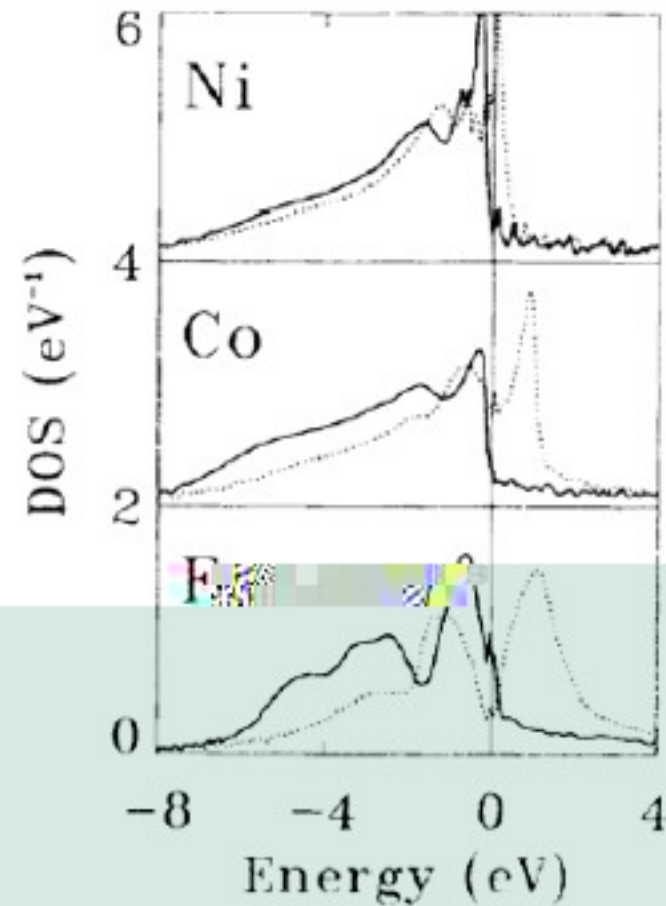
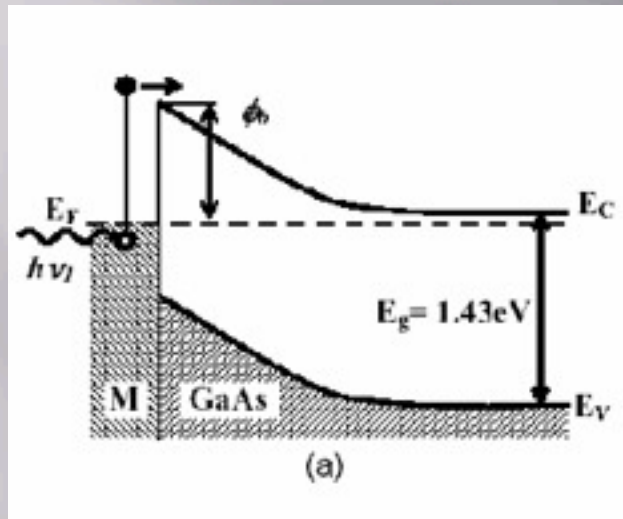
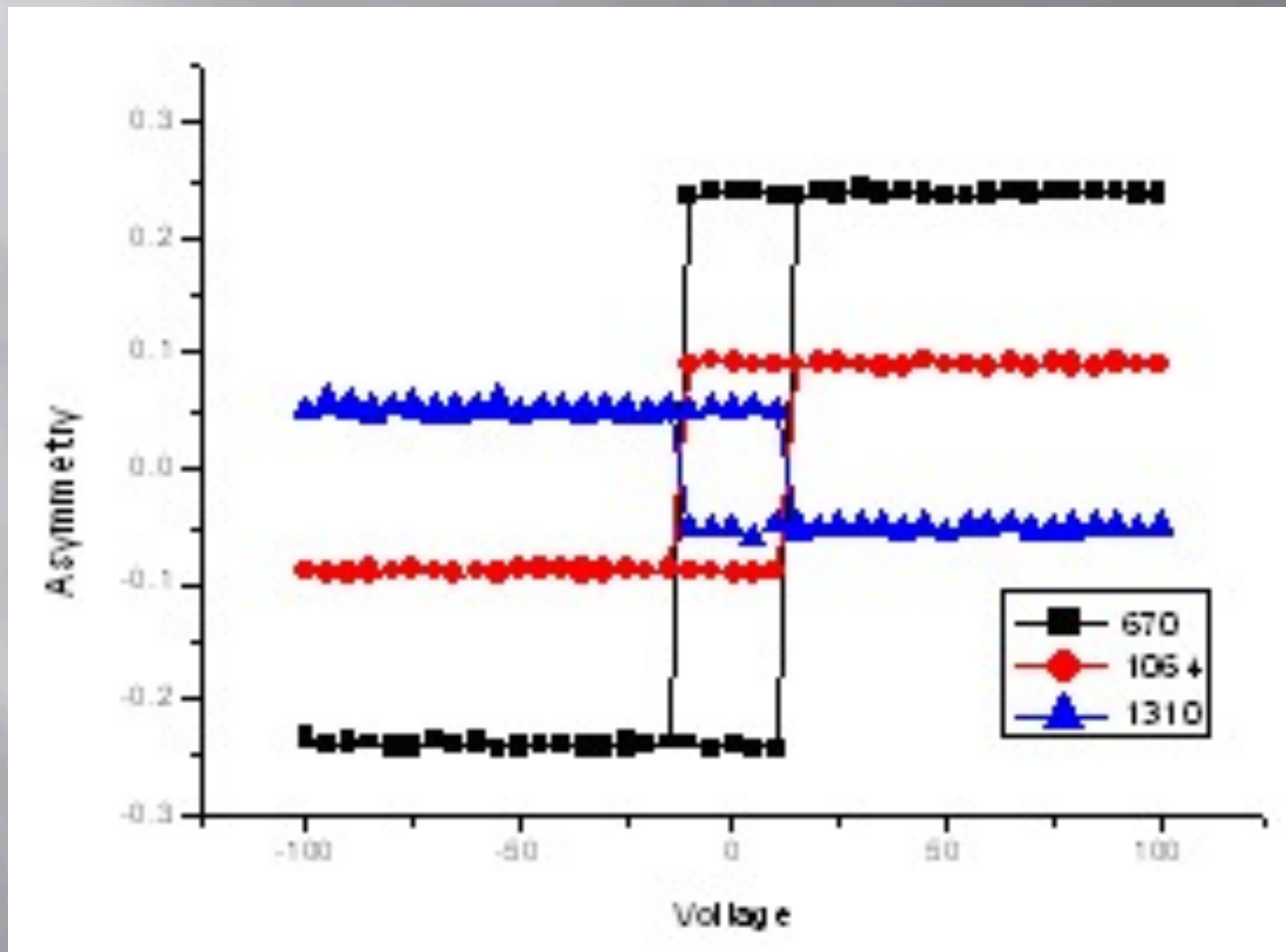


Figure 7.1.2.2: The spin-resolved density of states (DOS) for the 3d ferromagnets (solid/dotted line = majority/minority states). The energy has been shifted so the Fermi level E_F is at zero energy.



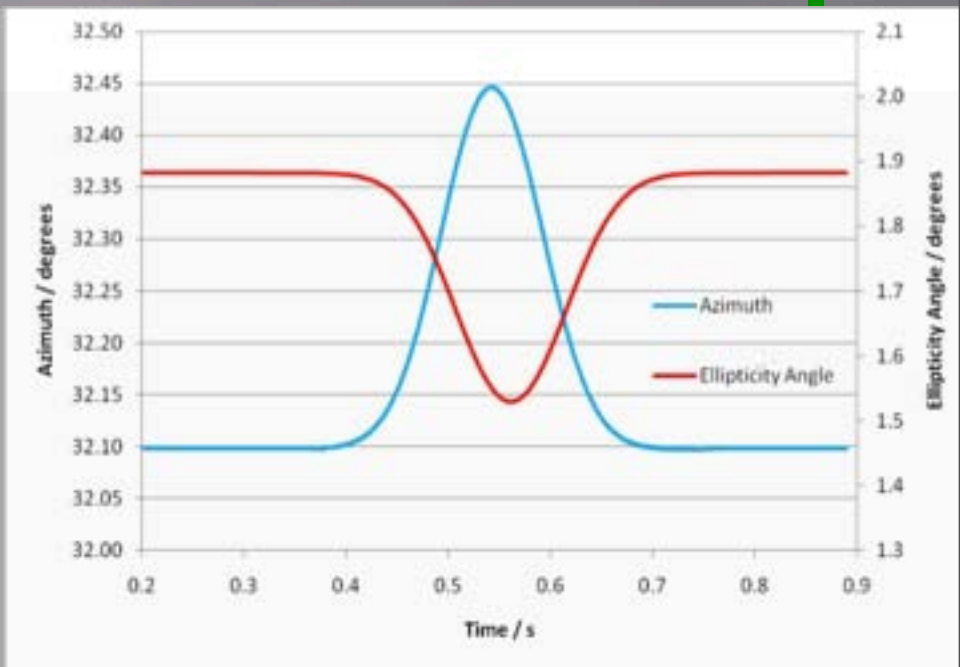
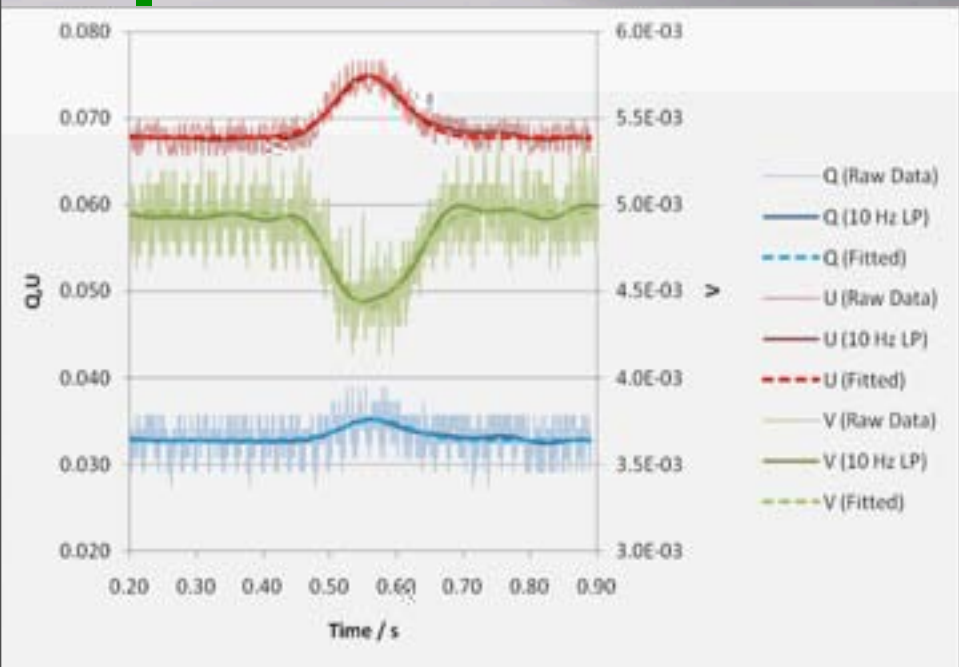
POLARISATION CHANGES IN CELLULAR DYNAMICS OF CARDIOVASCULAR CELLS

a f f c ce





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Summary/Future work



Acknowledgement



