Magnetic Domains and Domain Walls

a)

b)

c)

200 µm

200 µm

100 µm

100 µm
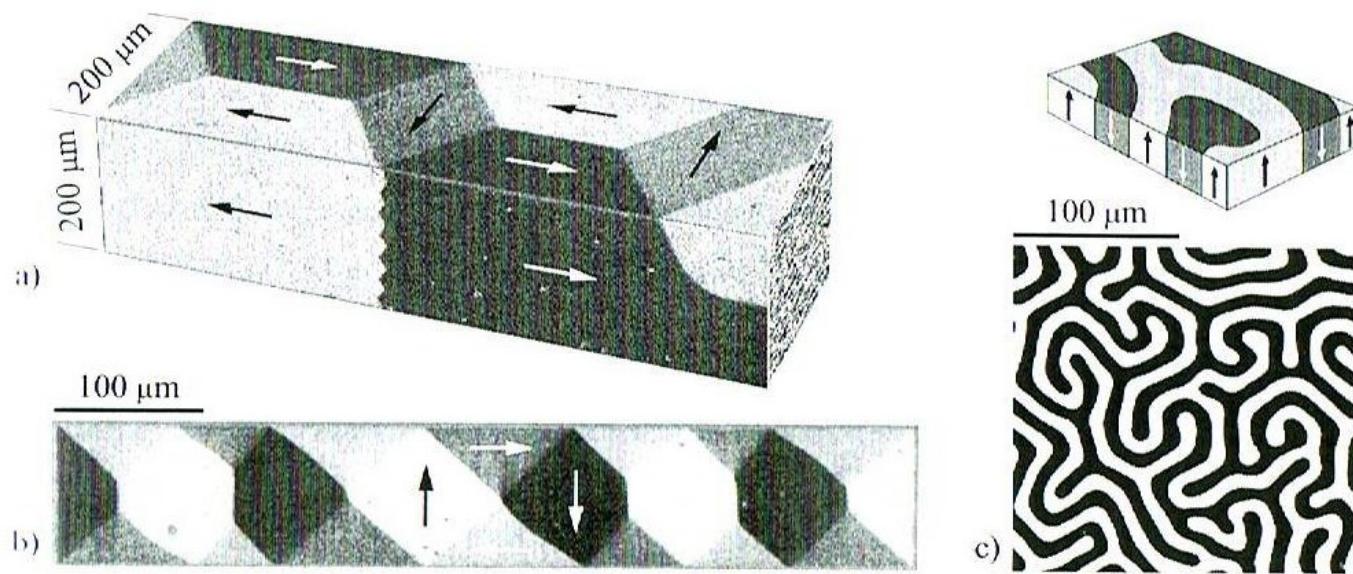
Bitter-Technique (ferromagnetic colloids on surfaces)
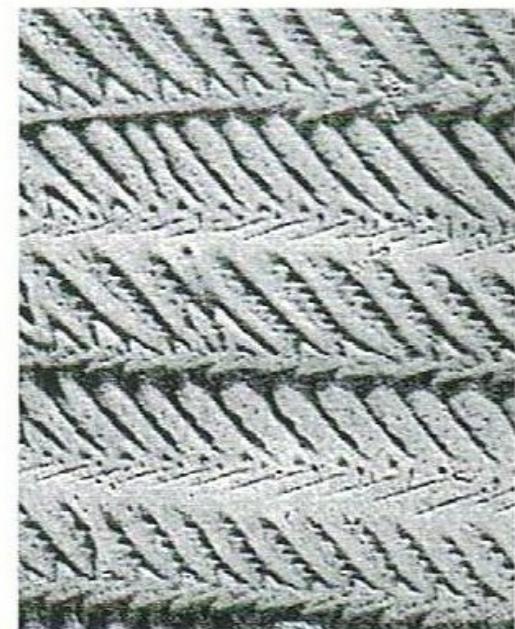
Stress induced domains in NiFe single crystal

Magneto-optics
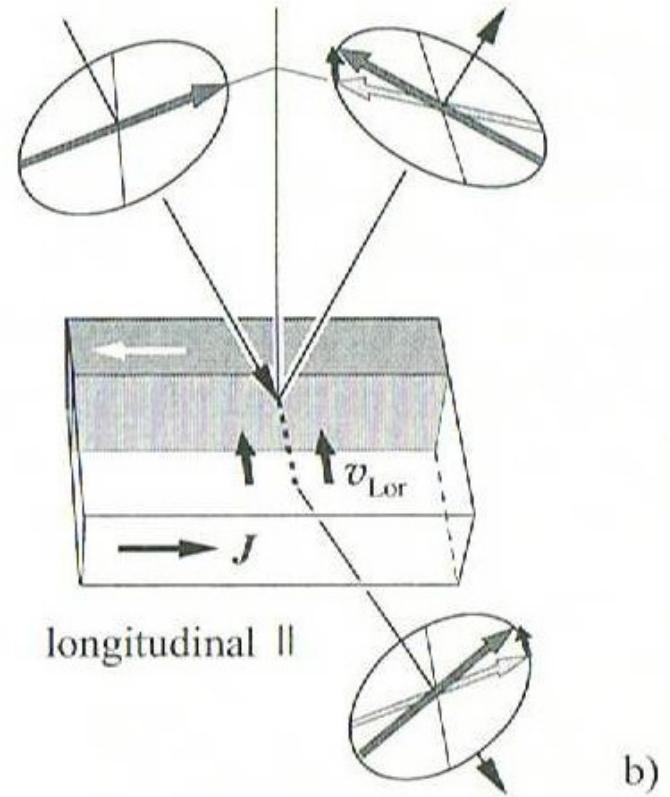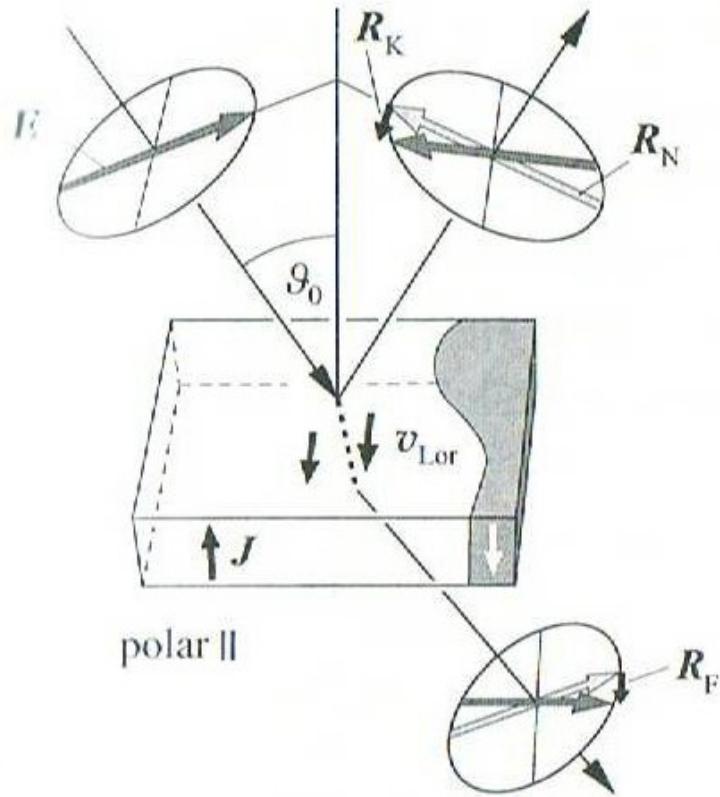
Magneto-optical Kerr Effect

longitudinal ⊥

transverse
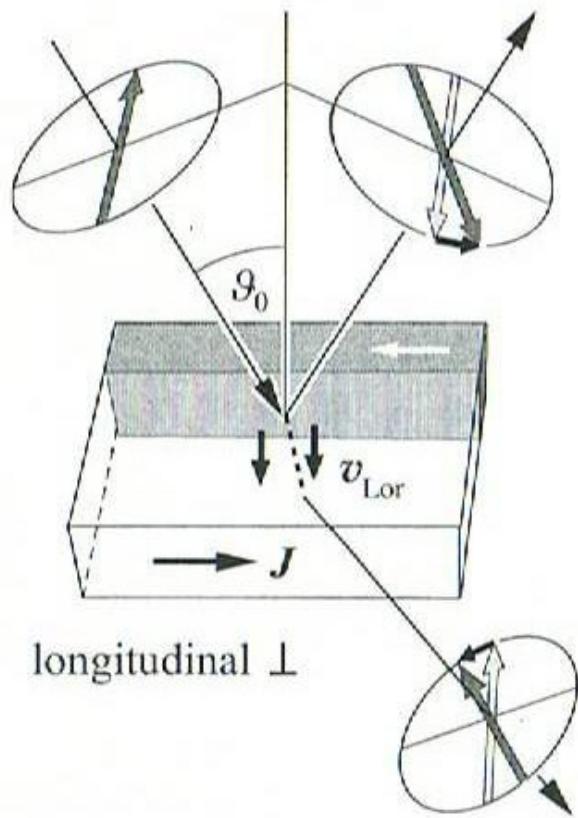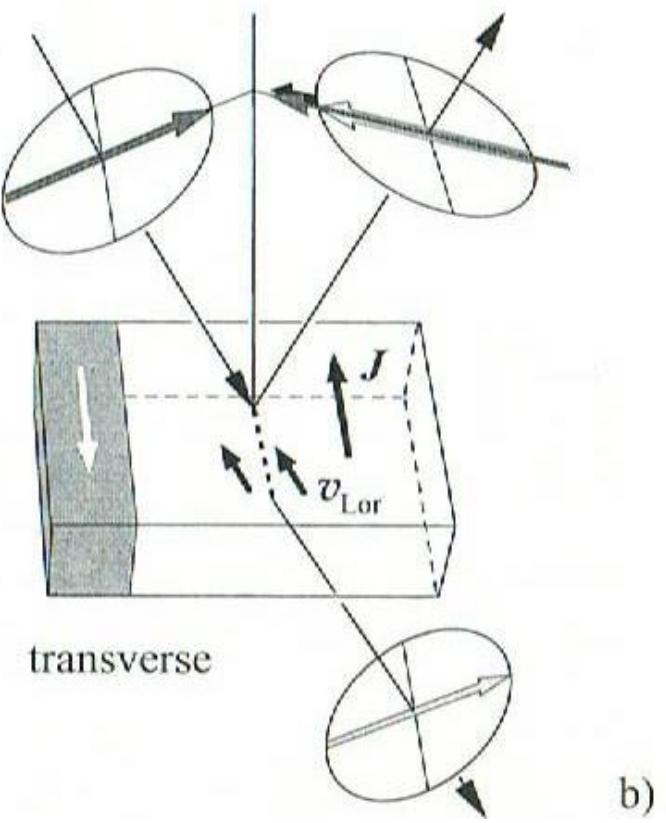
Magneto-optical Kerr Effect

Kerr microscopes
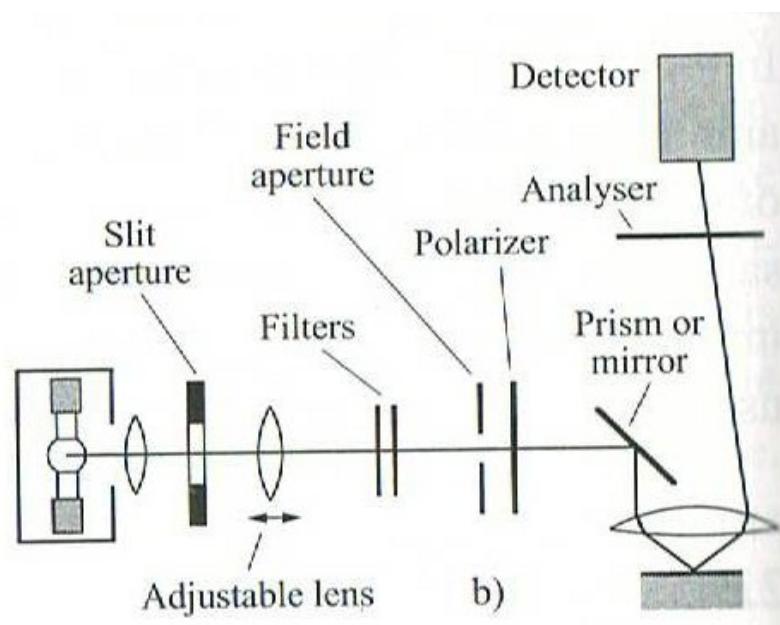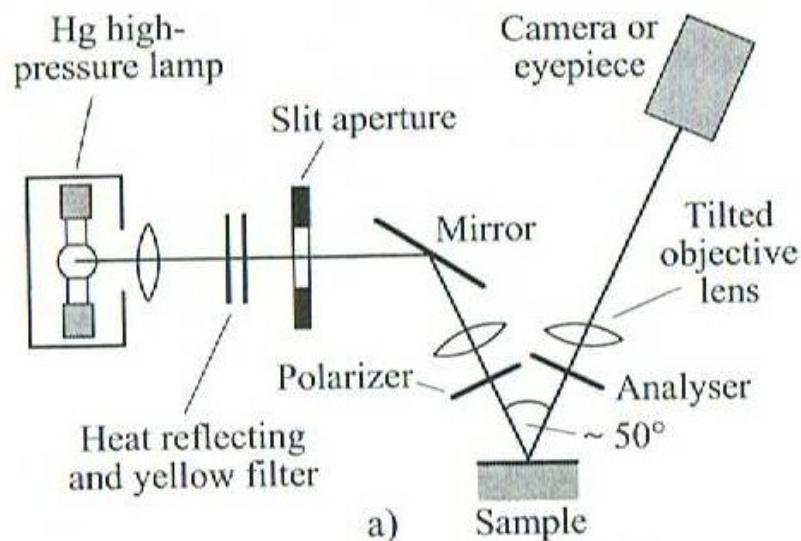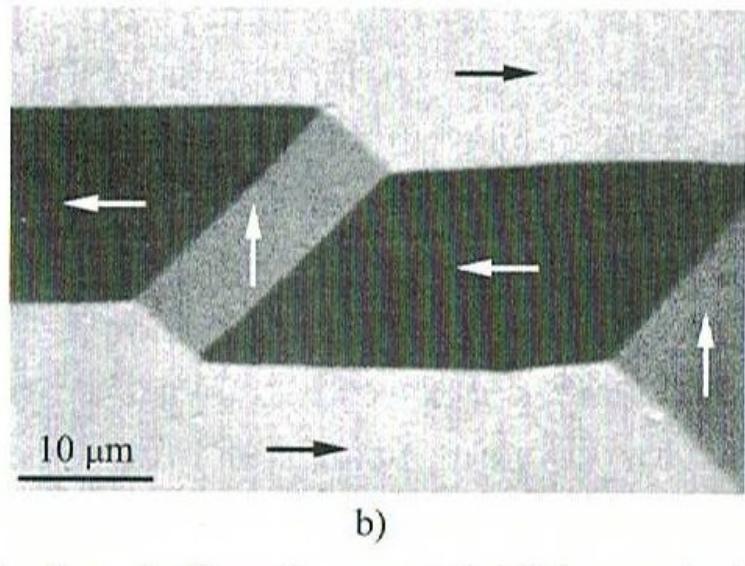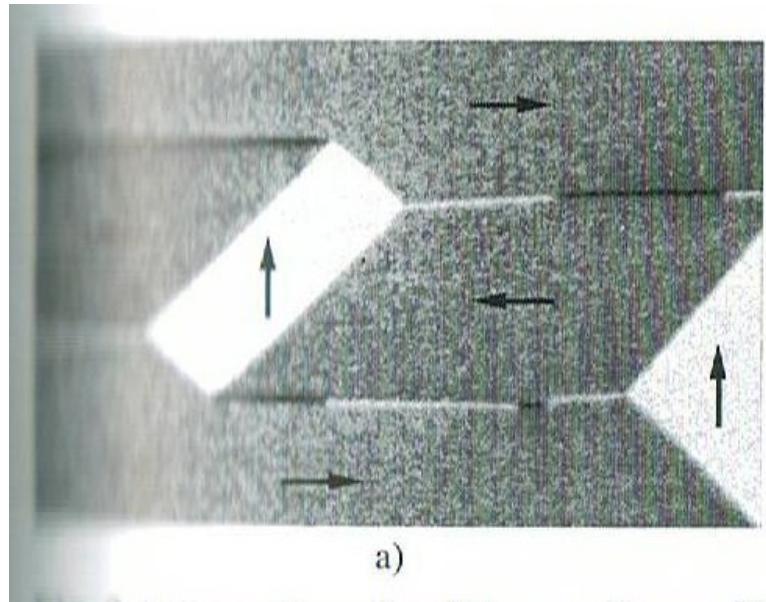
Domains in Fe single crystal

# Transmission electron microscopy
Lorentz microscopy
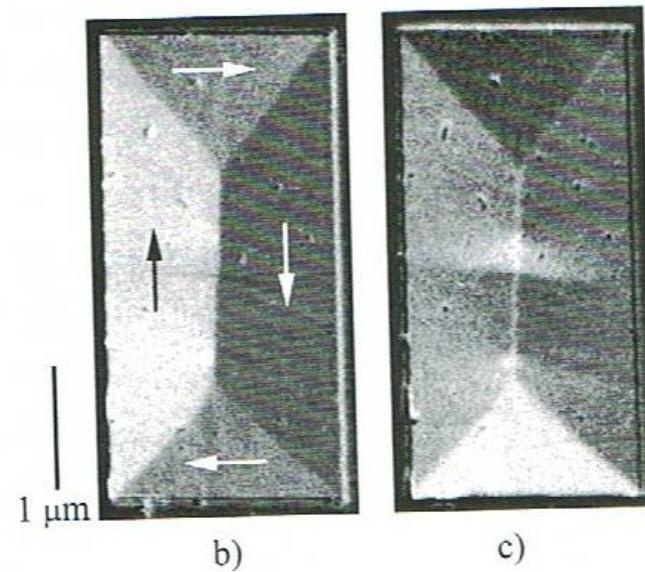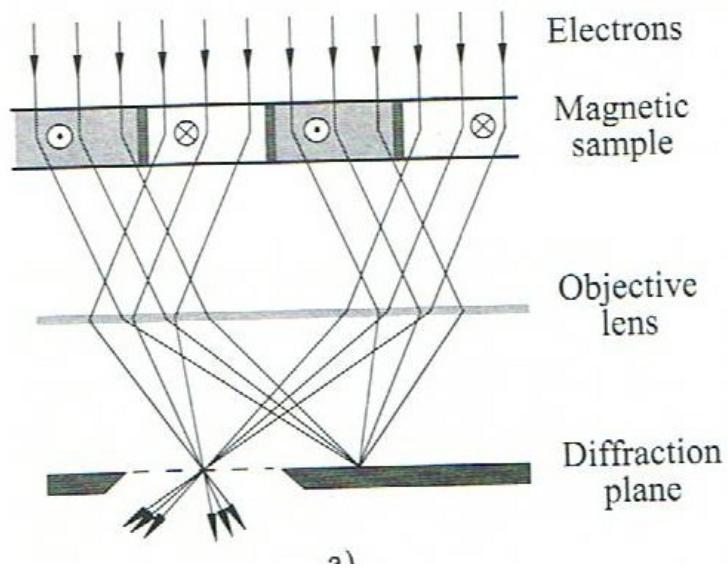
Scanning electron microscopy with polarization analysis (SEMPA)
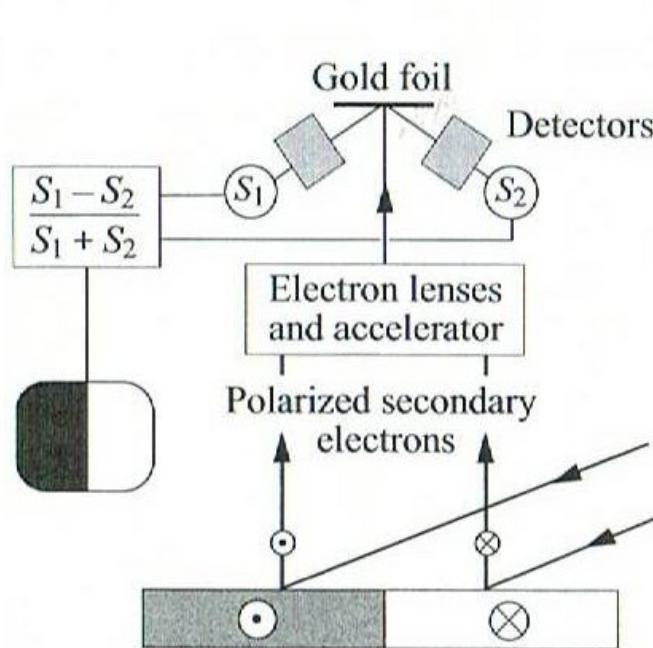
a)
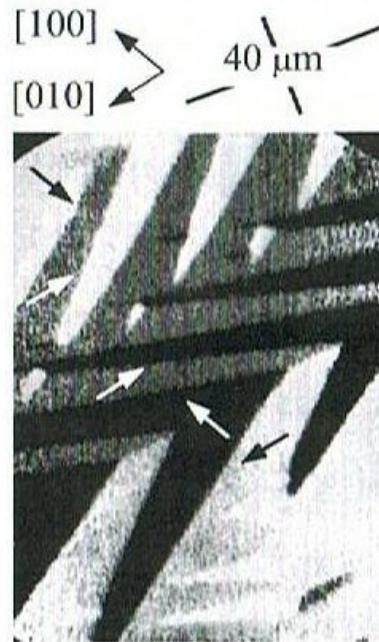
b)
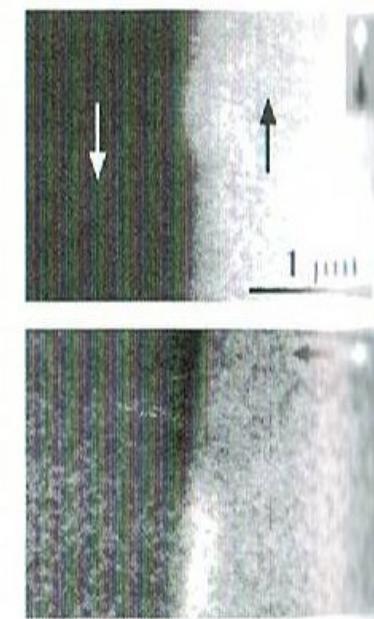
c)

SiFe single crystal
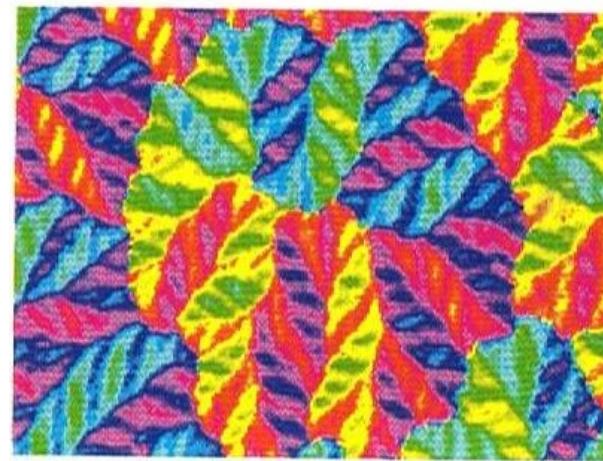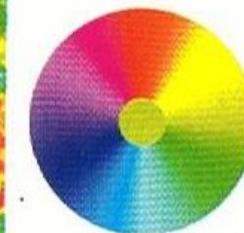
Co single crystal (0001)

# Magnetic Force Microscopy
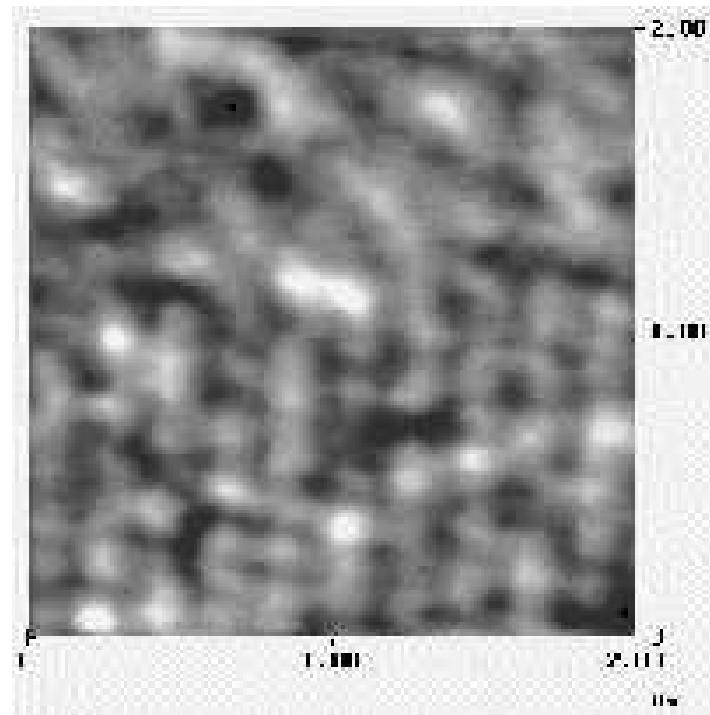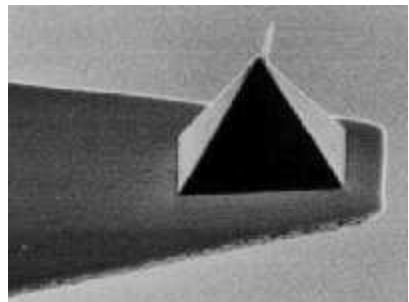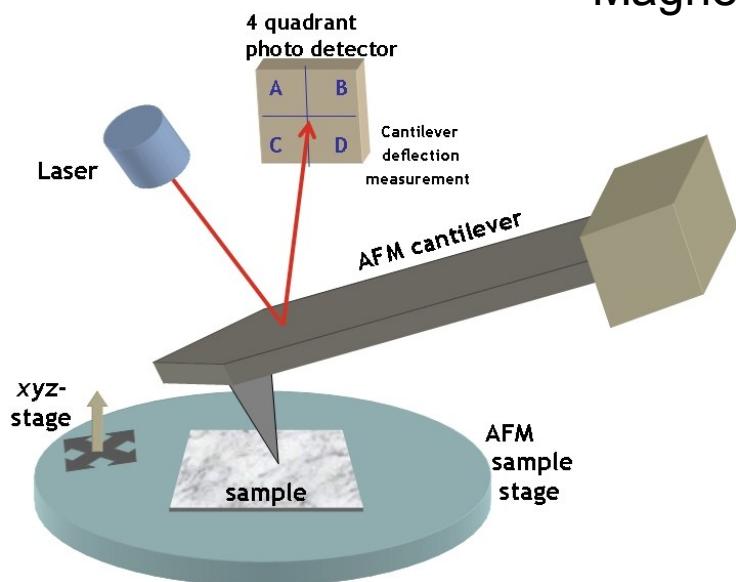
Image: Border of a 30 μm wide bit track of 300 kfrpi (89 nm bit length)

Magnetic Force Microscopy
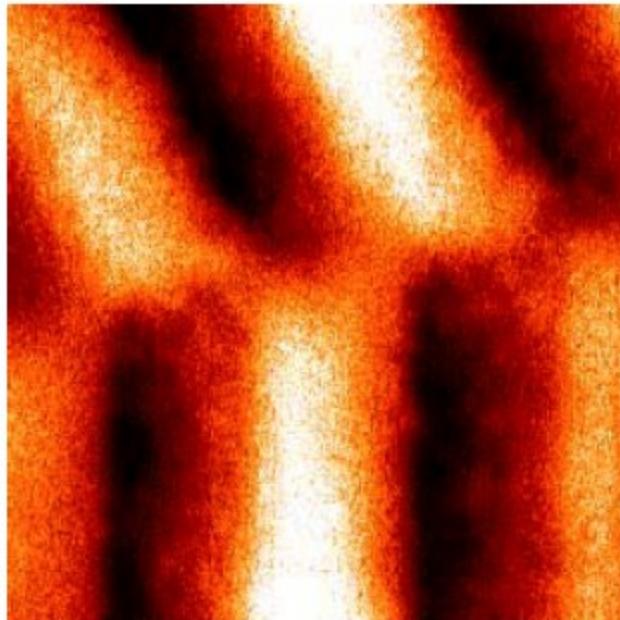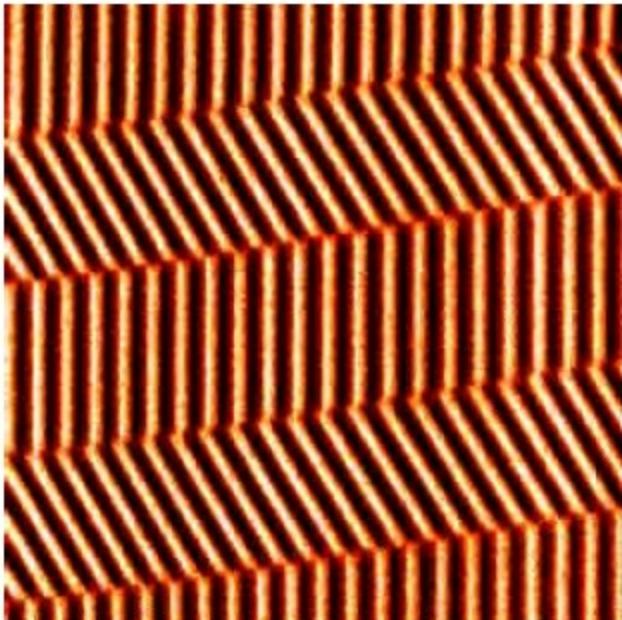
Two MFM images of closely spaced bit tracks on a tape, which is used as mass data storage device. While the read head can only disinguish "1" and "0" along the tracks, MFM is able to resolve the fine structure of the magnetic bit structure. Regarding device optimations the area where neighbouring meet (right image) are of particular importance to increase the bit density.
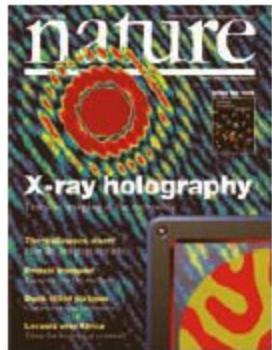
XMCD in der Röntgen-Holographie

Eisebitt et al., Nature **432**, 885 (2004)
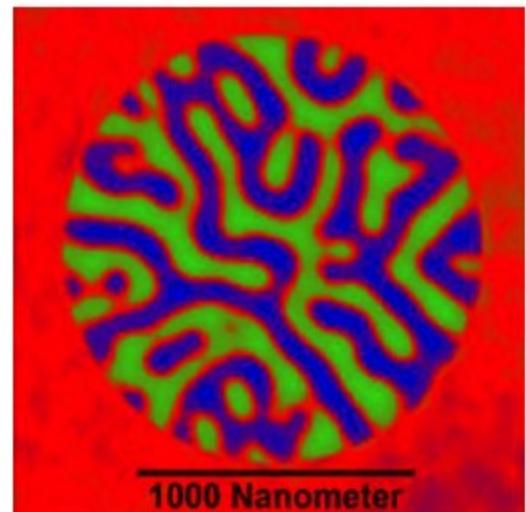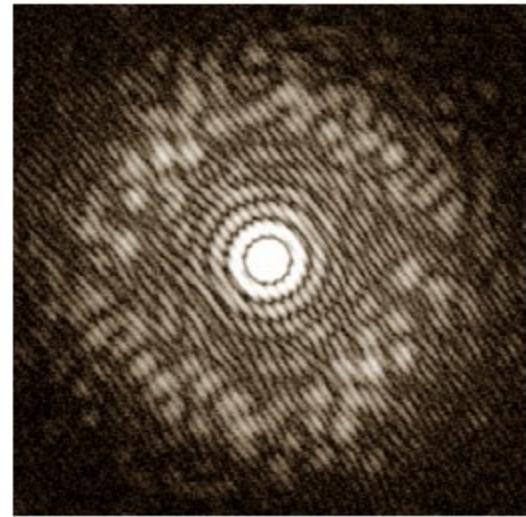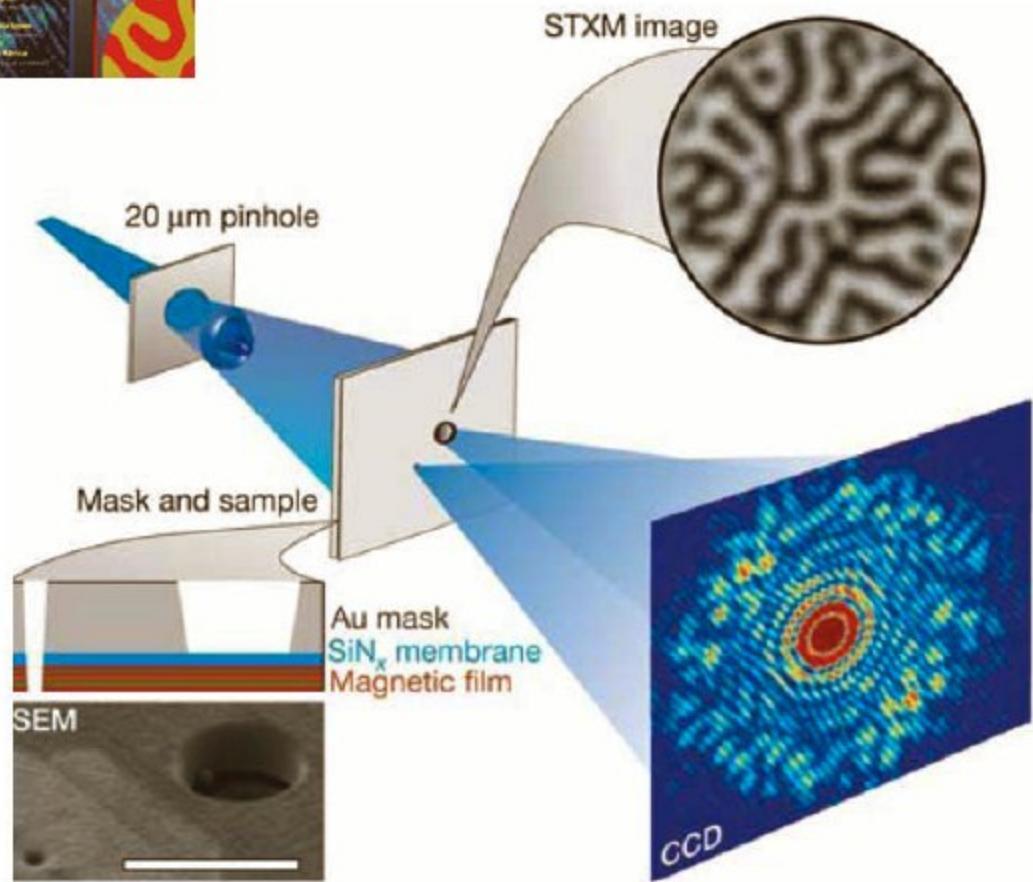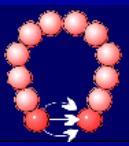
Photo electron emission microscopy

phosphor screen

projective lens II

projective lens I

deflector/ stigmator

contrast aperture

immersion lens system

Electrons
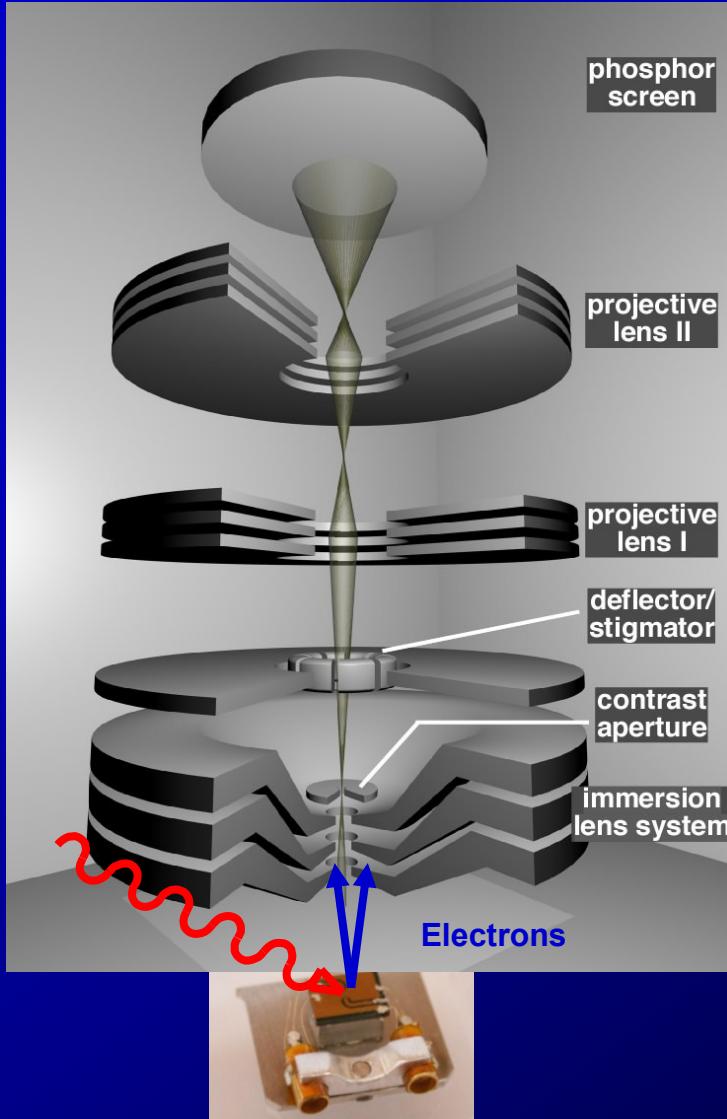
Excited oscillation modes

16x32 μm²
10 nm Py/Cu
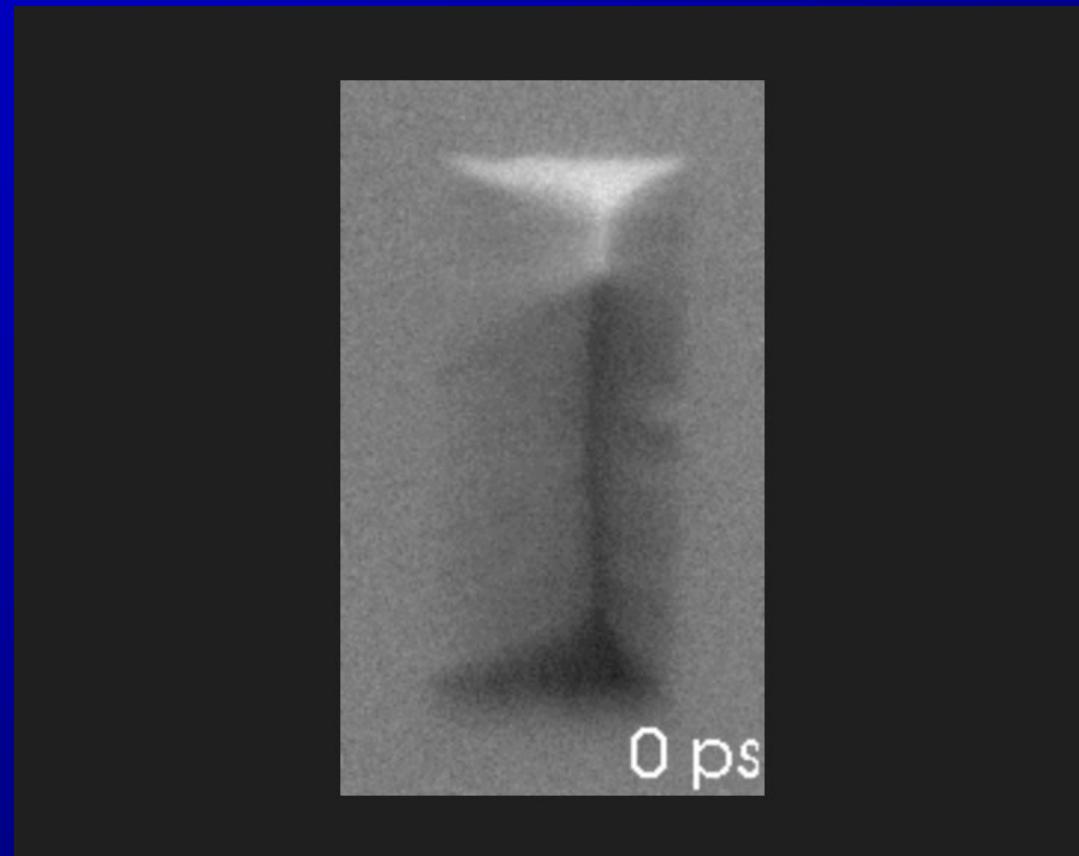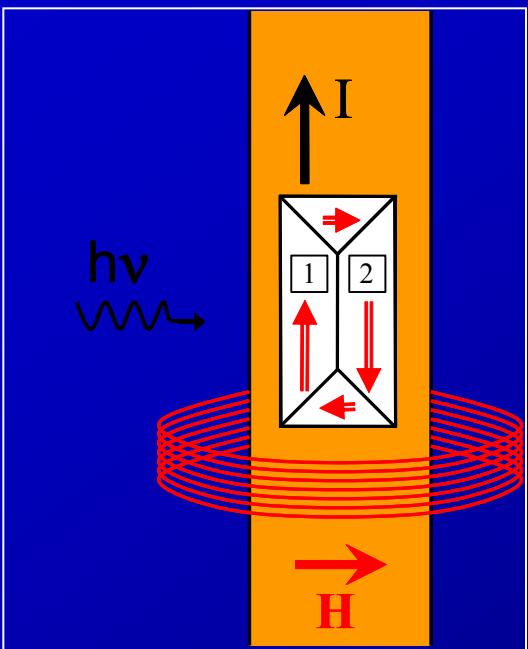

$$A_{XMCD} \sim M \cdot \sigma \sim \cos\varphi$$

Oscillating field , 1GHz, 0.2mT

PhD-thesis of A. Krasyuk

SP-STM and magnetic contrast
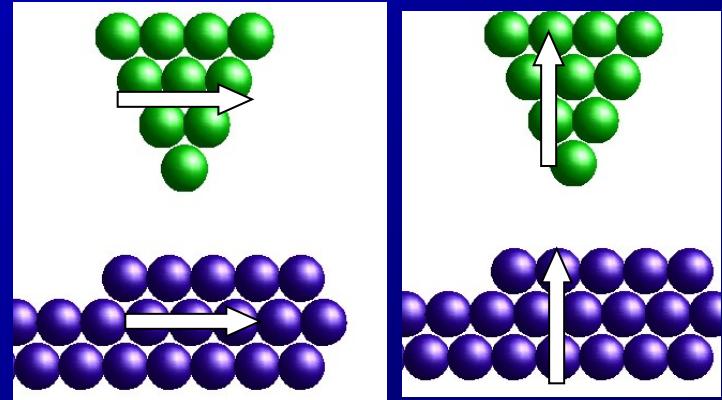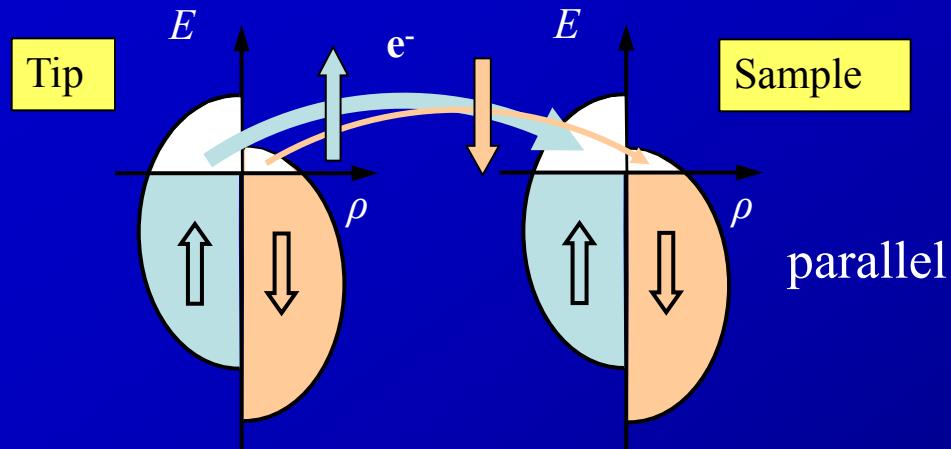
$$\frac{dI}{dU}(U) \propto n_T^{\Uparrow}(0)n_S^{\Uparrow}(eU) + n_T^{\Downarrow}(0)n_S^{\Downarrow}(eU) \propto n_T n_S(eU) + m_T m_S(eU) \cdot \cos \angle(\vec{M}_T, \vec{M}_S)$$

parallel

antiparallel
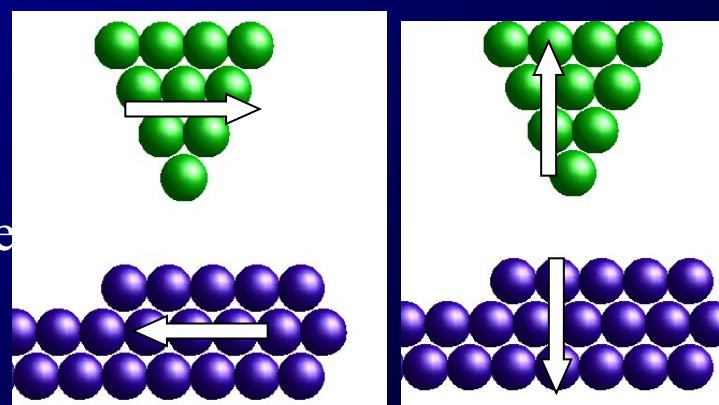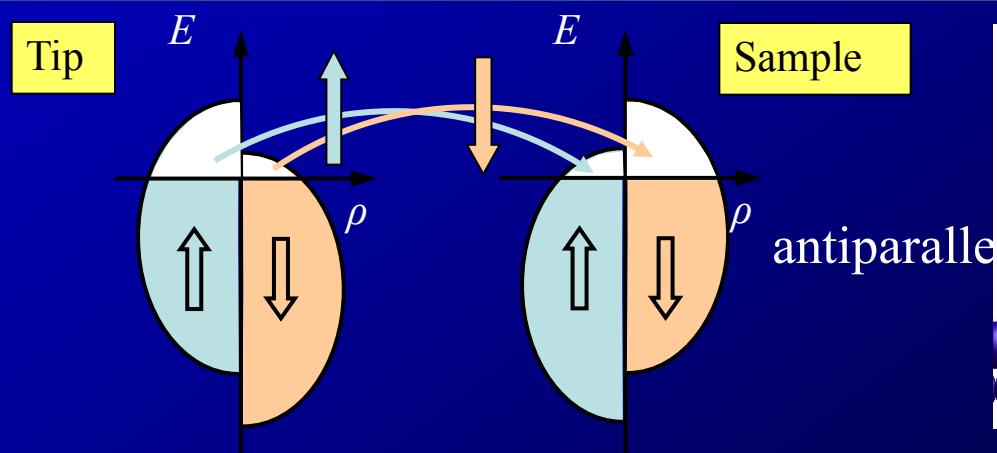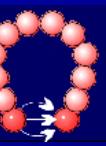
Tip and sample preparation

T. Duden and E. Bauer,

M. R. S. Proc.,287 (1997).

Co ⇧
Au(111)
W(110)

Co ⟹
Au(111)
W(110)

0.8 mm

1 μm

[110]
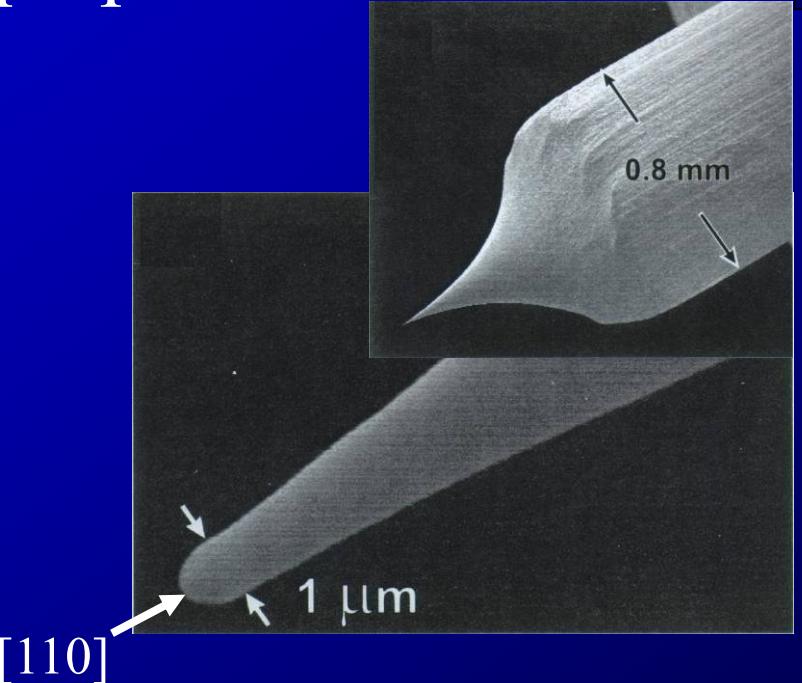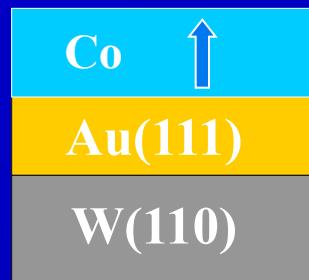
W tips -
flashing 2000 K

W(110)

evaporation - RT
10 ML **Au**
4 – 16 ML **Co**

Au
Co
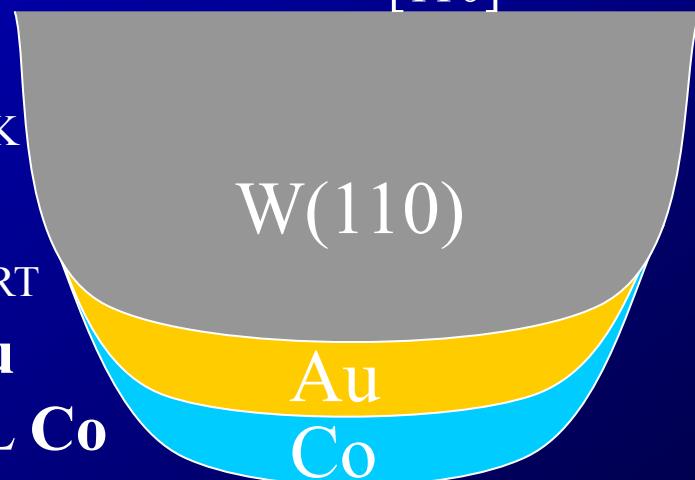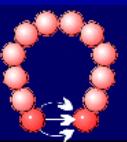
Out-of-plane magnetic contrast

4 ML Co/Au/W

T = 5 K   I = 1.5 nA U = 0.3V

T = 5 K   I = 1.5 nA U = 0.4V

(500×500) nm^2

(500×500) nm^2
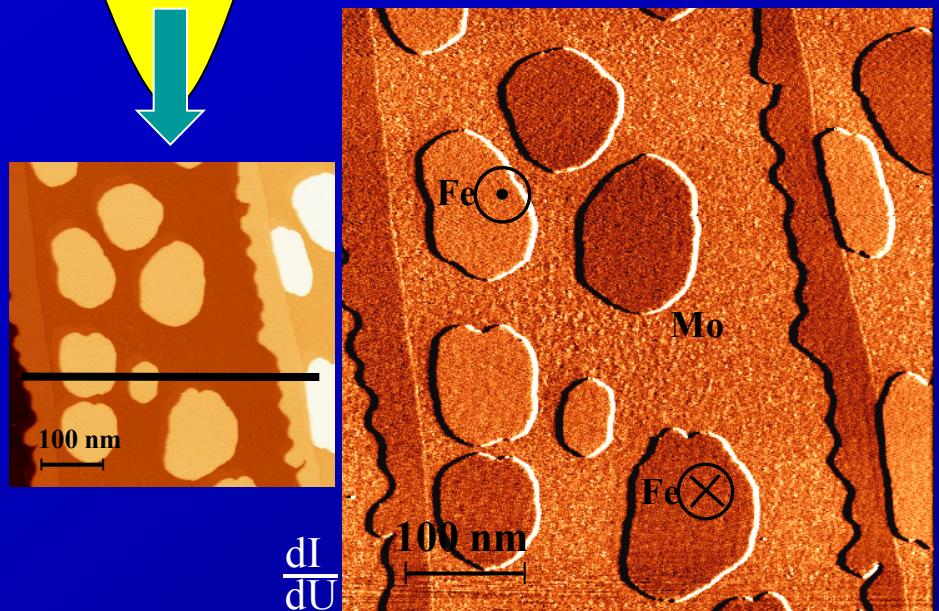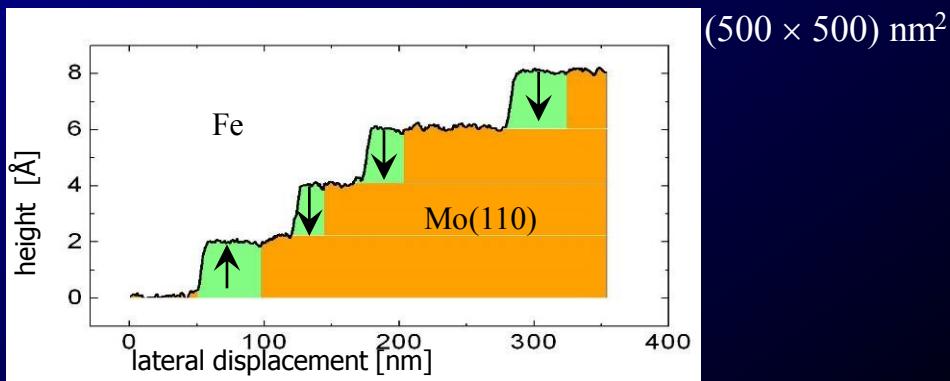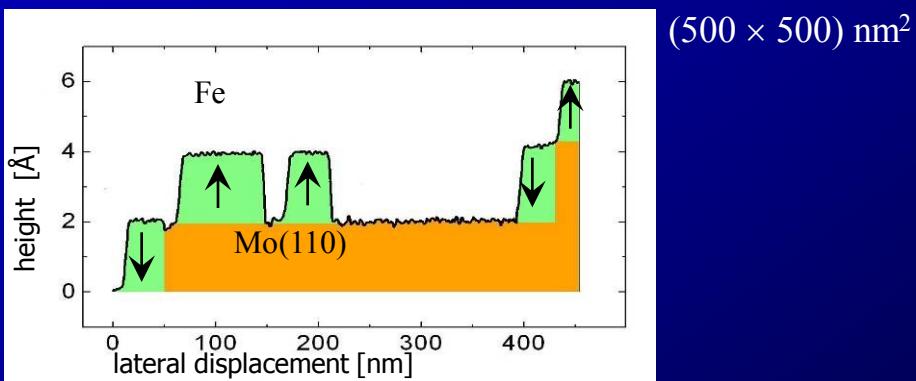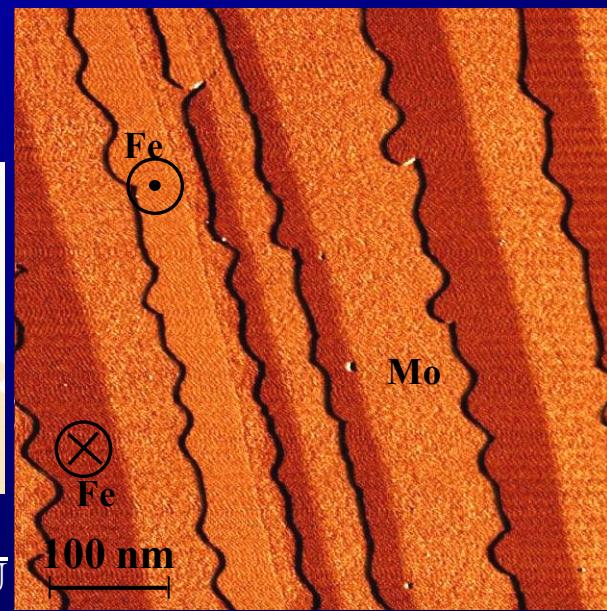
Domain wall width in the ML Fe nanowires

4 ML Co/Au/W

Topography

40nm

$\frac{dI}{dU}$

T = 5 K   I = 1.5 nA U = 1 V

Fe $\otimes$

Mo

Fe $\odot$

40nm

$\frac{dI}{dU}$

(200×200) nm²

[001]

[1$\bar{1}$0]

1.2±0.2 nm

14nm
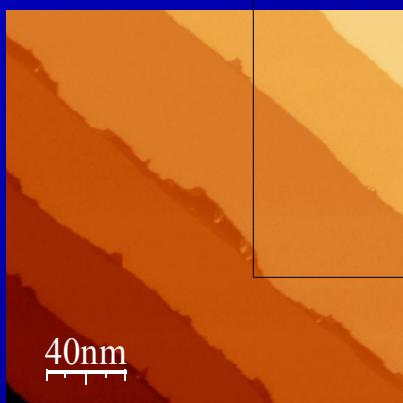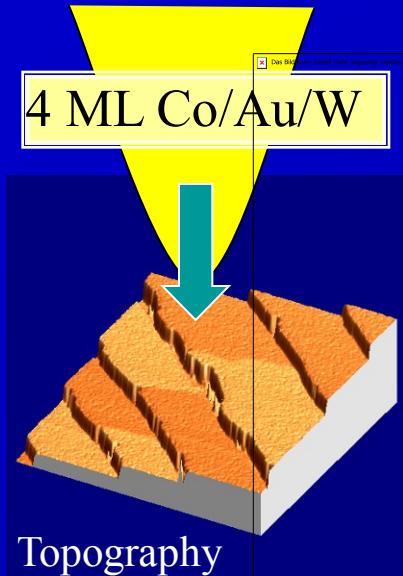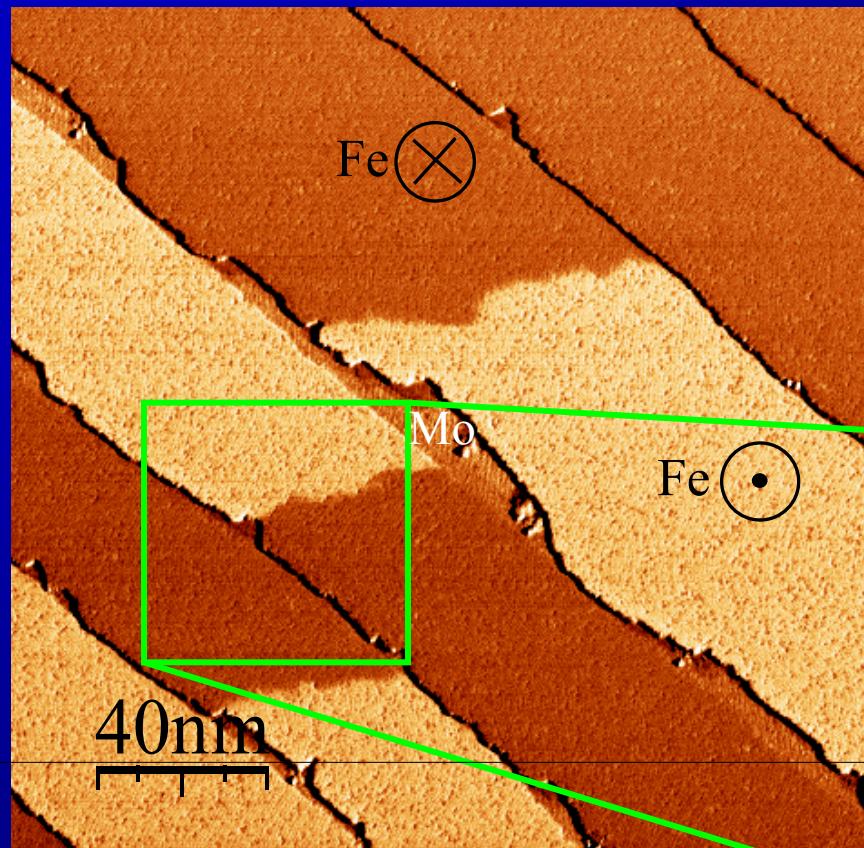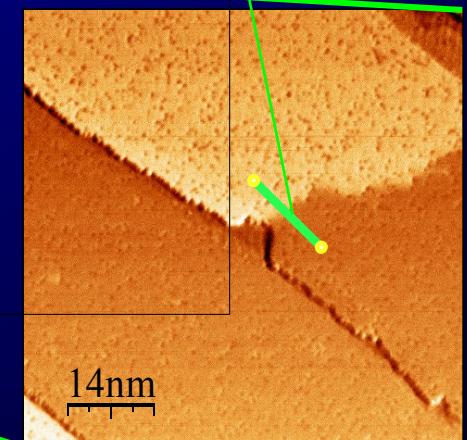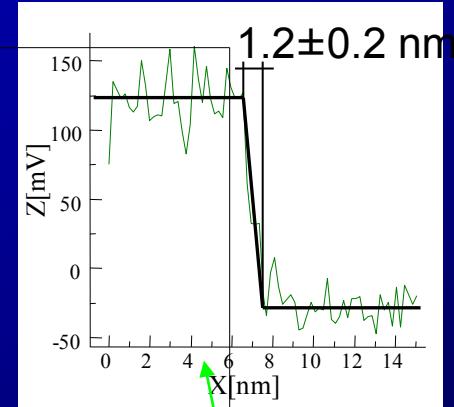
$\frac{dI}{dU}$ (70×70) nm²

Domain wall width in Fe on W(110)

(a)

50 nm

(b)

ML

DL

20 nm
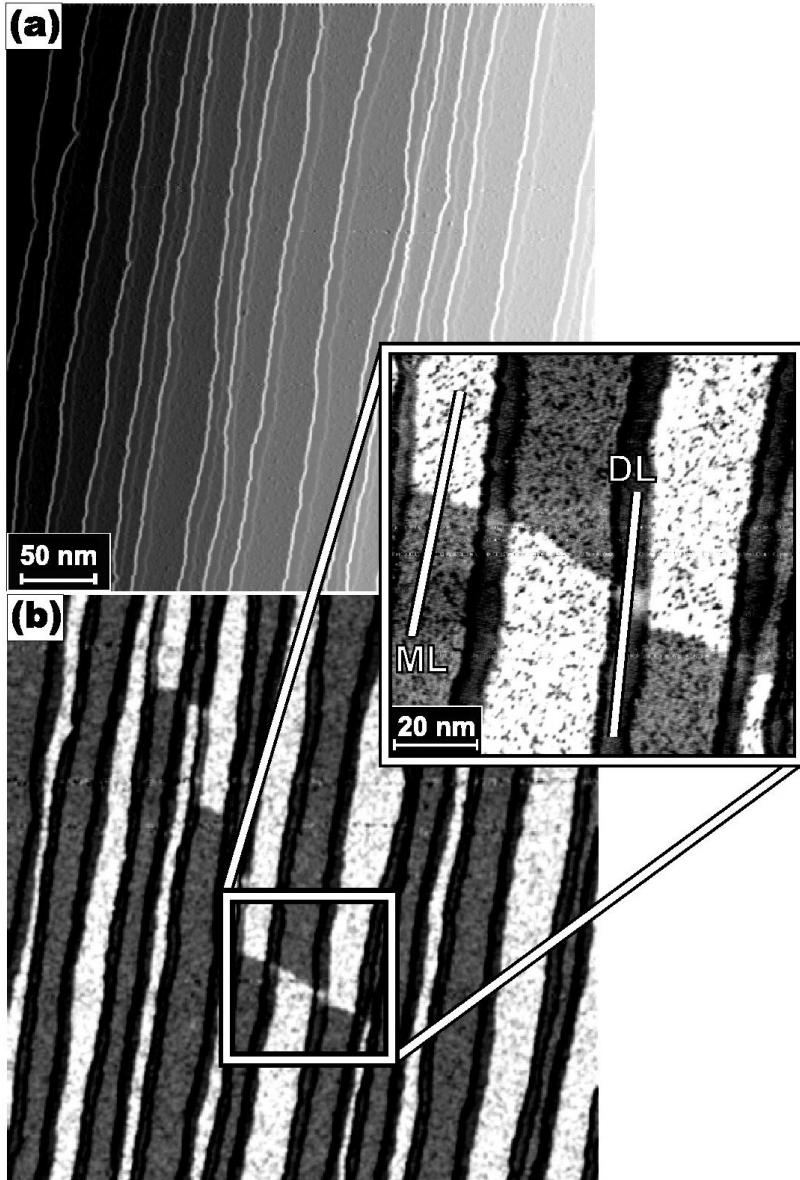
Domain wall
Width: w_{ML} = 6 Å
Energy: e_{ML} =15.2 meV/atom row

Exchange stiffness
   A = 3.6 pJ/m (8.2 meV/atom)
Anisotropy constant
   K = 41 MJ/m^3 (4.0 meV/atom)

M. Pratzer, H.J. Elmers, M. Bode, O. Pietzsch, A. Kubetzka, and R. Wiesendanger, Phys. Rev. Lett. 87, 127201 (2001).

A. Hubert and R. Schäfer
Springer 1998
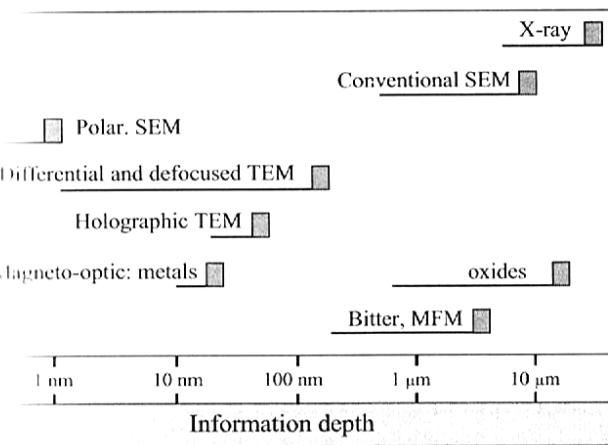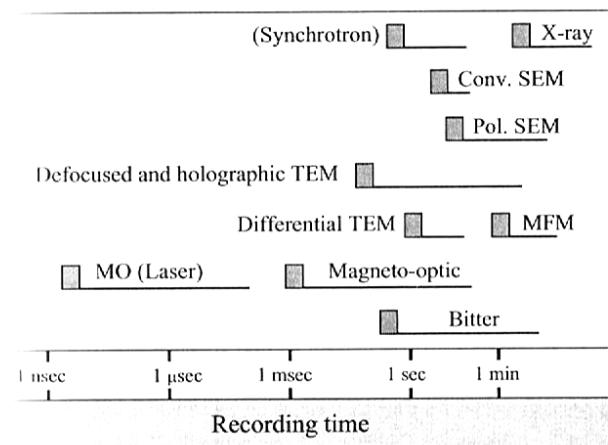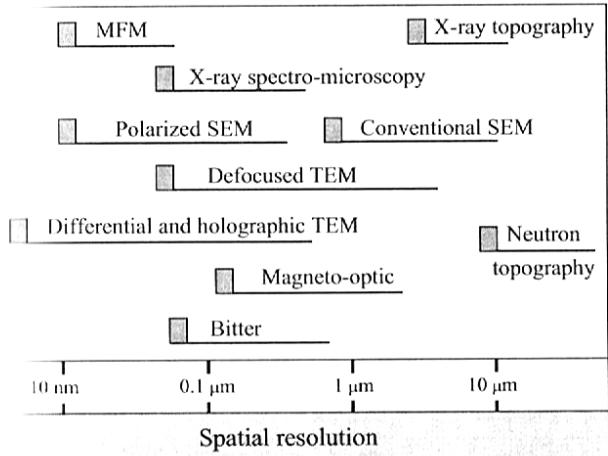
Fig. 2.56 Comparison of different domain observation techniques. Indicated are the estimated limits of the properties and their approximate range, depending on the experimental conditions