Introduction to Magnetic Recording

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Summary

I- Recording

II- Physical Effects/Competing Technologies

III- Magnetic Recording

Physics and materials (mainly for HDD)

IV- MRAMs and next

I- Recording

Analog recording (sound, images)

imperfect transfer, low quality, difficult to process

Digital recording (data, now sound and images)

analog-digital conversion (ADC-DAC) : imperfect
digital write/read : perfect fidelity

Digital recording is now the main recording method
It is more universal
data transfer whatever the origin
whatever the technology

Quantity of data to store :

One computer instruction	32 – 64 bits
Microprocessor memory	1 Megabyte (MB)
One hour of music (CD-ROM)	700 MB
Computer RAM memory	1 Gigabyte (GB)
One Hour of video (DVD-ROM)	4 GB
Hard Disk Capacity	100 GB 1 Terabyte (10^{12} TB)
LHC(CERN) data/year	15 Petabyte (10^{15} PB)
Google Storage	200 PB
Hard Disk Drive shipment /year	400 million HDD x 100 GB = 40 exabytes (10^{18} EB)

Storing information : what conditions ?

Digital storage (binary coding)

Two states : 0 and 1 or up and down
More states / memory cell is possible
(FLASH cell, 4 bit/cell = 16 states)
(DVD 2 surfaces+2 sides)

Permanent storage (volatility) : 1ms -1s-1y-10-100 years

Storage Density : 1 byte to 1 Terabyte on a given surface
1 mm^2 memory to 1 km-long tape

Access time : Random Access / Sequential Access
Minutes (tape), µs (FLASH) to ns (HDD)

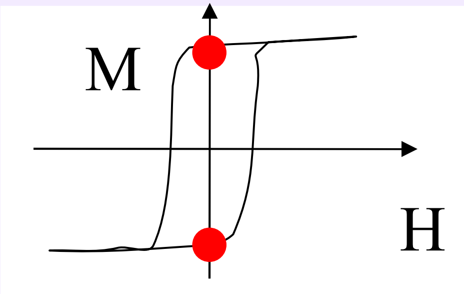
II- Possible Physical effects
Competing Technologies

We need physical effects and then technologies, which allow for

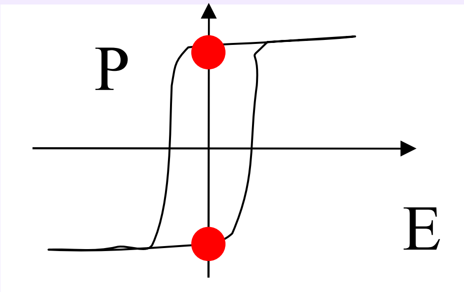
storing i.e. writing + reading (+erasing)

Storing : possible physical effects

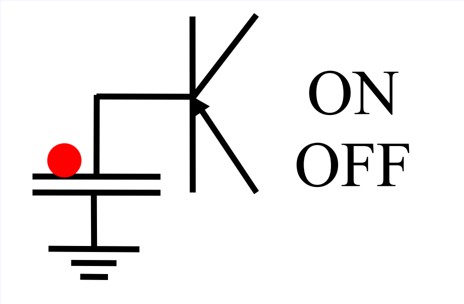
Magnetic : remanent state of
a ferromagnetic entity



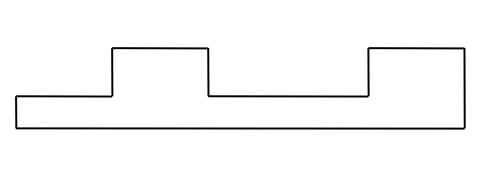
Ferroelectric : remanent state of
a ferroelectric entity



Electrostatic : presence or absence of
electrical charge



Mechanical : hole/no hole



Phase transition (metal - insulator)

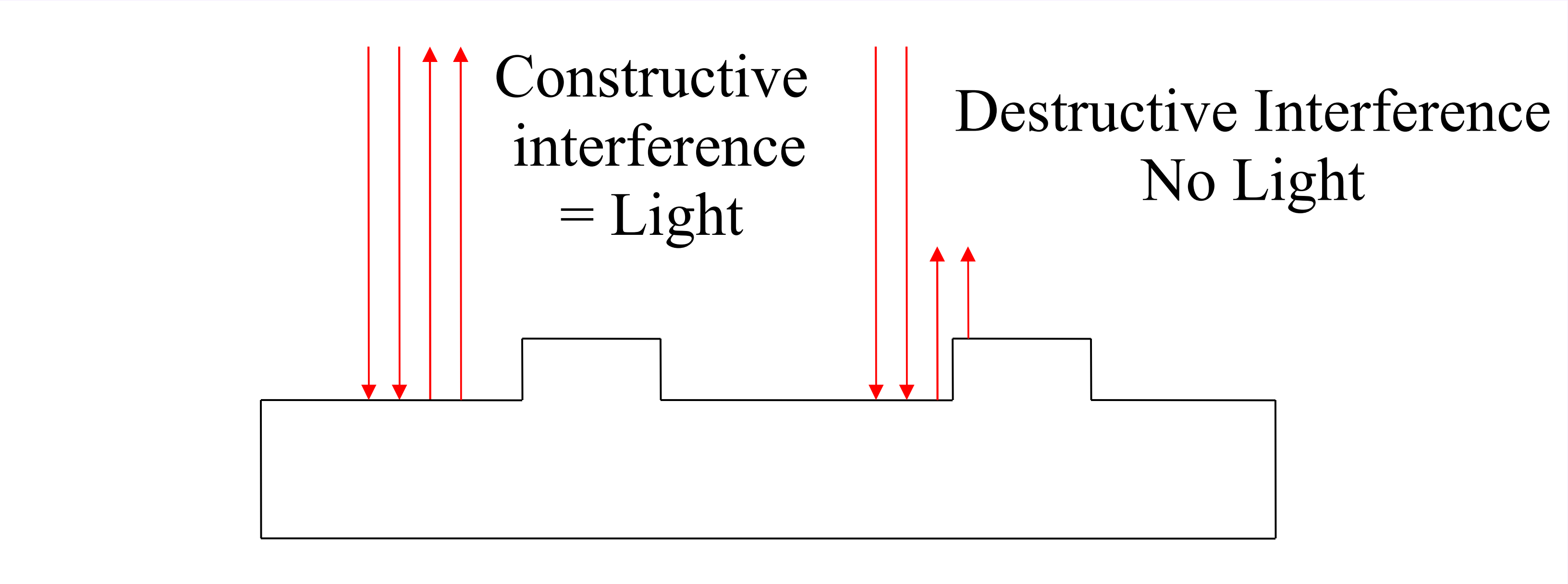
Writing + Reading information

Mechanical :

Write : Print, Press, Engrave ...

Read : mechanical needle (Edison 1877)
piezoelectric transducer (record player)
optical interference (CD-ROM)
heat dissipation (Millipede)

Mechanical Recording : CD-ROM, DVD, BlueRay/HDDVD

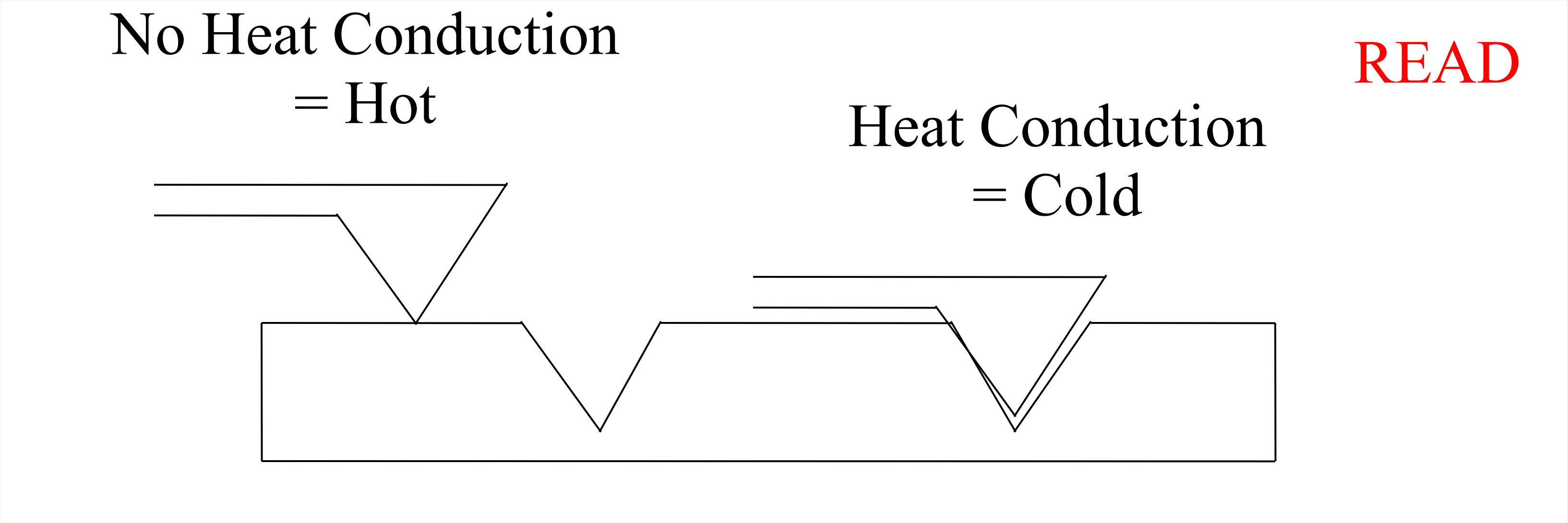


CD: 780 nm (I.R.)
DVD : 650 nm (red)
BlueRay : 405 nm (blue)

Mechanical Recording : Millipede (IBM Zurich)

40 nm hole in a polymer film

Mechanical Recording : Millipede (IBM Zurich)



Read = thermal sensor

Writing + Reading information

Electrostatic (semiconductor memories) :

Write	current pulse to charge a capacitor or a gate
Read	transistor open/close FLASH capacitor charged or not RAM

FLASH memory Principle

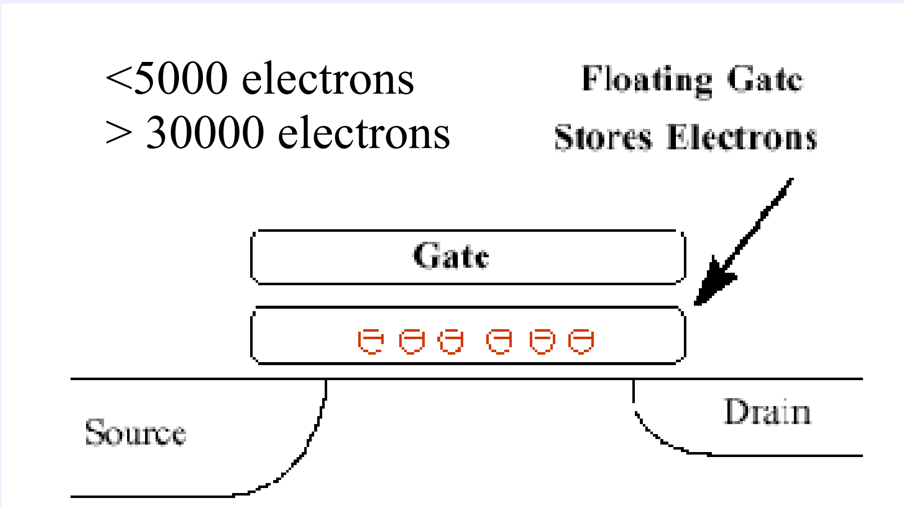


Figure 2: Single transistor flash memory cell

Intel corp.

Leakage < 1 e /day

Large voltage pulse
to inject the charge in the floating gate

Several level of Charge= multi-bit /cell

Characteristic charging time given by RC of the circuit

large RC, less volatile storage, less rapid

Usual FLASH : conducting floating gate

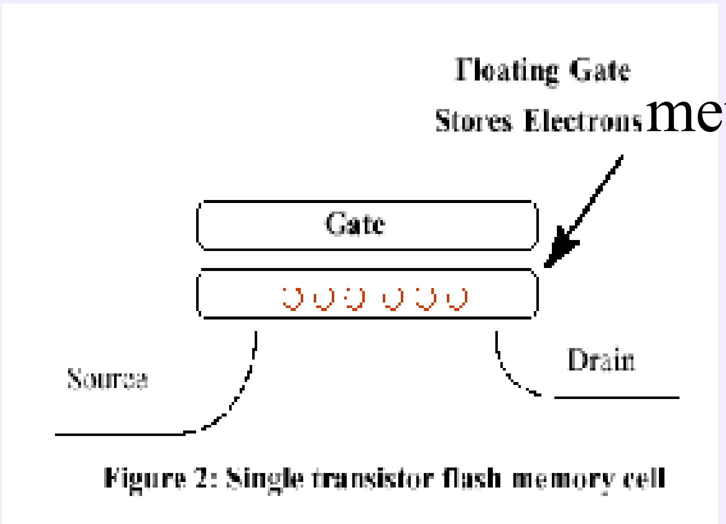
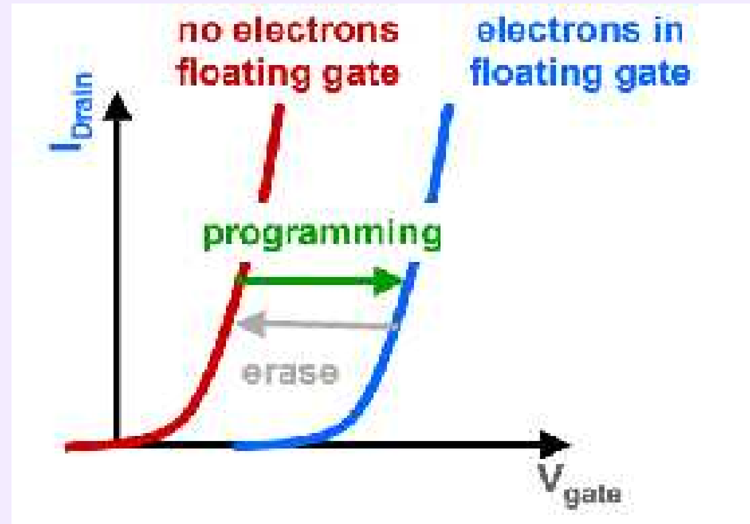


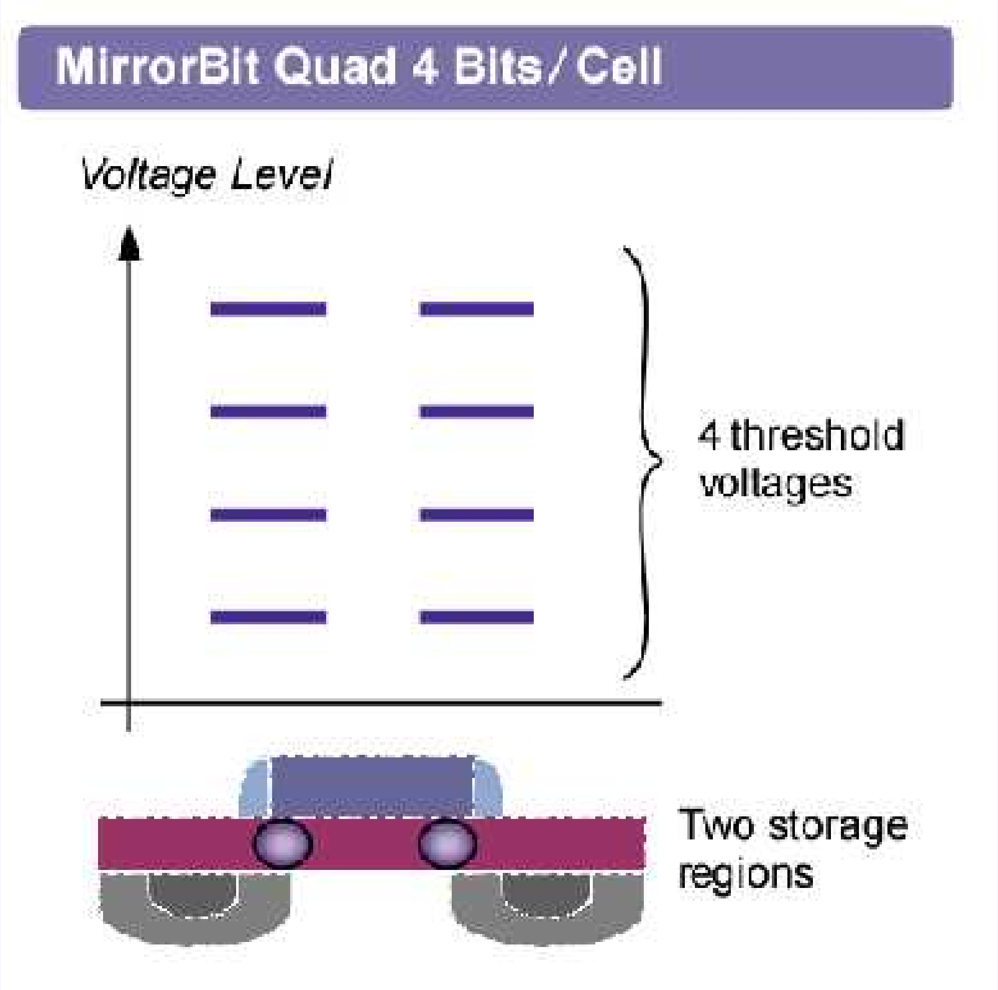
Figure 2: Single transistor flash memory cell

metallic



Spansion's technology : charging an insulating layer :
2 separated charges can be written

4 bits /memory cell



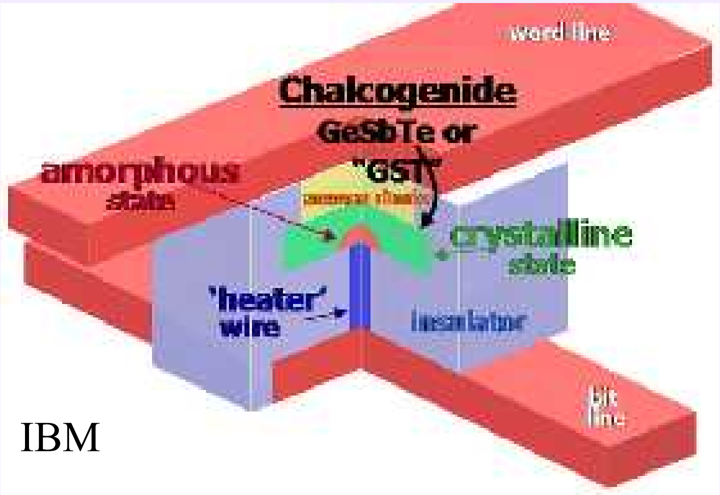
Writing + Reading information

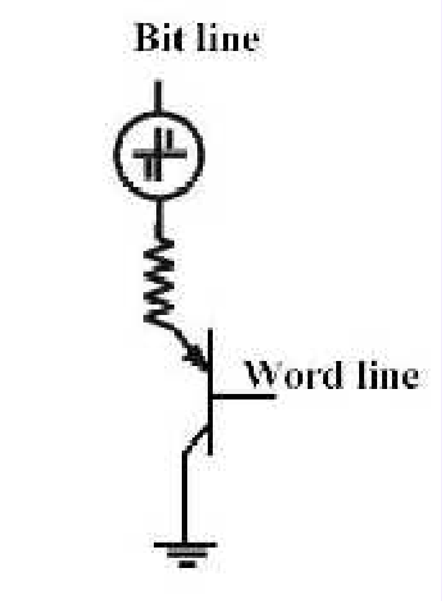
Phase-Change

Crystalline-amorphous (PC-RAM memories)

Write	current pulse heat the material (melt or crystallise)
Read	low/high resistance

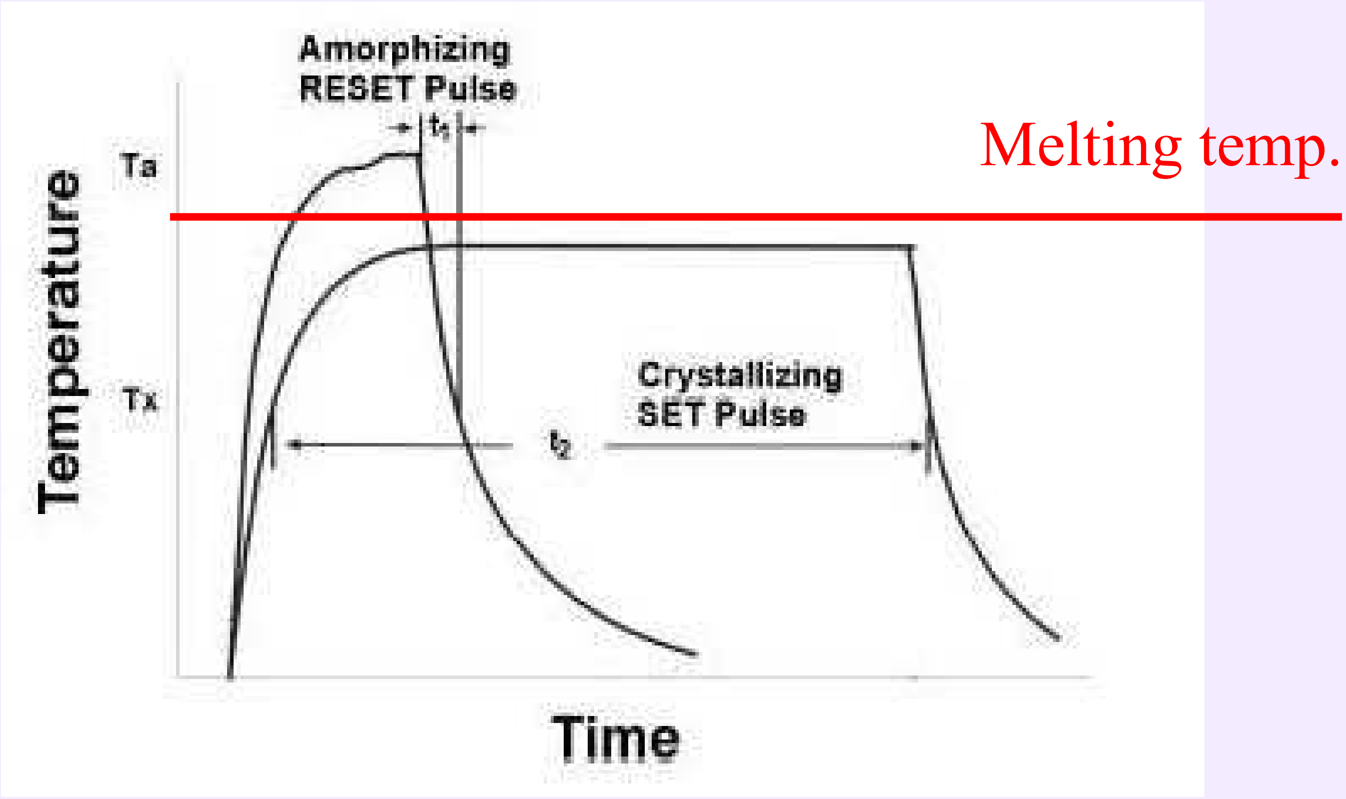
Phase Change Memory (PC-RAM)





$Ge_2Sb_2Te_5$: amorphous (resistive)
crystallised 40X more conducting

PC-RAM : Writing - Erasing



Writing + Reading information

Ferroelectric :

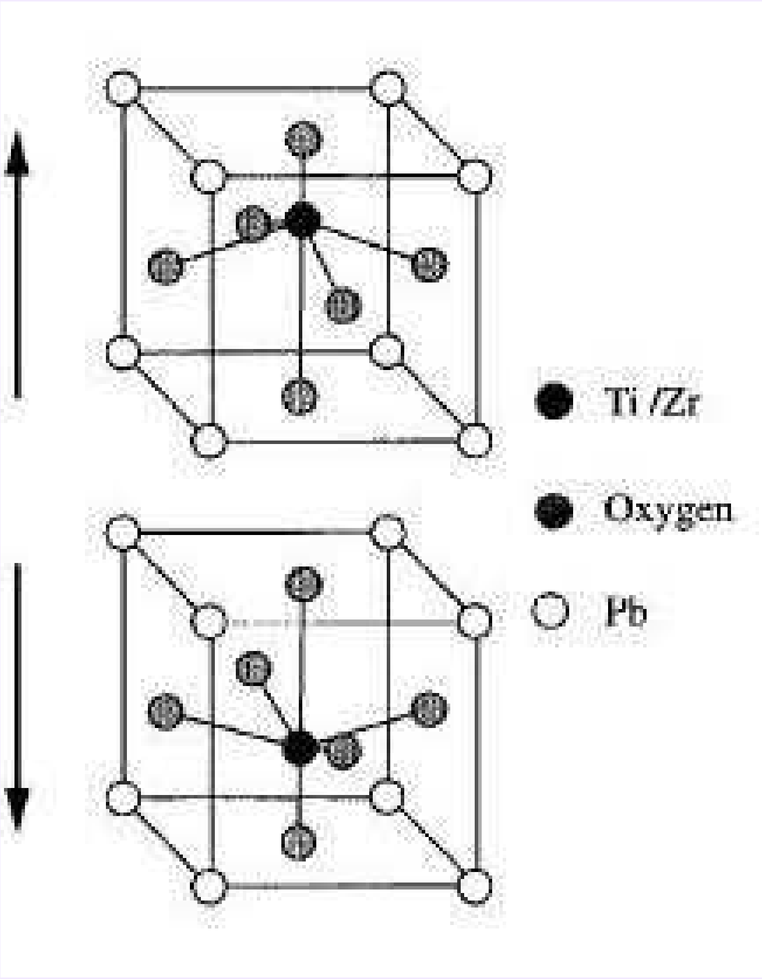
Write – Read

electric voltage
to polarise a ferroelectric

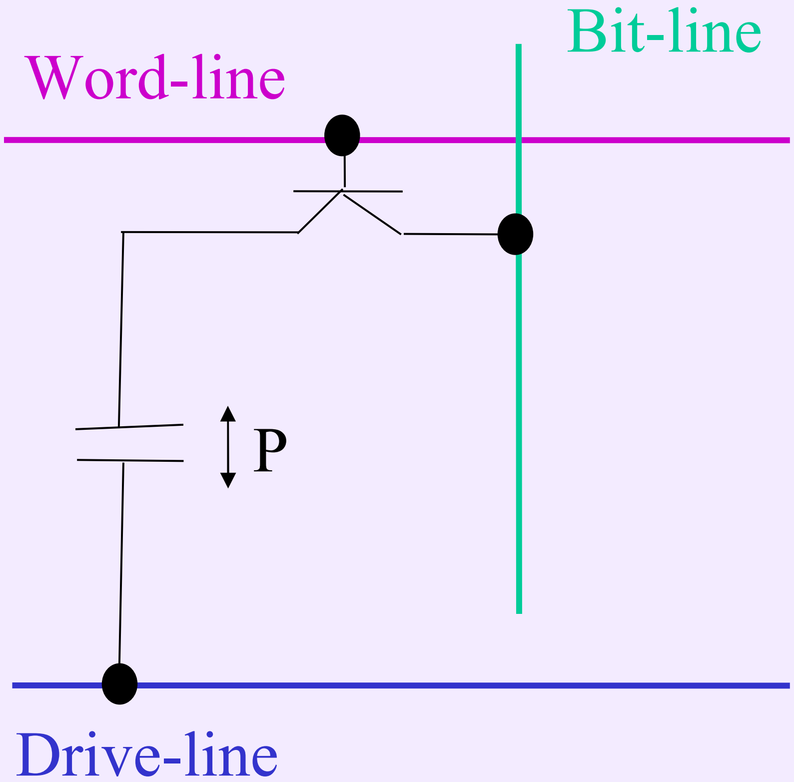
discharge to check polarisation

K. Doerr's talk last Friday

Ferroelectric RAM (FeRAM)
$Pb(Zr_xTi_{1-x})O_3$ or $SbBi_2Ta_2O_9$

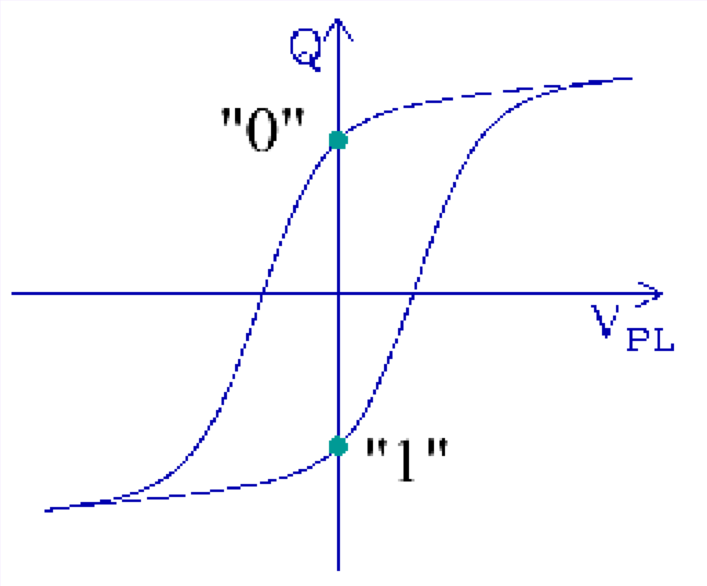


Condensator
with a ferroelectric dielectric



Reading destroys the information

Non square loop : remanence is not well defined, the access transistor is necessary



Commercial FeRAM :

2007

FM20L08

1Mbit Bytewide FRAM Memory – Industrial Temp.

RAMTRON

Features

1Mbit Ferroelectric Nonvolatile RAM

- Organized as 128Kx8
- Unlimited Read/Write Cycles
- NoDelay™ Writes
- Page Mode Operation to 33MHz
- Advanced High-Reliability Ferroelectric Process

SRAM Replacement

- JEDEC 128Kx8 SRAM pinout
- 60 ns Access Time, 350 ns Cycle Time

Superior to Battery-backed SRAM Modules

- No battery concerns
- Monolithic reliability
- True surface mount solution, no rework steps
- Superior for moisture, shock, and vibration
- Resistant to negative voltage undershoots

Low Power Operation

- 3.3V +10%, -5% Power Supply
- 22 mA Active Current

1 Mbit

read-write cycle 350 ns

nonvolatile 10 years

Writing + Reading information

Magnetism :

writing magnetic field

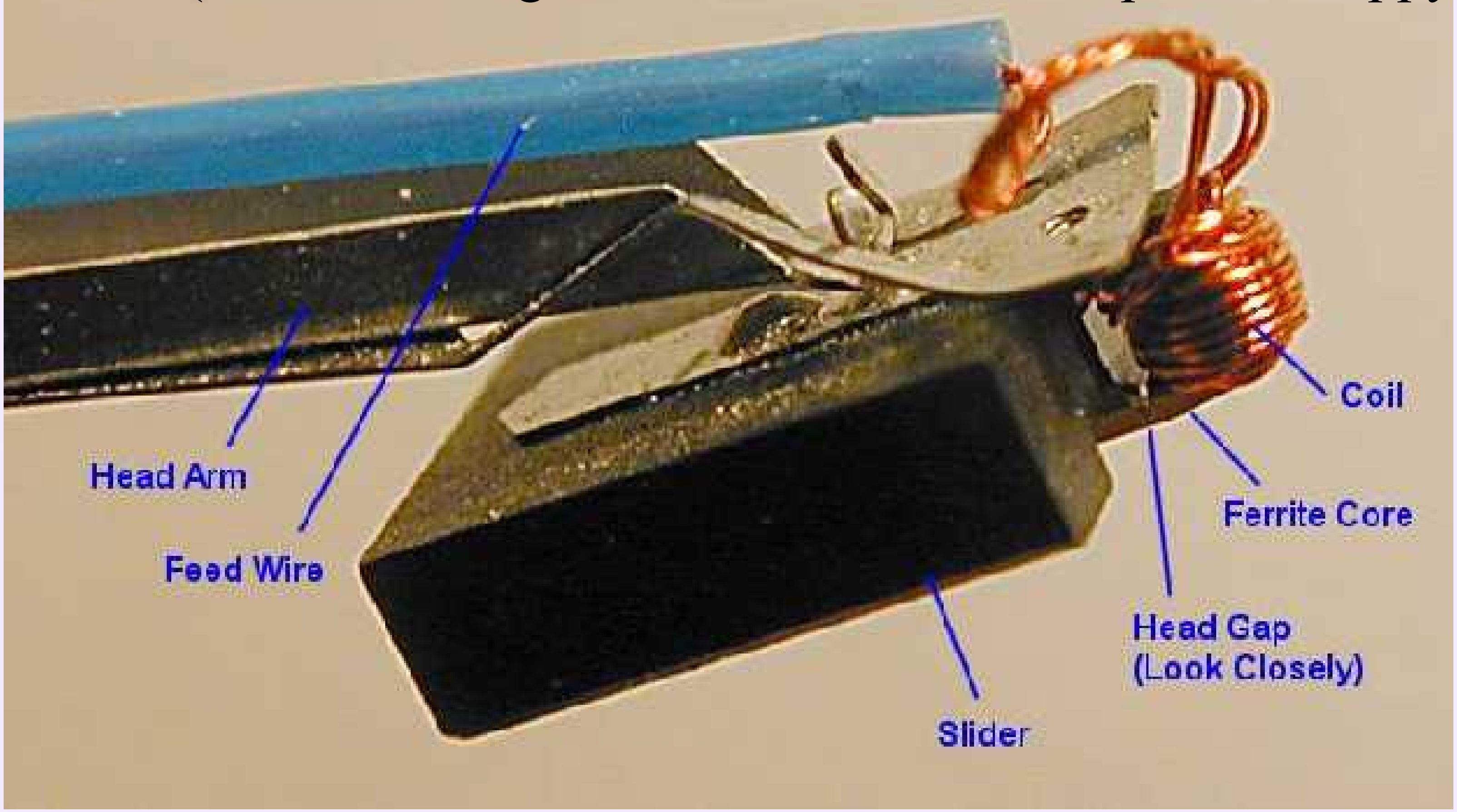
electric field

current pulse

light pulse

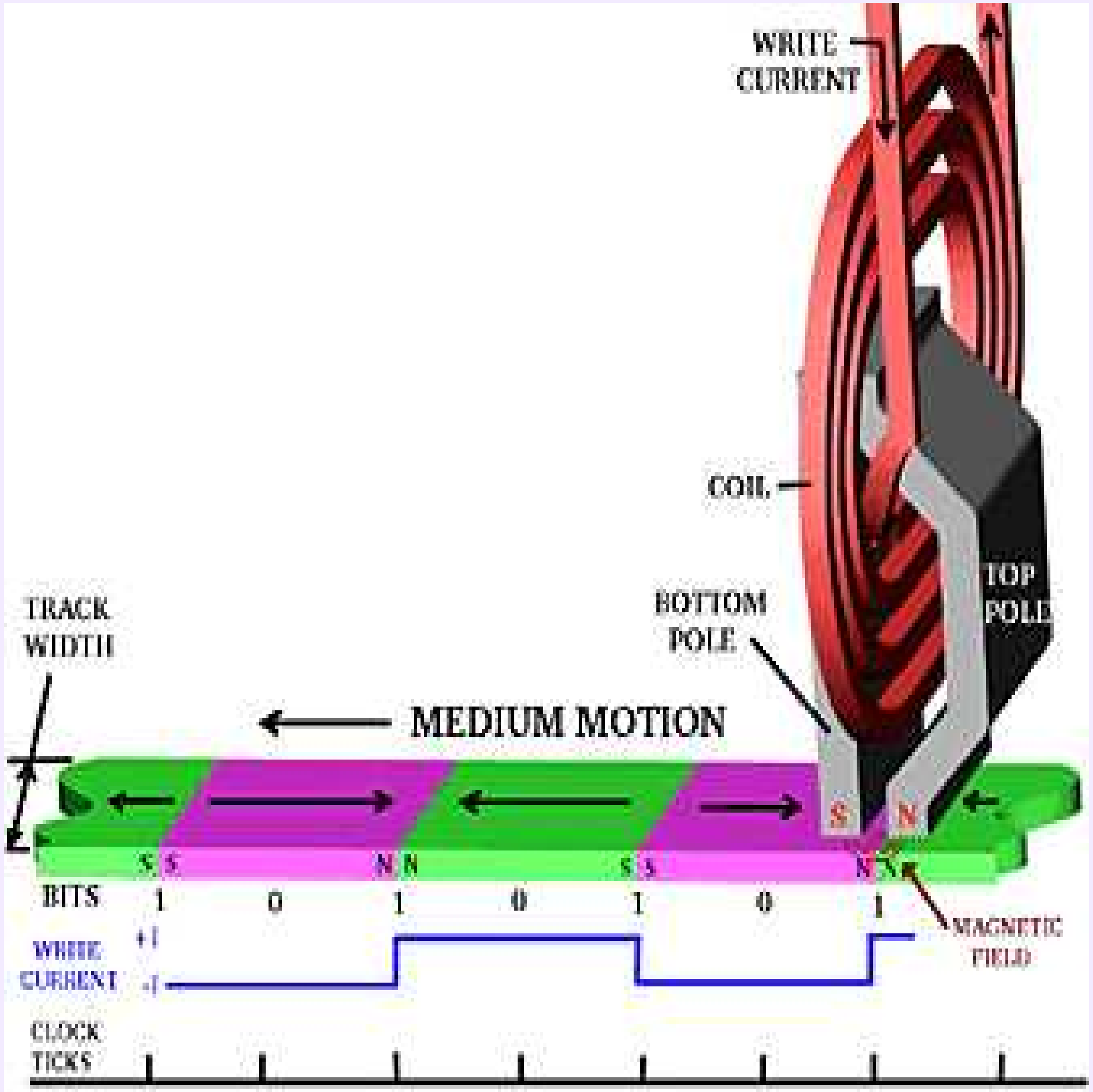
Writing Magnetic bits

Ferrite Head (hard disk Seagate ST251 50 MB 1990, present floppy head)



MIG (Metal-in-gap) head : deposition of an iron rich alloy onto the poles to increase their magnetisation (and thus, their saturation).

Magnetic Recording Heads : inductive heads



Thin film head

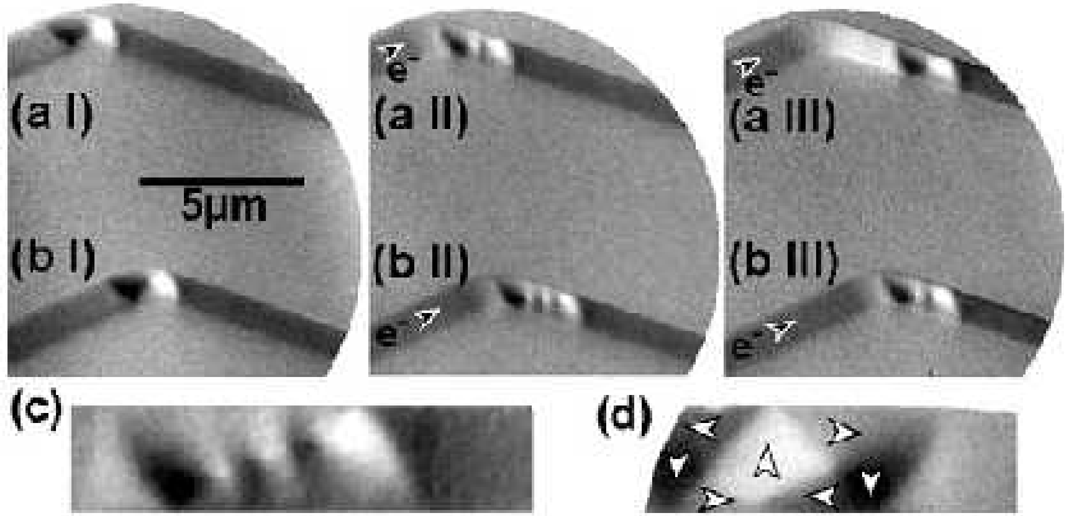
Bottom Pole (NiFe)
Copper windings
Top Pole (NiFe)

(Read-Rite)

Writing Magnetic bits : recent proposals

Spin polarised current induced
Magnetisation reversal
Domain wall displacement

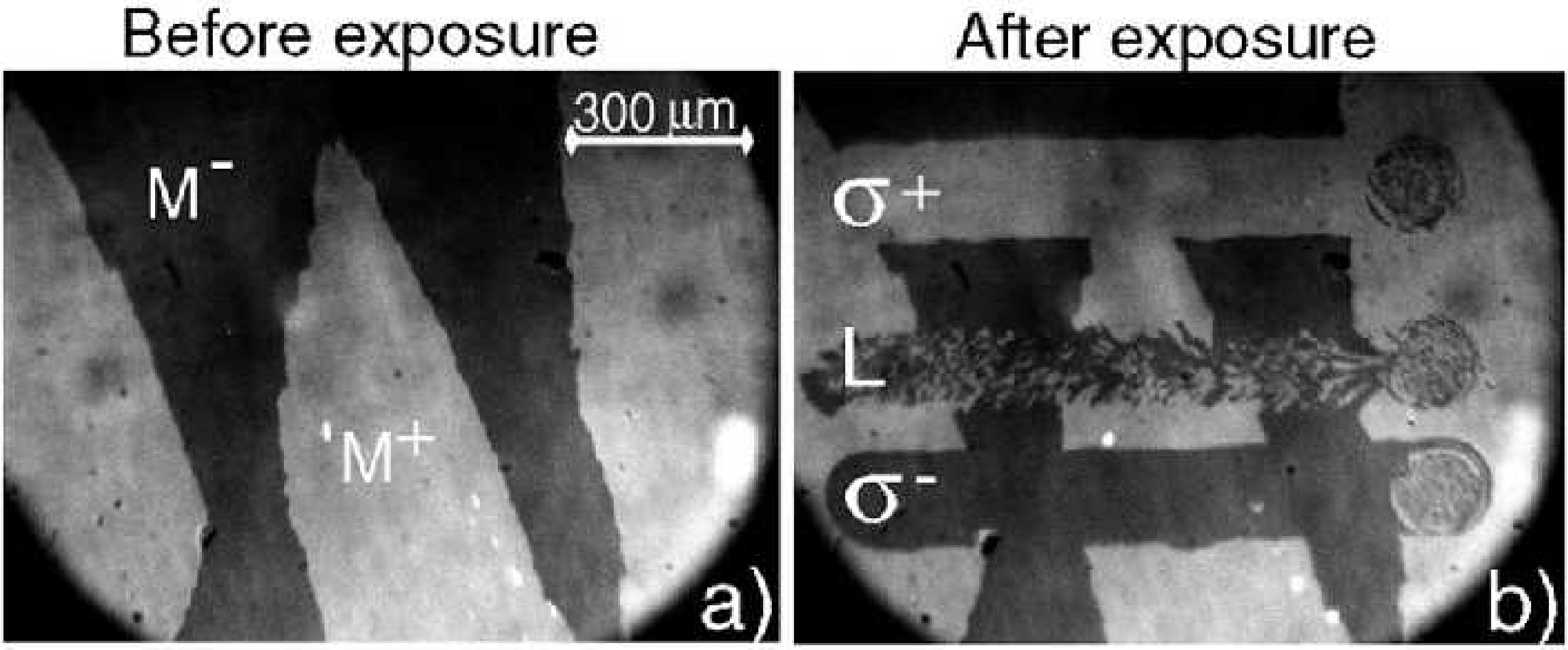
Klaui et al. Appl. Phys. Lett. 88, 232507 (2006)



See M. Viret's talk this afternoon

Writing Magnetic bits : recent experiments

Circularly-polarised light pulse : 800 nm, 40 fs



Stanciu et al. PRL(2007)

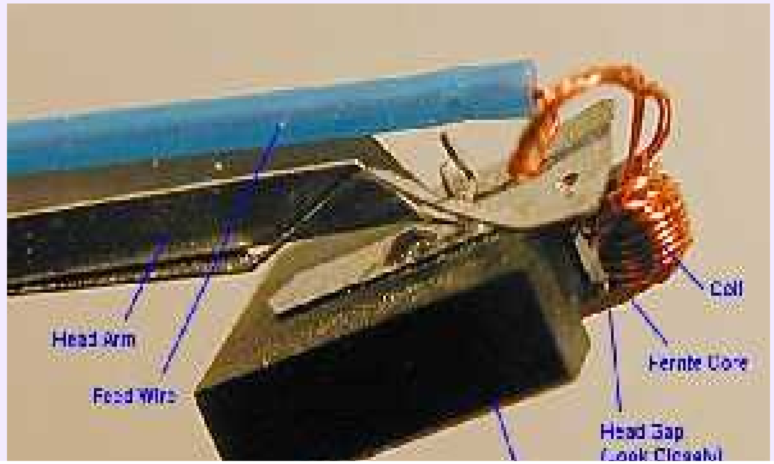
Writing + Reading information

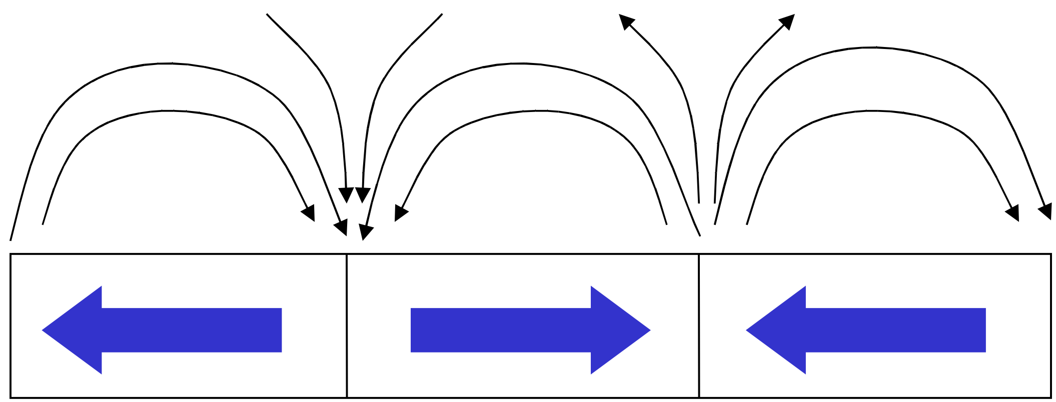
Magnetism :

writing	magnetic field electric field, current pulse, light pulse
reading	stray field (Floppy disk) magneto-optical effect (M-O disk) electrical effect (MRAM)

Reading Magnetic bits

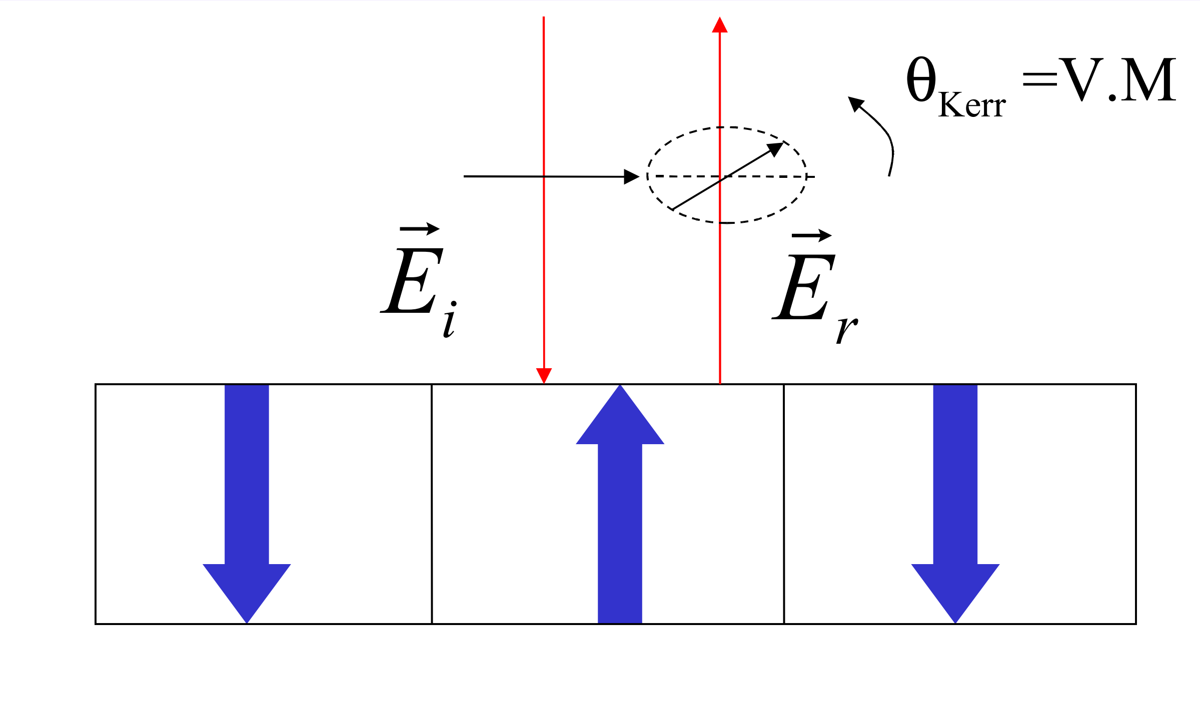
Magnetic Stray Field above a Longitudinal Media





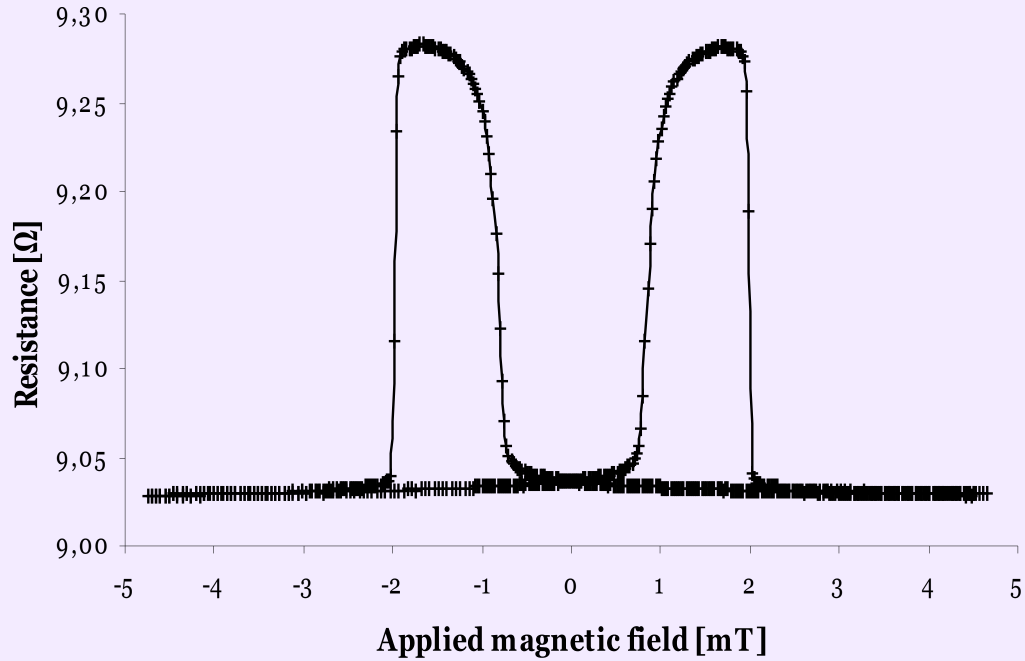
Longitudinal recording

Magneto-optical effect (polar Kerr)
Perpendicular Media

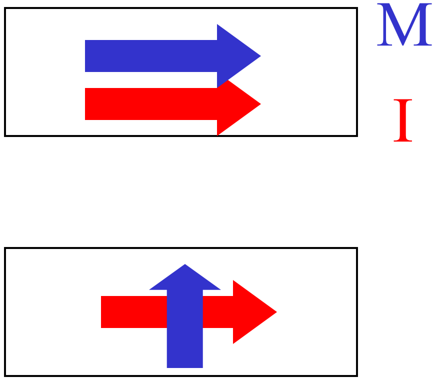


Reading Magnetic bits : Magnetoresistance

MR of the bit (MRAM)
MR of the sensor (read-head)

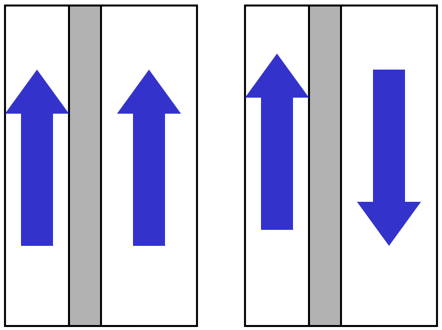


Anisotropic MR



1-2%

Tunnel MR



40%

See J M. de Teresa 's lecture tomorrow

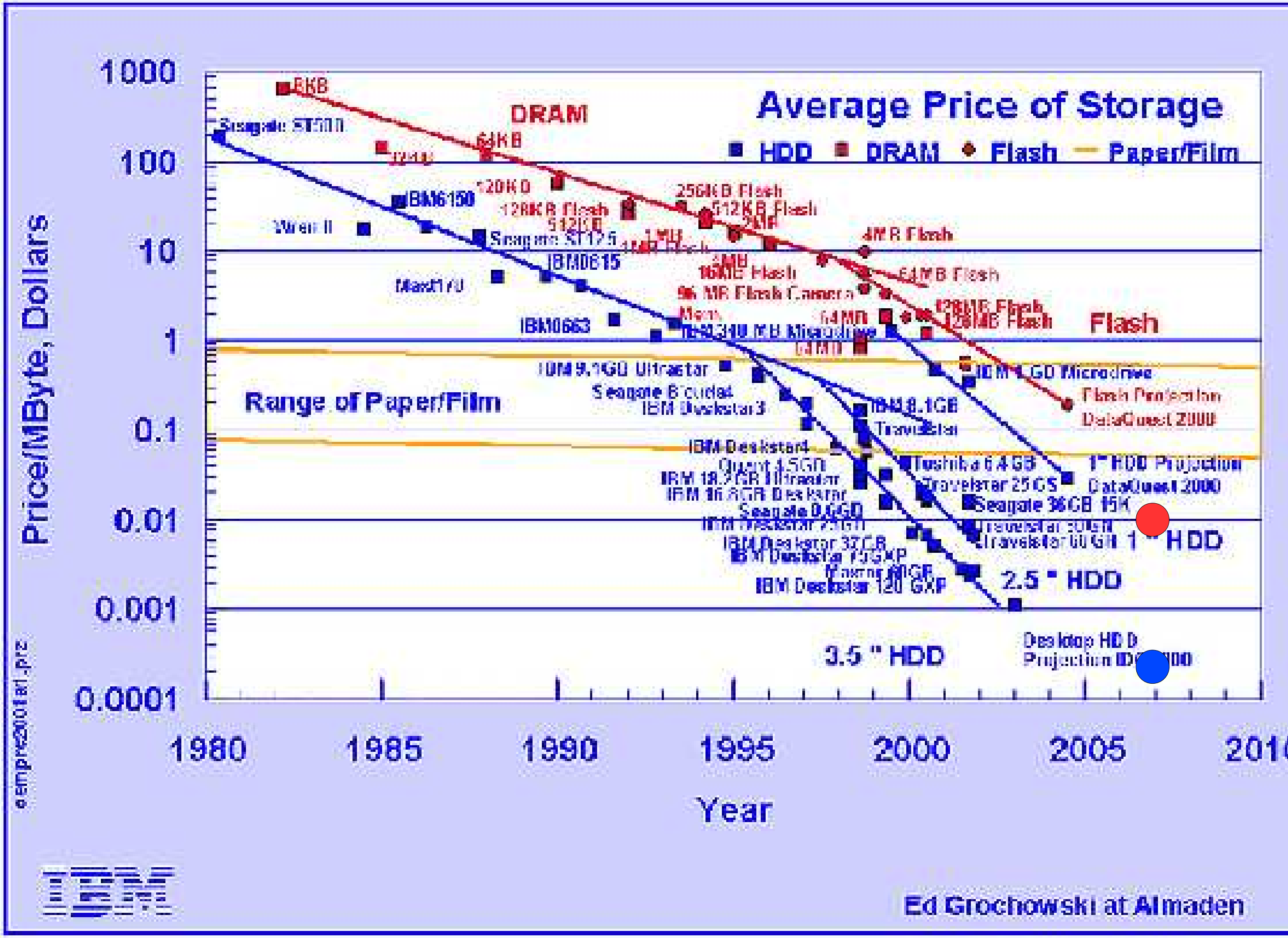
What makes the difference ?

Existing technology / not yet developped
existing memories (10 GB RAM and Flash)
no magnetism in Si technology --> no integrated MRAM yet

Maximum density : physical limits   Wavelength / Heating
Thermal stability (superparamagnetism)

Access time (ns) / Write time (1 ns) / Read time (1ns)

Life cycles 10^5 - 10^8 - $10^{infinity}$
(mechanical stress, electromigration ...)



Economics (cost, investment to develop)

Competing technologies

Exponential decrease of the €/bit

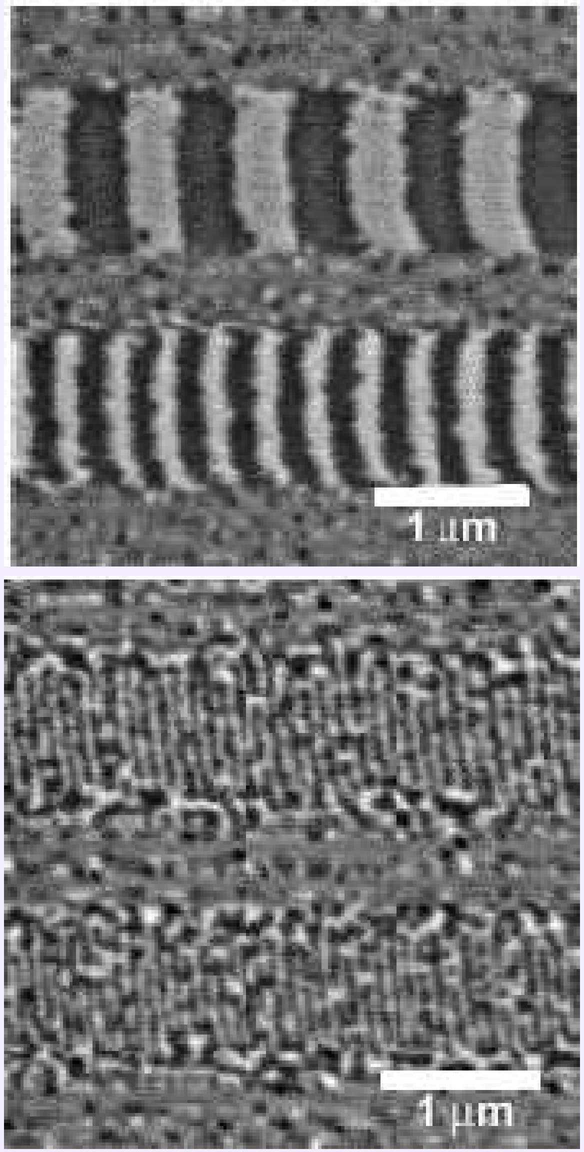
III- Magnetic Recording

Magnetic Recording Media

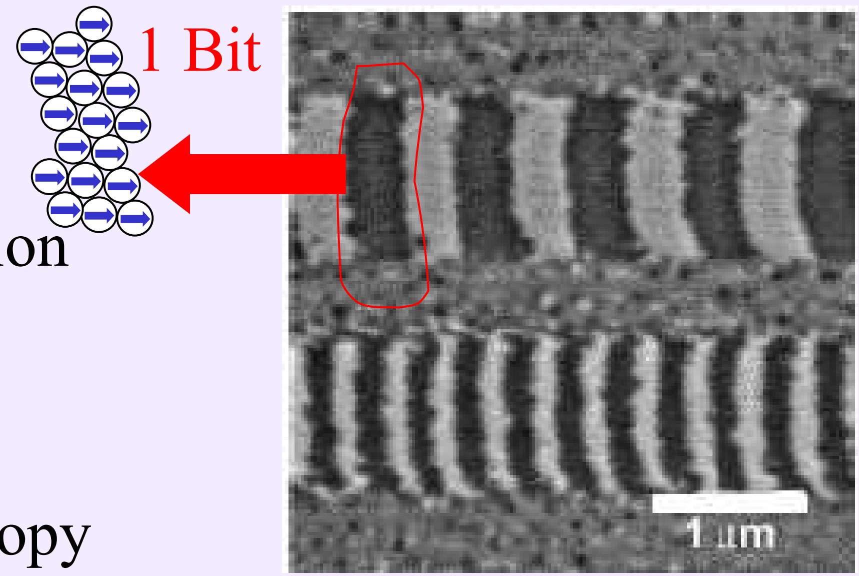
One Magnetic Bit = One information

Parameters

- Two states --> uniaxial anisotropy
- Stable --> anisotropy large enough
- Access --> how to write/read ?



Magnetic Recording Media



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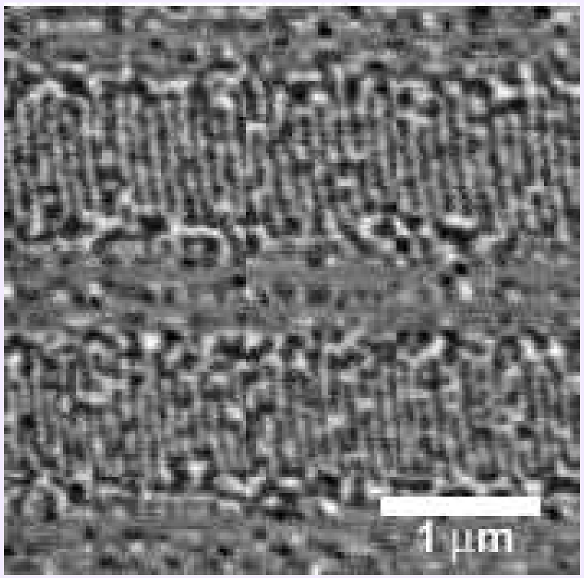
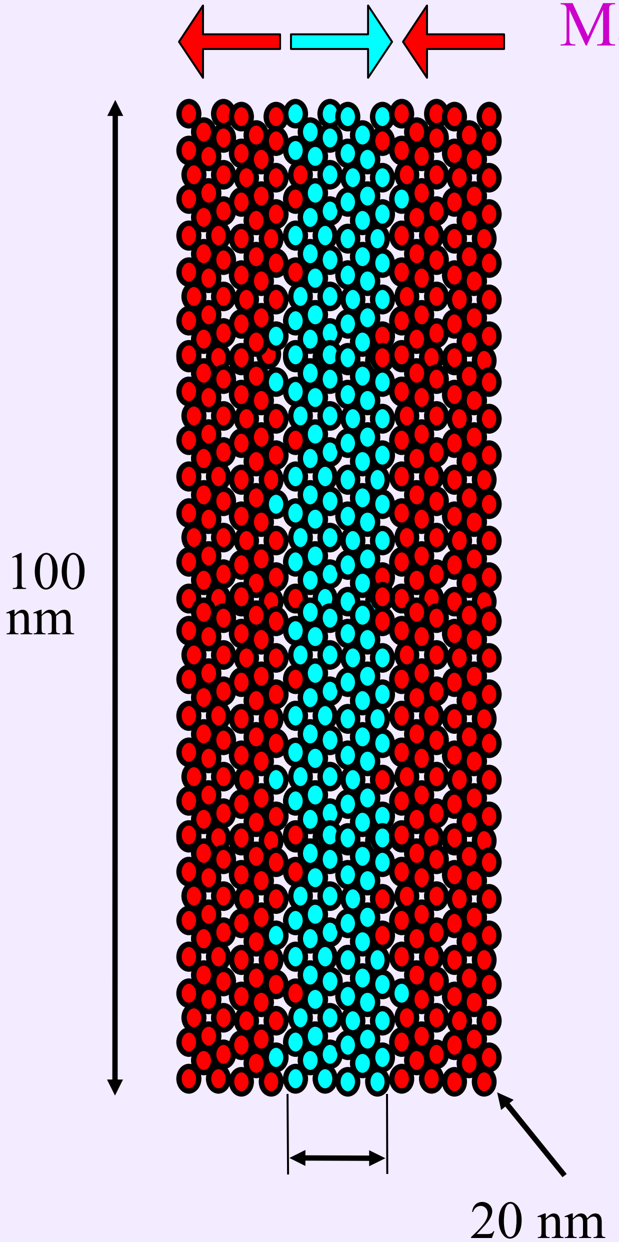
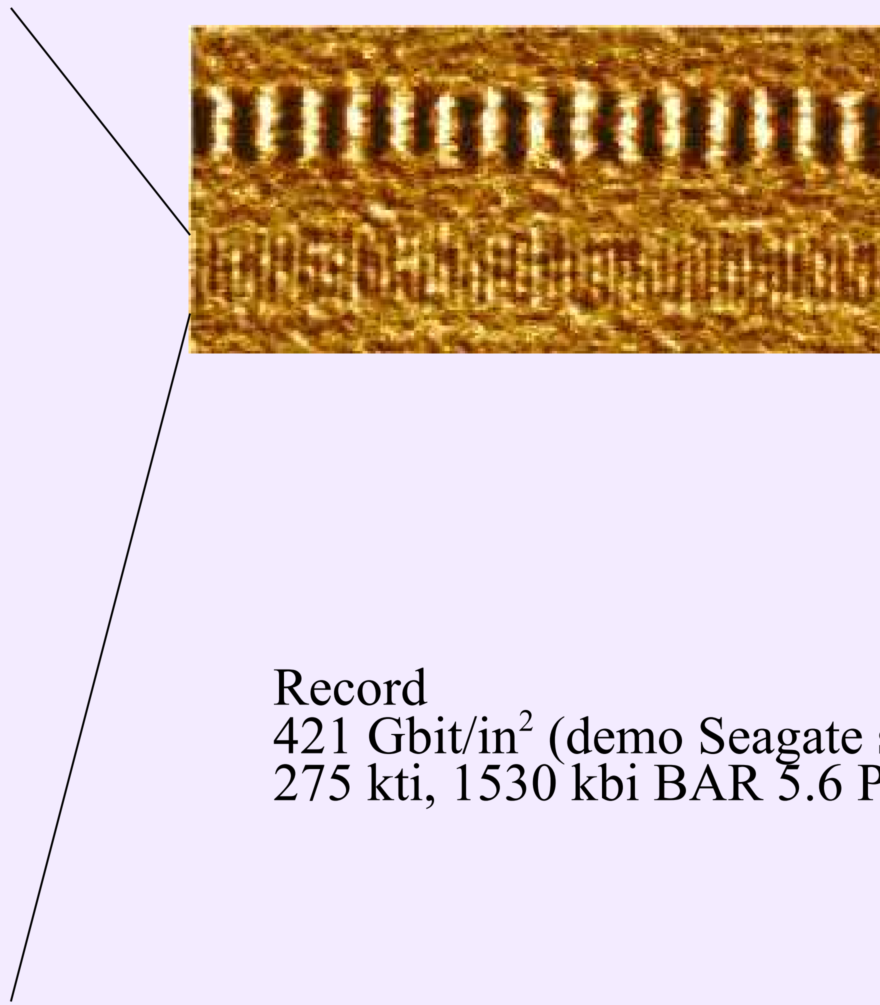


Magnetic Recording Media





Record
421 Gbit/in^2 (demo Seagate sept. 2006)
275 kti, 1530 kbi BAR 5.6 PMR

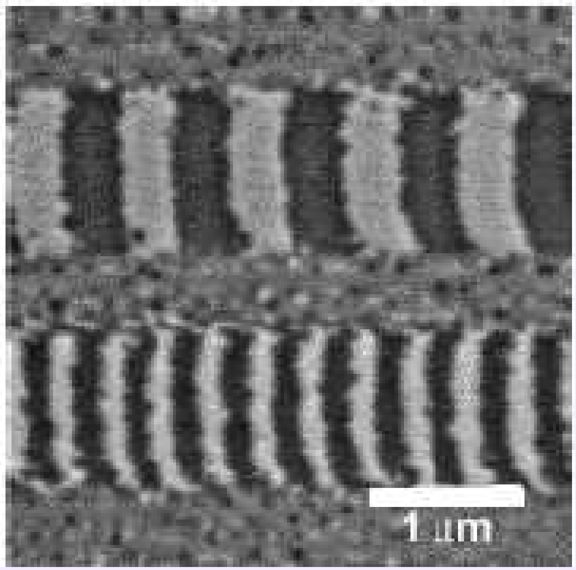
Magnetic Recording Media

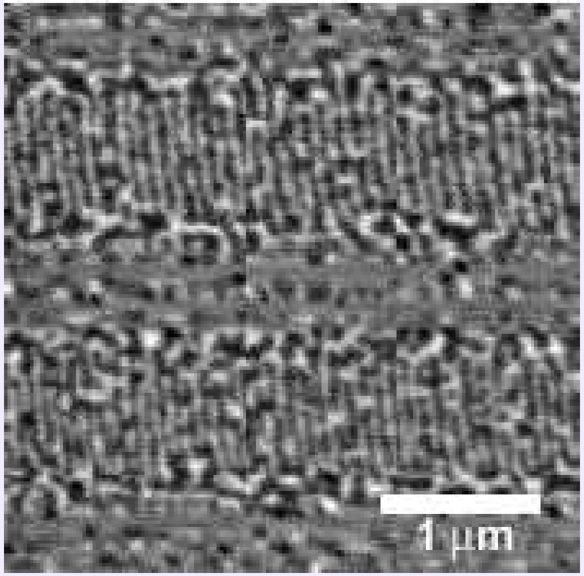
One Magnetic Bit = One information

Parameters

Two states --> uniaxial anisotropy
Stable --> anisotropy large enough
Access --> how to write/read ?

First solution : particulate media

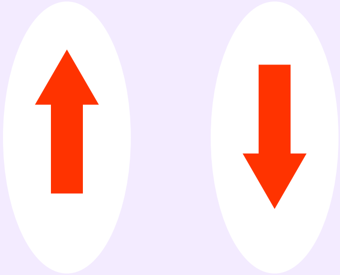




Magnetic Recording Media : Particulate Media

Origin of the Uniaxial anisotropy

$$E = K \sin^2 \theta$$

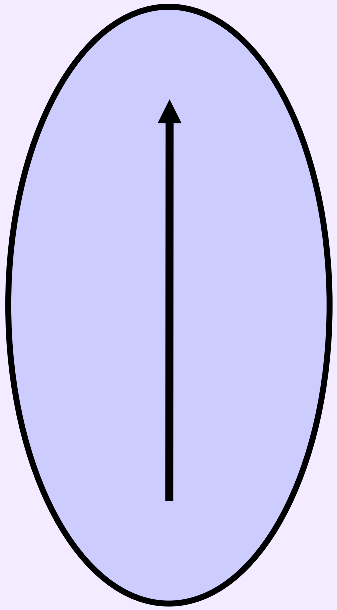


Shape Anisotropy vs Magnetocrystalline Anisotropy

Magnetic Recording Media : Particulate Media

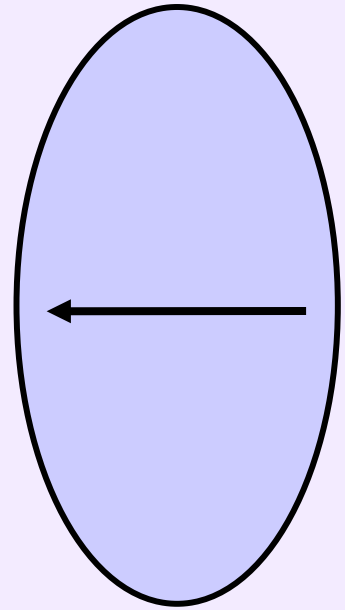
Coercicity : Anisotropy Field in a small particle

Saturated Magnetisation



$H>H_c$

Magnetisation Rotation

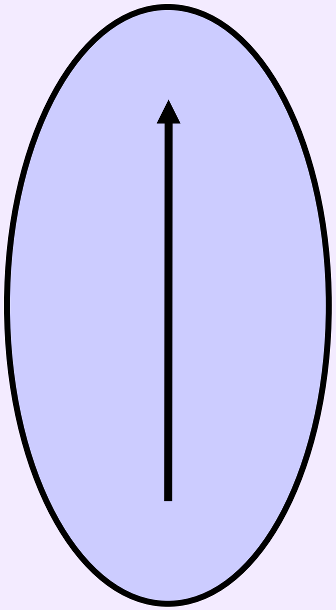


$H=H_c$

Magnetic Recording Media : Particulate Media

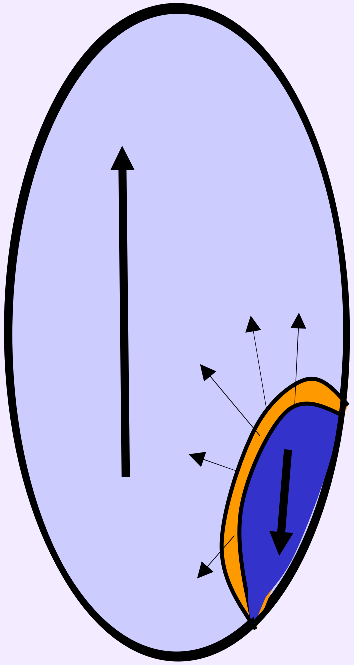
Coercicity : Much Smaller than Anisotropy in a larger particle

Saturated Magnetisation



$H > H_c$

Nucleation + Propagation



$H = H_c$

Shape anisotropy : $E = -\frac{\mu_0}{2}\vec{H}_d \cdot \vec{M} = \frac{\mu_0}{2}(N_{//}\vec{M}_{//} + N_{\perp}\vec{M}_{\perp}) \cdot \vec{M}$

$$= \frac{\mu_0}{2}(N_{//}M_{//}^2 + N_{\perp}M_{\perp}^2)$$

For a needle-like particle $N_{//}=0$ and $N_{\perp}=0.5$

i.e. $$E = \frac{\mu_0}{2}N_{\perp}M_{\perp}^2 = \frac{\mu_0}{4}M^2\sin^2\theta$$

$\mu_0 M$ = 0.5 to 1 T for oxides, 2.2 T for Fe and 2.5 T for FeCo

maximum shape anisotropy : 200 kJ/m^3 (using 1 Tesla magnetisation)

1250 kJ/m^3 absolute maximum

Magnetocrystalline Anisotropy : $E = K_1 \sin^2(\theta)$

	K_1 (kJ/m^3)
Ni	5
Fe	48
Co	530
PtFe	6 600
$SmCo_5$	17 200

Max shape anisotropy

Low symmetry structure (hexagonal, rhomb. tetragonal)
+ large spin orbit constant (rare-earth or platinum)

give MCA larger than the shape anisotropy

But Co, Pt are expensive (OK as thin films)

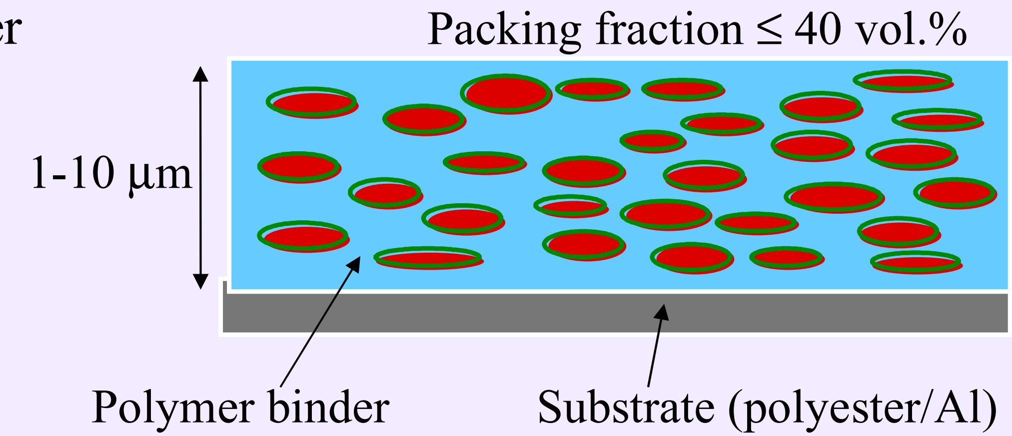
Rare earths are corrosive

Magnetic Recording Media : Particulate Media

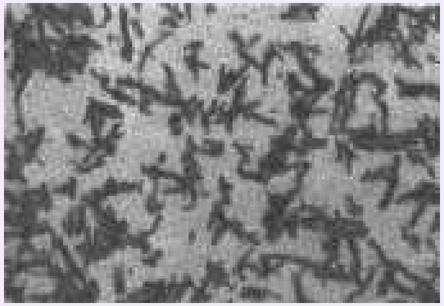
Ferro/ferrimagnetic particles in polymer binder

$\mu_0 H_C$ due to

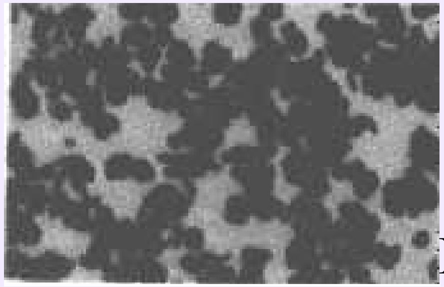
- Shape anisotropy
  - γ-$Fe_2 0_3$ (0.3 - 0.5 µm, 0.04 T)
  - CrO_2 (0.2 - 0.6 µm, 0.04 T)
  - $Fe_{1-x}Co_x$ (0.1- 0.3 µm, 0.25 T)
- Magnetocrystalline anisotropy
  - $BaFe_{12}O_{19}$ (0.05-0.15 µm , 0.25T)



γ-$Fe_2 0_3$



Fe



$BaFe_{12}O_{19}$

Max. storage density : 100 Megabits/in^2
Min. bit area ≈ 6.5 µm^2
Applications : Audio & video tapes, floppy disk

Magnetic Recording Media : Continuous Media

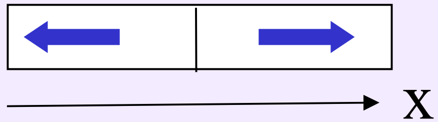
Beyond particle media

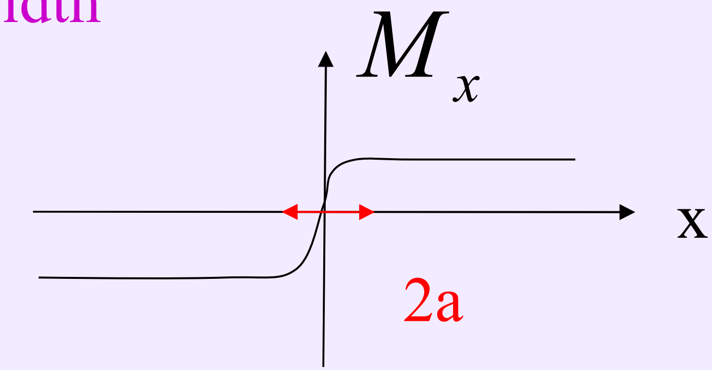
smaller particle --> continuous granular media

better materials --> cobalt based

Magnetic Recording Media : Transition Width

Longitudinal Media





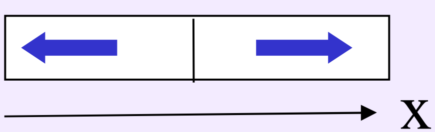
Let us suppose that M does not depend on thickness

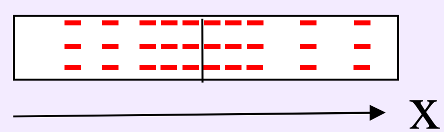
$$M_x(x) = \frac{2M_s}{\pi} \arctan \frac{x}{a}$$

The transition width is 2a

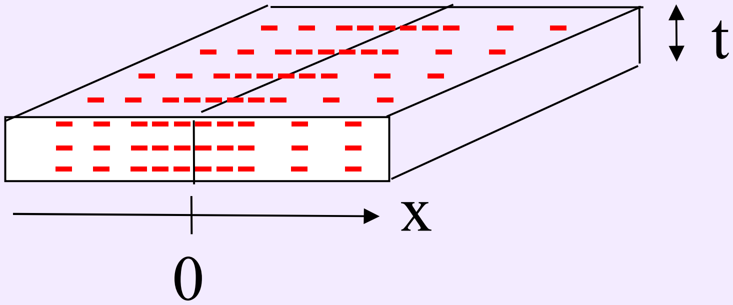
The density of « magnetic » charges is :

$$\rho = -div\vec{M} = -\frac{dM(x)}{dx} = -\frac{2M_s}{\pi \cdot a} \frac{1}{1 + \frac{x^2}{a^2}}$$





Magnetic Recording Media : Transition Width



$$\vec{H}_d = \frac{1}{4\pi}\iiint \frac{\rho \cdot \vec{r}\, dV}{r^3}$$

Bit width infinite
+ 2D charge

$$\vec{H}_d = -\frac{2M_s t}{\pi \cdot a}\,\frac{\frac{x}{a}}{1+\frac{x^2}{a^2}}$$

Maximum Demag field

$$H_d \leq \frac{2M_s t}{\pi \cdot a}\,\frac{1}{2} \leq H_c$$

$$a \geq \frac{M_s t}{\pi \cdot H_c}$$

$M_s t, (M_r t \text{ in fact})$ As small as possible

H_c As large as possible

Magnetic Recording Media : Transition Width

$M_r t$ As small as possible

Thin film media
Small magnetisation

Signal amplitude will also decrease !!!!

H_c As large as possible

Hard magnetic materials

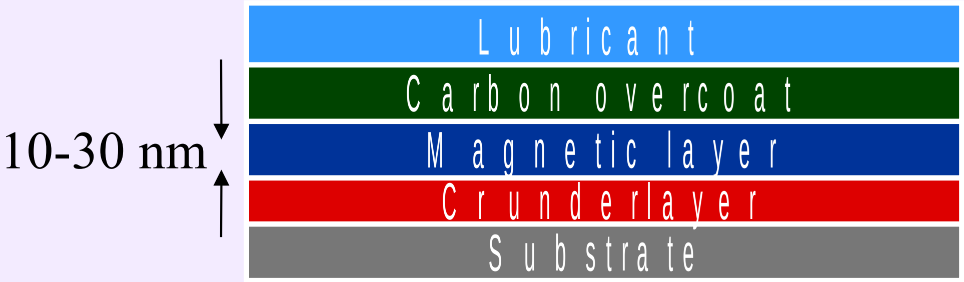
(see N. Dempsey's talk)

The write field should be larger than H_c !!!

Magnetic Recording Media : Continuous Media

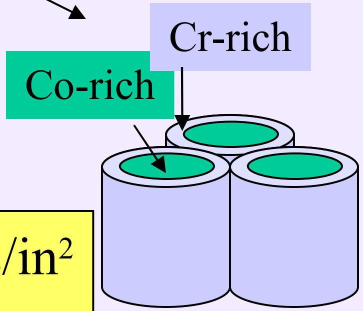
Need to reduce $M_r t$
to increase $\vec{H}_C$
CoCrM / Cr (M=Ta, Pt)

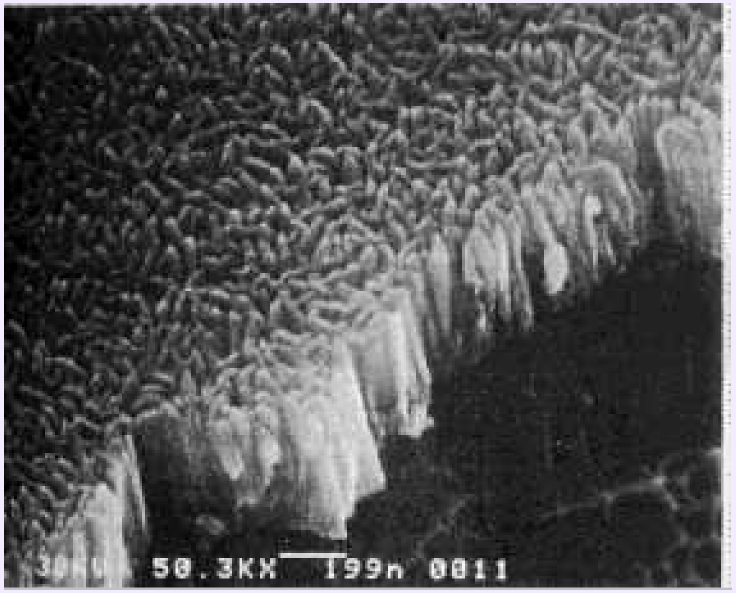
Thin film media



Exchange coupling → transition noise
Has been limited by :

- Physical grain segregation (process / underlayer effects)
- Compositional segregation





Max. storage density ≈ 100 Gbits/in^2
Min. bit area ≈ 10^{-2} µm^2
Applications : disk drives

Magnetic Recording Media : Continuous Media Multilayers

Substrate : Aluminium (Al-Mg) or glass (stiffer)

Underlayers : smoothing (NiP), Nucleation, texture (Cr, CrV)

Magnetic layer : Co-rich CoCrPt(Ta)

Hard layer : Diamond-like Carbon DLC

Lubricant layer : fluorocarbons

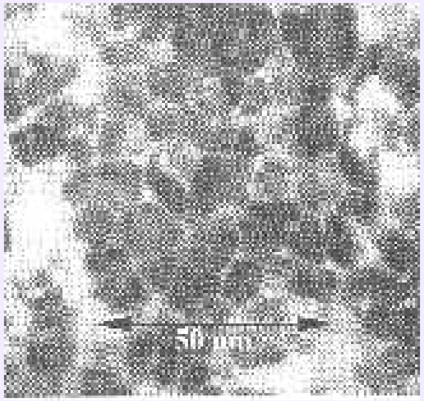
CoCr lattice parameter evolves with Pt or Ta substitution
Cr underlayer becomes CrV or CrW to match lattice parameters
Nucleation and texture layer could be NiAl (produces Co(100))

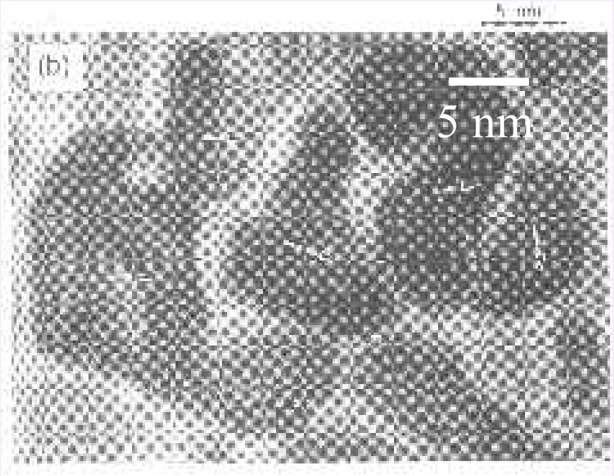
Longitudinal media

26.5 Gb/in^2 demonstrator

M.A. Schultz et al. (Read-Rite), IEEE Trans Mag. **36** (2000)2143

CoCrPtTaB/Cr

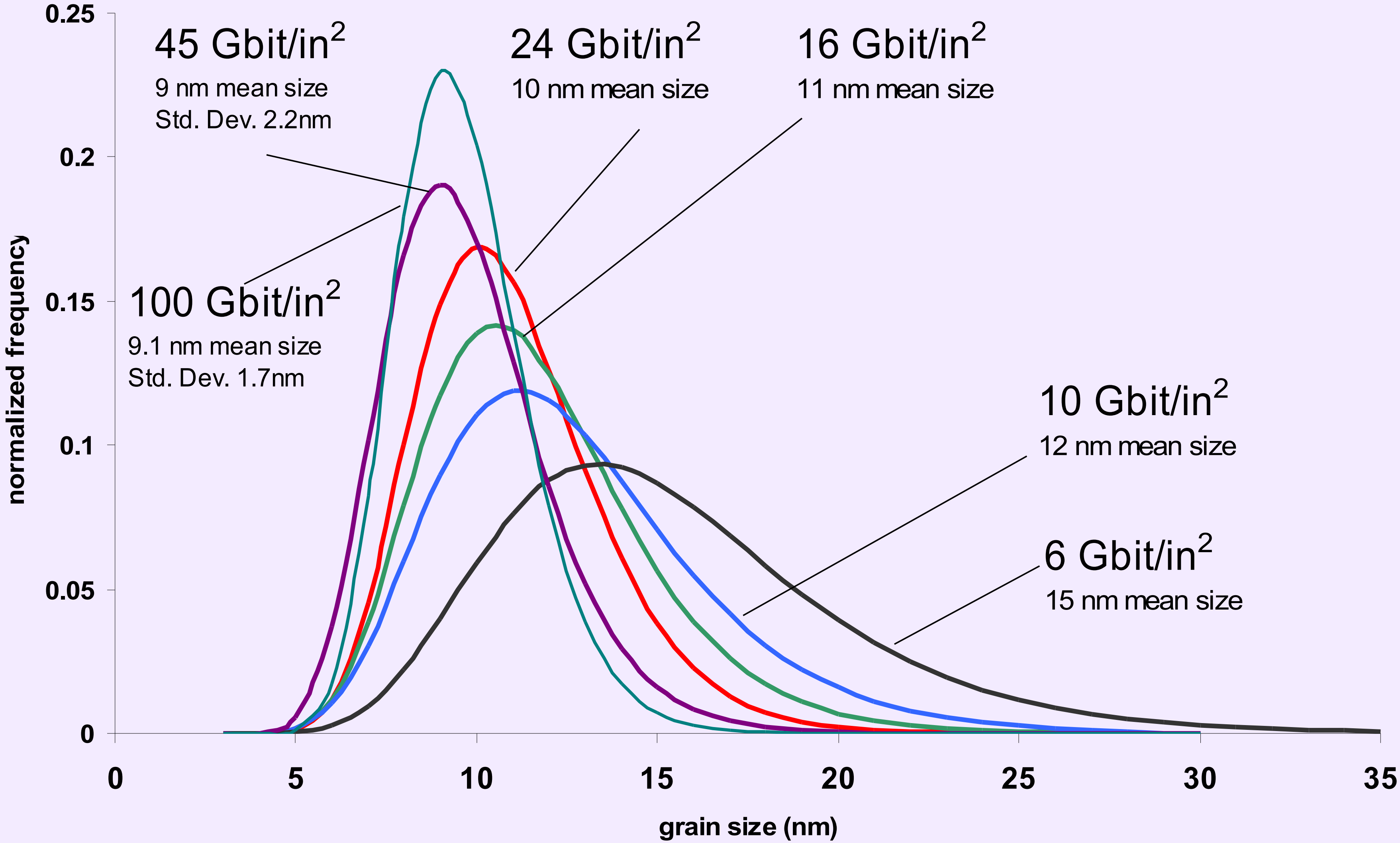




μ_0Hc : 0.25 T
M_rt : 0.4 x10^{-3} emu/cm^2
Film thickness : 19 nm
Average grain size : 11 nm
Transition parameter : 20 nm

Intermag 2002
(Seagate and Fujitsu)
100 Gbit/in^2
μ_0Hc : 0.48 T
M_rt : 0.35 x10^{-3} emu/cm^2
AFC Film
Average grain size : 9 nm

Magnetic grains size distribution

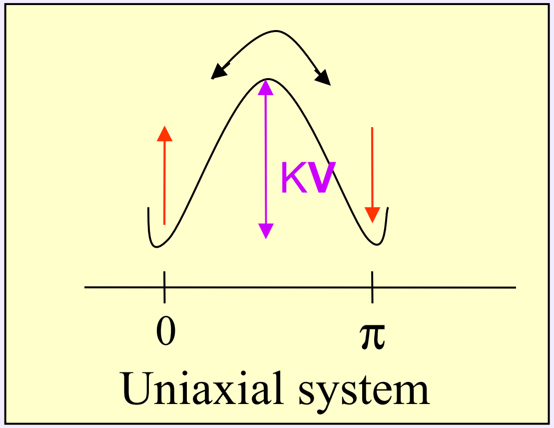


Kryder, Seagate

Magnetic Recording Media : A physical limit : Superparamagnetism

Remanent state is bistable

if anisotropy energy < thermal energy
i.e. $KV < kT$



thermal relaxation time, τ

$\tau = \tau_0 \exp(KV / kT)$

$1/\tau_0$ is the attempt frequency ($\tau_0 \approx 10^{-9}$ s)

Superparamagnetism
lower limit to the size of a stable ferromagnetic particle

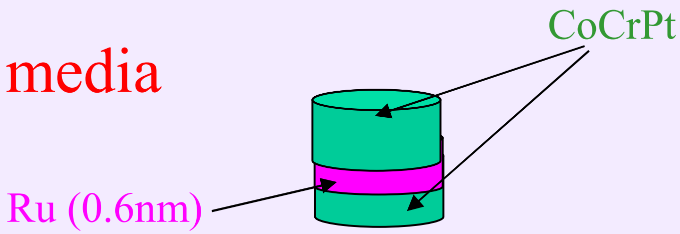
for data storage want $\tau >$ 10 years
i.e. must have $KV / kT > 60$

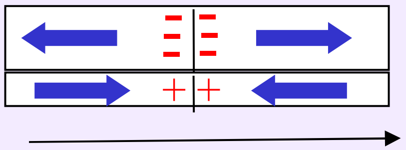
at 300 K

	K_1 (MJ/m^3)	ϕ_{min} (nm)
Fe	0.05	20
Co	0.5	8
$Nd_2Fe_{14}B$	5	4
$SmCo_5$	17	2

Magnetic Recording Media : Enhanced Continuous Media

AFC coupled media





RKKY AF coupled bilayer Co/Ru/Co

$M_r.t$ becomes $M_r.t_1$-$M_r.t_2$

Fullerton et al. APL 2001

Total $M_r.t$ decreases : less sensitive to demagnetising fields
but less signal also

Total $M_r.t$ decreases : but V does not, so K.V can be maintained

Max. storage density ≈ 100 Gbits/in^2
Min. bit area ≈ 10^{-2} µm^2
Applications : Ultra High Density

130 Gbit/in^2 in 2002 (Read-Rite)
150 Gbit/in^2 in 2006 (Hitachi)

Magnetic Recording Media : Enhanced Continuous Media

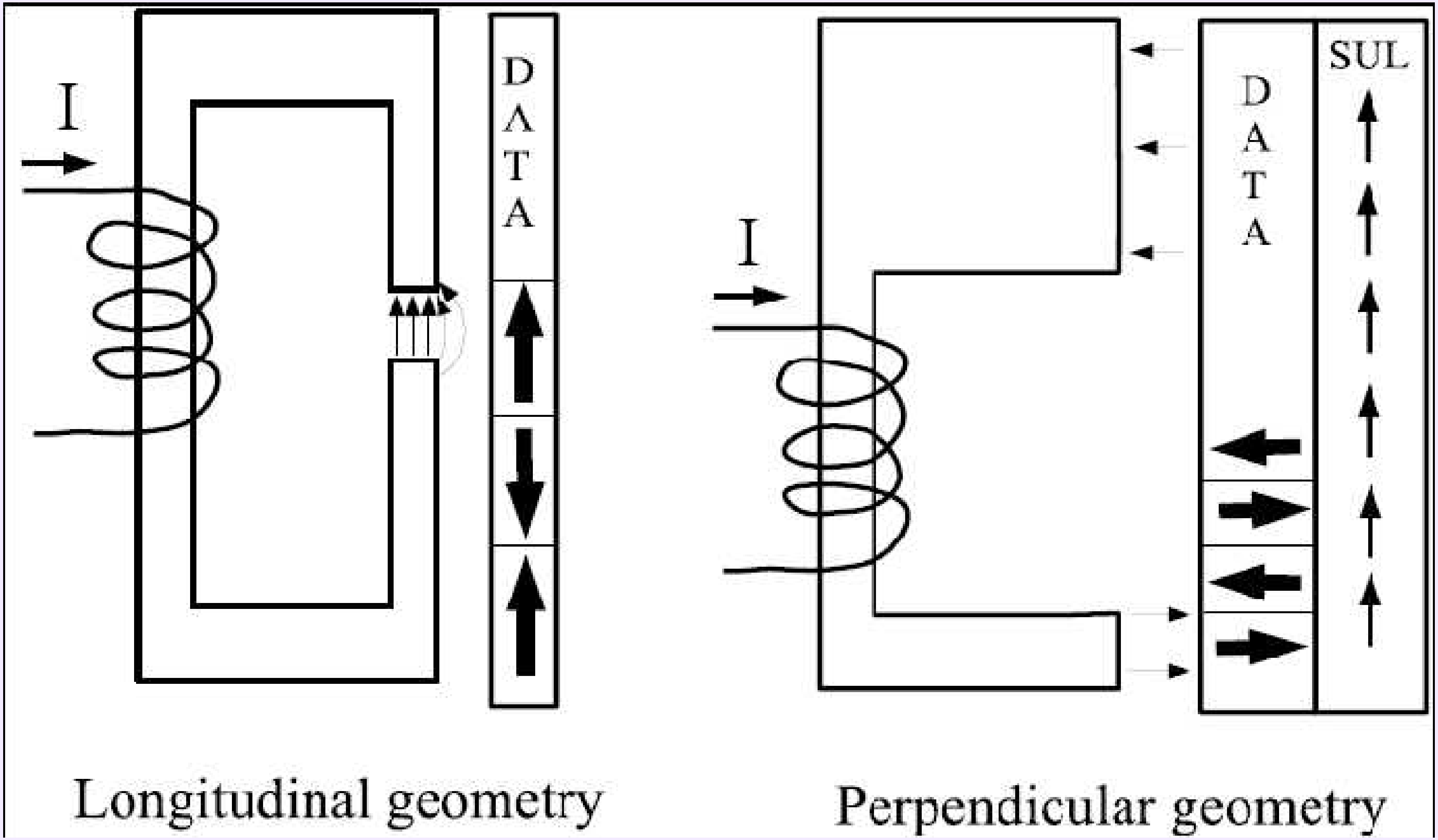
The limit of longitudinal media has been reached

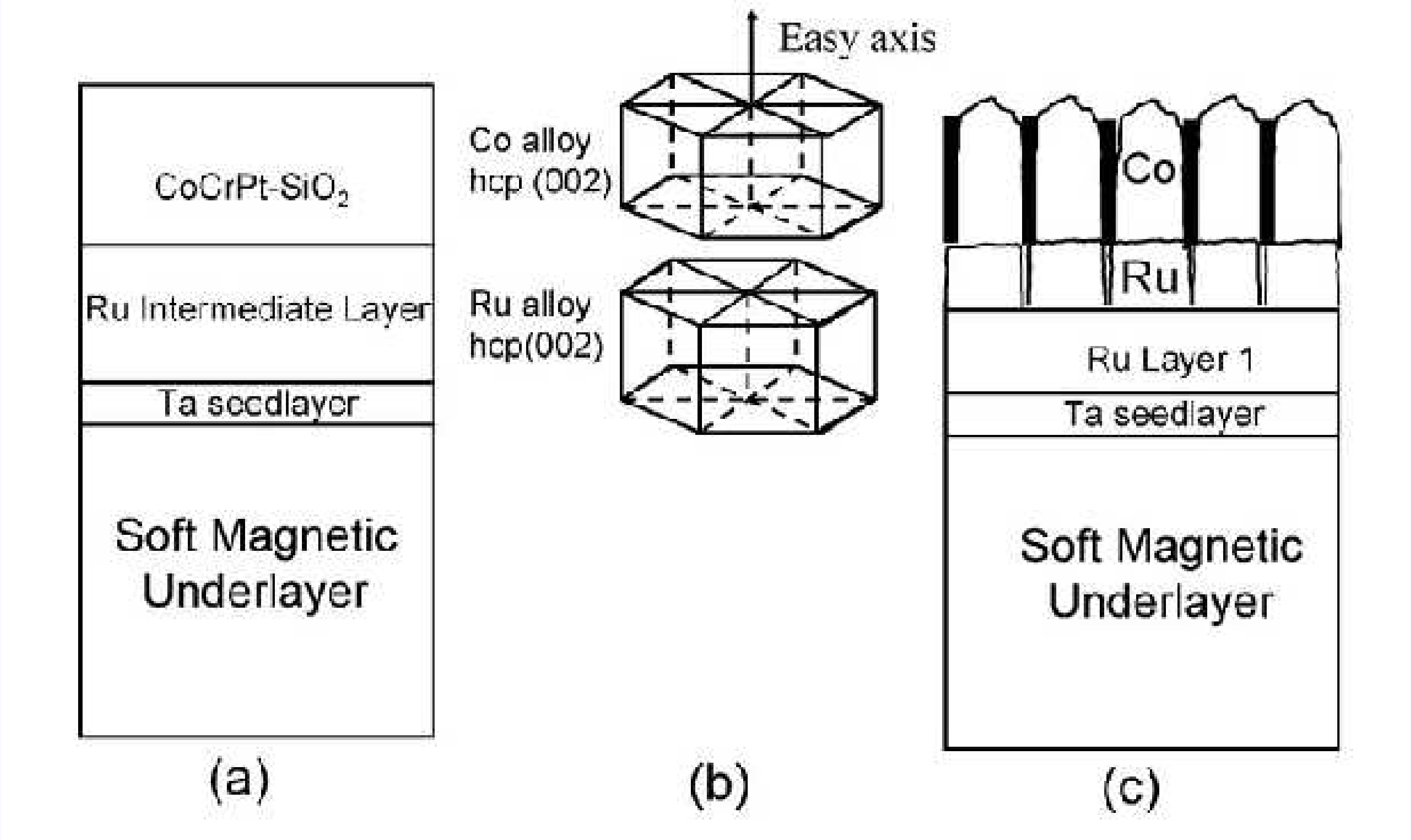
Signal M.t vanishes

Coercivity is becoming larger than available write field

----> transition to perpendicular recording

Magnetic Recording Media : Beyond Longitudinal Media





New SUL layer

Induce Co recording layer with c-axis out-of-plane

Magnetic Recording Media : Beyond Longitudinal Media

Perpendicular recording (commercial early 2007)

Overcoat/lubricant 4 nm

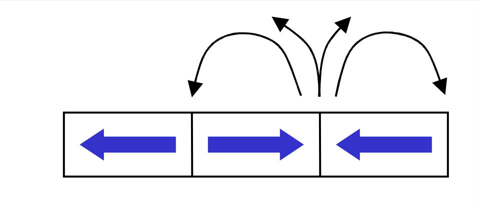
Recording layer 15 nm — CoCrPt+SiO2 (7 nm + R.C. 2-3°)

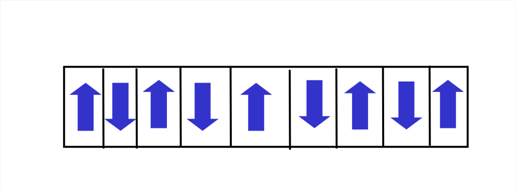
Decoupling+Texturing layer 20 nm

SUL 80 nm — $Co_{100-x}Ta_{6-12}Zr_{2-6}$ amorphous

Seedlayer+substrate

Magnetic Recording Media : Perpendicular Media





Different aspect ratio : Decrease of demagnetising field

Thicker films allowed

SUL : Soft Underlayer to double the thickness

Write field twice as large available

The write head should now provide perpendicular fields

new head design

HDD PMR 2007
130 Gbit/in^2
μ_0Hc : 0.4 T
$M_r t$: 0.7 x10^{-3} emu/cm^2
Grain size 7 nm

Sept. 2006
Demo Seagate 421 Gbit/in^2

Magnetic Recording Media : Perpendicular Media

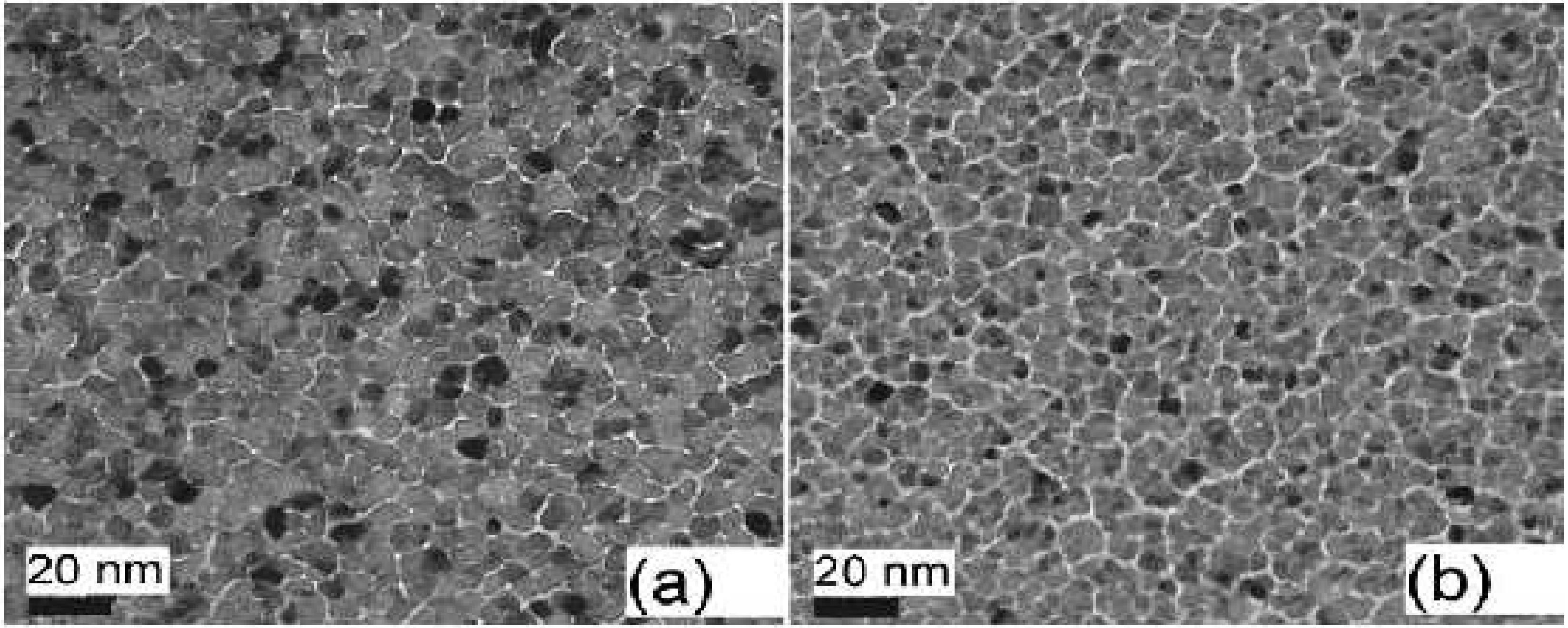


FIG. 20. TEM planar view of grains in (a) RuCr intermediate layer and (b) RuCr-oxide intermediate layer.

S. N. Piramanayagam J. Appl. Phys. **102**, 011301 (2007)

Magnetic Recording Media : Perpendicular Media

What's the next step?

FePt could be stable down to 3 nm grain size

BUT : only in the bct L10 phase (needs annealing)

Hc is very large (large K)

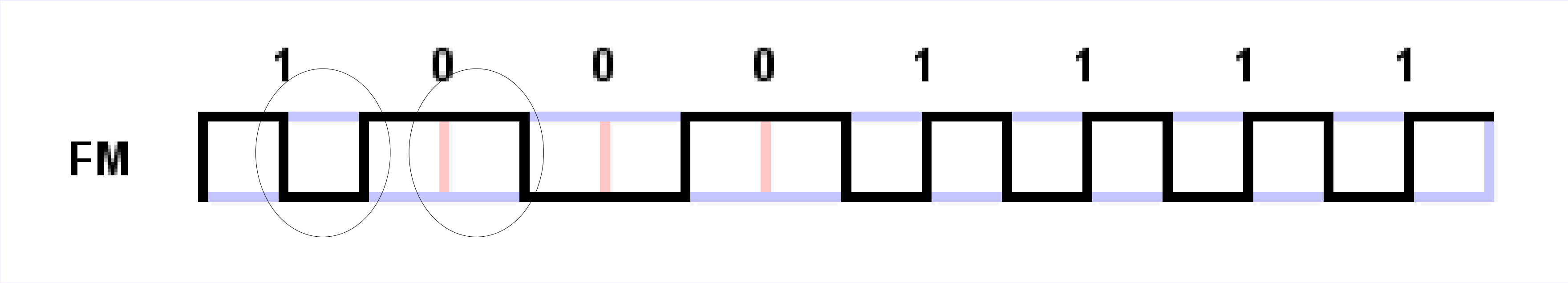
Magnetic Recording Drive : Data transfer, coding

Original Floppy disk Coding system

Frequency Modulation :

- 2 Clock periods / information bit
- 1 is flux reversal + flux reversal
- 0 is no reversal + reversal

(simple density recording)



Shortest magnetic bit is one clock-period-long

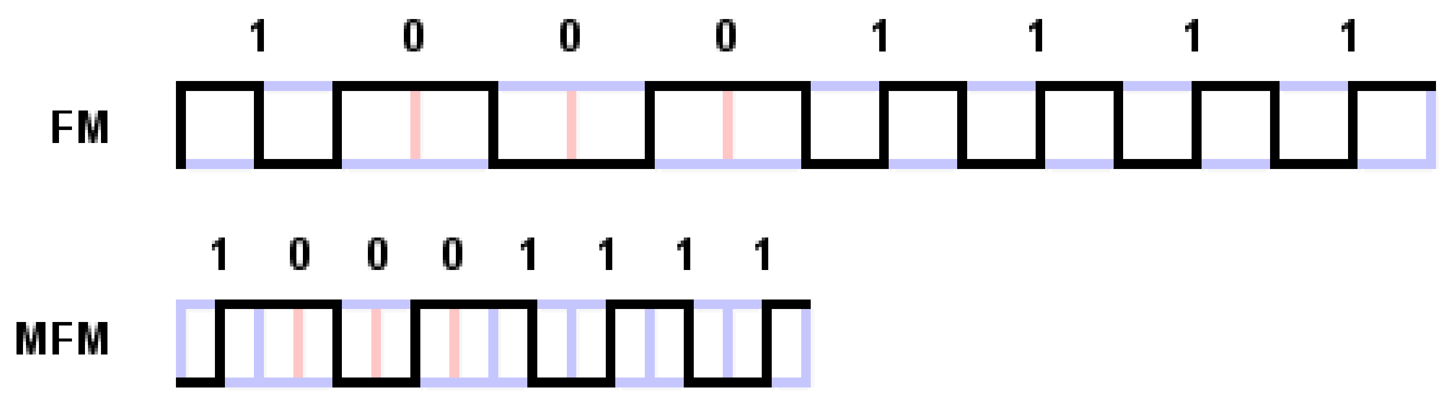
Magnetic Recording Drive : Data transfer, coding

Better Coding system

Modified Frequency Modulation

1 : N R
0 after a 1 : N N
0 after a 0 : R N
(present double density Recording)

2 clock periods /bit but never RR
Shortest magnetic bit is 2 clock-long



Magnetic Recording Drive : Data transfer, coding

Hard Disk Coding

MF : 1.5 flux reversal /bit

MFM : 0.75 flux reversal /bit

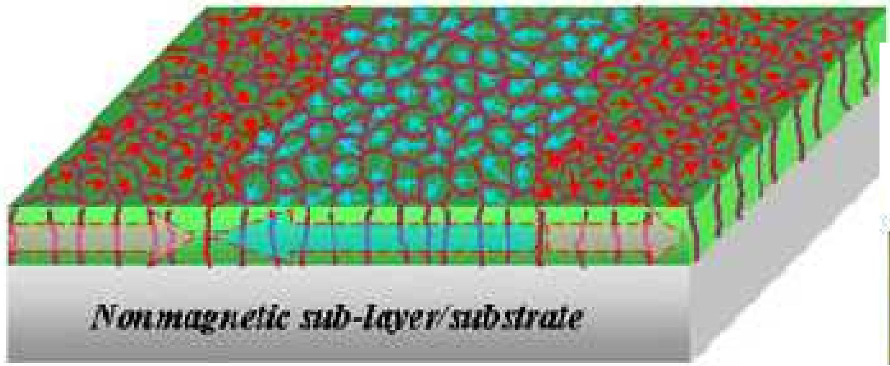
RLL (Run Length Limited) 0.46 flux reversal /bit

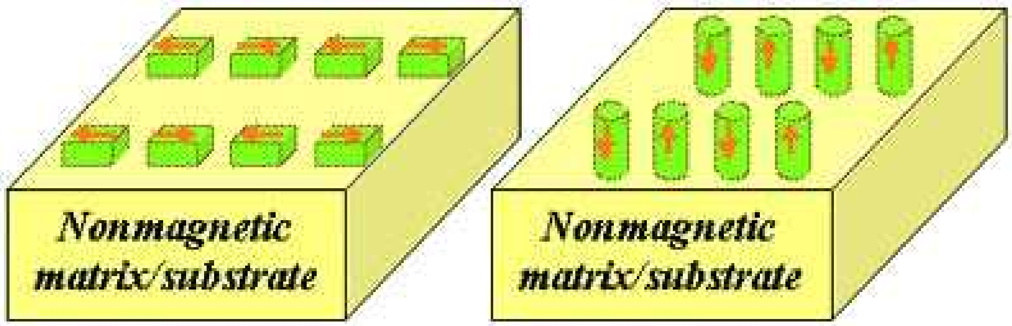
PRML (Partial Response Maximum Likelihood) increase 30%

EPRML increase 20%

GRANULAR MEDIA
10^2 10^3 GRAINS = 1 BIT

PATTERNED MEDIA
1 GRAIN = 1 BIT





granular media give also rise to media noise (not well defined transition)

And 100 grains means 10 % statistical noise

Magnetic Recording Media : Beyond Continuous Media

Patterned media : How to make them ?

e-beam lithography

Nano-imprint

self assembly + self organisation

moiré arrays

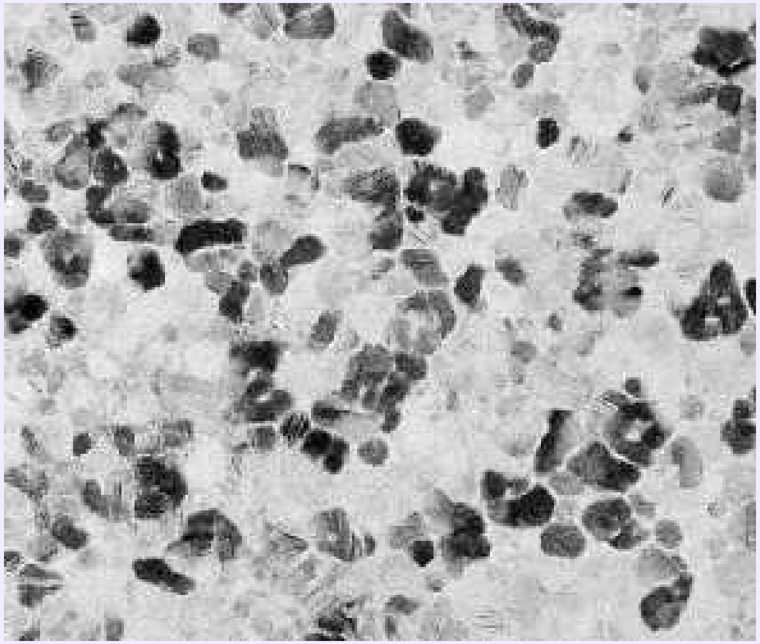
Grain Dispersion Narrowing

SOMA : Self Organised Magnetic Array

45 Gbit/in^2 demo media (Seagate)

•8.5 nm grains

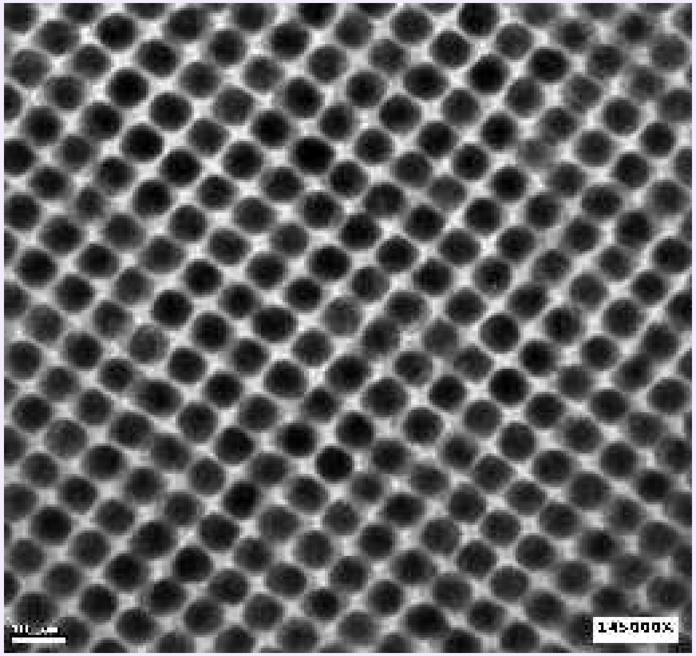
$\sigma_{area} \cong 0.5$



Nanoparticle arrays

•6 nm FePt particles

$\forall\ \sigma_{area} \cong 0.1$



S. Sun, Ch.Murray, D. Weller, L. Folks, A. Moser, Science, 287, 1989 (2000)

(slide courtesy of D. Weller - Seagate)

APPLIED PHYSICS LETTERS VOLUME 74, NUMBER 22 31 MAY 1999

Sub-50 nm planar magnetic nanostructures fabricated by ion irradiation

T. Devolder and C. Chappert
Institut d'Electronique Fondamentale, Université Paris Sud, 91405 ORSAY Cedex, France

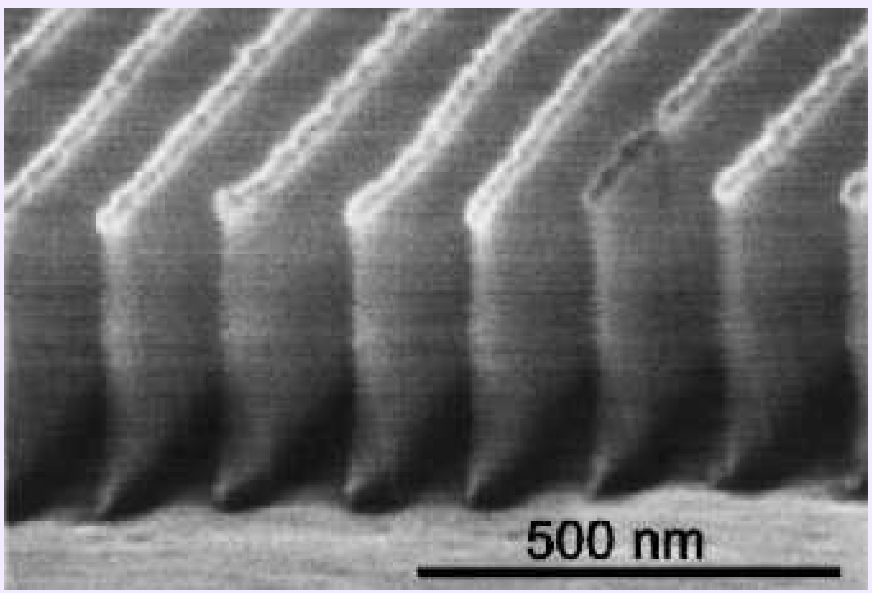
Y. Chen and E. Cambril
Laboratoire de Microstructures et Microélectronique, 196 rue H. Ravera, BP 107, 92220 Bagneux, France

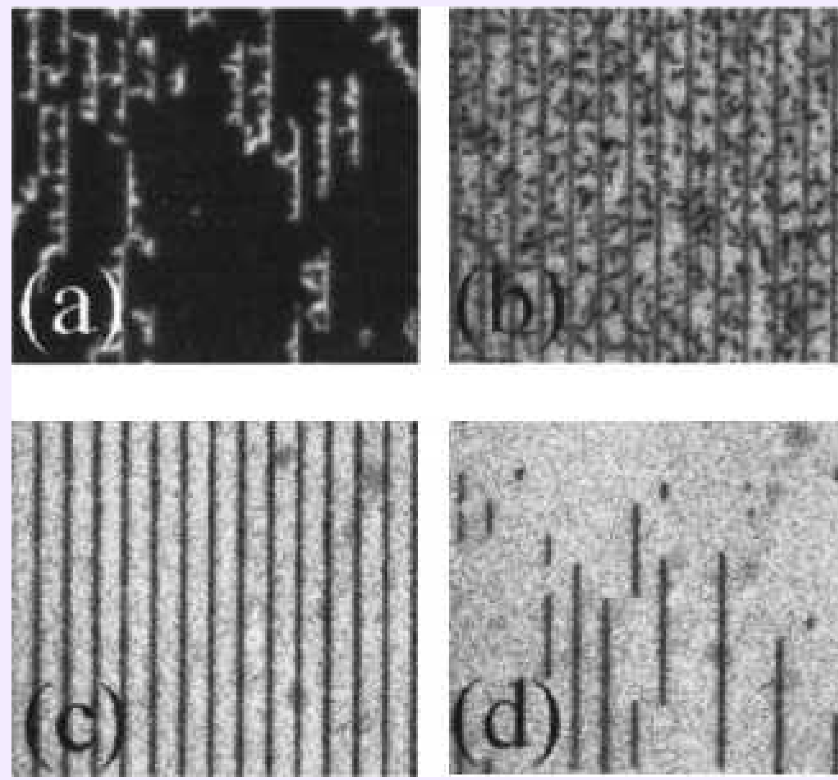
H. Bernas
Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Université Paris Sud, 91405 ORSAY Cedex, France

J. P. Jamet and J. Ferré
Laboratoire de Physique des Solides, Université Paris Sud, 91405 ORSAY Cedex, France

Co-Pt multilayers irradiated by a He^+ beam
Change of magnetic properties

Same idea with FePt L_{10} phase





JOURNAL OF APPLIED PHYSICS VOLUME 91, NUMBER 10 15 MAY 2002

Domain structure in magnetic dots prepared by nanoimprint and e-beam lithography

J. Moritz,[a] B. Dieny, and J. P. Nozières
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S. Landis
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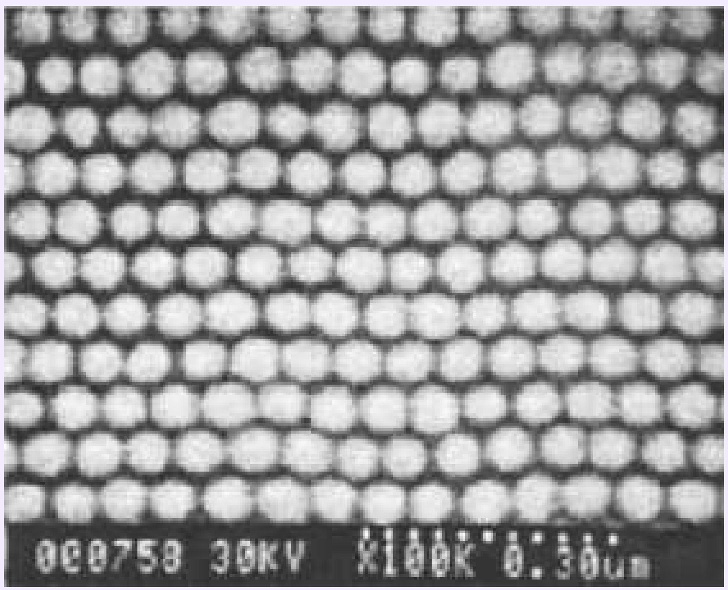
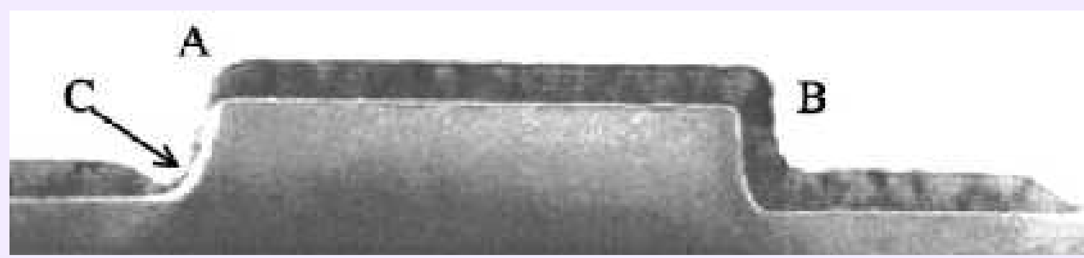


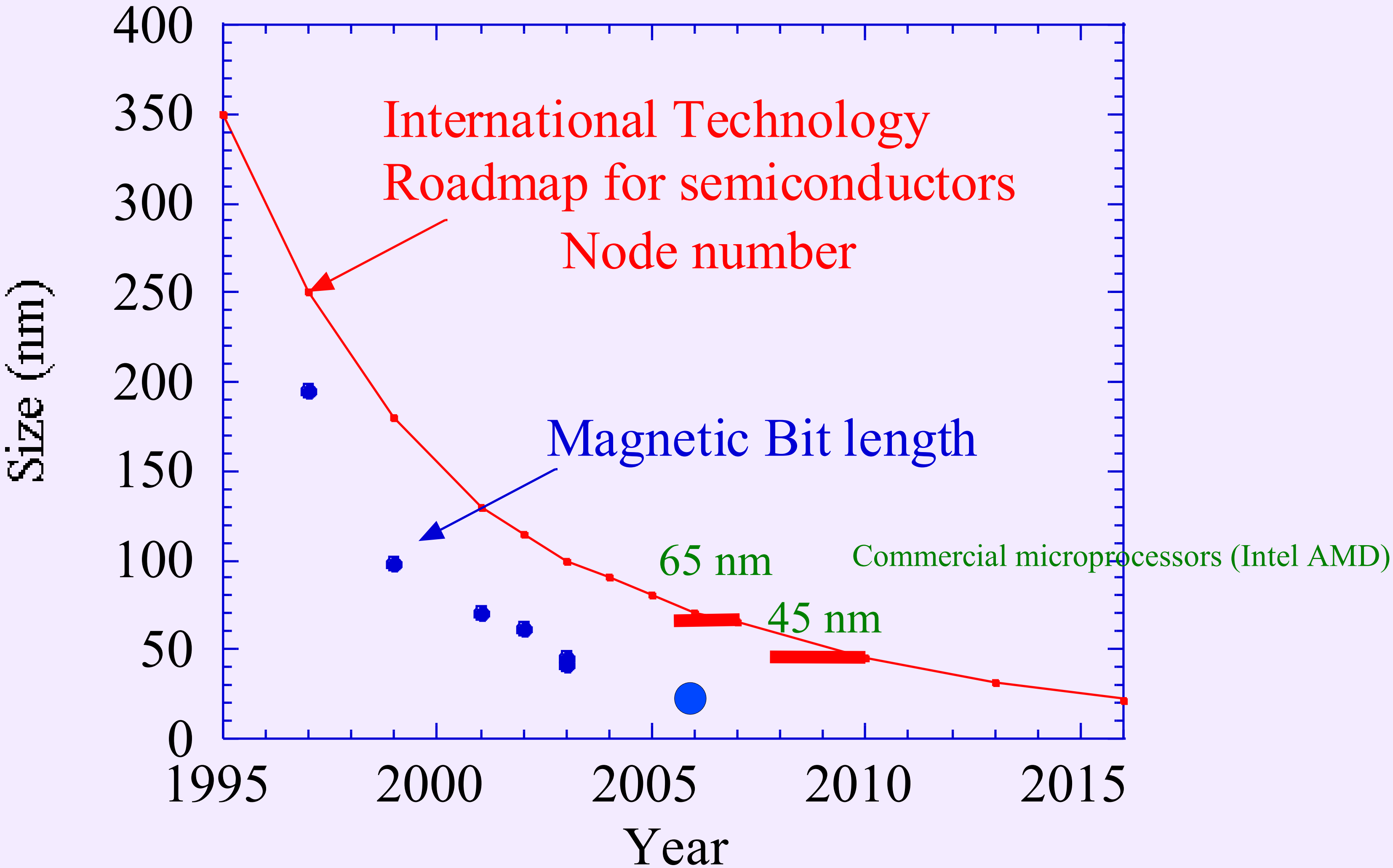
Nano-imprint + RIE + Lift-off Ni + Si RIE

+ Co-Pt mutilayers



60 nm dot array

Magnetic dimensions are smaller than semiconductor industry lithography tools



Magnetic Recording Heads

- Stray field measurement
  only magnetic transition contribute
- M-O signal
  laser wavelength limit (diffraction)
- Solid state (resistance)
  electrical connection
  memory matrix

Magnetic Recording Heads : inductive heads

Mini electromagnet

Write head was the same as Read head

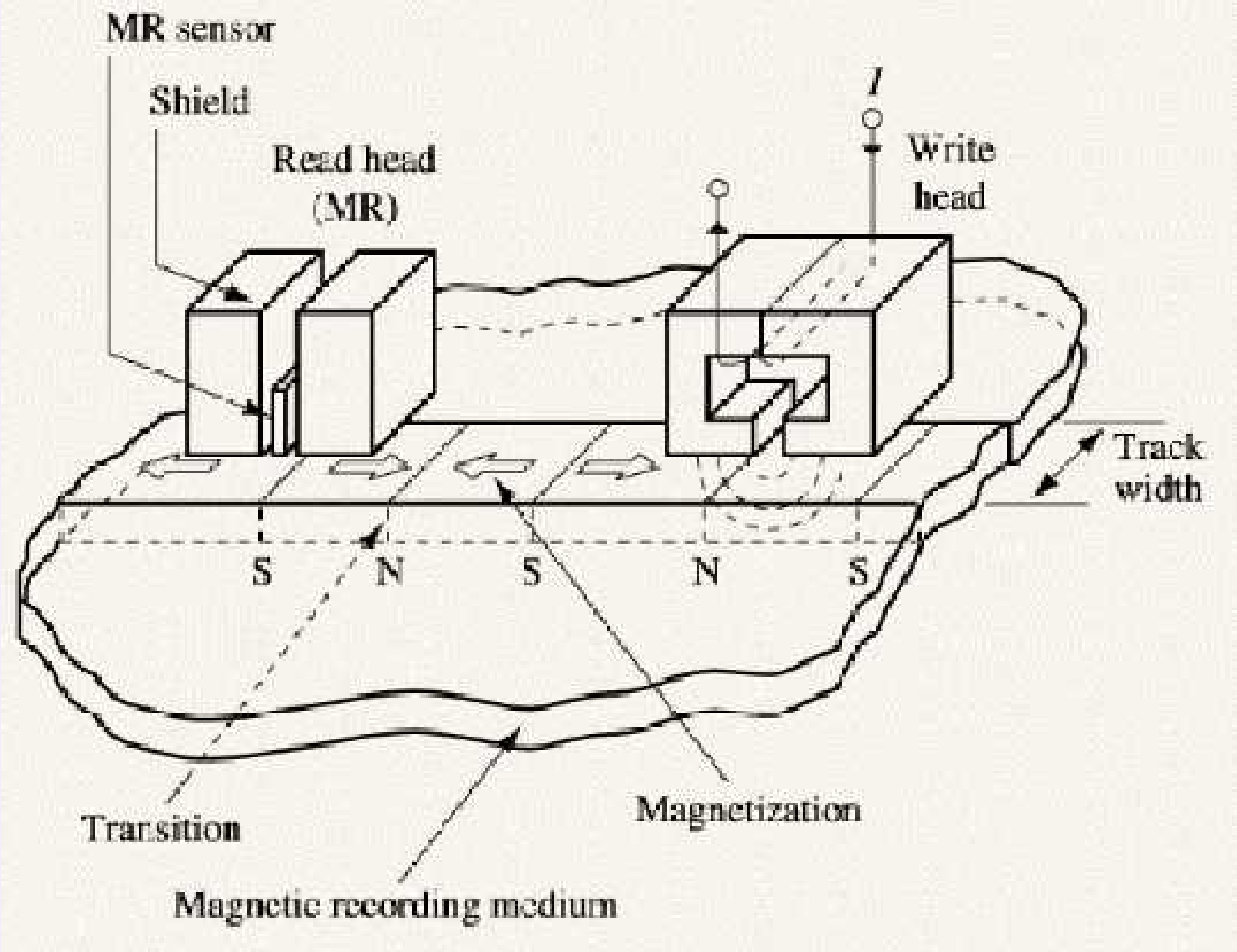
$$e = -\frac{d\varphi}{dt} = -\frac{S \cdot dB}{dt}$$

velocity : moving media and/or moving head

surface : signal proportional to coil area

now floppy, VHS ...

Still the write head in up-to-date HDD


MR sensor
Shield
Read head
(MR)
I
Write
head
Track
width
S
N
S
N
S
Transition
Magnetization
Magnetic recording medium

$B_{gap}=f(I)$

Higher Magnetisation Materials to create larger magnetic fields

NiFe ---> FeCo based (and soft)

Presently demonstration with 2.4 Tesla materials

Problem : The largest M at room temperature is 2.5 T

new materials required

Magnetic Recording Heads : MR heads

Larger signal : electrical response to stray fields

AMR (Anisotropic Magnetoresistance) : $Ni_{80}Fe_{20}$ (permalloy) film

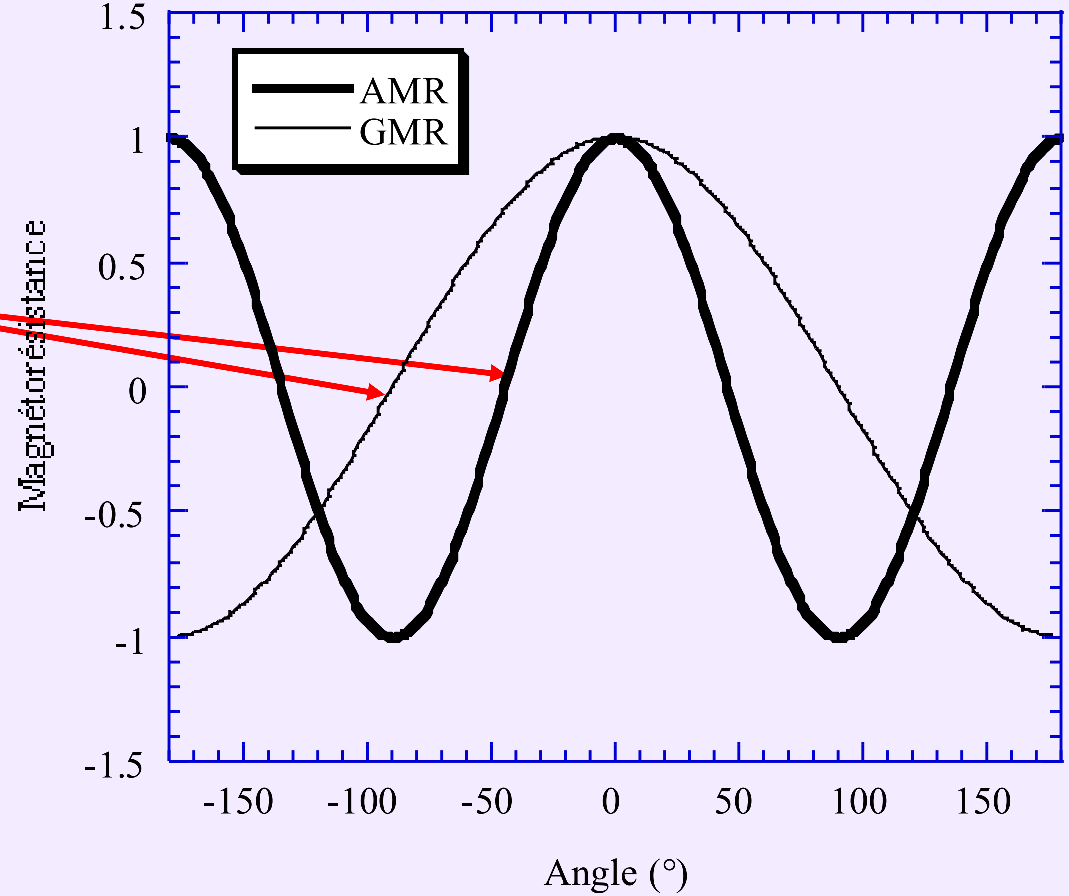
GMR (Giant Magnetoresistance) : Fe / Cu / NiFe

TMR (Tunnel Magnetoresistance) : Fe / Al_2O_3 /NiFe

Magnetic Recording Heads : MR heads

Angular dependence of MR

Work-points



Signal processing people want linear response

Consequence for linear sensing : Angle at 45° or 90°

Magnetic Recording Heads : material development

High spin polarisation materials : CoFe

Spin filtering effects : CoFeB / MgO / CoFeB
TMR >>100 %

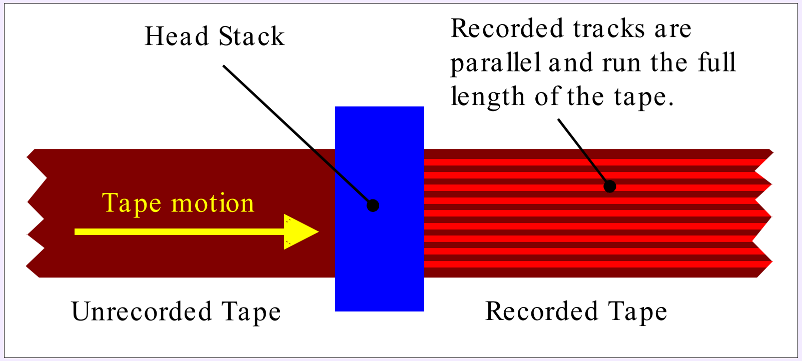
Magnetic semiconductors : GaAsMn ...
electronics + spin + optics ...

One word about tapes

Tape media went from particle to continuius media too

Mechanically less stable --> wider tracks

But parallel tracks is possible



MR heads (multiheads) are being implemented

100 GB tape EMTEC 2003
600 m (thickness 9 microns)
coercive field : 185 mT
track/inch : 923 (27.5 micron)
bit/inch : 93000 (270 nm)

IV - MRAM

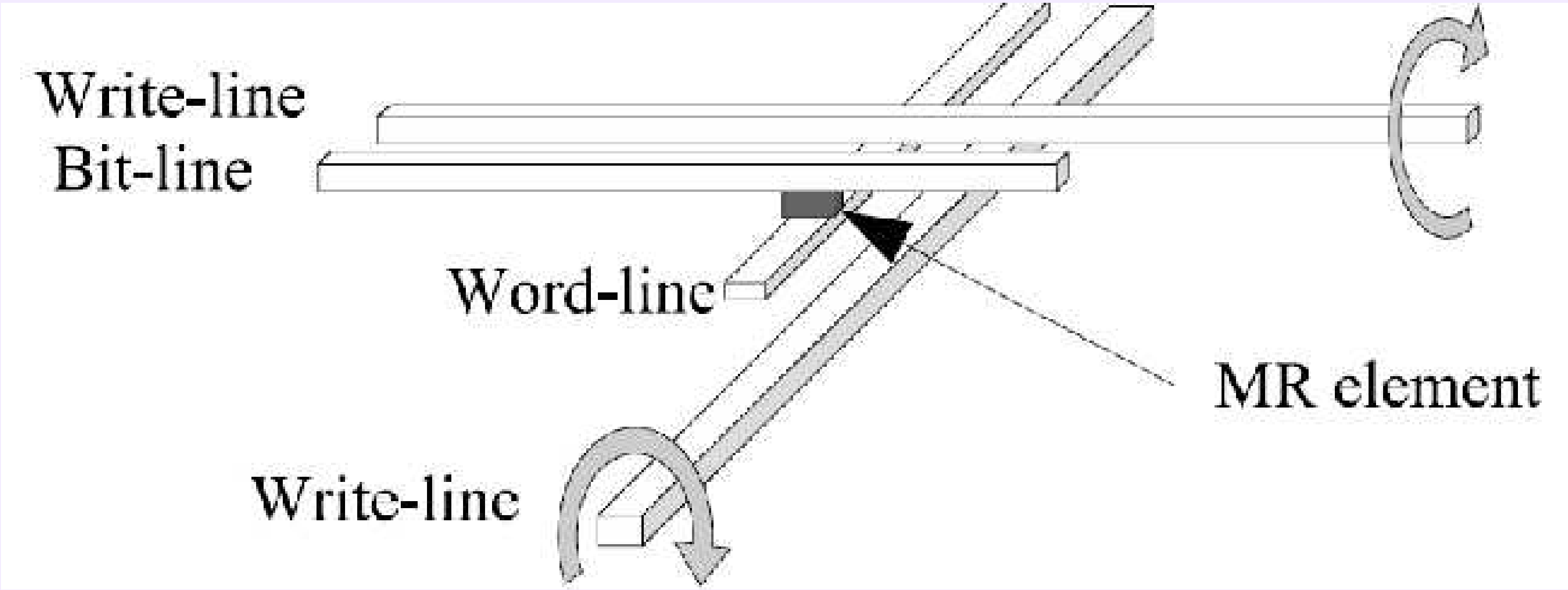
MAGNETIC
RANDOM
ACCESS
MEMORY

Non volatile

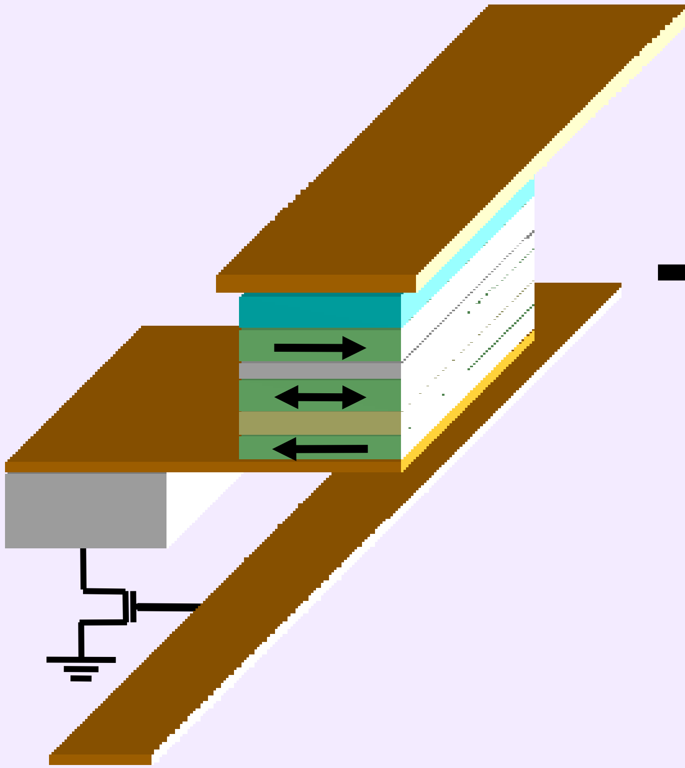
Fast < 50 ns read and write cycle time

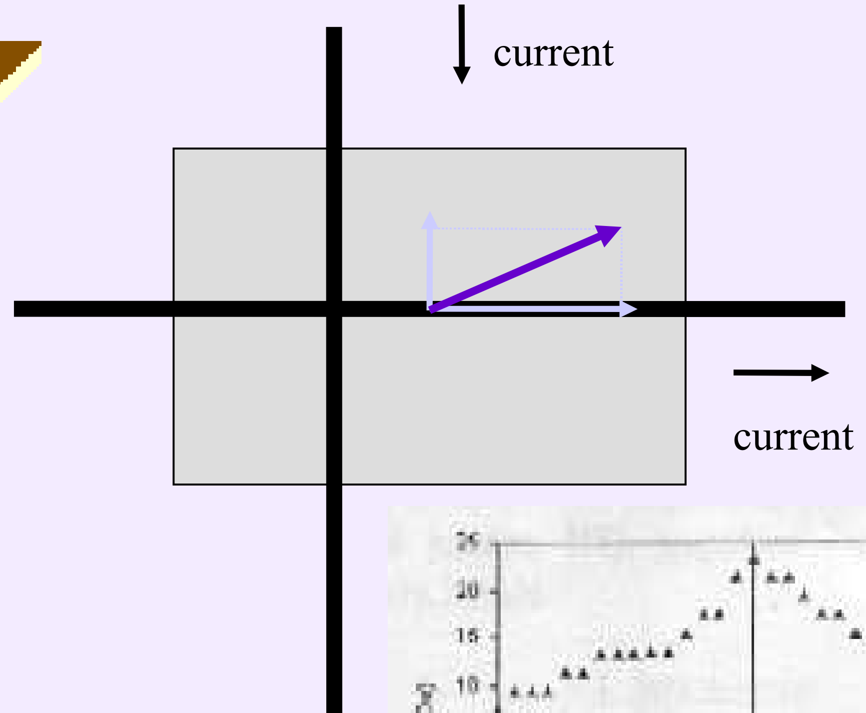
infinite cyclability

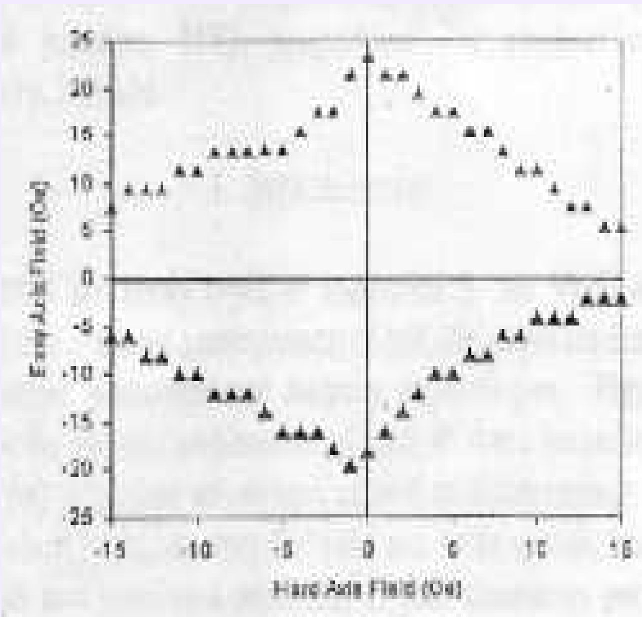
Memory cell MRAM



Switching Field of the free layer







Stoner-Wohlfarth astroid
(coherent rotation of magnetisation)
(uniaxial anisotropy)

First generation : current generated magnetic field
+Stoner Wohlfarth reversal

large current
poor selectivity

improve cell selectivity and decrease current

Second generation : Toggle (Freescale)

Heat assistance to decrease Hc (Crocus)

Third generation : Spin torque reversal

First Commercial MRAM :
4 Mbit
35 ns write-read cycle
20 year non volatility

Freescale Semiconductor
Data Sheet

256K x 16-Bit 3.3-V Asynchronous Magnetoresistive RAM

MR2A16A

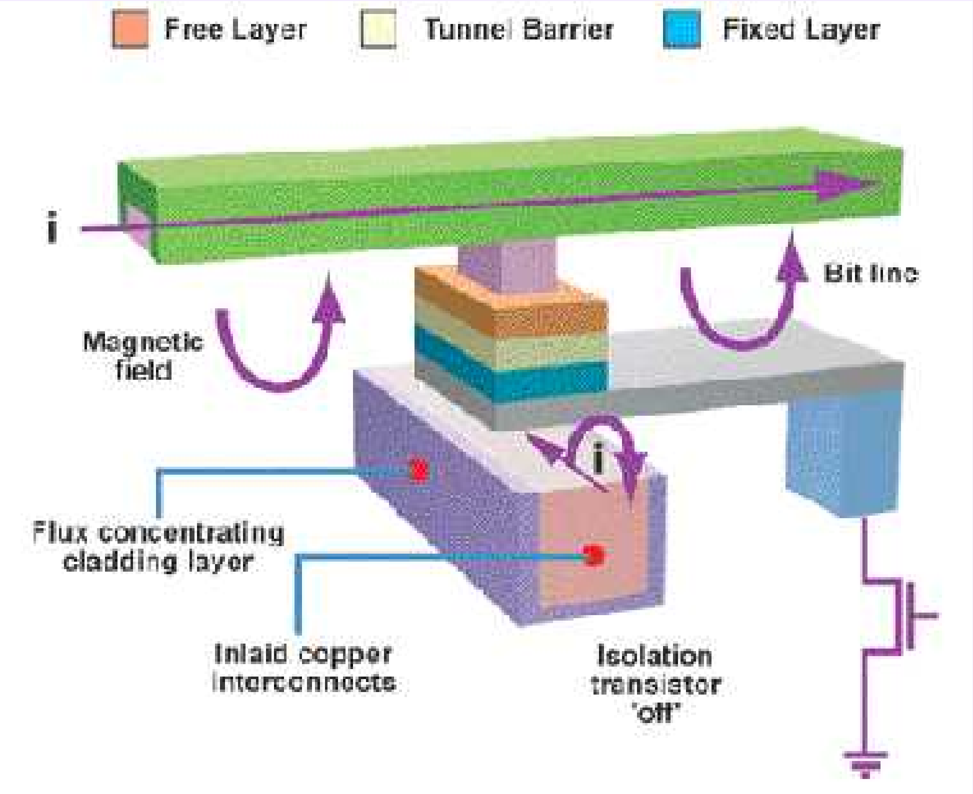
44-TSOP
Case 924A-02

Introduction

The MR2A16A is a 4,194,304-bit magnetoresistive random access memory (MRAM) device organized as 262,144 words of 16 bits. The MR2A16A is equipped with chip enable ($\overline{E}$), write enable ($\overline{W}$), and output enable ($\overline{G}$) pins, allowing for significant system design flexibility without bus contention. Because the MR2A16A has separate byte-enable controls ($\overline{LB}$ and $\overline{UB}$), individual bytes can be written and read.

Features

- Single 3.3-V power supply
- Commercial temperature range (0°C to 70°C), Industrial temperature range (-40°C to 85°C) and Extended temperature range (-40°C to 105°C)
- Symmetrical high-speed read and write with fast access time (35 ns)
- Flexible data bus control — 8 bit or 16 bit access



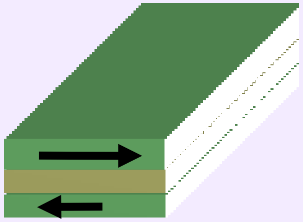
MOTOROLA 1T-1MTJ cell

fabrication :
0.6 µm technology + Cu (1 Mb)
0.18 µm (4 Mb)
7 µm²/cellule   25 mm²
wafer 200 mm

performance :
3 Volt 20 MHz
45% TMR (low bias)
30% at operating bias
(1% uniformity)
25 Oe coercivity
cladded lines
50 ns access time

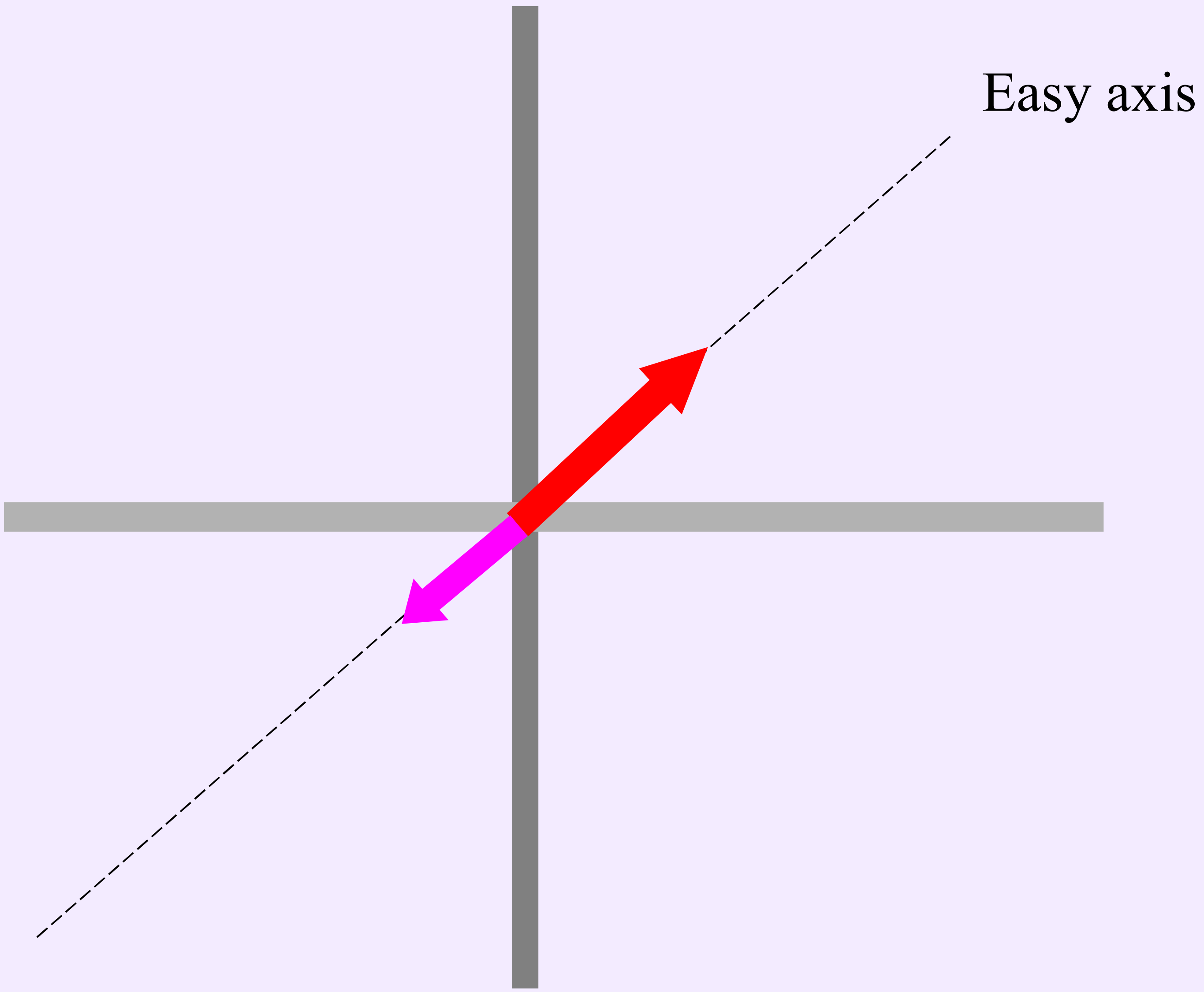
Motorola « Toggling Mode »

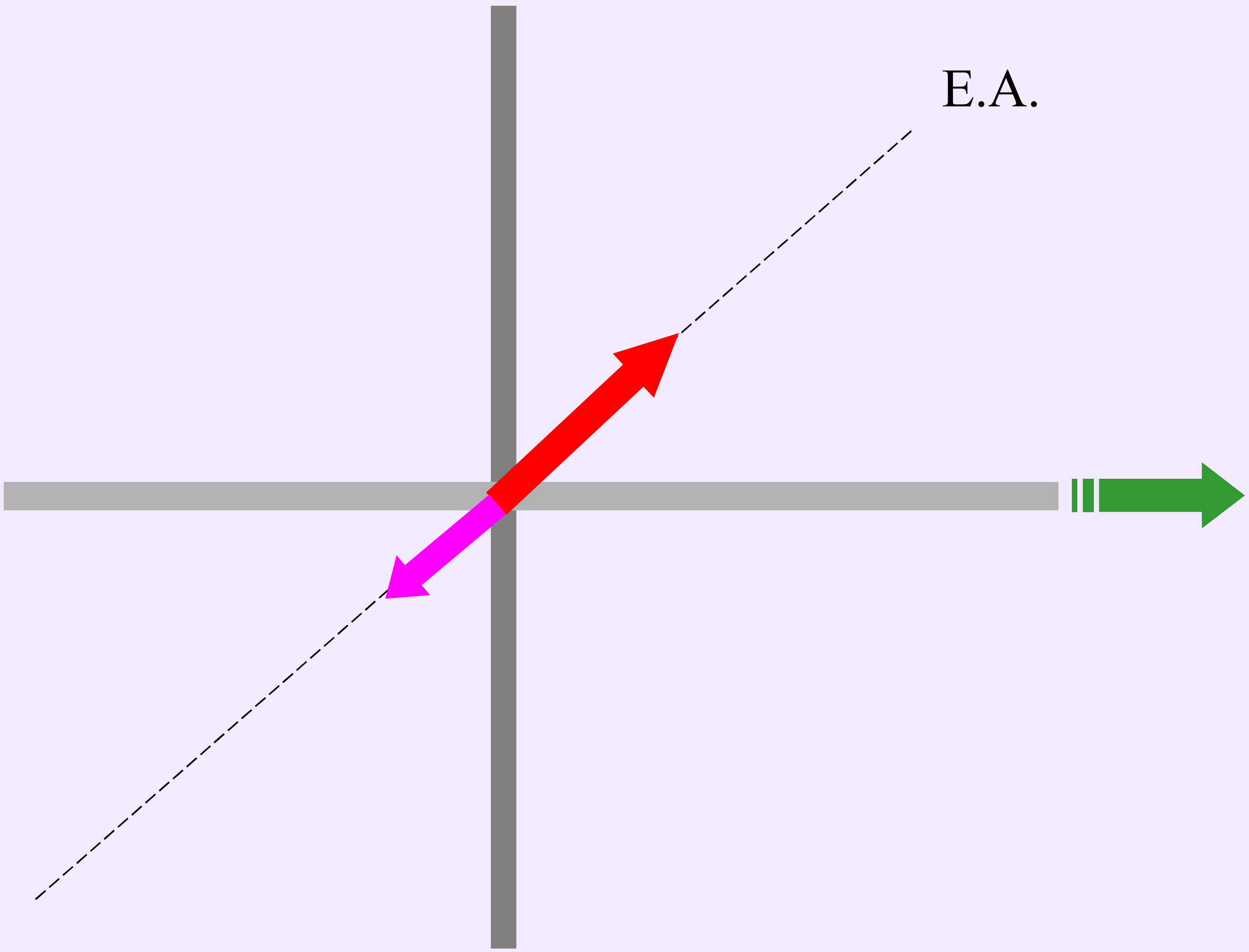
S.A.F. free layer

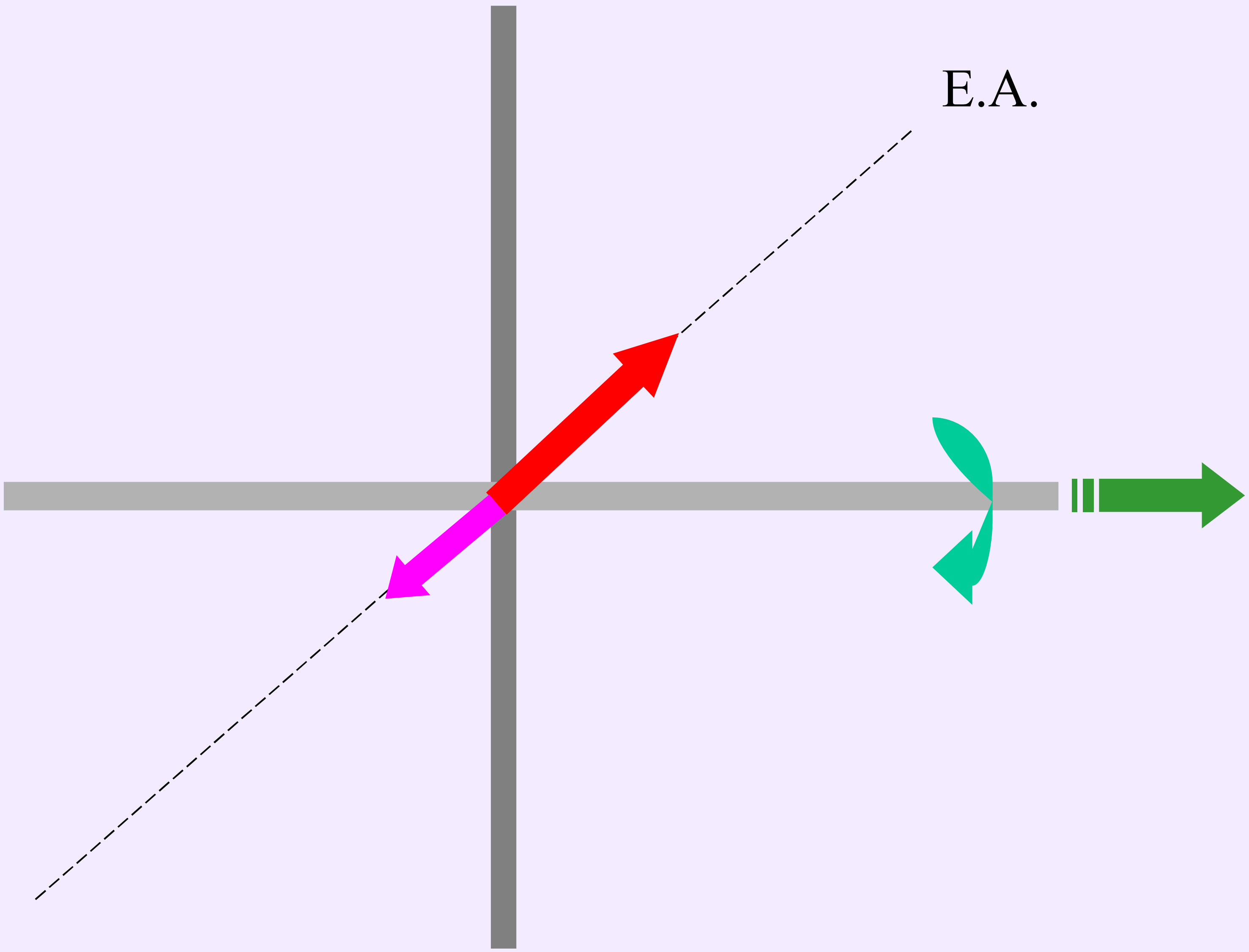


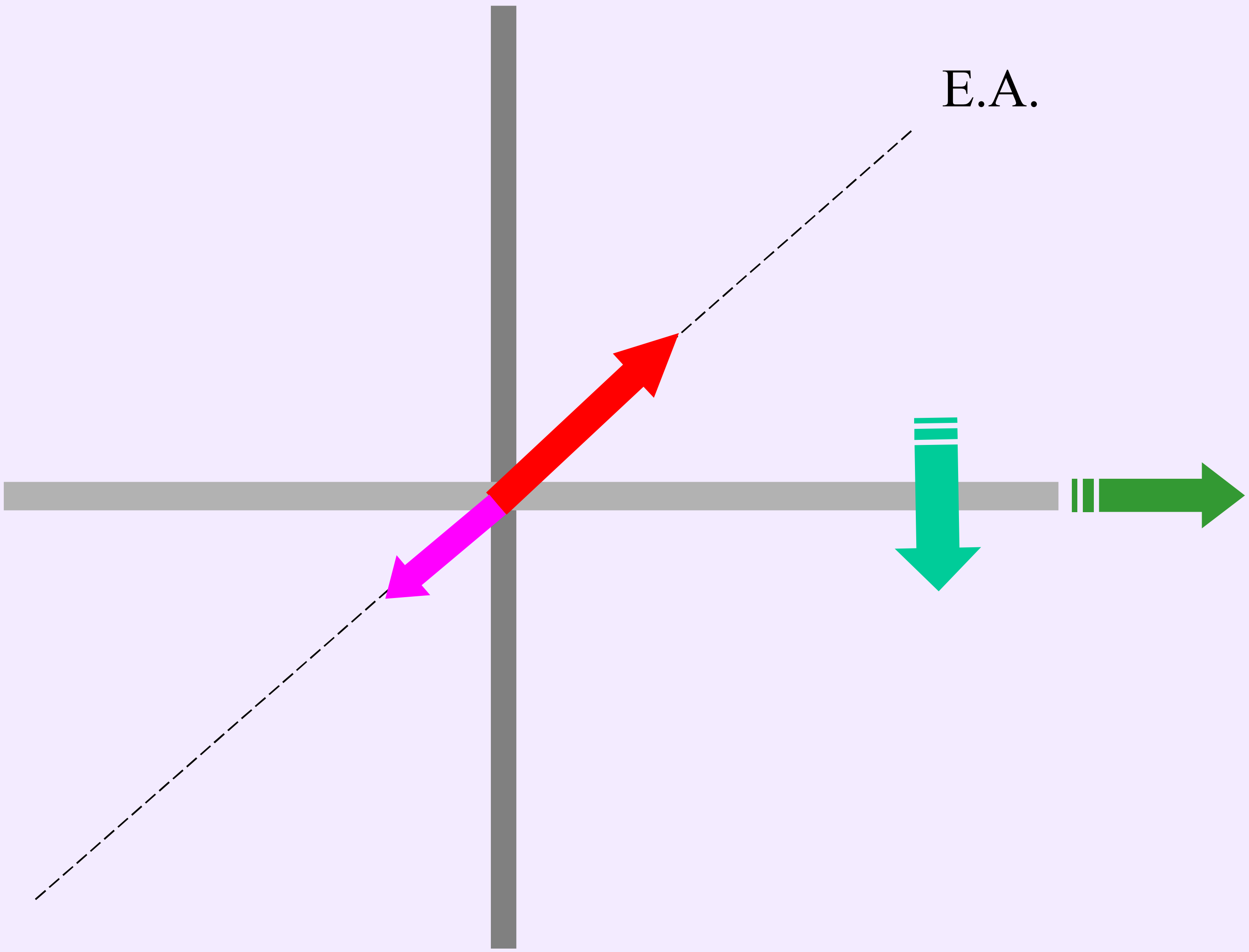
Co / Ru / Co
RKKY A.F. coupling

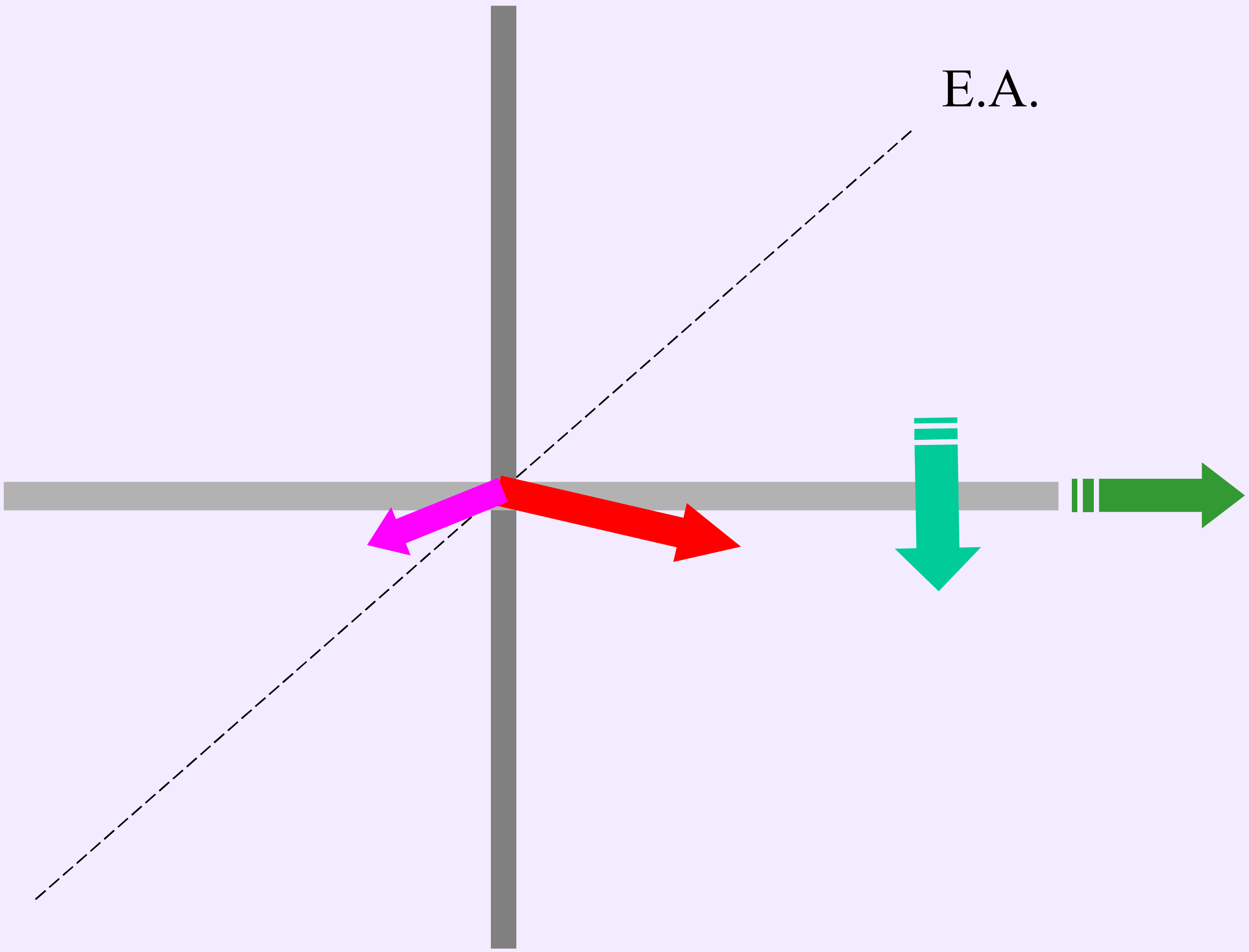
H>Hc Spin flop transition

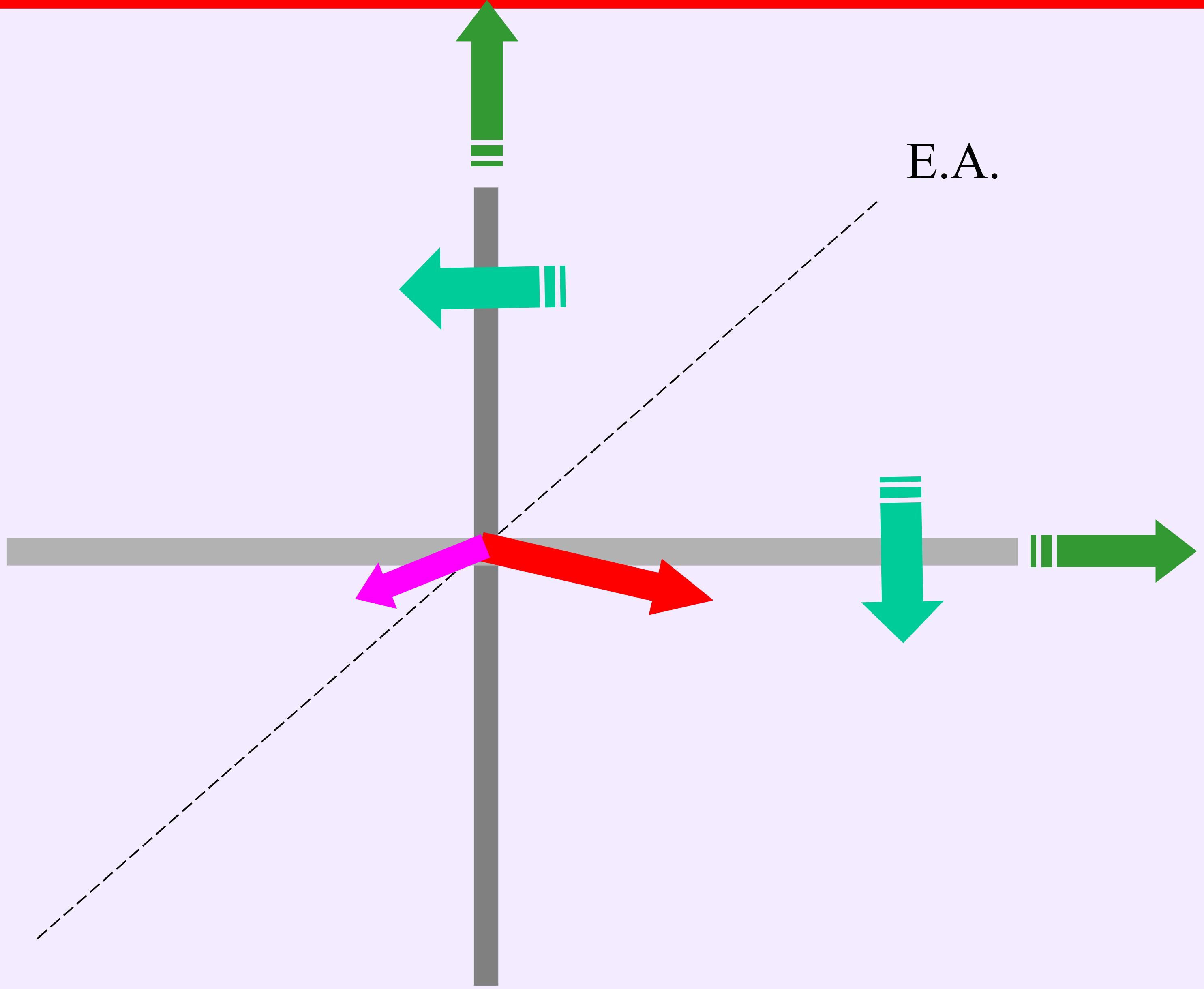

Easy axis

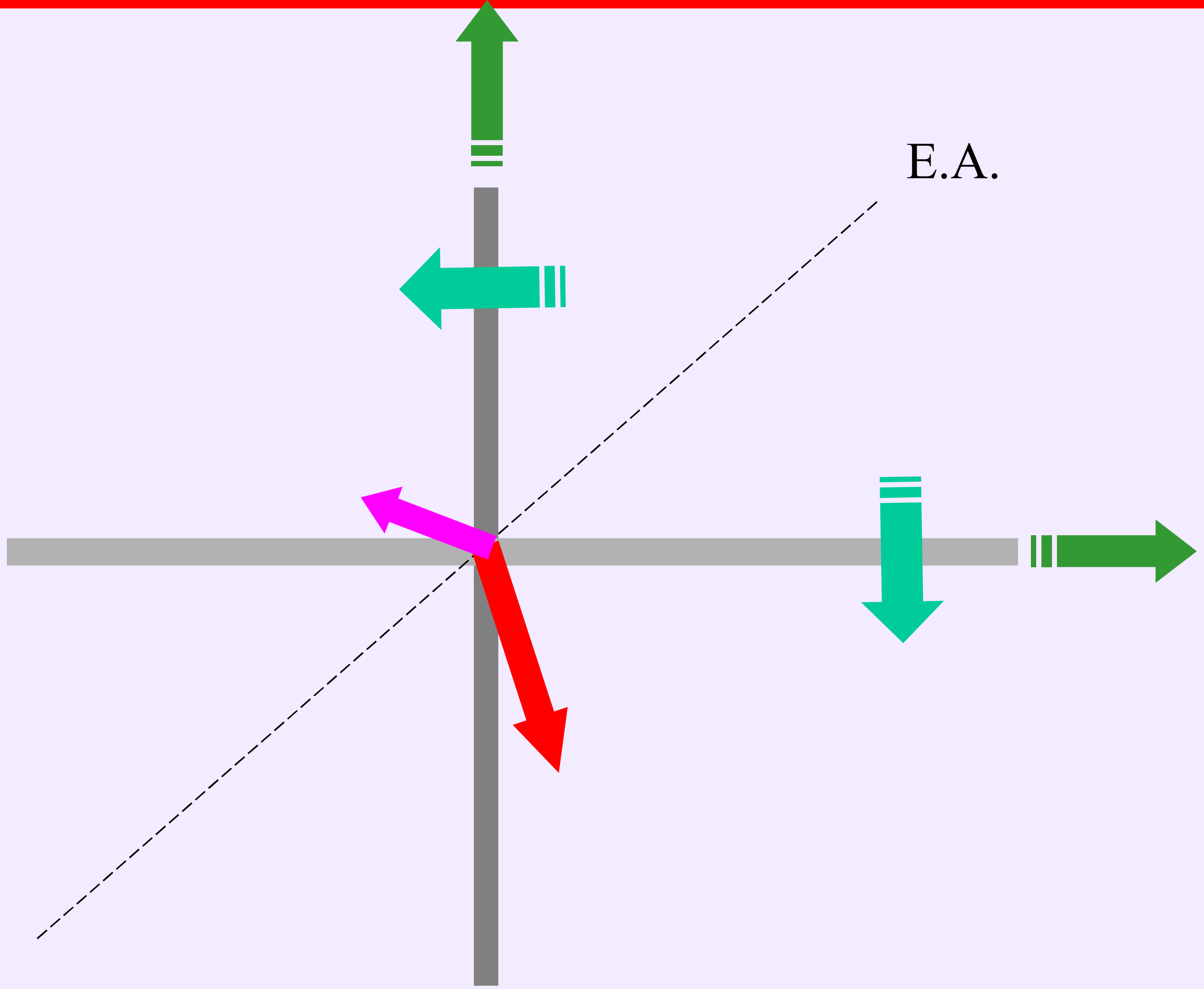

E.A.

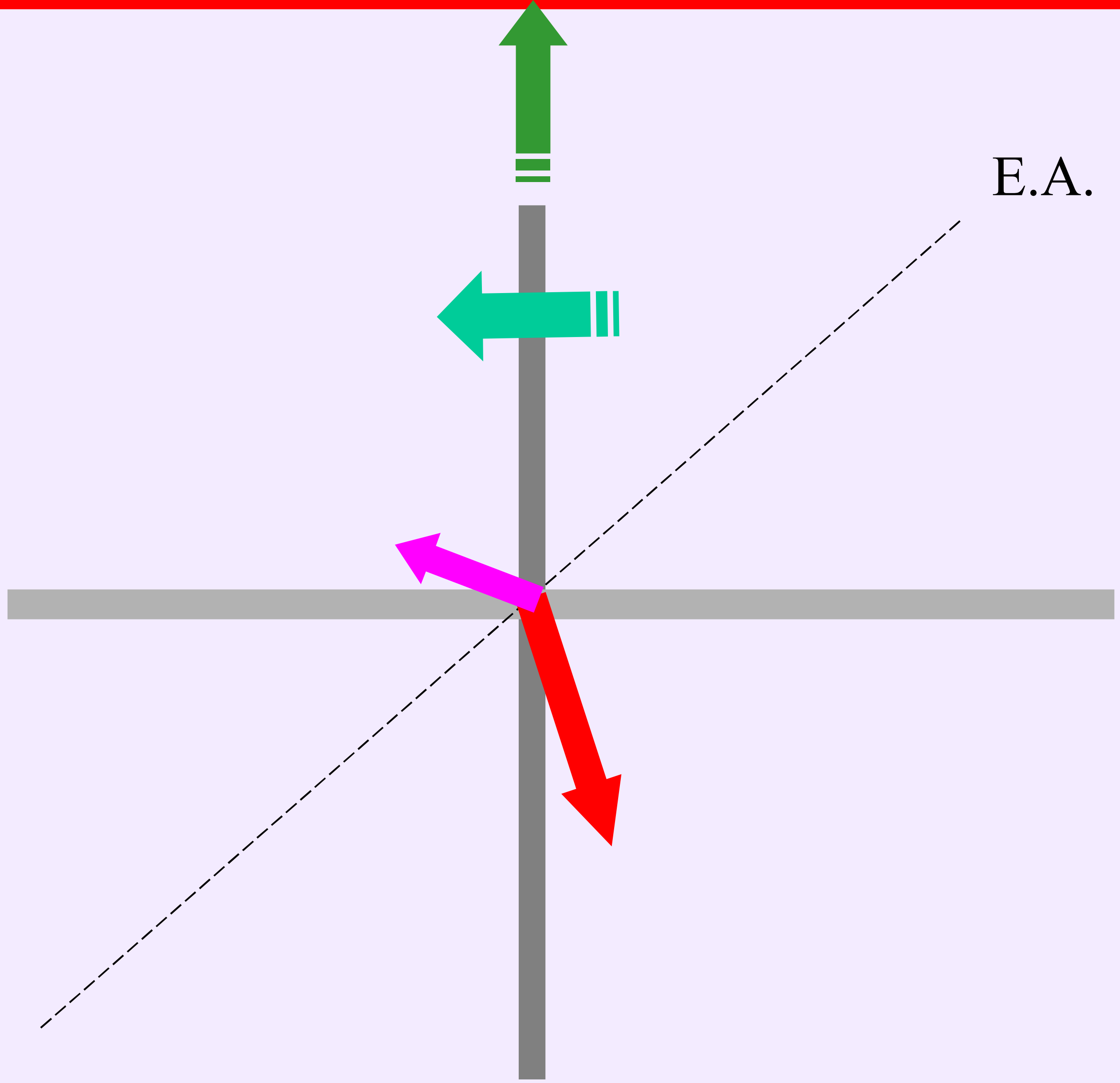

E.A.

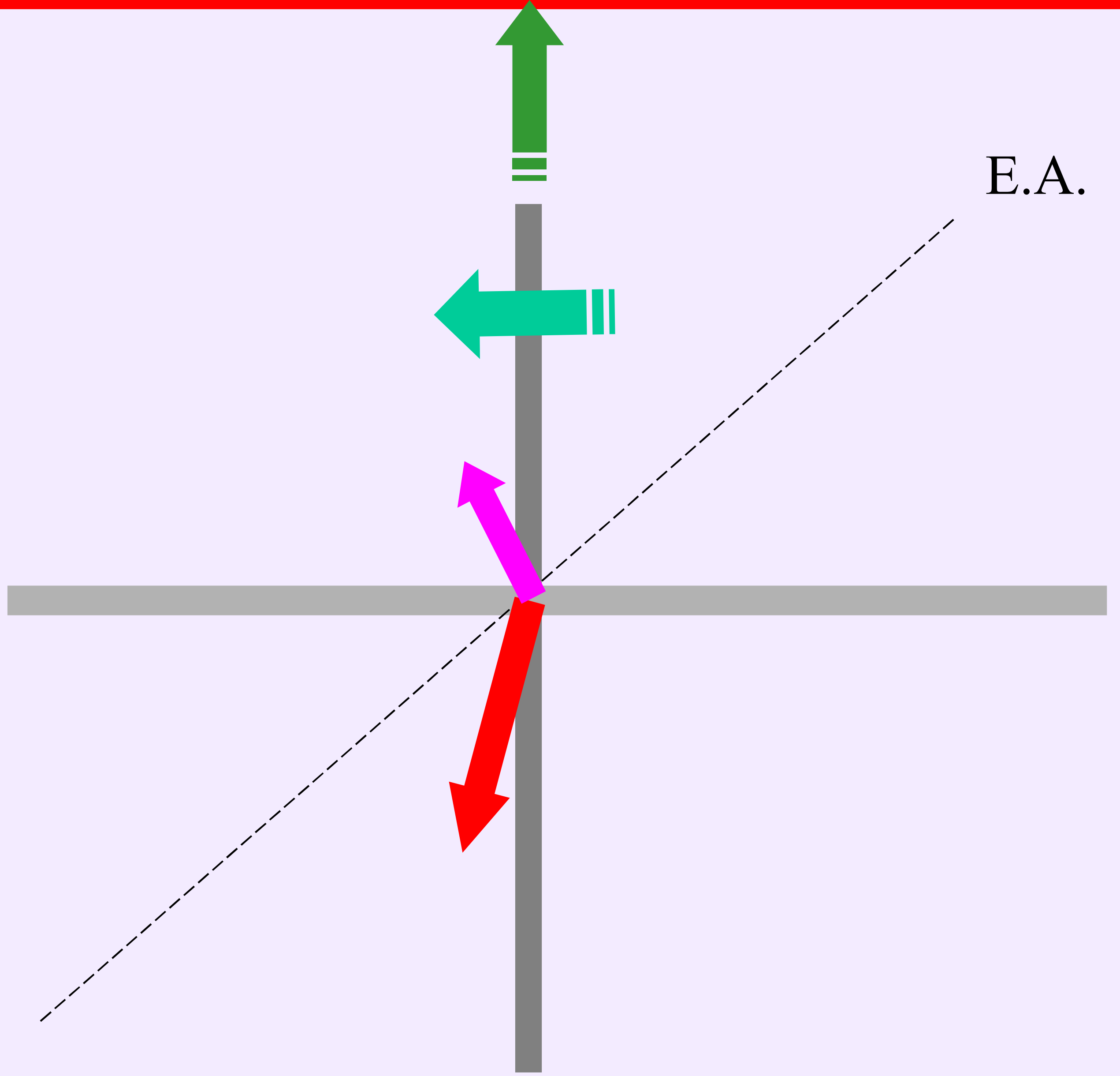

E.A.

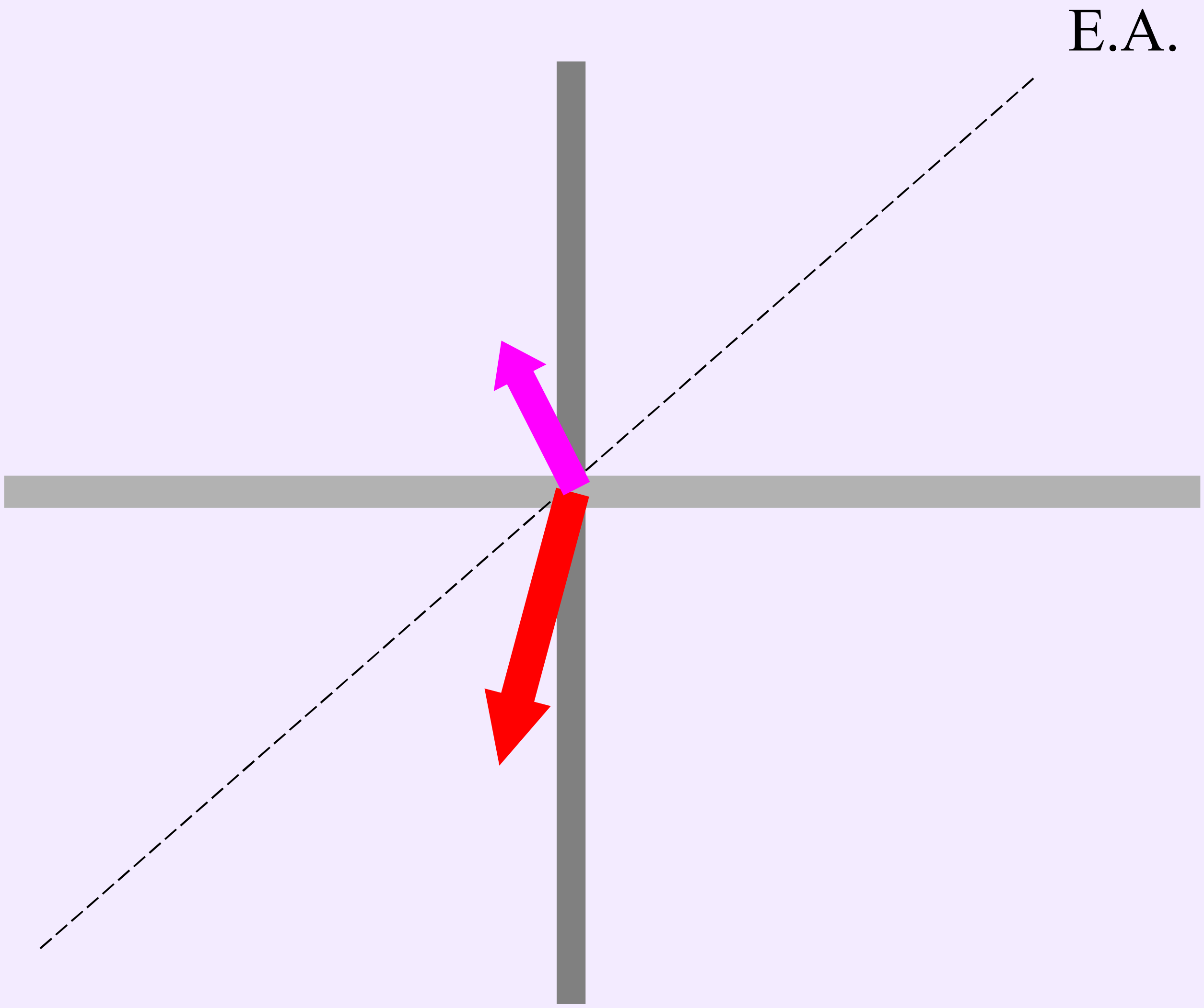

E.A.

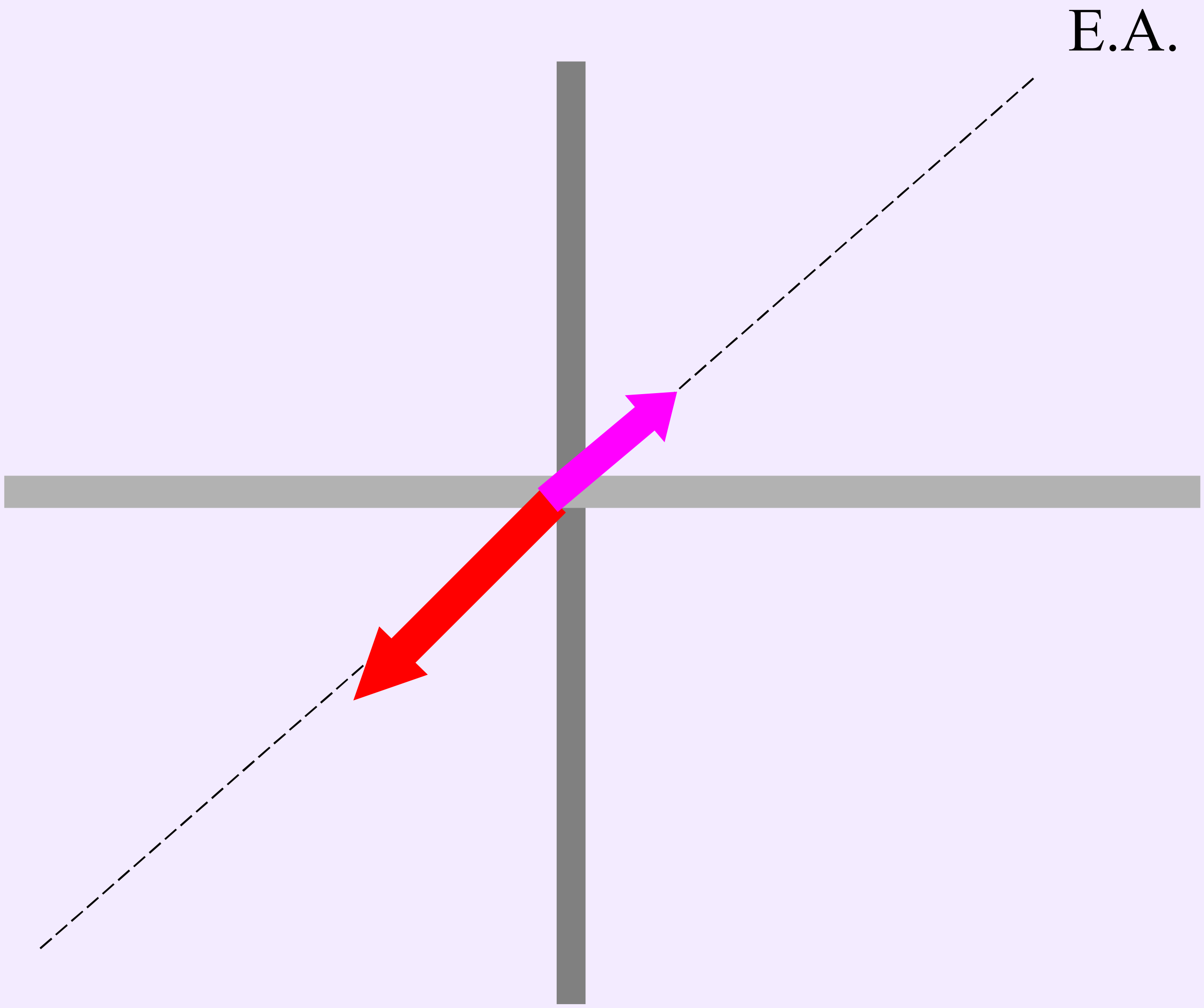

E.A.


E.A.


E.A.


E.A.


E.A.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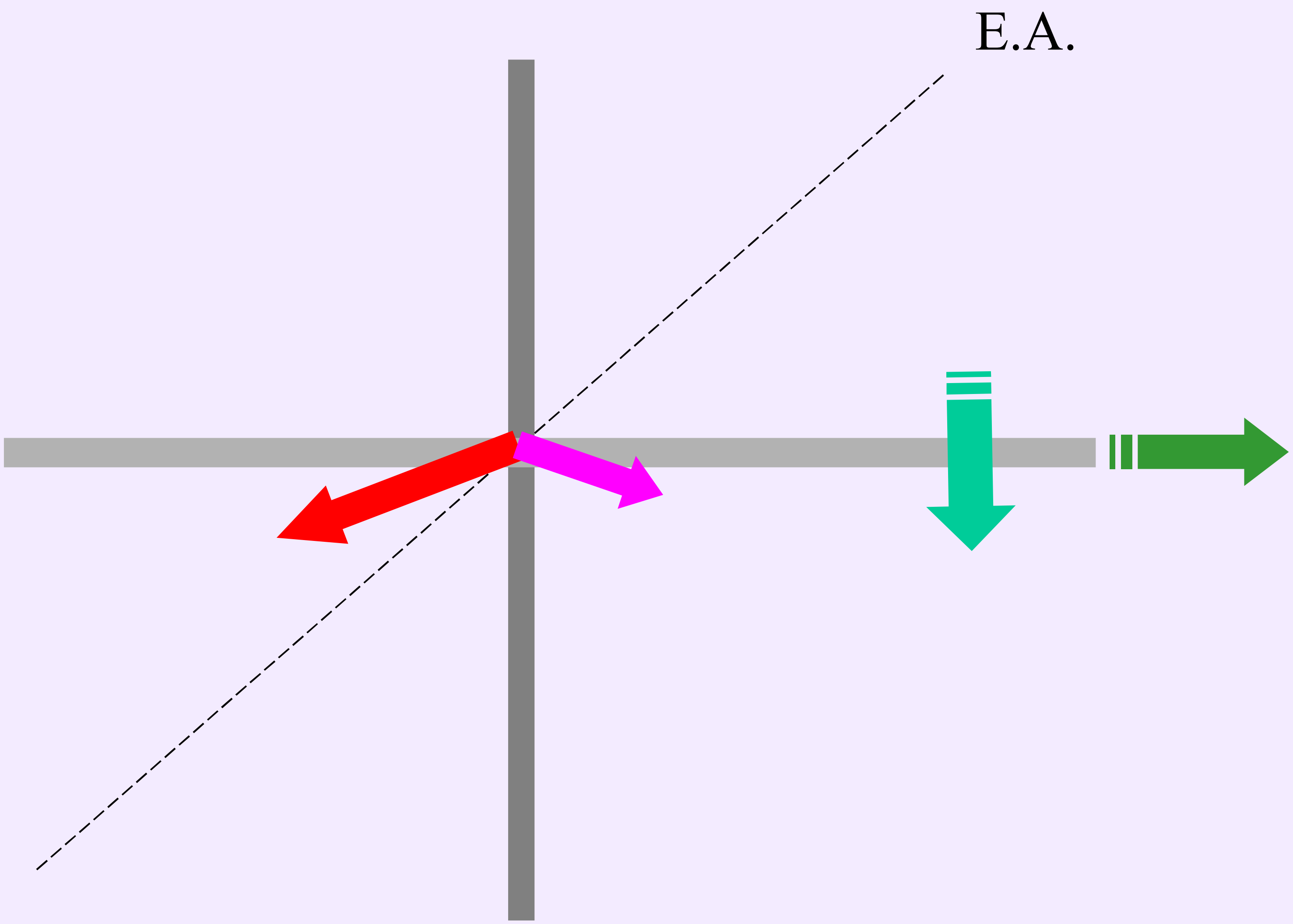
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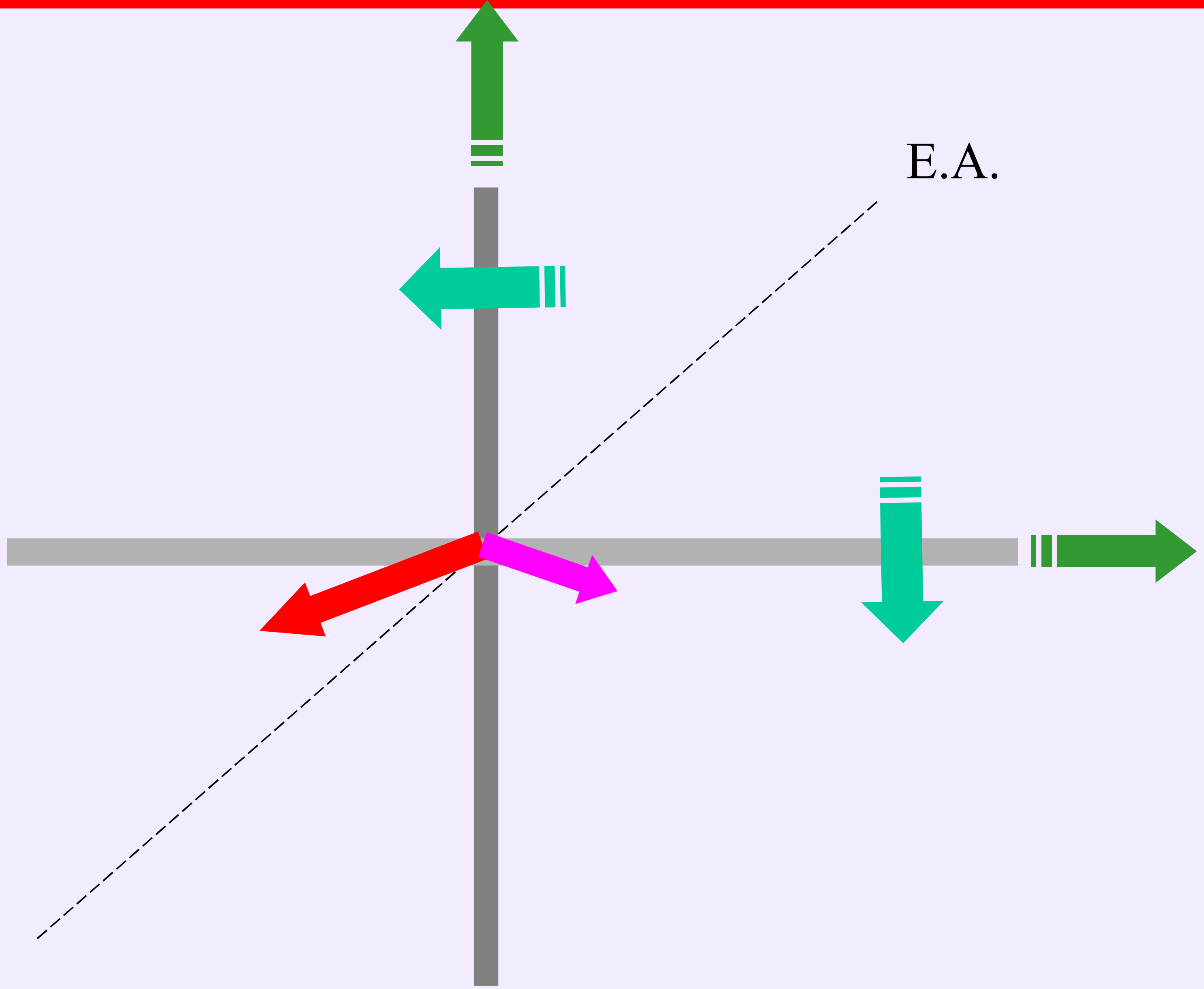
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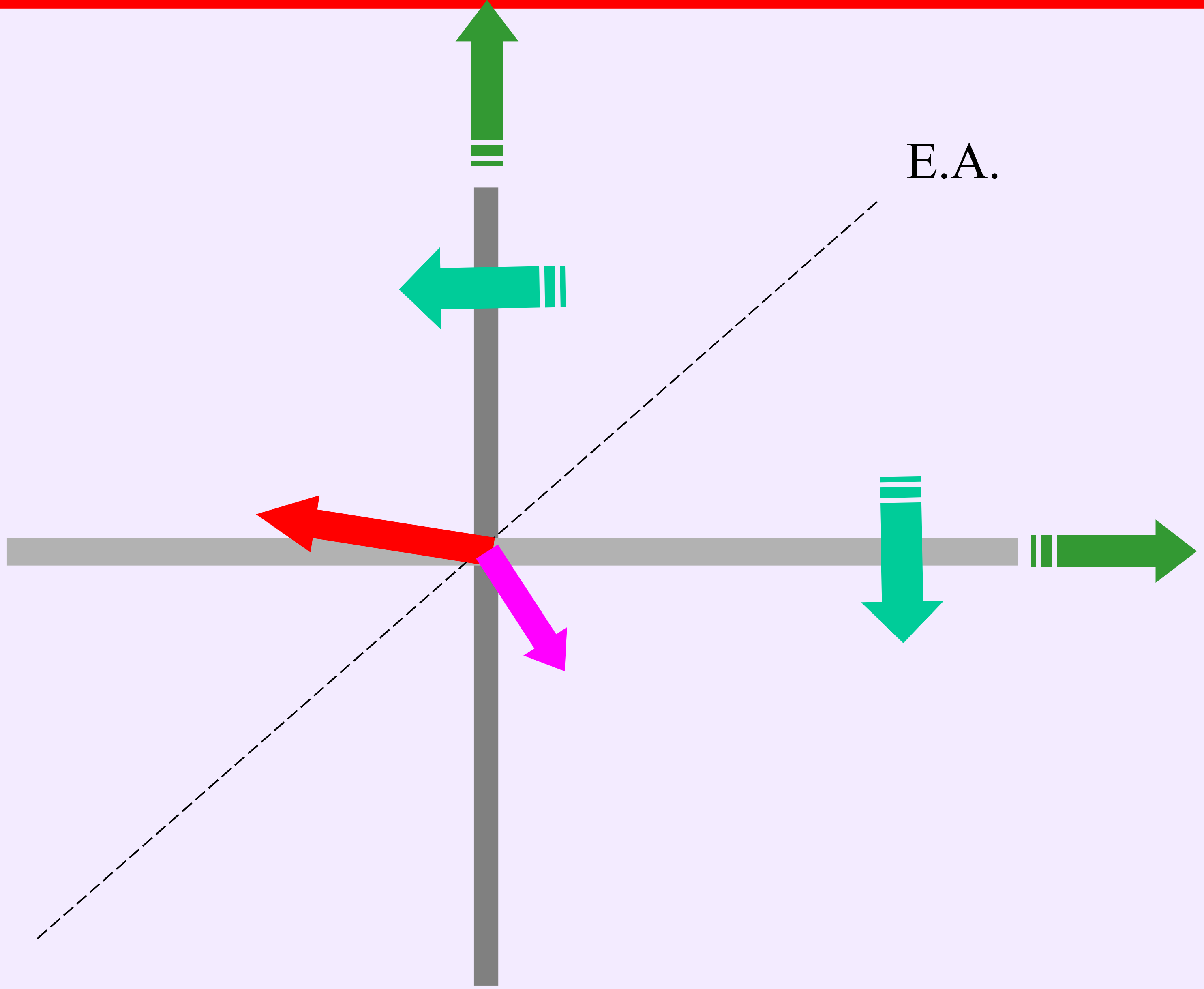
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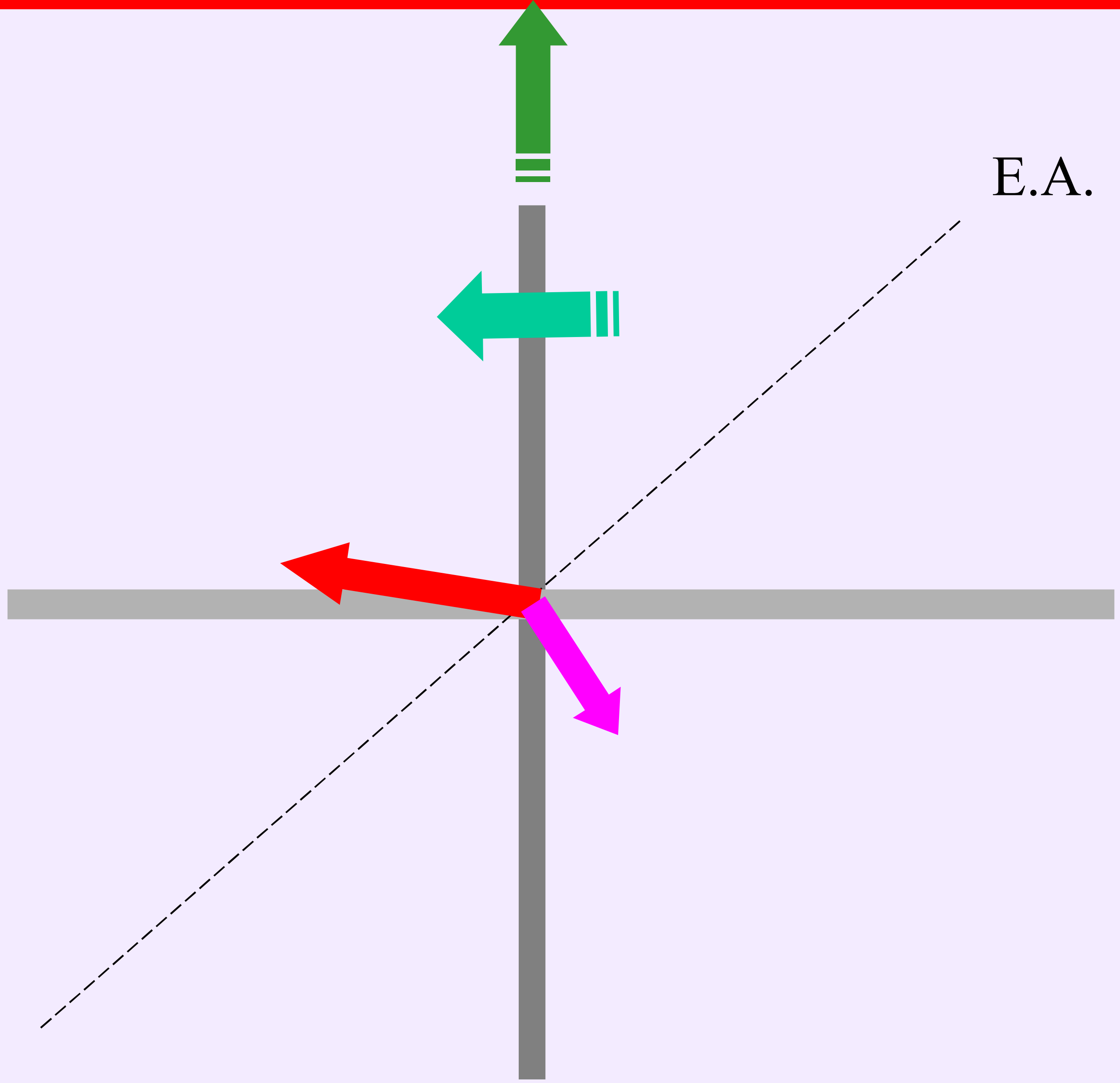
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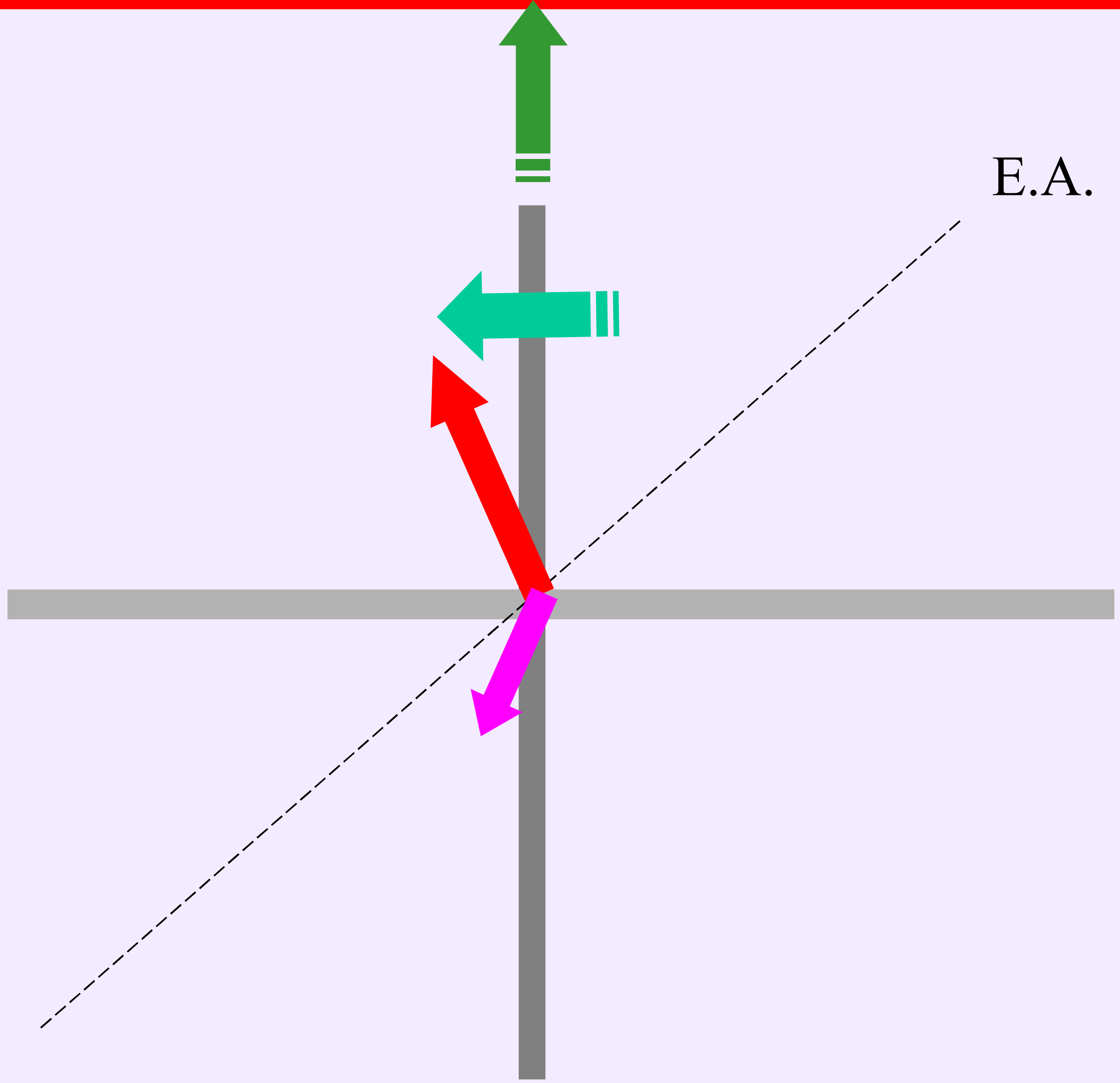
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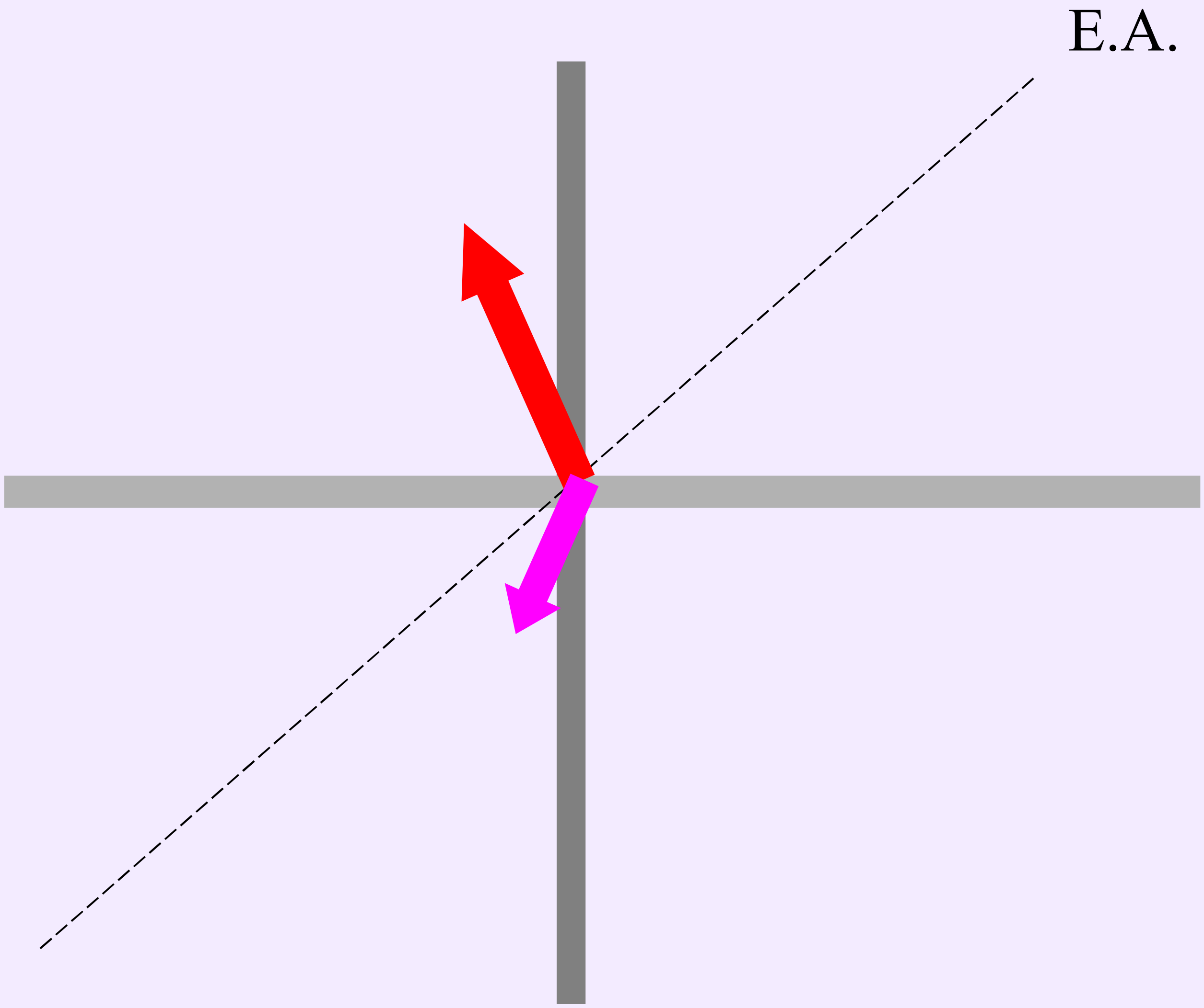
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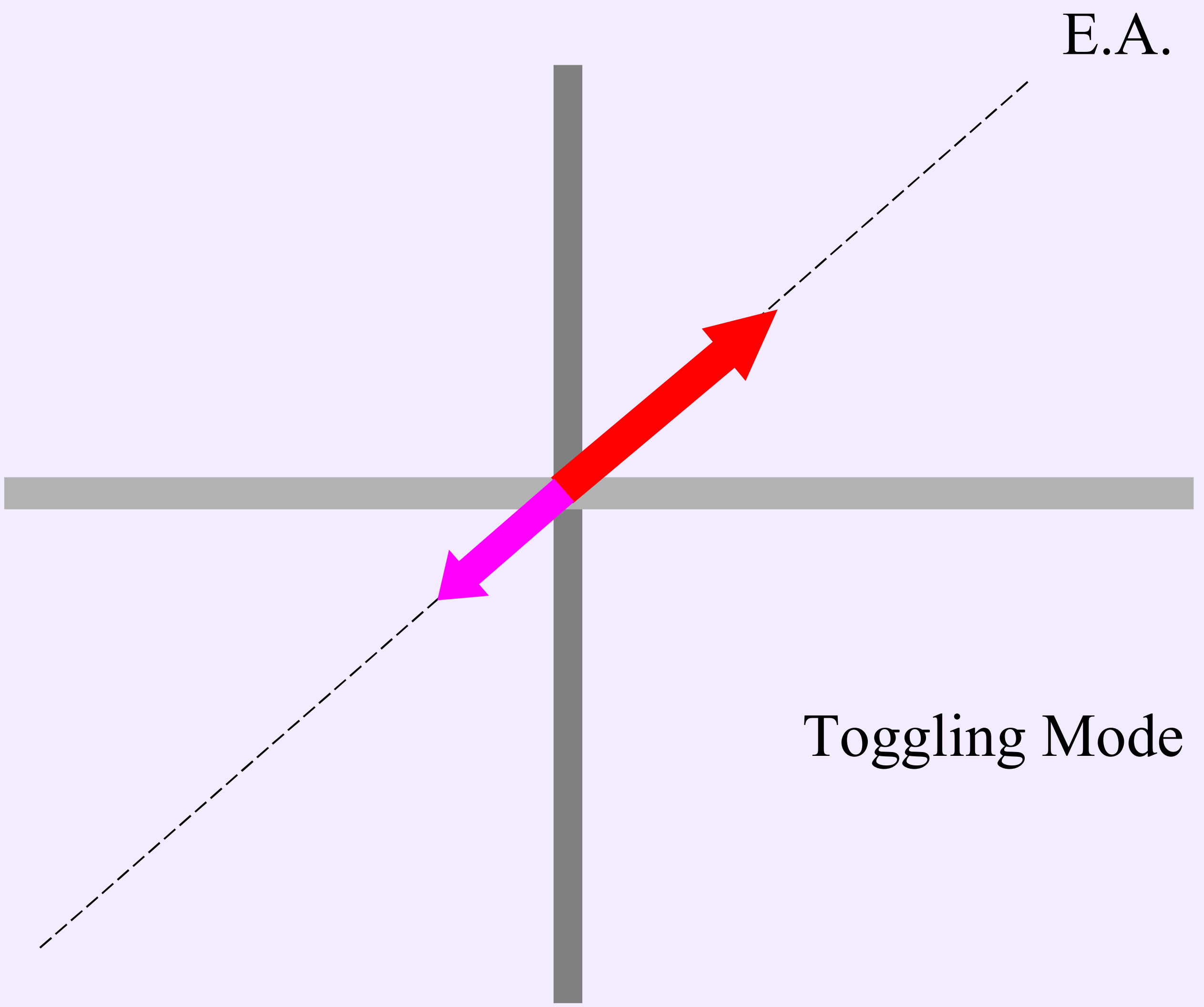
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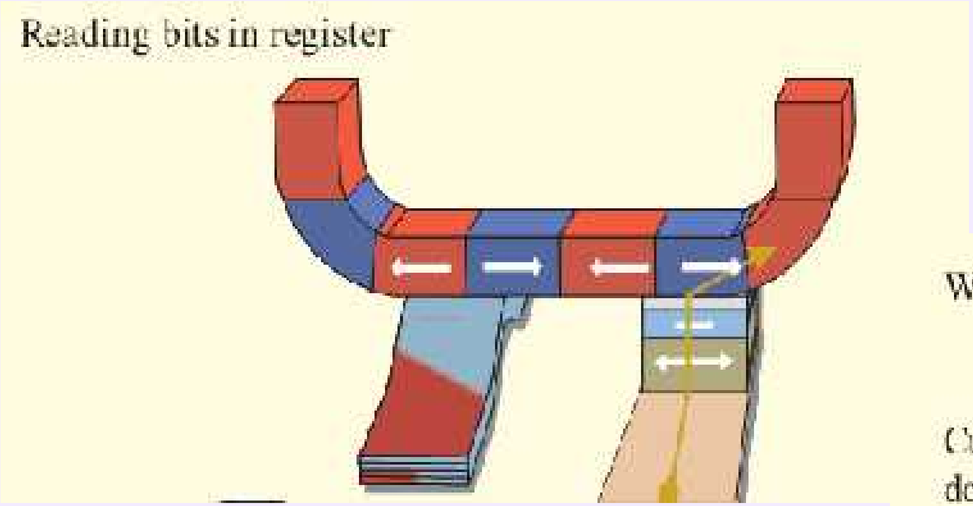
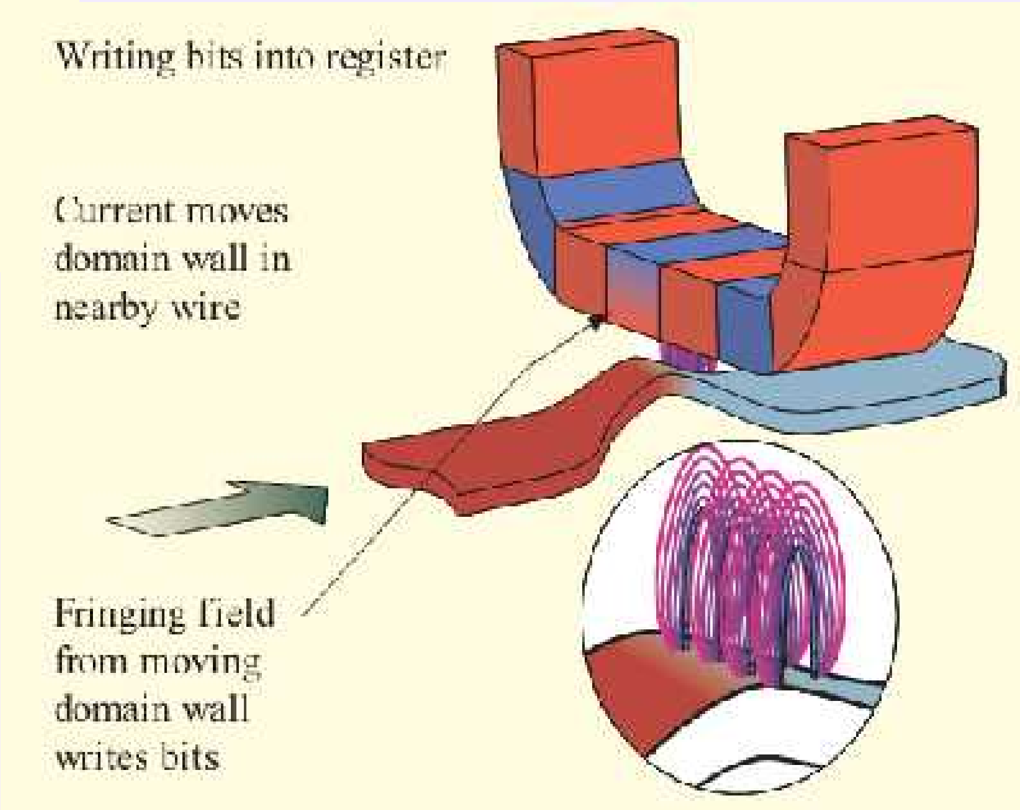
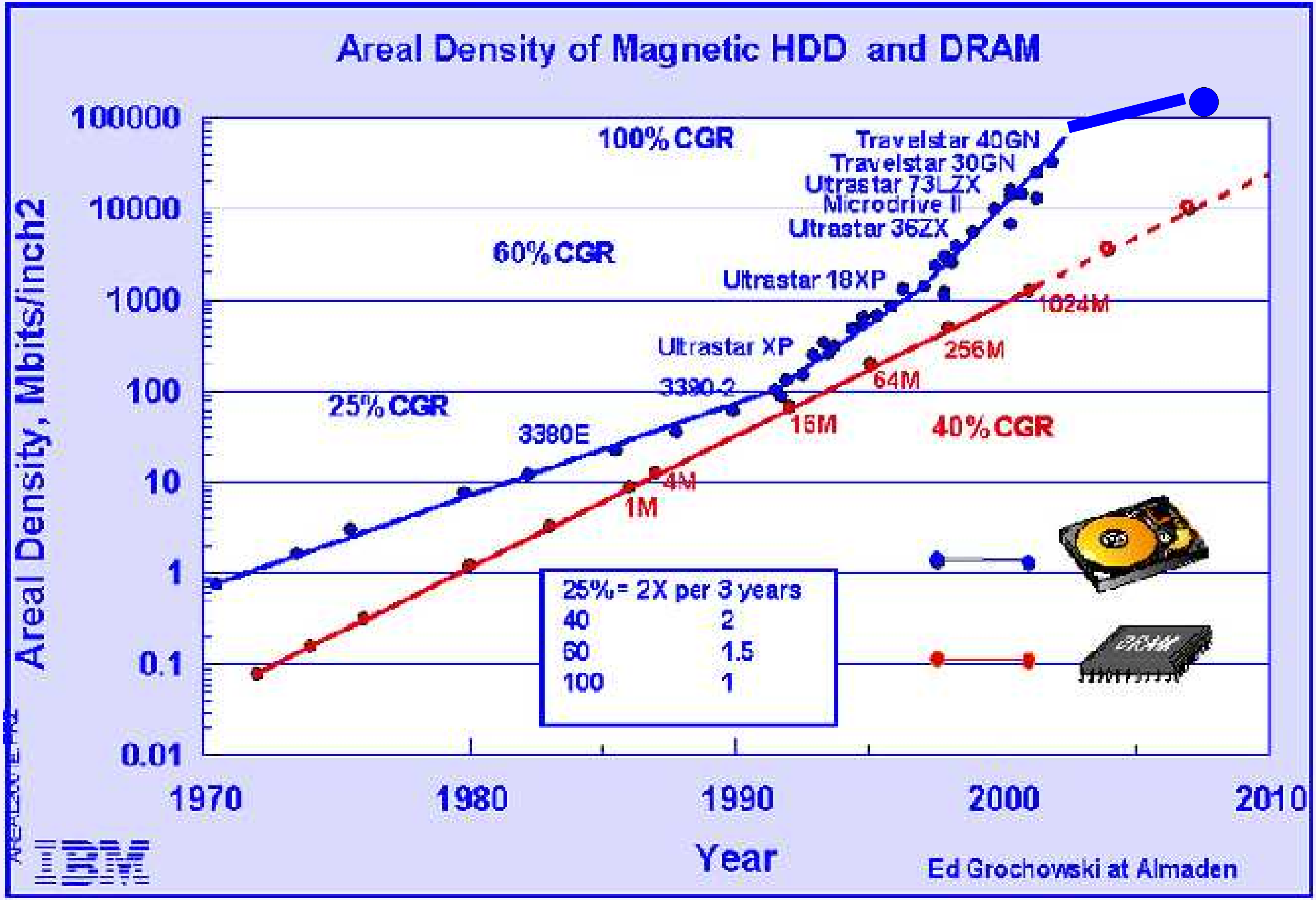
Toggling Mode

S.S.P. Parkin(IBM) 's racetrack memory

Using the third dimension : bits are domain walls







DRAM nearly passed HDD in 1992. ? 2010

Merci !

Thanks for your attention