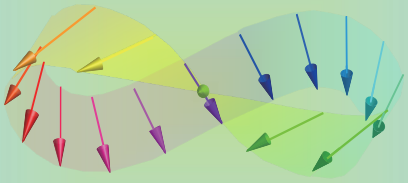
Information Storage and Spintronics 05



Atsufumi Hirohata

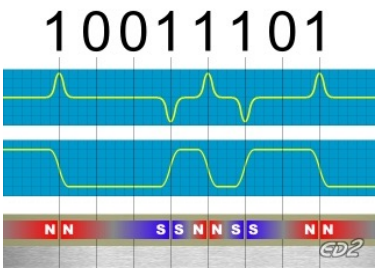
Department of Electronic Engineering

THE UNIVERSITY of York

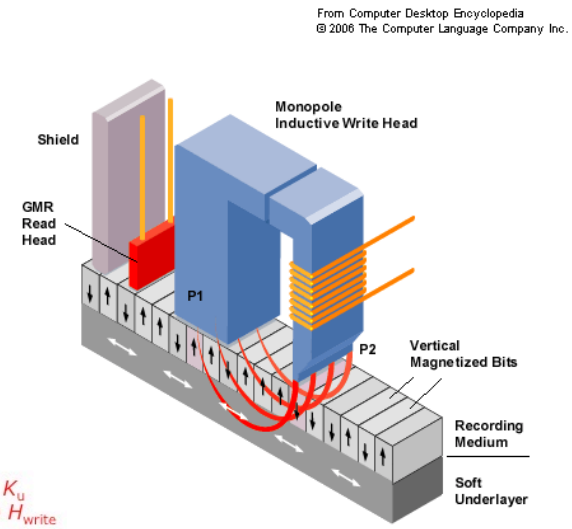
10:00 Monday, 17/October/2022 (SLB 004)

Quick Review over the Last Lecture

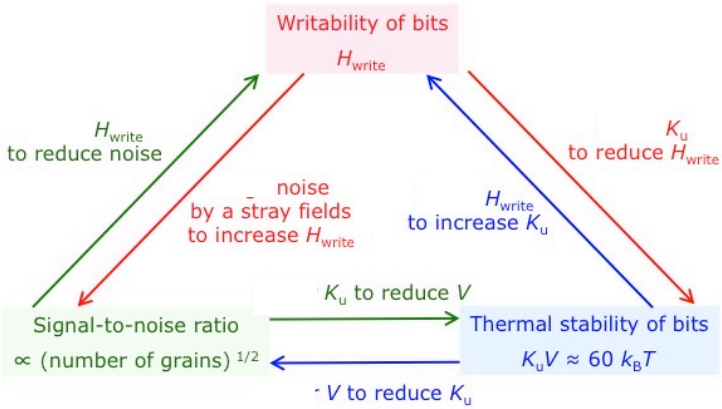
Recording data onto a HDD :



Perpendicular recording :



Requirements for higher-density recording :



* http://www.kayoo.info/jyouhou-kiki/sozai/1504/index.html
** http://www.hitachigst.com/

05 Energy Assisted Recording

- Thermal fluctuation
- Areal density
- Anisotropic materials
- Writing field
- Energy assist
- HAMR
- MAMR

Thermal Fluctuation

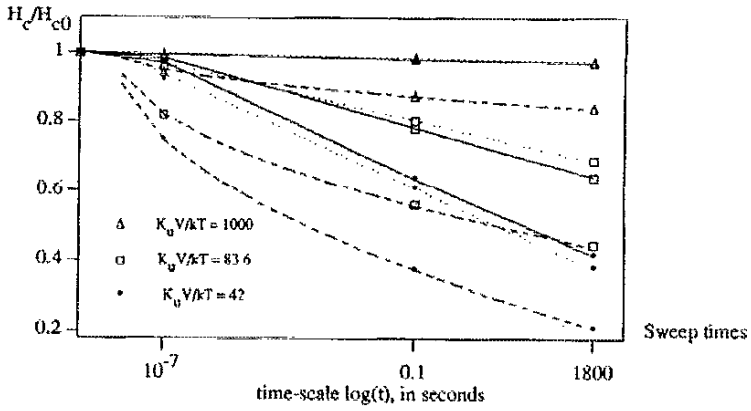
Thermal stability of recorded data bits :

can be defined by the competition between

- Thermal energy :
  (: Boltzmann constant and : absolute temperature)
- Magnetic energy :
  (: magnetic uniaxial anisotropy constant and : grain volume)

determines a signal-to-noise ratio for the bit read-out.

Monte Carlo simulations were carried out to determine the minimum requirement for 30-year recording : *



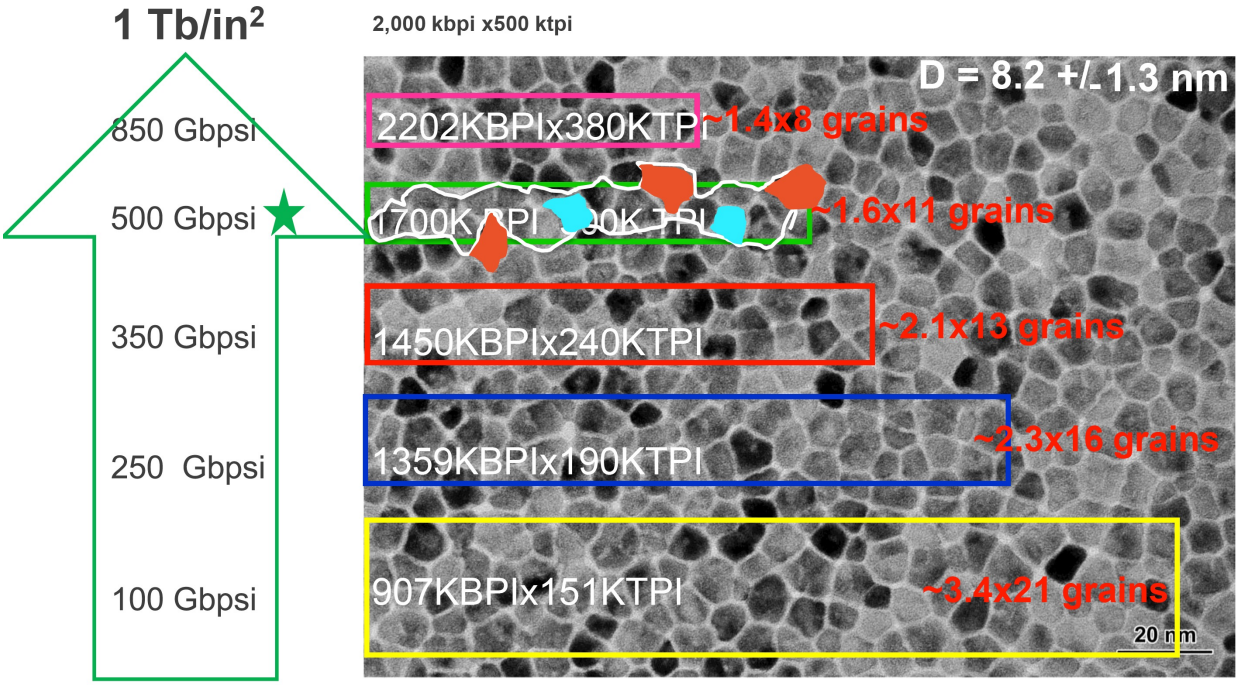
Minimum requirement :

> 60

* P.-L. Lu and S. H. Charap, *J. Appl. Phys.* **75**, 5768 (1994).

For Higher Areal Density ...

Areal Density ≡ TPI * BPI (Tracks Per Inch X Bits Per Inch)

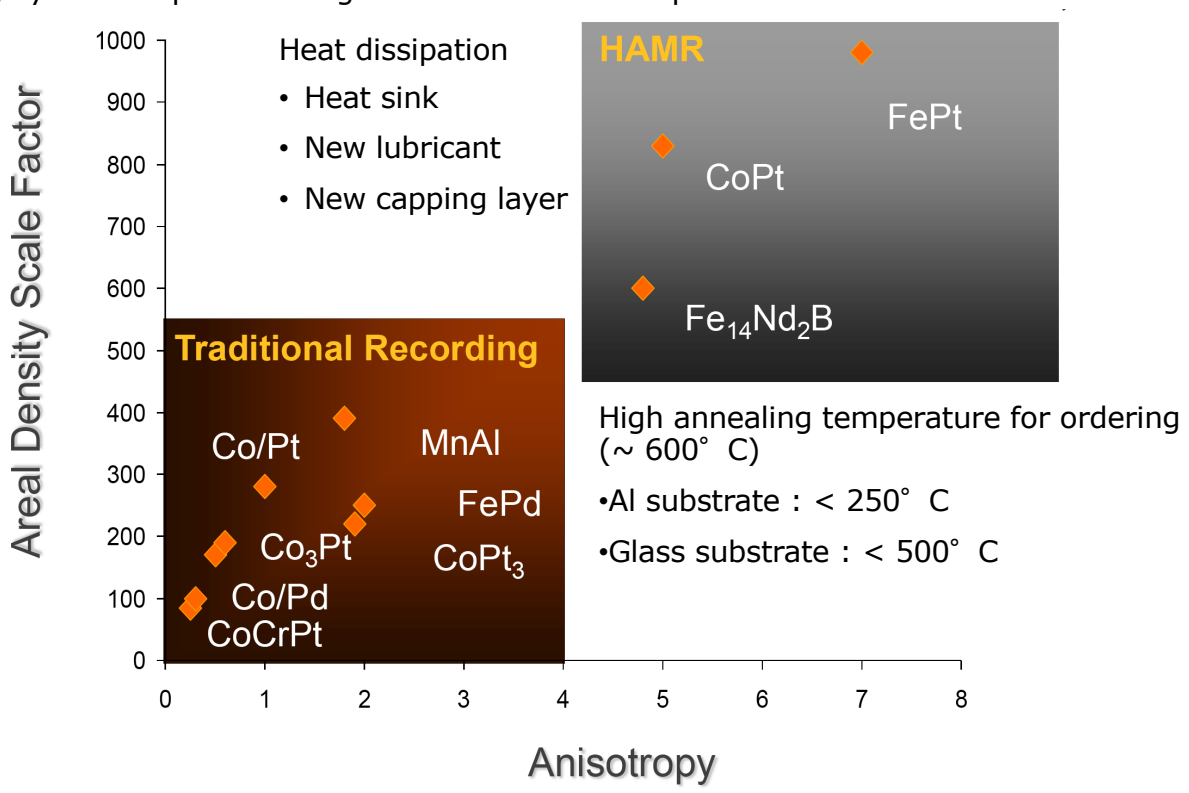


Decreasing Bit Size→ Increase Areal Density

* http://www.seagate.com/

To Reduce Grain Volume ...

Highly anisotropic ferromagnetic materials are required : *



High annealing temperature for ordering (~ 600° C)

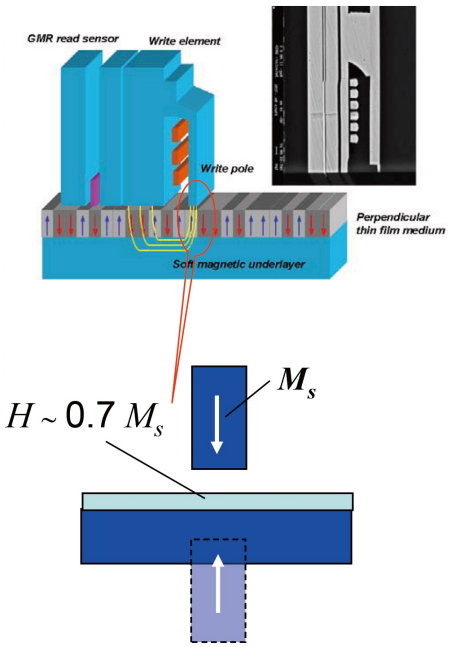
•Al substrate : < 250° C

•Glass substrate : < 500° C

* http://www.seagate.com/

Maximum Writing Field

Writing a data bit in a HDD uses a stray field from the write head : *



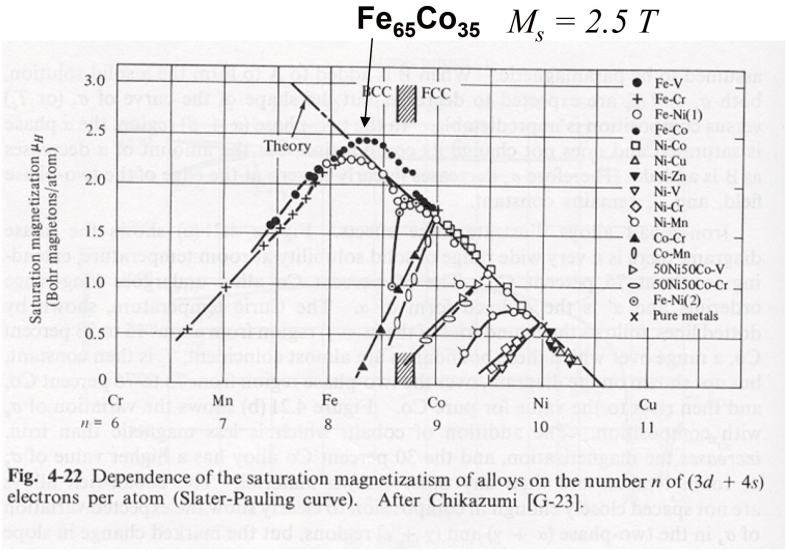


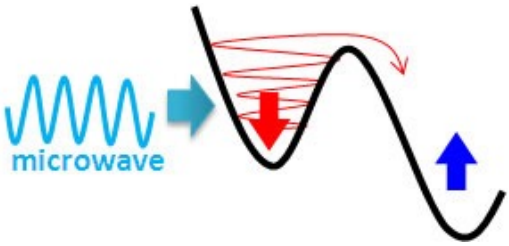
Fig. 4-22 Dependence of the saturation magnetizatism of alloys on the number n of $(3d + 4s)$ electrons per atom (Slater-Pauling curve). After Chikazumi [G-23].

* http://www.idema.org/wp-content/downloads/1856.pdf

Writing on Highly Anisotropic Grains

In order to write data bits onto highly anisotropic grains :

Energy-assisted recording is required to overcome the energy barrier of . *



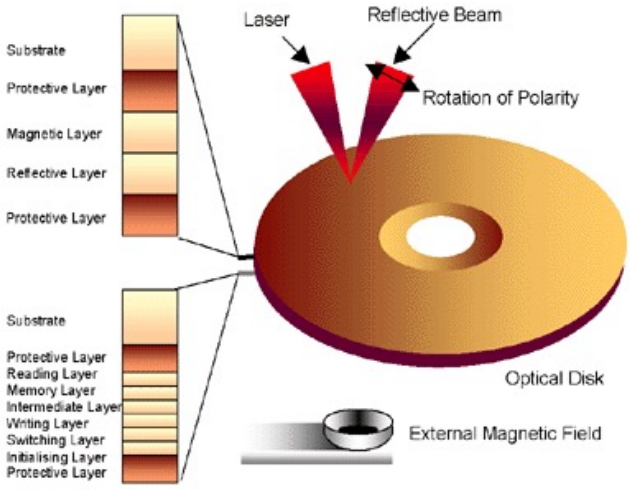
These energy can be either heat or microwave.

* http://www.tagen.tohoku.ac.jp/labo/kitakami/J/research_j/research_j.html

Heat Assist

In 1954, RCA filed a principle patent to use heat with a magnetic field for recording.

In 1980s, magneto-optical (MO) disks utilised the heat-assist mechanism. *

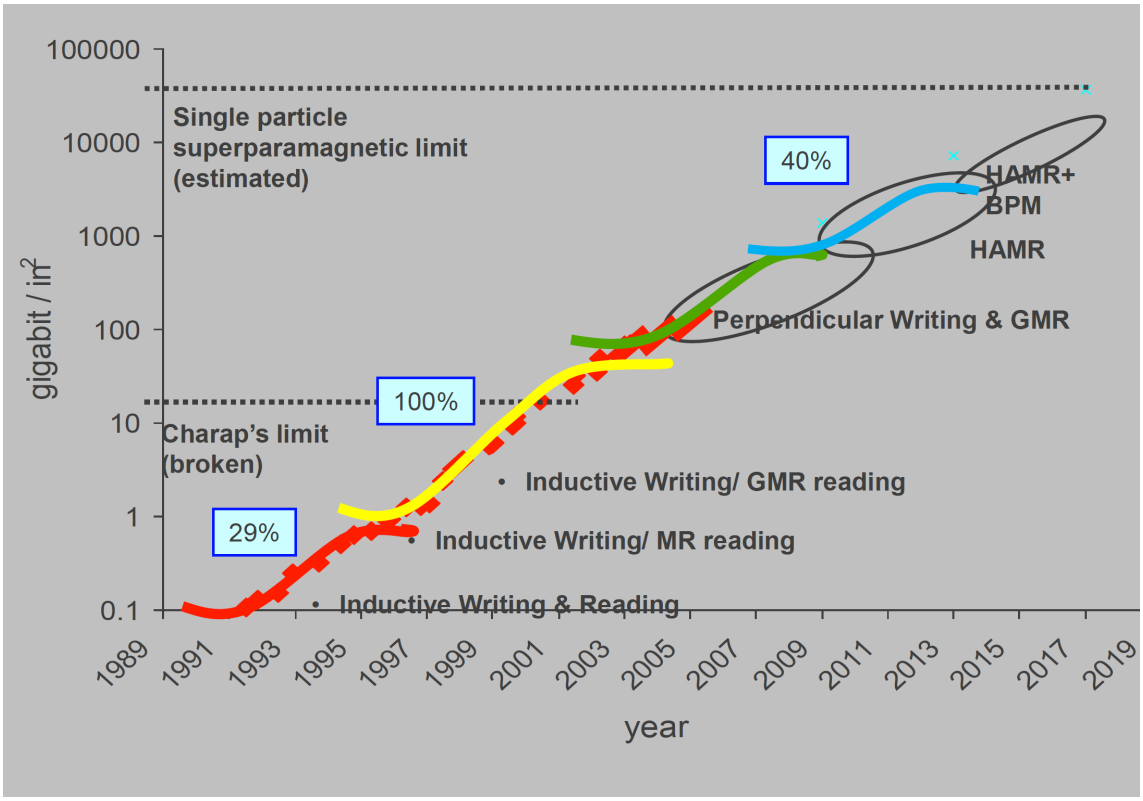


Since ~ 2002, HDD manufacturers started to develop heat-assisted magnetic recording (HAMR) to overcome the superparamagnetic limit.

* http://www.cdrinfo.com/Sections/Reviews/Print.aspx?ArticleId=1427

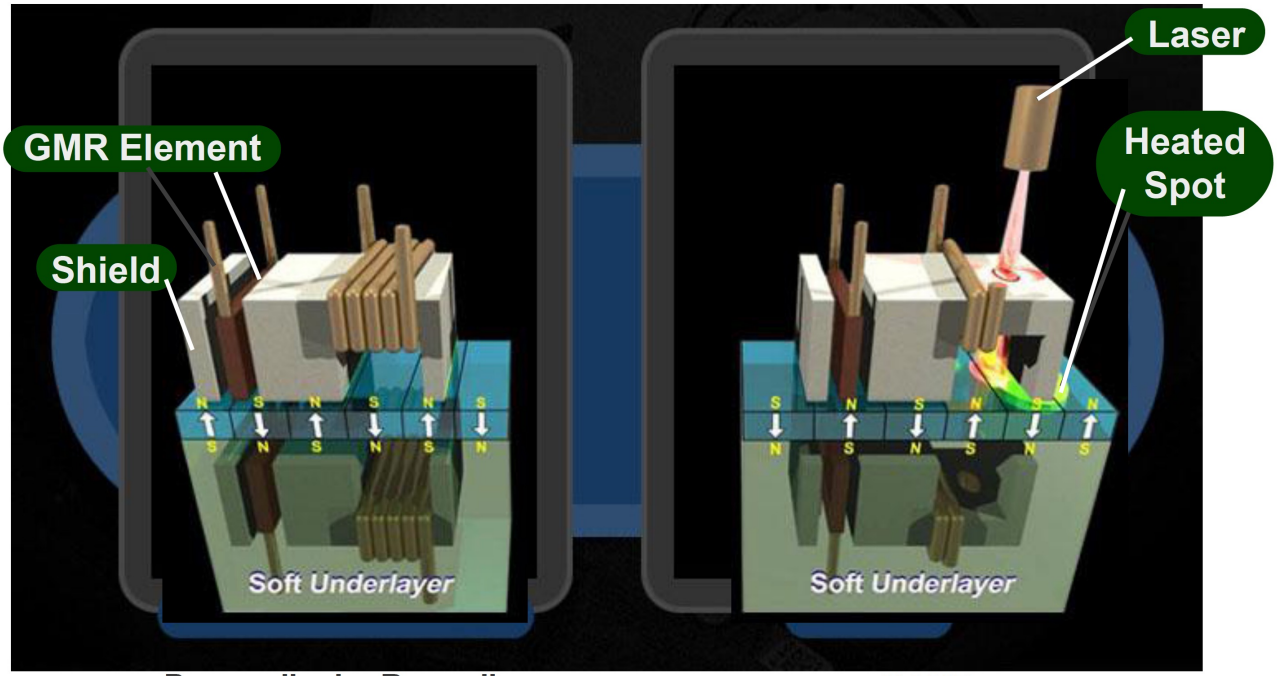
Heat-Assisted Magnetic Recording (HAMR)

Seagate and Hitachi GST (Western Digital) have been working on HAMR : *



* http://www.seagate.com/

New HAMR Head



* http://www.seagate.com/

Near-Field Optics

Laser light to be introduced using near-field optics : *

Temperature requirement : ° C

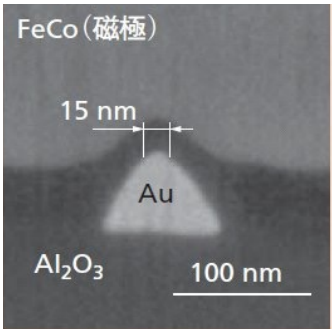
rise / fall time

Distance between the light source and the disk : nm

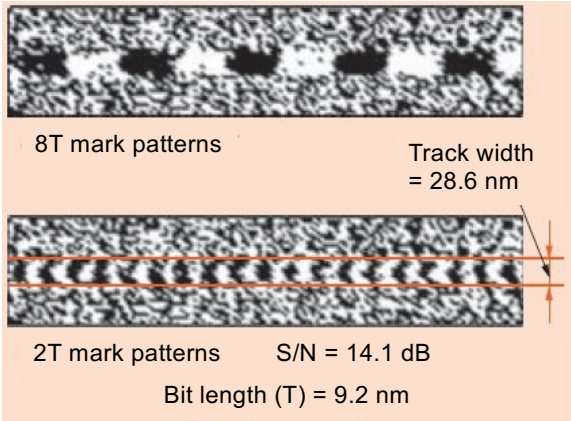
* http://ascii.jp/elem/000/000/695/695849/index-2.html

HAMR Writing Simulations

Hitachi GST demonstrated a new HAMR head : *



Simulated bit patterns : *



* http://digital.hitachihyoron.com/pdf/2011/01/2011_01_tenbo06.pdf

HAMR Latest Developmenet

In 2012, TDK demonstrated a new HAMR head : *

1.5 Tbits/inch^2

1350 kBPI × 1113 kTPI

Bit-error rate (BER) : 10^{-2}

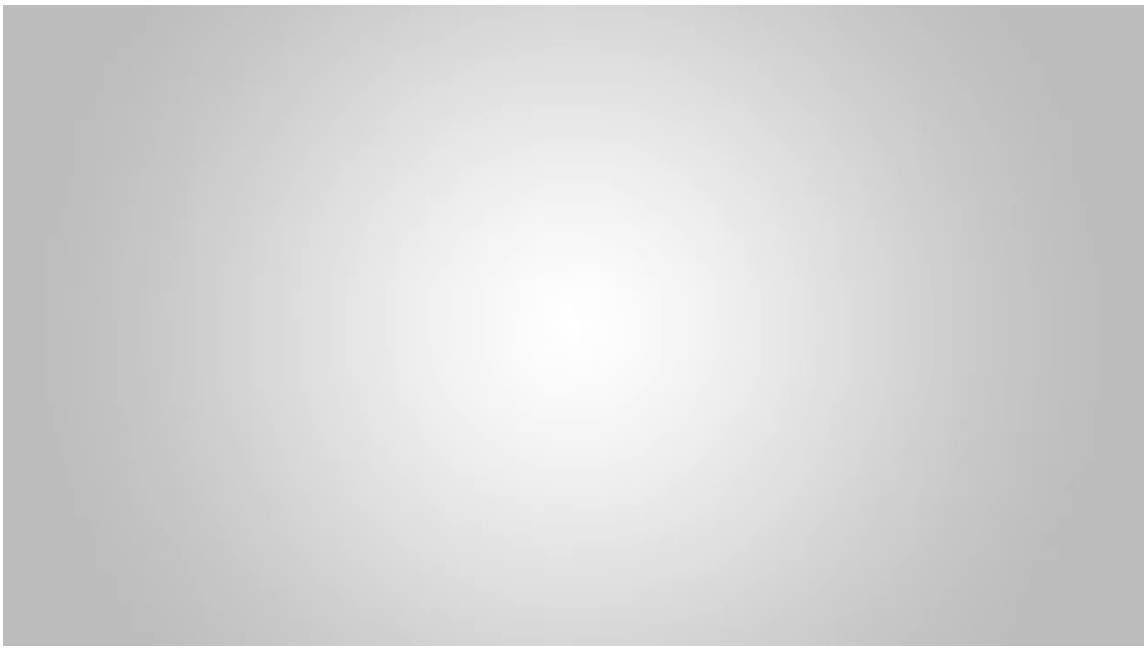
Seagate also demonstrated a new HAMR drive : **

* http://techon.nikkeibp.co.jp/article/NEWS/20121001/243091/?ST=device

** http://www.forbes.com/sites/tomcoughlin/2012/08/22/digital-storage-our-only-hope/

HAMR Latest Development

In 2018, Seagate demonstrated a new HAMR HDD : *



* https://www.youtube.com/watch?v=aUHAd36BDTc&app=desktop

HAMR Product

In 2021, Seagate shipped HAMR HDD : *

Seagate confirms 20TB HAMR hard disk drives have been shipped

By Desire Athow

First Published 9 months ago

But you won't be able to buy them just yet

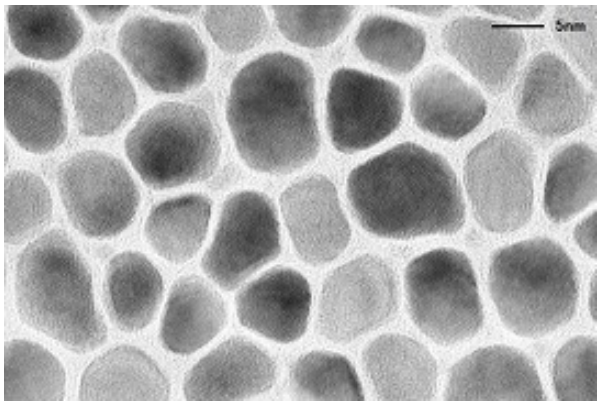
(Image credit: Future)

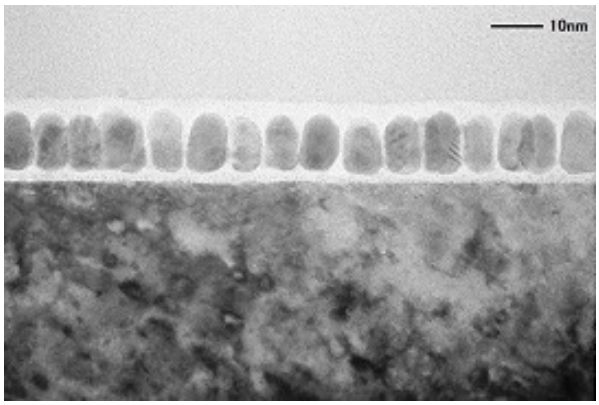
"The HAMR technology that powers this new hard disk drive is expected to be at the core of Seagate's ambition to deliver a 50TB hard disk drive by 2026."

* https://www-techradar-com.cdn.ampproject.org/c/s/www.techradar.c…ws/seagate-confirms-20tb-hamr-hard-disk-drives-have-been-shipped

HAMR Media Development

In 2020, Showa Denko announced a new HDD media with Fe-Pt : *



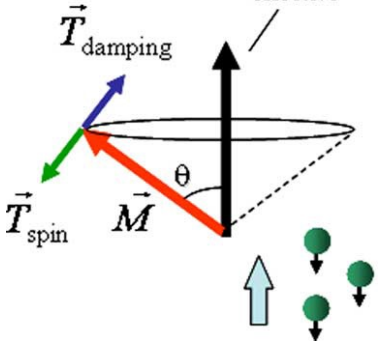


* https://www.sdk.co.jp/news/2020/37881.html

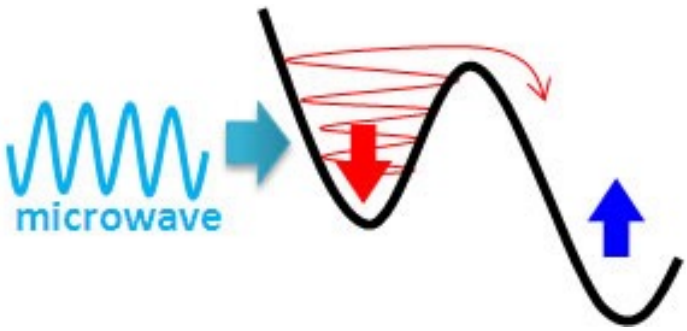
Microwave-Assisted Magnetic Recording (MAMR)

In 2007, J.-G. Zhu proposed to use ferromagnetic resonance (FMR) to recording : *, **

$$\vec{H}_{\text{effective}} = \left(\frac{\sigma_{\text{int}}}{M_S \delta} - 4\pi M_S \cos\theta \right) \hat{e}_z$$



Perpendicularly polarized spins

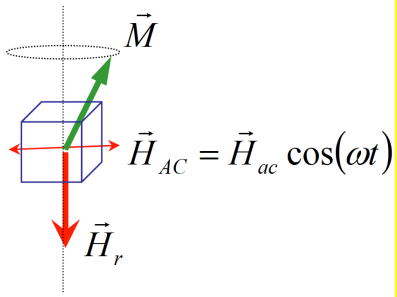


* http://www.ece.cmu.edu/;
** J.-G. Zhu, H. Zhu and Y. Tang, *IEEE Trans. Magn.* **44**, 125 (2008);
*** http://www.tagen.tohoku.ac.jp/labo/kitakami/J/research_j/research_j.html

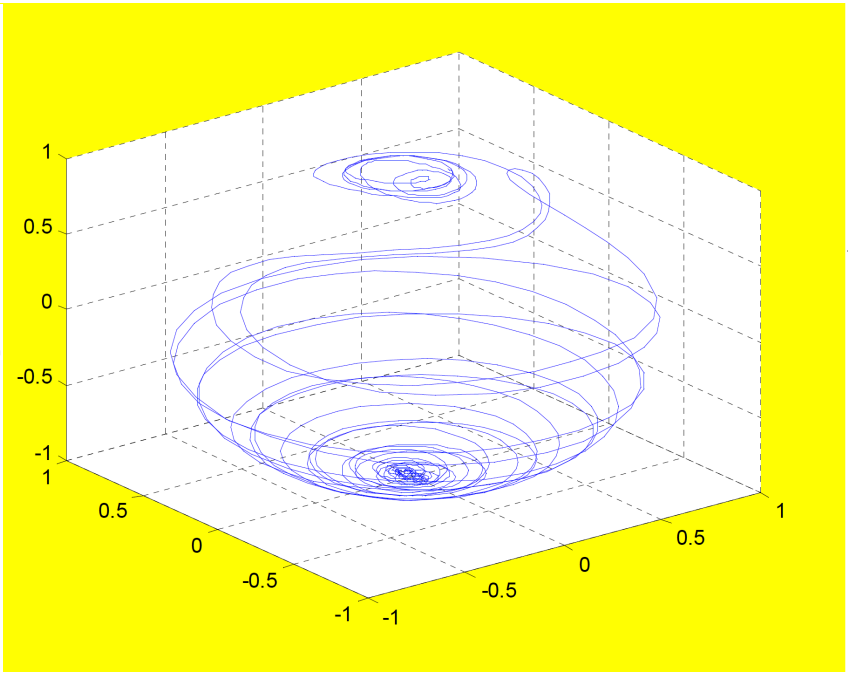
AC Field Recording

AC magnetic field can write a bit with much smaller amplitude : *

$$H_{ac} = 0.1H_k$$



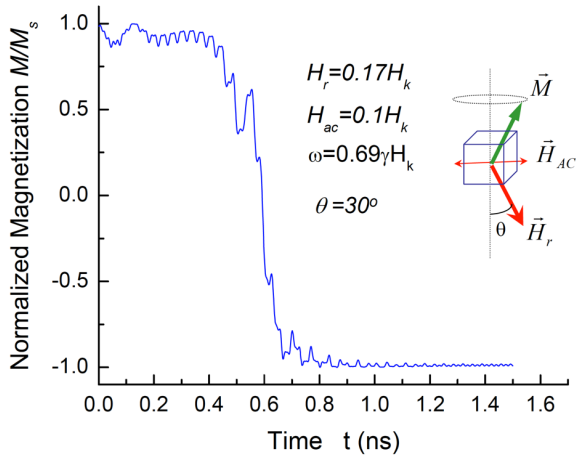
$H_r = 0.5H_k$

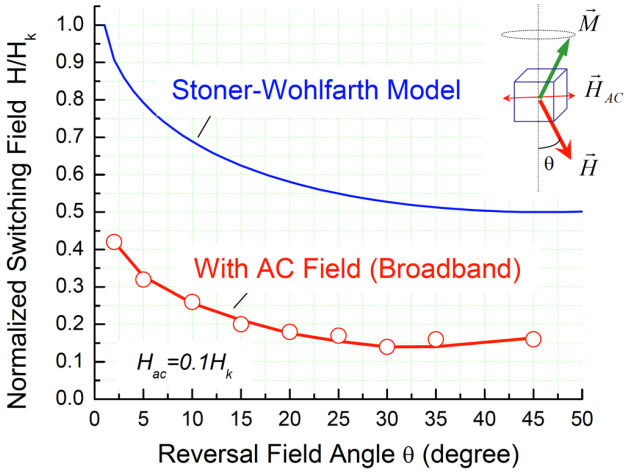


* http://www.idema.org/wp-content/downloads/1856.pdf

AC Field Magnetisation Switching

Fast magnetisation reversal can be achieved by an ac magnetic field : *

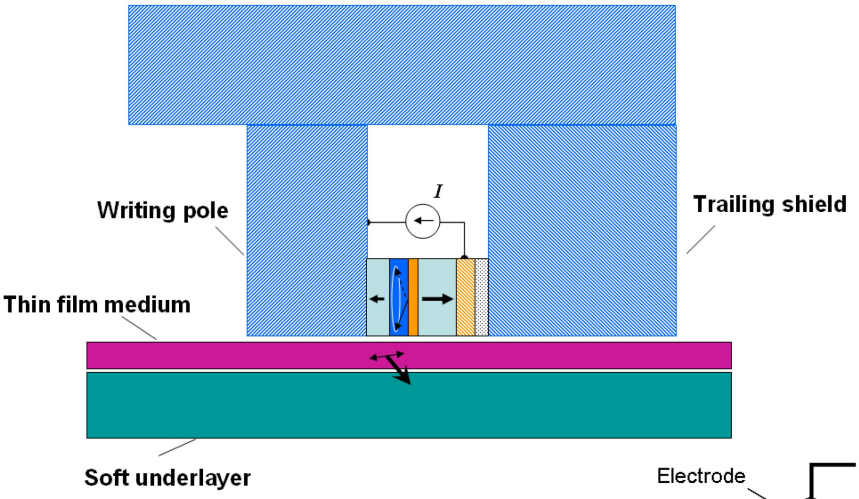


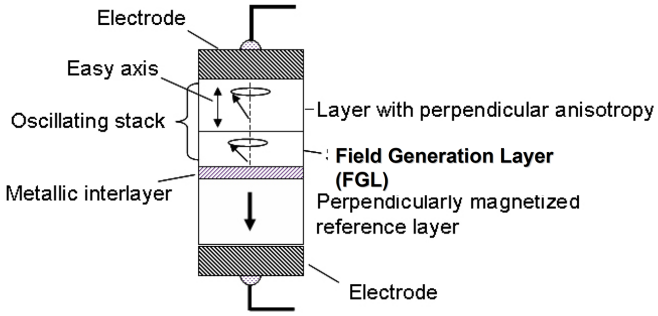


* http://www.idema.org/wp-content/downloads/1856.pdf

MAMR Head

Microwave to be generated by a spin-torque oscillator : *

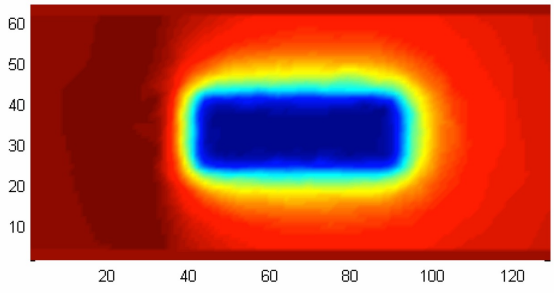


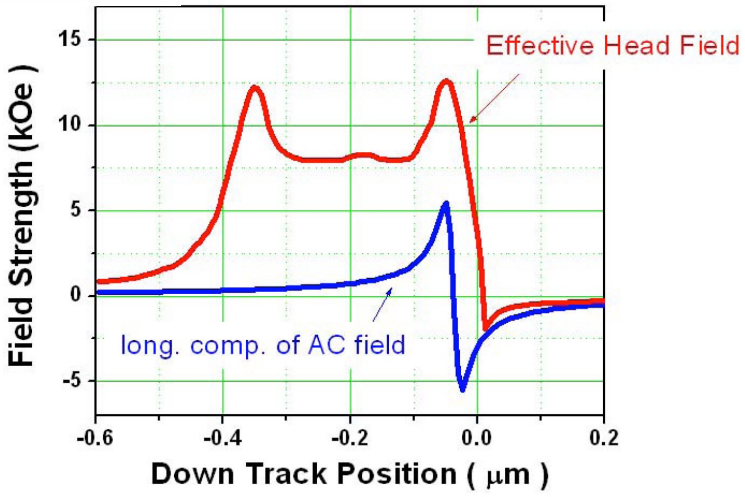


* http://www.idema.org/wp-content/downloads/1856.pdf

MAMR Writing Simulations

Physical write head track width : 120 nm *





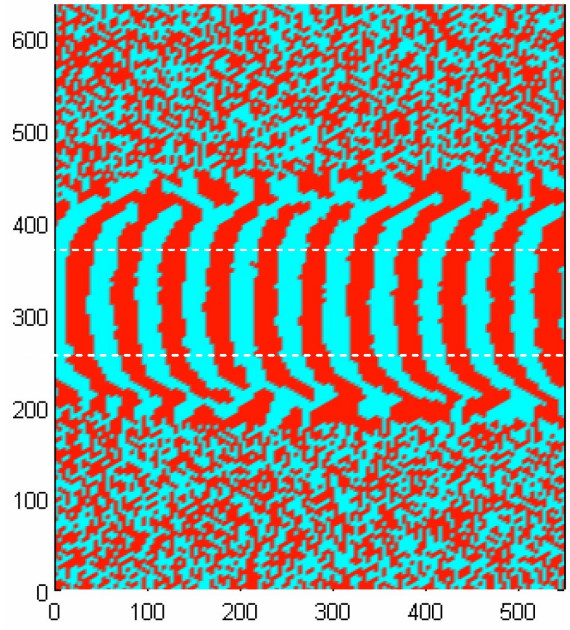
* http://www.idema.org/wp-content/downloads/1856.pdf

Comparison with the Current Technology

Conventional recording : *

H_{head} = 12 kOe

H_K = 10 kOe

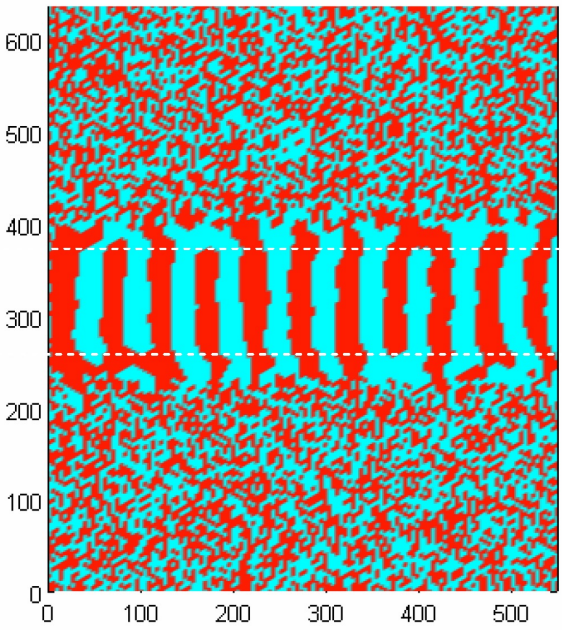


MAMR : *

H_{head} = 12 kOe

H_K = 30 kOe

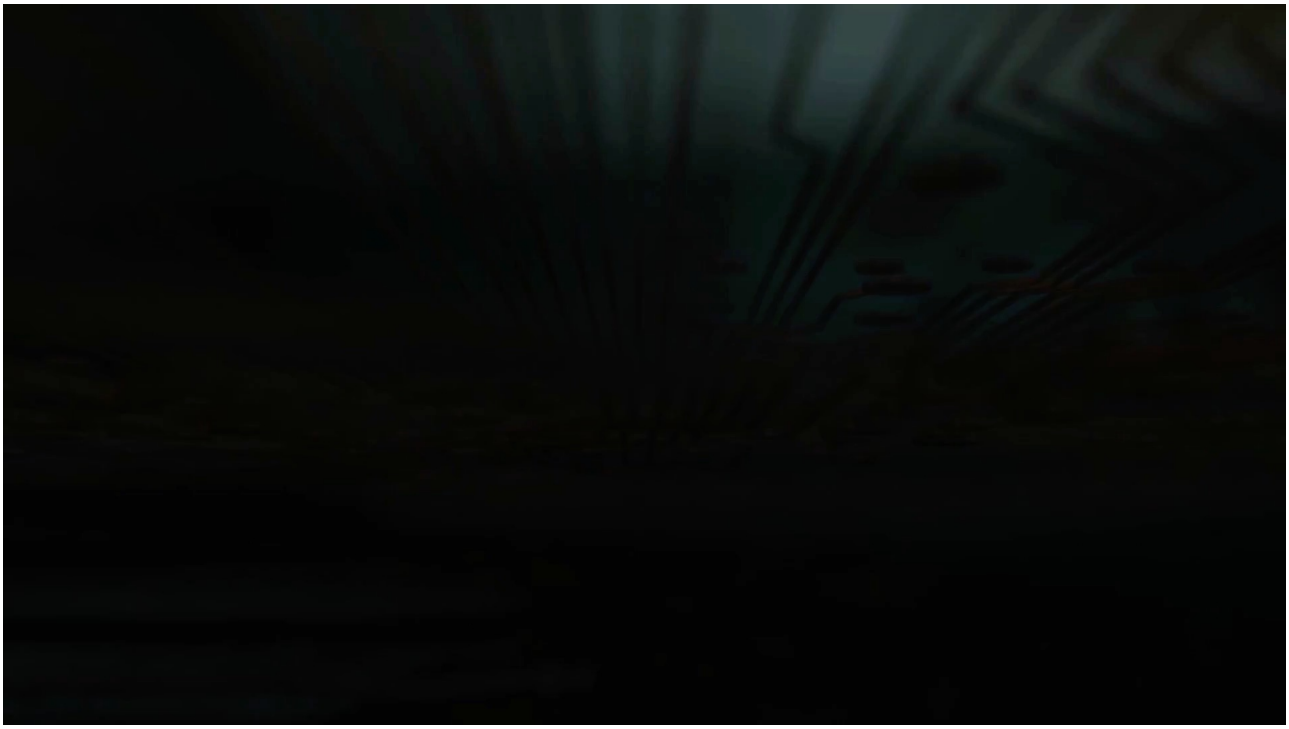
f = 32 GHz and H_{ac} = 3 kOe



* http://www.idema.org/wp-content/downloads/1856.pdf

MAMR Latest Development

Western Digital plans to introduce a new MAMR HDD : *



* https://www.extremetech.com/computing/283200-western-digital-plans-first-16gb-mamr-hdds-in-2019

MAMR Product

In 2021, Toshiba shipped a MAMR HDD : *

Product Specification

Form Factor		3.5-inch
Buffer Size		512MiB
Rotation Speed		7200rpm
Data Transfer Speed (Sustained)(Typ.)		268MiB/s
Power Consumption (Idle-A)(Typ.)	SATA	4.16W
	SAS	4.54W
MTTF/AFR		2 500 000h/0.35%
Weight (Max)		720g

* https://toshiba.semicon-storage.com/ap-en/storage/product/data-center-enterprise/cloud-scale-capacity/articles/mg09-series.html

MAMR Product

In 2021, Toshiba shipped a MAMR HDD : *

* https://toshiba.semicon-storage.com/ap-en/storage/product/data-center-enterprise/cloud-scale-capacity/articles/mg09-series.html