HDDs- We're not Dead Yet! We are Still Very Alive

Dr. Mark Re
SVP, Recording Media Operations
Seagate
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Outline

"We are Not Dead Yet!" We are Still Very Alive.

1. The Facts About Data Storage
2. Cloud
3. HDD vs SSD Comparisons
4. Areal Density – Seagate Focus

Some Facts About Data Storage

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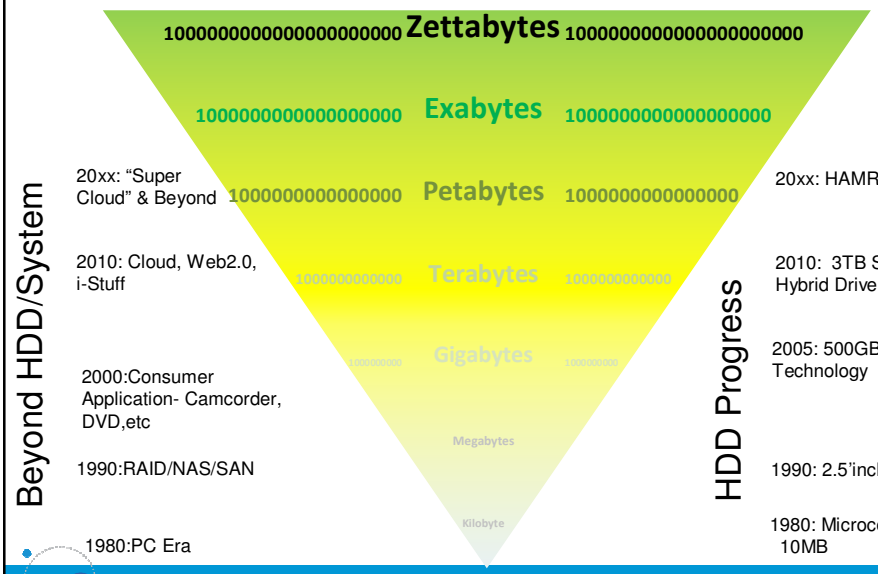
HDDs Delivers to Growing Storage Demand



Beyond HDD/System

20xx: "Super Cloud" & Beyond

2010: Cloud, Web2.0, i-Stuff

2000:Consumer Application- Camcorder, DVD,etc

1990:RAID/NAS/SAN

1980:PC Era

HDD Progress

20xx: HAMR/PM

2010: 3TB STX Drive, Hybrid Drive

2005: 500GB & PMR Technology

1990: 2.5'inch-100MB

1980: Microcomputer 10MB

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Fact 1: Consider That

40 exabyte(10^{18}) of Unique new information will be generated worldwide this year

Fact 2: Digital Content Generated in 2010- is more than has been created in the previous 5,000 years

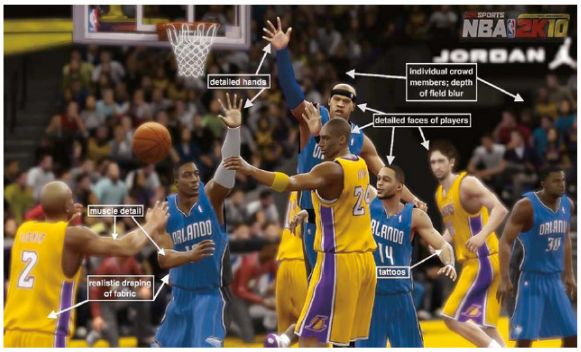
Google

Source: Gartner

Fact 3 : The Ever Expanding Growth of Information

How Much Information? 2009 Report on American Consumers

32GBs passes the human eye every day
18 GB of Games
12 GB of Video
3 GB of Movies



Sponsors:

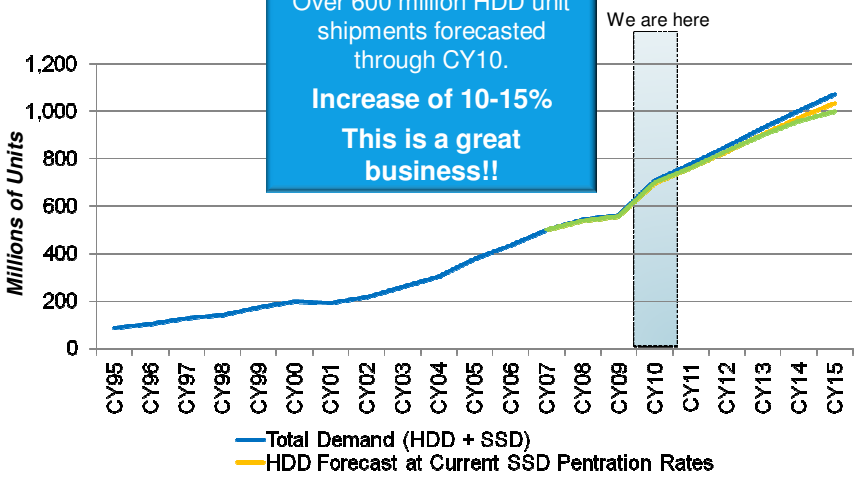
Source: How Much Information? 2009 UCSD

Fact 4: The Need for HDDs to Store Information

Over 600 million HDD unit shipments forecasted through CY10.

Increase of 10-15%

This is a great business!!



What is the "Cloud"?

"Cloud" is:

- a new delivery and consumption model for IT resources
- driven by explosion of digital content, mainly entertainment growth

"Cloud" enables:

- Ubiquitous availability
- Ability to share/combine content
- On-demand, self-service
- Pay-as-you-use and low cost option
- Economies of scale
- Rapid, dynamic provisioning

Cloud Model

Simplified Shared Dynamic

"Cloud" represents:

- The industrialization of Delivery for IT supported Services
- More efficient data centers with flexibility to respond
- additional opportunity to invest in all areas related to data centers

Multiple Types of "Cloud will co-exist:

- Public (where it started)
- Private (outsource and insourced)
- Hybrid (integration of clouds, burst)
- Community (medical, academia)

What Kind of Drives Do the Clouds Storage Use?

- All of Them!

160GB SATA SSD (MLC)

Pulsar

Savvio 10K

Savvio 15K

Cheetah 15K

ES NL 7200

Barracuda XT DT

Barracuda LP 5900

Solid State Drives (SSD): for critical latency apps like CDN and I/O bound server workloads

Enterprise Mission Critical (15K and 10K): for email apps (Exchange) and other latency sensitive apps

Enterprise Nearline (7200): majority SATA: for persistent data storage

Client: Desktop (7200 & 5900): for low work load apps, like backups

Hard Disk Drive vs. Solid State Drive

Speaking at this year's IDF San Francisco, **Intel's SSD guru, Knut S. Grimsrud**, Technology and Manufacturing Group Director of Storage explained that time may be running out for the SSD. …He suggests that the **timeframe for SSDs becoming cheaper than traditional spinning platter hard drives - on a price per gigabyte level - is "quite a way off."** Grimsrud followed that up by saying that it **"may actually never be the case."**

September 16, 2010
http://www.techradar.com

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Hard Disk Drive vs. Solid State Drive

	10K HDD	SSD
Price/GB	~.05cent/GB- Desktop ~.10-.20 cents/GB Mobile	~$2.00/GB
Capacity / Price Source: Newegg 7/30/10 **10kRPM-WD vs SSHD SSD Data- Intel	300 GB: $259 600 GB: $279	64GB: $124 80GB: $207 128GB: $290 256GB: $1069 500GB: $1596
Volume Manufacturability	$	$$$
Technology Areal Density Growth	10 Tpsi	20-22nm limitation
Target Market Segment	ALL- High Areal Density requirement	High End/Performance/Tablet
Overall Performance	Performance Does Not Significantly degrade/change over time	Write History/Workload Affect Performance & hence performance changes over time
Read/Write Performance	Good	Best: Faster 4X-10X
Power- Active Affects both consumption and thermals**10kRPM vs SSHD SSD Data- Intel	Read: 6.2W Write: 6.2W	Active: 4.3W
Power- Idle Affects both consumption and thermals**10kRPM vs SSHD SSD Data- Intel	Idle: 4.3 W	Best: Idle: .15W
Acoustics User Experience **10kRPM-WD vs SSHD SSD Data- Intel	Idle: 30 dBA Seek: 37 dBA	"Silent "

HDD & SSD BOTH have appropriate storage applications- pending performance and customer requirements.
- SSD for High Performance/ Fast Response (IOPs/sec), certain Tier
- HDD for Lower Cost, Large Storage Requirements

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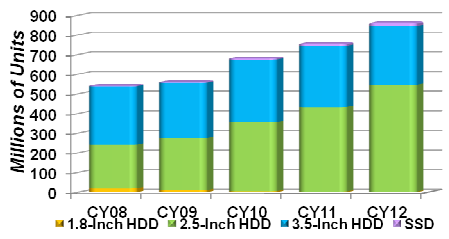
HDD vs. SSD and Hybrid

	10K HDD	SSD	7200 RPM SS-Hybrid
Price/GB	~.05cent/GB- Desktop ~.10-.20 cents/GB Mobile	~$2.00/GB	~.20-40cents/GB
Capacity / Price Source: Newegg 7/30/10 **10kRPM-WD vs SSHD SSD Data- Intel	300 GB: $259 600 GB: $279	64GB: $124 80GB: $207 128GB: $290 256GB: $1069 500GB: $1596	¼ the price of SSD ½ the price of 10K HDD
Volume Manufacturability	$	$$$	$
Technology Areal Density Growth	10 Tpsi	20-22nm limitation	10 Tpsi
Target Market Segment	ALL- High Areal Density requirement	High End/Performance/Tablet	All
Overall Performance	Performance Does Not Significantly degrade/change over time	Write History/Workload Affect Performance & hence performance changes over time	Twice as fast as traditional HDD, Performance does not degrade over time.
Read/Write Performance	Good	Best: Faster 4X-10X	Same as 7200-RPM HDD
Power- Active Affects both consumption and thermals**10kRPM vs SSHD SSD Data- Intel	Read: 6.2W Write: 6.2W	Active: 4.3W	Read: 2.4 W Write: 2.3W
Power- Idle Affects both consumption and thermals**10kRPM vs SSHD SSD Data- Intel	Idle: 4.3 W	Best: Idle: .15W	Idle: 0.8 W
Acoustics User Experience **10kRPM-WD vs SSHD SSD Data- Intel	Idle: 30 dBA Seek: 37 dBA	"Silent "	Idle: 23 dBA Seek: 26 dBA

Hybrid Meets the Performance, Volume , Cost Benefits and is still INDEPENDENT of the system.

Summary

- HDDs have been a critical part of the individual, local, and now global cloud systems and will continue to remain a critical component
- Explosion of Digital Content Growth driving storage demand
- As part of the Cloud expansion, investment in HDD and other data center components is as critical as ever.
- By 2012 >800M HDDs will ship as compared to only 20M SSDs
- Cost is the over-riding factor for success in the client space
- Enterprise Storage Tier 0 is most likely application for SSD
- Hybrid drive is an attractive solution – Seagate 500GBMomentus Hybrid drive, $124 vs. Intel 164GB SSD,$420



Areal Density & Executing to HAMR

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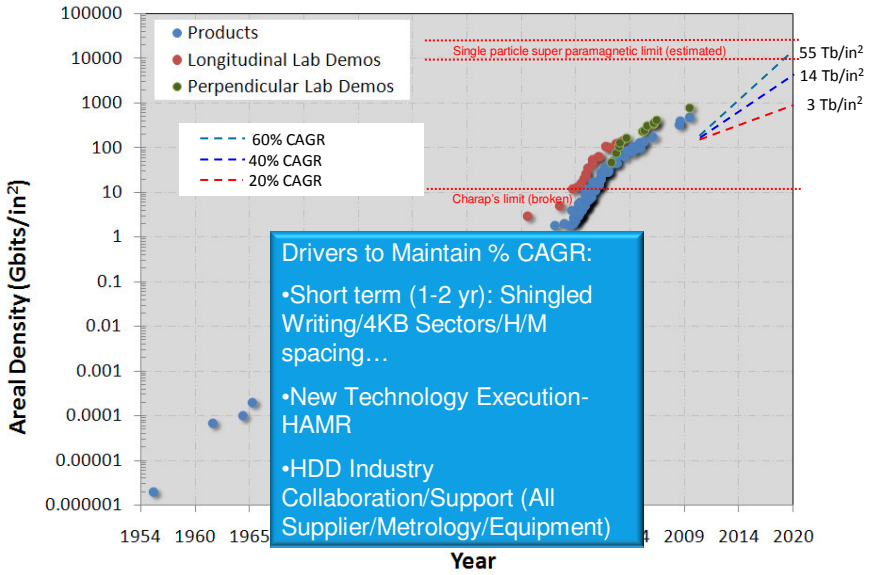
Areal Density Trends- The HDD Plan



Drivers to Maintain % CAGR:

- Short term (1-2 yr): Shingled Writing/4KB Sectors/H/M spacing…
- New Technology Execution- HAMR
- HDD Industry Collaboration/Support (All Supplier/Metrology/Equipment)

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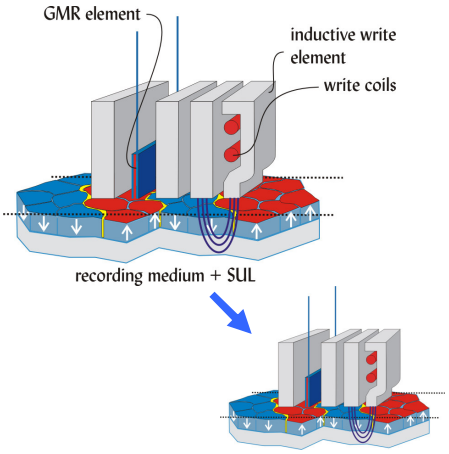
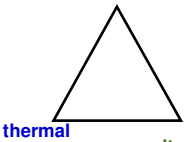
Scaling (and its limits) in magnetic recording



$SNR_P \propto 10 \cdot \log_{10}(N)$
$\cong$ 30 dB for N=1000

Signal-to-Noise Ratio



thermal stability

writeability

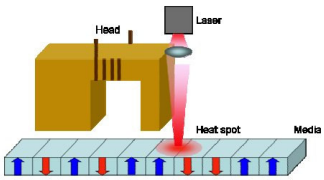
$$\text{stability} \sim \frac{K_u V^*}{k_B T}$$

$B_{S,\,max}$= 2.4 T

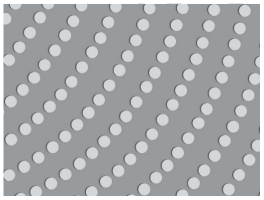
The achievable areal density using 'conventional' scaling is limited by trade-off between SNR, thermal stability and writeability

Seagate' Focus: New Technologies to Drive Areal Density

HAMR



Bit Pattern Media



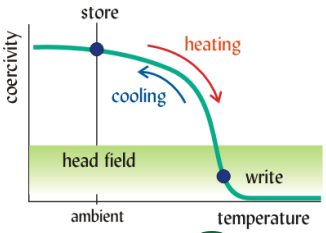
- **Driving future areal density will require:**
  - **Thinner & more robust films**
  - **Lower & controlled clearance**
  - **Improved tracking capability**
- **New technologies such as HAMR & bit pattern media are key to the industry's future**
- **Need continued improvements in shock, power, reliability, acoustics & interfaces**

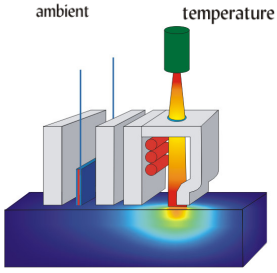
Heat Assisted Magnetic Recording - in a nutshell

- enables use of high-H_K, small grain size media by temporarily heating the media
- thermal spot in NF optical regime easier to confine than magnetic field

  ⇒ narrow tracks
- thermal gradient can be higher than magnetic field gradient with appropriate high-H_K&low-T_C media

  ⇒ higher linear density

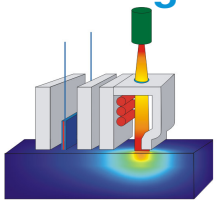


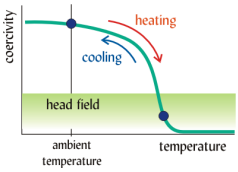


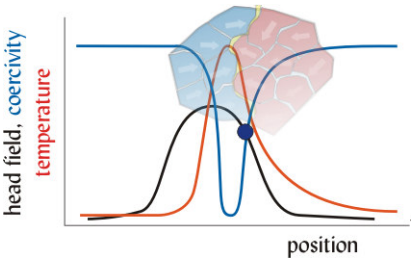
Key media and head challenges:

- optical/thermal efficiency
- sub-100 nm heat spot overlapping with magnetic field
- media w/ high-K_U, moderate T_{write}, small grain size & distribution
- integration

HAMR - the recording process: magnetic vs. thermal gradient



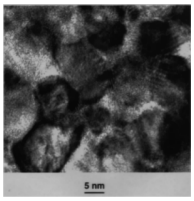




$$dH_{eff}/dx = dH_W/dx + dH_K/dT \cdot dT/dx$$

- write process determined by head field gradient and “effective thermal field” gradient
- convolution of thermal and magnetic head and media properties
- if these are of comparable size, best performance expected with alignment of trailing edges of thermal & magnetic field profiles ⇒ **challenge for head design**

Grain size scaling in recording media

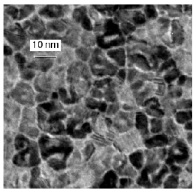


10 Gbit/in^2 product media

12 nm grains

$\sigma_{area} \cong 0.9$

J. Li, *et al.*, J. Appl. Phys. **85**, 4286 (1999)

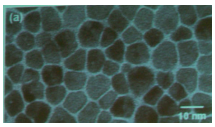


35 Gb/in^2 prototype media

8.5 nm grains

$\sigma_{area} \cong 0.6$

M. Doerner *et al.*, IEEE Trans. Mag. 37 (2001) 1052



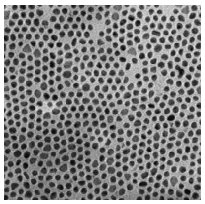
600 Gb/in^2 prototype media

8.5 nm grains

$\sigma_{area} \cong 0.2$

K. Tanahashi *et al.*

TMRC 2008



Nanoparticle arrays

4 nm particles

$\sigma_{area} \cong 0.05$

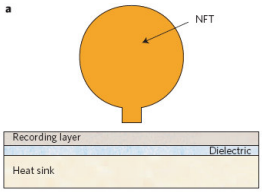
S. Sun *et al.*,

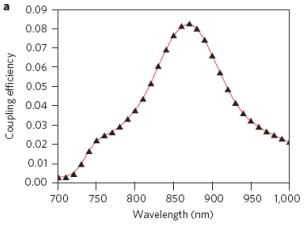
- … has not been a good predictor for advances in areal density
- transition from longitudinal to perpendicular magnetic recording gave reprieve from media grain size scaling
- ultimately we do expect to be grain size limited

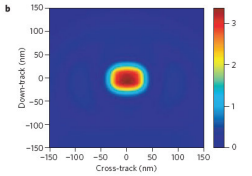
Recording Head - Optical Light Delivery

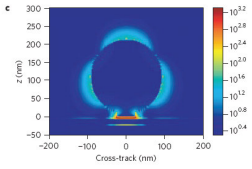
·wave guide patterned as planar solid immersion mirror (SIM)

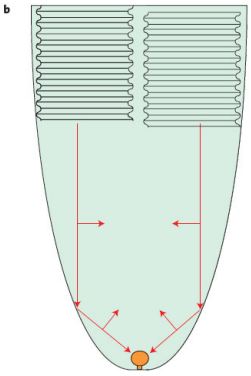
·"lollypop" near field transducer patterned onto SIM











The Diffraction limit

For HAMR to be successful, we must have optical spot sizes smaller than the diffraction limit.

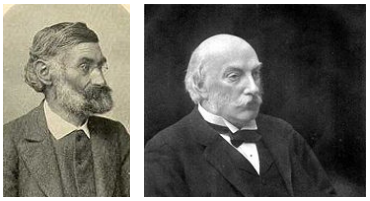
We've known for over 100 years that diffraction limits the minimum optical spot size of focused propagating light waves in the far field

$$d_{FWHM} \cong \frac{0.5\lambda}{NA}$$

Short wavelength example

- λ = 405 nm
- n = 1.5
- sin θ = 0.85

} $d_{FWHM} \approx 160$ nm



Abbe, *Archiv f. Miroskop. Anat.*, **9** (1873) 413.
Lord Rayleigh, *Phil. Mag.*, **5** (1896) 167.

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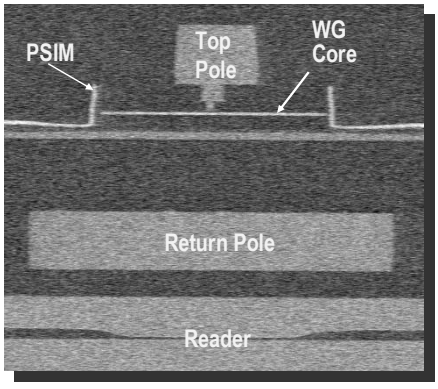
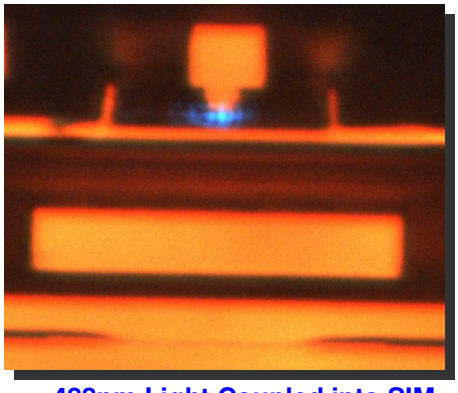
Air Bearing View

SEM



Optical Microscope



488nm Light Coupled into SIM spot size ~200nm

M. A. Seigler et al, IEEE Trans Magn vol. 44, 119-124 (2008)

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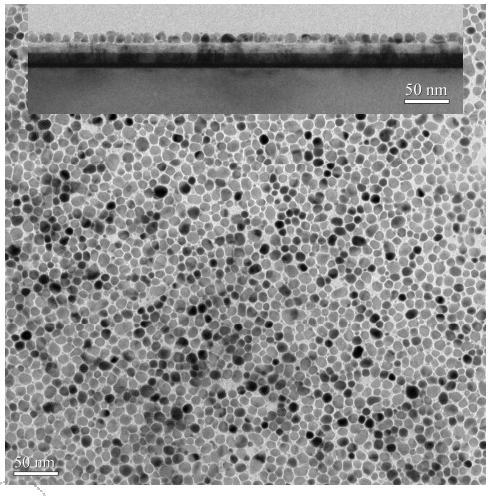
$L1_0$ FePt-X media



1. Achieve high anisotropy

   H_C : ~ 30kOe
2. Improve linear density capability

   Grain size: ~ 11nm
3. T_C ~ 500C

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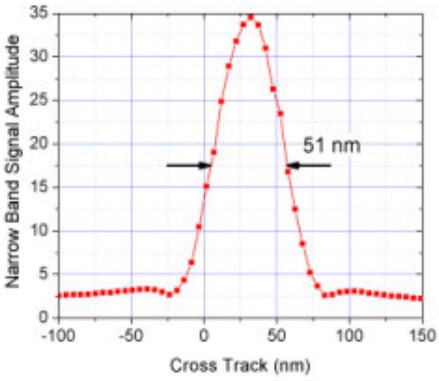
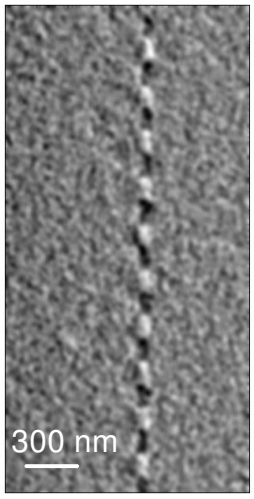
Spin Stand Recording





2700 rpm (7.2 m/s)

100 MHz freq.

Bit length ~ 36 nm

Track width ~ 50 nm

NFT to data layer: 15 nm

240 Gb/in^2 with 15.5 dB ACSN

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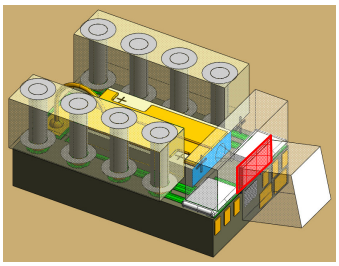
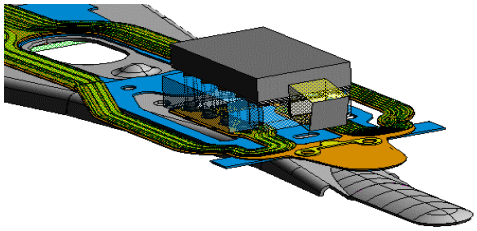
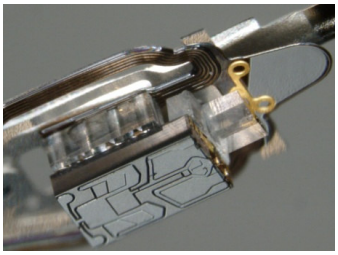
Seagate Light Delivery Test Platform

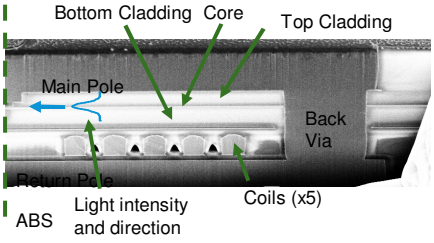
Spin stands with free space coupling are a good place to start but you need an integrated HGA for more advanced testing (tribology, media, lube, etc).

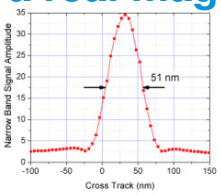


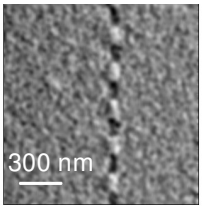


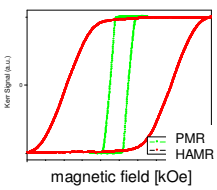


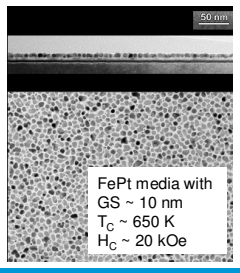
HAMR starting to look like a real magnetic recording technology











2700 rpm (7.2 m/s) Track width ~ 50 nm
100 MHz freq. NFT to data layer: 15 nm
Bit length ~ 36 nm 240 Gb/in^2 with 15.5 dB ACSN

Challener *et al.*, Nature Photonics **3**, 220 - 224 (2009)

Conclusions

- HDD's remain a critical part of the our digital world
- There is no current competing technology that will replace HDD's
  - Flash is too expensive for mass storage applications and there is not enough semiconductor manufacturing capacity to replace HDD's
  - Hybrid Drives are a more logical alternative
- Explosion of digital content growth will continue to drive storage demand
  - HDD's will be the place to store data in the cloud and locally
- Continuous improvements in areal density will ensure HDD's place in the information technology infrastructure
  - Heat Assisted Magnetic Recording is a path to these areal density increases.

THANK YOU

Momentus® XT Solid State Hybrid Drives

Powerful, intelligent, affordable–Solid state hybrid drives deliver SSD-like performance without sacrificing storage capacity and affordability.

- Adaptive Memory™ technology
- 80% faster than traditional 7200–RPM drives
- Boots within seconds of a laptop with SSD
- Works in any standard laptop with any OS
- Seagate 5-year Limited Warranty

Capacity

500 GB | 320 GB | 250 GB

Model ST9500562DAS | 500 GB

Seagate