Status and Prospect on Heat Assisted Magnetic Recording (HAMR)

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Seagate Research

Seagate
We turn on ideas

Outline for Heat Assisted Magnetic Recording

–Introduction

–HAMR systems

–Integrated head

- Challenge #1: Delivering the Light
- Challenge #2: Delivering the Field

–HAMR media and HDI

–HAMR recording results

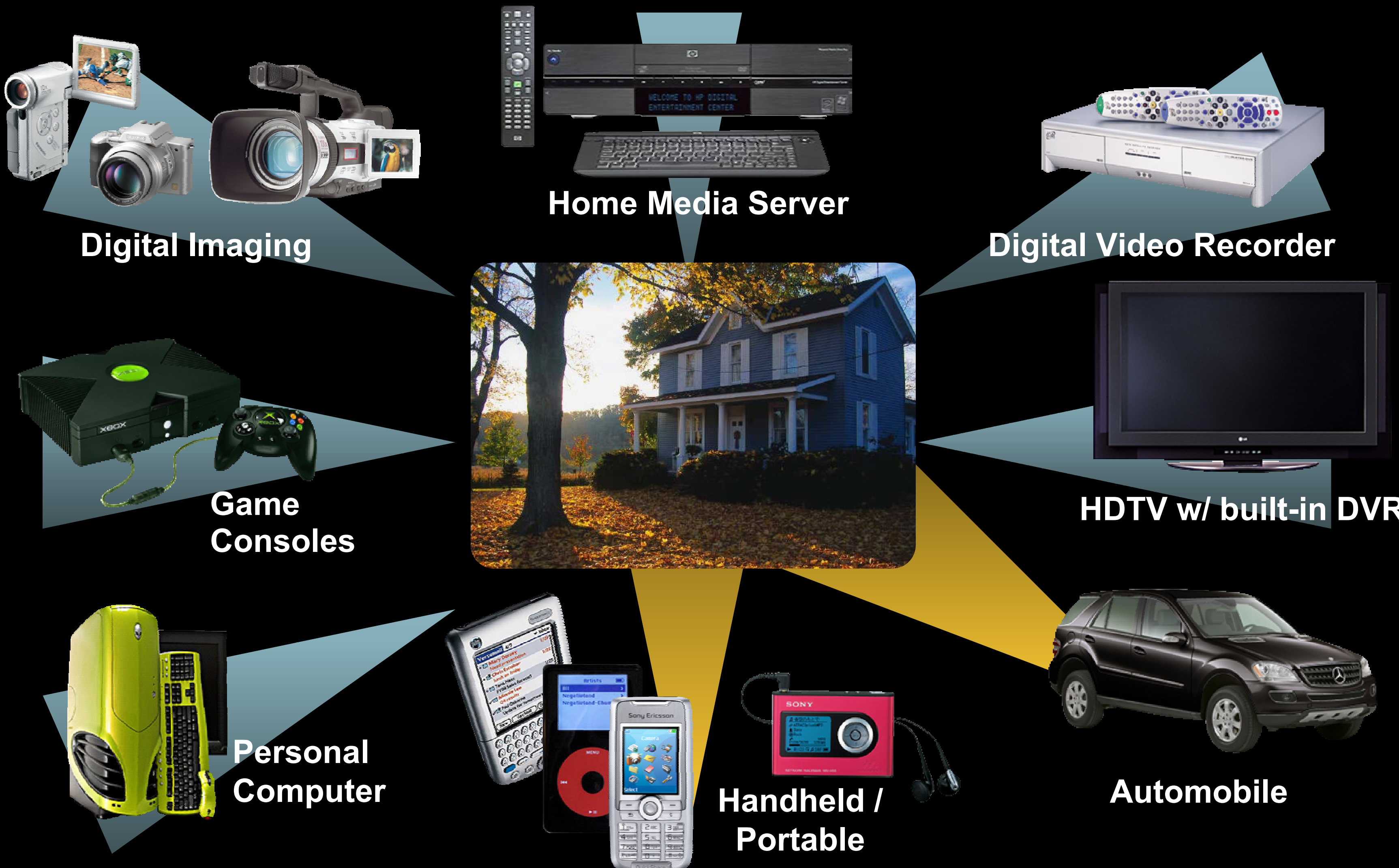
–Future prospects

–Conclusion

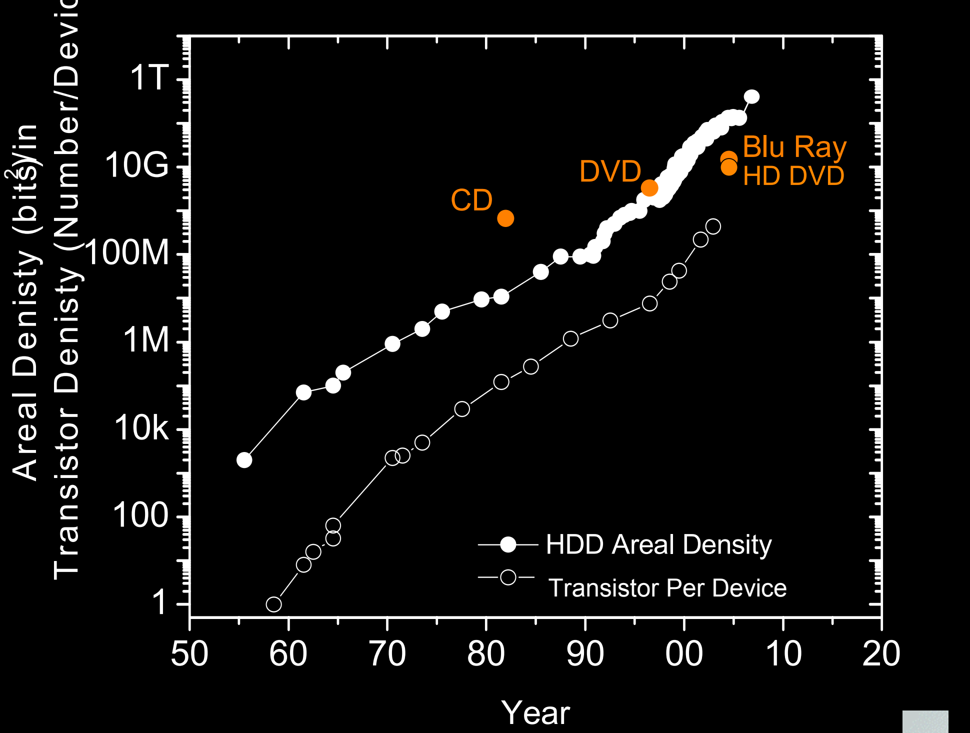
Introduction

Insatiable demand for Digital Storage

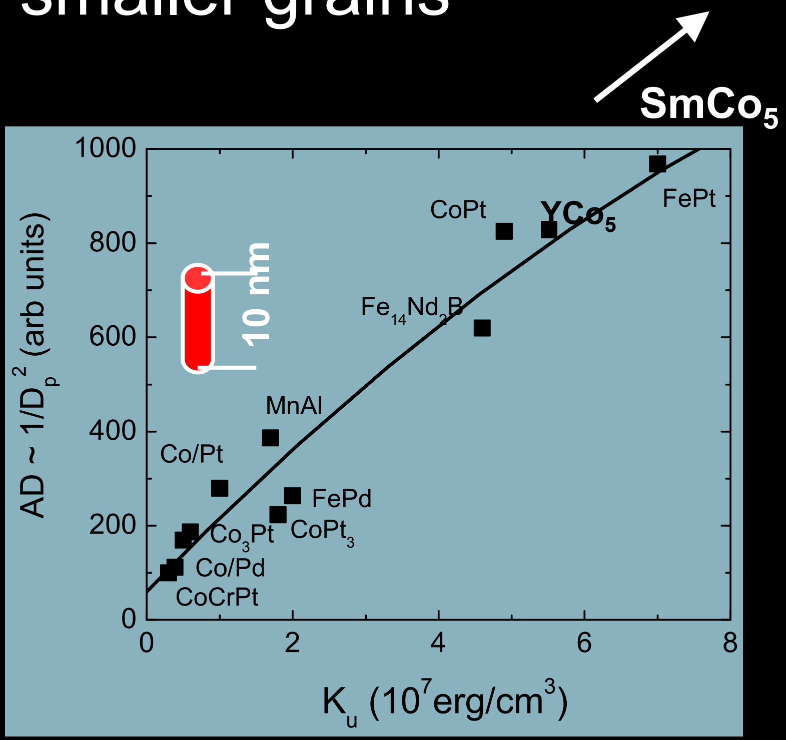
Storage has become personal…



Areal Density Growth

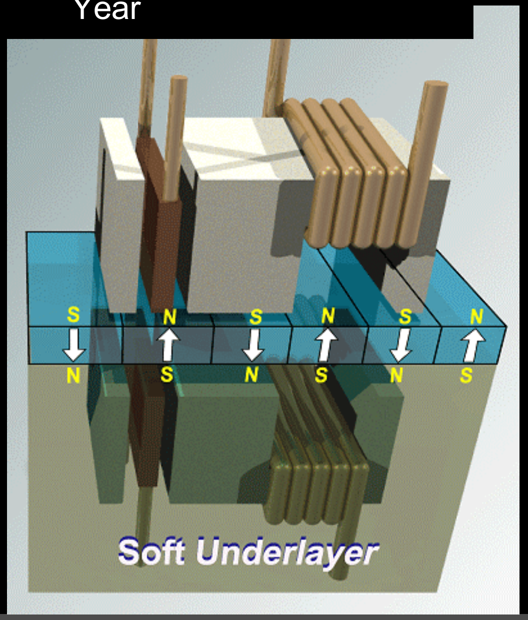


- Areal density growth calls for media with higher anisotropy and smaller grains



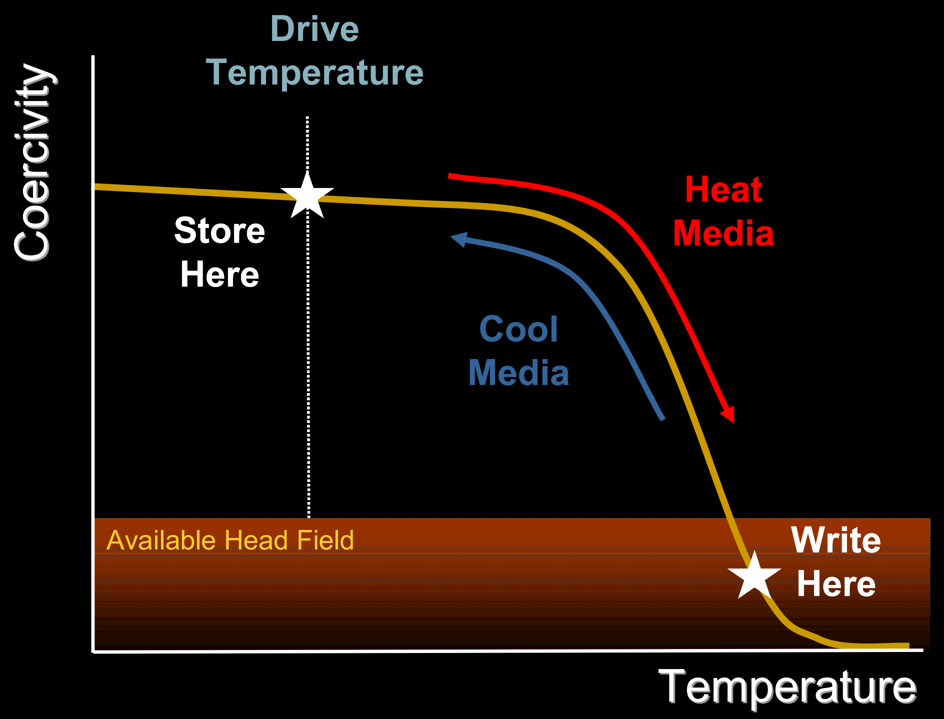
Dieter Weller

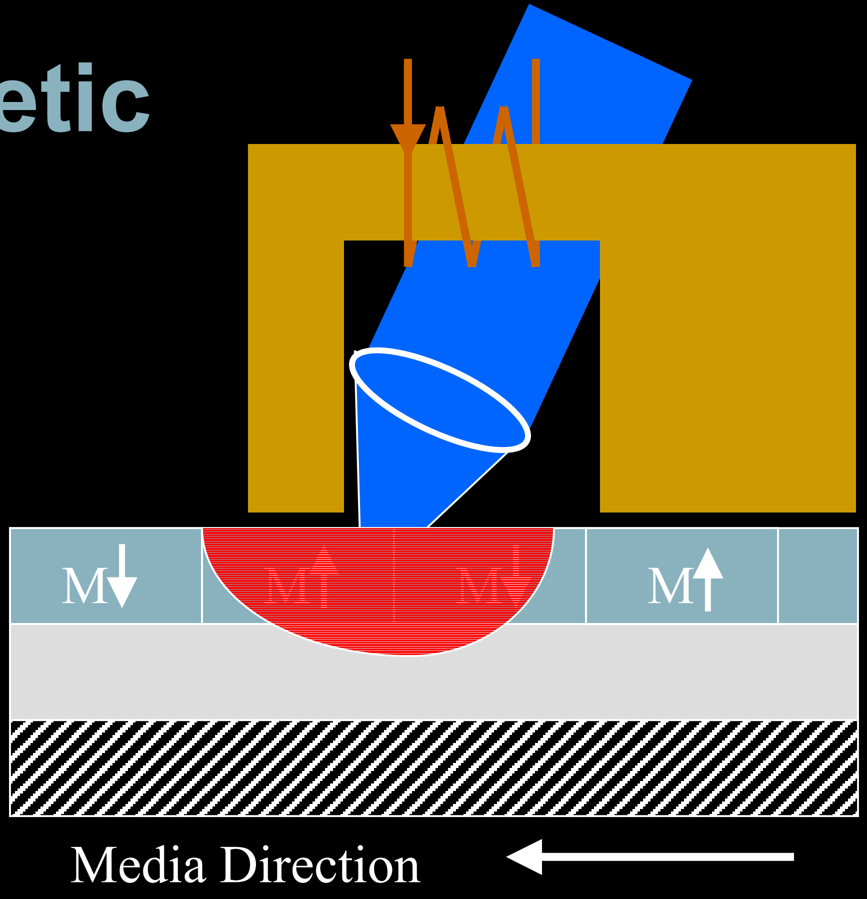
- **Writability limitation due to limited B_S from write pole materials**



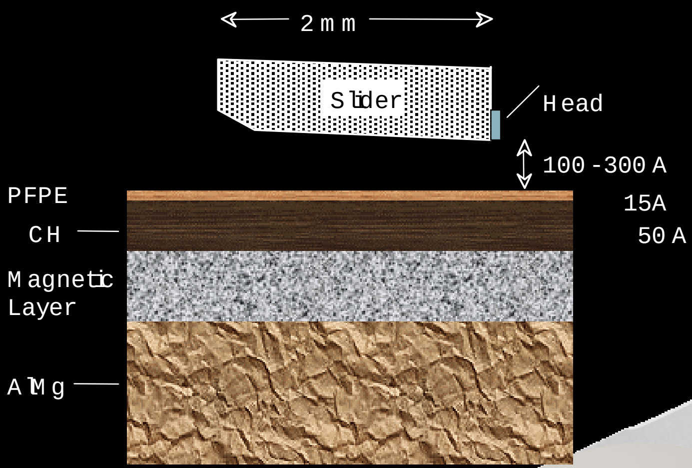
Heat Assisted Magnetic Recording

Lower K_u by temporarily raising Temperature





HDD Recording Subsystem Components

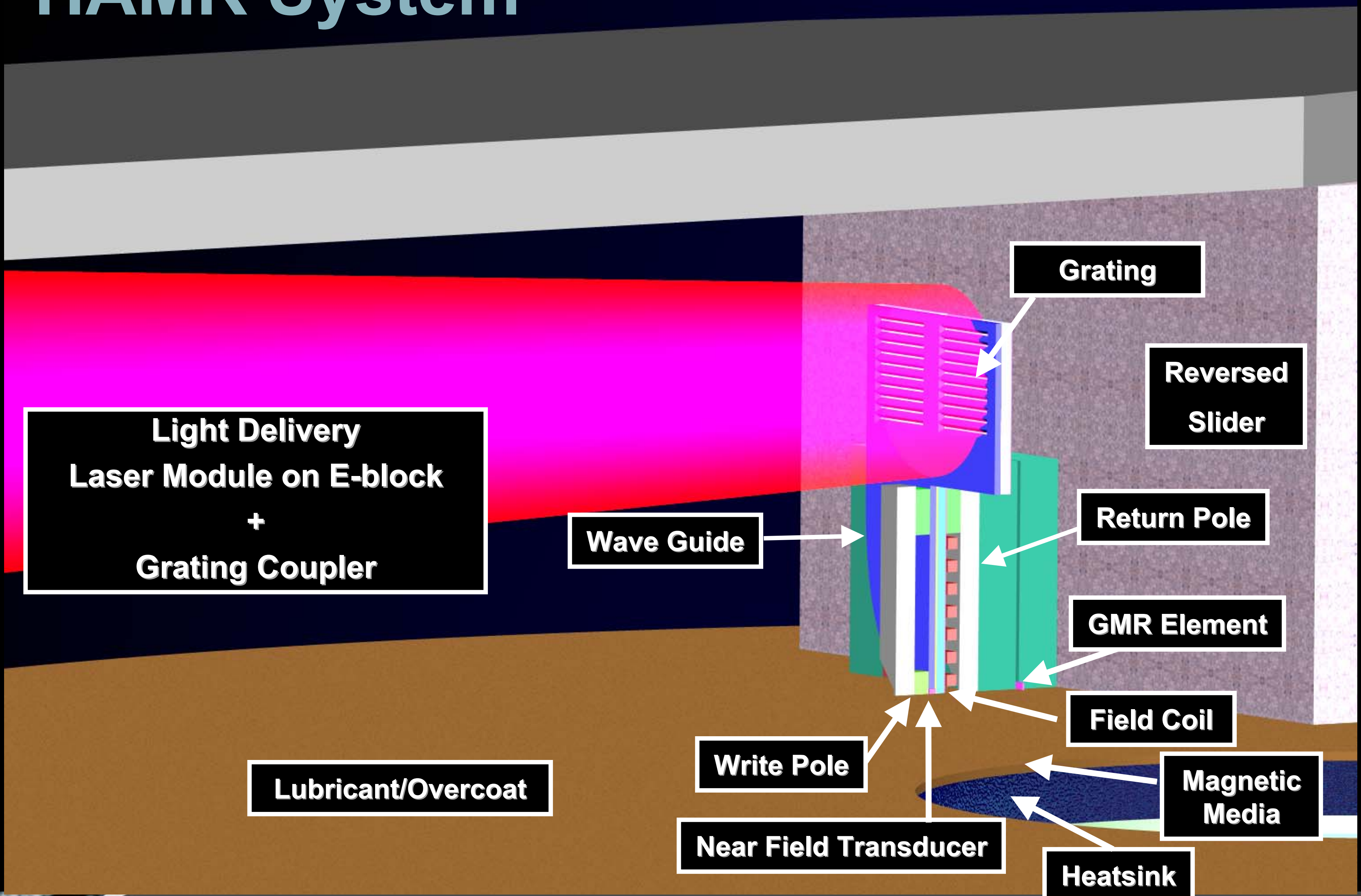


Seagate
Barracuda ATA II

Major Elements of HAMR HDD

- Recording Head
  - Optical Delivery
  - Magnetic Field Source
  - Magneto-Resistive Reader
- Media
  - Lubricant
  - Overcoat
  - Recording Layer
  - Heatsink/Soft Underlayer
  - Disk Substrate
- Mechanical Integration
- Servo
- Preamp
- Data Channel

HAMR System



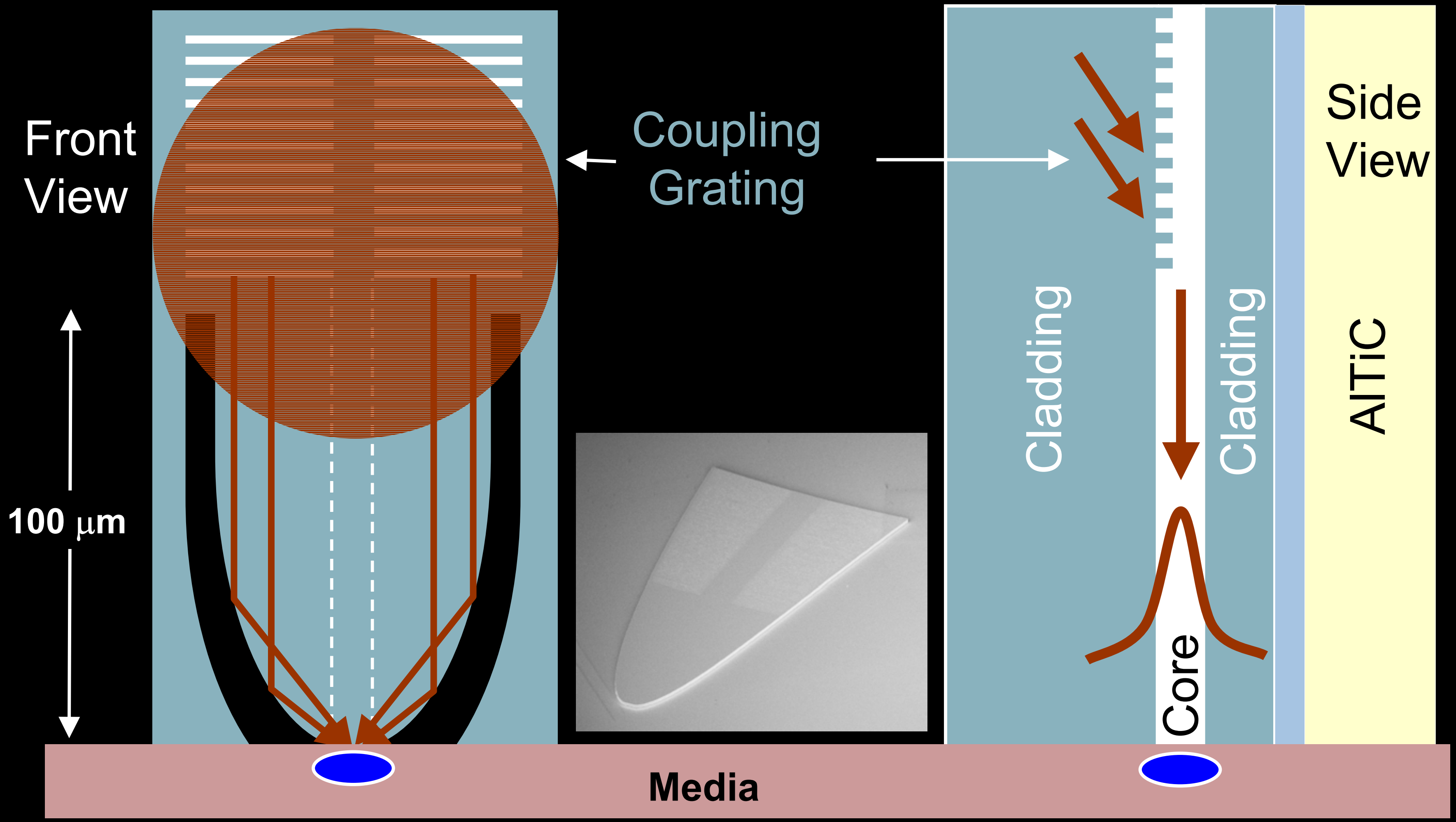
Grating
Reversed Slider
Light Delivery
Laser Module on E-block
+
Grating Coupler
Wave Guide
Return Pole
GMR Element
Field Coil
Write Pole
Lubricant/Overcoat
Magnetic Media
Near Field Transducer
Heatsink

Integrated HAMR head:

Challenge#1: Delivering the Light

Challenge#2: Delivering the field

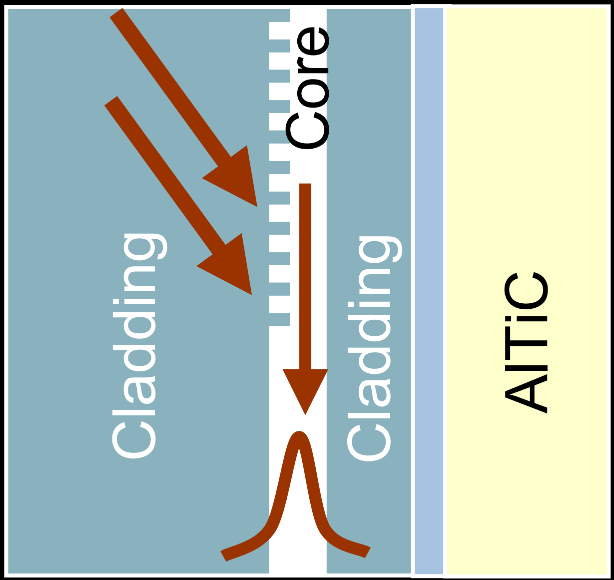
Recording Head - Optical Light Delivery
Planar Solid Immersion Mirror



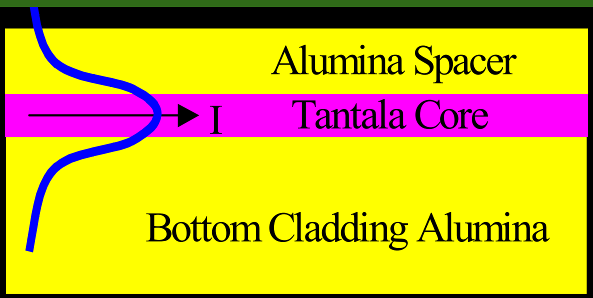
W. Challener *et al.*, Optics Express 2005;13(18):7189-7197

Optical Components

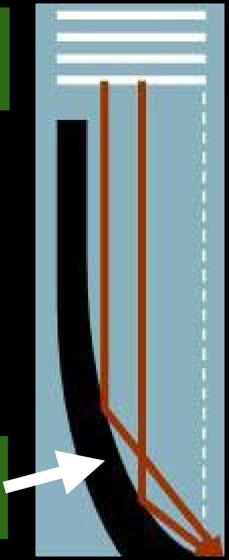
Coupling Grating

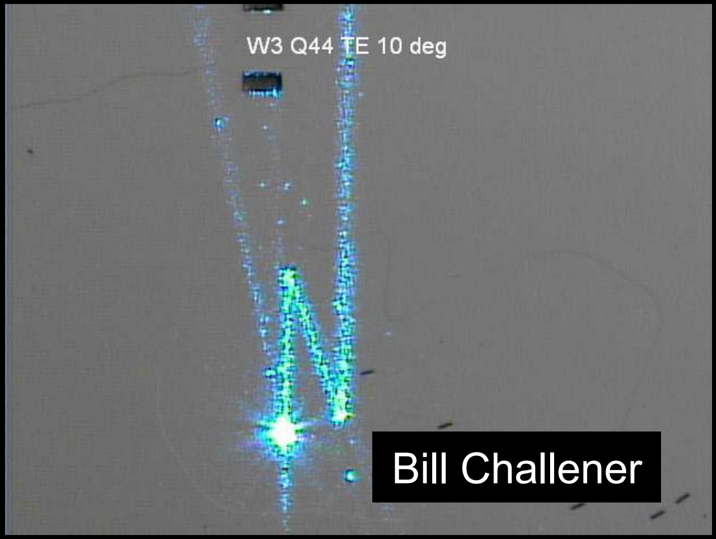


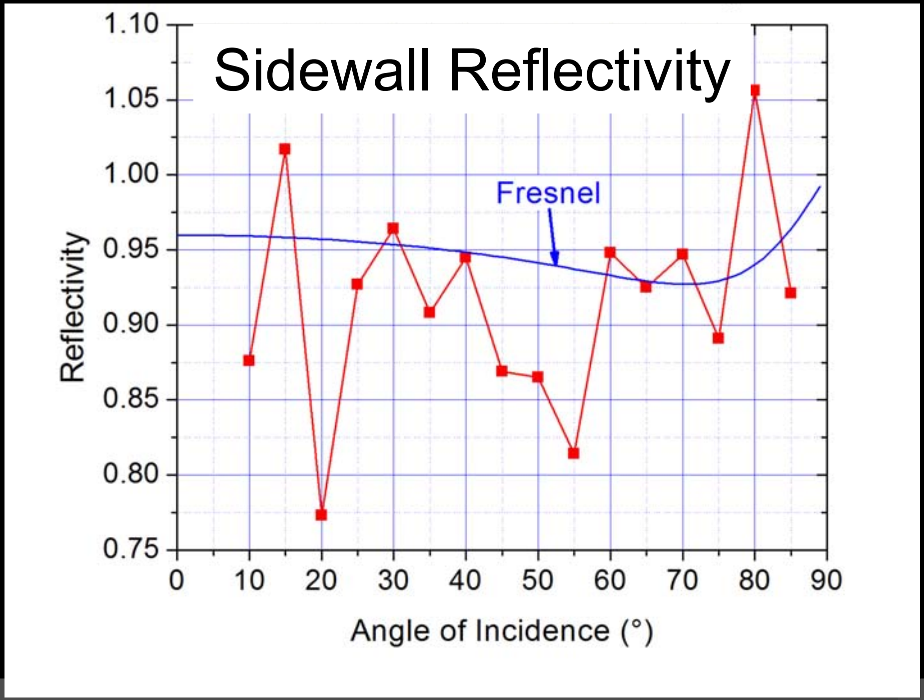
Optical Waveguide



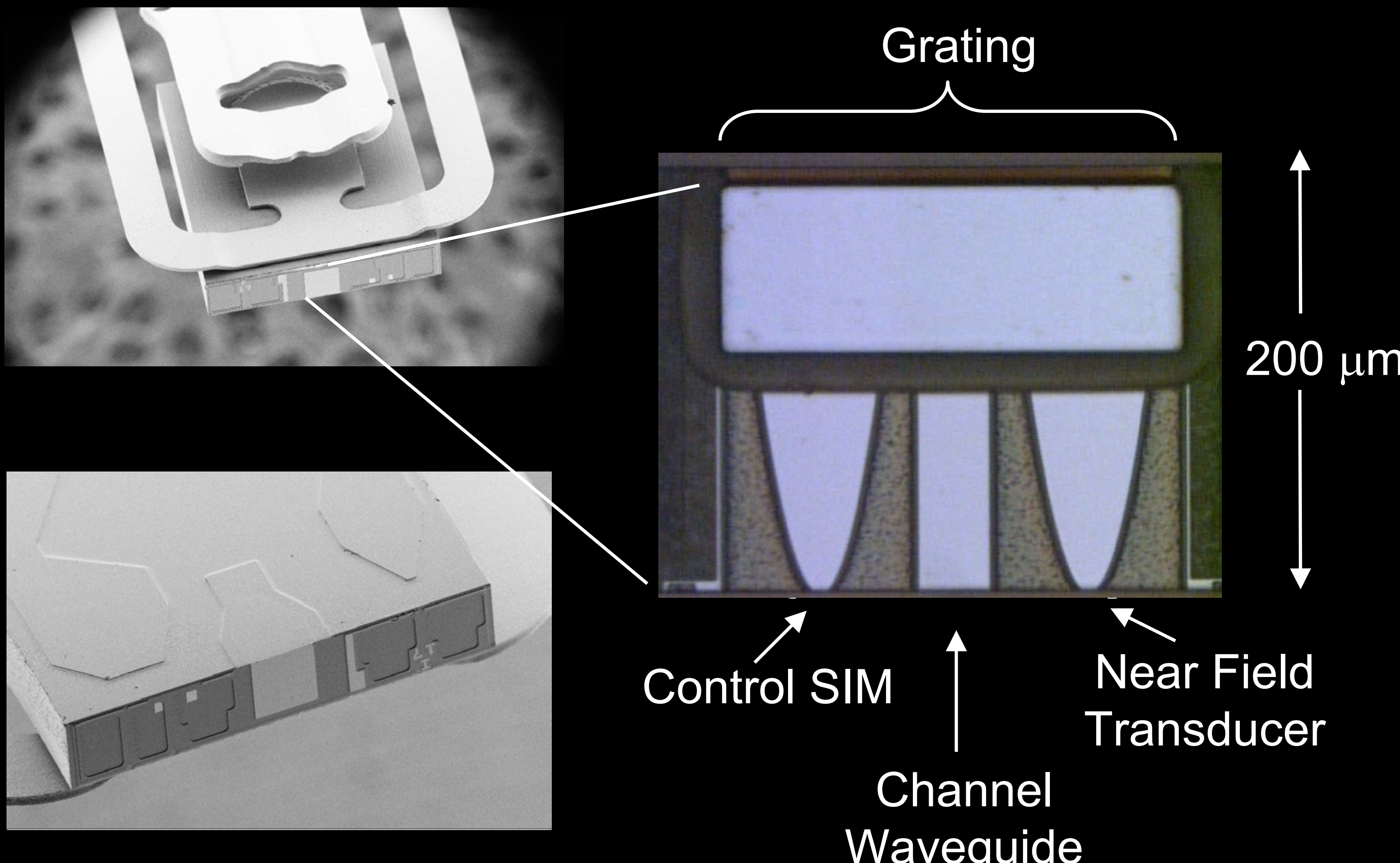
Sidewall Mirror





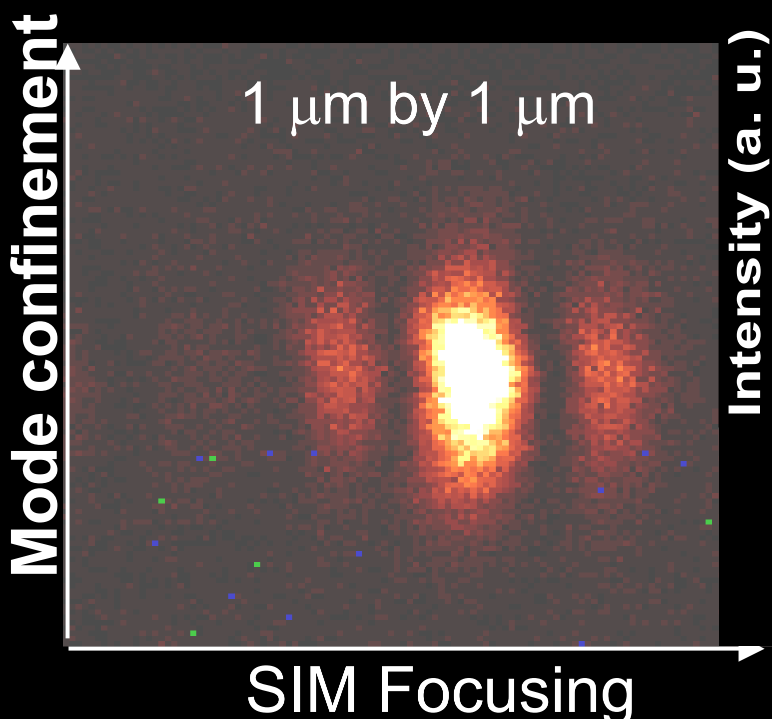


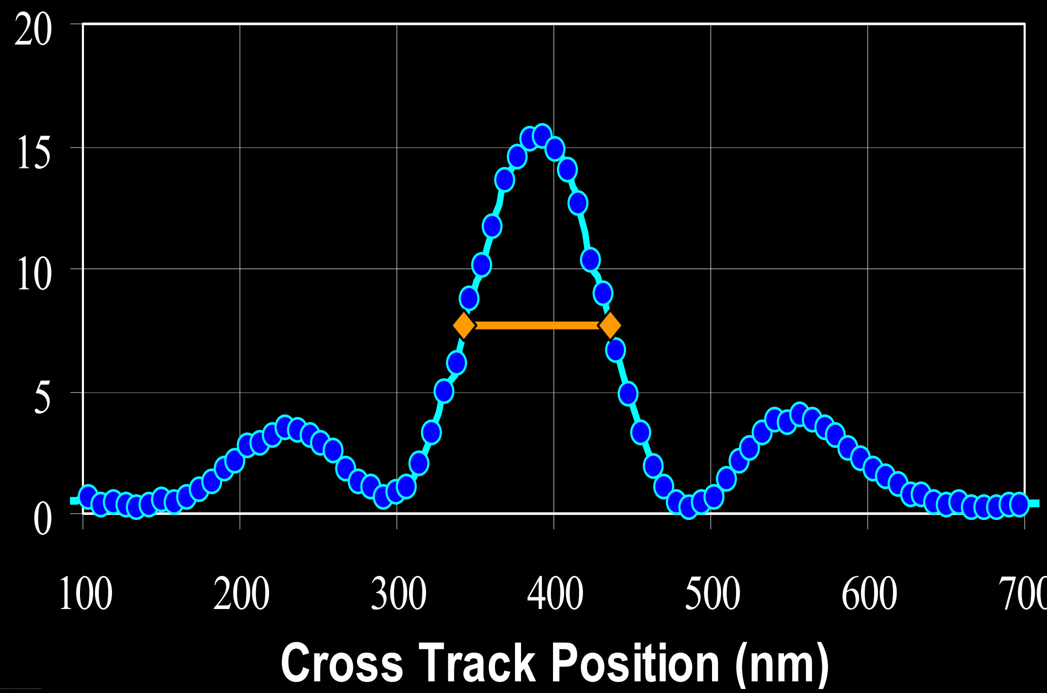
Completed Optical Heads



PSIM Near-field Intensity

- SNOM scans over focal plane at ABS.
- PSIM with tantala core layer sandwiched between two alumina cladding layers.
- At blue light (413 nm), FWHM focused spot size = 90 nm.



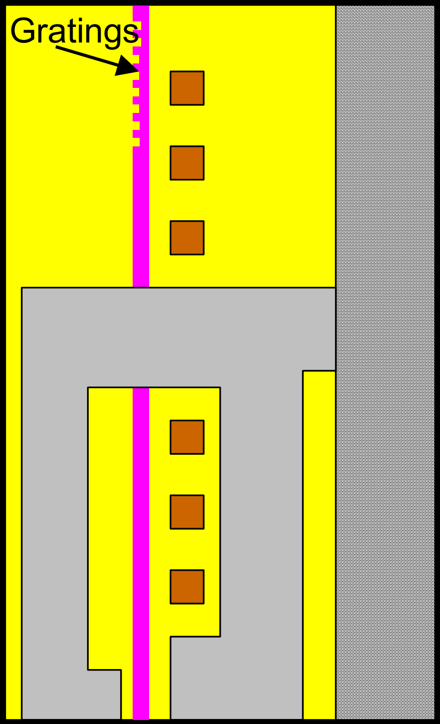


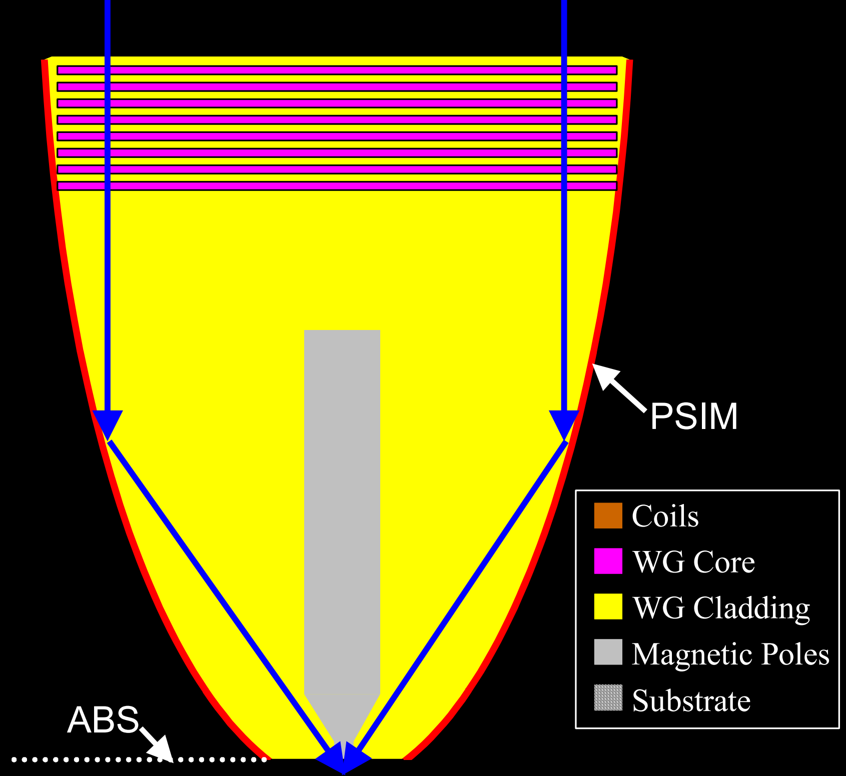
Integrated HAMR head:

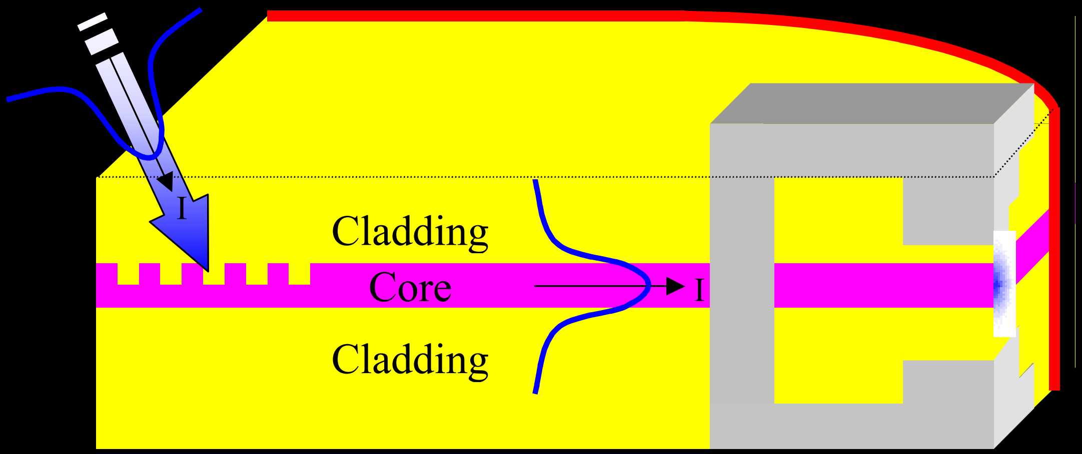
Challenge#1: Delivering the Light

Challenge#2: Delivering the field

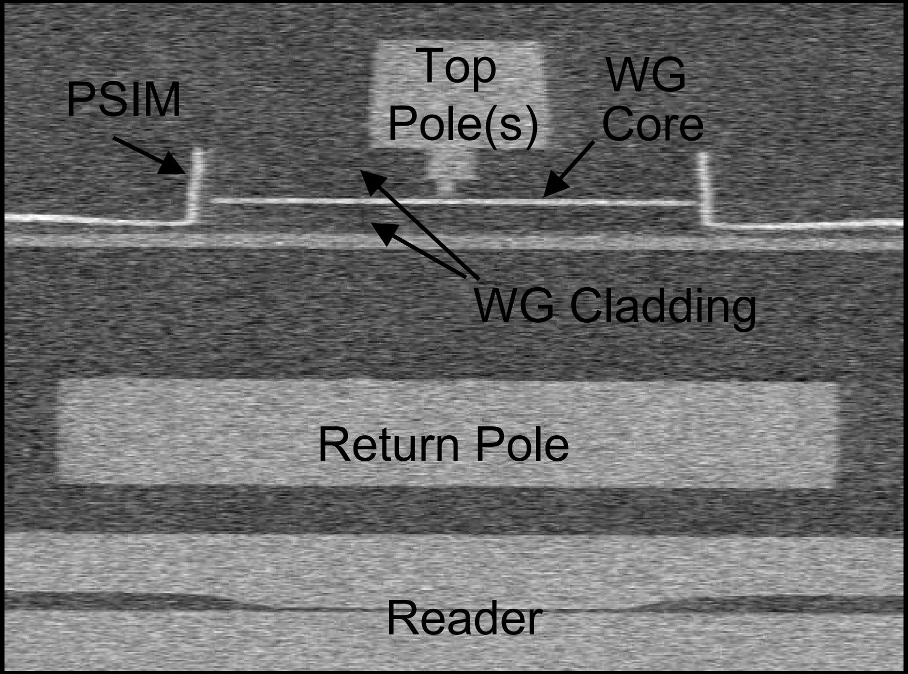
Implementation of Ring head

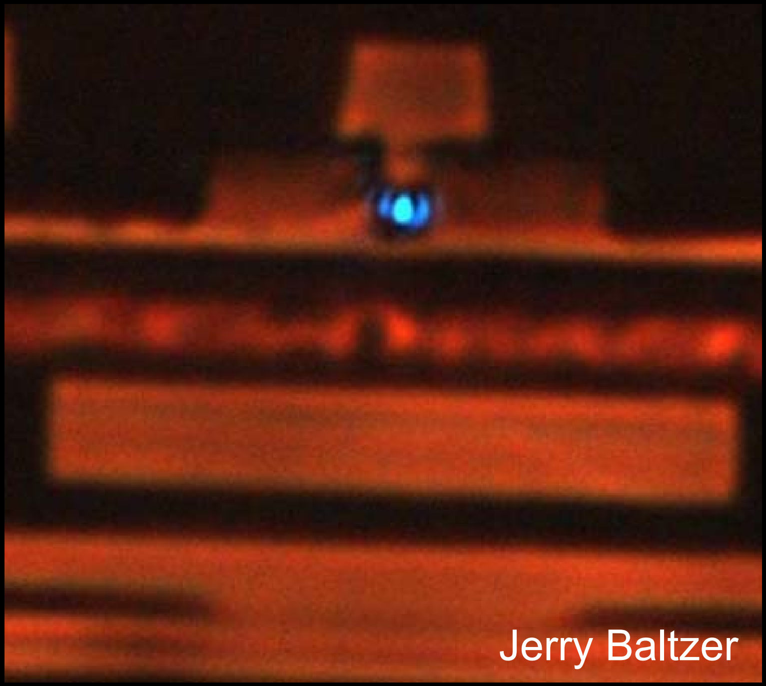




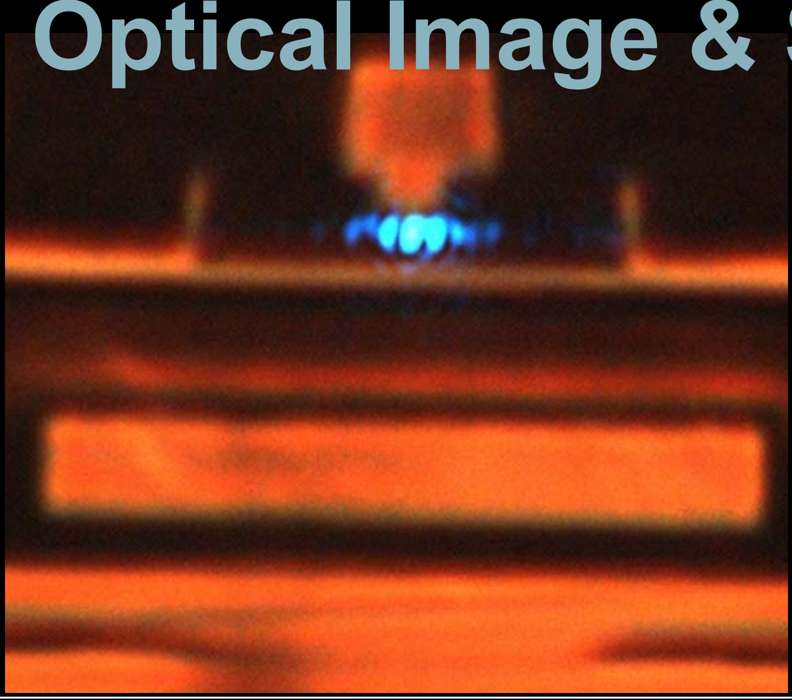


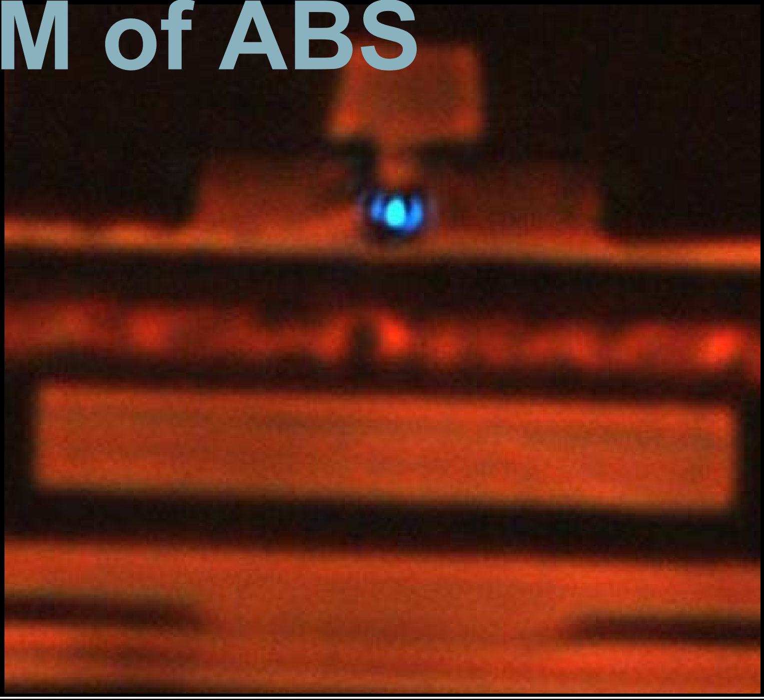
Built Integrated HAMR Head: ABS View

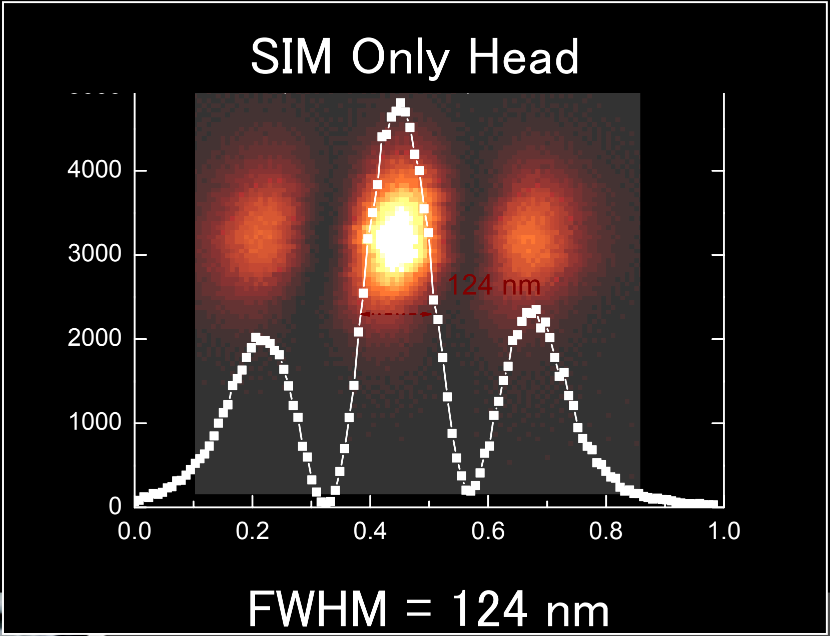


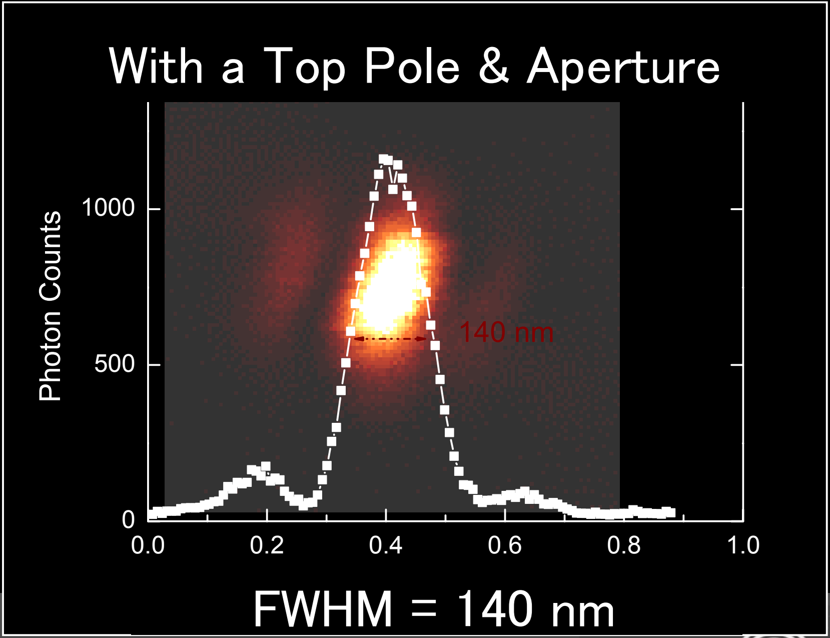


Optical Image & SNOM of ABS

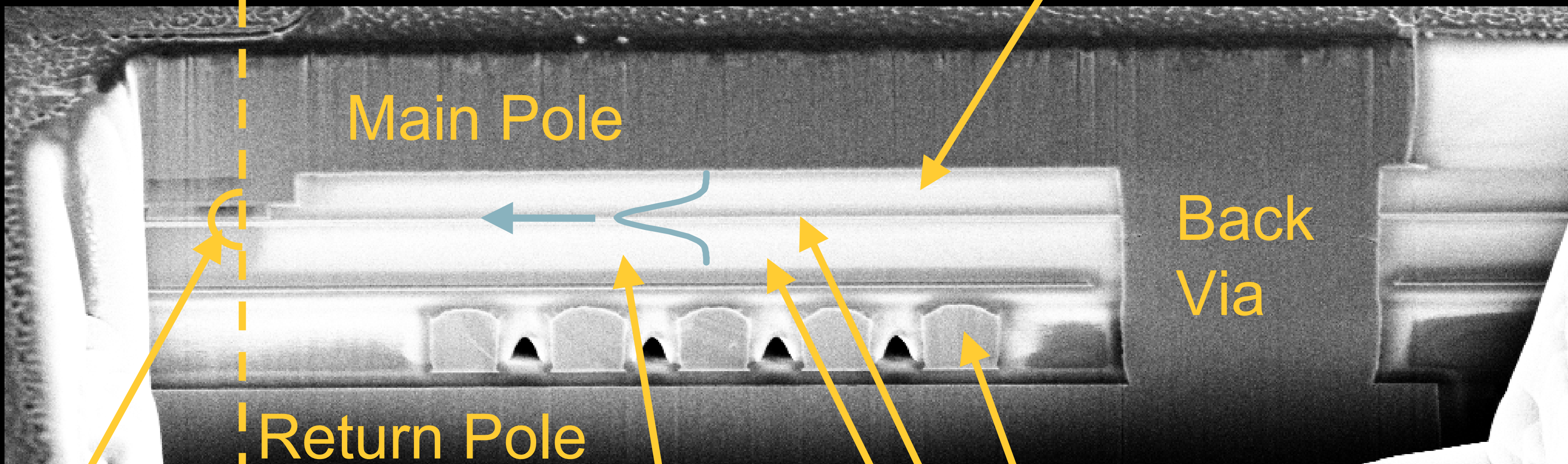








Integrated HAMR Head Cross-section



FIB by Kathy Trumbull

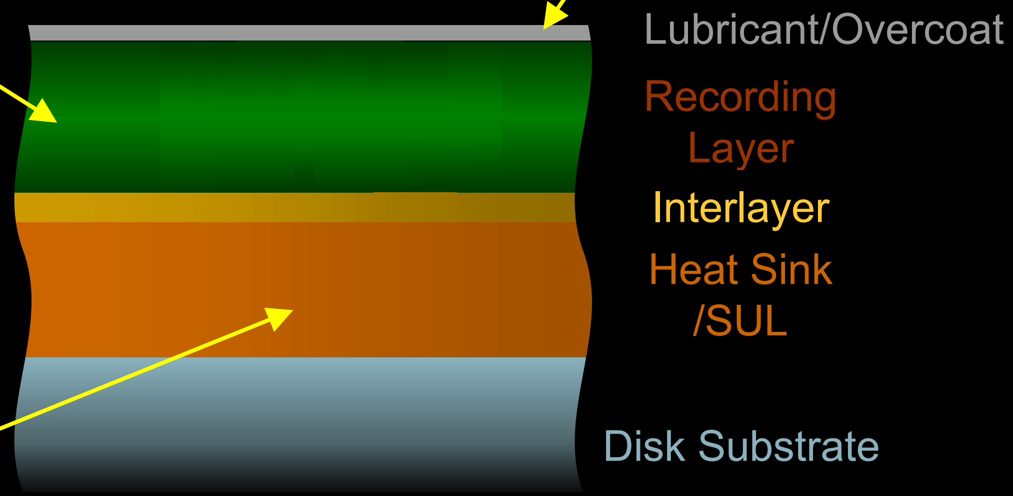
HAMR media + HDI

HAMR Media

Overcoat and lubricant materials

High anisotropy media

Thermal management via heat sink to obtain rapid cooling after writing doable; 100-500 ps thermal relaxation times observed (J. Hohlfeld, G. Ju-Seagate)



Specially designed heat sink and SUL

Recording at or near Curie Temperature
HDI Issue: >770K interface temperatures
Reducing Tc by doping, e.g. with Ni also reduces Ku

(e.g. J.Thiele, JAP 91, 6995 (2002))

HAMR Media with thermal design

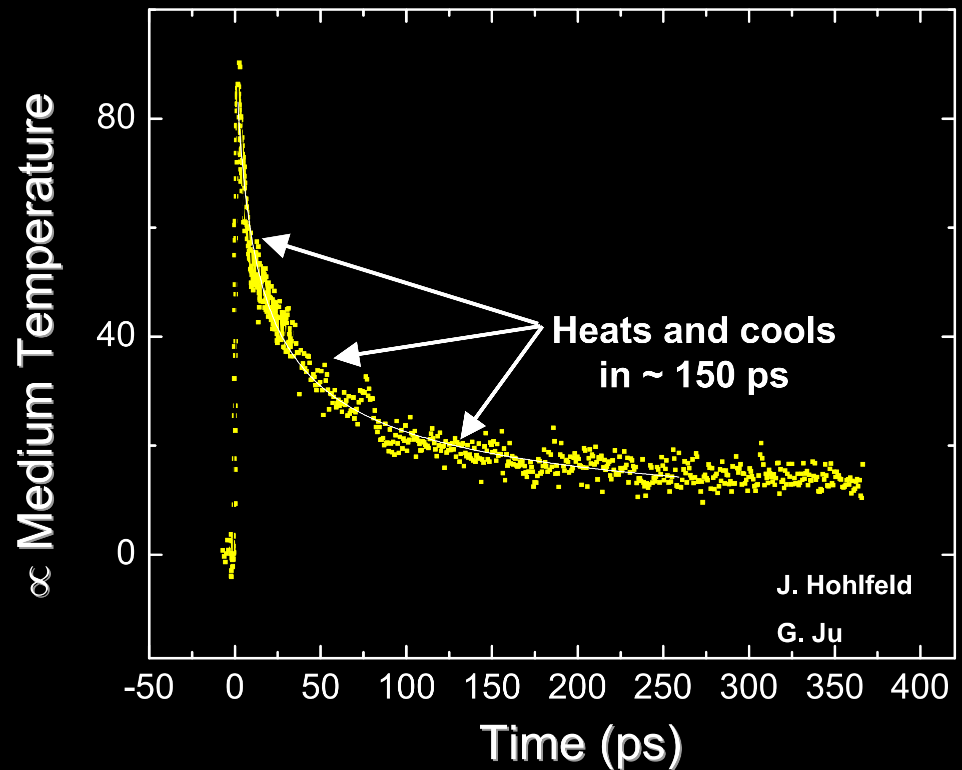
- High anisotropy

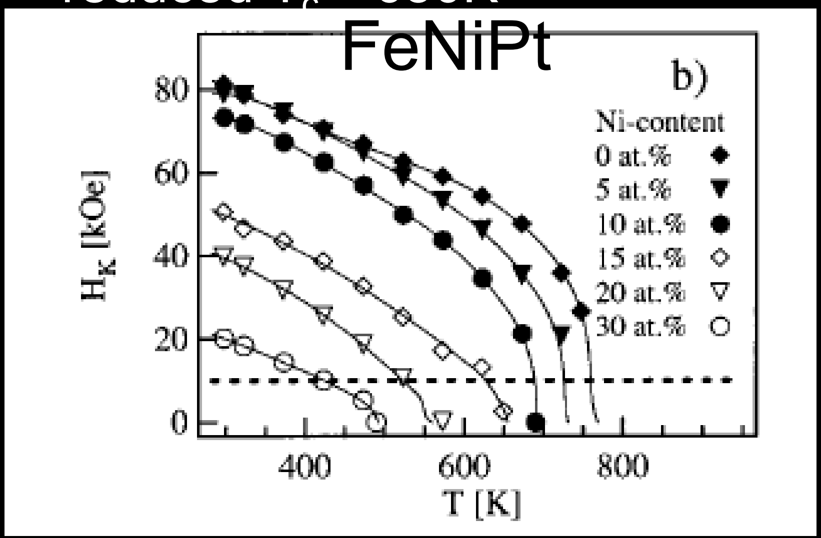
-Optimize thermal design

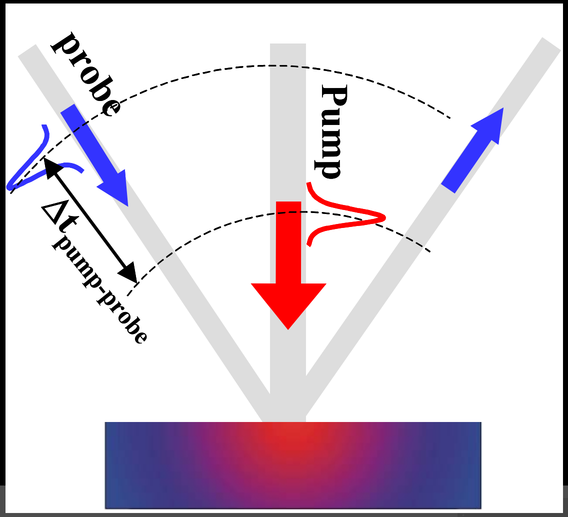
- Vertical thermal flow

-Lateral thermal diffusion

-reduced T_c ~ 650K

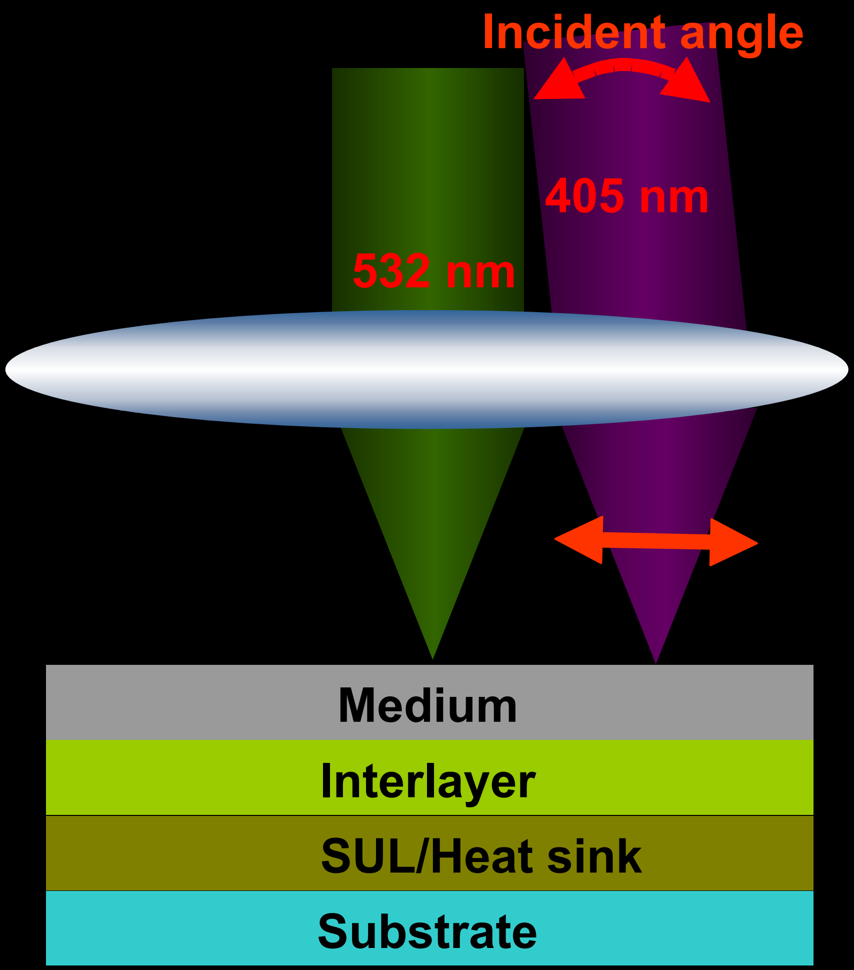






J.-U. Thiele et al, JAP Vol. 91, pg 6595, 2002.

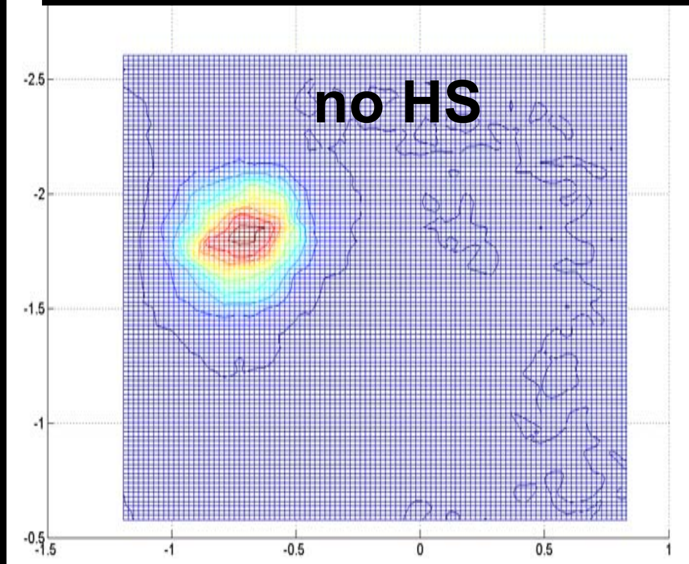
Measuring Lateral Temperature Profiles

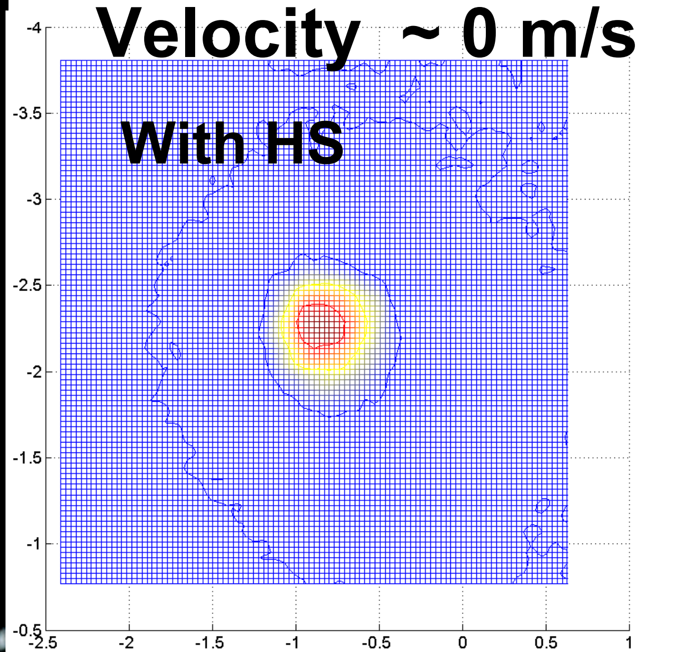


- Pump induced thermal profile measured as reflectivity changes by the XY scanning probe
- Signal is convolution of media thermal profile and probe profile
- Focus servo to ensure repeatable pump focusing and ability to spin disk
- Probe/Pump spot size ~280/380 nm
- Pump frequency up to 100 MHz (10 ns)
- Capable of supporting disks instead of samples

Scanning pump-probe spin-stand (D. Karns)

Effects of HS thickness for model media

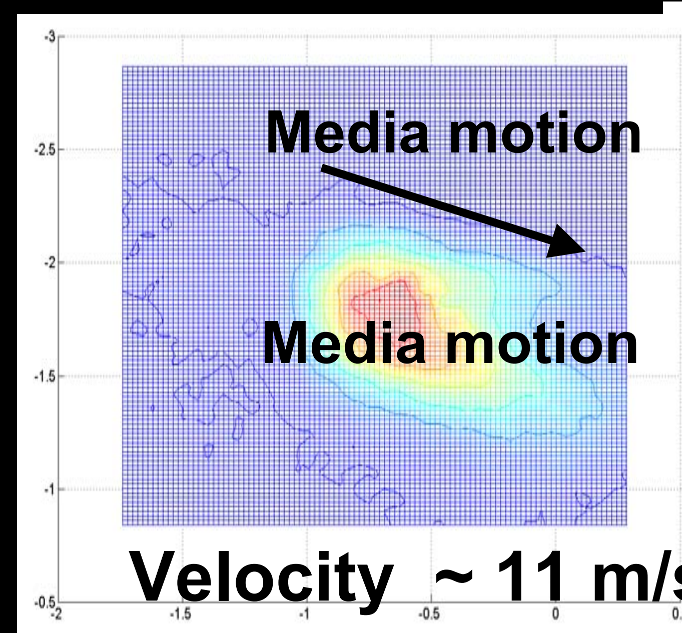


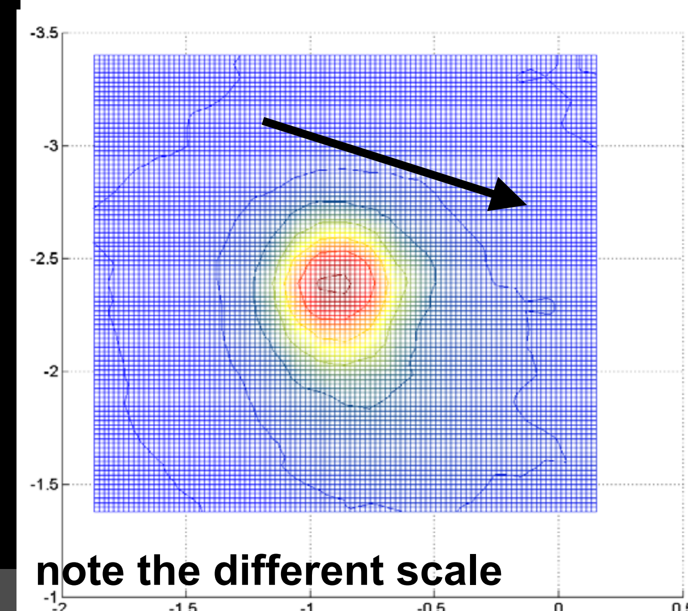


mag. media
Interlayer
Glass

•Proper thermally designed heat sink prevents preheating effects, very confined T-profiles

mag. media
Interlayer
HS (600 nm)
Glass

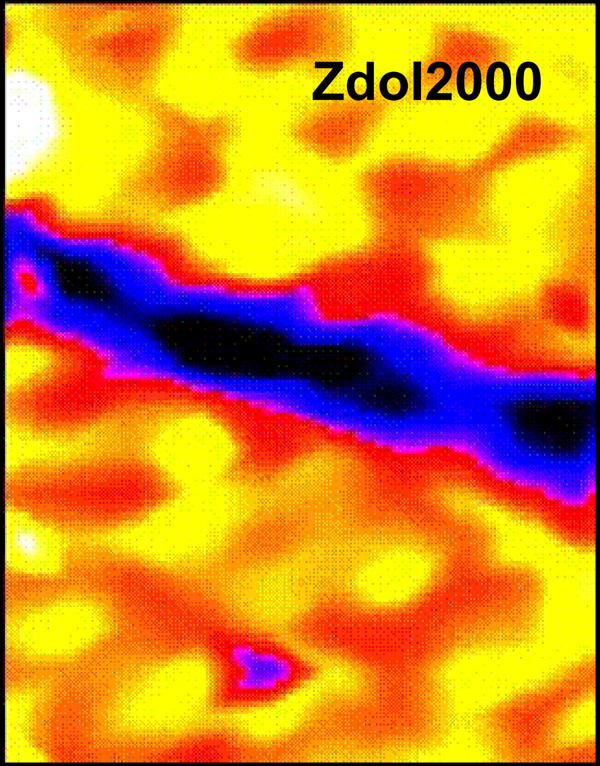




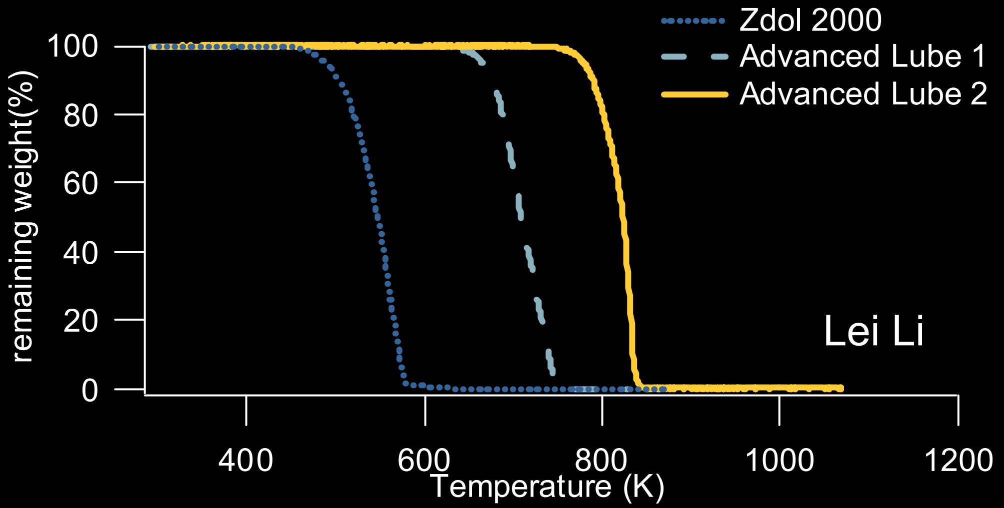
D. Karns, B. Lu, G. Ju

HAMR HDI

- Zdol2000 won't work

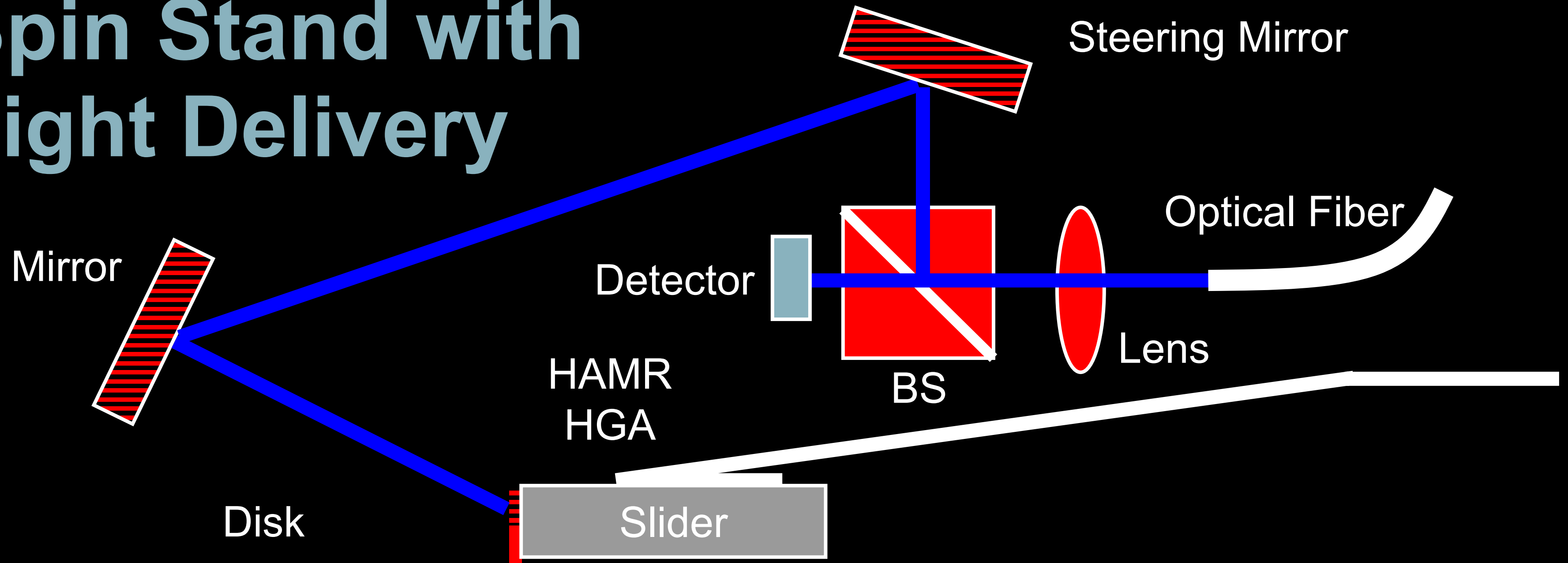


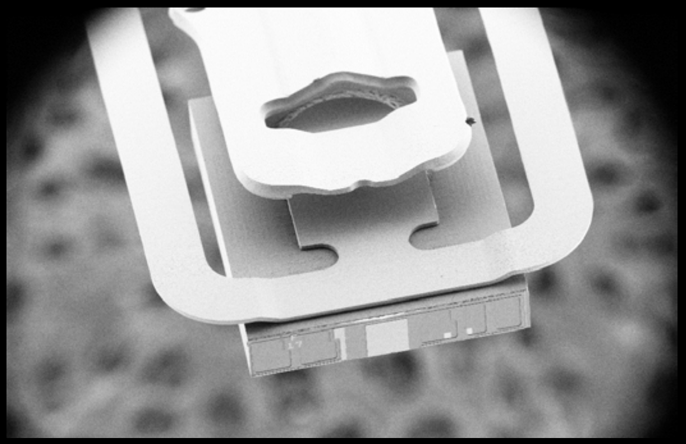
Lube Desorption

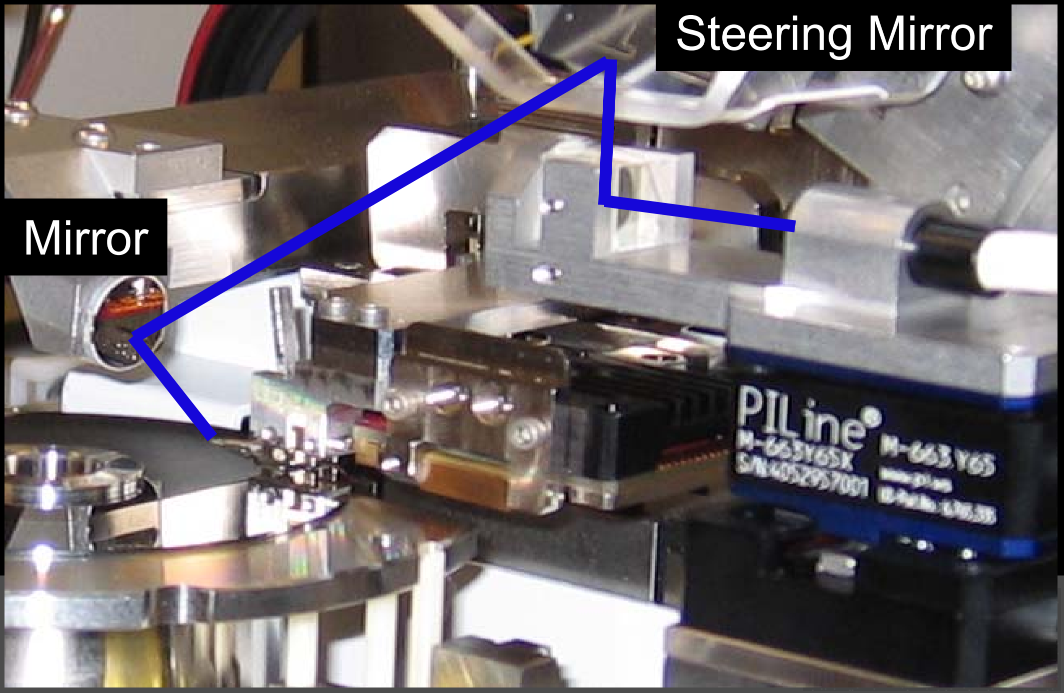


HAMR recording and MFM

Spin Stand with Light Delivery





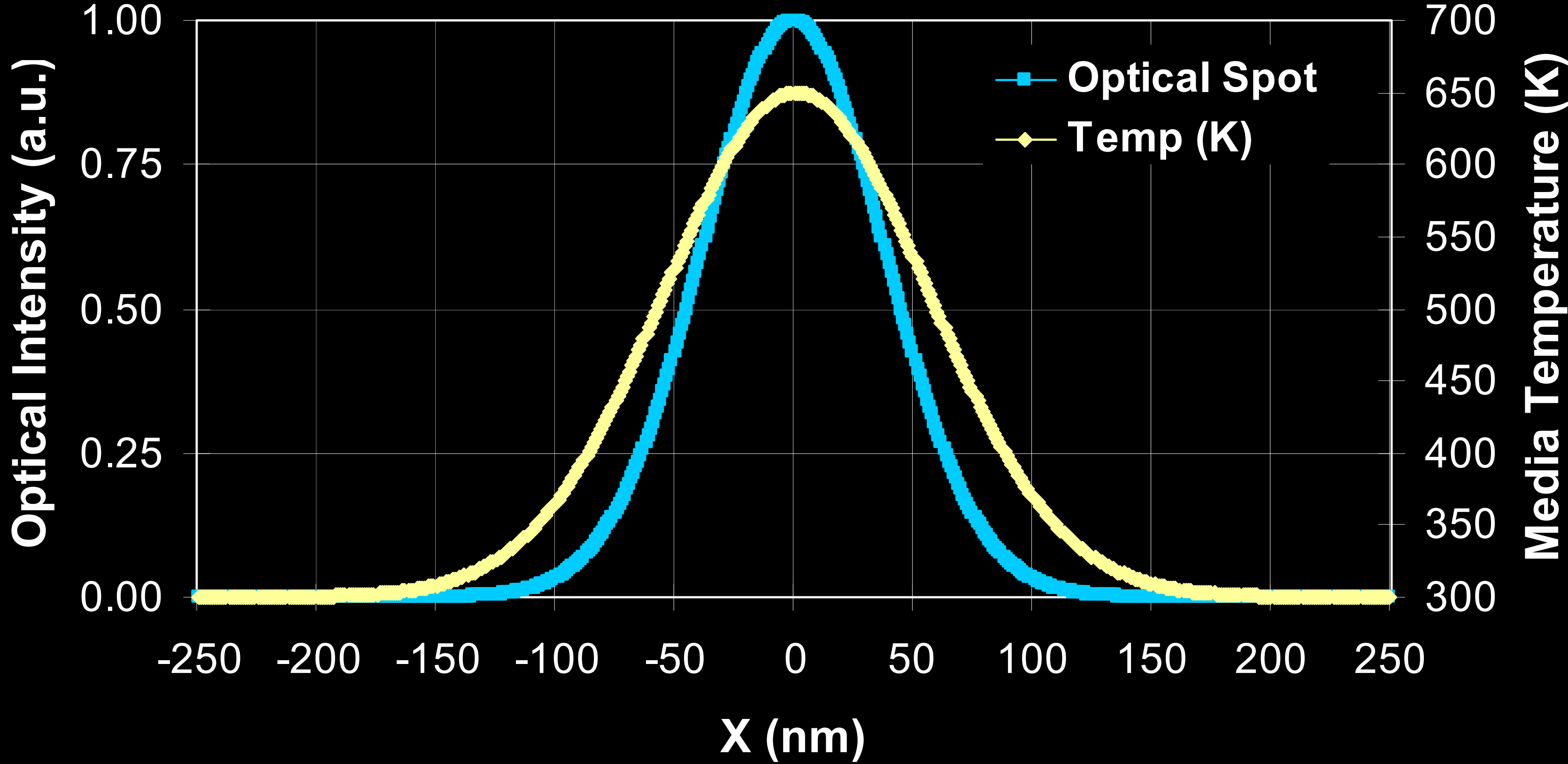


Magnetic Field – Optical Spot Registration

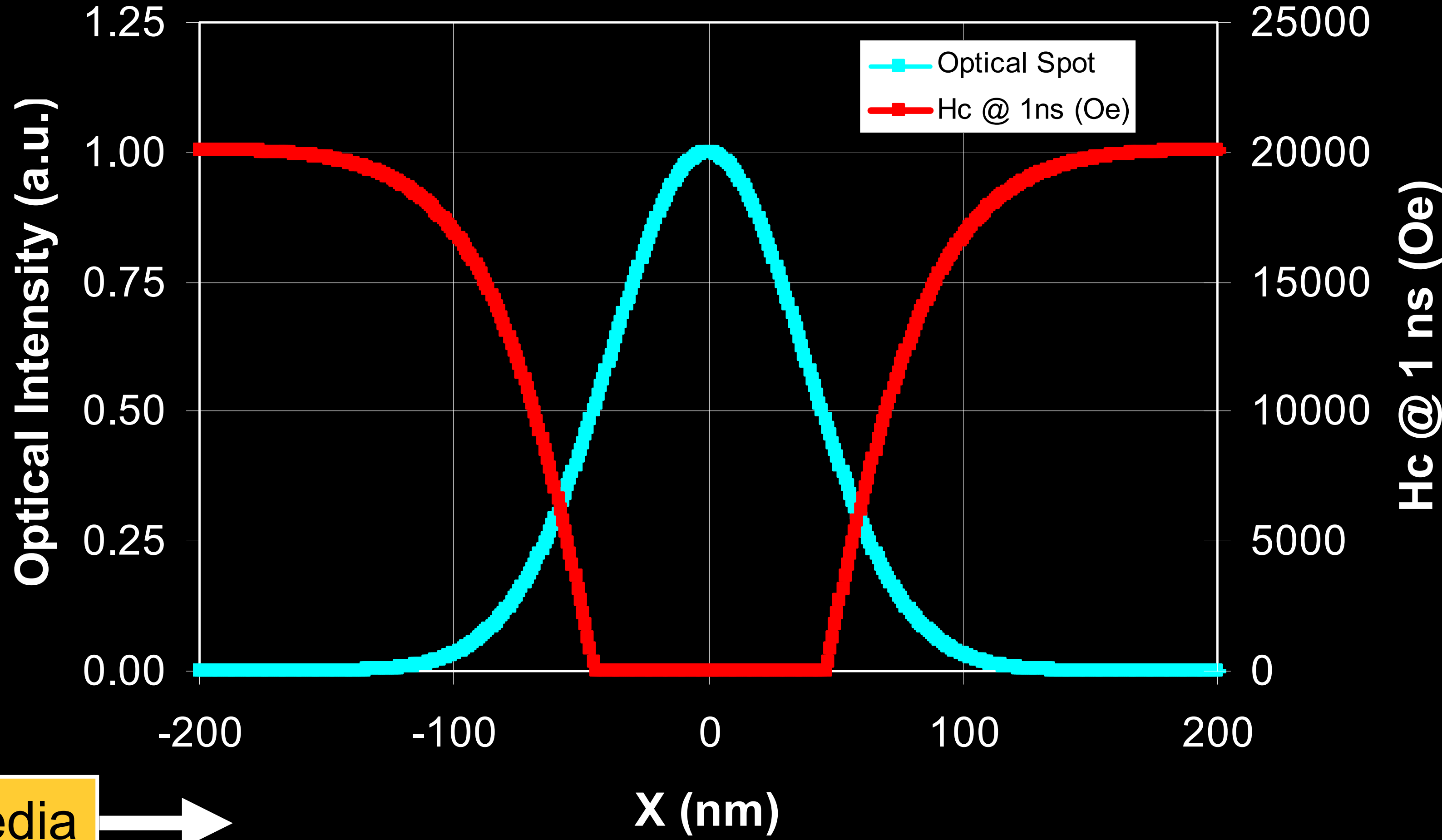
Blue PSIM Optical Spot with FWHM = 90 nm

Rapid Cooling Limits Thermal Spread, $FWHM_{thermal}$ ~ 130 nm

Power Chosen for Tmax = 650 K

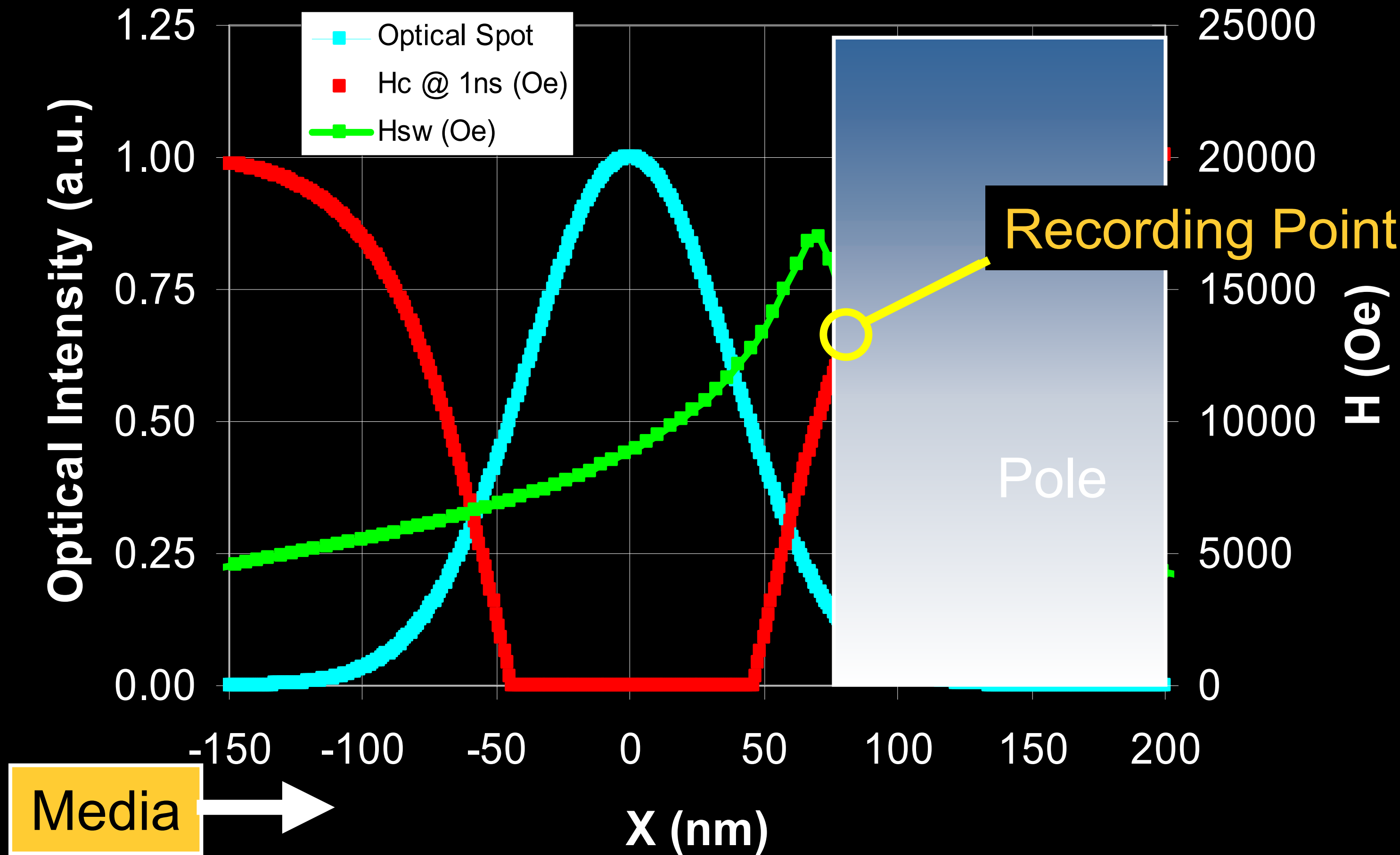


Optical Spot and Media Short-time Coercivity



Media

Recording Point



- **Pole 75 nm from center of optical spot**
- **Write gradient (thermal and magnetic field) is not optimum**
- **Recording point is under the pole => Light Blocked?**

How to optimize recording point which is a function of

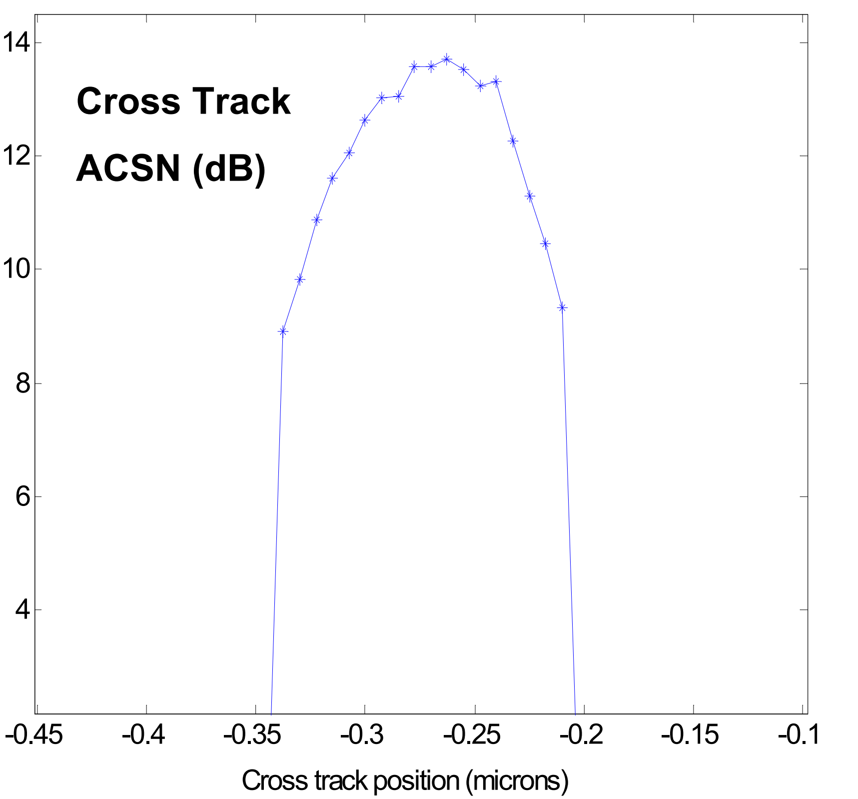
- **Magnetic field (pole position, writer design, write current)**
- **Thermal spot (optical spot, power, media thermal properties)**
- **Media magnetic properties (Hc, Curie temperature)**

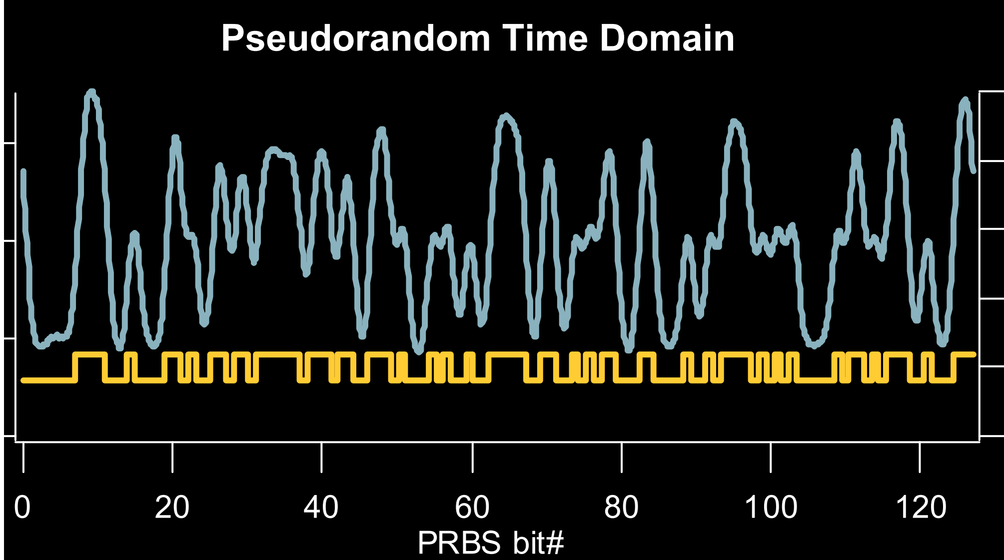
Wrote and read back data

HAMR data was written and read back using an integrated HAMR read write head.

- The written track width was less than 150 nm.
- The physical magnetic pole width was ~300 nm.

HAMR writing dominated by the thermal spot.





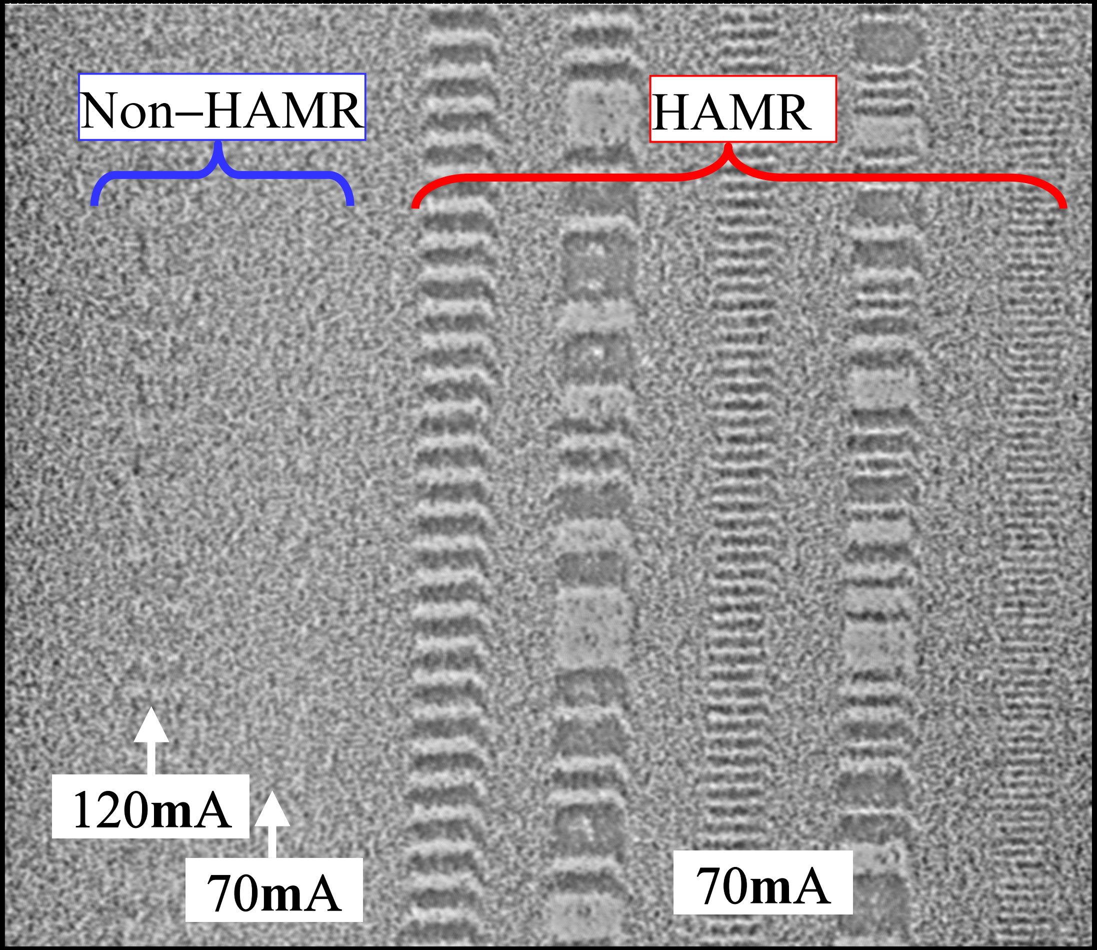
Duane Karns

MFM of Non-HAMR & HAMR Tracks

Fully Integrated HAMR Head

HAMR Unique Media

- High Anisotropy
- Proper Heatsinking



Tim Rausch, Xiaobin Zhu

MFM images of recorded tracks

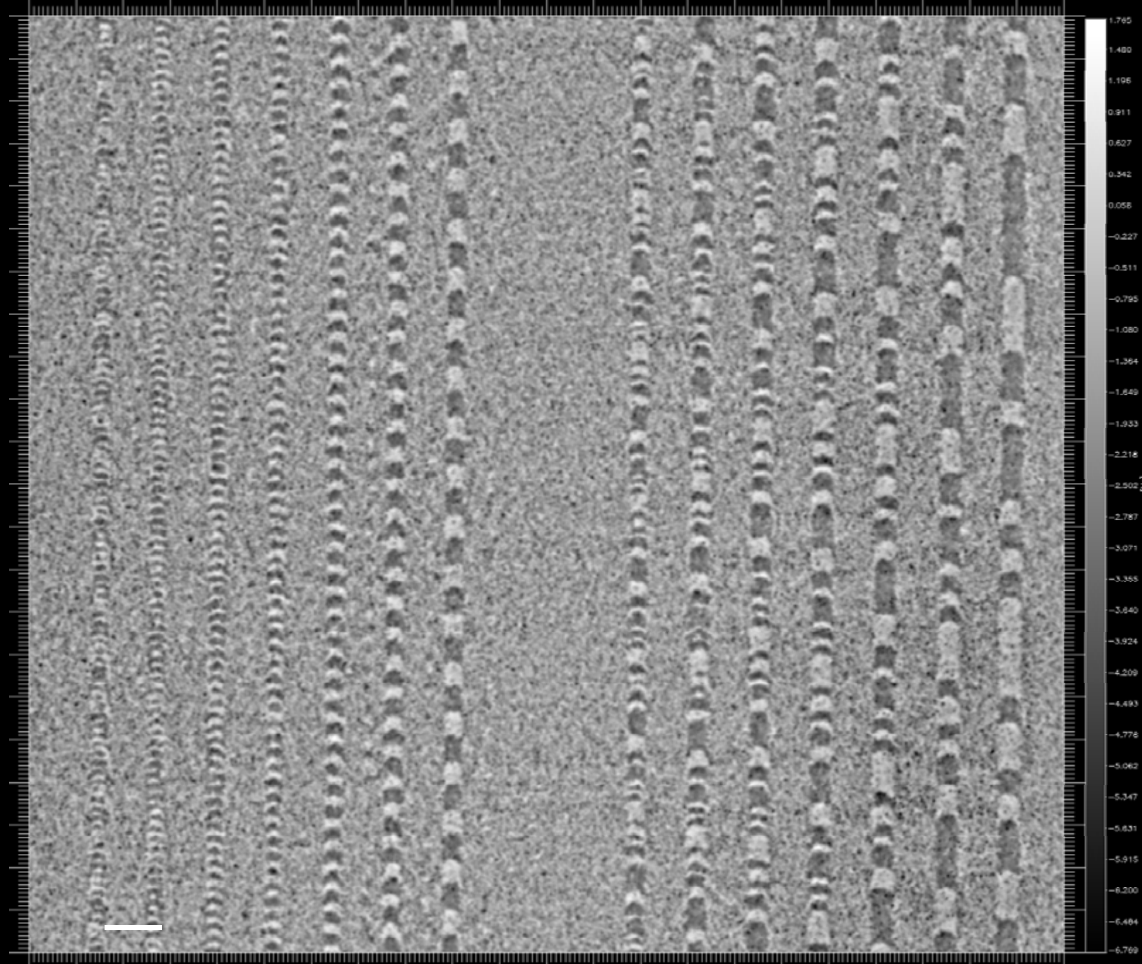
Fully Integrated HAMR Head

HAMR Unique Media

- High Anisotropy
- Proper Heatsinking

Both single tone and PRBS have been recorded

Thermally dominated regime



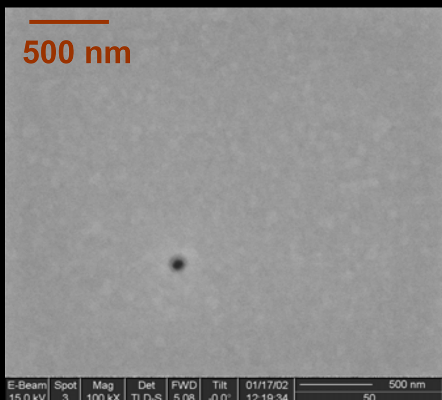
Xiaobin Zhu, Tim Rausch

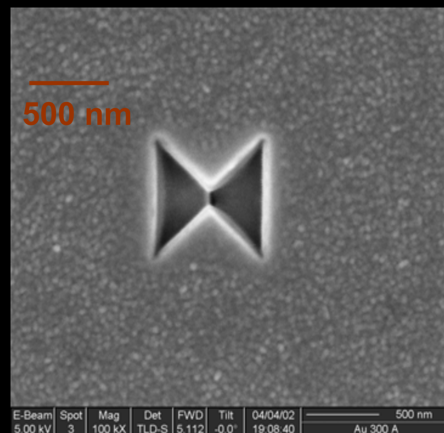
Future prospects

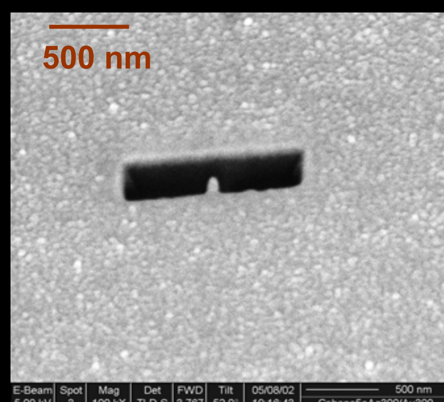
What is next: Near Field Transducers

NFT to reduce the optical spot size.

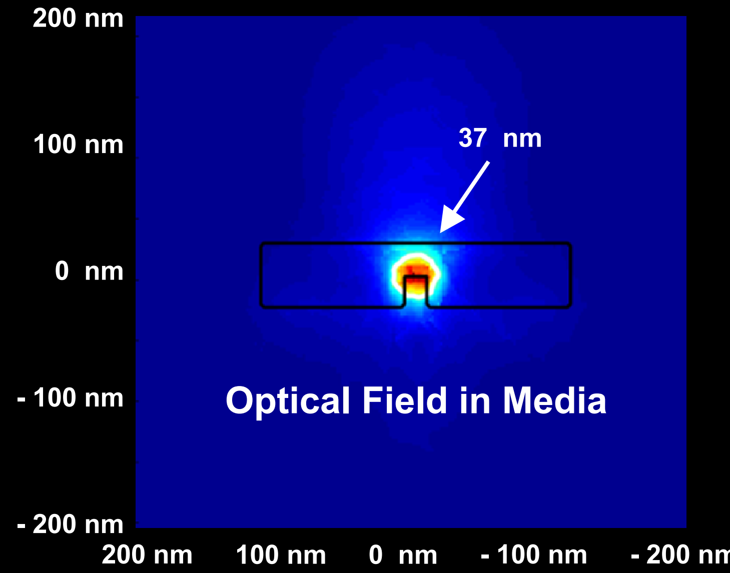
- Aperture, bowtie, ridge WG, beaked antenna, …





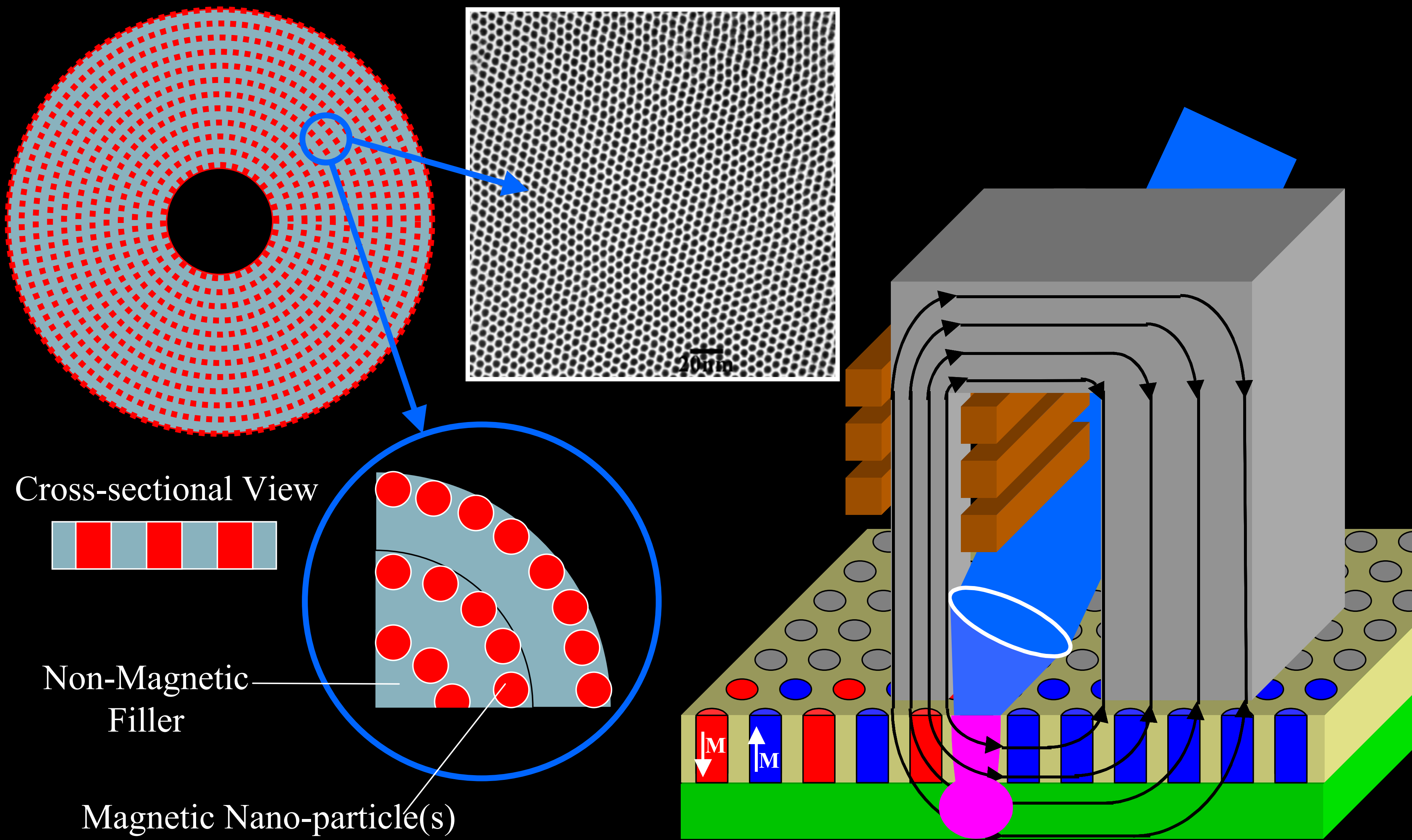


Ridge Waveguide



- Nano-Holes
  - L.Yin et al., APL 85 (3), pp. 467-469 (2004).
  - E. Popov, et al., *Appl. Opt*. 44, pp. 2332-2337 (2005).
- Rectangular Aperture
  - Shi, et al, Jap. J. Appl. Phys. 41 (2002).
- Bowtie
  - R. Grober, et al, APL 70, pp. 2368-2370 (1997).
- Hitachi - Beaked Antenna
  - T. Matsumoto, et al, ISOM/ODS'05, (2005).
- Sharp - Smash Head
  - S. Miyanishi INTERMAG (2005).
- Sony - SIL + Single Pole Head
  - N. Kojima, et al, INTERMAG (2007).

HAMR + Bit Patterned Media



Conclusion

- Fabricated a thin film integrated HAMR head containing a reader, a magnetic writer, and an efficient blue light delivery system

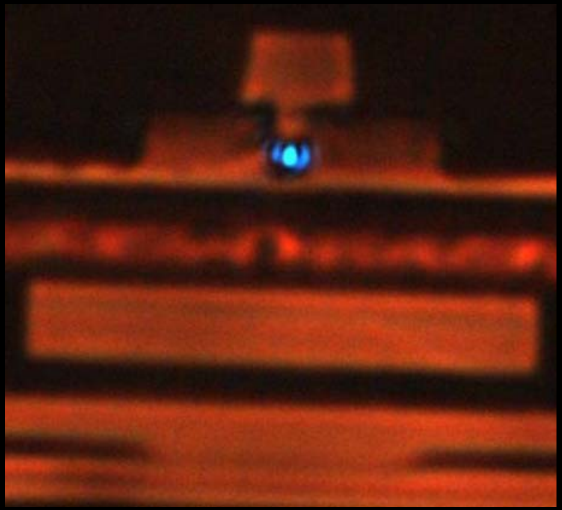
- Optical FWHM is ~ $\lambda/4$

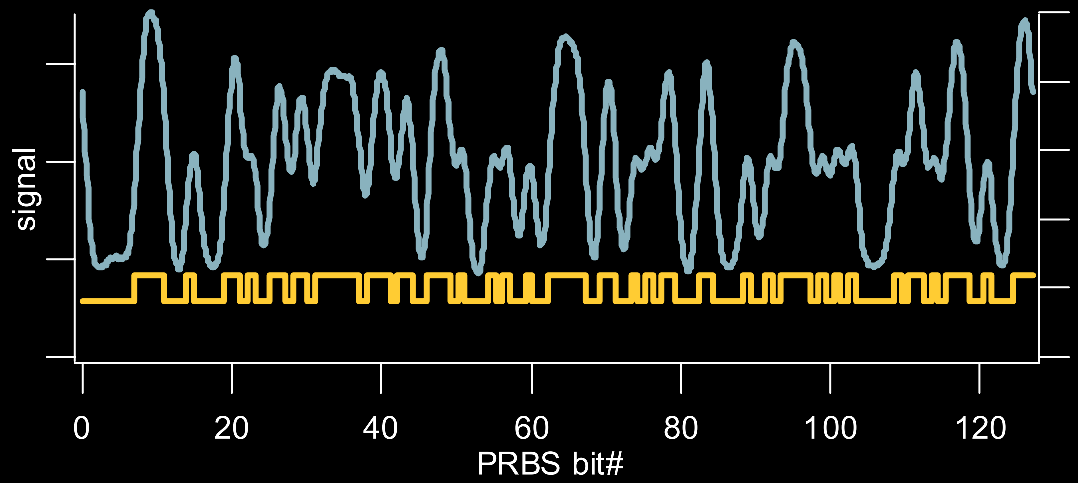
- Created high anisotropy media with rapid cooling design

- Built a spin stand with light delivery system

-HAMR Recording was achieved

-For productization, Near Field Transducer needs to be integrated.





Acknowledgements

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Seagate Research Heads Group, Media Group, Mechanical Integration Group, Servo Group, and Characterization Group

INSIC HAMR ATP Joint Venture Partners

This work was performed as part of the Information Storage Industry Consortium (INSIC) program in Heat Assisted Magnetic Recording (HAMR), with the support of the U. S. Department of Commerce, National Institute of Standards and Technology, Advanced Technology Program, Cooperative Agreement Number 70NANB1H3056