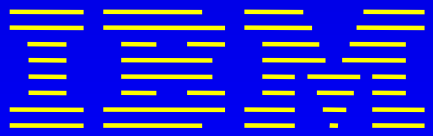
# Test System Requirements For Wafer Level MRAM Test

Raphael Robertazzi
IBM/Infineon MRAM Development Alliance



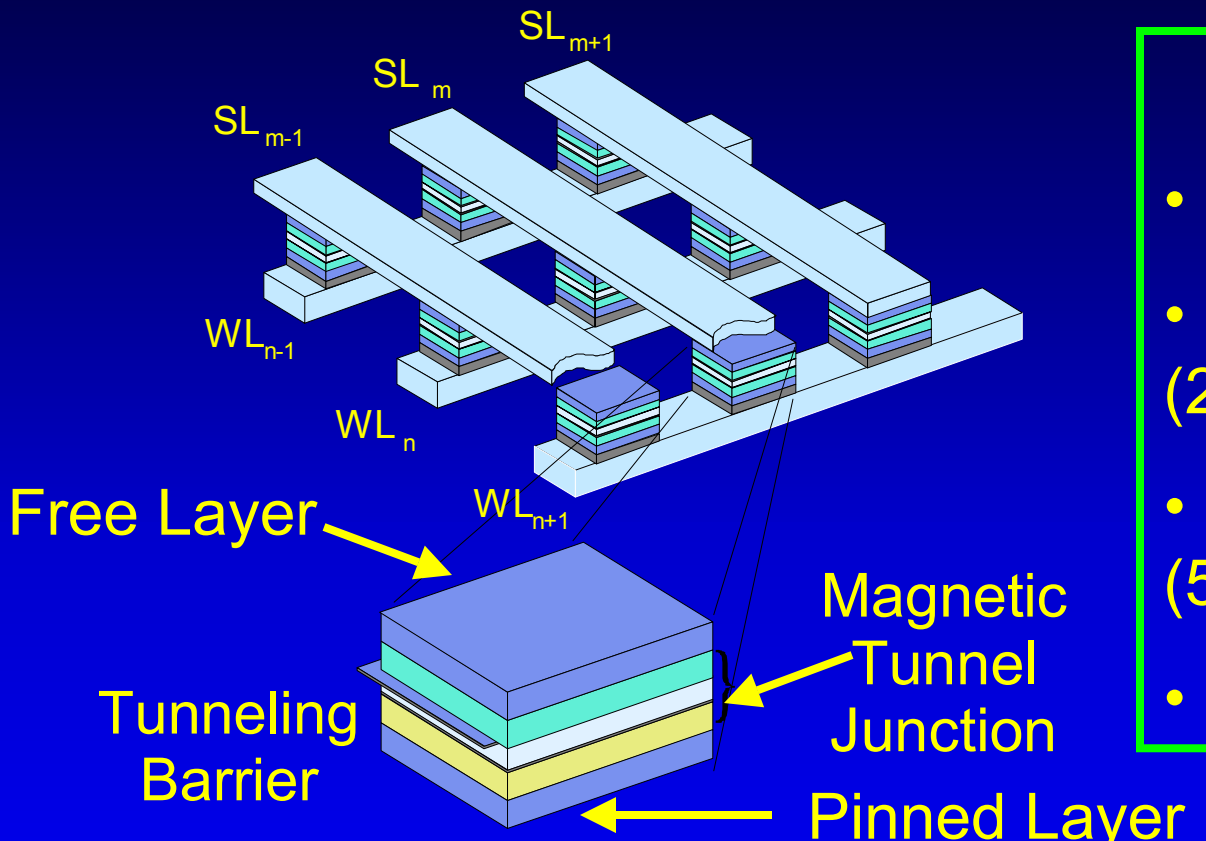
*With Acknowledgement To*
Cascade Microtech Inc.
And
Temptronics Inc.



# Outline

- Brief Introduction To MRAM Technology.
- MRAM Specific Test Challenges For Analytical Test.
- Brief Review Of Magnetism.
- YKT  Analytical MRAM Test System.
- Experiments: Magnetic Characterization Of Summit 12K Probe Station With Thermal Chuck.
  - Ambient Field, With And Without Temperature Control.
  - Field With Applied Magnet.
  - AC Field Characterization.
  - Degaussing Experiments.
  - Conclusions.

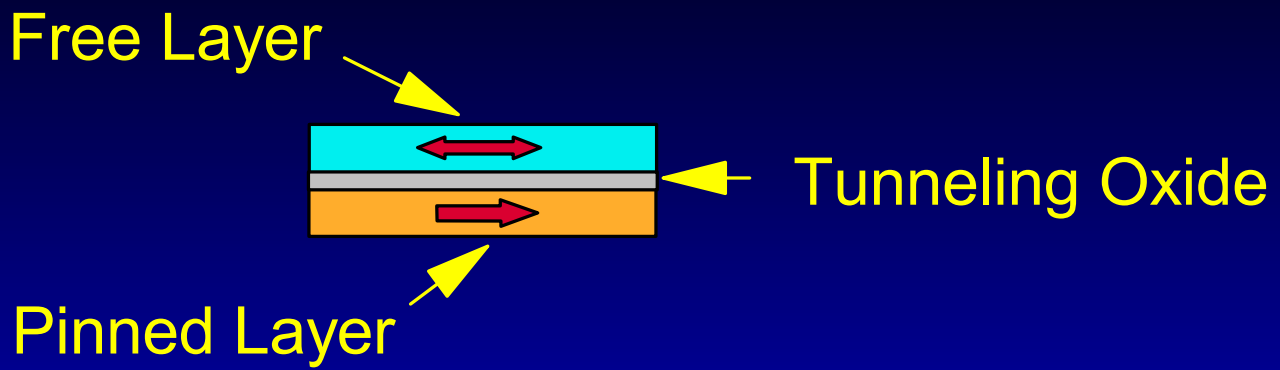
# What Is MRAM?



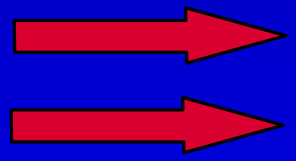

**Characteristics**

- High Density.
- SRAM Read Speed. (2ns)
- SRAM Write Speed. (5ns)
- Non-volatile

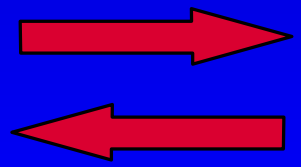
# Data Storage




Magnetization

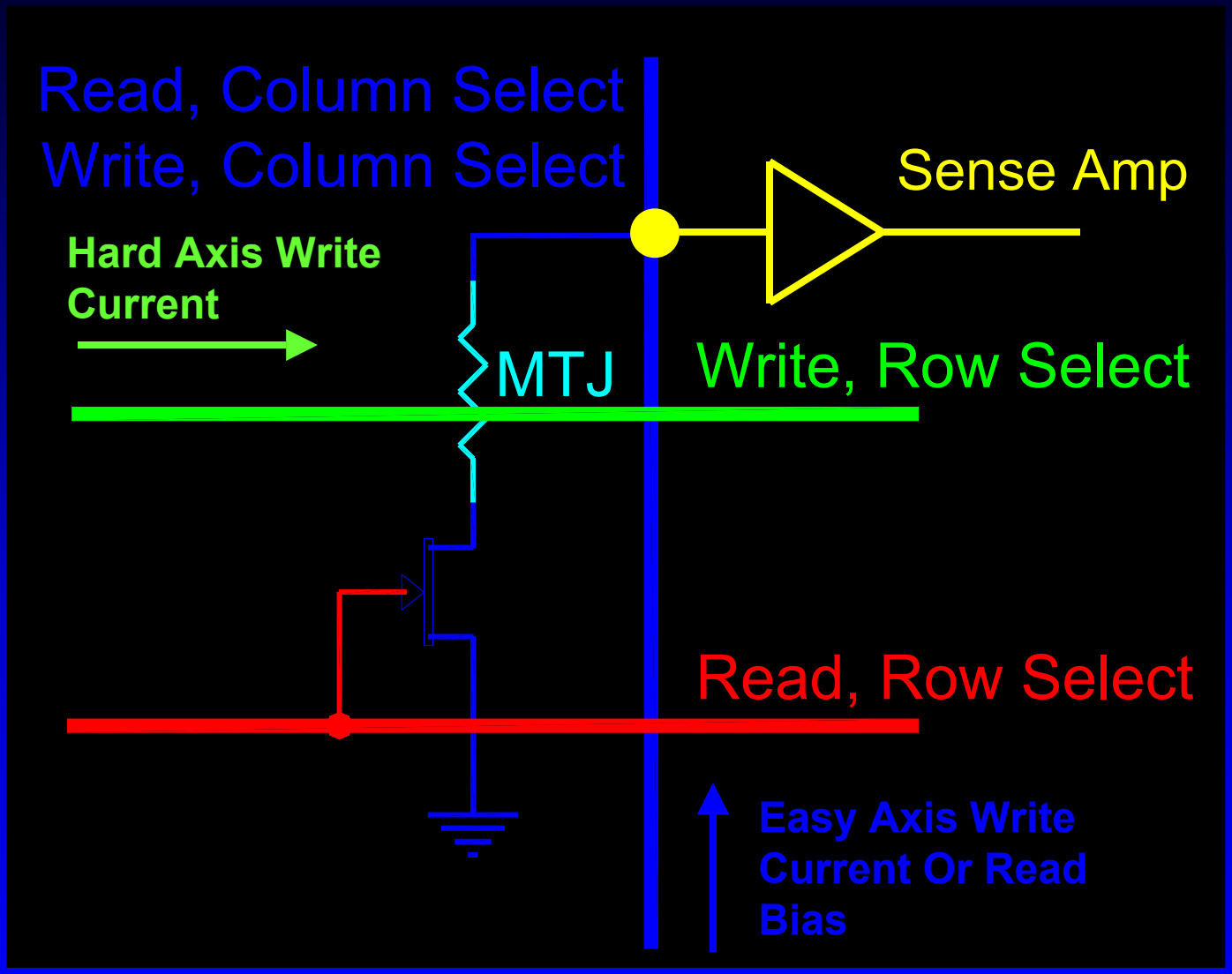


Low Resistance, "0"

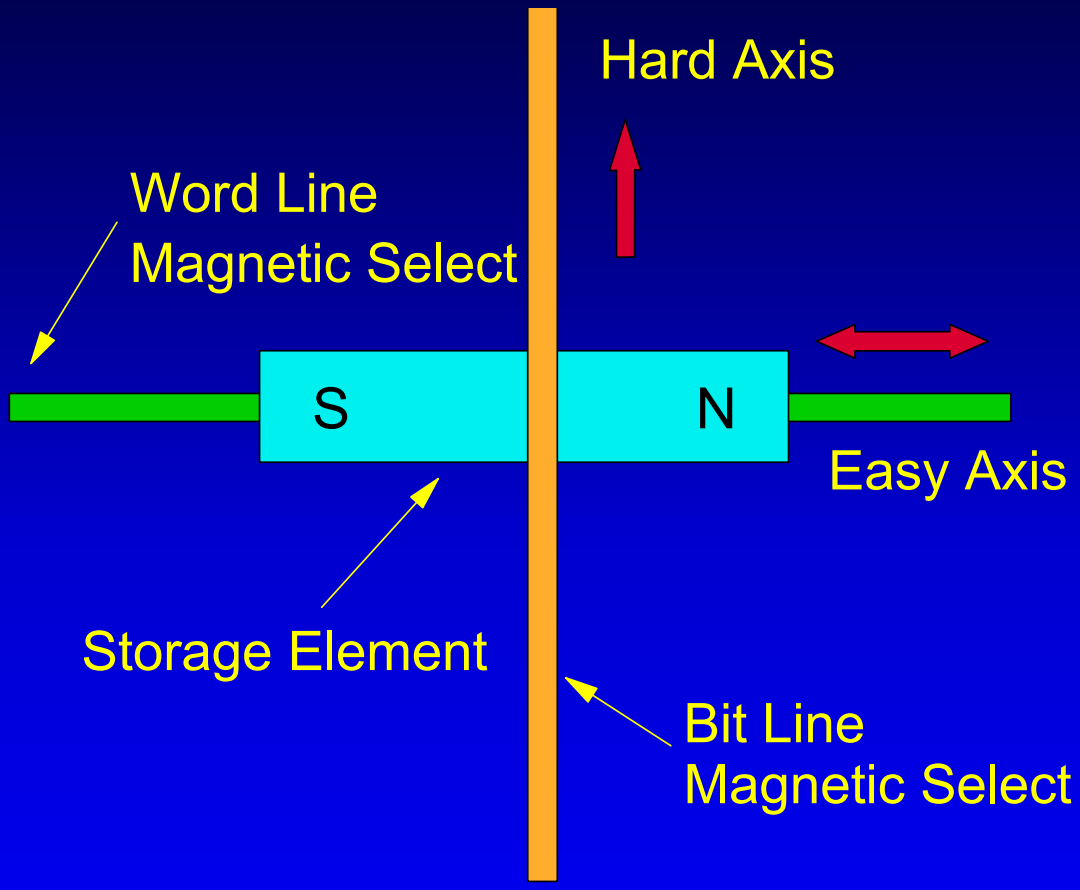


High Resistance, "1"

# FET Cell Architecture



# Write Selection



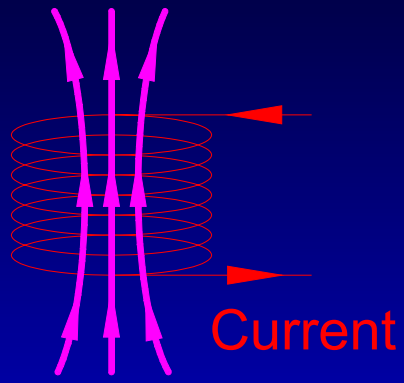
# Analytical Test System Requirements

- Digital Tester With Highly Flexible Test Pattern Capability.
- High Bandwidth Connections To The DUT.
- Low Level Of Electrical Noise.
- Mixed Signal Capability.
- Temperature Control.
- “Magnetics Package” (Experiments)
  - Ability To Apply Arbitrary Magnetic Fields In The Plane Of The Wafer.
  - Magnetically Characterized Chuck, $B_A$ < 1 G.

# Magnetism Basics

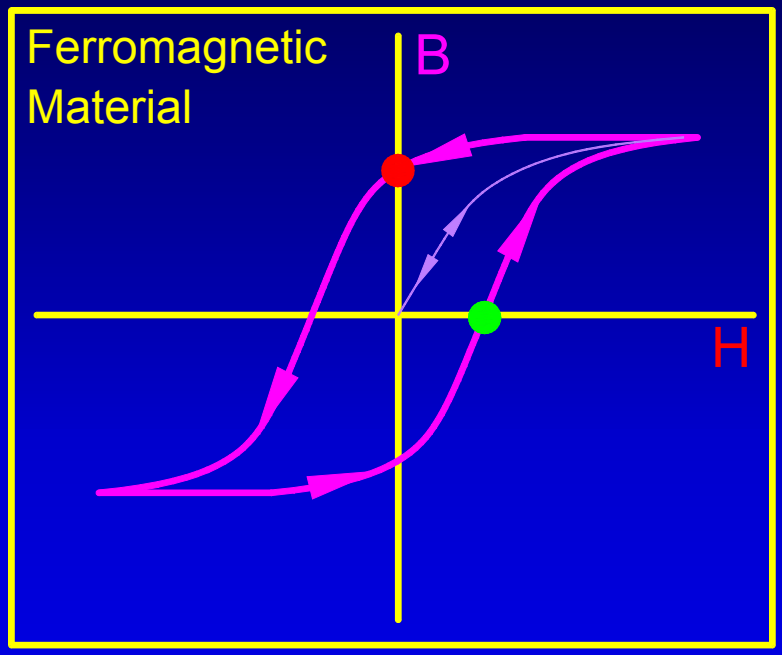
B: Magnetic Field

H: Magnetizing Force

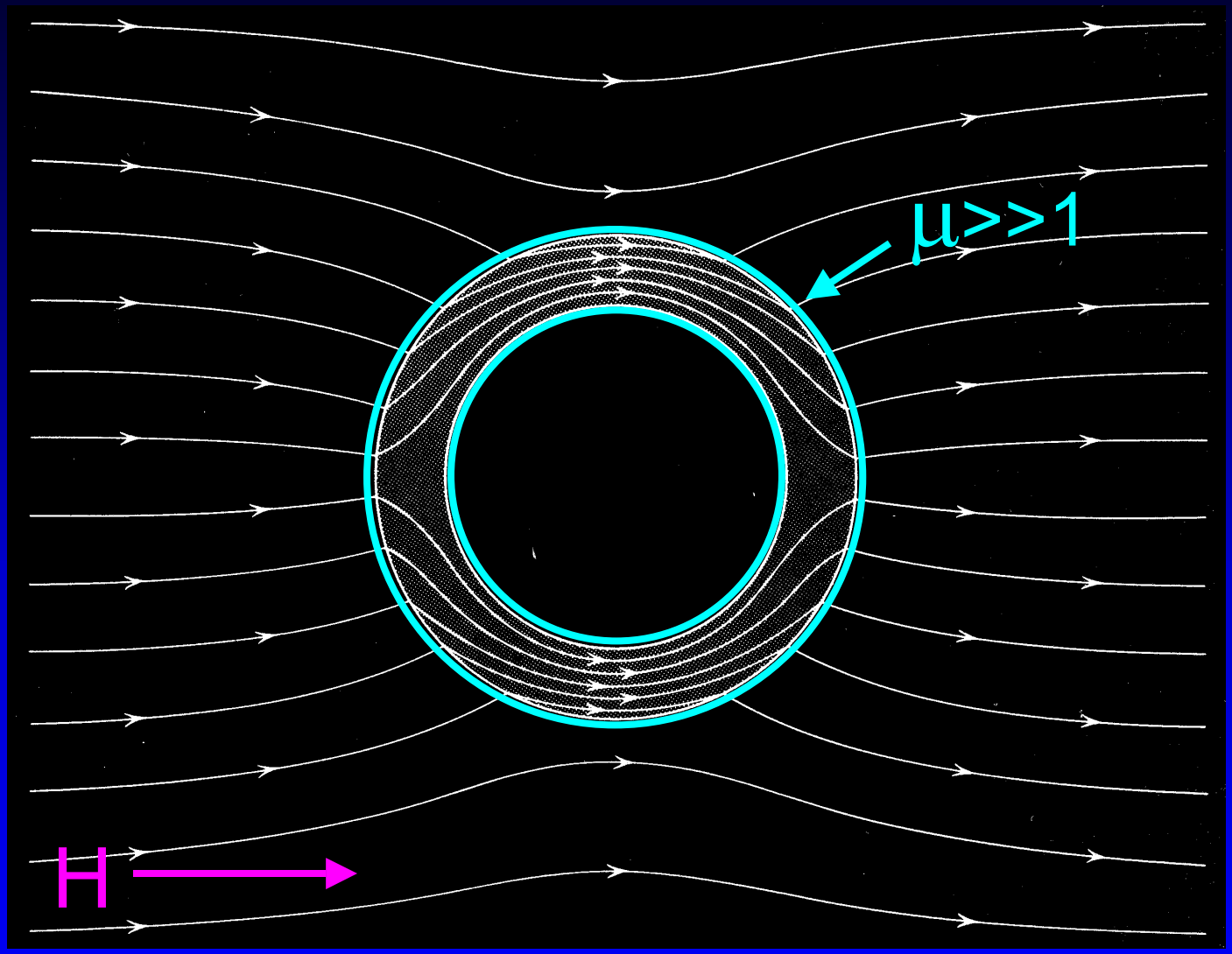



$\vec{B} = \mu \vec{H}$ (Paramagnetism $\mu \sim 1$)
(Diamagnetism $\mu < 1$)

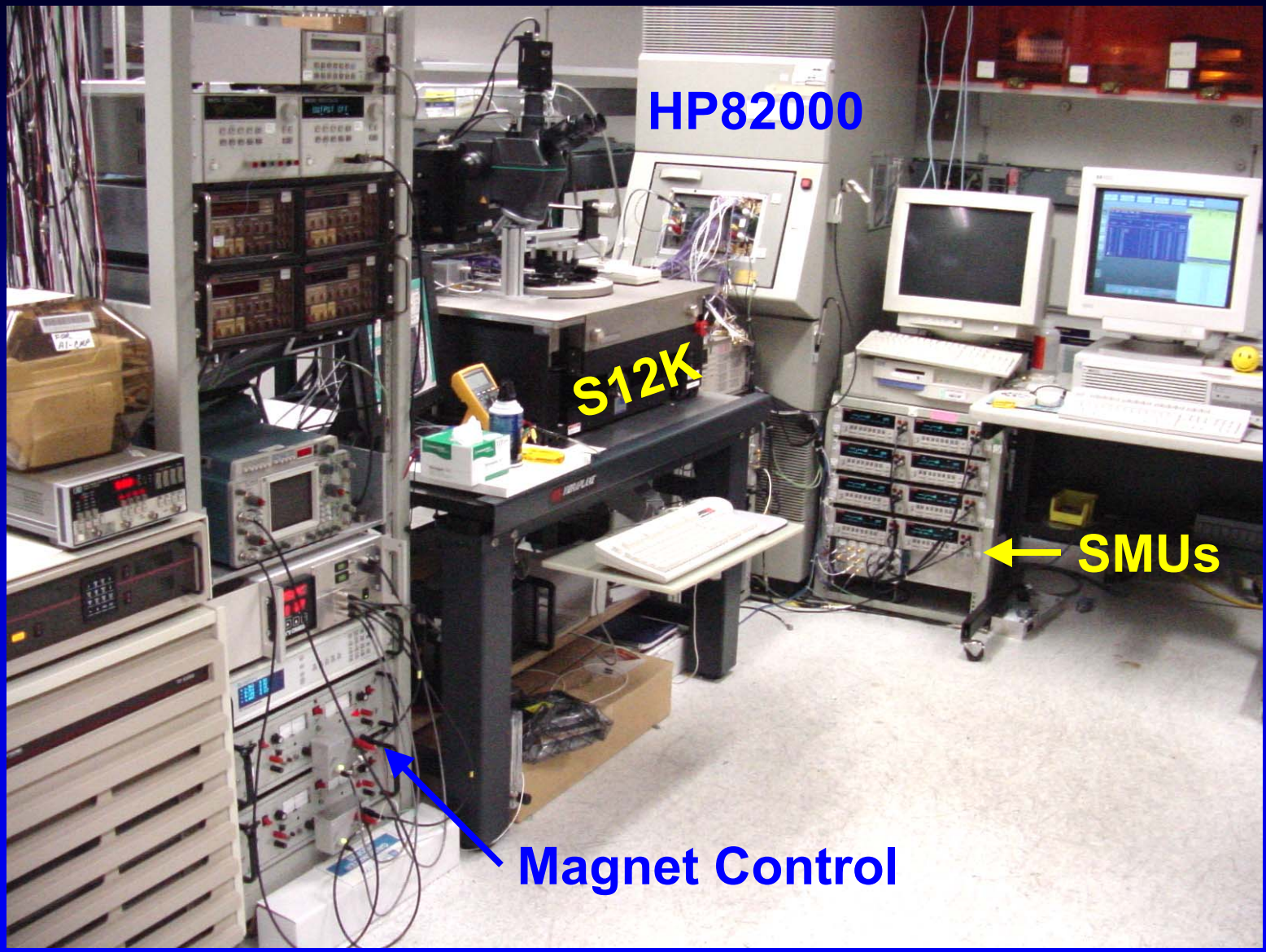
$\vec{B} = \vec{F}(H)$ (Ferromagnetism)



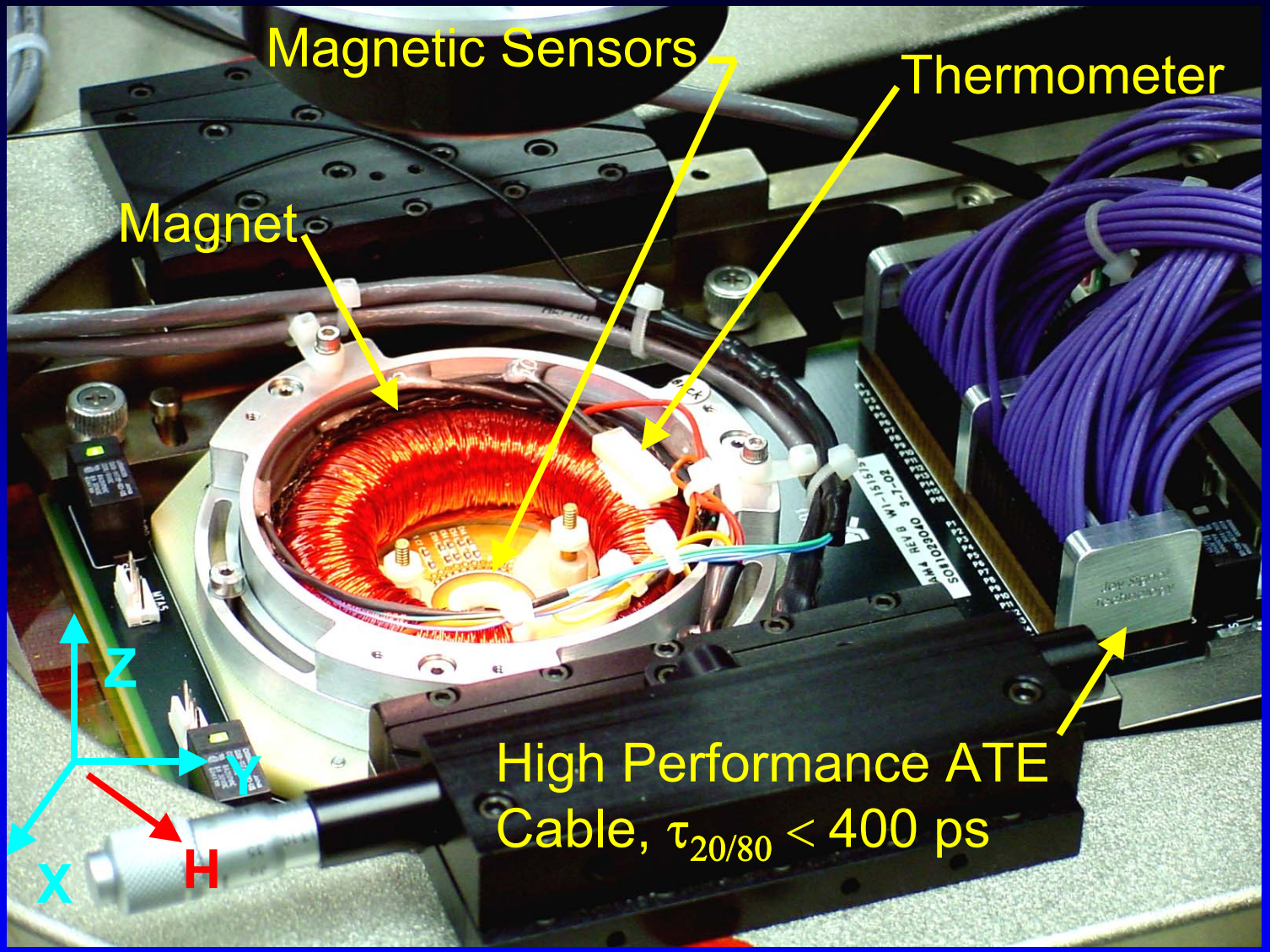
# Permeable Materials Disturb Applied Fields



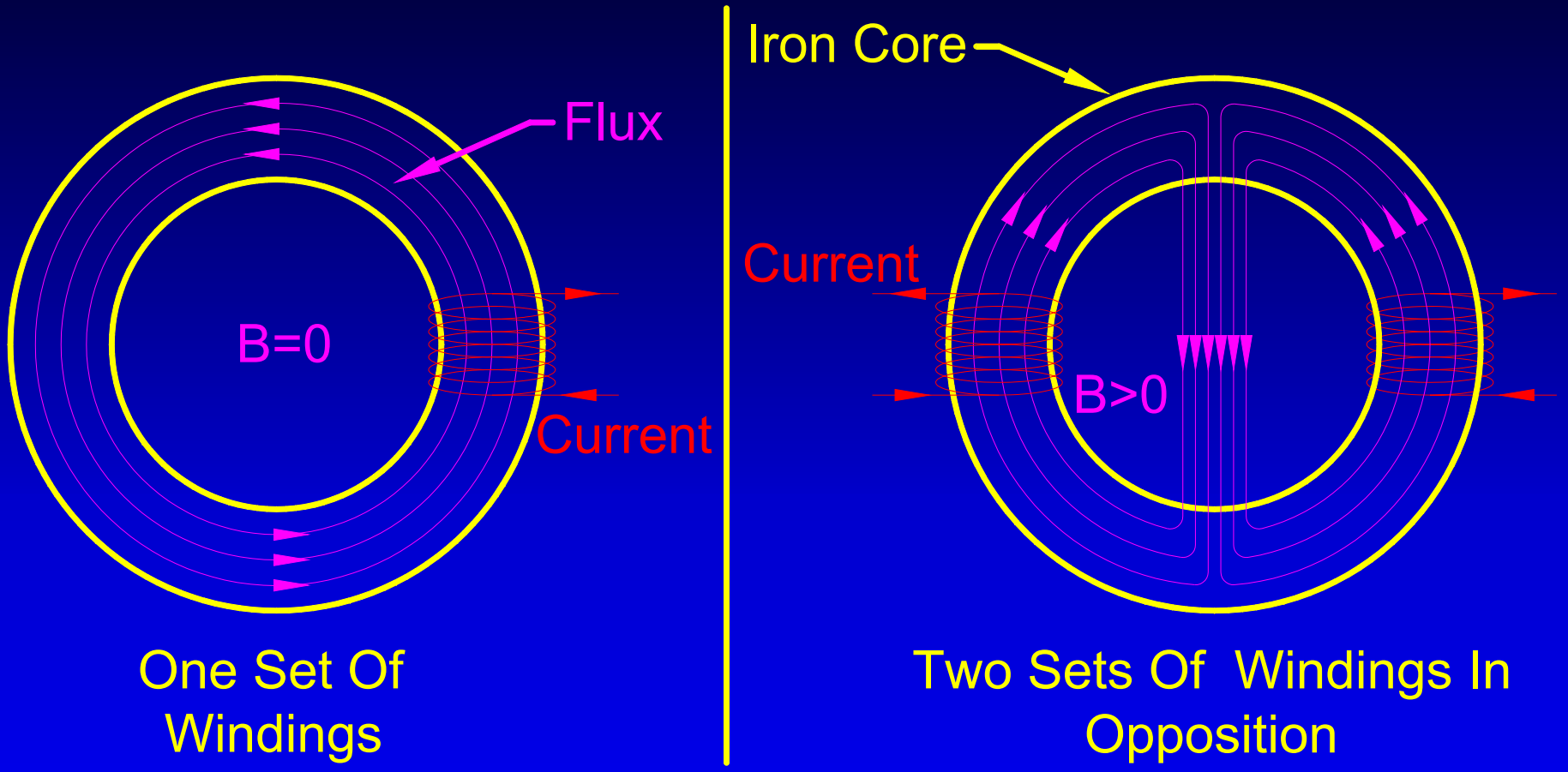
# MRAM YKT Test System



# MRAM Probe Card



# *Magnet




One Set Of Windings

Two Sets Of Windings In Opposition

**** IBM Almaden Research Center***

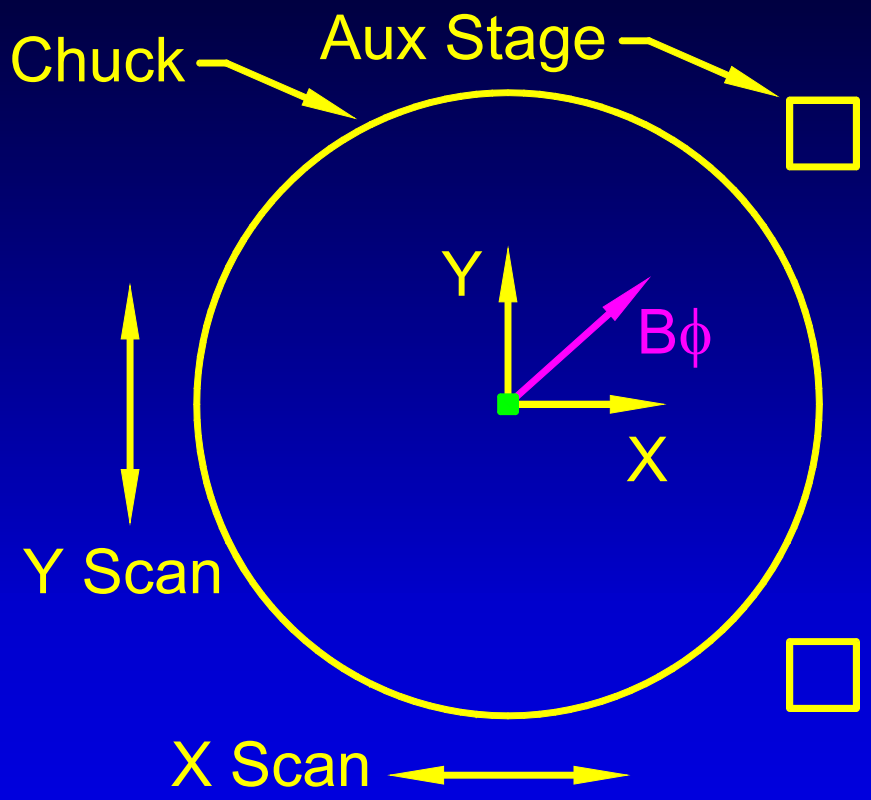
# Chuck Characterization

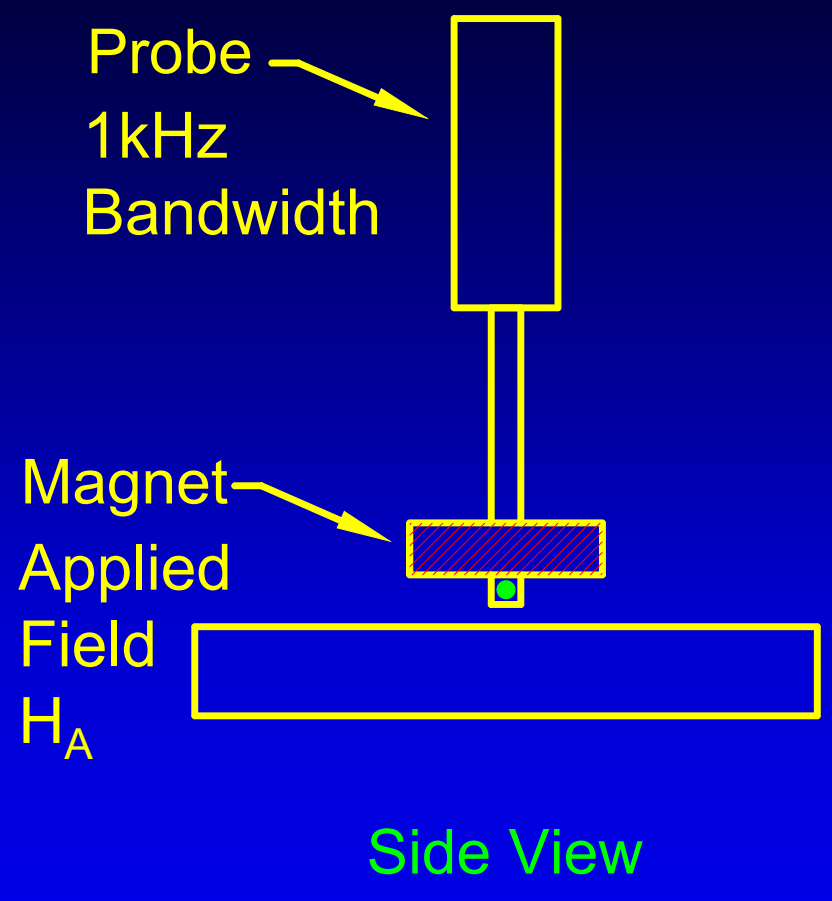
1. Remnant Field Experiments (H = 0).
   ***Focus On Variation Of In Plane Fields***.
   [Static (DC) Measurements.]
   - Thermal Chuck Off.
   - Thermal Chuck On.
     - T = 25 C, Scalar And Vector Measurements.
     - T = 40 C.
2. Field Measurements With Applied In Plane (H > 0).
   ***Focus On Search For Highly Permeable Magnetic Materials In The Chuck.*** [Static (DC) Measurements.]
   - Thermal Chuck Off.
3. AC Field Measurements ($H_A$ = 0) For Different Temperature Set Points.
   ***Focus On Current Induced Fields.***
   - Thermal Chuck Off.
   - $T_{\text{Set Point}}$ = 25 C.
   - $T_{\text{Set Point}}$ = 200 C.

# Chuck Characterization

4. Remnant Fields Revisited.
   ***Focus On Absolute Remnant Field Measurements, Remnant Fields After Application Of Large Magnetizing Force.***
   [Static (DC) Measurements.]
   - Absolute Field Away From The Chuck.
   - Absolute Field Near Center Of Chuck And Aux Stage.
   - Degaussing Experiments.

# Chuck Magnetic Characterization Set Up

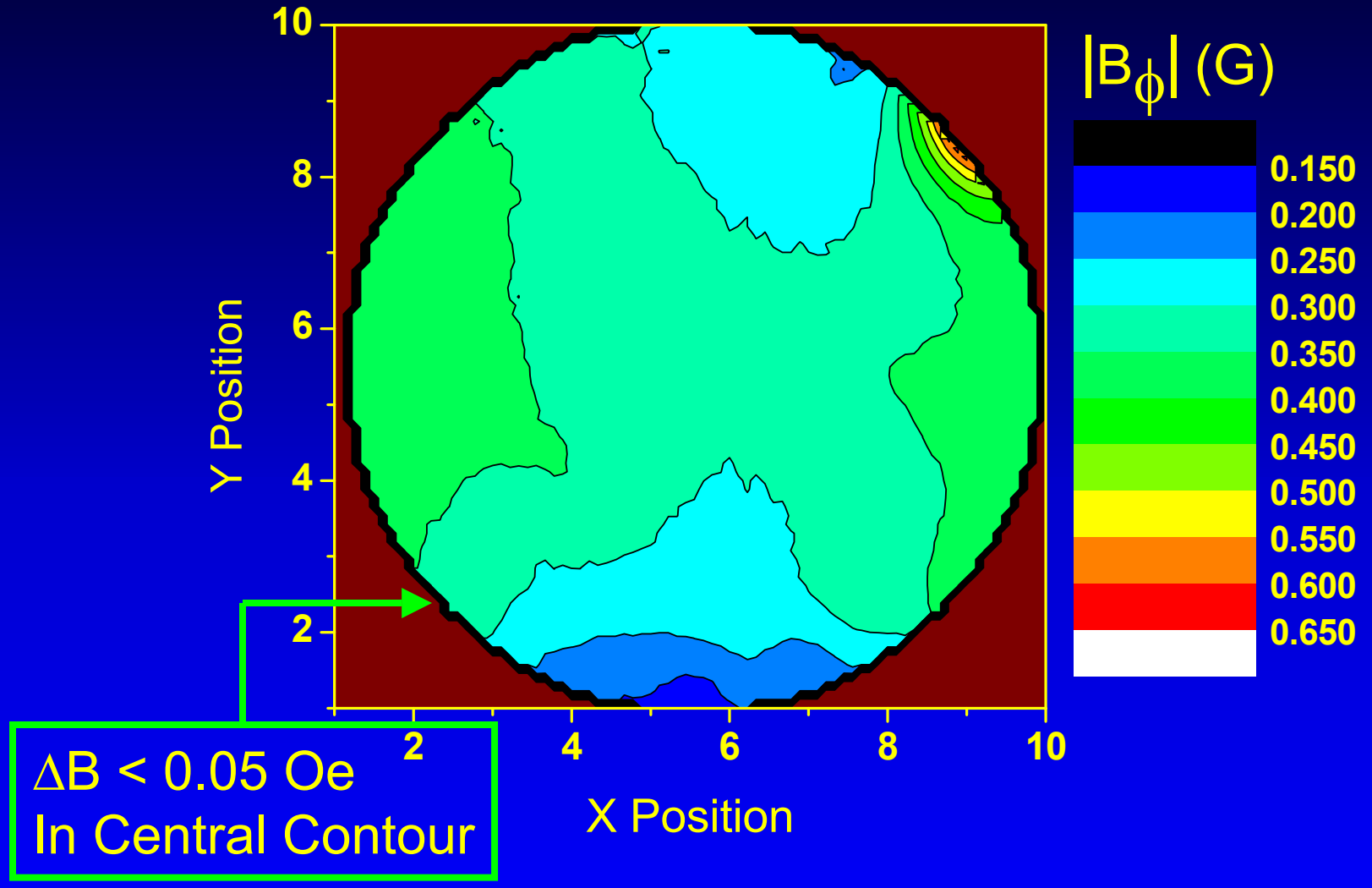



- Probe Hall Sensors Positioned Where Wafer Surface Would Be.
- Chuck Is Scanned In X &Y, Scan Step 2.5 mm.

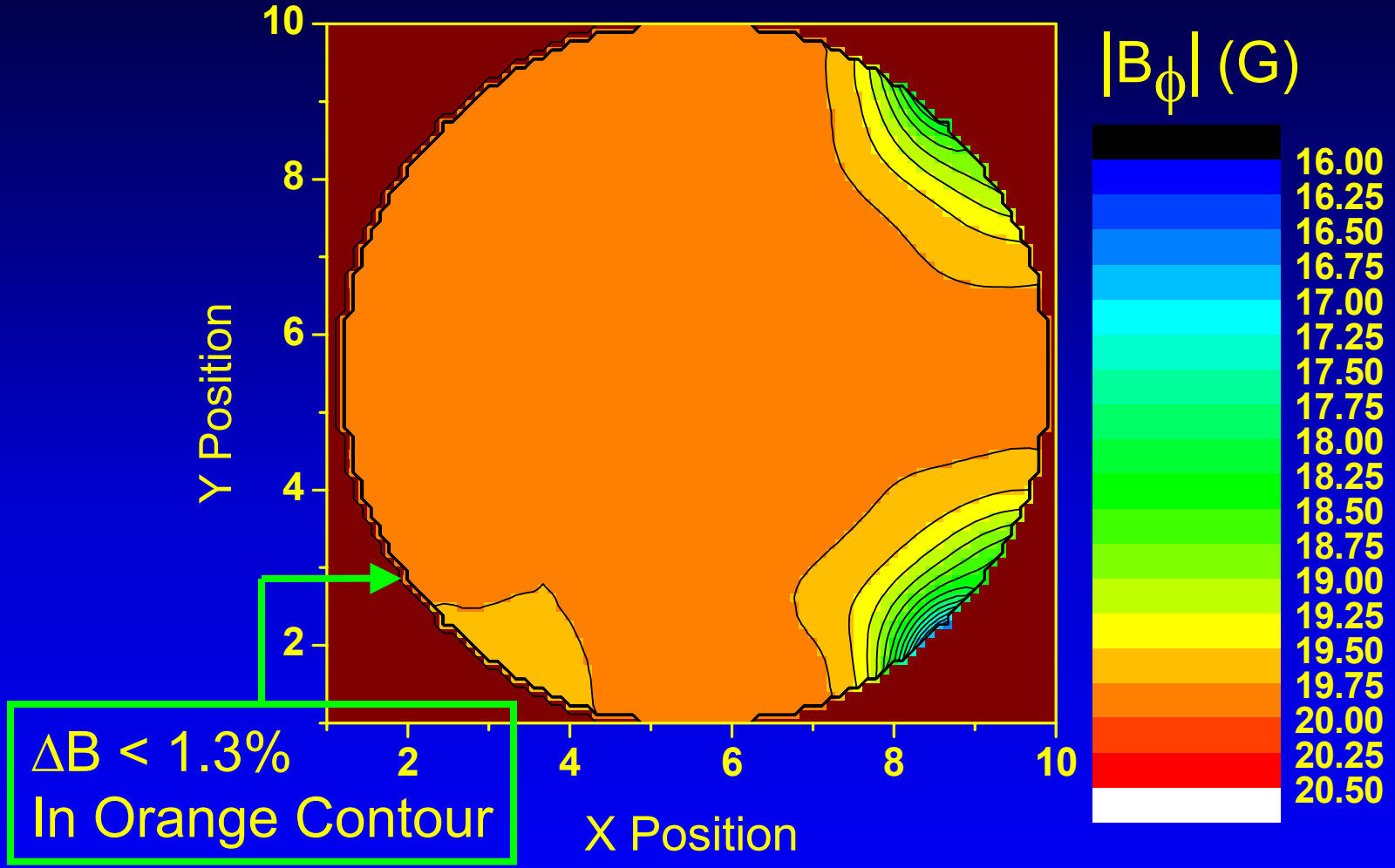
# Ambient Magnetic Field Of Chuck

Ambient Field, (Hx = Hy = 0), Thermal Unit Off



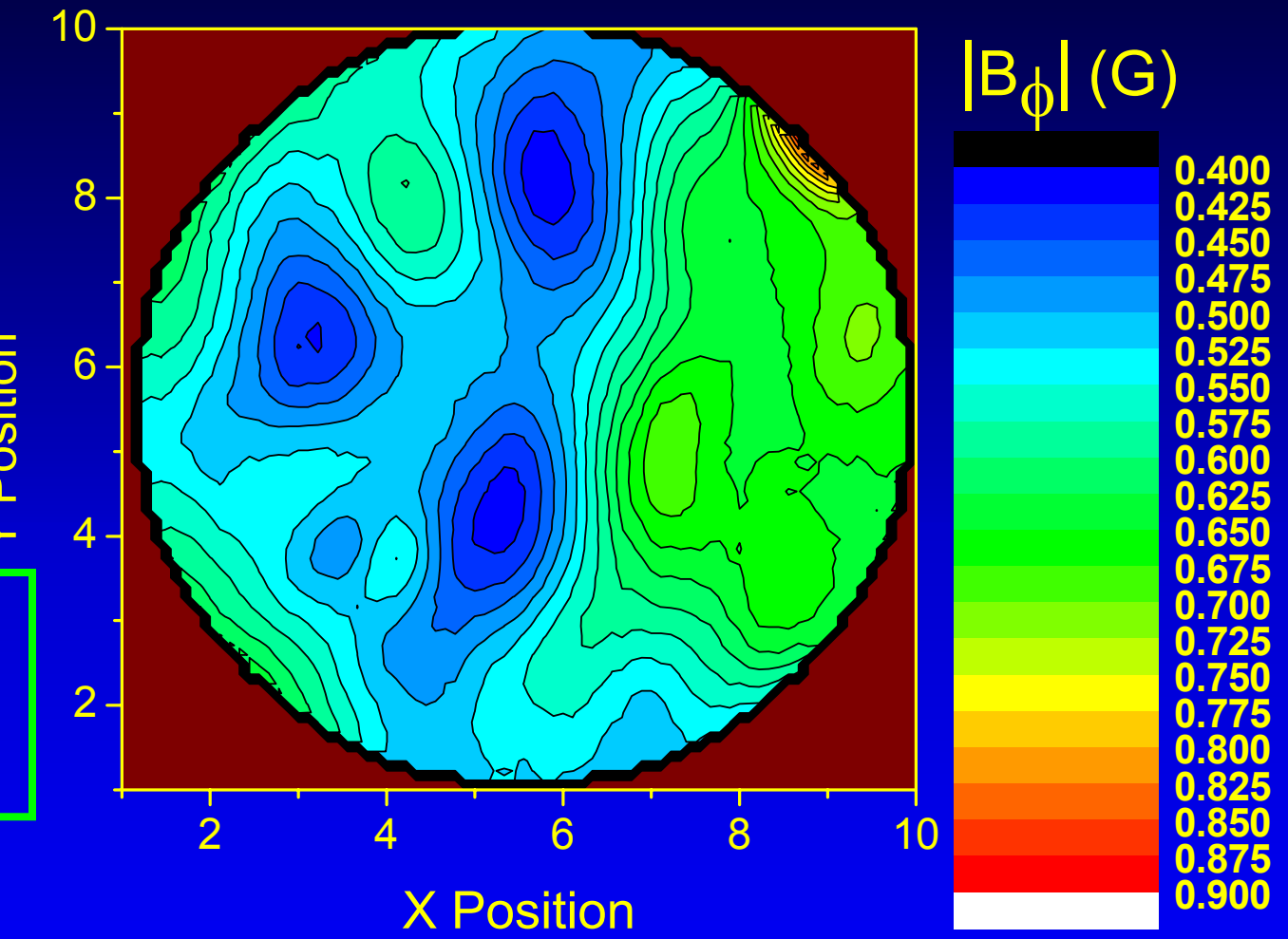
# Response To Applied Field

Applied Field, (Hx = 0, Hy = 19.9 Oe), Thermal Unit Off



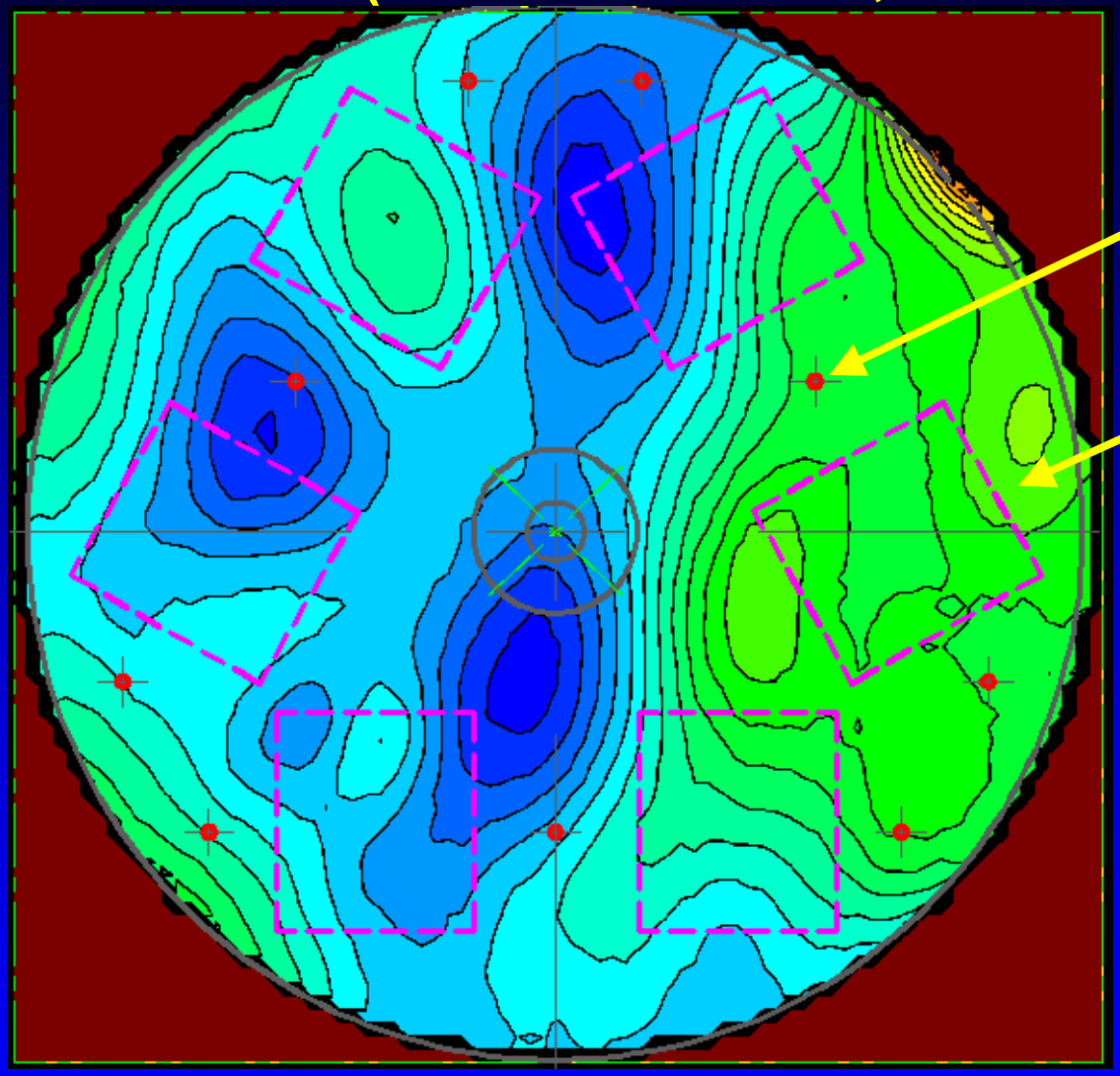
# Ambient Magnetic Field Of Chuck

Ambient Field, (Hx = Hy = 0), Thermal Unit On, T = 25C




Variation < 0.3 G Away From Aux Chucks

# Thermal Module And Screw Locations*
## (Thermal Unit On, T = 25 C)



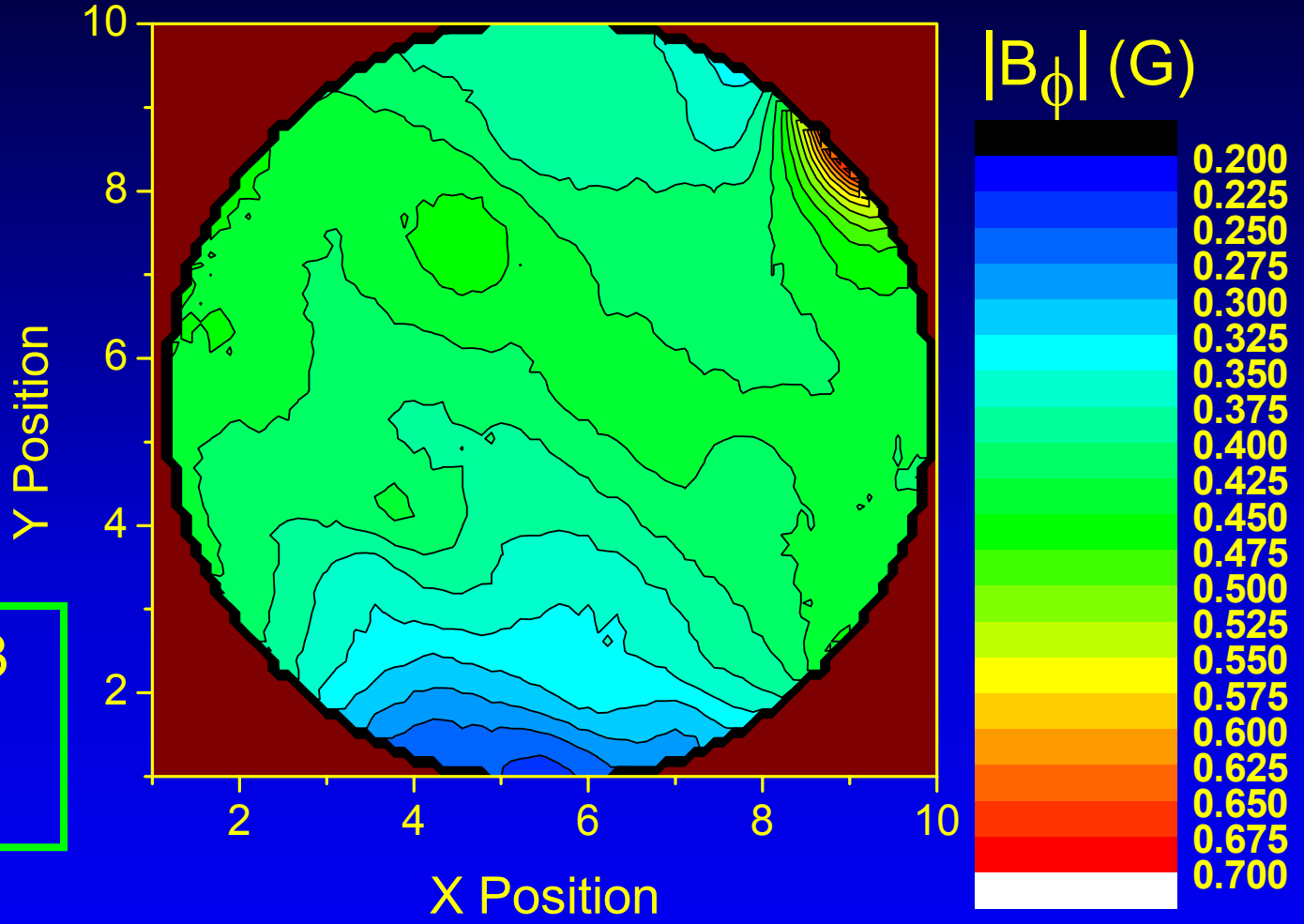
# 5-40 Screw

Thermoelectric Module

*** Courtesy Of *Temptronics Inc.***

# Ambient Magnetic Field Of Chuck

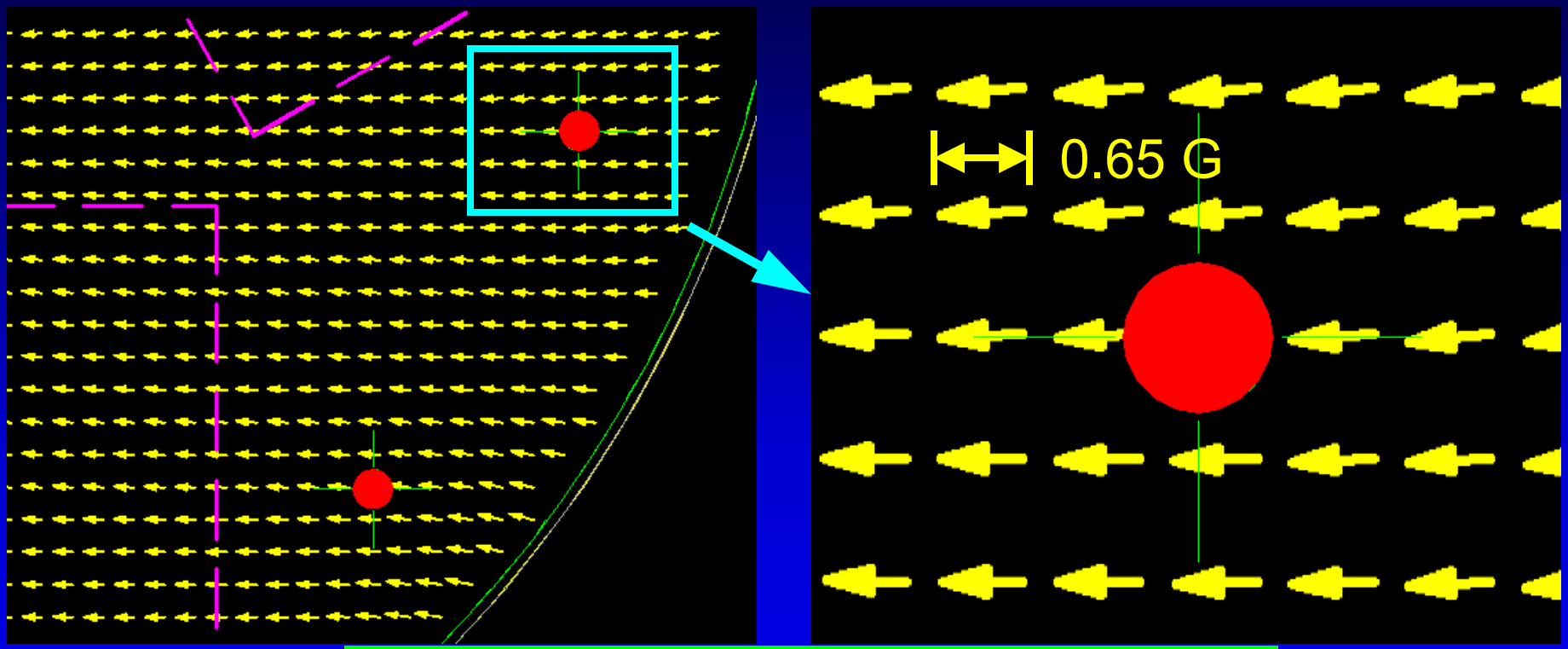
Ambient Field, (Hx = Hy = 0), Thermal Unit On, T = 40C




Variation < 0.3 G Away From Aux Chucks

# Vector Field Plot

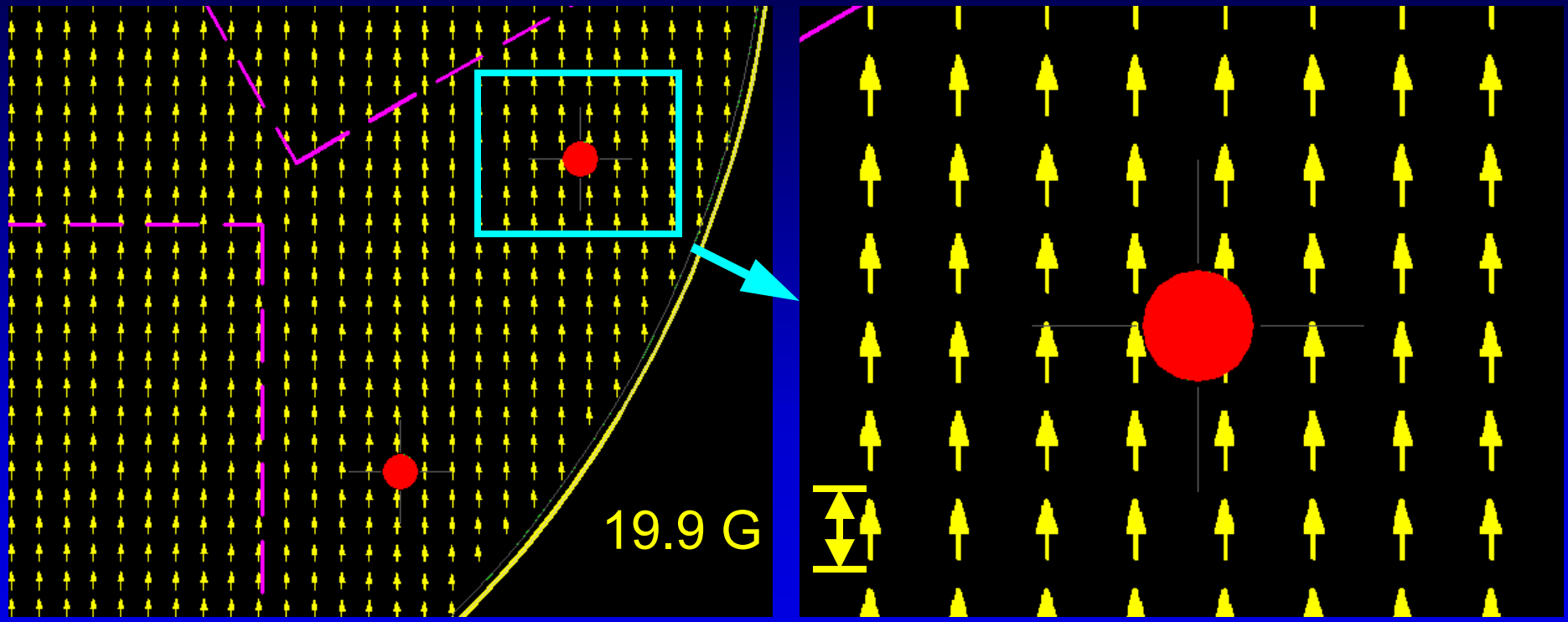
## Ambient Magnetic Field Of Chuck
## (Thermal Unit On, Ts = 25C)




Ambient Field Very Constant Both In Magnitude And Direction

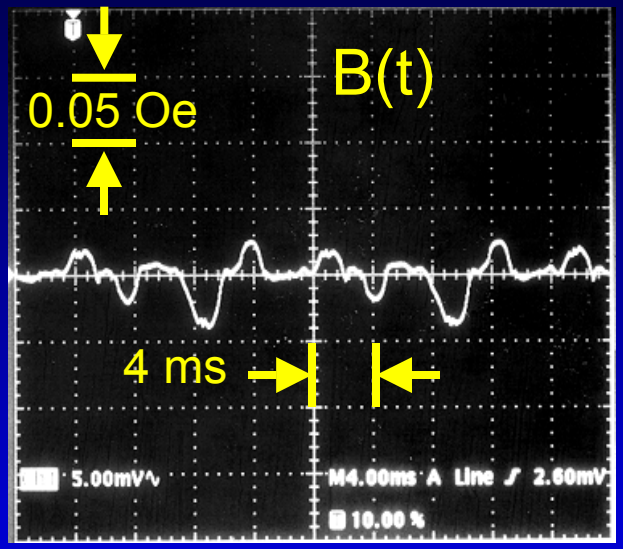
# Vector Field Plot

## Applied Field (Hx = 0, Hy = 19.9 Oe)
## (Thermal Unit Off)

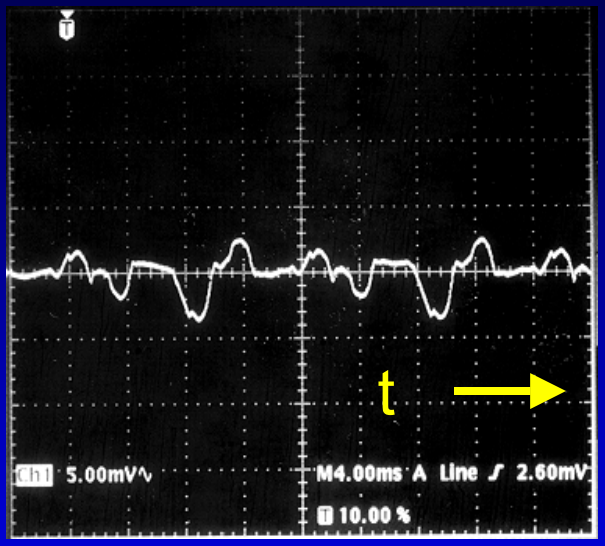



Almost No Distortion Of Applied Field Magnitude Or Direction Near Studs

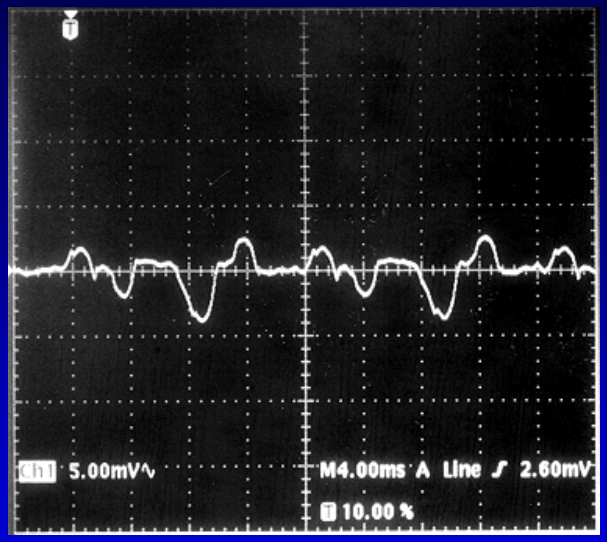
# AC Magnetic Field Characterization
## (Center Of Chuck)




Thermal Chuck Off



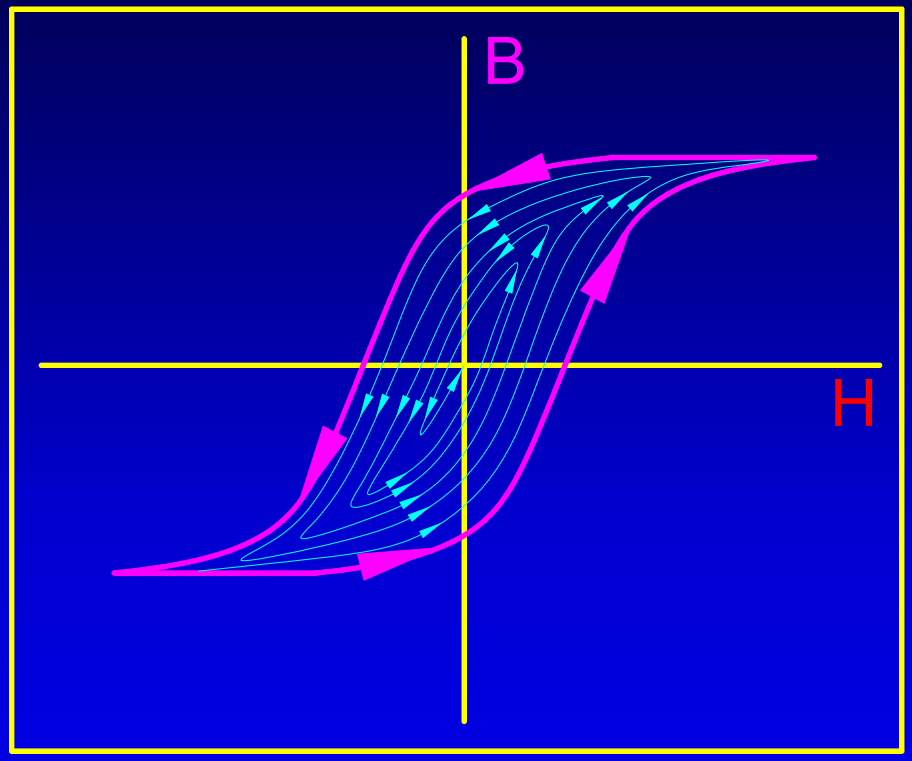

Thermal Unit On,
$T_{Set\ Point}$ = 25 C
$T_{Chuck}$ = 25 C

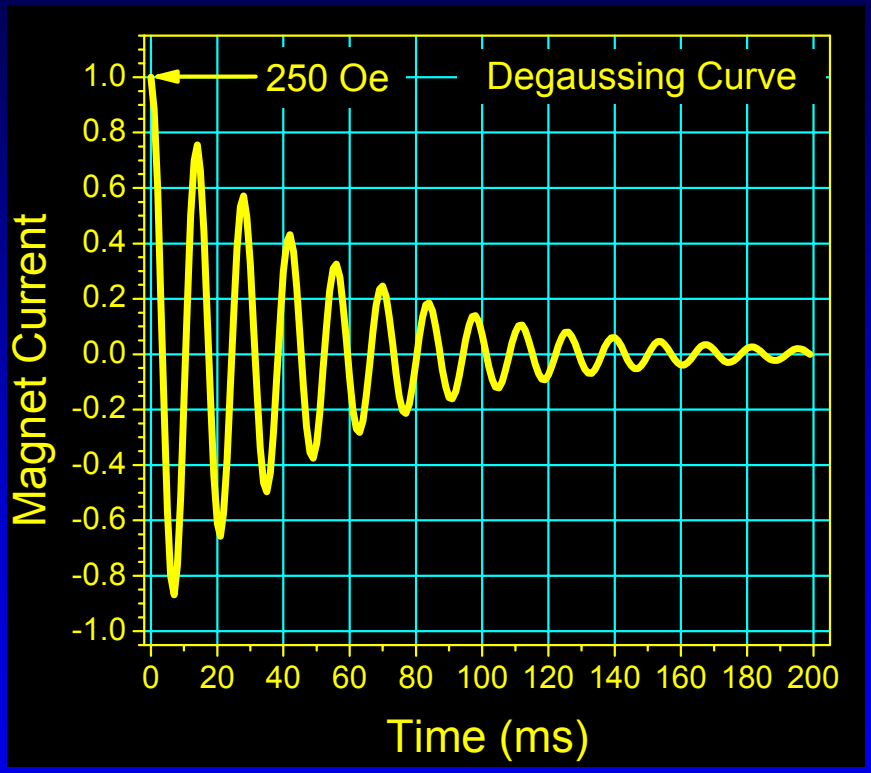



Thermal Unit On,
$T_{Set\ Point}$ = 200 C
$T_{Chuck}$ = 40 C

No Differences Observed

# Degaussing Procedure



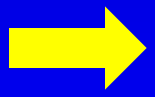
# Degaussing Experiments

## Measure Baseline Fields

1. Zero Probe In Zero Gauss Chamber.
2. Read Field In Lab Far From Probe Station: |B| = 0.34 G.
3. Read Field At Center Of Chuck: |B| = 0.35 G.
4. Read Field Near Aux Chuck: |B| = 0.35 G.

## Apply Hy = 250 Oe And Measure Remnant Fields

1. Read Field At Center of Chuck: |B| = 0.45 G. (Remnant Magnet?)
2. Degauss And Read Field At Center Of Chuck: |B| = 0.44 G.
3. Read Field Near Aux Chuck: |B| = 0.85 G.
4. Degauss And Read Field Near Aux Chuck: |B| = 0.5 G.



Application Of Large Fields Produced Some Remnant Offsets, Which Can Be Reduced By Degaussing.

# Conclusions

- Summit 12K Demonstrated Excellent Magnetic Performance For Demanding Analytical Studies Of MRAM Devices.
- Best Magnetic Performance Observed Near The Center Of The Chuck.
- Aux Stages Perturbed Applied Fields And Had Remnant Offsets, But The Stages Can Be Easily Removed Or Replaced With Parts Made From Non-magnetic Materials.
- Turning Thermal Unit On Did Not Significantly Degrade Magnetic Performance.
- Negligible AC Fields Detected.