Micromagnetic Analysis of Write Head Dynamics Using FASTMAG

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Goals

- **Modeling of realistic write heads**
  - Large aspect ratios, complex geometry
  - Wrap around Shield, trapezoidal pole, SUL
  - High switching rates

- **Study of magnetization dynamics**
  - Effects of mesh
  - Effects of shields

![Diagram showing disk motion, soft underlayer (SUL), and trailing-shield details.](image)
Write head geometry and materials

$M_s = 1270 \text{ emu/cm}^3$

$M_s = 1580 \text{ emu/cm}^3$

$M_s = 1425 \text{ emu/cm}^3$

$M_s = 1100 \text{ emu/cm}^3$

$M_s = 1900 \text{ emu/cm}^3$

$1.1 \mu m$

Shield and pole tip

Head configurations

Pole tip at ABS

Pole tip in the vertical cross-section

$3 \mu m$

$5 \mu m$

$5 \mu m$

$150 \text{ nm}$

$460 \text{ nm}$

$80 \text{ nm}$

$60 \text{ nm}$

$30 \text{ nm}$

$3000 \text{ emu cm}^3 \text{s}$

$1100 \text{ emu cm}^3 \text{s}$

$1580 \text{ emu cm}^3 \text{s}$

$1425 \text{ emu cm}^3 \text{s}$

$1900 \text{ emu cm}^3 \text{s}$
Outline

- Introduction

- Effects of Discretization

- Effects of the Shield

- Nudged Elastic Band Method

- Future Work
Effects of discretization: Mesh definition

- **Mesh 1 (M1)**
  - Surface of pole tip, nearby SUL and shield at ~7nm
  - The rest at ~150 nm

- **Mesh 2 (M2)**
  - Entire pole tip and shield at 12nm
  - SUL below shield at 24nm

- **Mesh 2, no shield (M2_{ns})**
  - Entire pole tip and shield at 12nm
  - SUL below shield at 24nm

- **Mesh 3 (M3)**
  - Entire SUL at 24 nm
  - The rest at 45nm

- **Mesh 4 (M4)**
  - The rest at 24nm

<table>
<thead>
<tr>
<th>Mesh</th>
<th>NODES</th>
<th>Tetrahedrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>83,000</td>
<td>283,000</td>
</tr>
<tr>
<td>M2</td>
<td>156,000</td>
<td>552,000</td>
</tr>
<tr>
<td>M2_{ns}</td>
<td>75,000</td>
<td>296,000</td>
</tr>
<tr>
<td>M3</td>
<td>1,000,000</td>
<td>5,300,000</td>
</tr>
<tr>
<td>M4</td>
<td>4,000,000</td>
<td>23,000,000</td>
</tr>
</tbody>
</table>
Effects of discretization: Magnetization

Effects of discretization: Fields

- **Coil current**
  - Rate: 1 Gbit/s
  - Rise time: 250 ps
  - No overshoot
  - Current: 50 mA

- **Fields**
  - Rise time: 360ps
  - Delay: 350ps

- **Mesh dependence**
  - Delay
  - Amplitude
FastMag: Recording head simulations

- **Coil current**
  - Rate: 2 Gbit/s
  - Rise time: 125 ps
  - 100% overshoot
  - Current: 50 mA

- **Fields**
  - Rise time: 150 ps
  - Delay: 223 ps

- **Mesh dependence**
  - Delay & amplitude
  - Stronger dependence

Diagram showing the variation of magnetic field ($H_z$, [kOe]) with time (ns) for different coils (M2, M3, M4) and a coil designation. The graph demonstrates the impact of different mesh configurations on the magnetic field characteristics, with some coils showing stronger dependence.
Effects of shields: Fields

- **Coil current**
  - Rate: 1 Gbit/s
  - Rise time: 250 ps
  - No overshoot
  - Current: 50 mA

- **Shield dependence**
  - Different amplitude
  - Similar rise time and delay

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The diagram shows the comparison between fields with and without a shield, with coil current parameters.
Outline

- Introduction
- Effects of Discretization
- Effects of the Shield
- Nudged Elastic Band Method
- Future Work
Effects of shields: No shield case

- Gradients
  - At 12 nm below ABS
  - Downtrack: 165 Oe/nm
  - Crosstrack: 120 Oe/nm
Effects of shields: Domain walls

- **Gradients**
  - At 12 nm below ABS
  - Downtrack: 265 Oe/nm
  - Crosstrack: 170 Oe/nm

- **Adjacent track erasure**
  - Substantial fields (up to 3 kOe)
  - Asymmetry
Effects of shields: Domain walls

- **Far track erasure**
  - Domain walls move near and far from the tip
  - DWs depends on the initial state, switching signal, and switching rate
  - Fields generated by the DWs can be substantial, up to 3 kOe
Summary

- Study of magnetization dynamics
  - Effects of mesh at 1Gbps and 2 Gbps
  - Effects of shields at 1Gbps and 2 Gbps