HDD Opportunities & Challenges, Now to 2020

Seagate

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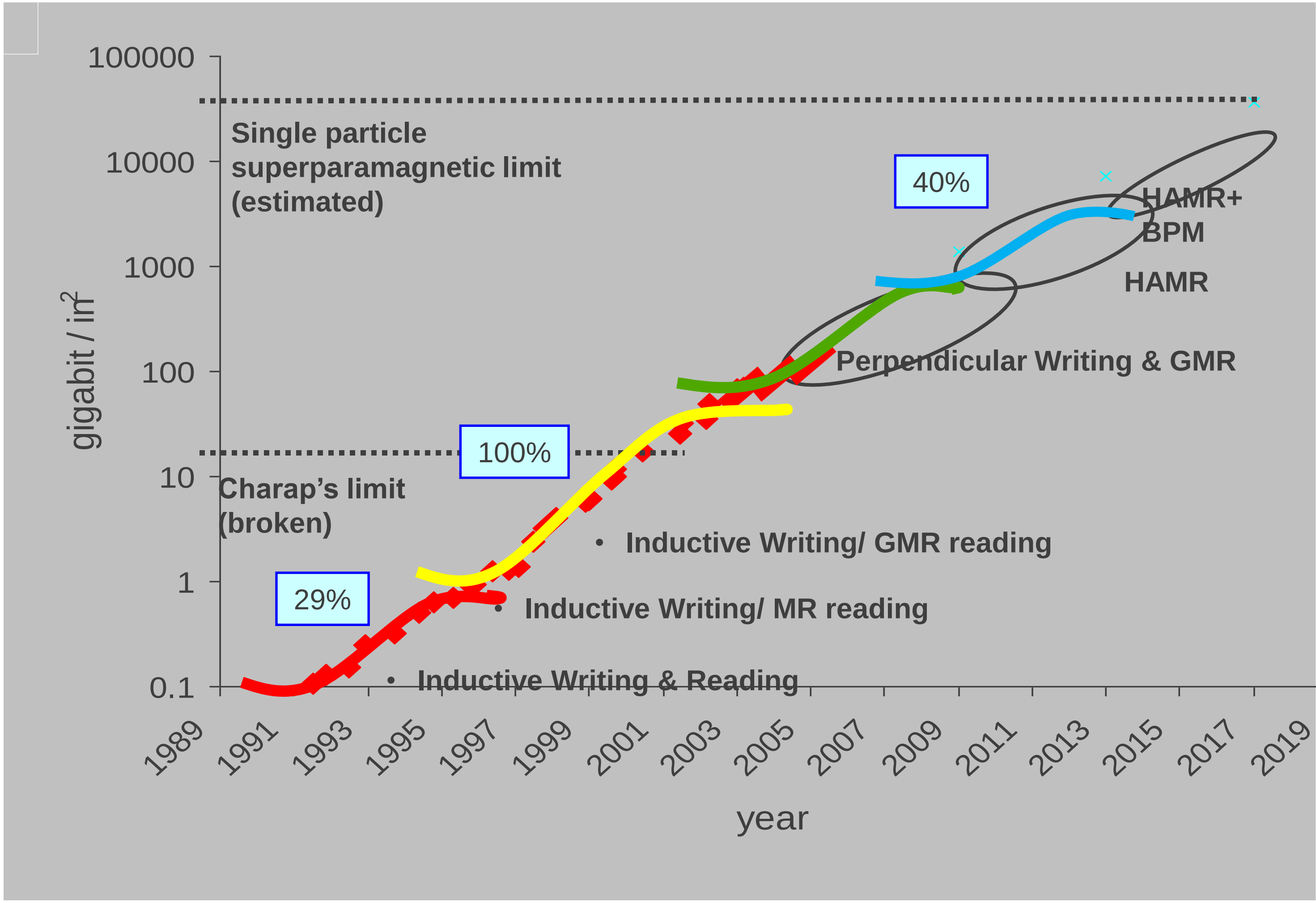
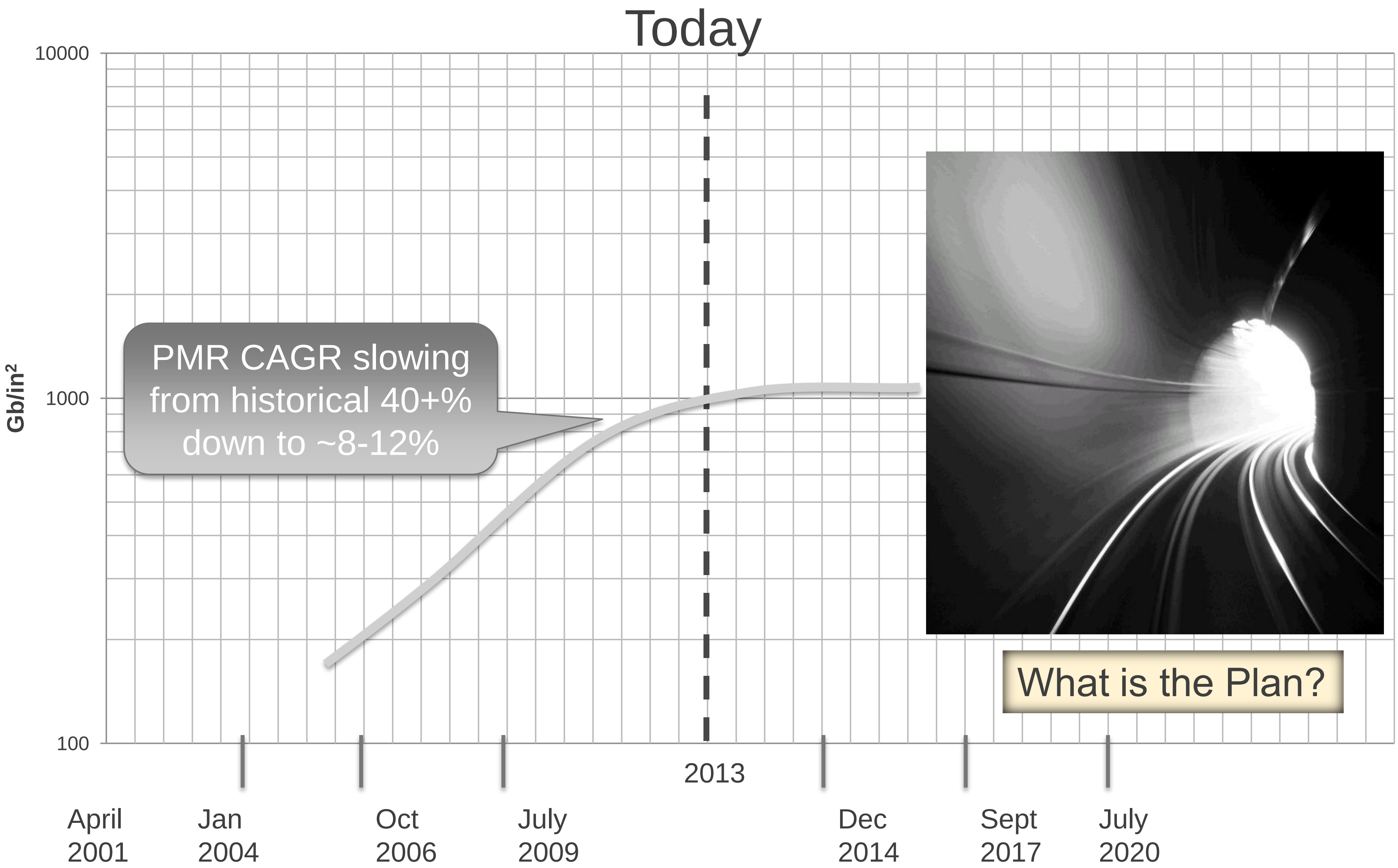
Areal Density Growth

- **Areal Density CAGR 40%**
- **Transfer Rate CAGR 20%**

- **Late 1990s – super paramagnetic limit demonstrated through modeling**
- **Perpendicular expected to extend to 0.5-1 Tb/in²**
- **Additional innovations required at that point**
  - **heat-assisted recording**
  - **bit patterned media recording**



Areal Density Trends



Exabyte Growth Over the Last 5 Years

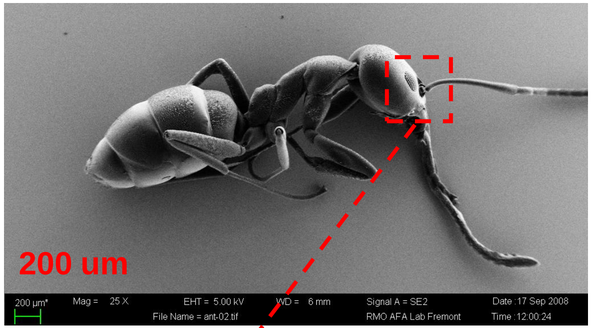
Averaged ***40%*** per Year

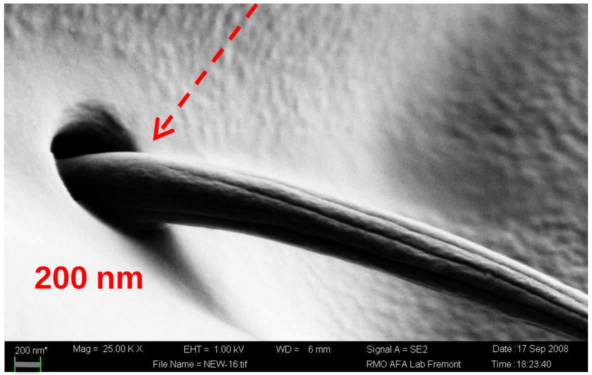
While Areal Density Is

Growing at only ***<10%*** per Year

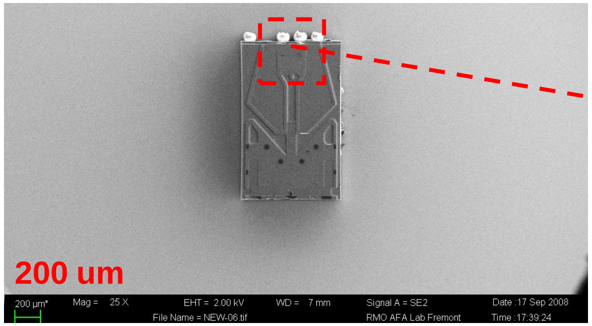
Source: Seagate Strategic Marketing and Research 2013

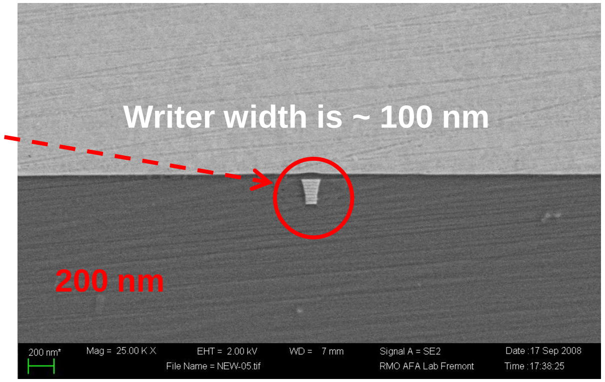
Particle Trends





A Recording Head under SEM

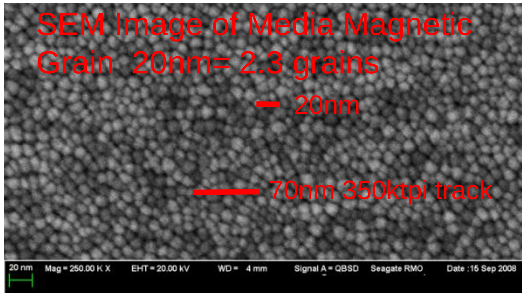




Media magnetic grain is ~9-10 nm diameter

Today's data bit is ~ 25 nm wide.

Critical magnetic and contamination features are nm scale.



100 Gb/in² — **0.20 x 0.032 μm, 130 ktpi x 800 kbpi**

1 Tb/in² — **50 nm x 12.7 nm, 500 ktpi x 2,000 kbpi**

2 Tb/in² — **38 nm x 8.5 nm, 660 ktpi x 3,000 kbpi**

We are here

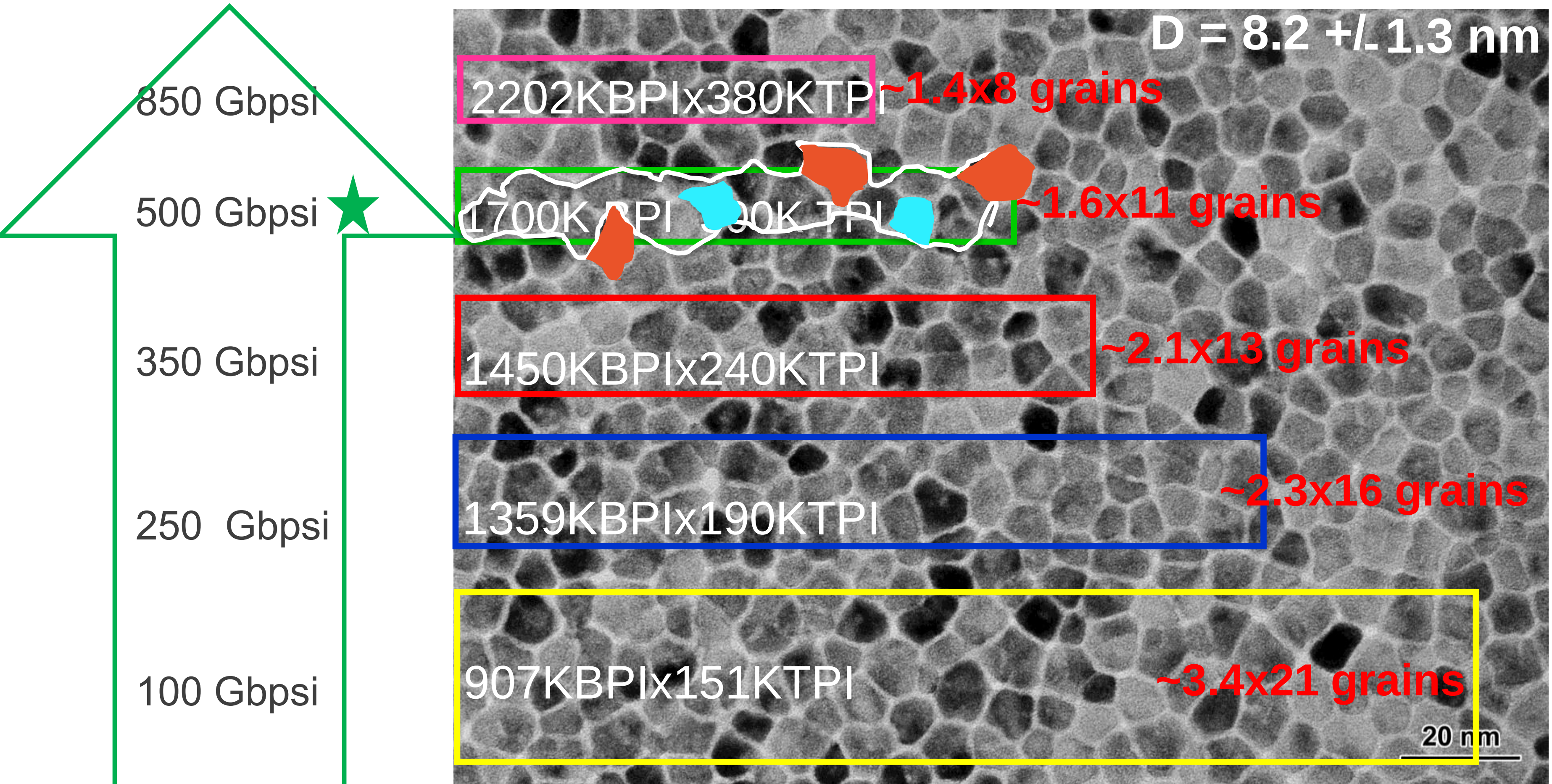
300K TPI
1700K BPI
≈500 Gb/in2

Recording Bit Scaling

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

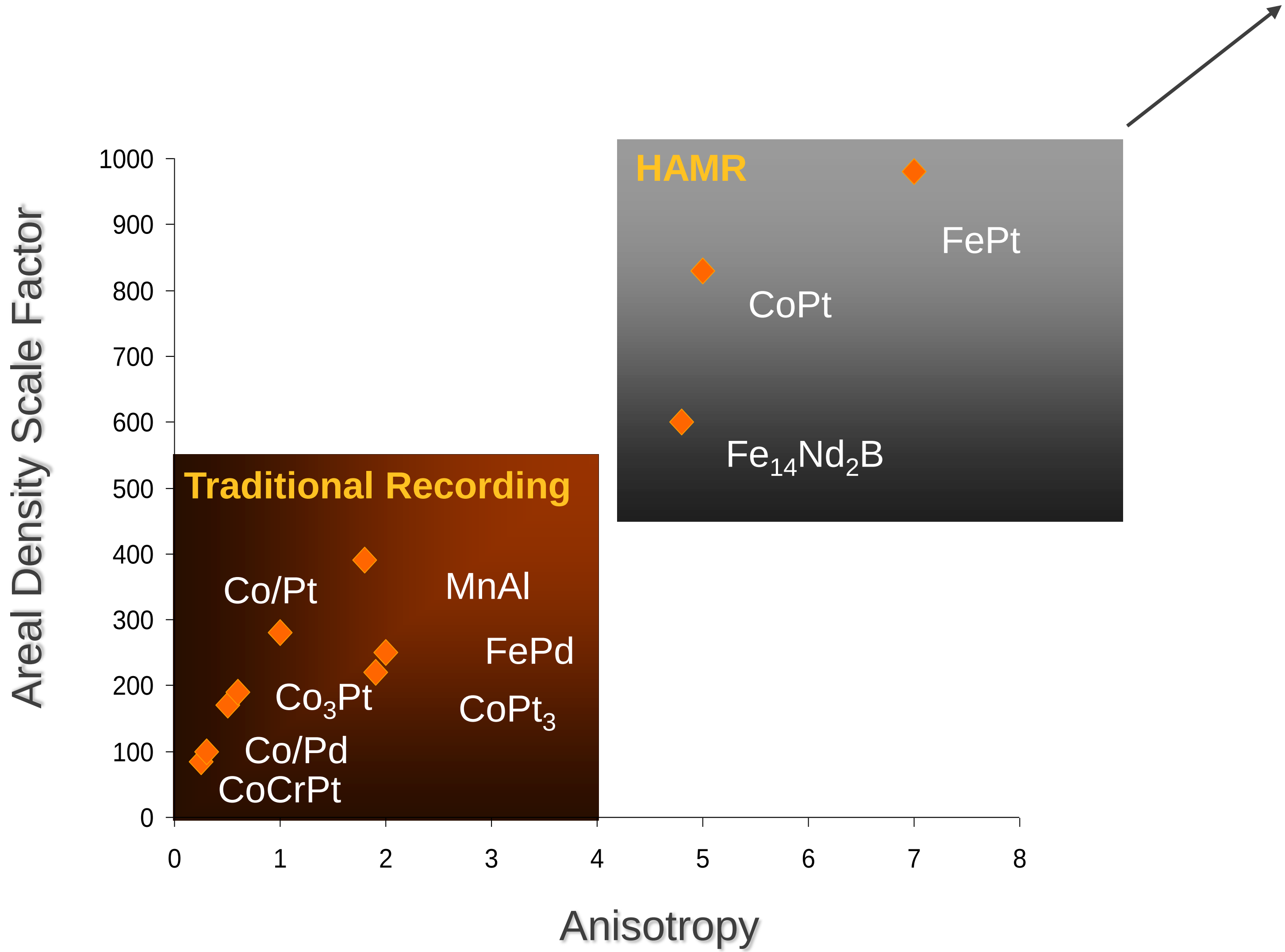
1 Tb/in²

2,000 kbpi x500 ktpi

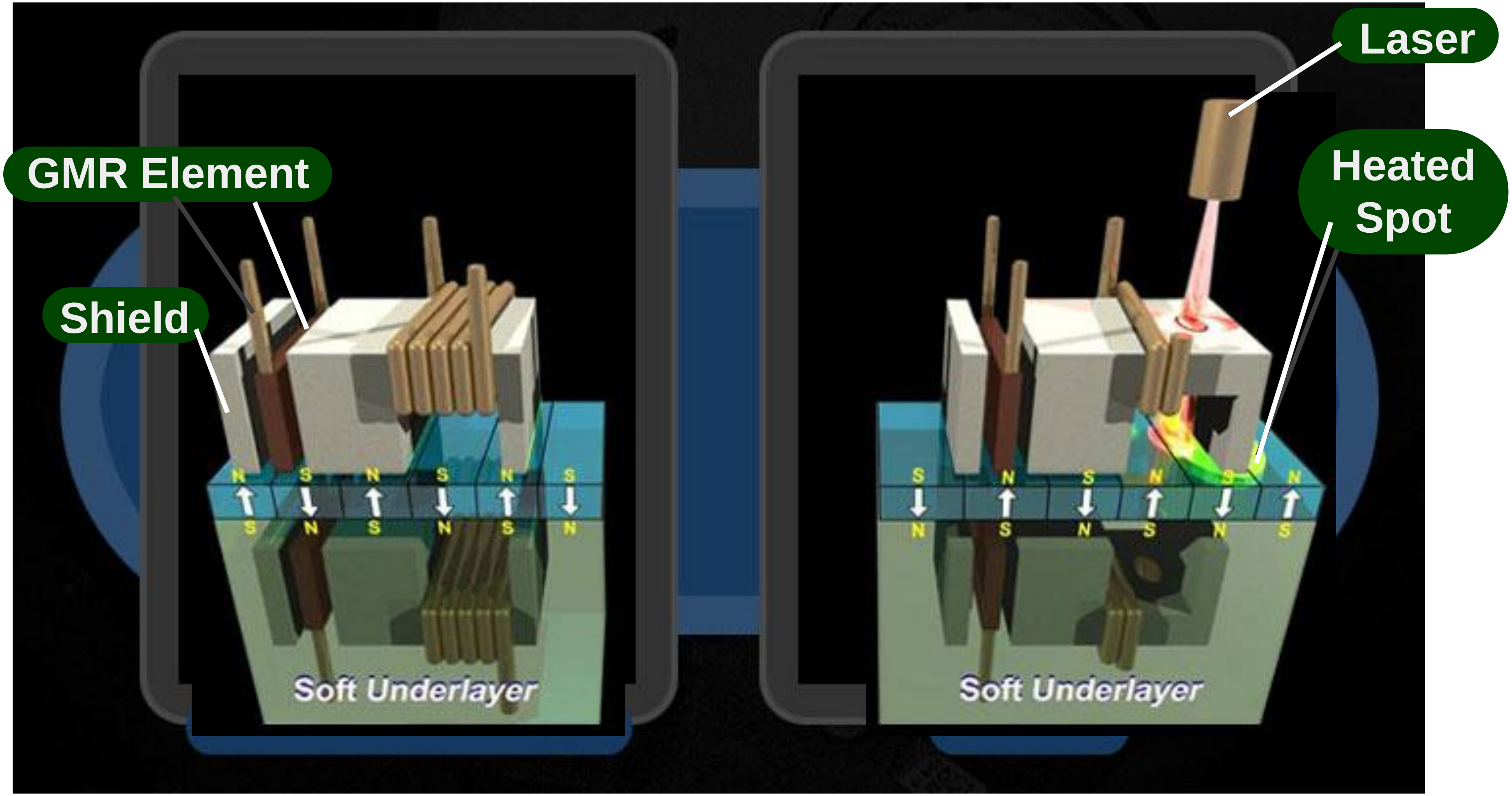


Decreasing Bit Size→ Increase Areal Density

Materials for Higher AD



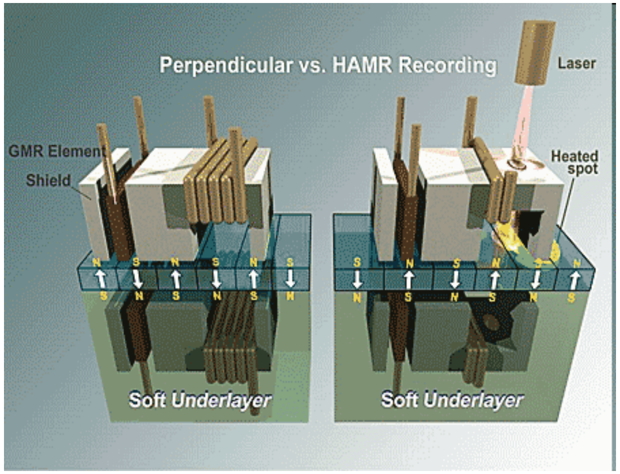
Heat Assisted Magnetic Recording (HAMR)

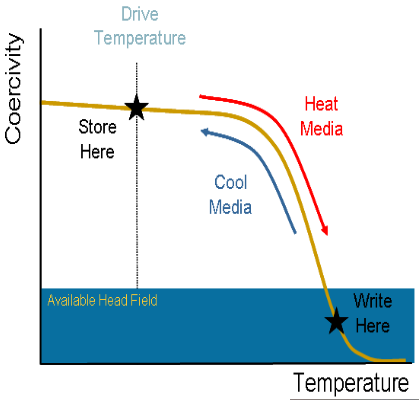


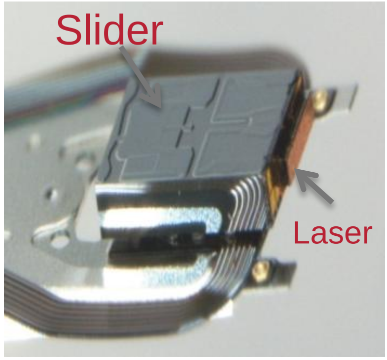
Perpendicular Recording **HAMR**

Heat Assisted Magnetic Recording (HAMR) Technology

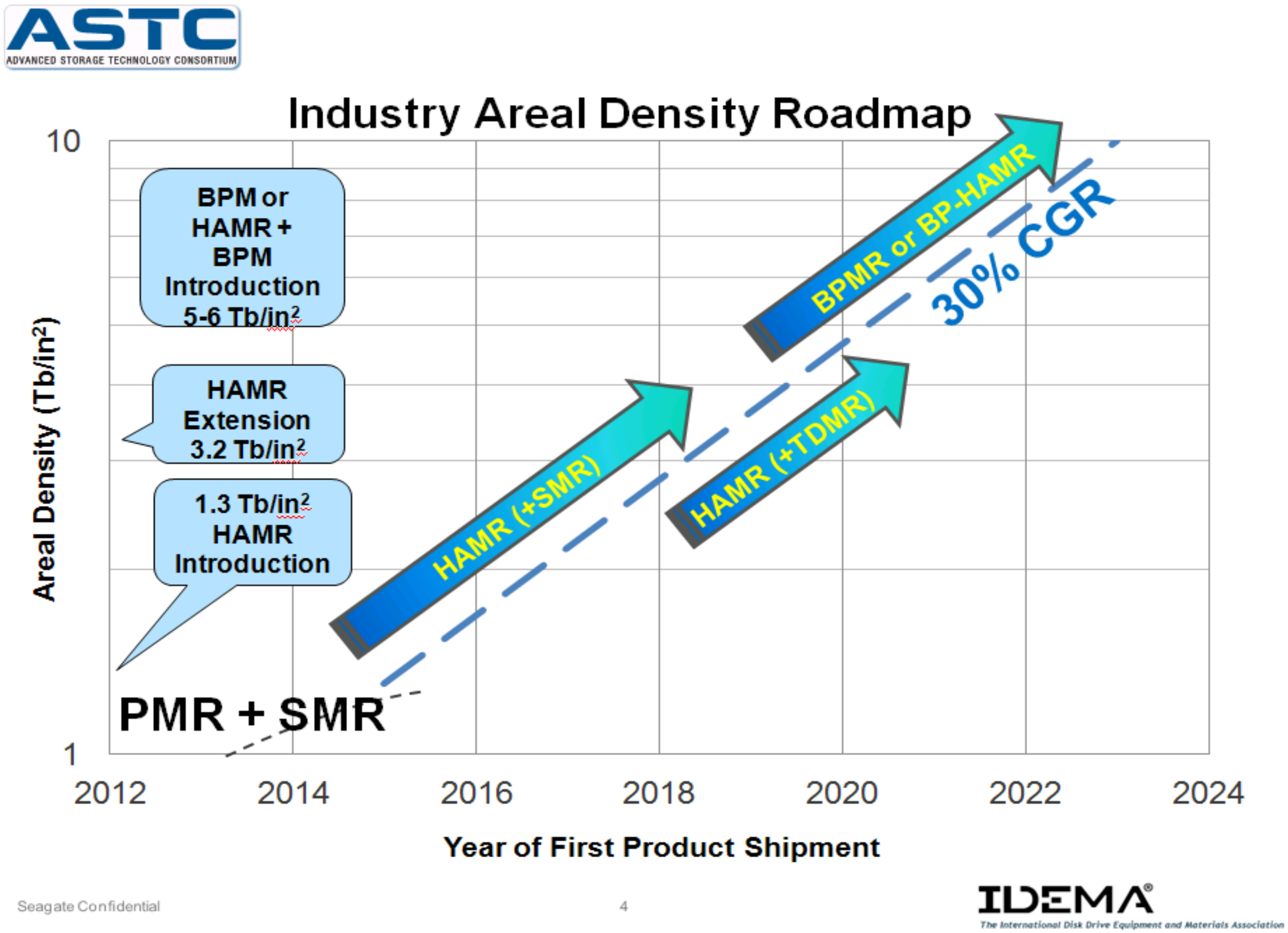
- HAMR takes advantage of magnetic media materials with higher thermal stability to push out the onset of the superparamagnetic effect limiting Perpendicular Magnetic Recording (PMR) technology used in current hard disk drives.
- These magnetic materials with higher thermal stability are heated with a tiny laser spot for just long enough to write the magnetic data bits, allowing smaller bit sizes and therefore higher areal densities and capacities than conventional PMR technology.
- A laser is integrated into the HAMR recording head.
- Seagate demonstrated HAMR areal density of 1 Tbit/in^2 in March 2012.
- Seagate CEO Steve Luczo gave a presentation to Wall Street analysts using a fully functional HAMR drive on Sept. 21, 2012.
- PMR technology is likely limited to ~1 Tbit/in^2, HAMR is thought to push that limit to ~5 Tbit/in^2
- Market introduction of drives using HAMR technology is currently envisioned for 2015/2016.







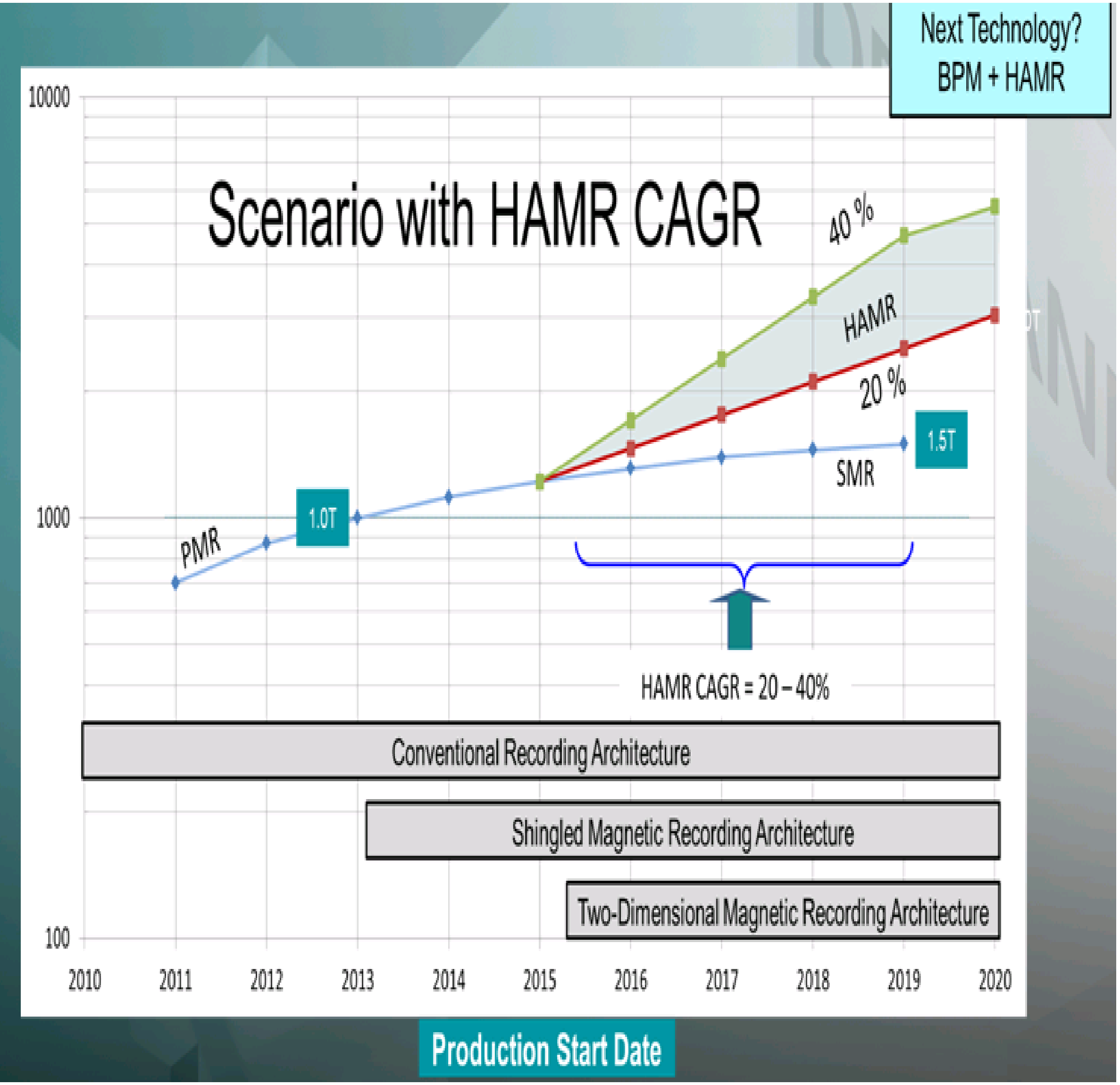
ASTC Technology Roadmap



Technology **Alignment**:

1. Industry (ASTC) and Seagate staged for HAMR Technology
2. Bit Patterned Media (BPM) post HAMR introduction

Head/Media Technology Focus



Component Technology **Strategies**:

1. PMR Extension & Shingled Magnetic Recording (SMR)
2. HAMR/Extension
- 2015-2016 Product Introduction
- 20-40% CAGR
3. BPM+HAMR

Conclusion

- Worldwide need for storage continues to grow and there is no viable alternative to HDDs in sight to meet this demand

- To address the slowing areal density growth, HDD technology roadmap and component strategy includes:
  - Extending Head/Media perpendicular recording technologies
  - Productizing shingled magnetic recording (includes new Writer Design & Media optimizations)
  - Introduce HAMR technology (integrated laser on head heats media)