One Terabyte and beyond

The technology for high capacity serpentine recording

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THIC Inc.

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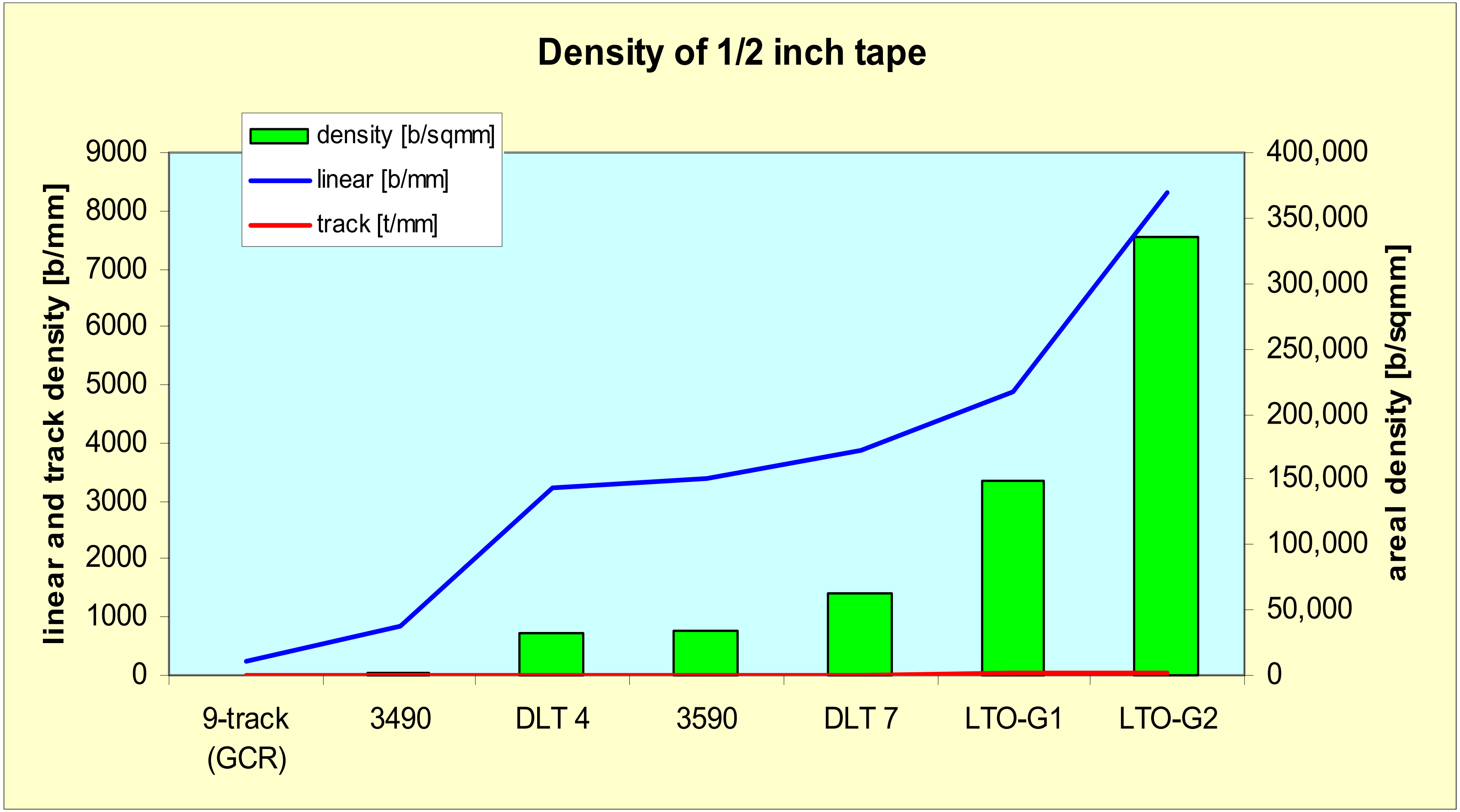
Recording density of ½ inch tape

- Recording density of ½ inch tape below 0.4Mb/mm²
  - User capacity about 60% - 70% of recording capacity
- For 1 TB cartridge capacity: ~ 1Mb/mm²
- MEII technology: increase above 10 Mb/mm²

Areal density of ½ inch tape



Capacity increase

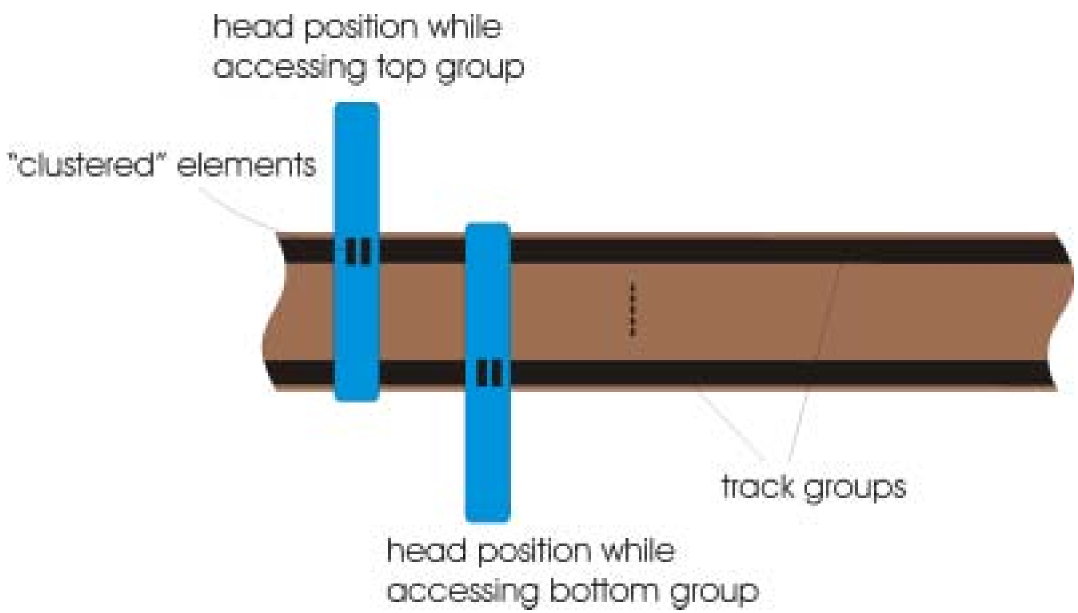
- Future capacity increase will come from several sources
  - Increase in track density
    - Track density about 1/300 of linear density
  - Increase in linear density
  - Increase in tape length
    - Tape thickness is currently 7 μm
    - Future: 5 μm and below
      - Tape length ~1km with 5 μm
- Increase in track density is important for future capacity increase

Increasing the capacity

- With improvements of current technology capacity may approach 1TB
- To go beyond 1TB an enabling technology is required

Obstacles

- Decrease in track width requires very fast frequency response of the actuator
  - Mass of head imposes limits
  - Mass of heads increased because of "clusters"
    - Length of head ≈ 2x tape width



Obstacles

- Flying height of tape over head difficult to control
  - Two major parameters for flying height:
    - Winding tension
      - Decreases with thinner tape
      - ~ 0.5N for 7 μm thick tape
    - Tape speed
      - Increases for faster transfer rate

Obstacles

- Number of passes to access all data on tape is increasing
  - Number of tracks on tape is increasing faster than number of simultaneously accessed tracks
  - Currently ~ 100 passes
  - Future > 1,000 passes
  - Tape wear and contamination is increased
    - Contamination critical with high density recording

Obstacles

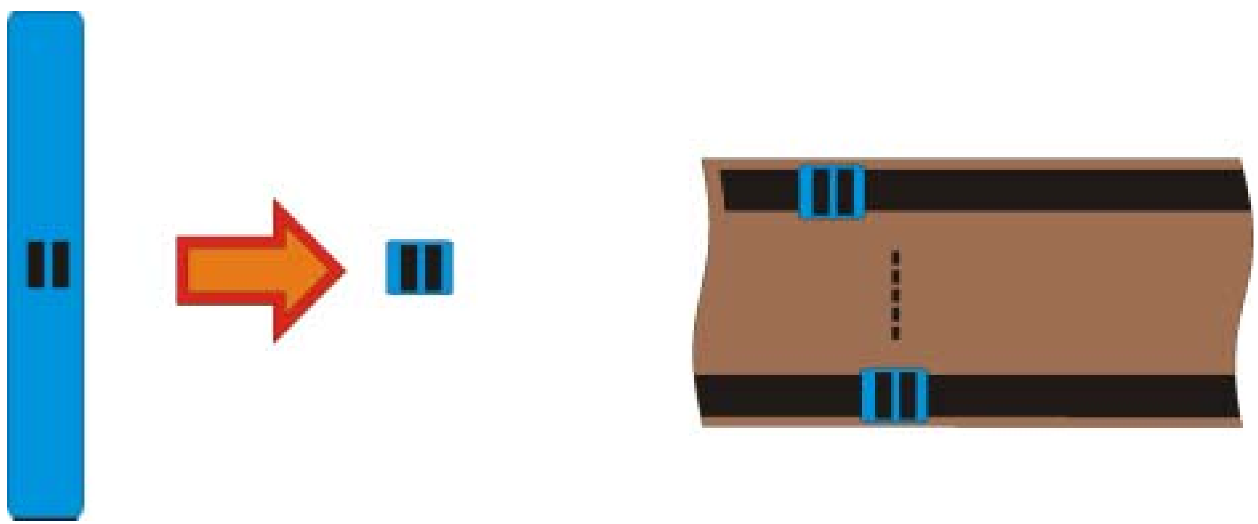
- Biggest obstacles to increase recording density in tape drive
  - Bit errors caused by contamination
  - Errors caused by mis-registration (TMR)
  - Loss of signal caused by tape/head separation

MEII Technology

- Technology to solve all three problems
  - Contamination caused by high number of passes
  - Low mass head for fast track following
  - Tight control of flying height

MEII Technology

- Traditional system: tape flies over head
  - Large, rigid head with one degree of freedom
- MEII technology: head flies over tape
  - Small, movable head
  - Length of head << tape width

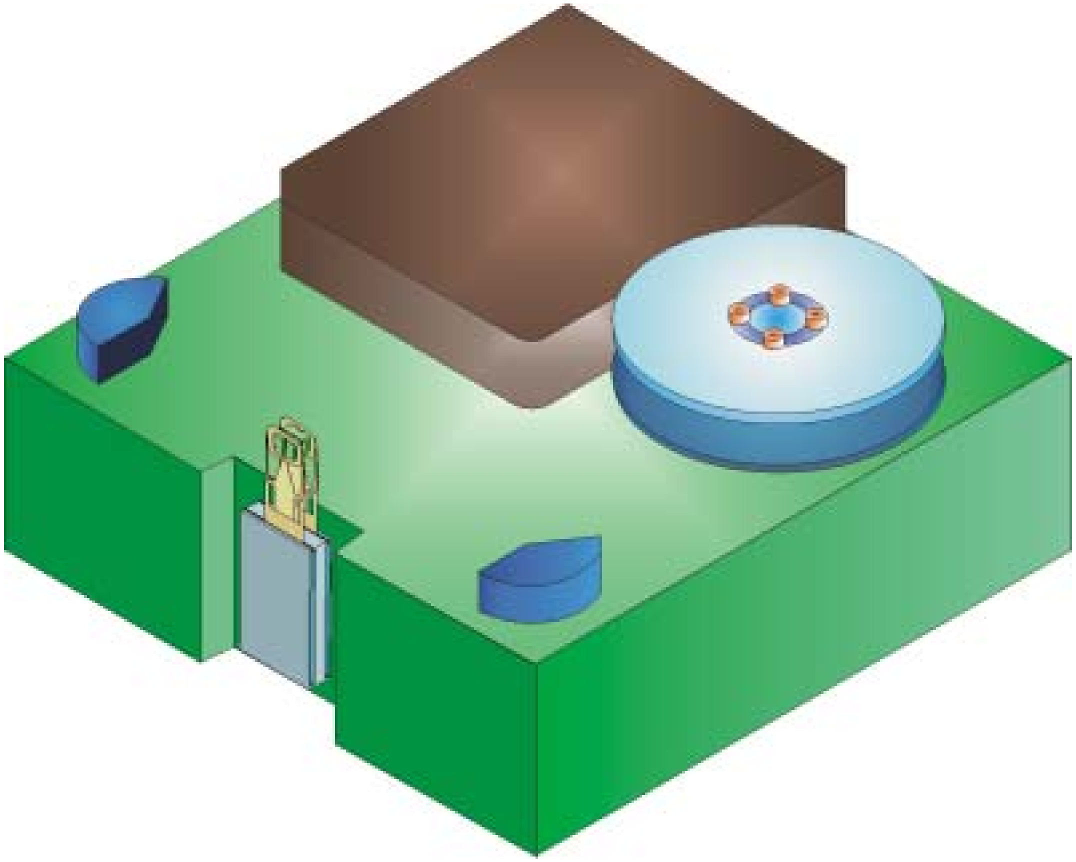


MEII Technology

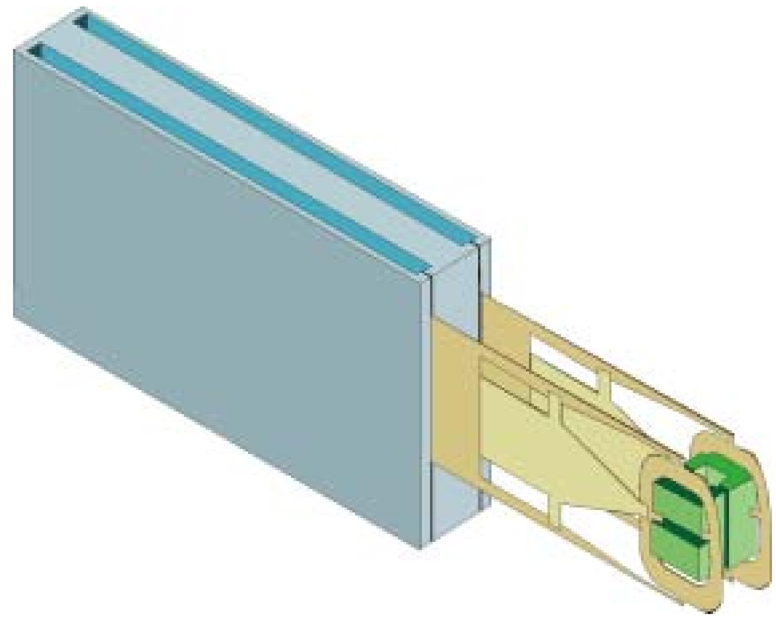
- MEII technology
  - Head to tape contact only in groups that are accessed
    - Number of head-tape passes is reduced
  - Small head
    - Length of head << tape width
    - Low mass – less than 1g
  - Control of flying height
    - Flying height is independent of tape tension
    - Flying height can be controlled

Implementation 1

- ½ inch cartridge tape drive
- Dual arm actuator



Actuator and head

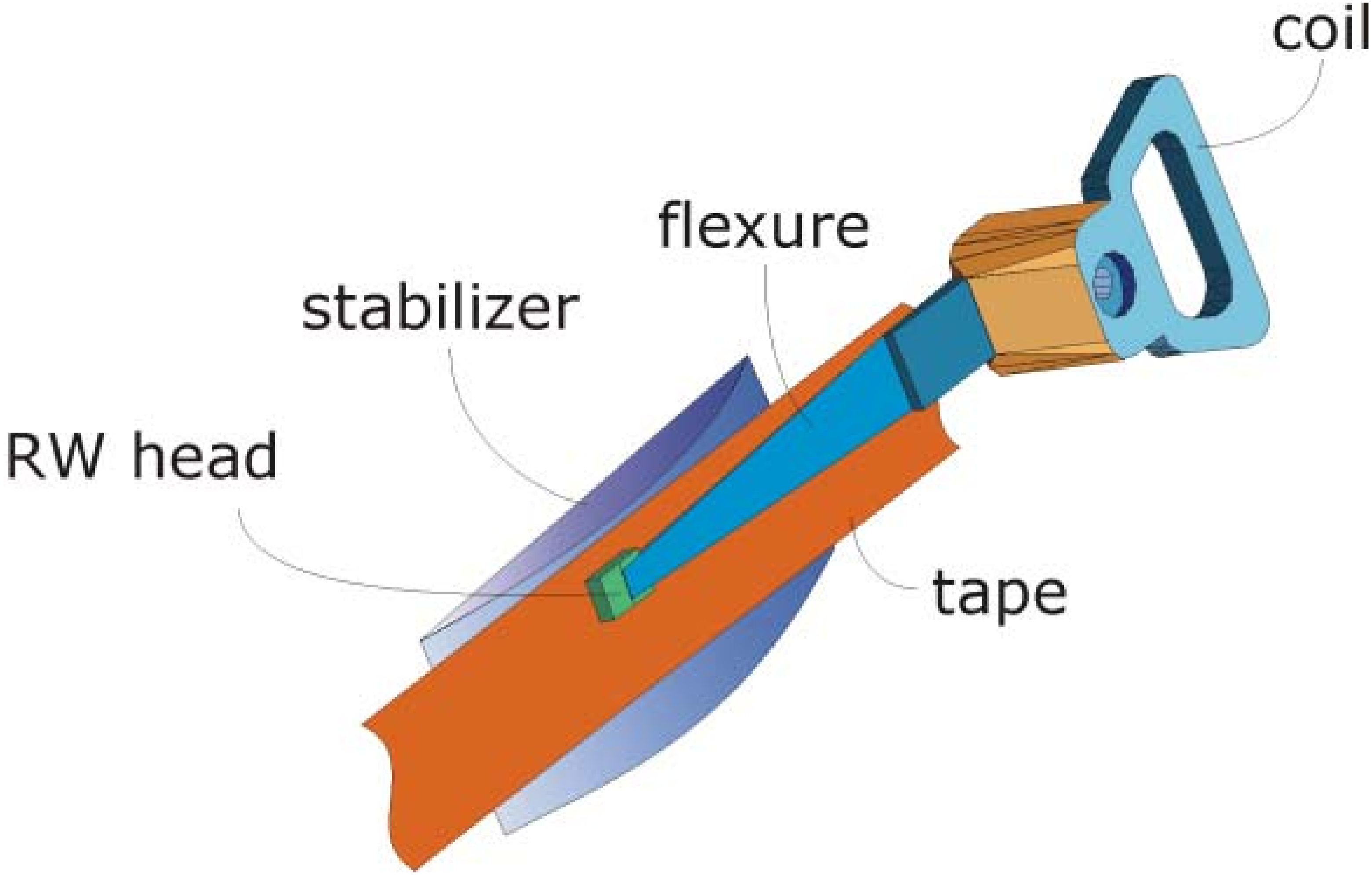


- Head is mounted on flexure
- Flexure on opposite side of tape has opposing surface
- Flexure force controls flying height
- Opposing surface can be replaced by second head
  - Dual sided recording requires modification of tape

Advantages

- Compatible with existing formats
  - LTO
  - SDLT
- Possibility of dual side recording
- Maximum track density
  - With current tape and head: 5,000 tpi
    - 5 μm track pitch
  - With modified tape and head: 20,000 tpi
    - 2,5 μm track pitch
    - Dual sided tape

Implementation 2



Implementation 2

- Lower, balanced mass
- Electronics (write driver, read pre-amp) can be mounted on arm
- Maximum track density
  - With current tape and head: 5,000 tpi
    - 5 μm track width
  - With modified tape and head: > 50,000 tpi
    - Sub-μm track width

Implementation 2

- Recording at a small azimuth
- Very fast track following
- Requires stabilizer
- Single sided or dual sided

Development tasks

- Technology is “borrowed” from disk industry
  - Using disk technology in tape has many advantages
  - Adaptation of disk technology to tape is challenging

Development tasks

- Head
  - Smaller track width
  - Carrier
  - Contour
- Actuator
  - Loading mechanism
  - Control of force to counteract flying height

Development tasks

- Tape
  - Dual sided
    - Magnetic imprint between layers
    - Inner layer friction
- Tape path
  - Improved guiding (control of lateral tape movement)
  - Improved tape handling
- Servo
  - Improved pre-written servo band
  - Improved tension control

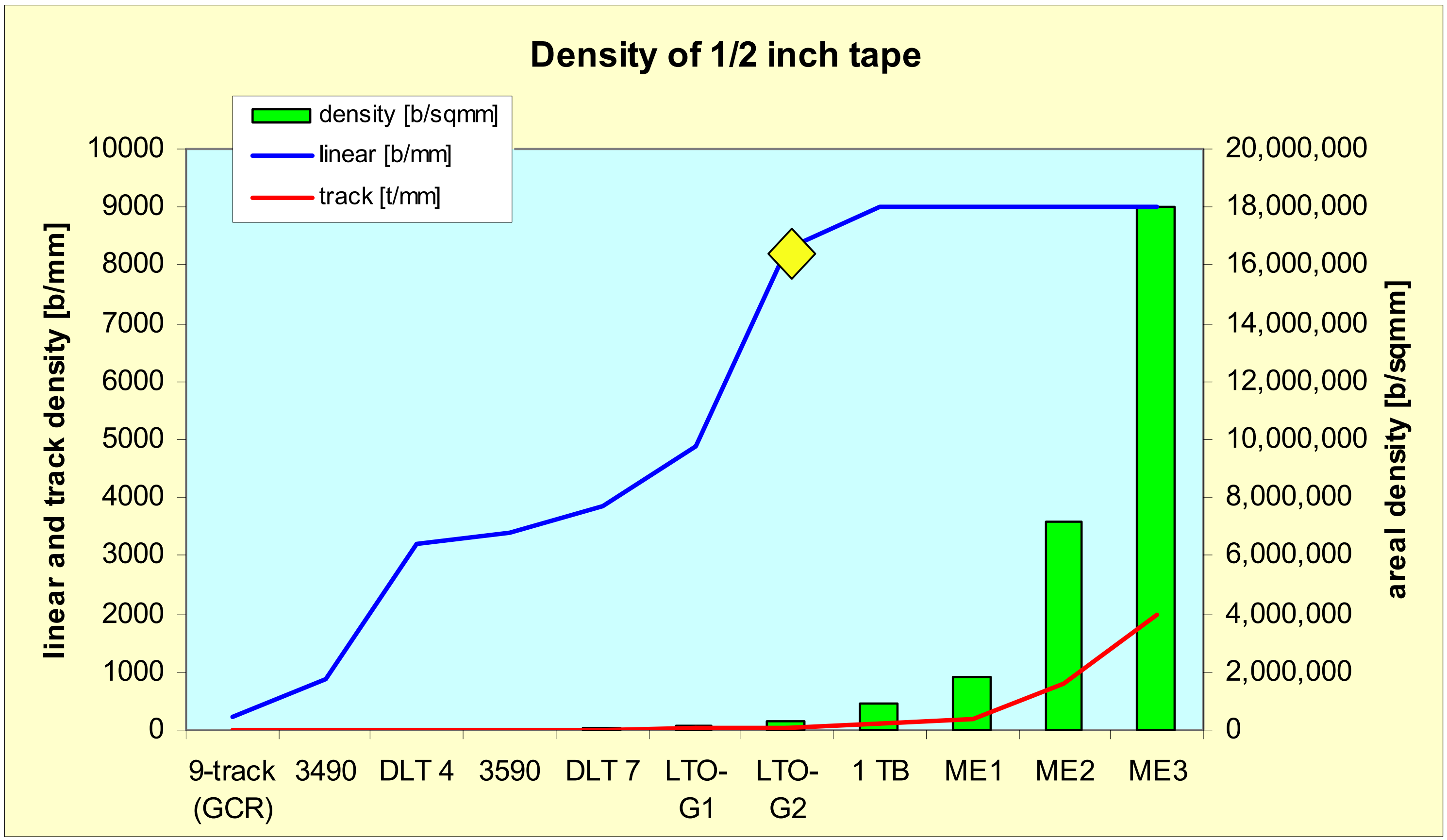
Development steps

- Step 1
  - 5 μm track width, single sided, actuator 1
  - 2 Mb/mm^2
- Step 2
  - 2.5 μm track width, dual sided, actuator 1
  - 7 Mb/mm^2
- Step 3
  - 1 μm track width, dual sided, actuator 2
  - >15 Mb/mm^2

Areal density of future ½ inch tape

- Assumptions
  - Increase of linear density to 9,000 b/mm (~10% increase above LTO)
  - Tape length 800 m (~ 30% increase)
- 1TB ~1 Mb/mm^2
- ME1 2 Mb/mm^2
- ME2 7 Mb/mm^2
- ME3 >15 Mb/mm^2

Areal density of future ½ inch tape



Status

- Technology not new
  - Bernoulli drives
  - Disk drives
- Technology new for tape

  Technology modifications
  - Testing
- Goal: First implementation in 2004

Tape is alive

- Primary function of tape will be archive
  - High volumetric capacity
  - Low cost
  - Very high reliability
- By adopting disk technology tape will stay ahead of disk