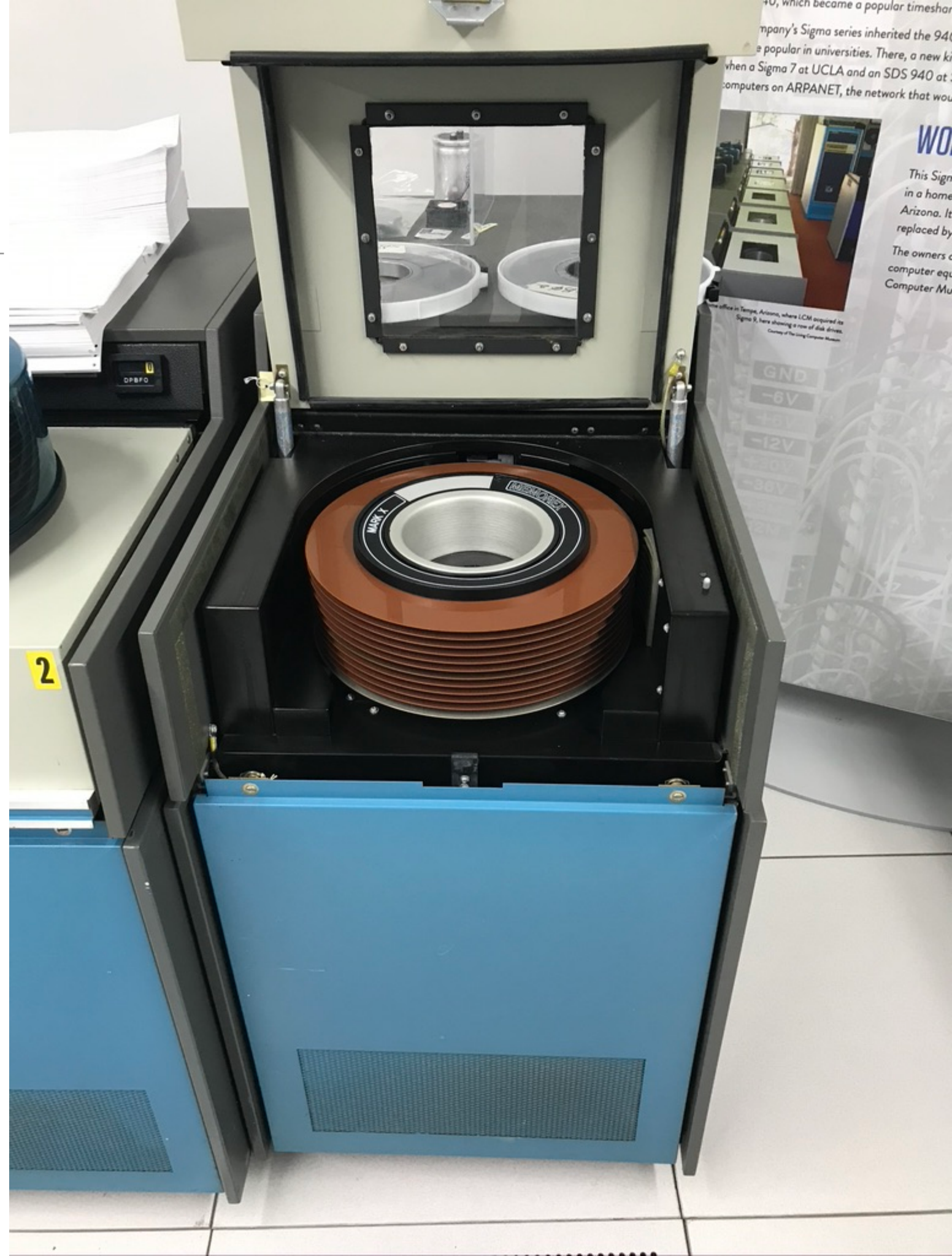


Quantum electronics

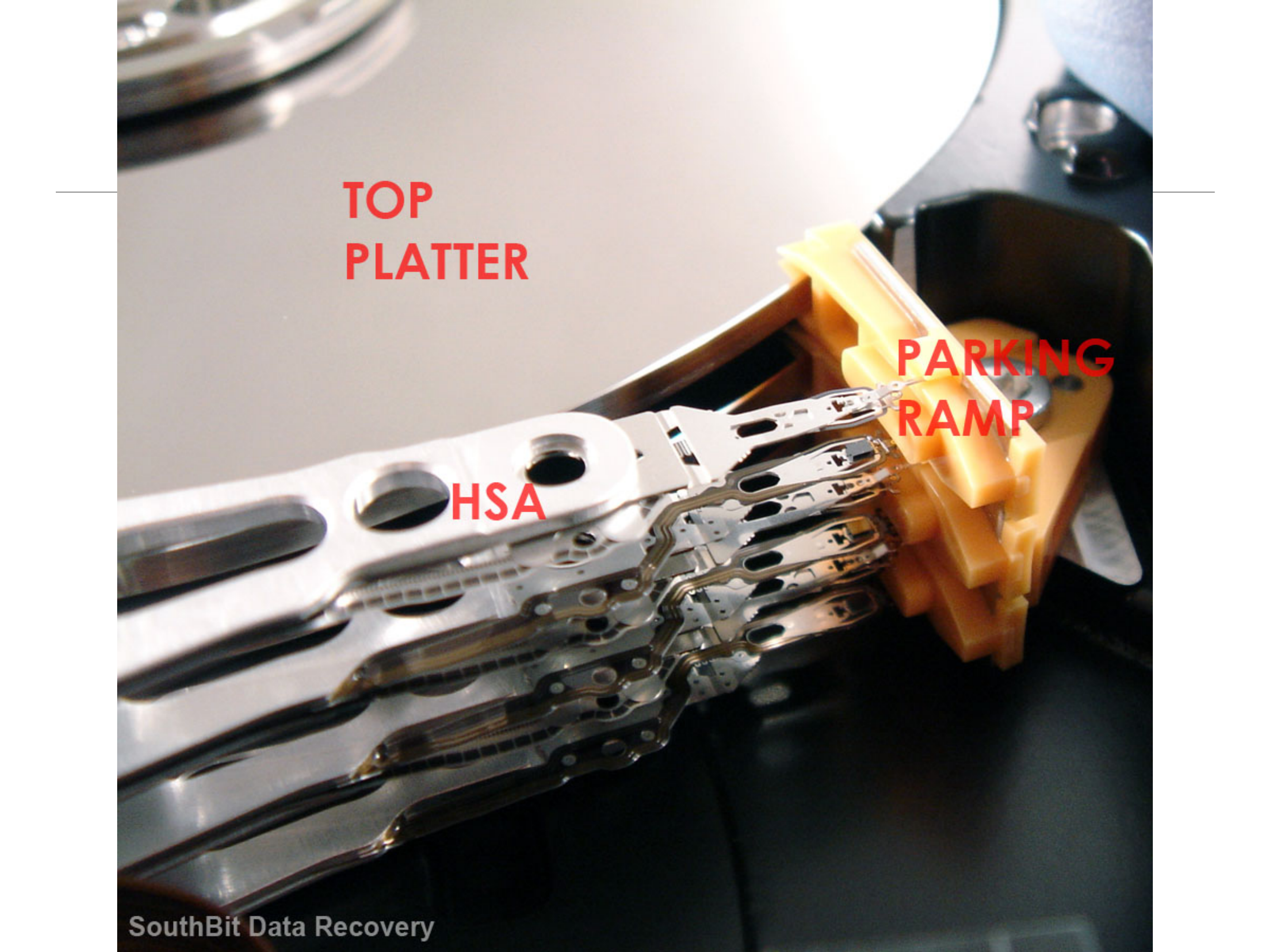
Hard disk drives

- Platters
- Magnetic material, orientation of magnetic particles records 1's and 0's
- Enormous progress in speed and density



Hard disk drives



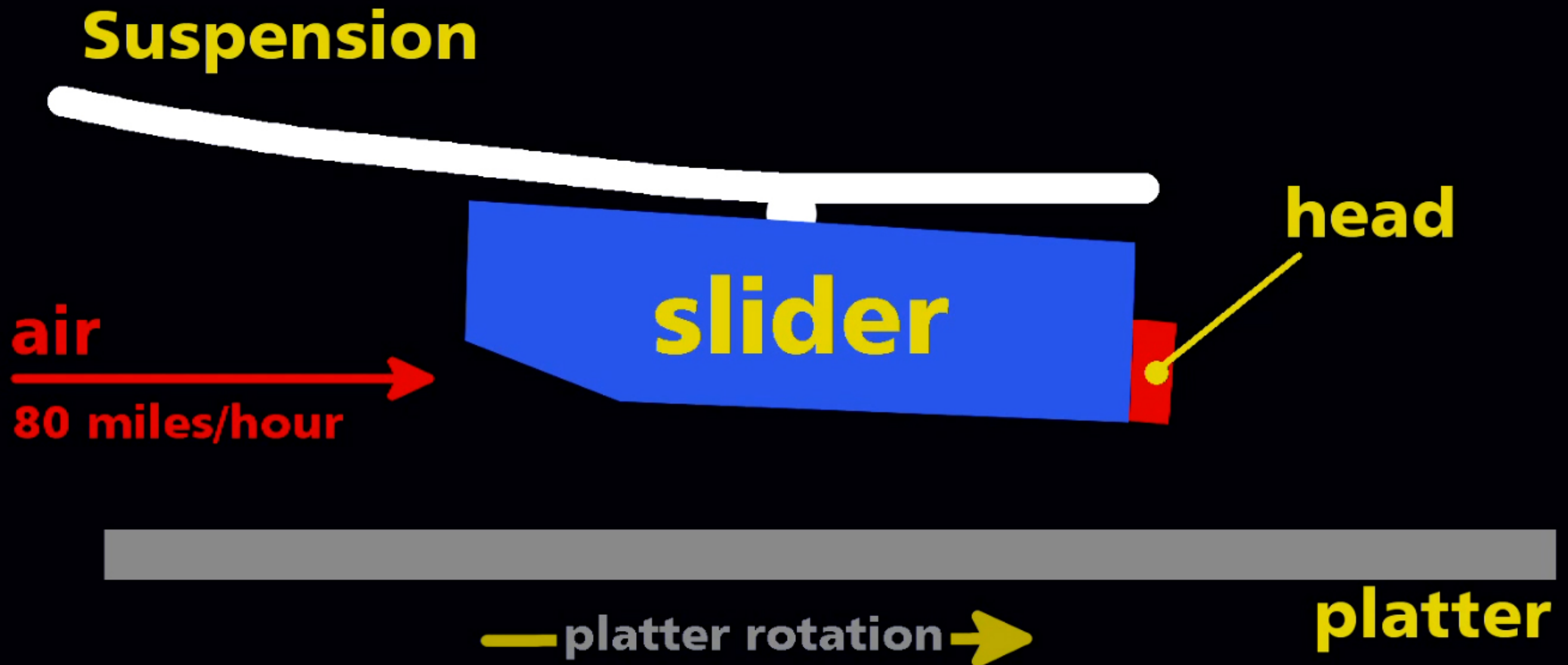
A close-up photograph of a hard drive's internal components. The image shows several stacked, highly reflective metal platters. A white actuator arm is visible, holding multiple read/write heads. A yellow plastic parking ramp is positioned to move the heads away from the platters. The background is a dark, metallic surface.

**TOP
PLATTER**

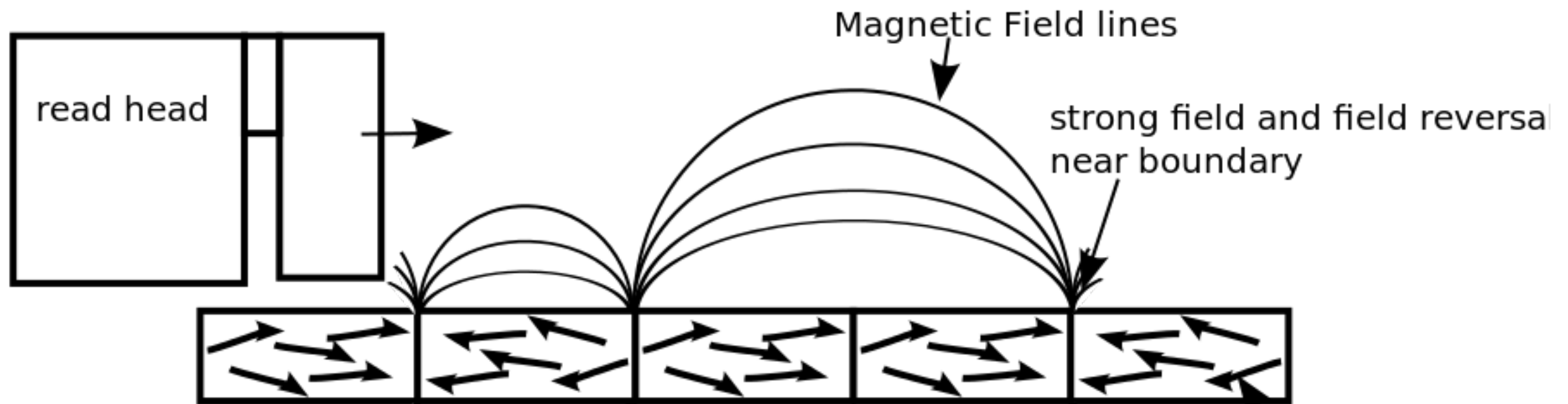
**PARKING
RAMP**

HSA

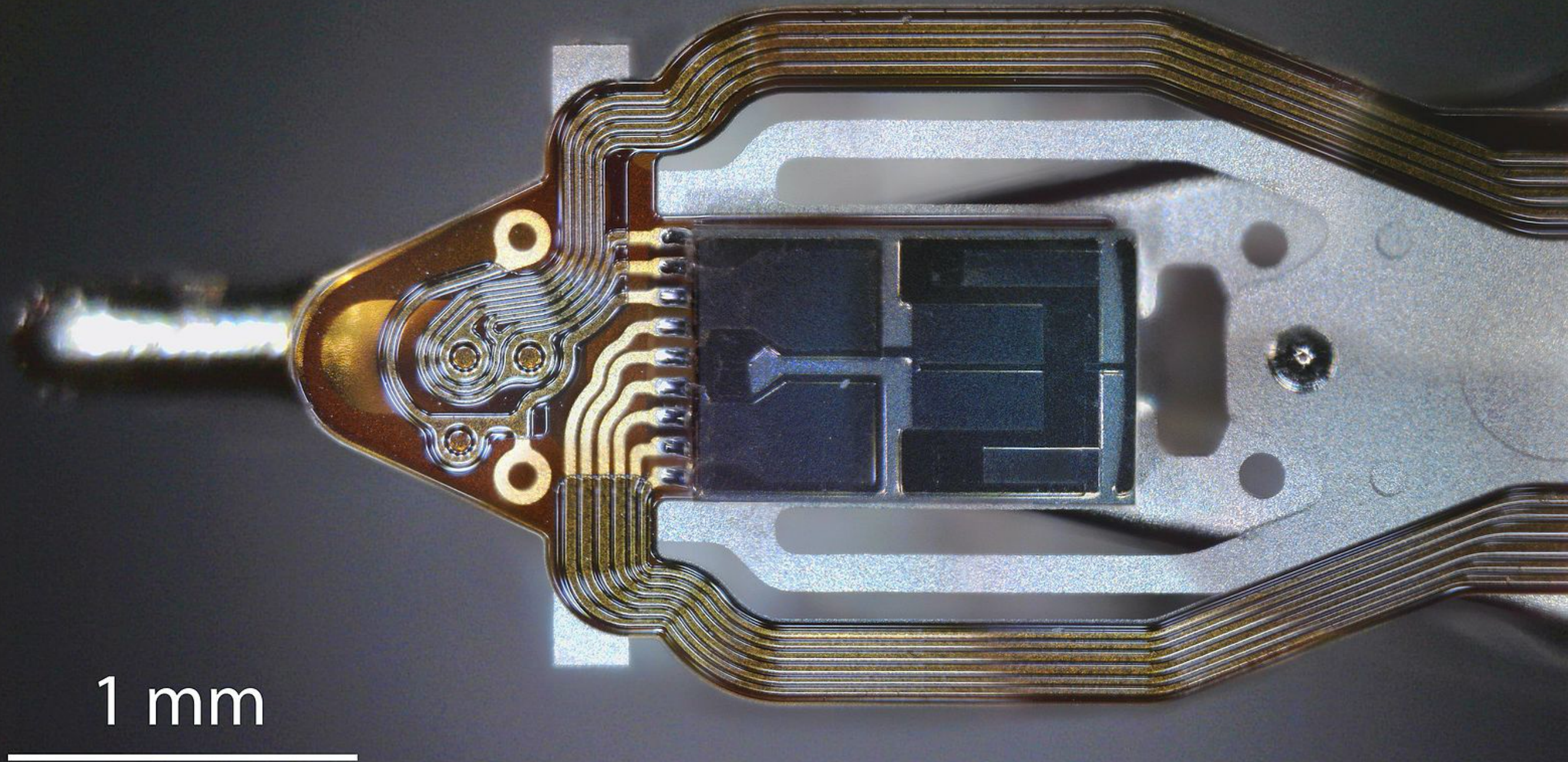
Floating head



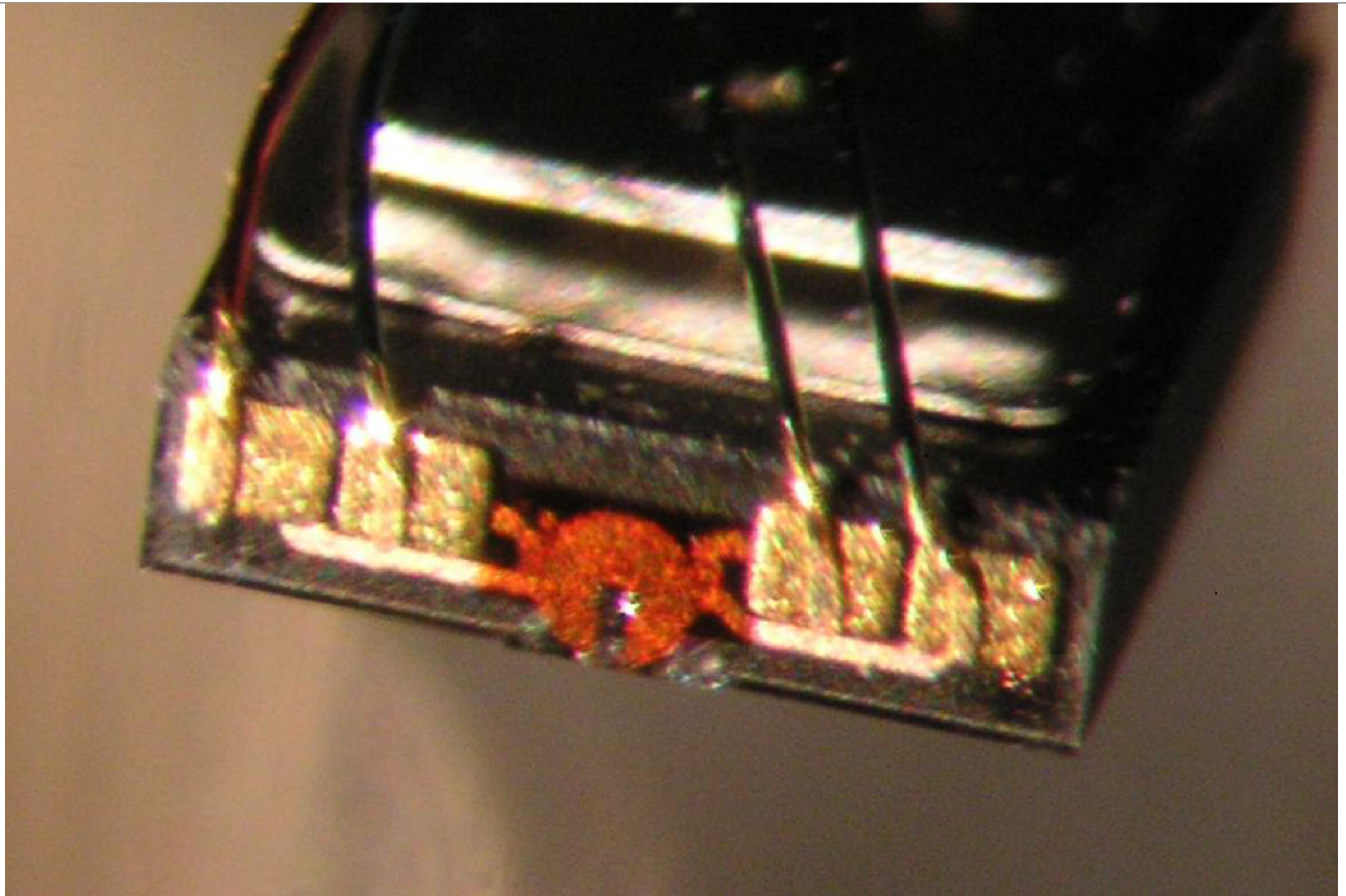
Data storage



Read head

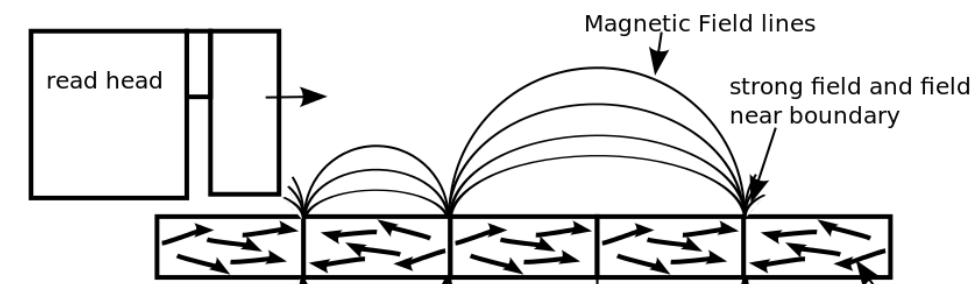


Read head



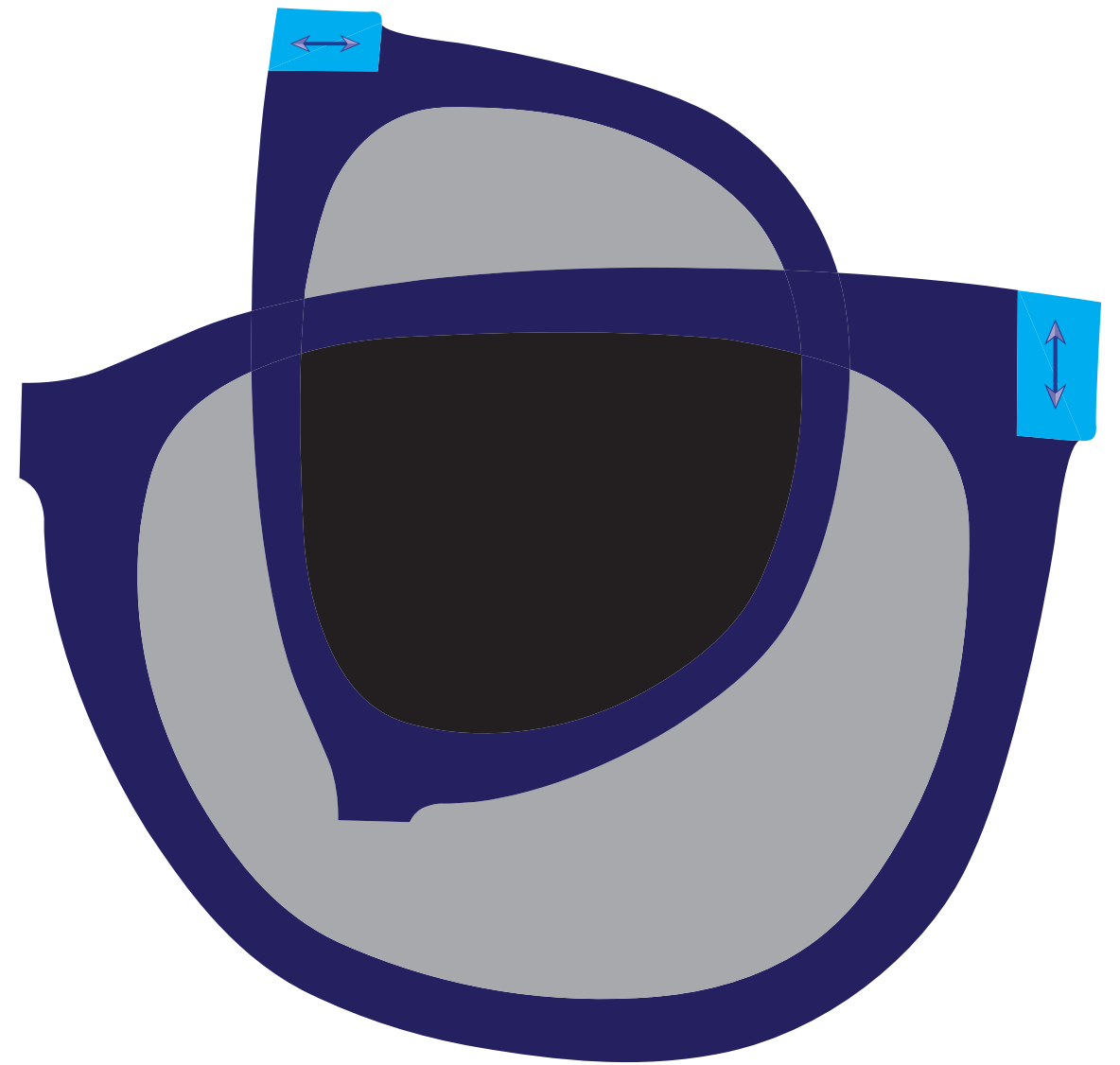
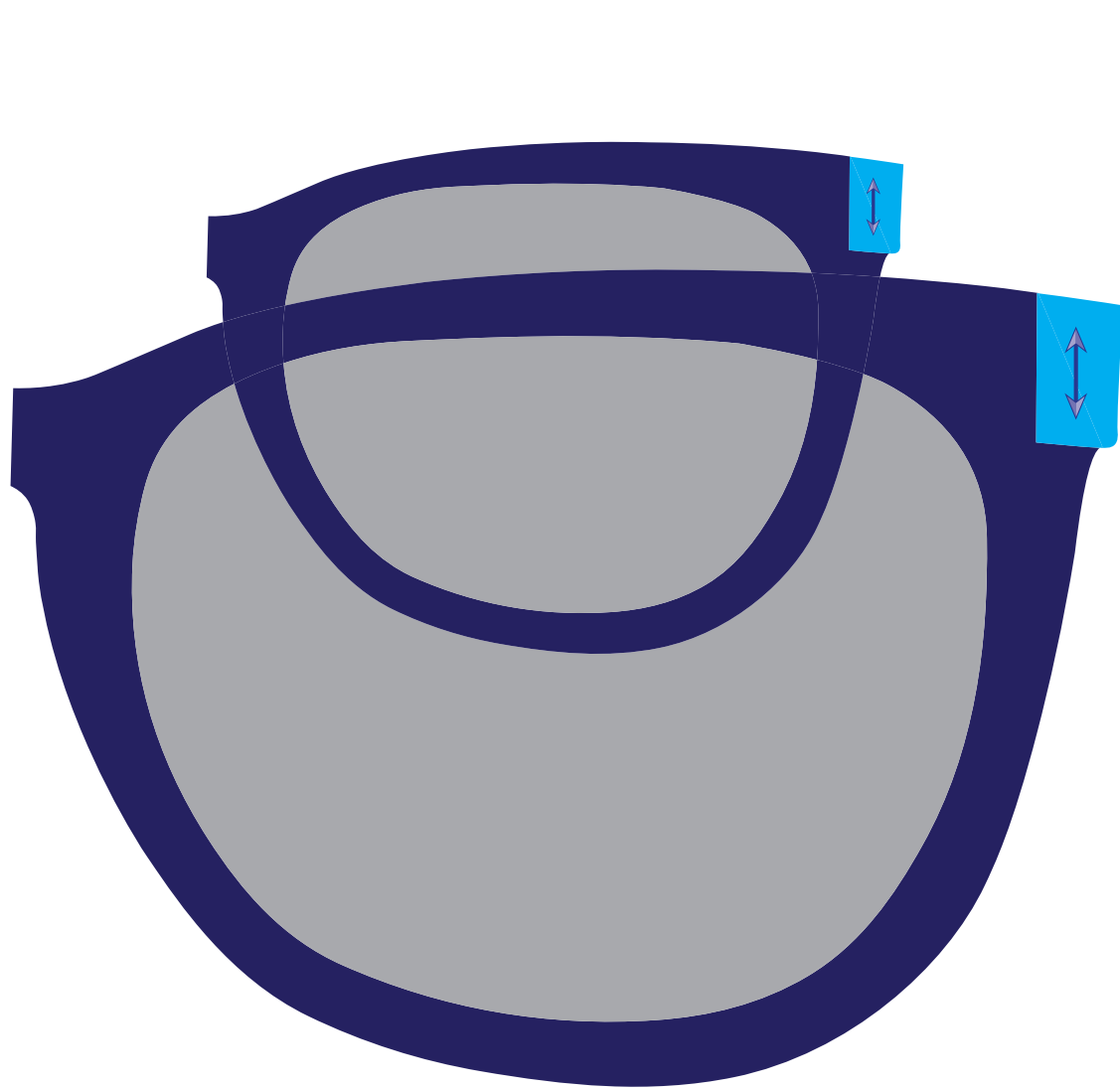
Modern drives

- Up to 18 trillion bytes per disk (stack of platters)
- Magnetism is read by a little loop of wire
- As magnetic particles (bits) get smaller, signal in loop gets smaller and smaller
- In 1997 the particles became too small to read...

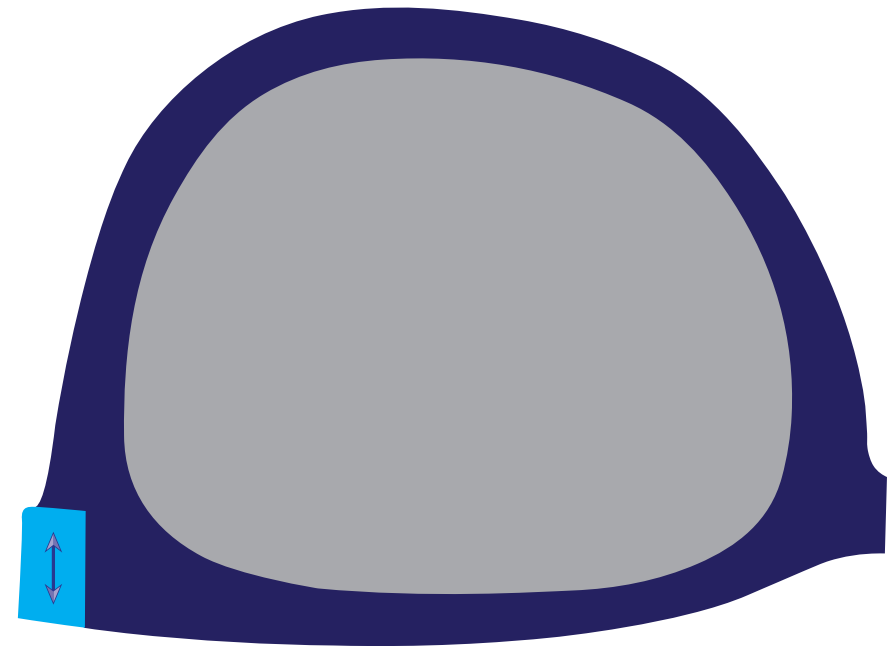
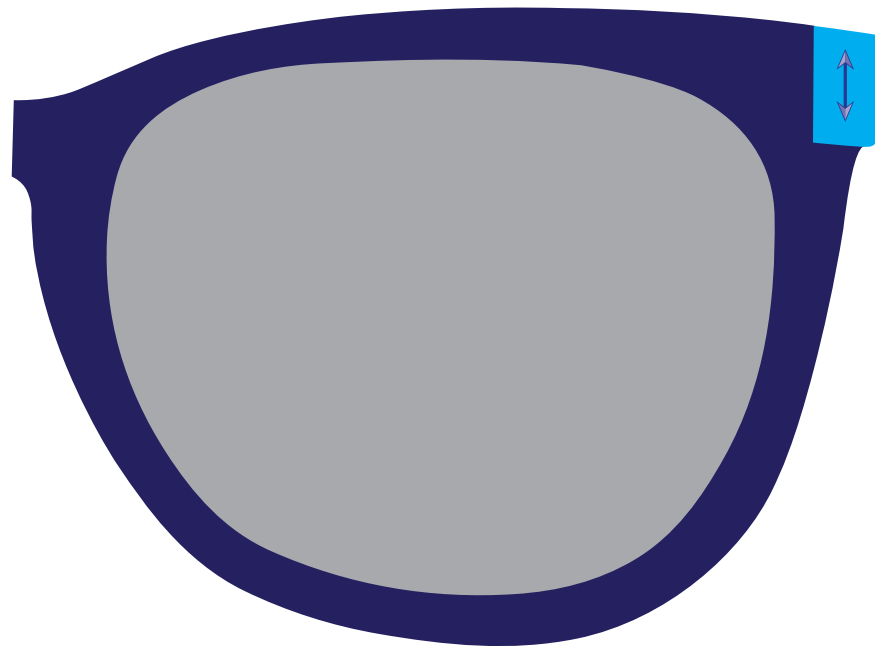


Polarized particles

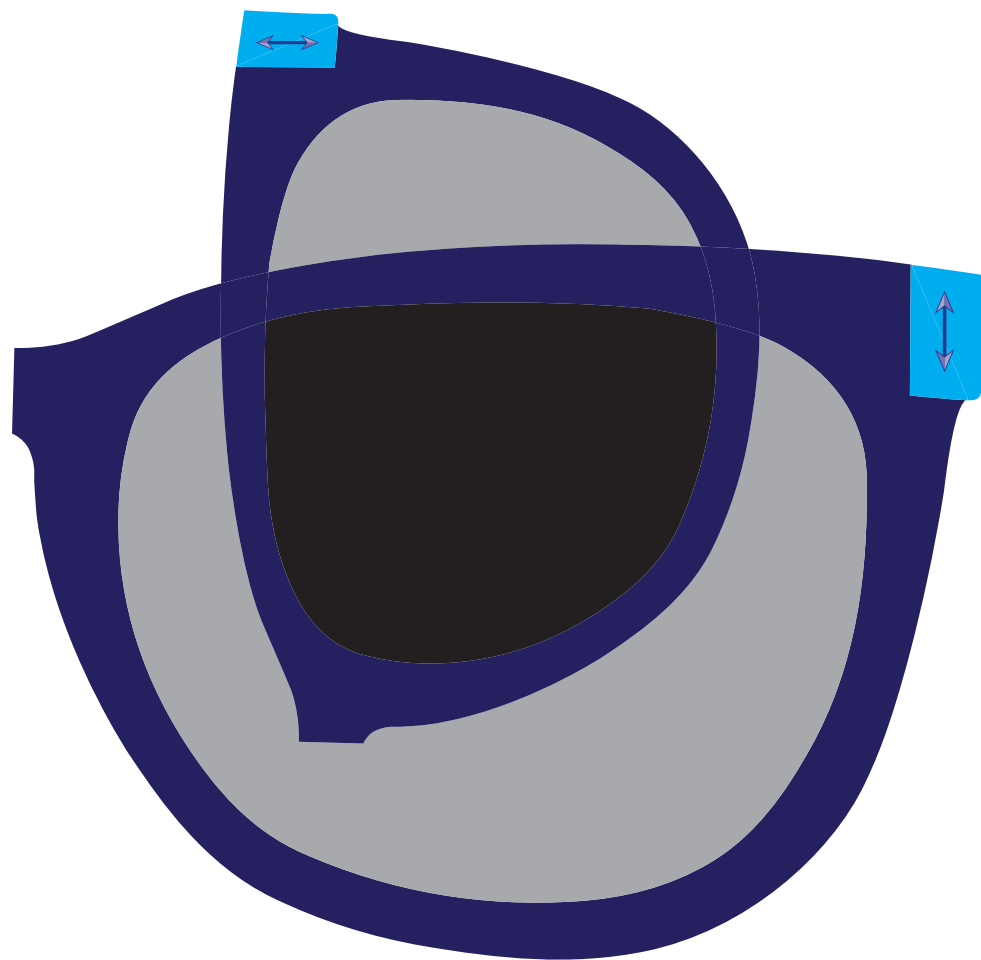
Light polarization



Same polarization if rotated 180°



‘Opposite’ polarization for photons

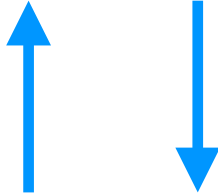
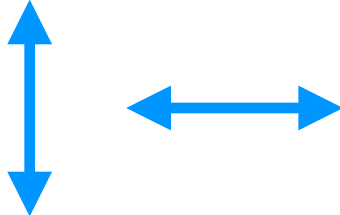
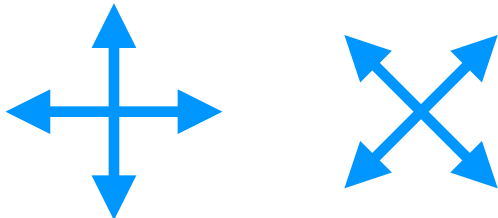


90°

Electrons 'opposite' with 180°



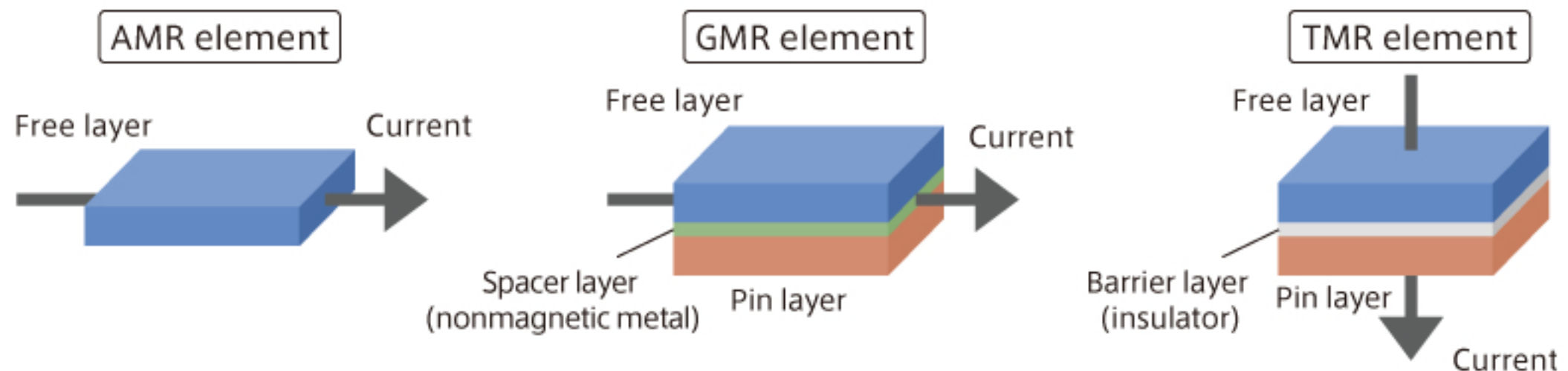
Other combinations

- electrons, protons, neutrons, quarks, ...  180°
- photons, pions, gluons, mesons...  90°
- Graviton  45°
- Higgs boson has no polarization at all

Back to hard drives

Since late 1990's all hard drive heads use electron polarization to read bits

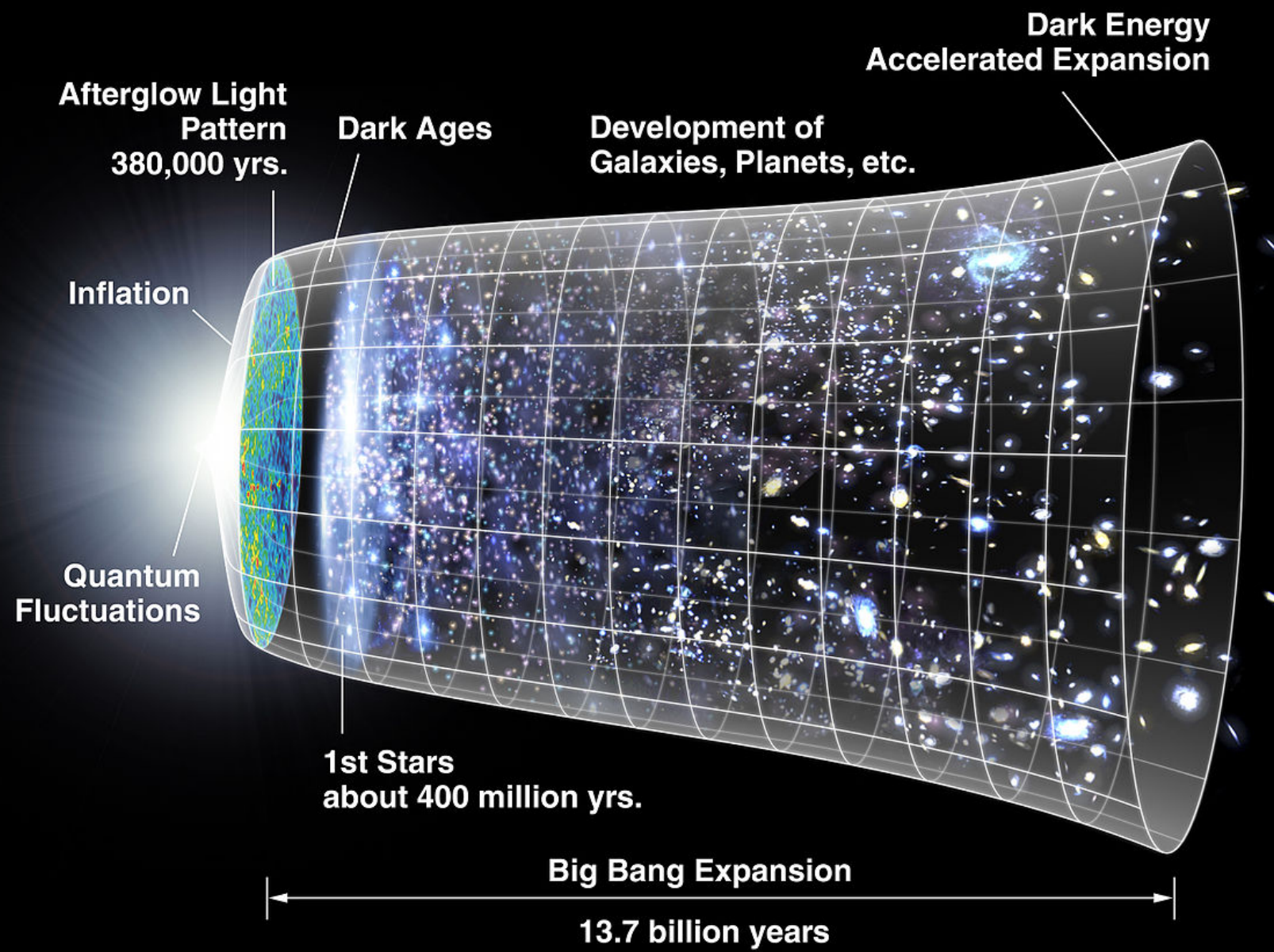
- Giant magneto resistance 1997
- Tunnelling magneto resistance 2004
- All modern hard drives *require* quantum mechanical read heads

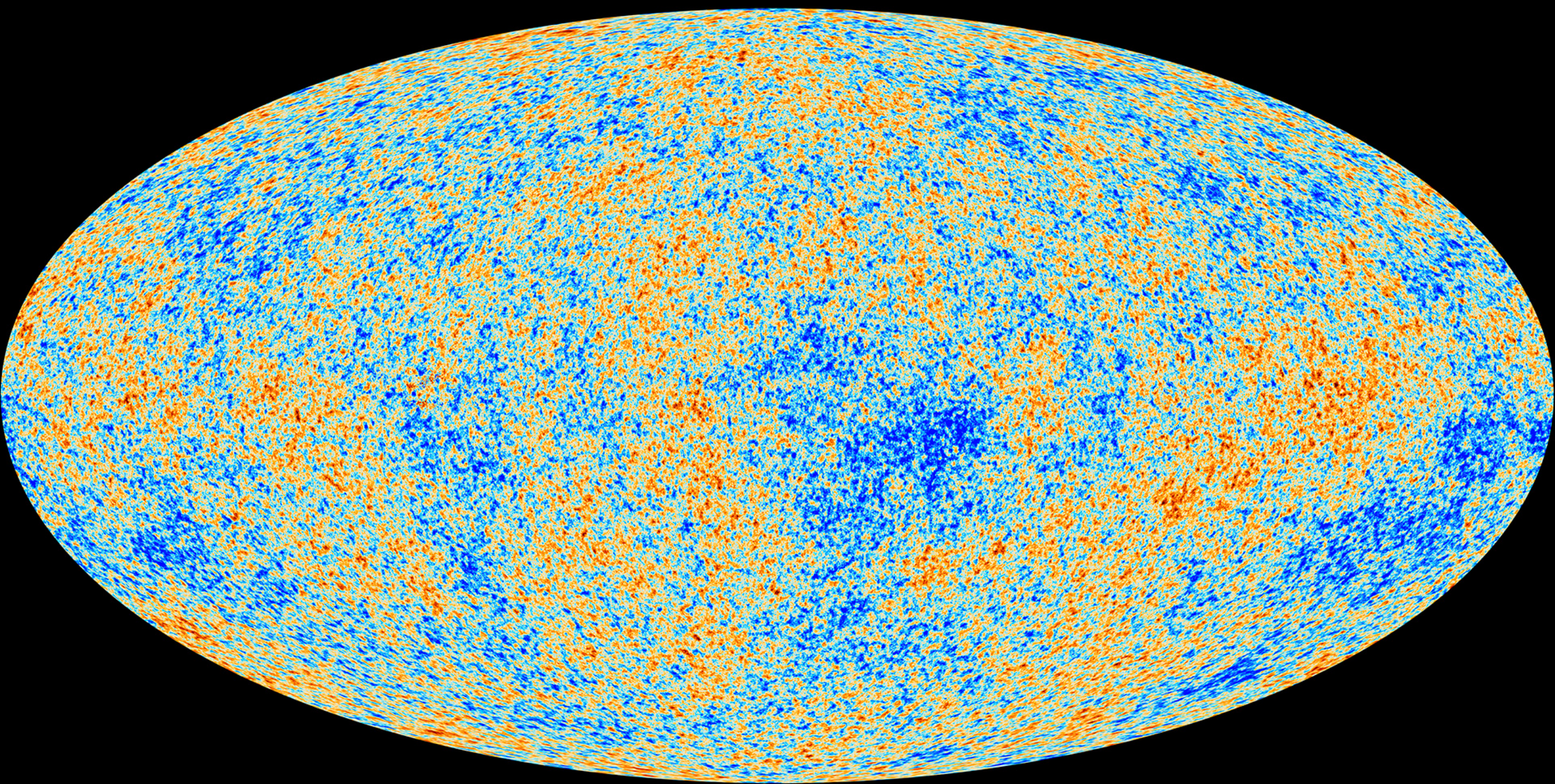


Quantum electronics

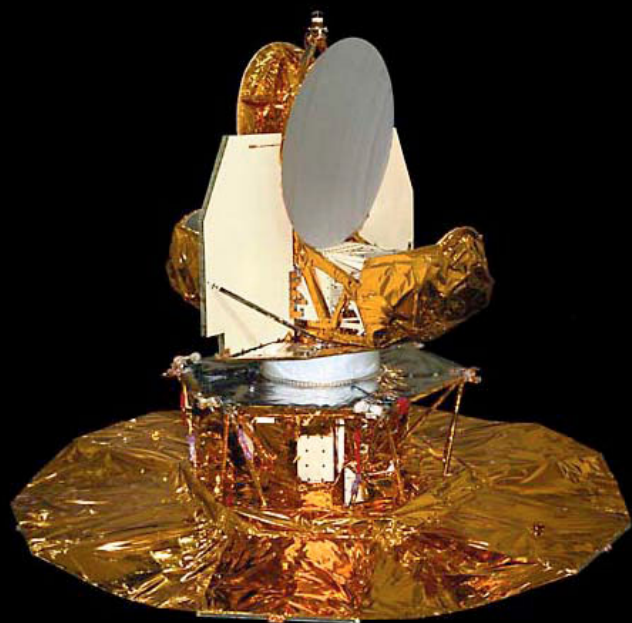
Quantum electronics

- Spintronics (use electron polarization)
- Tunneling electronics (use electron waviness)
- Super-conducting electronics (use superconductors)
- Quantum electronics (require all the above)

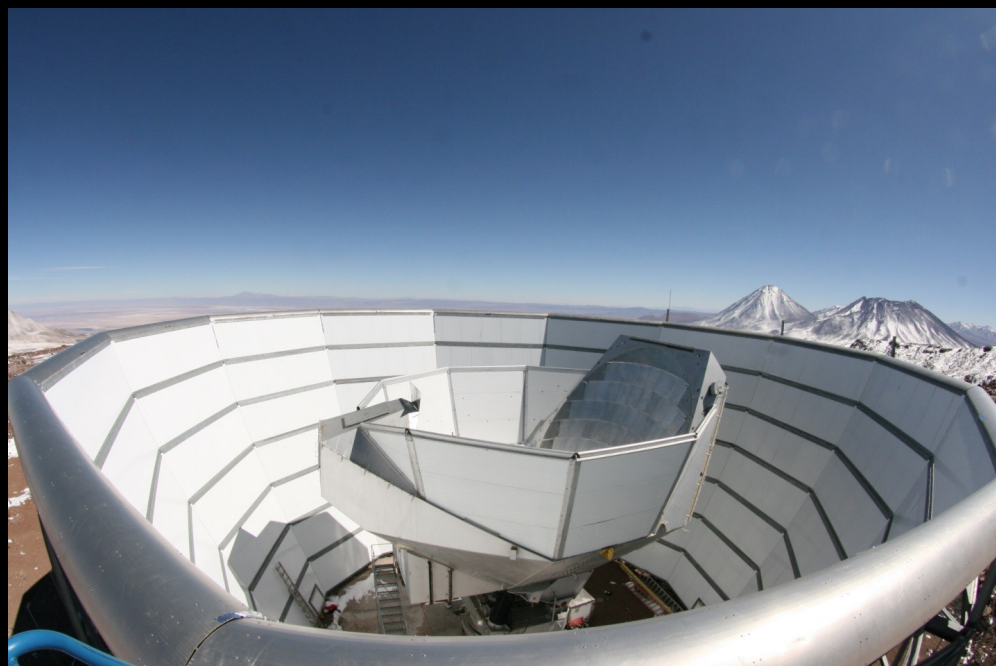
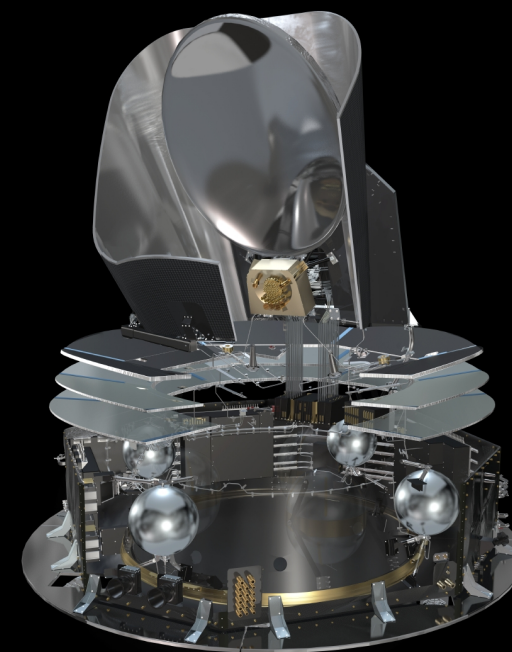
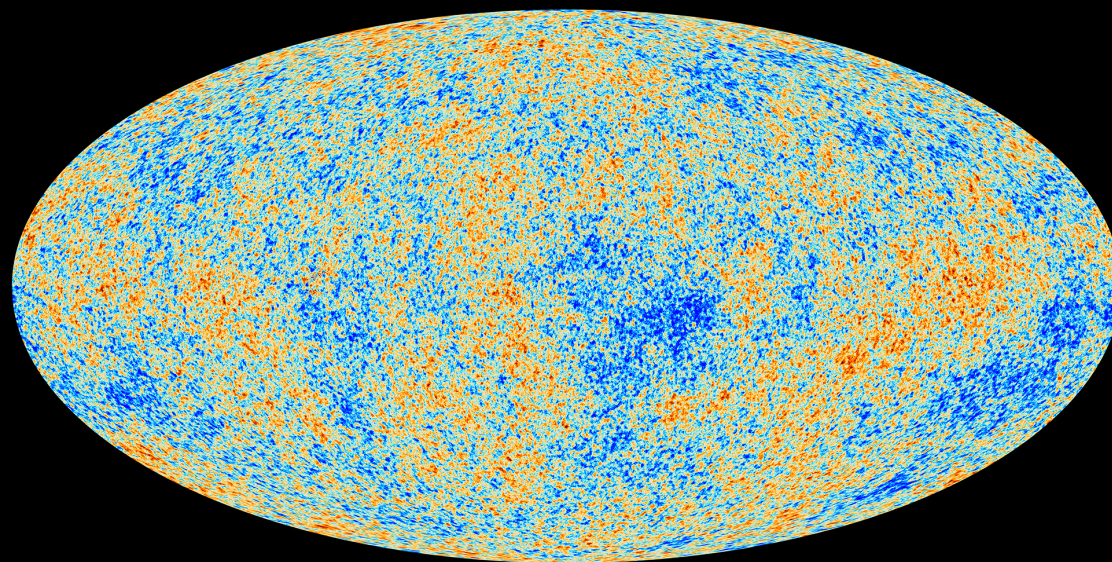




Planck



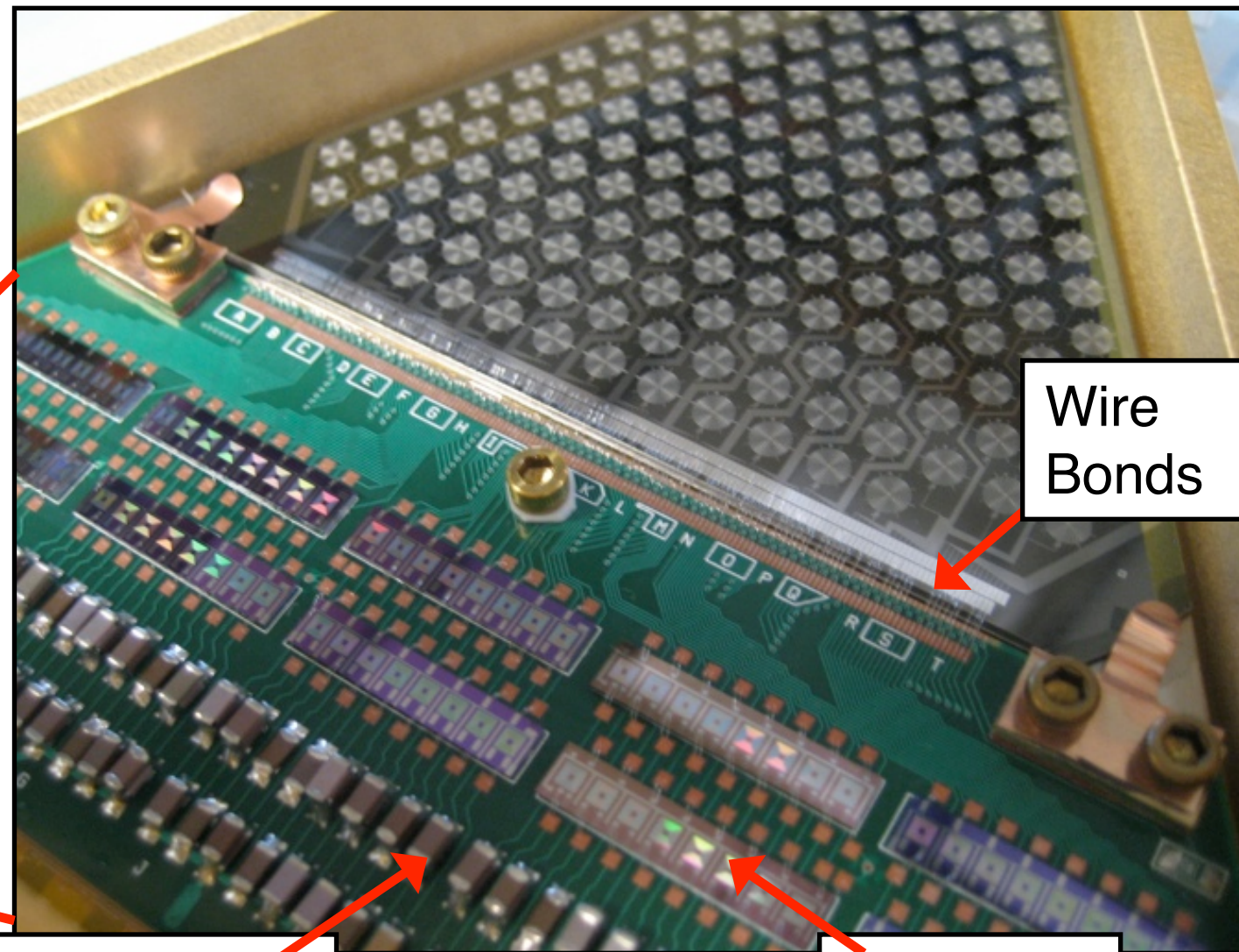
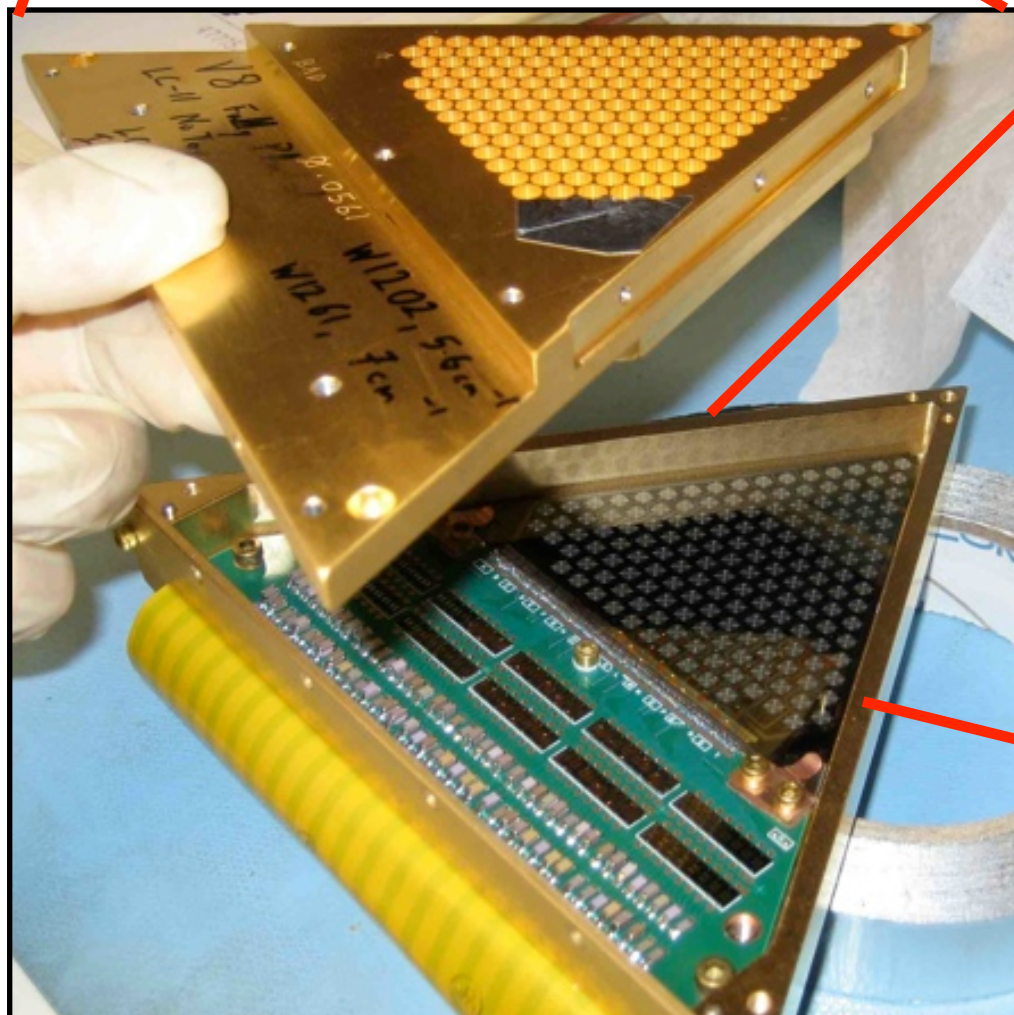
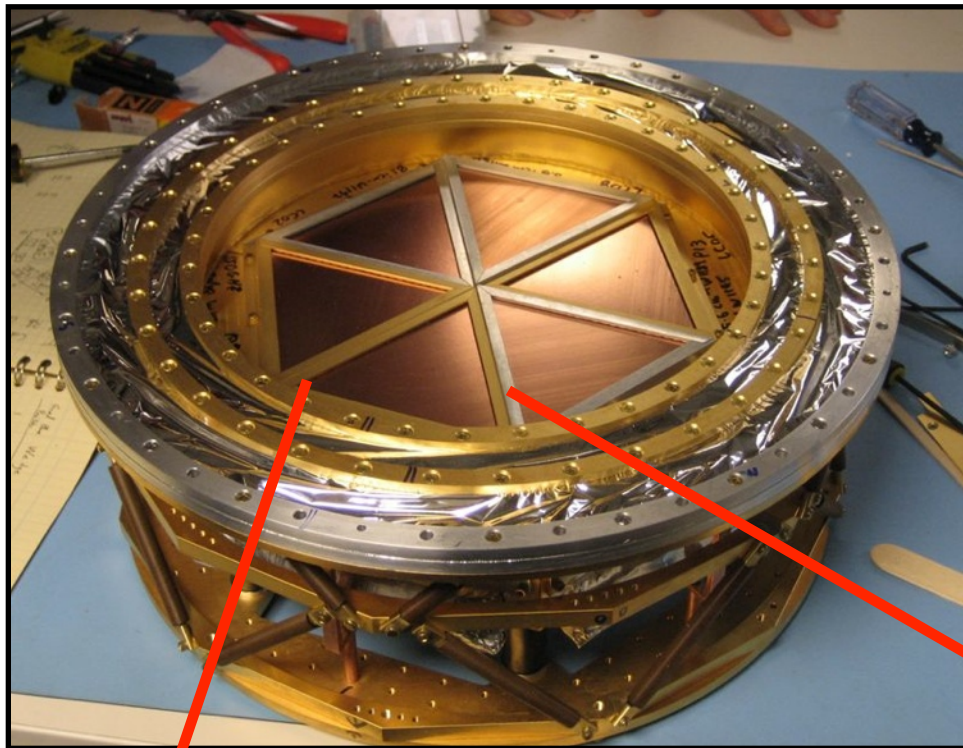
MAP990589



NASA/ESA/NSF

SPT-SZ Detector Module and LC Board

- Wafer wire-bonded to circuit board with LC circuit, which sets each bolometer's resonant frequency for frequency Multiplexing (fMUX)



Wire
Bonds

Ceramic
Capacitors
150-1500 pF

Niobium
Inductors
(16 μ H)

