Current Contrast Imaging with Magnetic Force Microscopy

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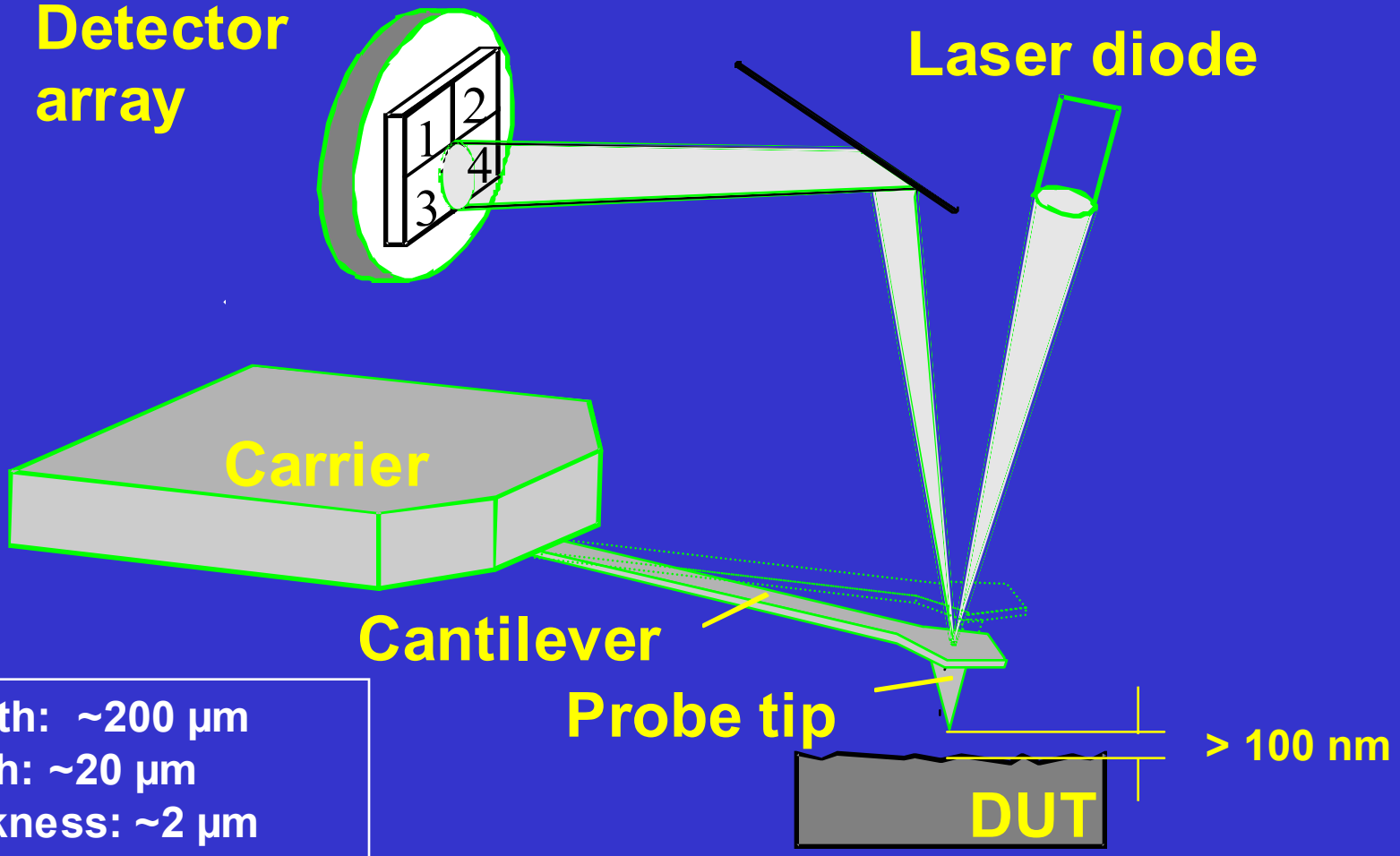
Outline:

- Basics
- Examples
- Conclusion

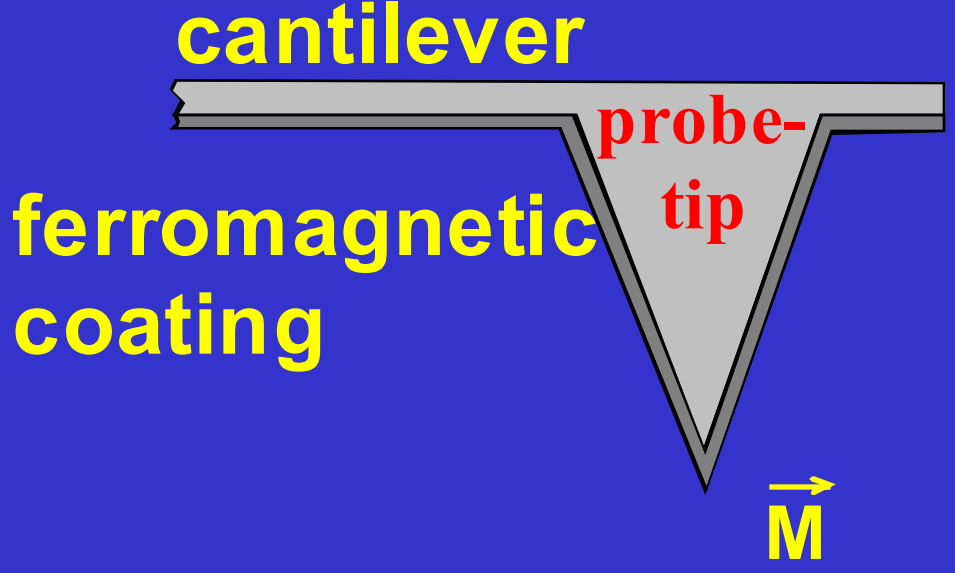
Standard Cantilever Probe and Optical Detection



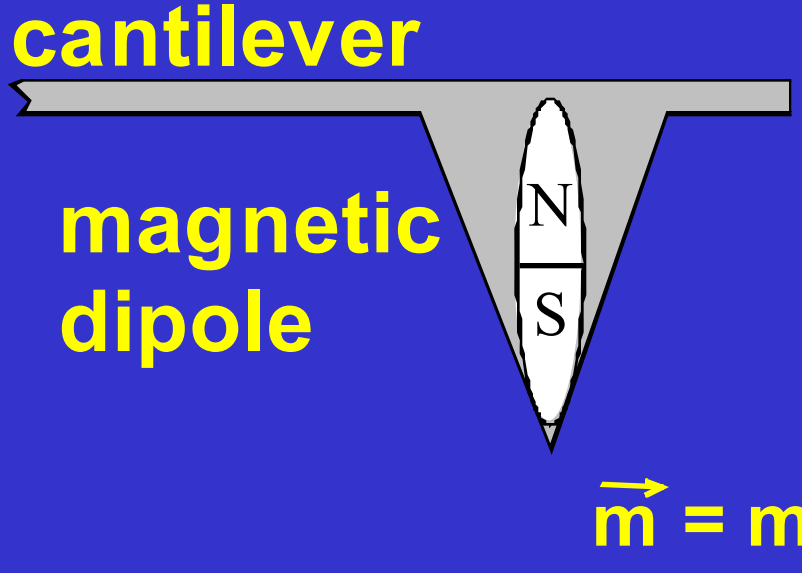
Cantilever length: ~200 µm
Cantilever width: ~20 µm
Cantilever thickness: ~2 µm
Probe tip height: ~10 µm
Probe tip radius: ~30 nm
Resonance frequency: ~100 kHz

Model for Magnetic Force Microscopy (MFM)

Reality

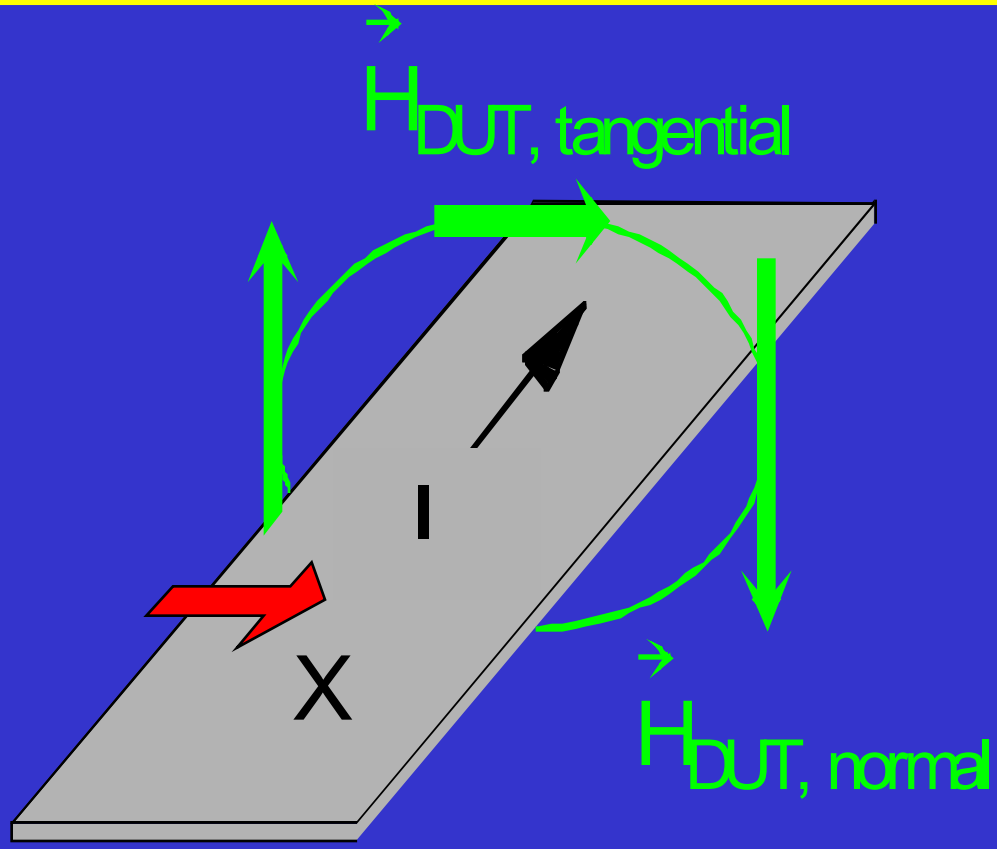


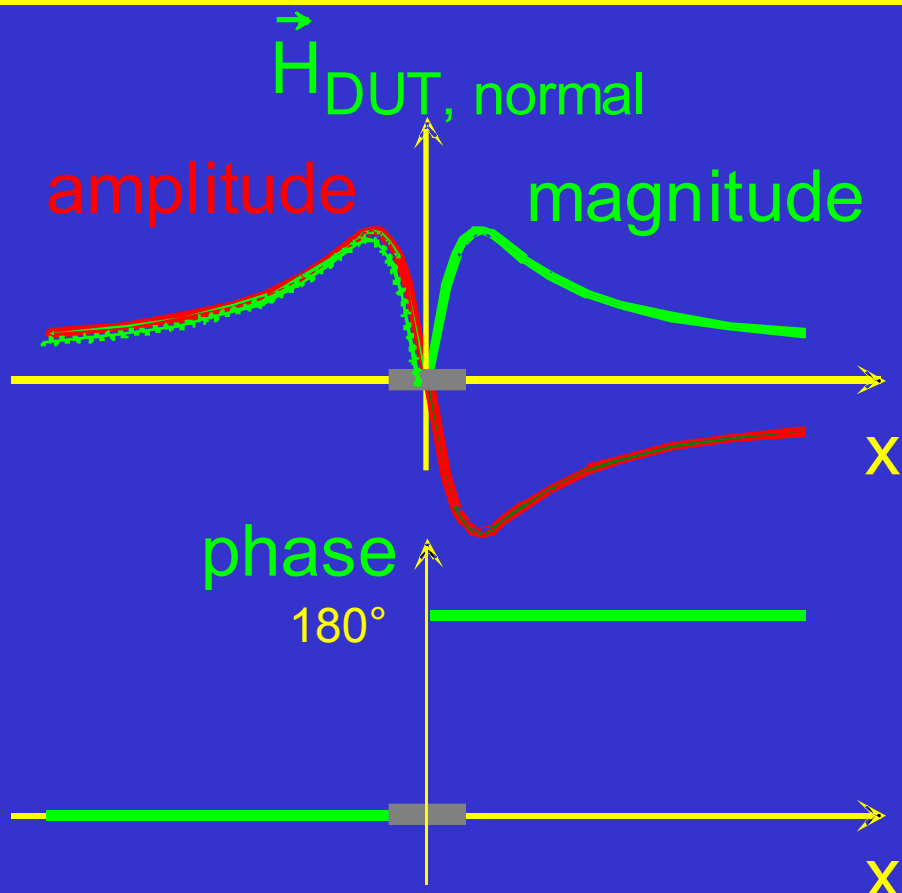
Model



$$F_{mag} \sim - \mu \cdot m_z(H) \cdot dH_z / dz$$

Principle of Current Contrast Imaging (CCI)





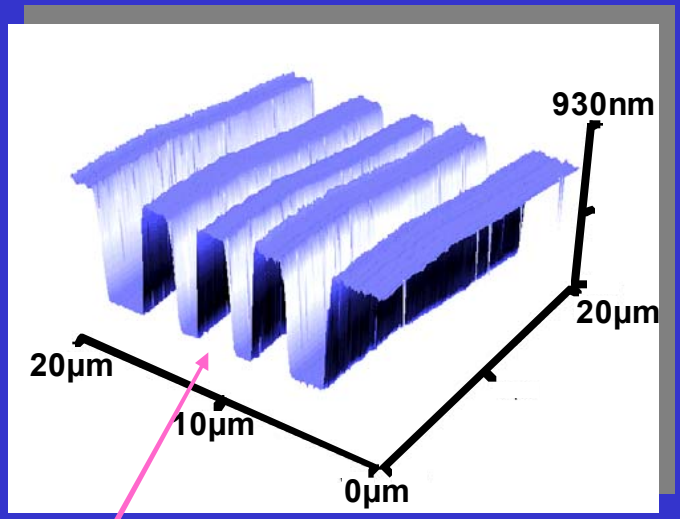
H ~ I

↳ $F_{mag} \sim - \mu \cdot m_z(I) \cdot dH_z(I)/dz \sim I^2$

↳ **Heterodyne mixing technique**

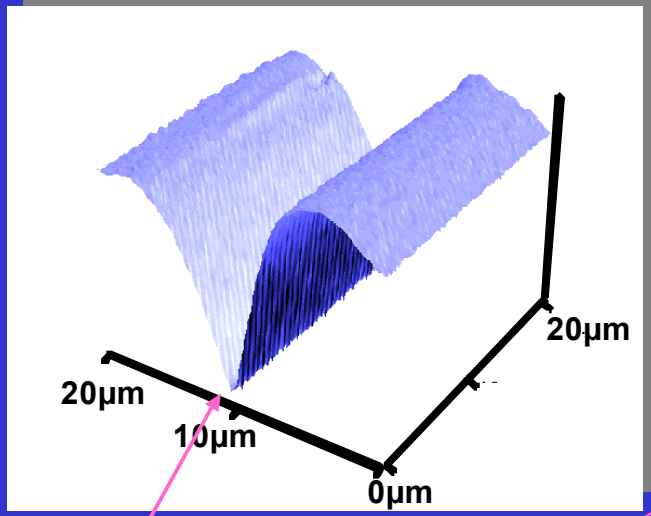
Example of CCI

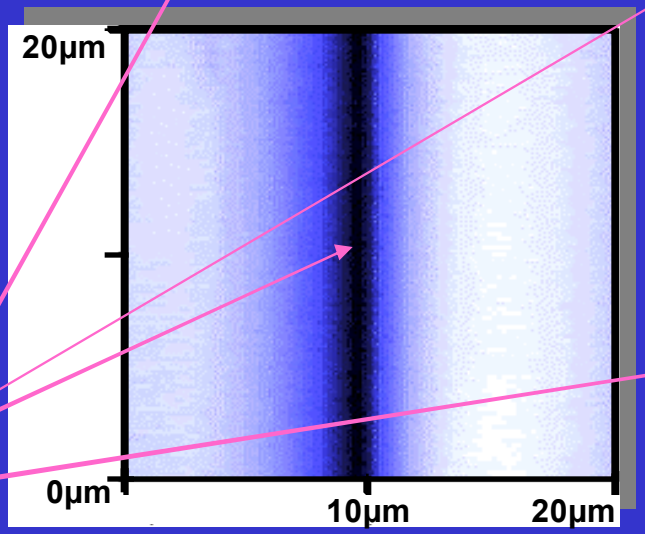
Topography



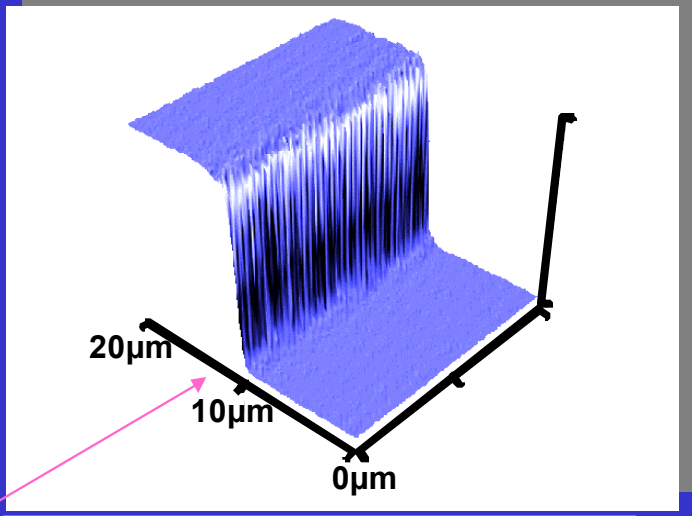
Biased line

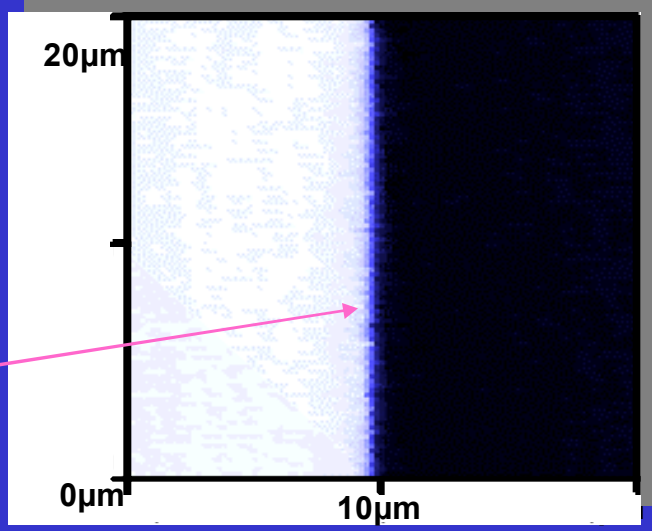
Magnitude





Phase

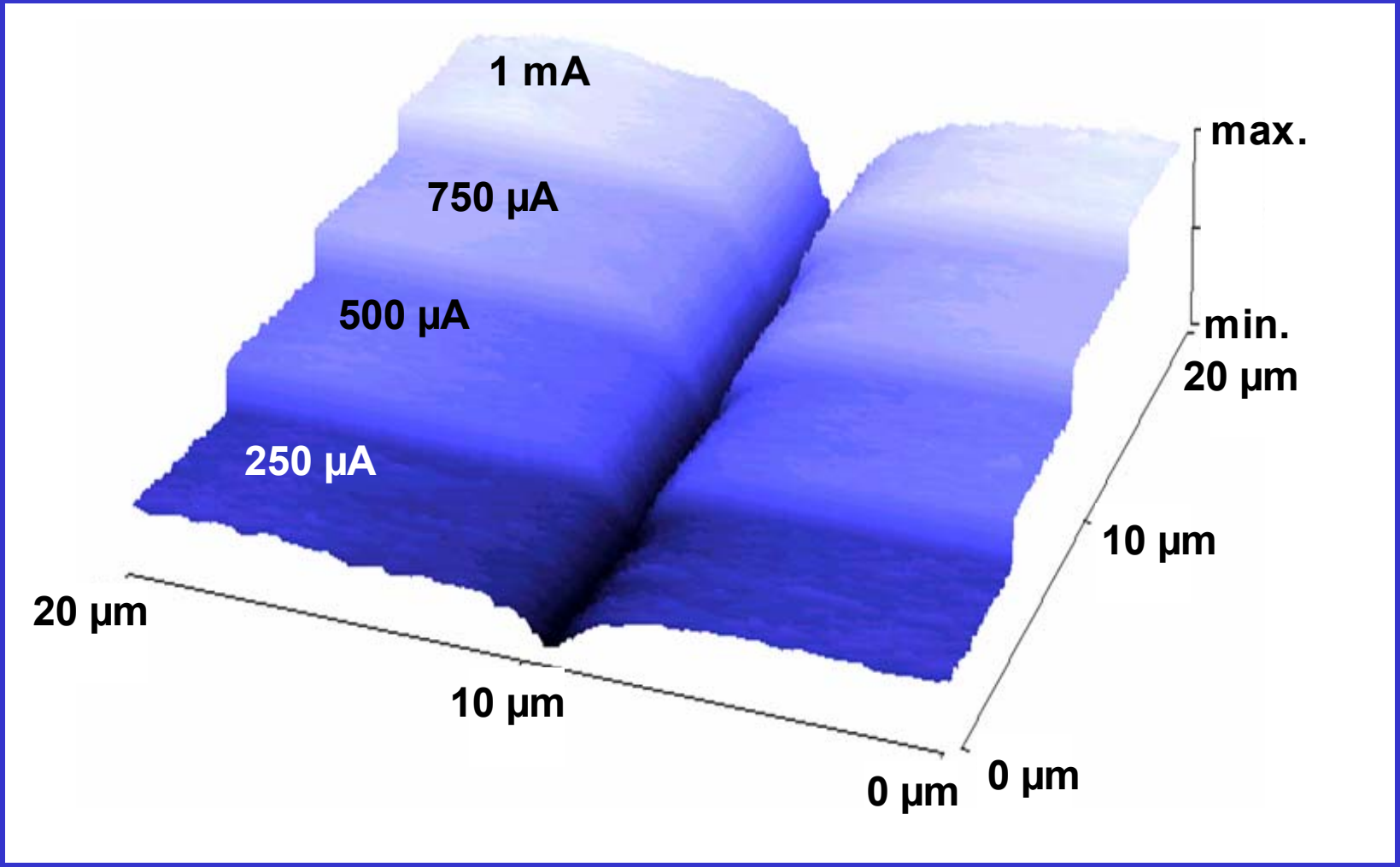




Test point: 2 µm line
Amplitude: 500 µA
f_{DUT}: 14 kHz

Position of biased line

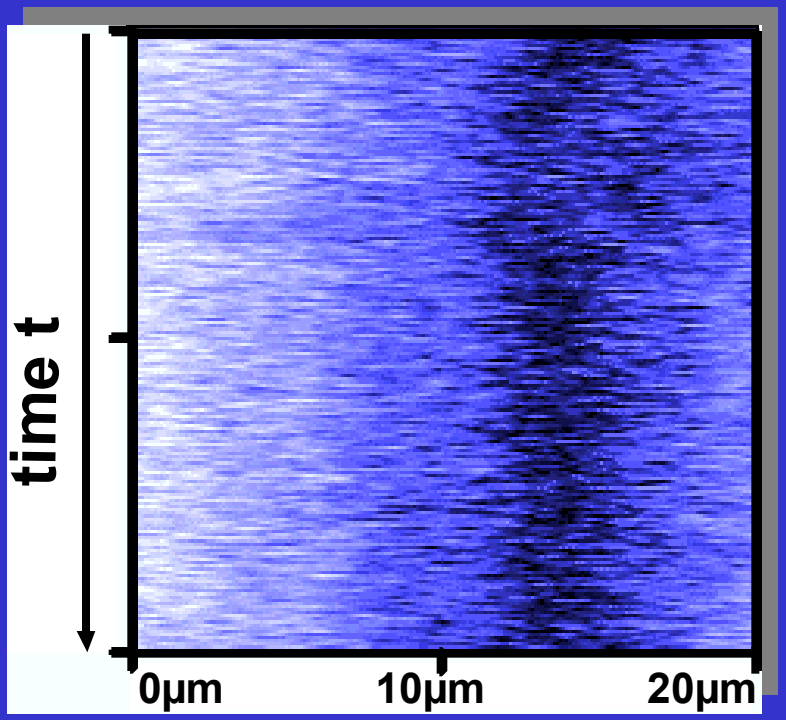
Example of CCI



↳ the smallest current measured was 1.7 µA

Current Measurement on a 100 nm Wide Conducting Line

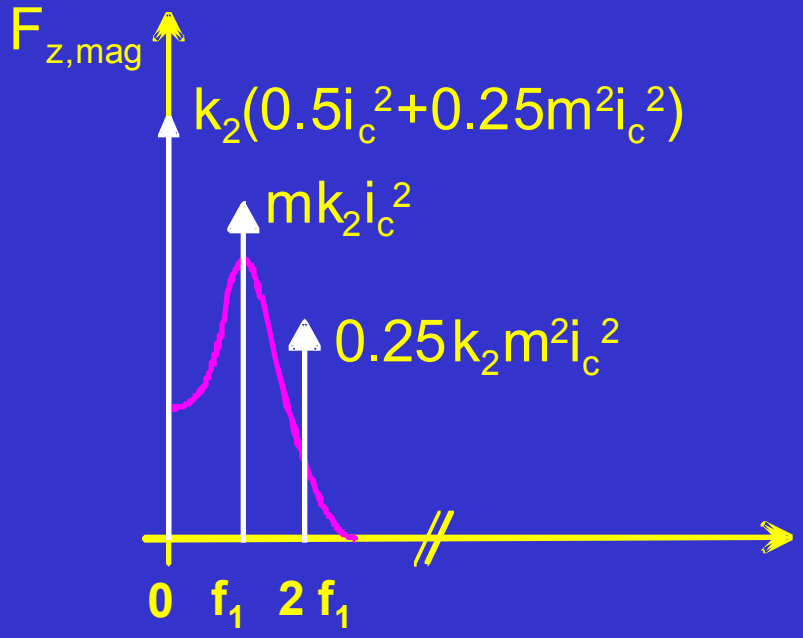
Magnitude



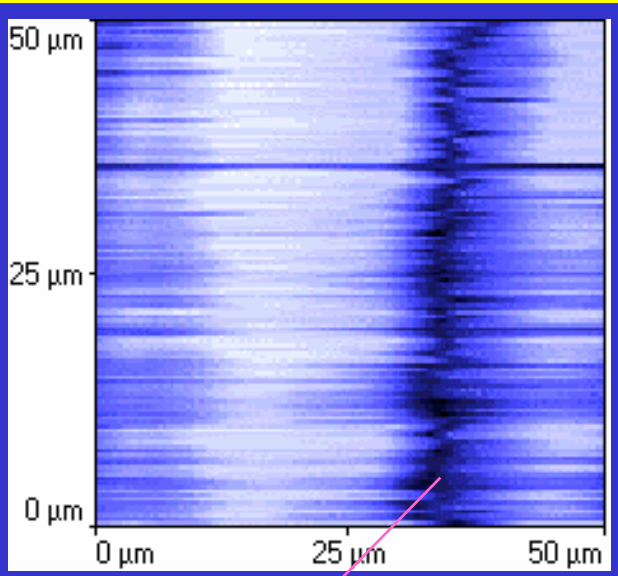
Current amplitude: 70 µA
Current frequency: 14 kHz
200 line scans at the same position

High-Frequency Current Measurement

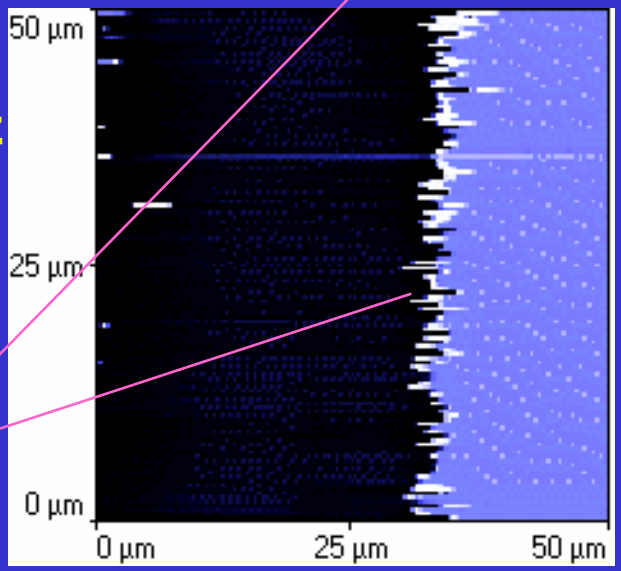
Using an amplitude modulated signal as DUT-signal (m: modulation index, f_1: modulation frequency, i_c: amplitude of the high-frequency carrier)



Magnitude @ 4.6 GHz



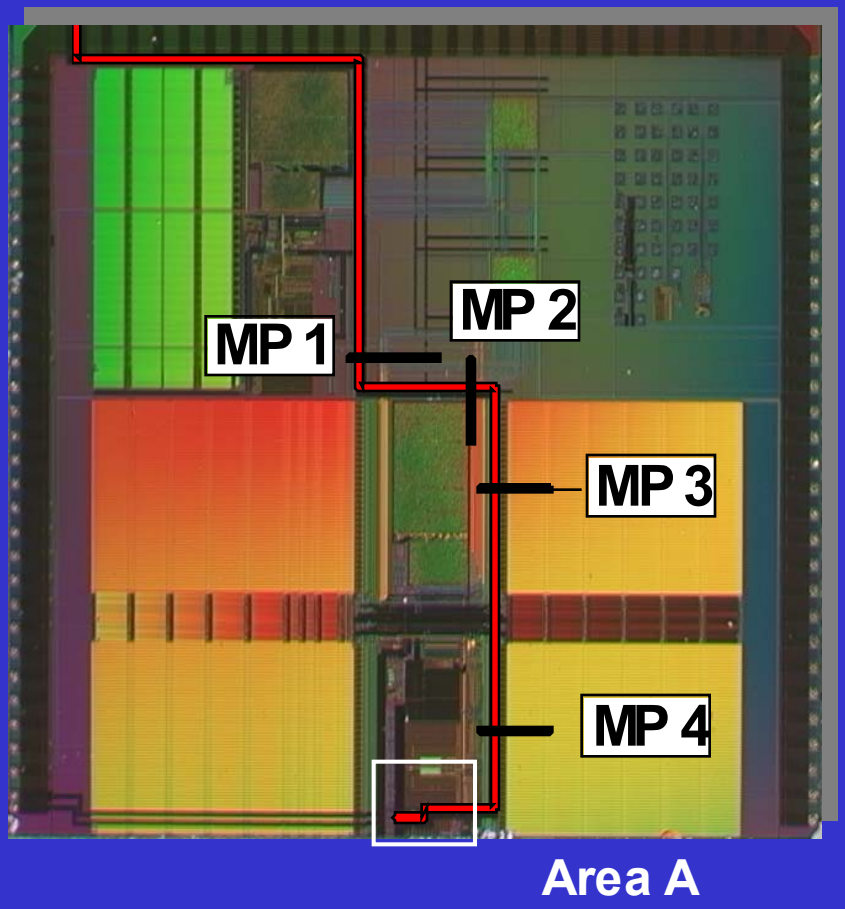
Phase @ 4.6 GHz



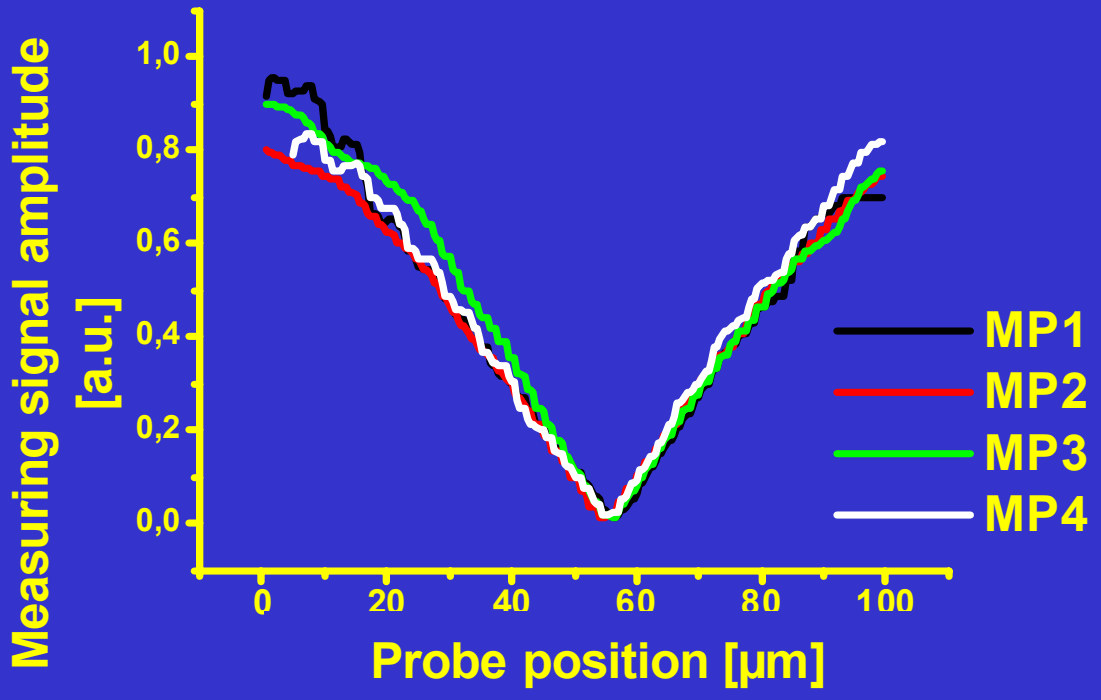
Position of biased line

Case Study

Passivated four metal layer IC showed to high power consumption

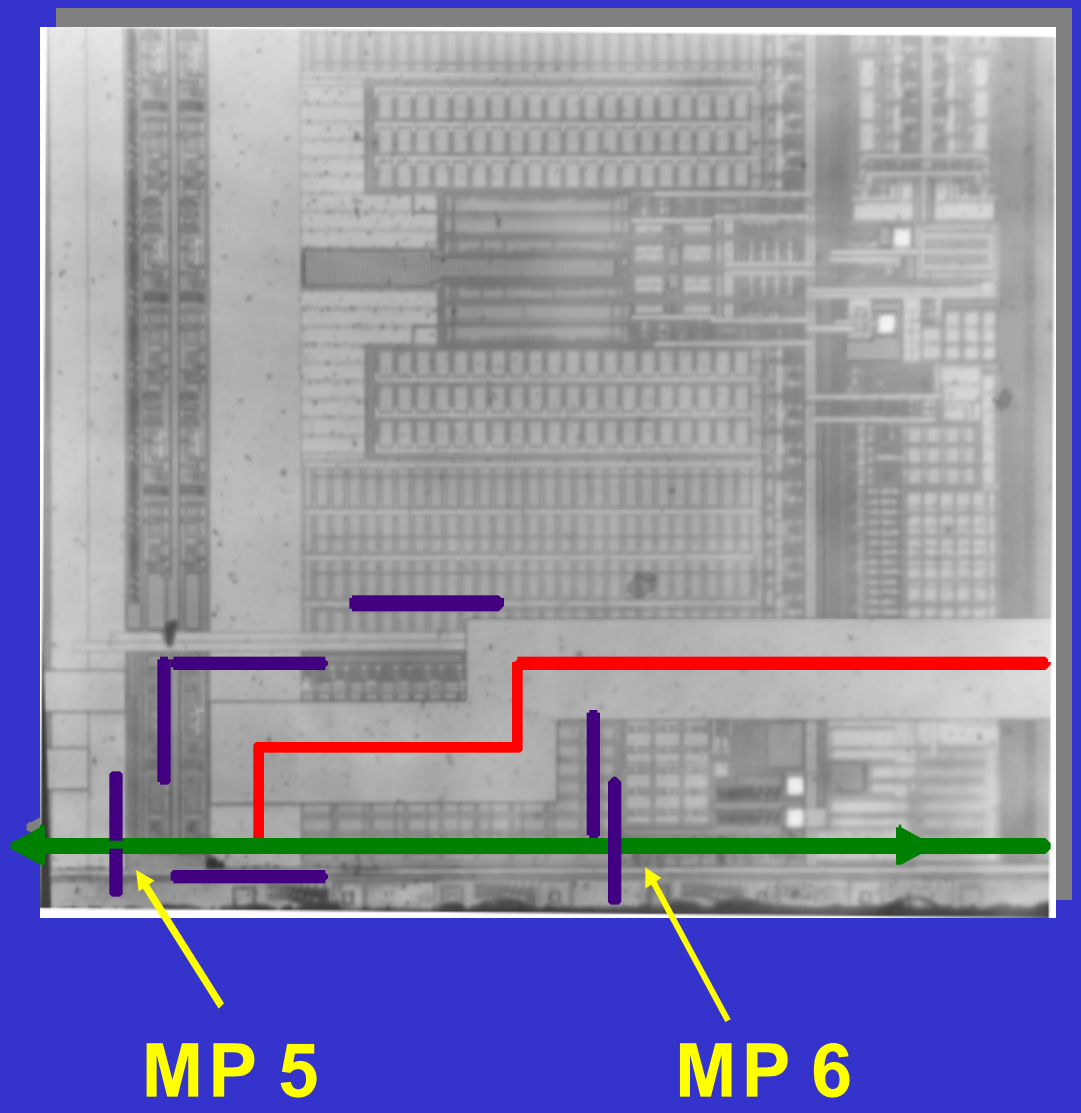


Area A



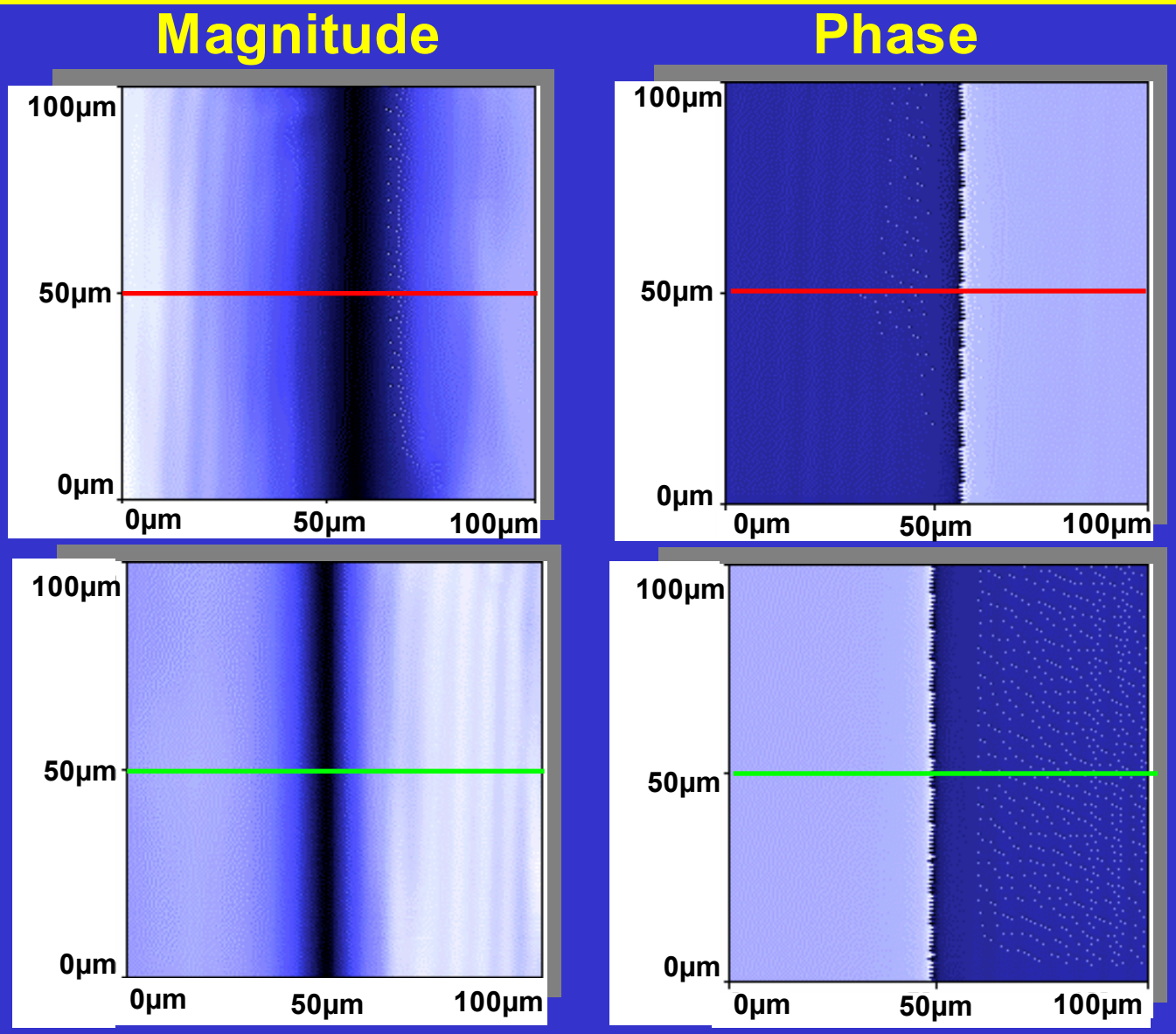
⇒ **no leakage current along this path**

Case Study



Verification of the current directions (Area A)

Case Study



Conclusion I: Performances

Spatial resolution:
Smallest measured linewidth 100 nm

Bandwidth:
DC – 4.6 GHz

Minimum detectable current:
AC ~ 2 µA
DC ~ 30 µA

Quantitative measurements:
Only with calibration

Scan area
100 µm x 100 µm

Conclusion II: Problems

Test access → needle sensor

Interpretation of the measurement results for more than one line → simulation

Cantilever influence → special probes

Voltage influence → multilever probes

Long measurement times for 2D scans → multilever probes

Small scan area → combination of coarse and fine positioning