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Novel Defect Detection Using Laser-Based Imaging and TIVA with a Visible Laser

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OUTLINE

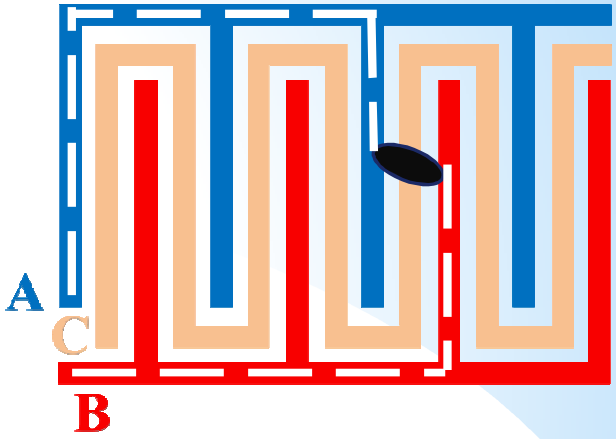
Purpose: ***To emphasize the use of laser scanning microscope reflected light images as a means of defect localization***

Two case studies:

- **Case I: Metal comb structure defects**
  - **Reflected light imaging comparison : 532-nm, 1064-nm and 1340-nm lasers**
  - **TIVA imaging comparison: 532-nm and 1340-nm lasers**
  - **Reflected light imaging and TIVA comparison**
- **Case II: SRAM bit failures**
  - **Reflected light imaging comparison : 1064-nm and 1340-nm lasers**
  - **TIVA and LIVA imaging comparison: 1064-nm and 1340-nm lasers**
  - **Reflected light imaging and TIVA/LIVA comparison**

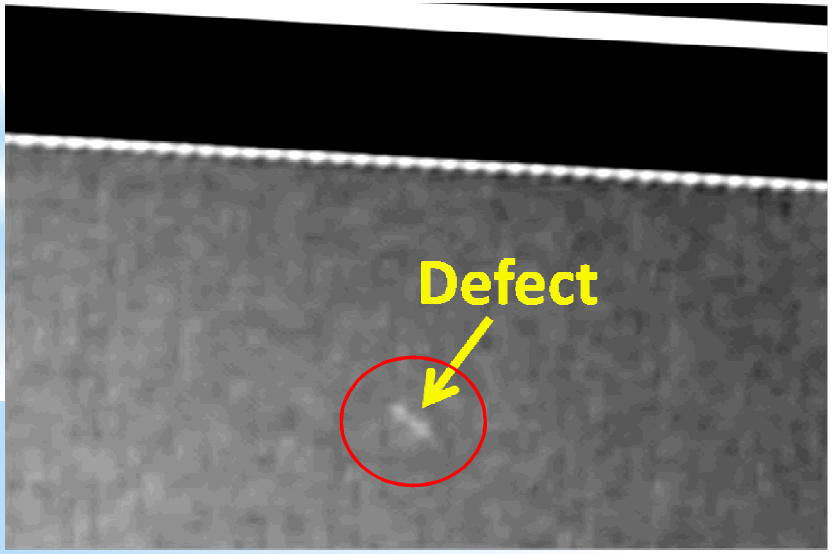
CASE I. Laser-based Imaging in Metal Combs

- Metal comb structures used as process monitors for back end of the line defects
- TIVA easily indicates current path but resolution is poor
- Reflected-light images more clearly define size and shape of defect sites than TIVA

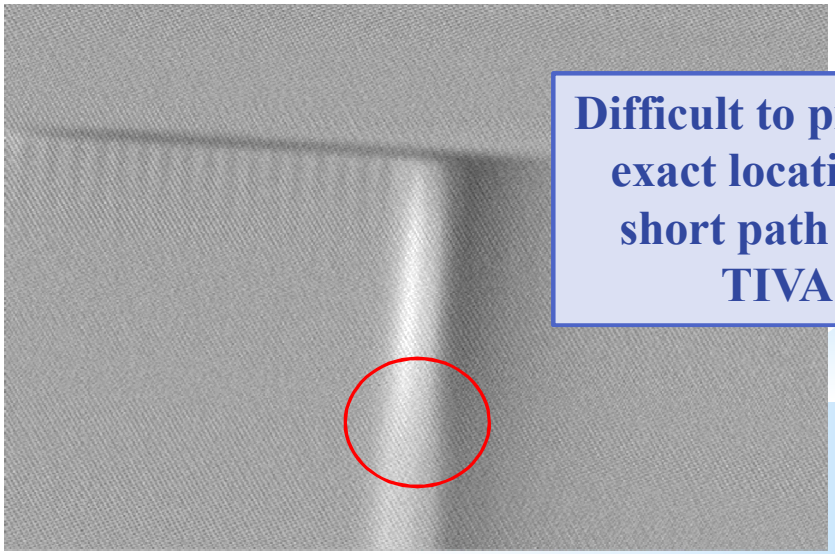


Metal comb structure layout

1340-nm Reflected Light Image



1340-nm TIVA map

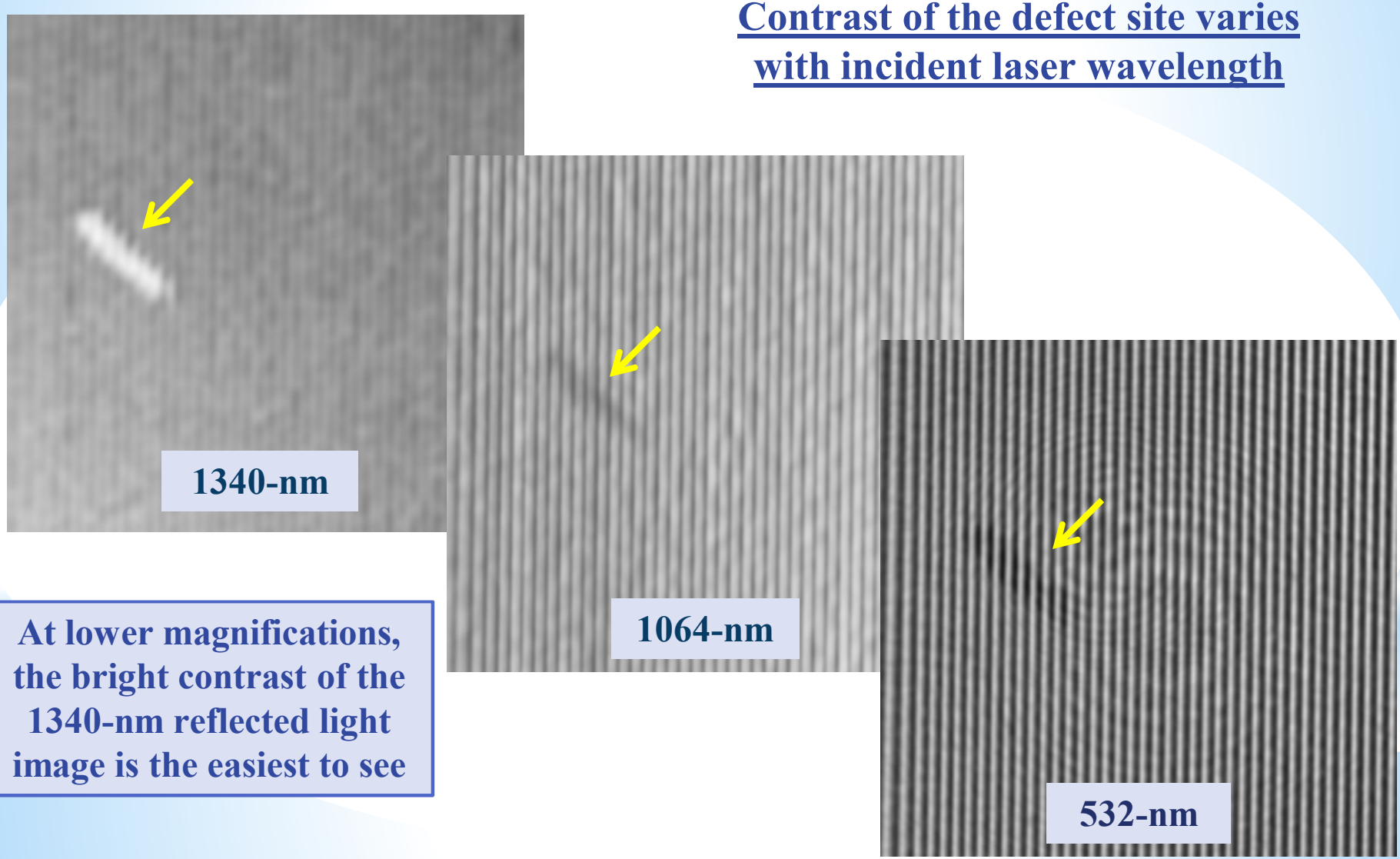


Difficult to pinpoint exact location of short path with TIVA

CASE I. Laser-based Imaging in Metal Combs

Reflected Light Images

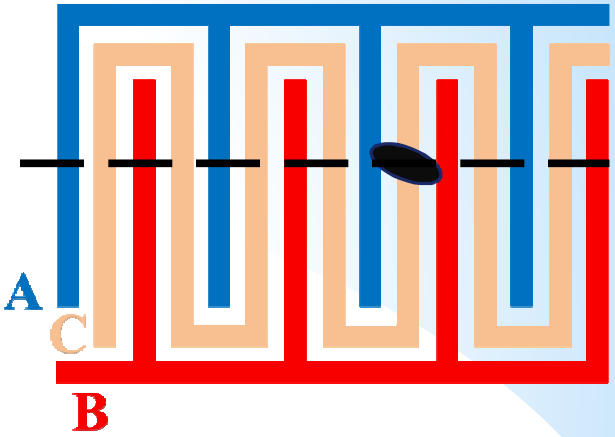
Contrast of the defect site varies with incident laser wavelength



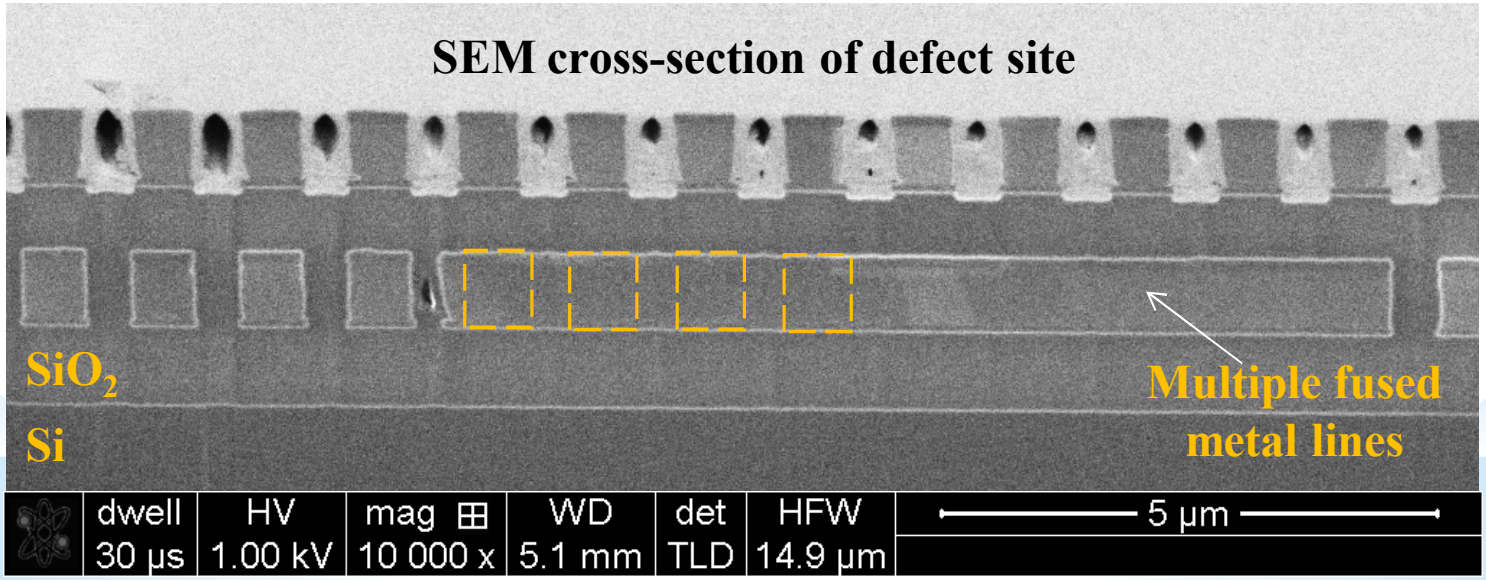
At lower magnifications, the bright contrast of the 1340-nm reflected light image is the easiest to see

CASE I. Laser-based Imaging in Metal Combs

- Multiple metal lines fused together
- Uniform, complete stack formation
- No indication of particle/contamination on top of stack

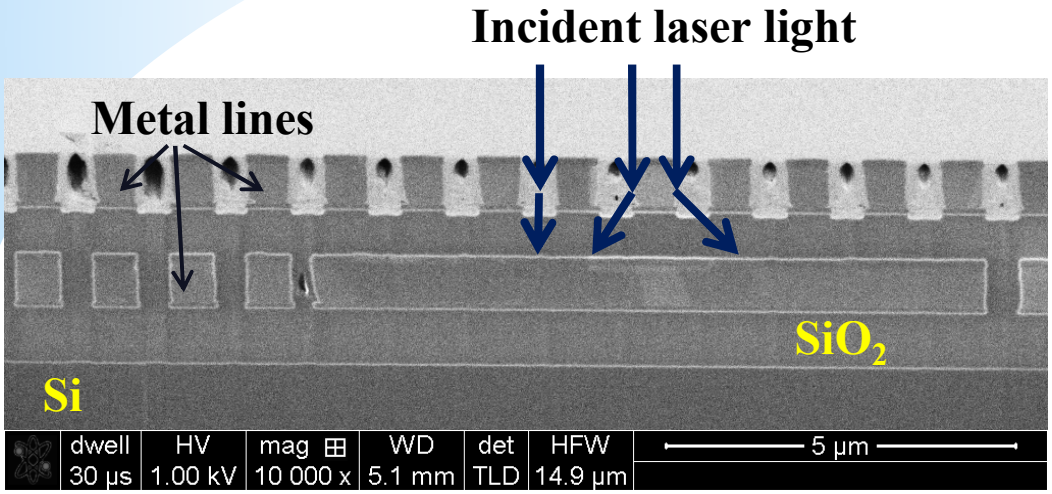


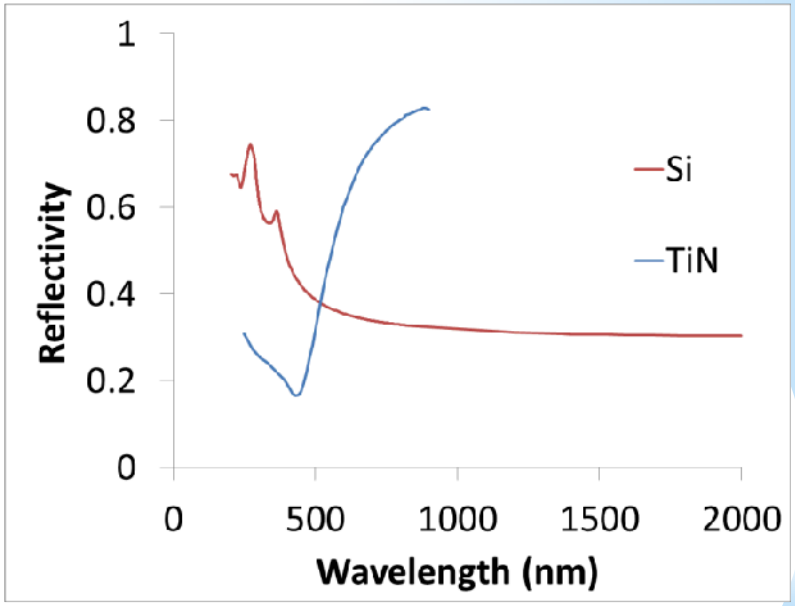
- Defect/particle likely fell on to patterned lines and was cleaned away with post-etch cleans



CASE I. Laser-based Imaging in Metal Combs

Contrast differences between laser wavelengths…

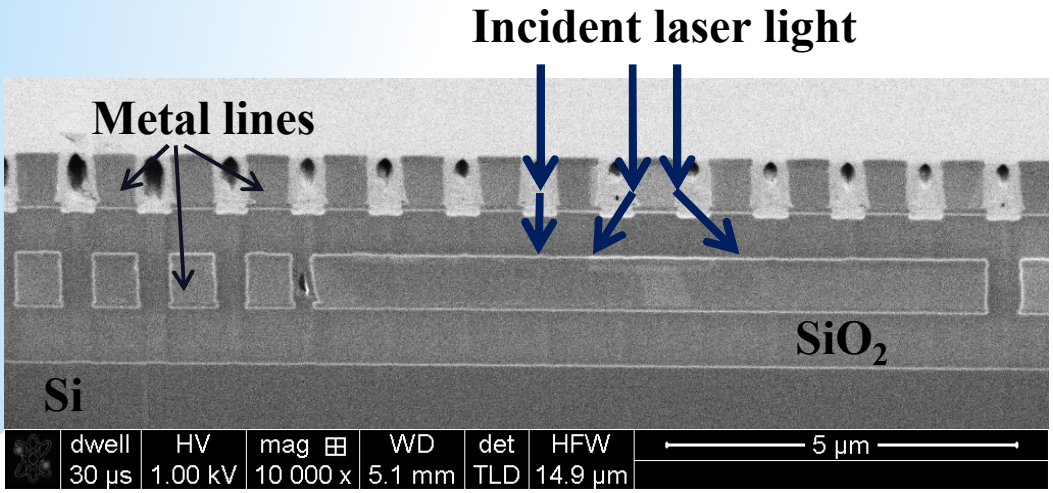




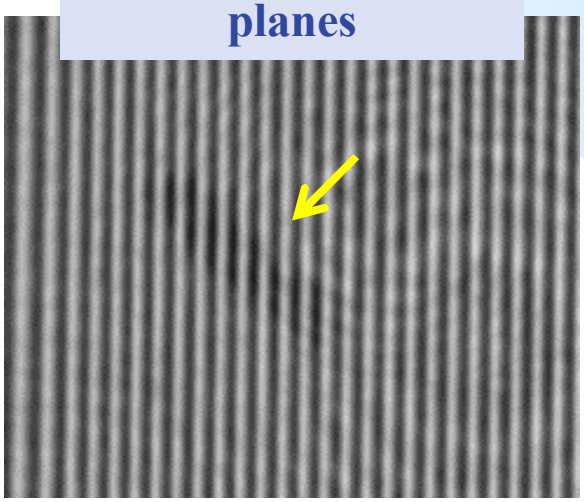
- **Reflectivity drops slightly for 532-nm laser wavelengths**
- **Index scattering with heat**

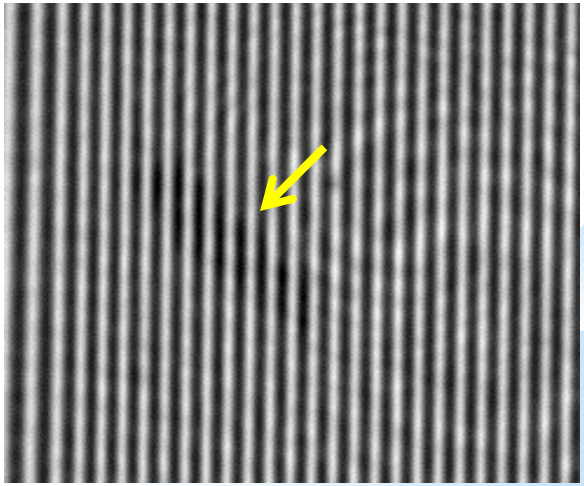
CASE I. Laser-based Imaging in Metal Combs

Contrast differences between laser wavelengths…



532-nm Reflected Light images at different focal planes

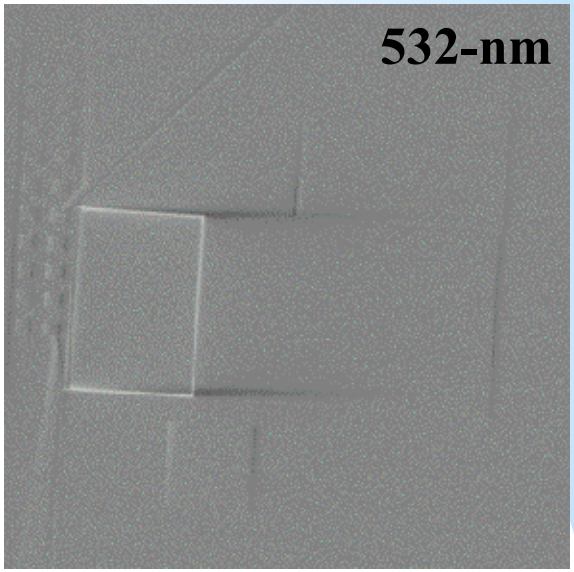




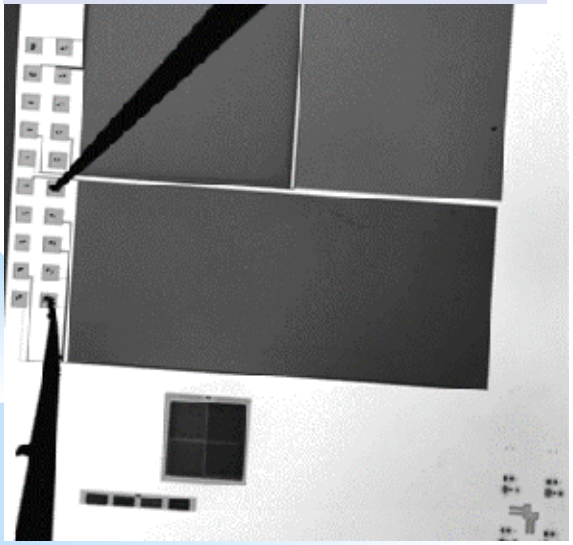
- **Focus up and down did not change contrast of defect**
- **Likely constructive and deconstructive interference and resolution of incident wavelength**

CASE I. Short-wavelength TIVA imaging

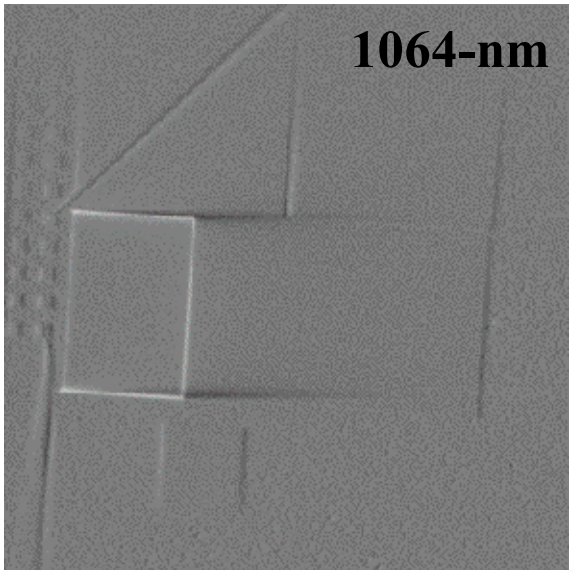
- Defect site creates metallic short, circuit made only of metal wiring
- The 532-nm laser causes increase in temperature in defect circuit → TIVA map
- Little electron-hole pair contrast swamping

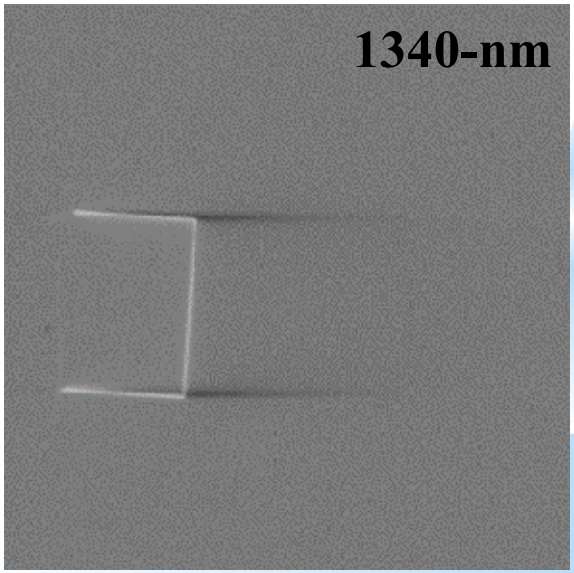


532-nm Reflected Light image



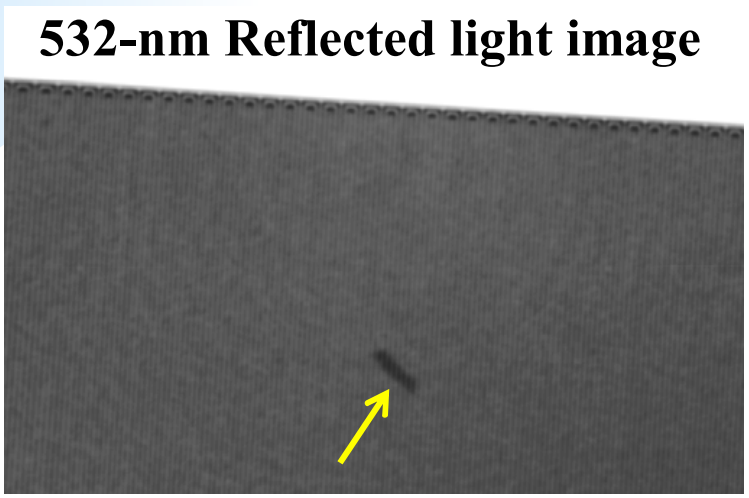
TIVA Maps

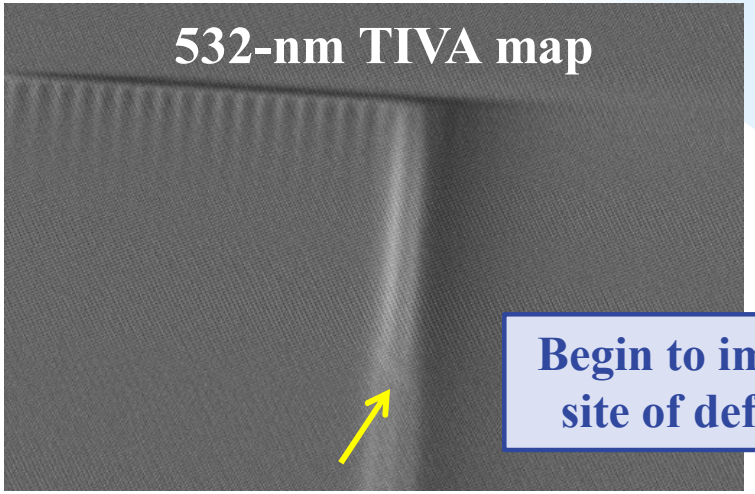


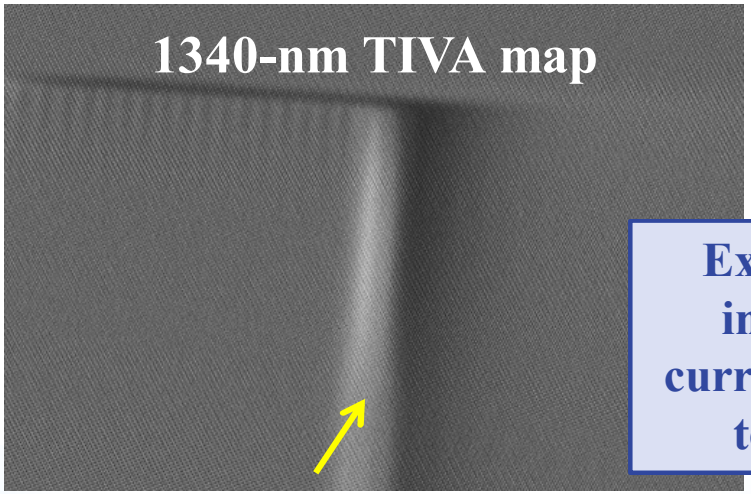


CASE I. Short-wavelength TIVA Imaging

- Increased resolution of 532-nm TIVA image makes localization easier
- Reflected light image still provides the easiest path for localization





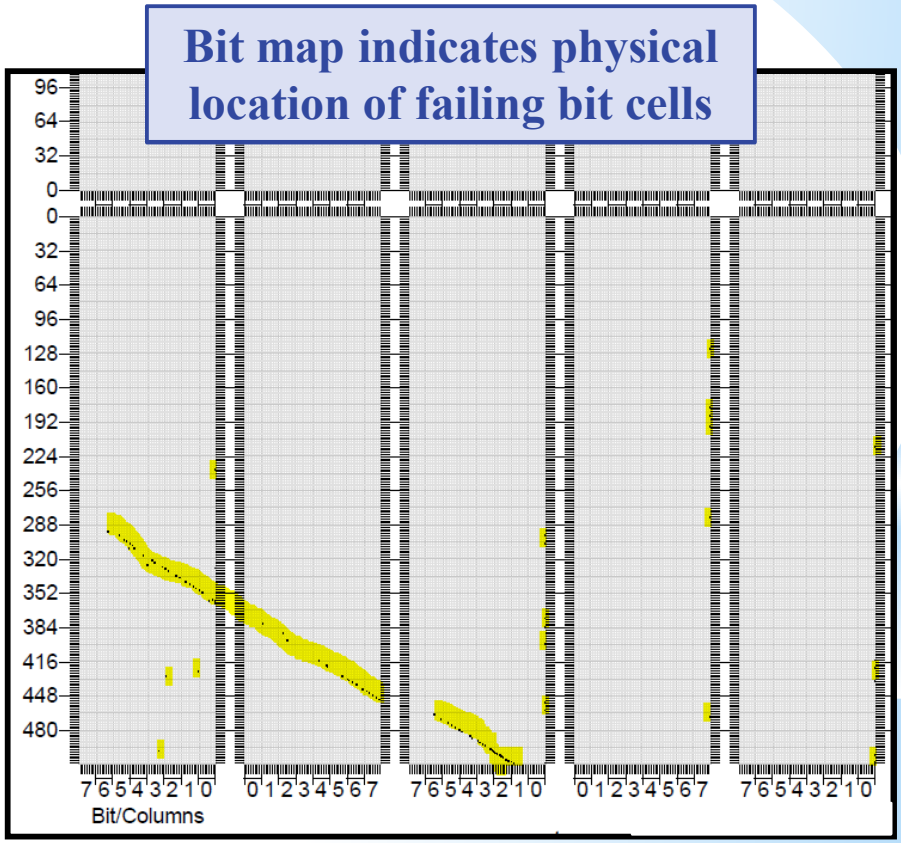


Case II. Linear Strings of Failing Bits

- SRAM dice were failing memory testing
- Same x,y coordinate over multiple lots
- Bitmapping revealed linear strings of failing bit cells, indicating a systematic failure mode

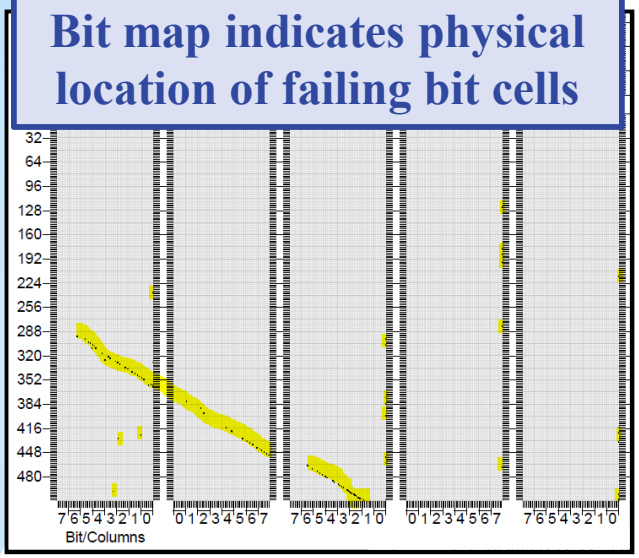
Initial Inspection

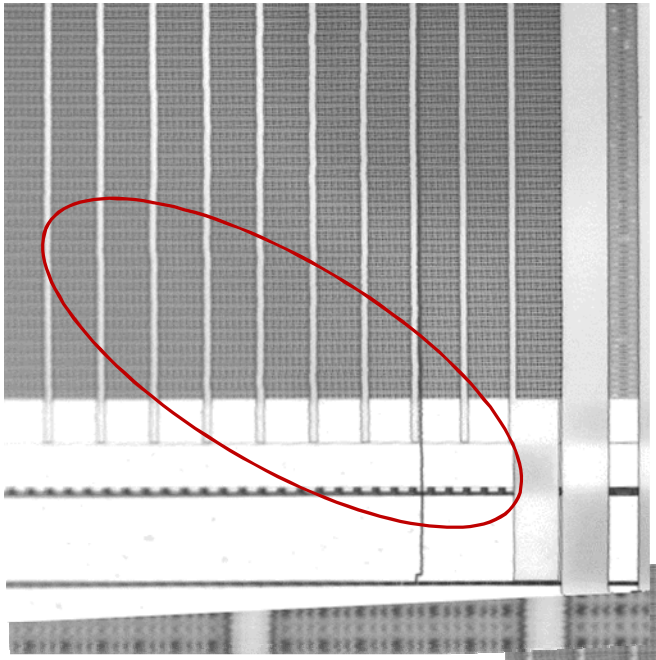
- Clean optical inspection
- Inconsistent light emission
- No TIVA signals under operating voltages
- LIVA signals at low currents matched the bitmap signature



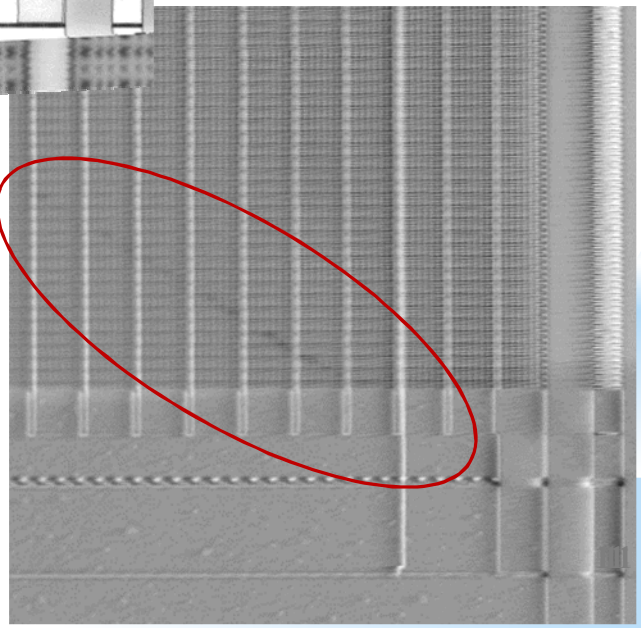
Case II. Linear Strings of Failing Bits

Bit map indicates physical location of failing bit cells





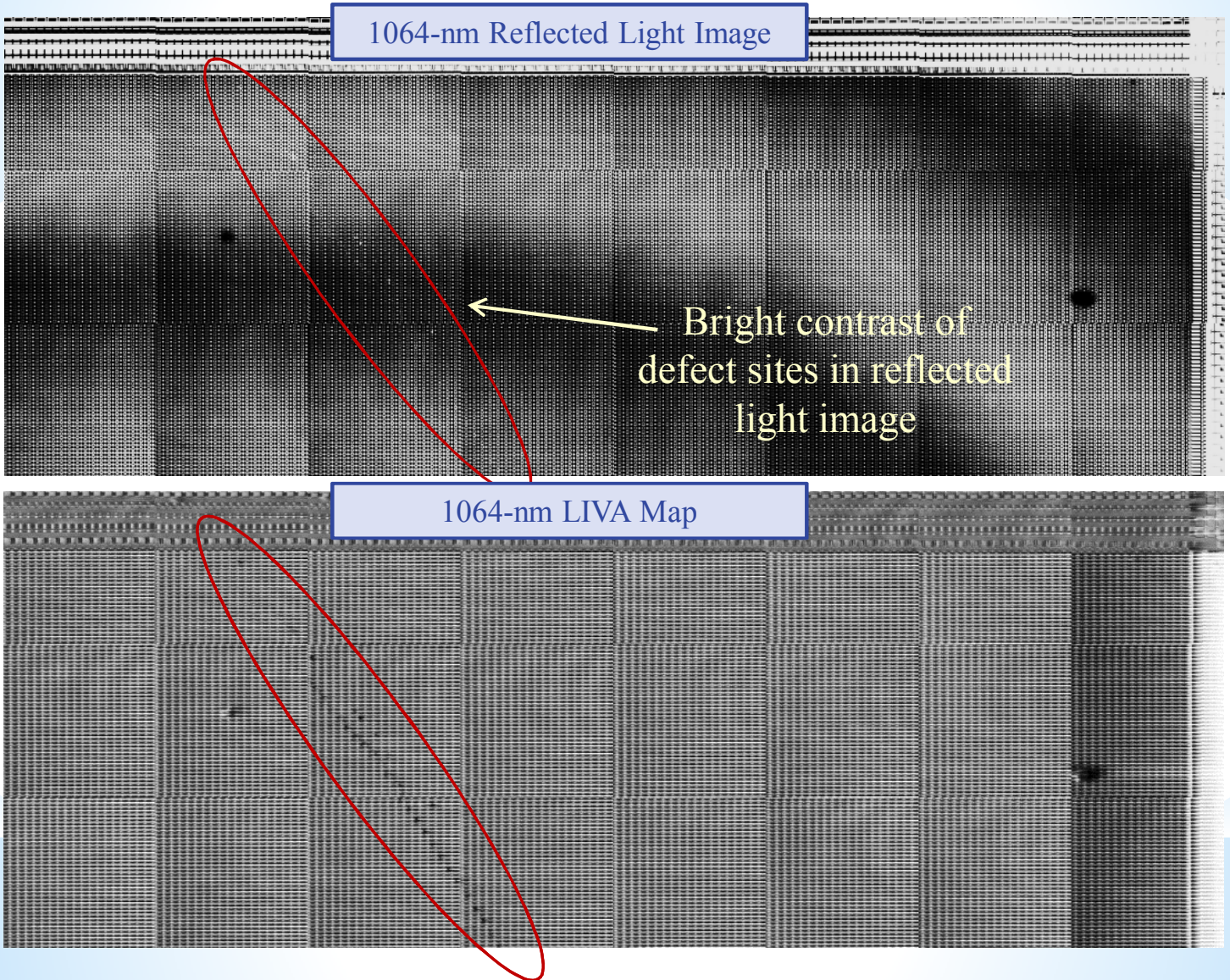
Frontside 532-nm Reflected light image (left) and LIVA image (below) at 100nA



- **Dark discrete LIVA signals matched the physical location of the failing bit cells**
- **Top-side analysis suggested only NMOS → implant?**
- **Metal coverage may obscure PMOS signal**

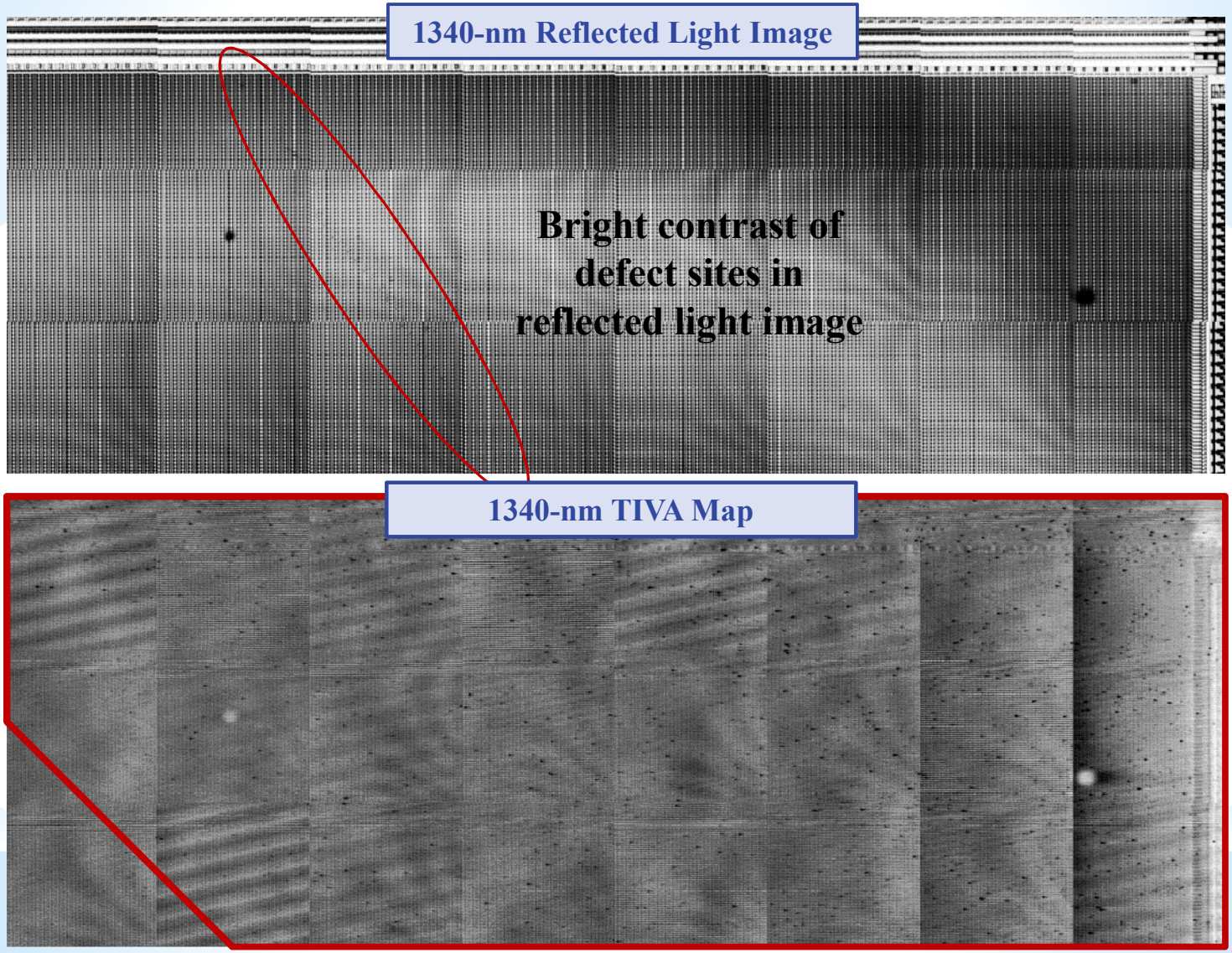
Case II. Linear Strings of Failing Bits

Backside imaging revealed good tracking of both the reflected light images and the LIVA map to the failing bit pattern.

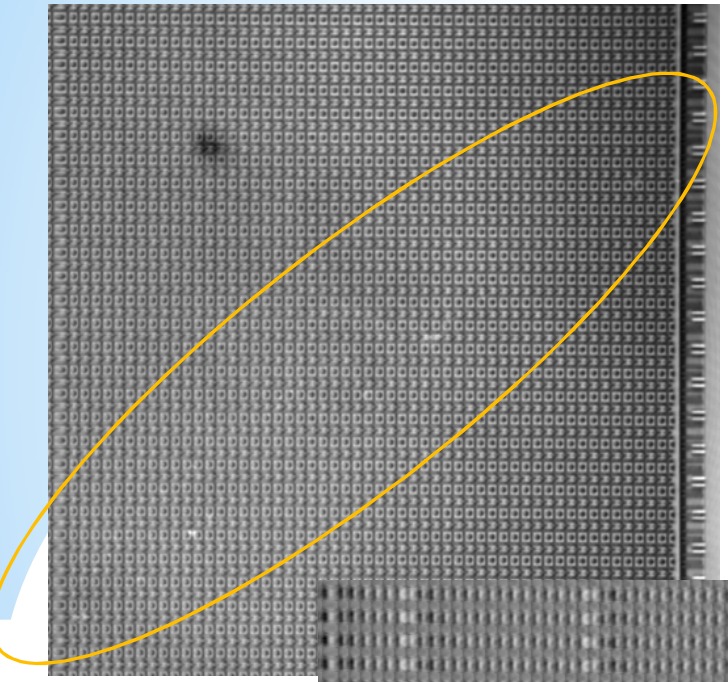


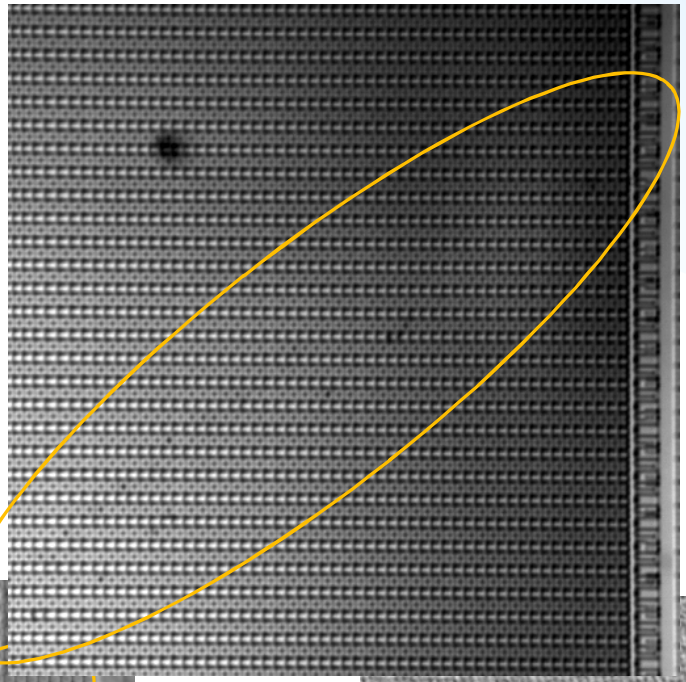
Case II. Linear Strings of Failing Bits

The TIVA map showed a high density of dark discrete signals



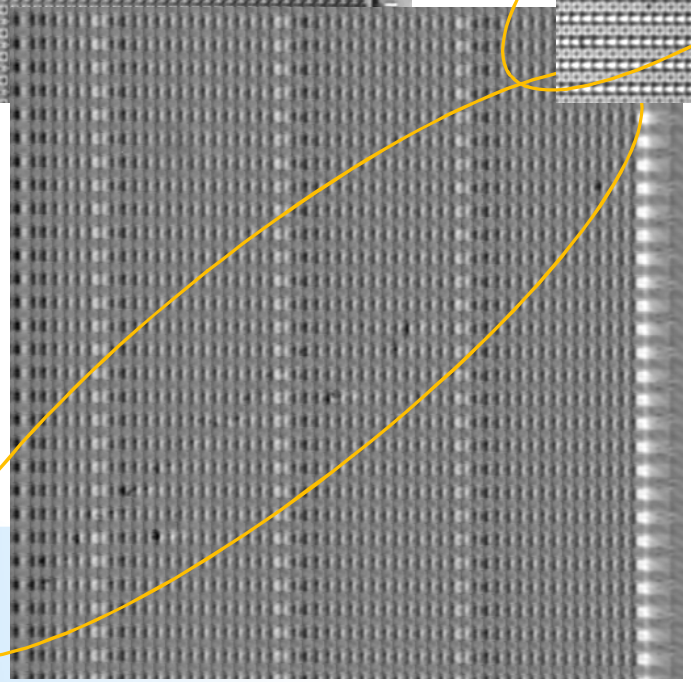
Case II. Linear Strings of Failing Bits

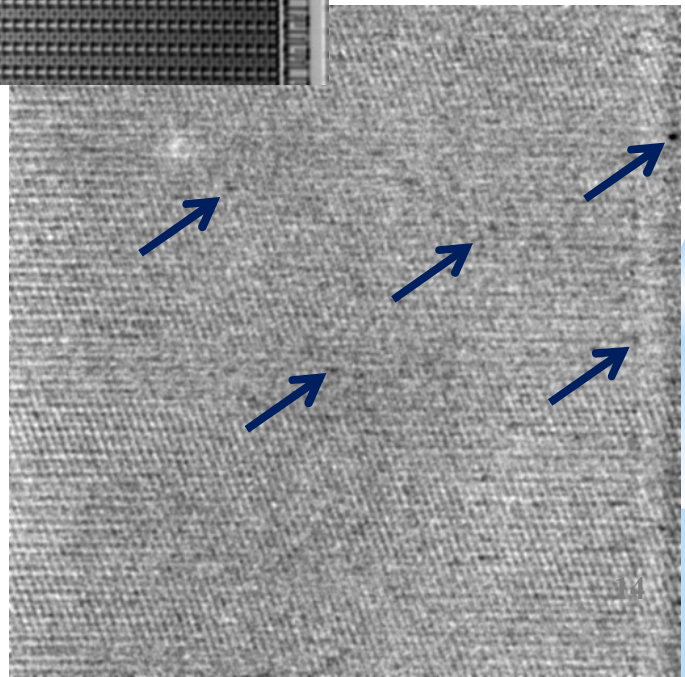




1340-nm Reflected light image (left) and TIVA map (below)

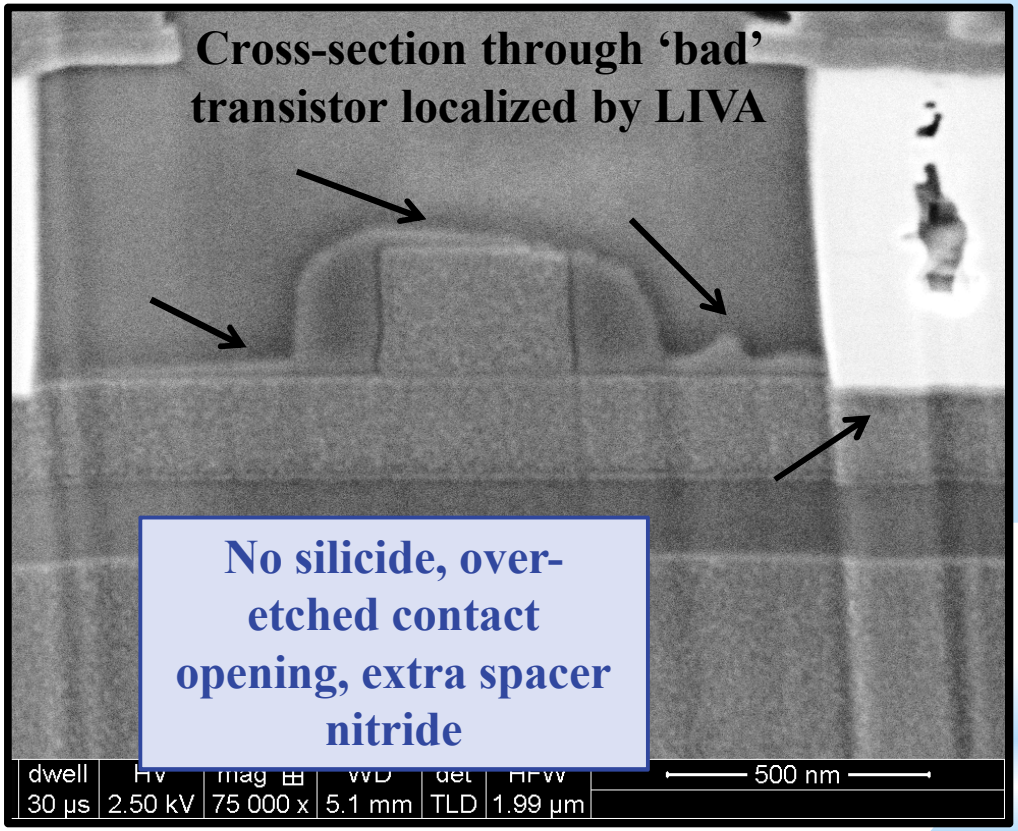
1064-nm Reflected light image (above) and LIVA map (right)

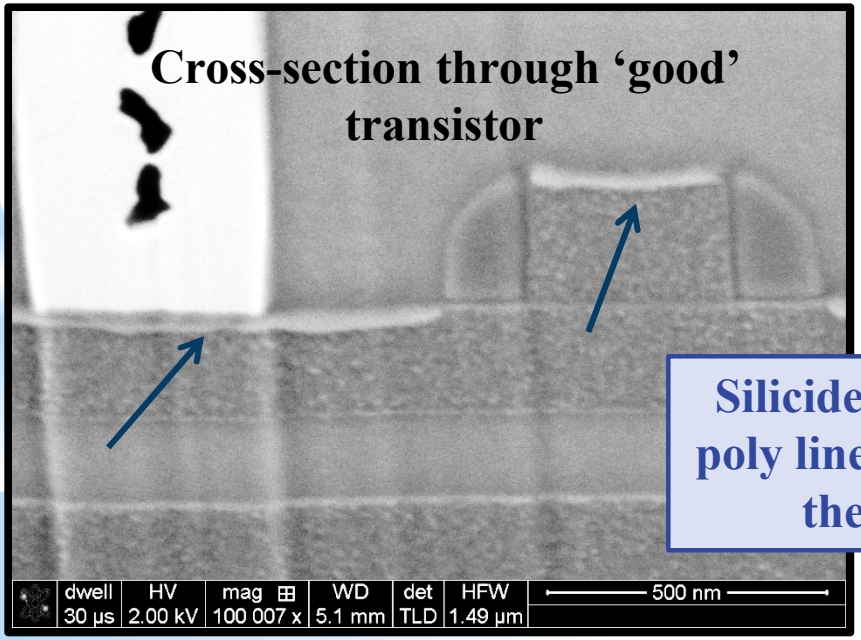




Case II. Linear Strings of Failing Bits

- Source of the scratch was found to be extra spacer nitride
- The nitride stopped the formation of Ti-silicide increasing the resistance of the contact
- The electrical response is suspected to come from differing contact resistance within a single bit cell

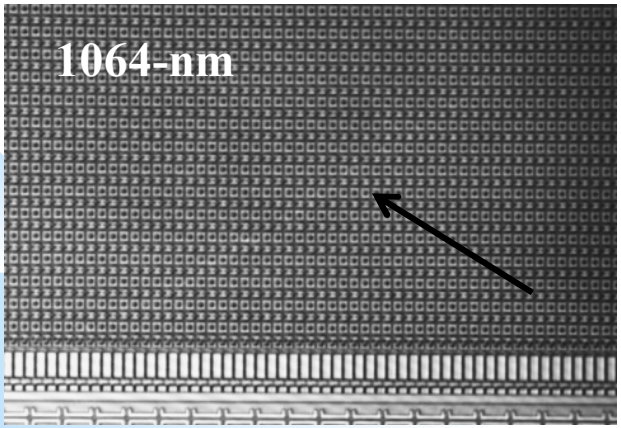


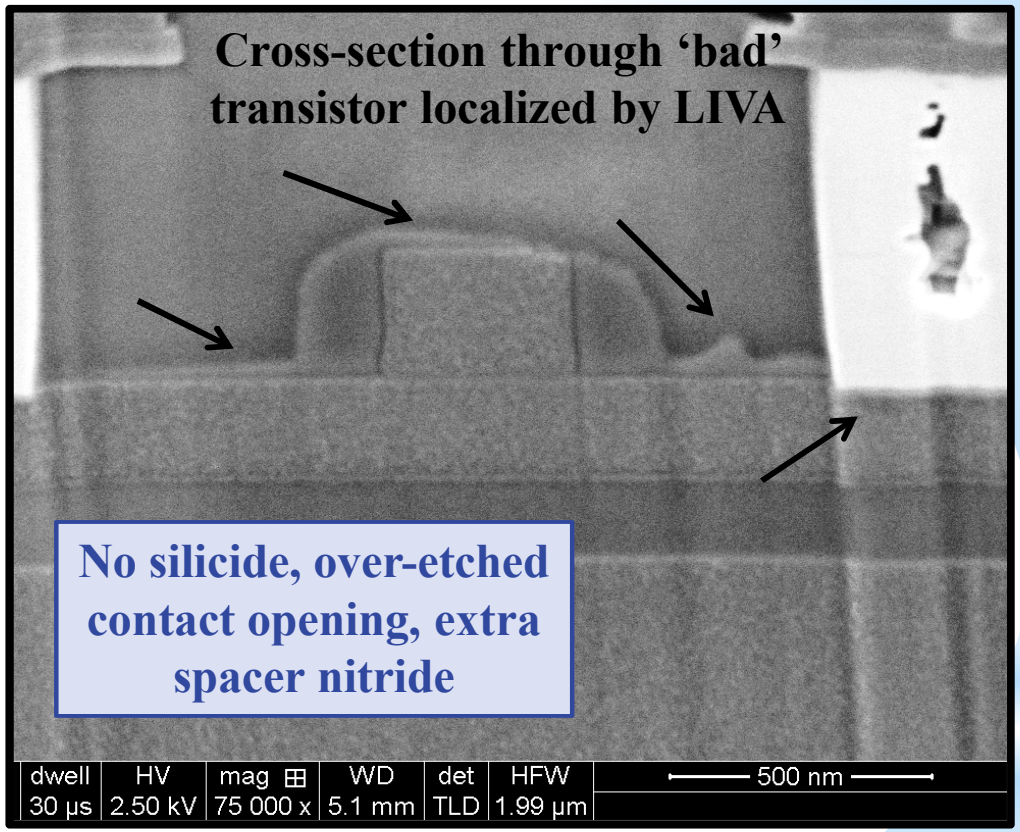


Case II. Linear Strings of Failing Bits

- FIB cross-sections through discrete TIVA signals did not show anything obvious → decorated dislocations
- Dark contrast in 1340-nm reflected light image from missing silicide
- Bright contrast in 1064-nm culmination of scattering (density of pattern) and reduced reflection

Reflected Light Image





SUMMARY AND CONCLUSIONS

- Case studies reveal importance of reflected light images in laser-based defect localization
  - Reflected light image can show position of defect
  - Contrast in reflected light images can show size and shape of a defect
  - In some cases, the reflected light image may be the best localization method
- Visible wavelength lasers do not always create electron-hole pair contrast swamping of TIVA measurements