DIGITCONCEPT
Microelectronics & HighTech Equipment

FA Instruments

Relationship of TLS/SIFT tools

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Outline

- The Broad Knowledge Base of FA Acronyms/Tools/Trends.
- Problematic Questions.
- IV Signatures and Characterization.
- Choosing the Appropriate Analysis Path.
- Differential Detection Methods (Stabilize/Lock In).
- Laser Stimulus Methods.

The Sea of Analysis Acronyms

XRF, SEM, EDX, C-SAM, TEM, AFM, AFP, SPM, TUNA, SSRM, SCM, C-AFM, EFP, MFP, PVC, FIB, EBIC, OBIC, LSM, LVP, VC, CVC, RCI, SEI, SOM, CIVA, EMMI, OBIRCH, INSB, SWIR, MWIR, LWIR, UV, FMI, SFMI, LC, TIVA, LIVA, XIVA, SQUID, SIFT, TLS, RCL, RIL, LADA, PIND, TDR, X-RAY, FTIR, ESCA, AES, SIMS, BIST, DFT, PICA, RIE, DPA …

I am the very model of a modern Major-General,
I’ve information vegetable, animal, and mineral…Gilbert and Sullivan

Contemporary Analysis Tools

- Extended CCD IR and InGaAs Photoemission Microscopy
- Moiré Thermal Pattern Analysis
- Scintillation Liquid Crystal*
- Stabilized VisGaAs/InGaAs/InSb/FMI Thermal Imaging
- Integrated Process Control Tester/Parametric Analyzer
- Laser Induced Stimulus Methods
- Magnetic SQUID
- SEM/C-SAM/X-ray

DPA Contemporary Analysis Tools

- SPM and AFP Family*
- Focused Ion Beam
- Cross Section/Lapping
- Delayering (Chemical, RIE, and lapping)
- TEM/SEM*

*Assumes the tool is used after destructive preparation

Analysis Tools Losing Ground to Scaling

- Frontside Focused Ion Beam Edits
- Photon Emission
- SEM/Voltage Contrast
- PICA
- LVP
- Liquid Crystal
- Traditional Differential Thermal Analysis

Impact of <90nm nodes on FA

- High gate oxide leakage coupled with short channel effects complicates thermal and photon emission analysis.
- The defect signal is typically no longer orders of magnitude greater than the background and is also deep submicron.

Problematic Questions

- How much current or voltage can you detect?
- How sensitive is the instrument?
- How long will the analysis take?
- My part fails, how much will it cost to analyze it?

Failure Analysis, like the medical field, is an art as well as a science.

Problematic Questions

- Tell me the final root cause of failure and I'll tell you how long the analysis will take. Without the details, only a guess is possible as the failure mechanism/location is unknown. It is unrealistic to expect FA to operate in a production mode!

The Importance of Characterization

- Hot/Cold Fail?
- Voltage/Timing Dependent?
- IDD/IDDQ outside of population?
- Stable Leakage or 1/f?
- Light Sensitive?
- Field Sensitive?
- Responsiveness to Stimulus?

The Importance of IV Curve Analysis

- IV curves serve as predictors for the type and likelihood of obtaining photon emission data.
- Linear responses generally are best detected with thermal methods whereas non-linear are usually photon emitters.

Know the proper operating point!

The Analysis Path

- Do not arbitrarily assume an analysis path based on leakage or a limited pass/fail test alone unless forced to do so.
- Data collection up front is key to choosing an analysis flow with minimal wasted time/poor results.
- Requestor and FA Engineer must both be on the same page!

Complimentary Tools

- TLS/OBIRCH/TIVA are not replacements for existing tools. They augment the analysis or enable the analysis where other tools fail to perform.
- Low ohmic shorts are more easily identified with thermal or magnetic mapping methods, as an example.
- The same differential methods used to build signal: Stabilized or “lock in” apply.

Fundamentals of Photon Emission or:

How much current can I detect?

Photon emission occurs strictly based on the nature of the material under bias. Resistive characteristics result in no photon emission unless the energy is sufficient to produce thermally generated photons within the response of the camera. Squid microscopes detect current.

Fundamentals of Photon Emission or:

How much current can I detect?

Insufficient! Needs 2 of 3 variables to solve ohms law.

Ohms Law: V=I*R and V^2/R=Power

Power Density/Conversion Efficiency must be considered!

10nA X 1 million emission sites = 10mA!

Thermal faces similar distribution issues.

Fundamentals of Thermal or:

How much current can I detect?

Ohms law still applies!

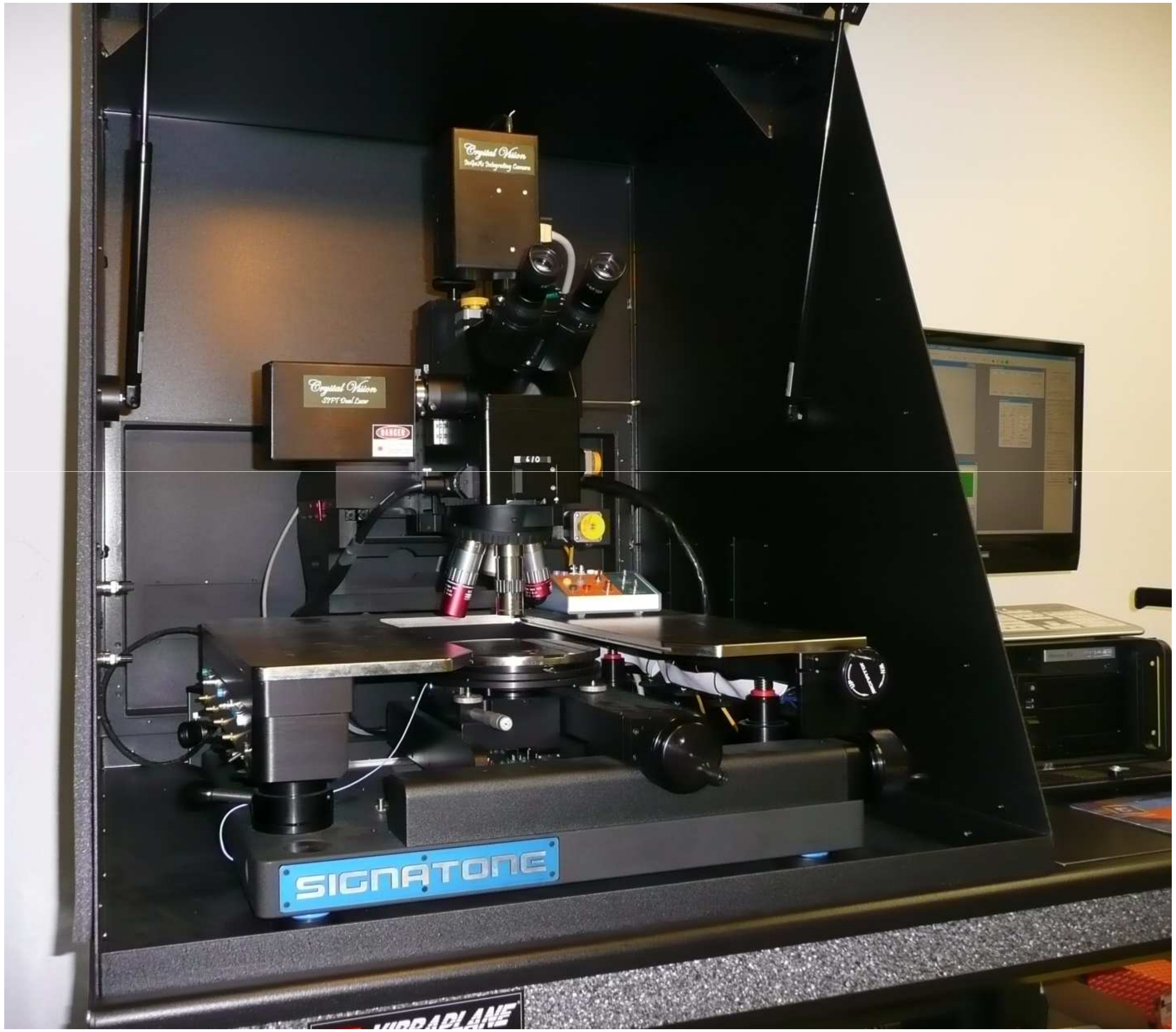
Thermal phenomenon detection is based on a deltaT, not on current. The location of the thermal source and distributed area of the source are deciding factors for detection. For IR cameras, black body radiation plays a major role in sensitivity. All thermal detection methods are relative.

Stabilized Thermal Imaging

Enhances all thermal imaging techniques by frame accumulation. Up to 2x more sensitive than “lock in thermography” by bypassing phase sampling requirements. Abs Value calculations capture phase differentials and stroboscopic timing can be “tuned” to optimize sensitivity.

- IR Cameras (InSb, InGaAs, LWIR MgCdTe)
- FMI
- Moiré
- Scintillation Liquid Crystal*

SIFT/Photon Emission System



Stabilized Thermal Control

Sequence for acquisition of 16 total frames with 8 frames biased.
All frames=1 are added to fron buffer and all frames=0 are added to froff buffer. Fron-froff=result. Gain reduction is applied to result.   Absolute val used to catch 180 phase.

Frame	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Stabilize 1X	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Stabilize 2X	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
Stabilize 4X	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
Normal	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

Why Use Stimulus Induced Fault Test (SIFT/TLS)?

- Emphasis is on knowing the physical position of the laser beam rather than on gathering tiled images and trying to match to layout. Actual coordinates are obtained making dependence on local feature overlays unnecessary.
- Allows parking and modulating the Laser over the region of interest.
- Initial scans can be done with large spot to mask unwanted local Seebeck effects in the case of OBIRCH/TIVA/TLS methods.
- Constant laser power to sample, due to tilt correction during scan and avoidance of spherical aberration from in lens scanning.

Stimulus Induced Fault Test (SIFT/TLS)

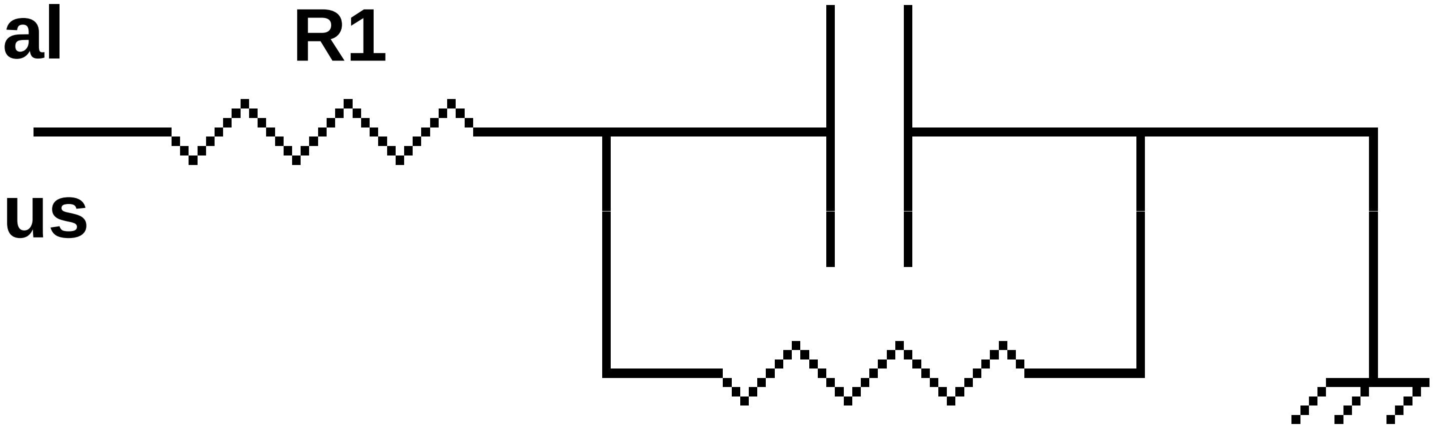
- Thermal Laser Stimulus
- Optical Injection
- Electrostatic Coupling
- Magnetic Mapping
- Logic Fault Mapping
- Raster head or stage for coordinate and constant power control without moving beam in optics but is slow compared to LSM.

- Raster Beam for traditional LSM like operation.
- Scan sample beam position rates: 250 KHz to DC.
- Contiguous full die scan (No image stitching if in SIFT mode).
- Accomodation for die tilt during scan to compensate focus.
- Variable stimulus spot size.
- Defineable scan window in camera view and for full die.

Where is TLS headed?

- Reducing the number of artifacts (false positives) and noise are underway. Stabilized or Lock In methods are used to improve S/N. Phase information is being investigated and related to layers local to the defect.
- Resolution improvements by SIL lens technology is being pushed but the discussion of actual resolution (triangulation of the defect itself) needs to be directly addressed.
- The Analyst needs to understand when to use TLS and how to select proper operating parameters to avoid possible local thermal stress to a fragile defect.

Thermal Laser Stimulus Model



Thermal
Laser
Stimulus

R1

C1

R2

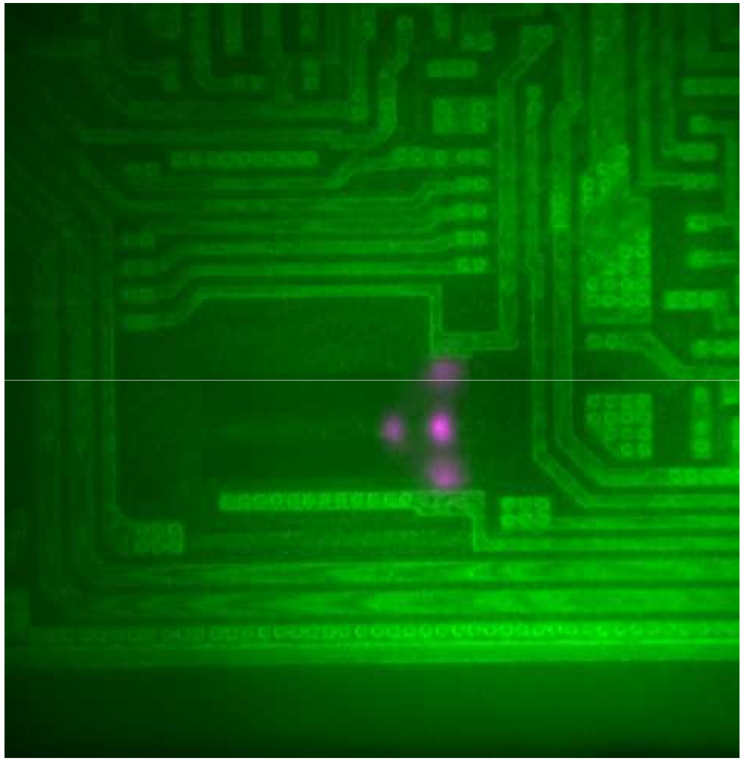
Subst.

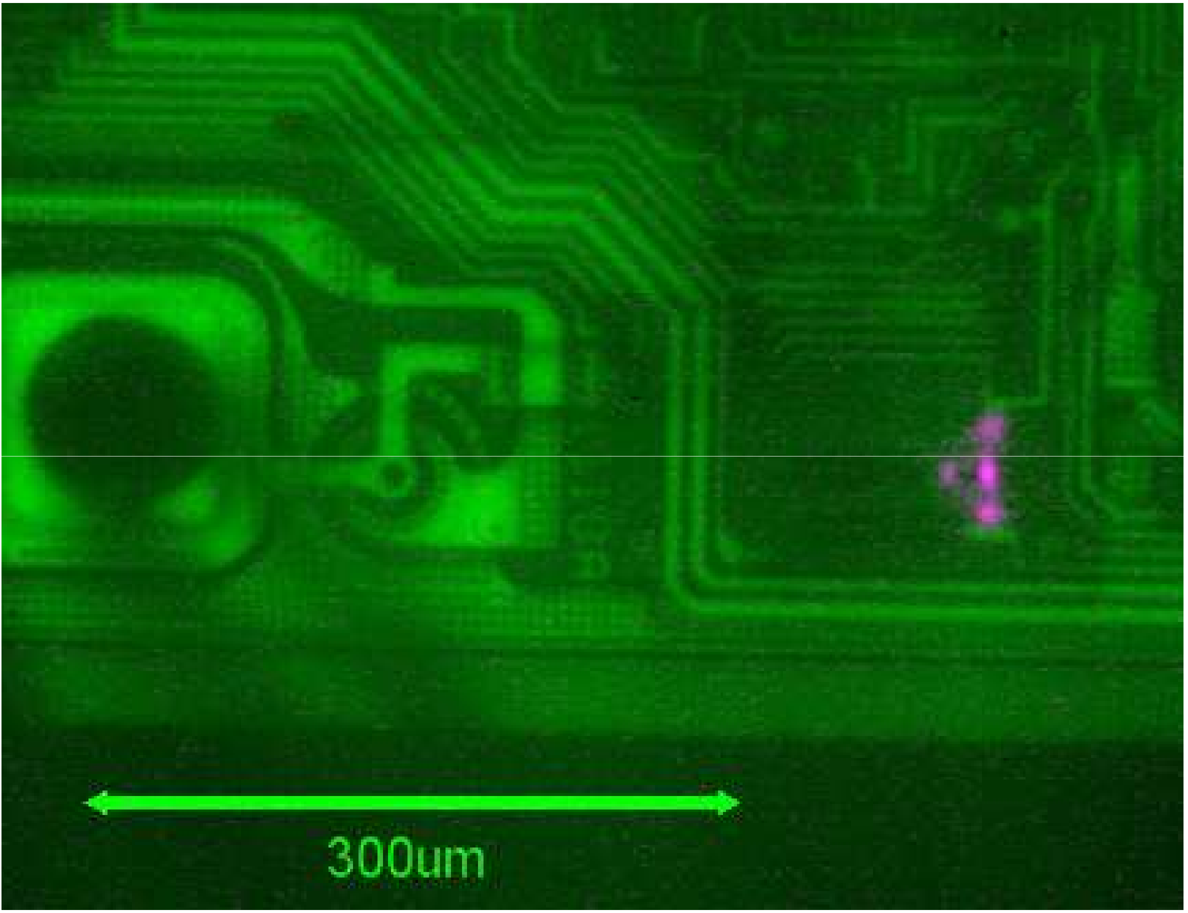
C1≈ Heat Capacity of Node

R1≈ TLS separation distance to C1

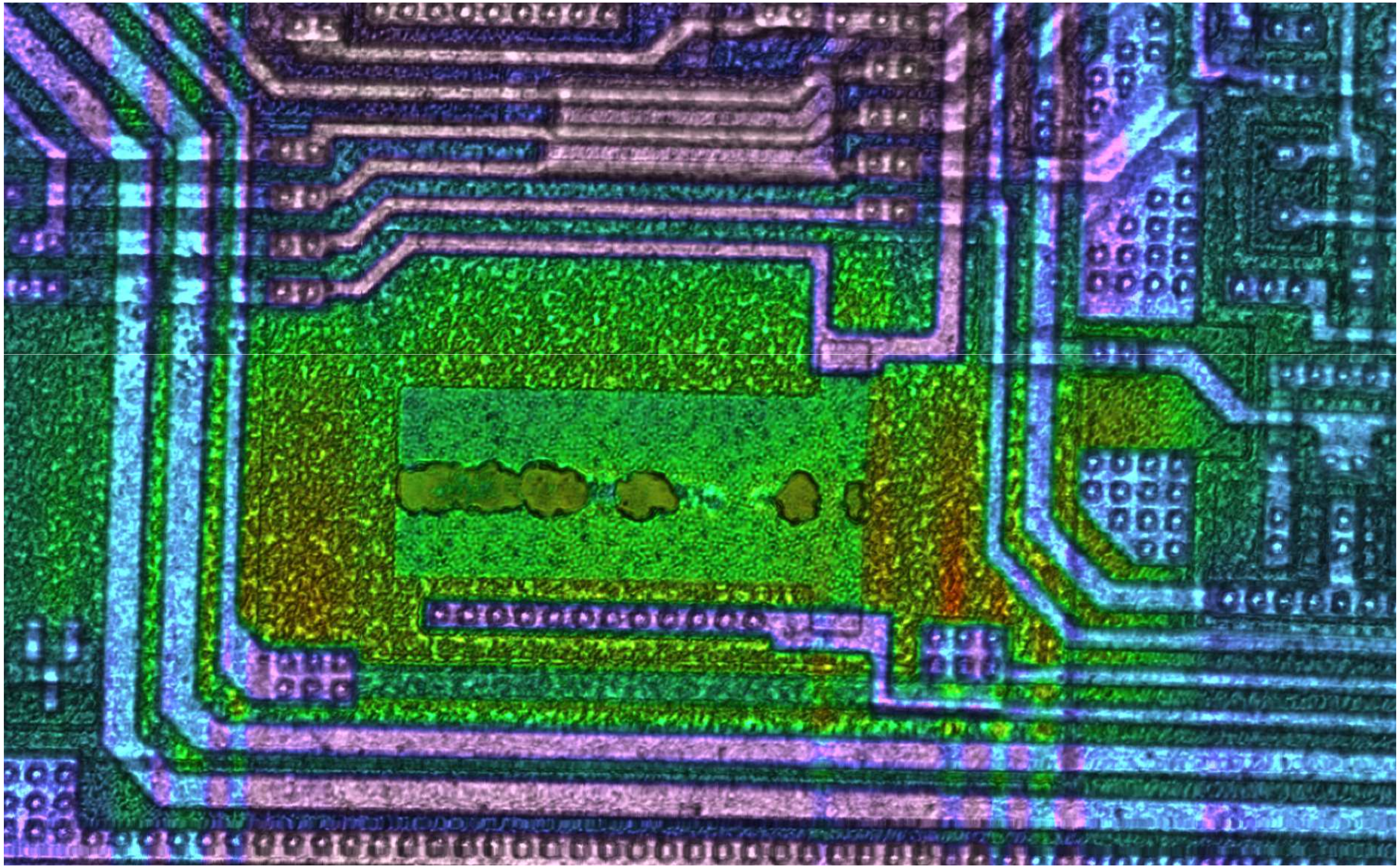
R2≈ Bulk Thermal Resistance

SFMI of 10K Ohm Leakage vs InSb

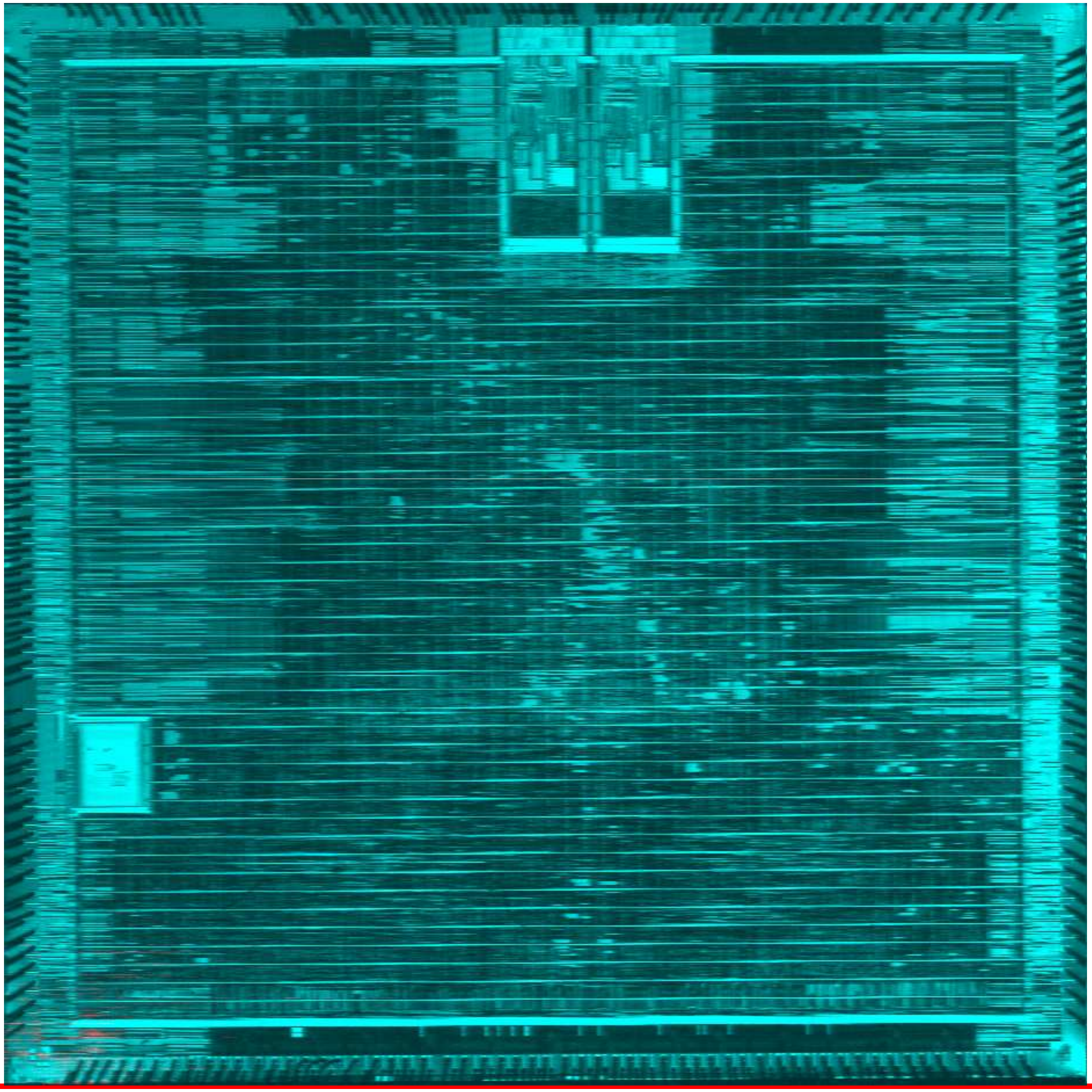




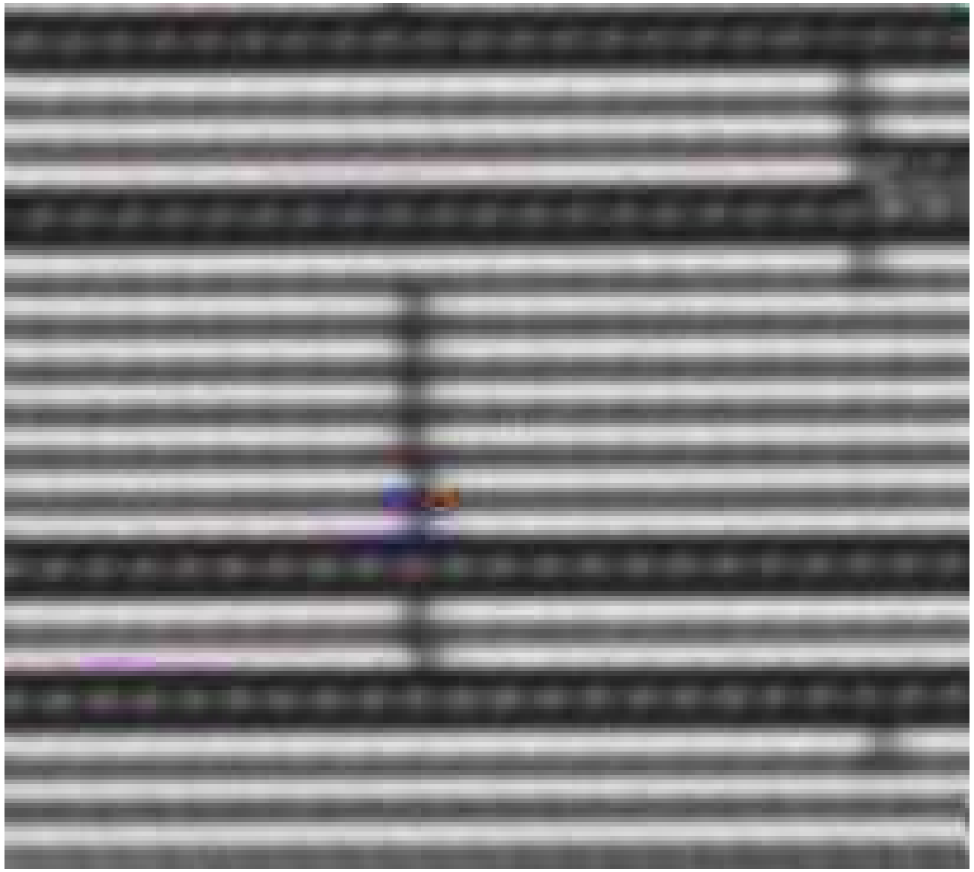
OBIC SIFT Scan of 10K resistor (TLS No Data)
Why did TLS fail to reveal this ohmic?



Full die SIFT scan overlay at 1480nm with a 10X NIR objective. Note the signal in red in the lower left. 0.3V bias

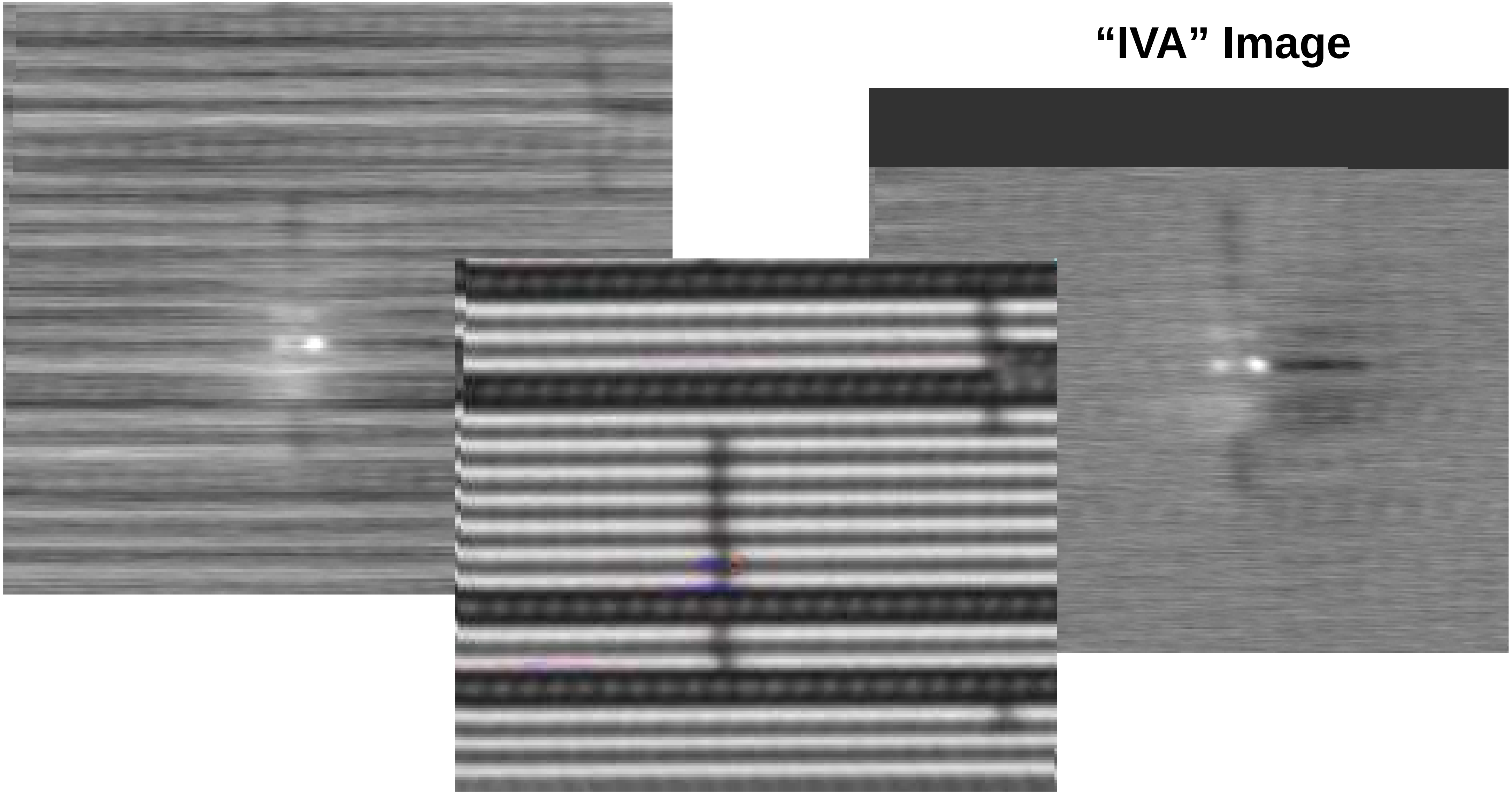


(SIFT 1340nm) Left no filter at 3.3V right with noise filter. (0V bias was best/SEI/Peltier defect) Scan at 1 um step. 20xNIR objective used.

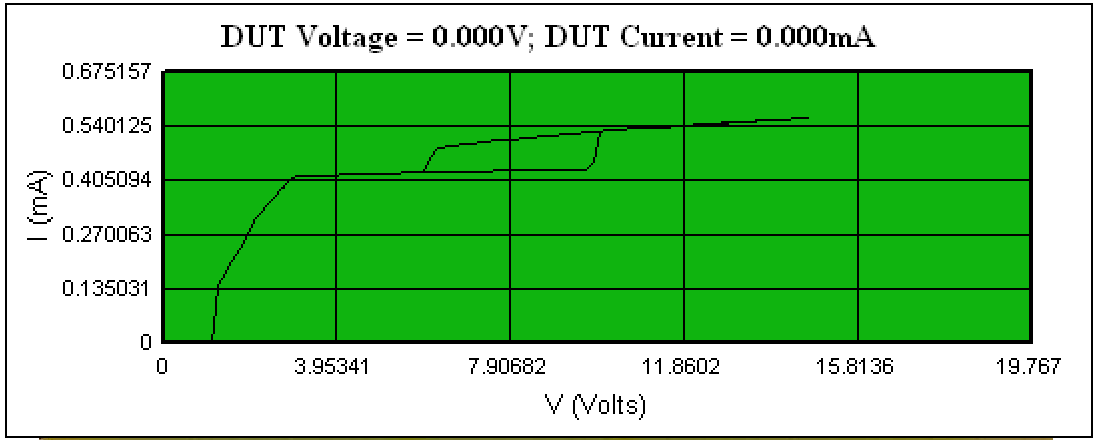


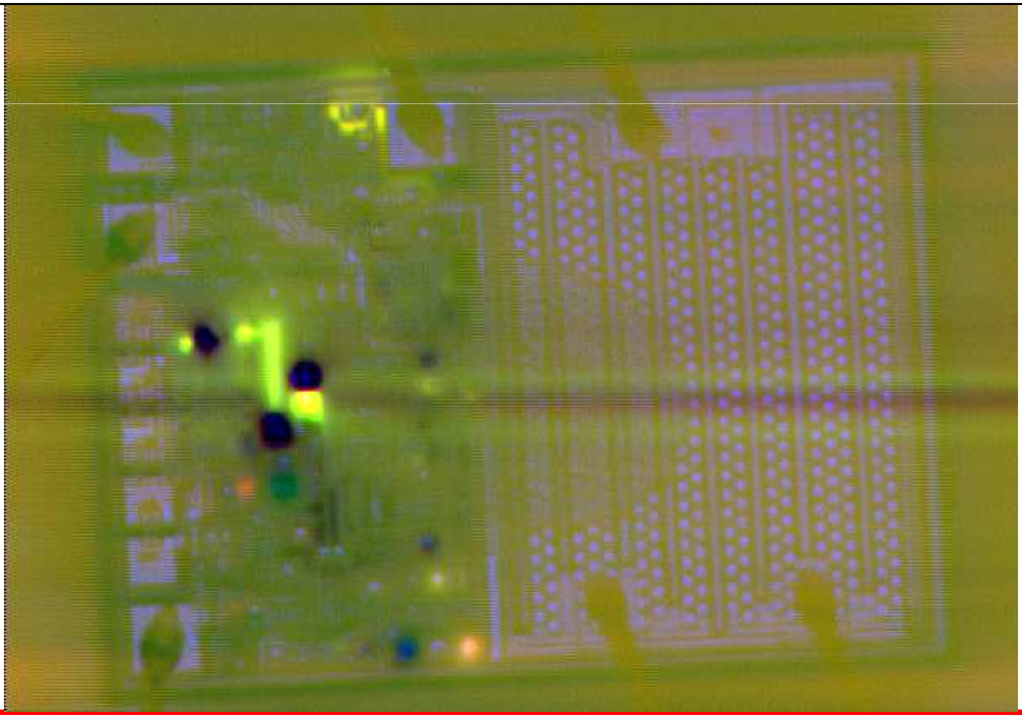
SIFT Image

“IVA” Image

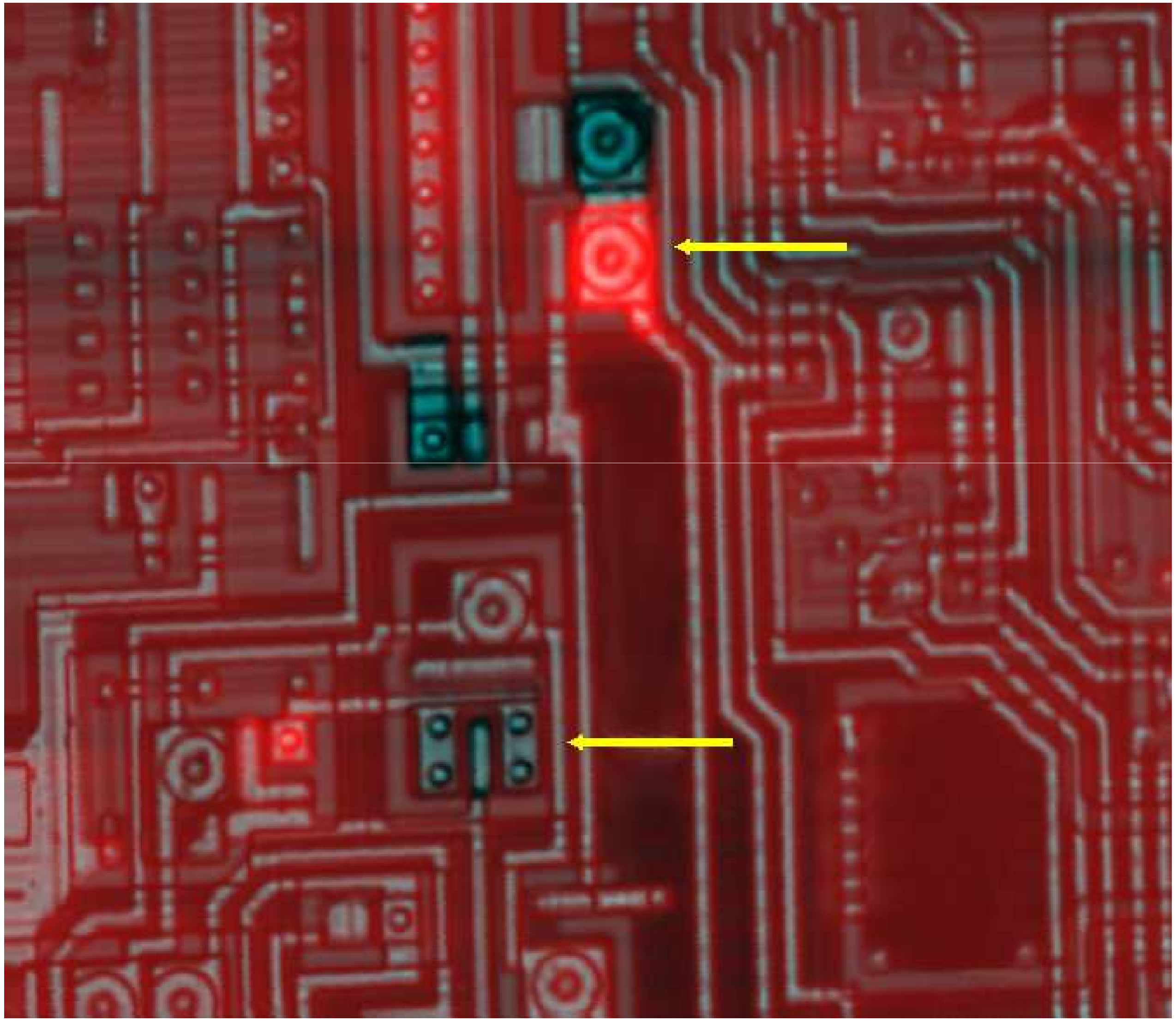


TLS SIFT Overlay of Bandgap Shift

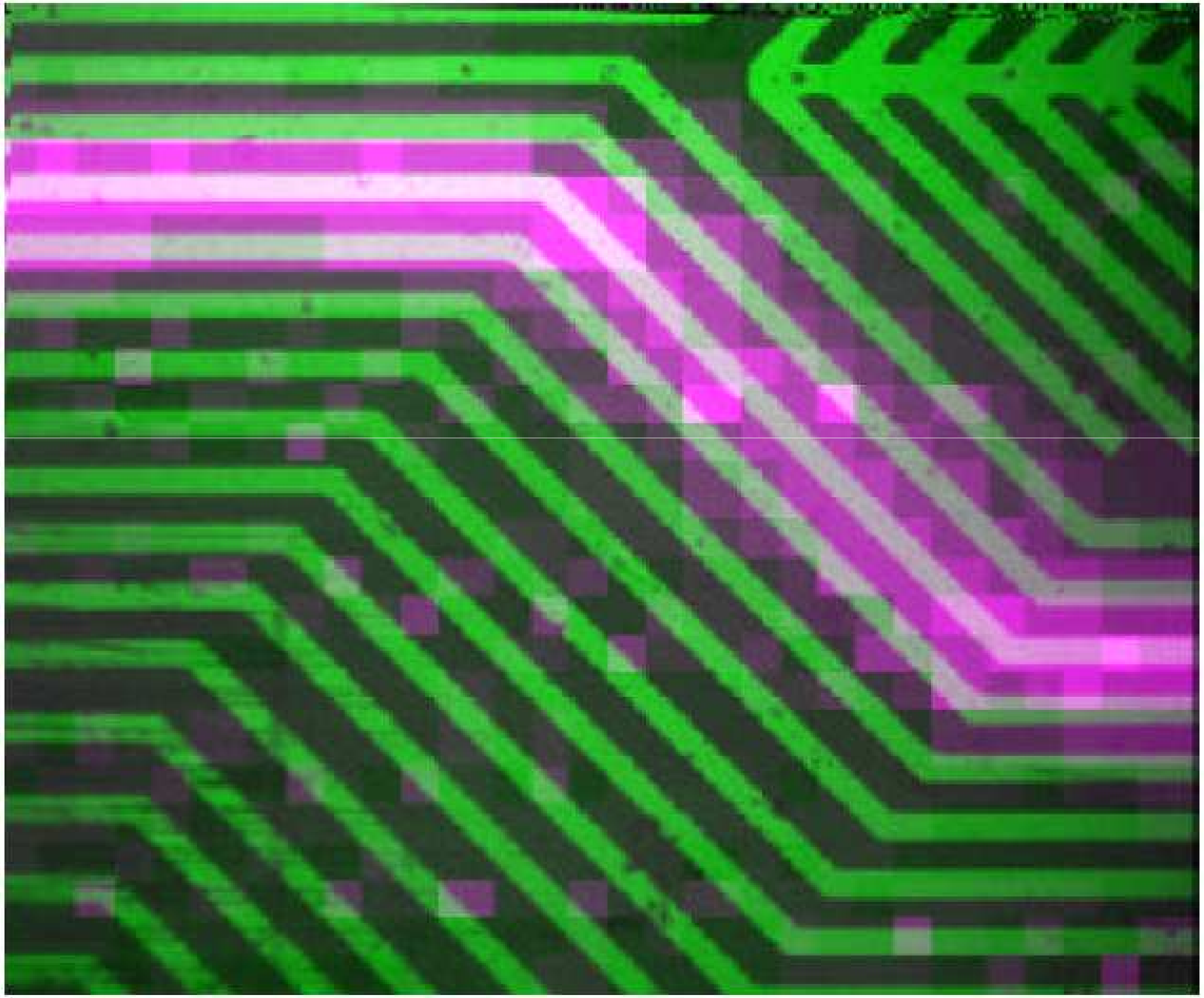




TLS SIFT Overlay of Bandgap Shift.
Laser can be “Parked” to measure local deviation.

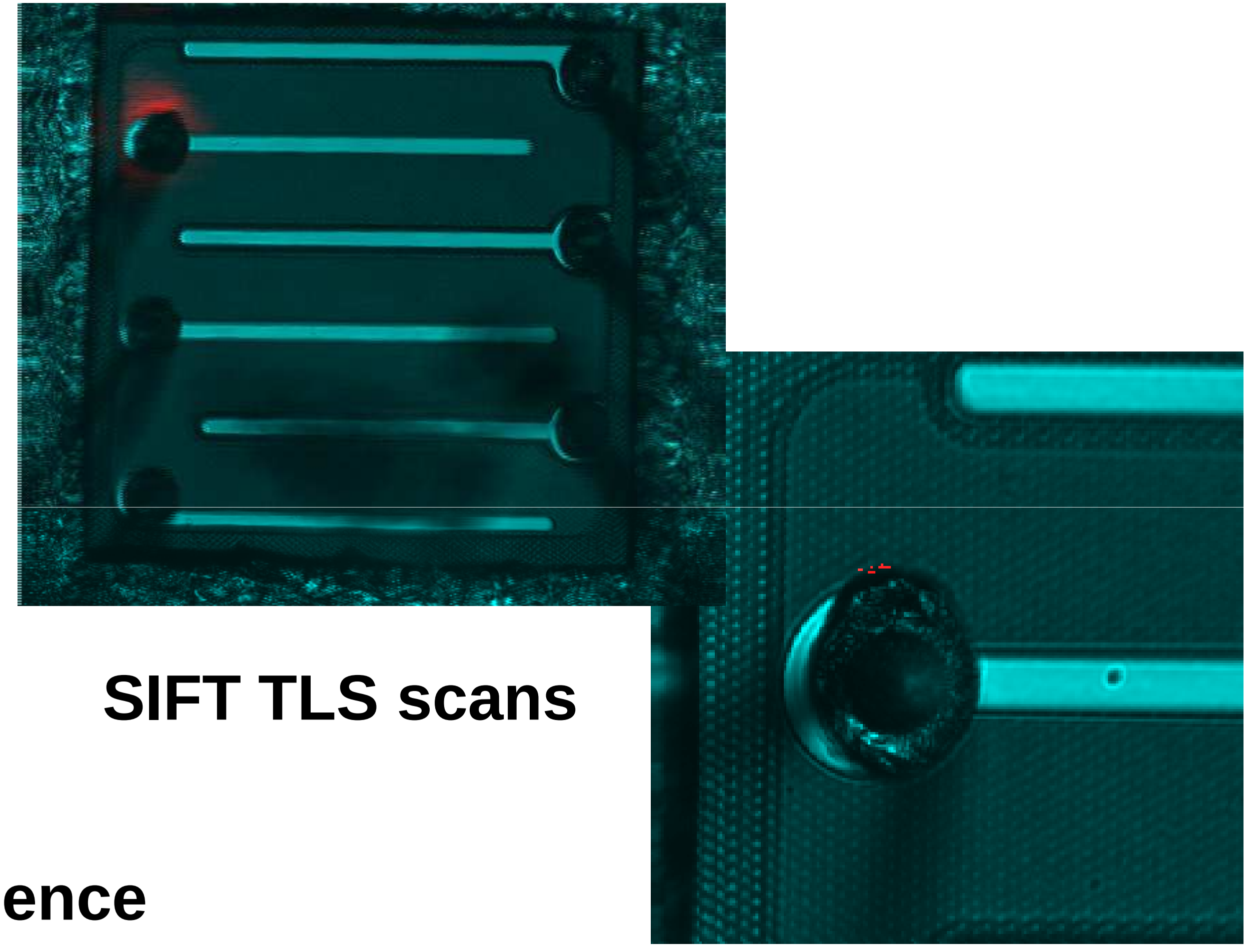


SIFT in Electrostatic Probe Mode 100KHz



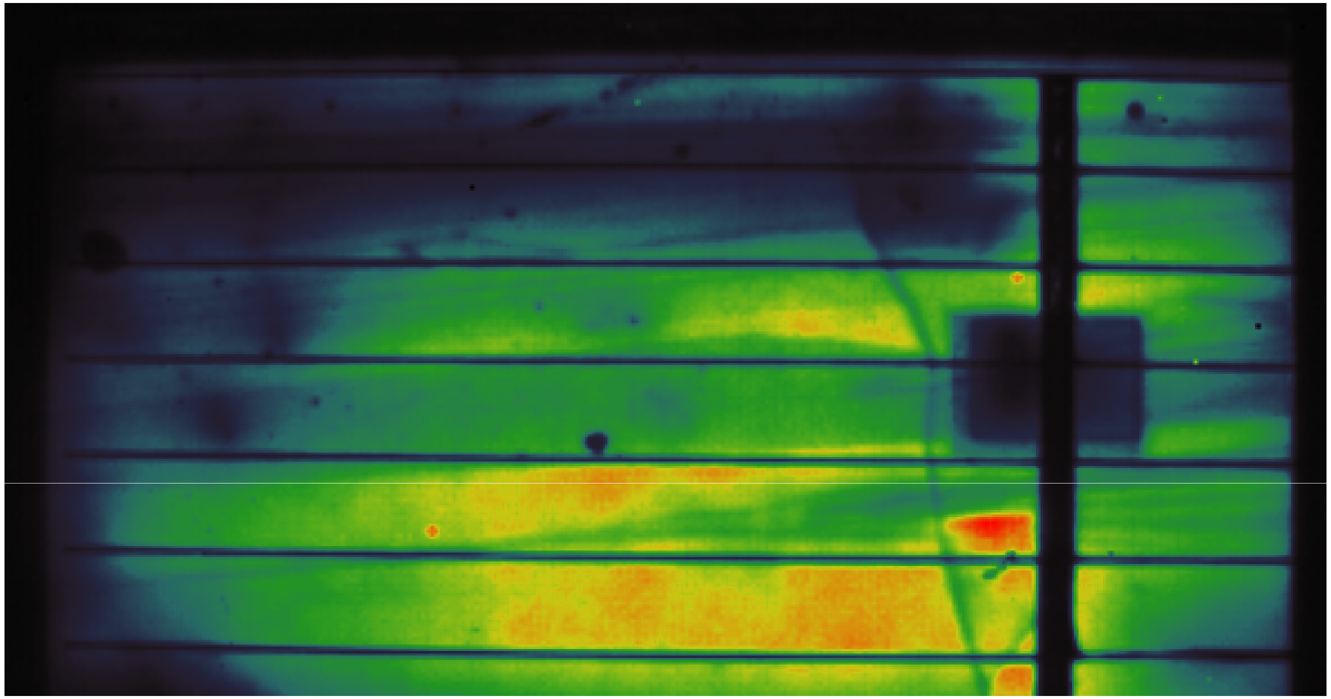
UV LED with ESD Damage. Compare SIFT to EL image

VisGaAs Electroluminescence Image

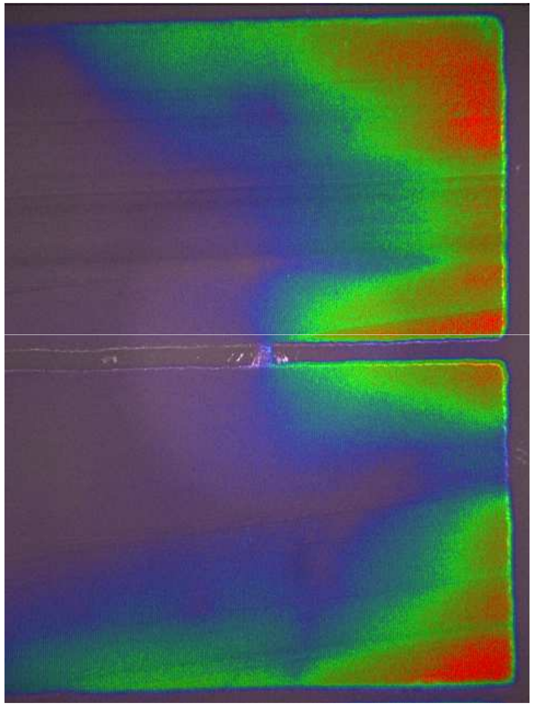


SIFT TLS scans

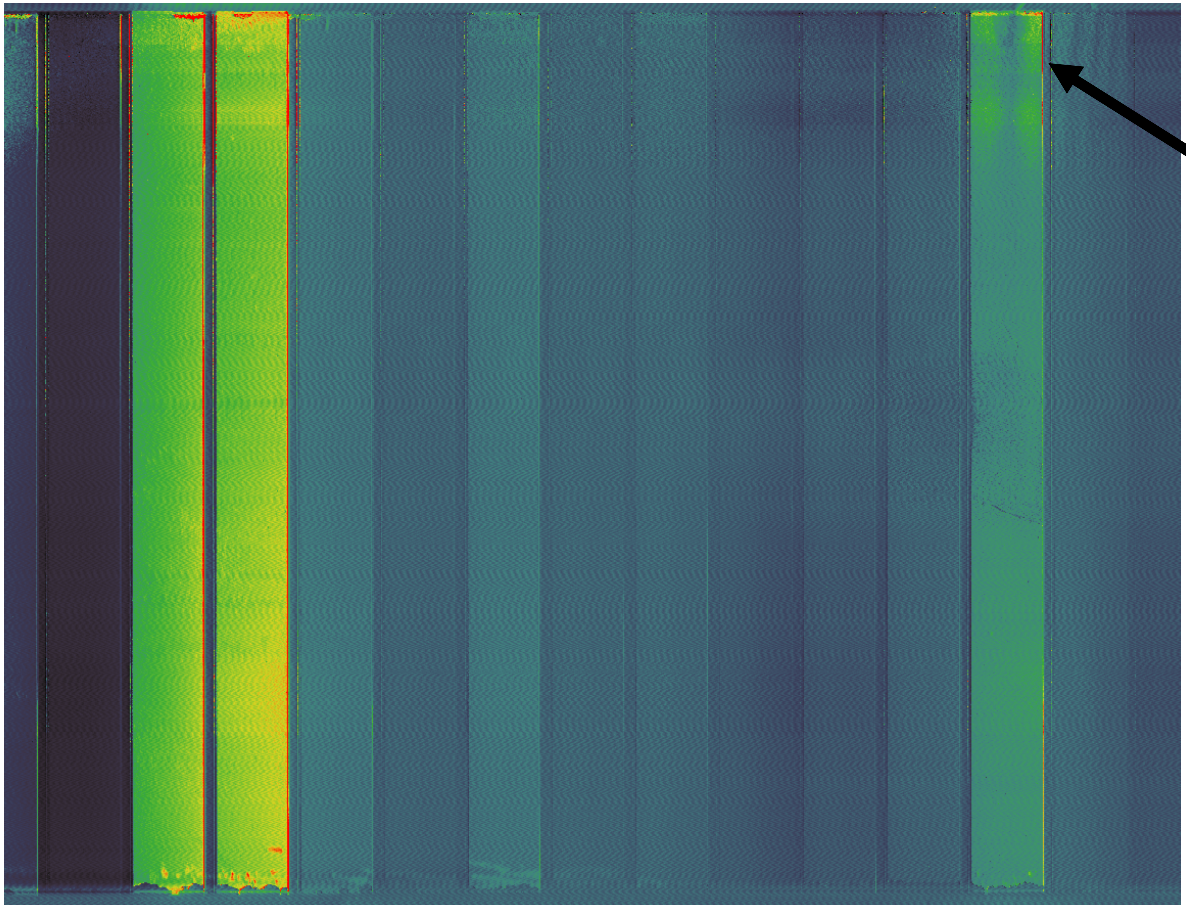
OBIC Crystalline Si Solar Cell with Discontinuity and Crack



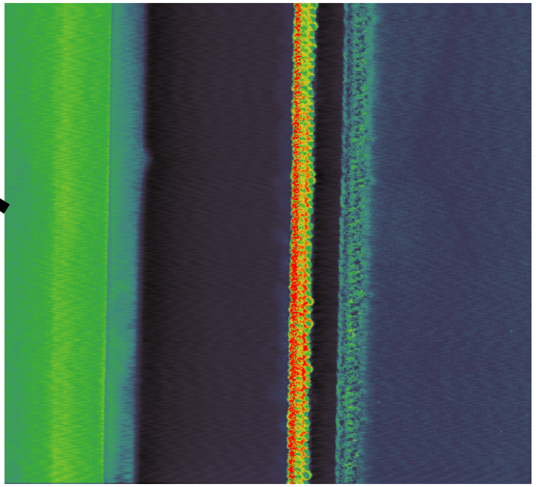
5.2mm Al Pitch Spacing



OBIC SIFT Large Area Scan of Amorphous Si Solar Cell

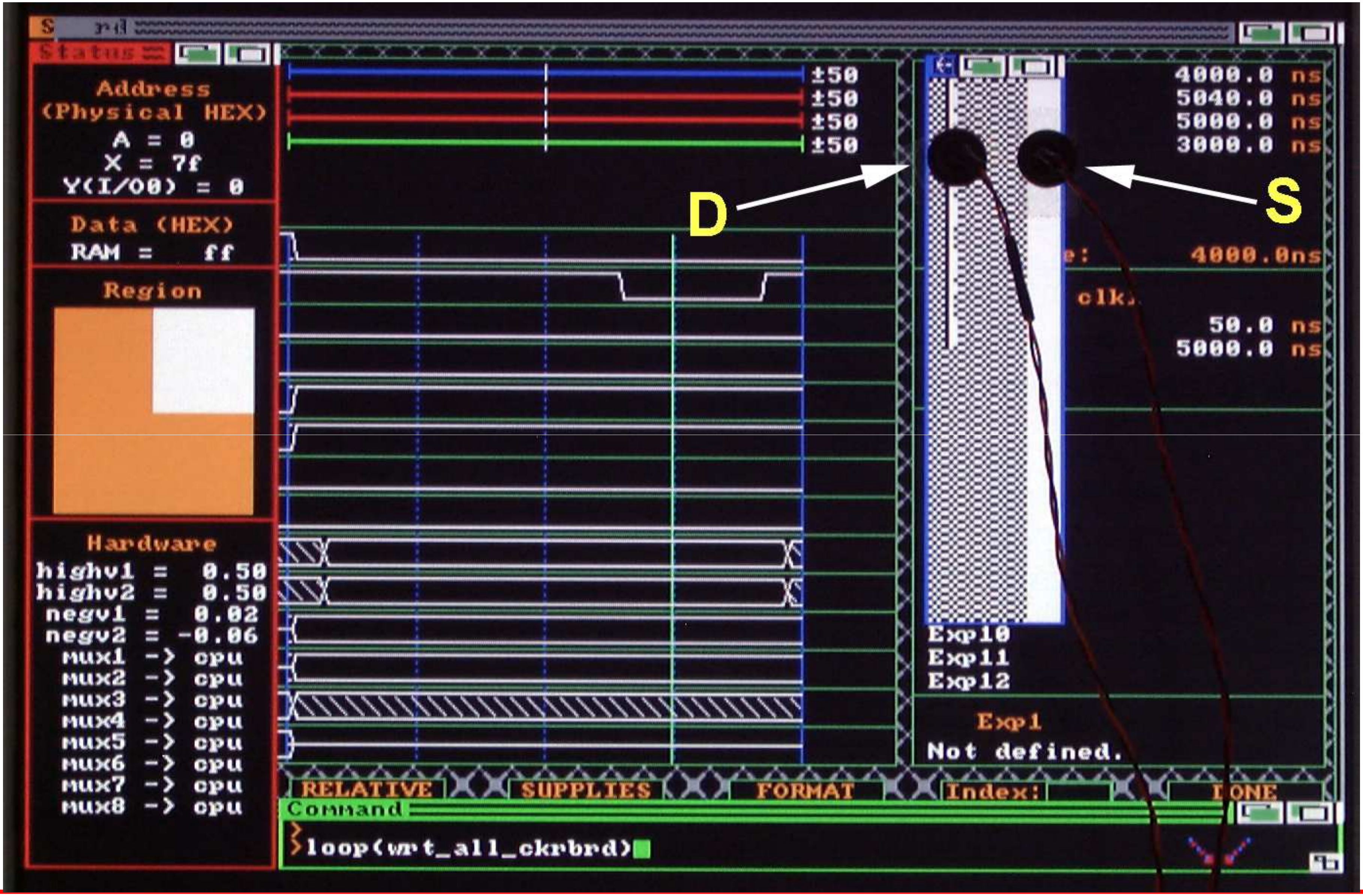


147488 x113041 um
scan area in
32.014um steps



2786x2542 um scan
area in 20.377um
steps

SIFT Configuration on Tester Screen

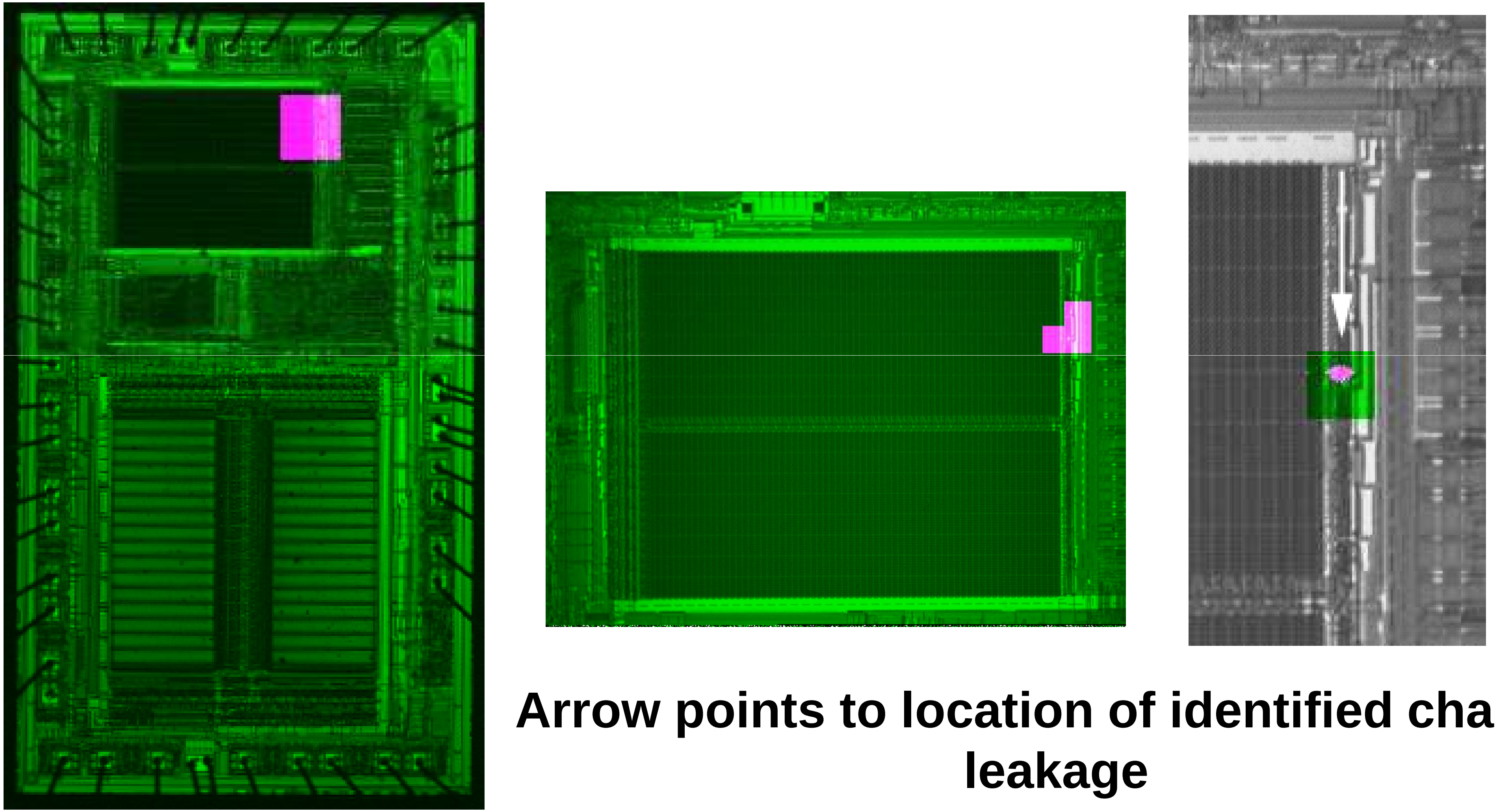


```
Address
(Physical HEX)
A = 0
X = 7f
Y(I/O0) = 0

Data (HEX)
RAM = ff

Region

Hardware
highv1 = 0.50
highv2 = 0.50
negv1 = 0.02
negv2 = -0.06
mux1 -> cpu
mux2 -> cpu
mux3 -> cpu
mux4 -> cpu
mux5 -> cpu
mux6 -> cpu
mux7 -> cpu
mux8 -> cpu
```

```
4000.0 ns
5040.0 ns
5000.0 ns
3000.0 ns
e:   4000.0ns
clk.
  50.0 ns
5000.0 ns
Exp10
Exp11
Exp12
Exp1
Not defined.
```

```
>loop(wrt_all_ckrbrd)
```

SIFT Analysis of Light Sensitive Column Decoder Failure Recently referred to also as LADA



Arrow points to location of identified channel leakage

Conclusion

The various modes of SIFT were shown with emphasis on the benefits of controlling the location of the laser and maintaining constant power. Memory or similar array devices lack unique local features complicating the triangulation. Sample tilt and beam abberation are virtually eliminated with SIFT scanning technology for laser and Magnetoresistive mapping modes.

Profile

Jim Colvin, CEO

- Mr. Colvin comes from the Midwest with a background in Electrical Engineering from Purdue University . He has 21 years of contributions to the Failure Analysis community through committee organizations for ISTFA, EOS/ESD, and IRPS and has published numerous award-winning papers on Failure Analysis techniques. Colvin has also been working as a Consultant for over 15 years and originated the Passive Voltage Contrast technique, the first portable Emission Microscope, the Vibration coupler, and the laser illuminator, to name a few. Currently he is the CEO of FA Instruments, Inc. founded to provide leading edge tools for Failure Analysis. Jim currently holds 7 patents for products relating to the semiconductor field and is recognized as a contributor to the advancement of semiconductor technologies.
    - Best Paper award from the EOS/ESD Symposium for his paper titled “The Identification and Analysis of Latent ESD Damage on CMOS Input Gates” 1993.
    - Outstanding paper award from ISTFA for his paper titled” Color Voltage Contrast: A New Method of Implementing Fault Contrast with Color Imaging Software” 1995.