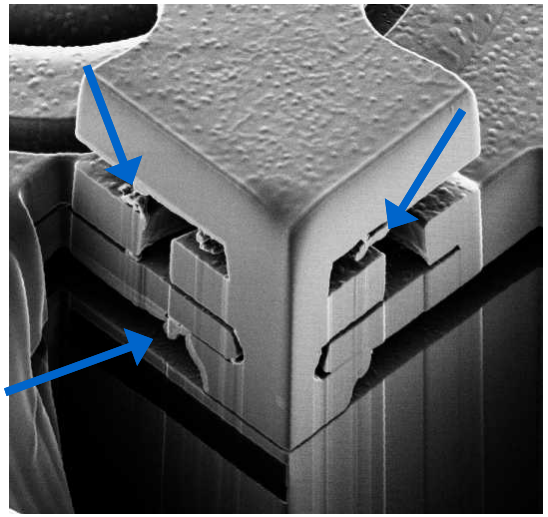
SAND2008-2414P

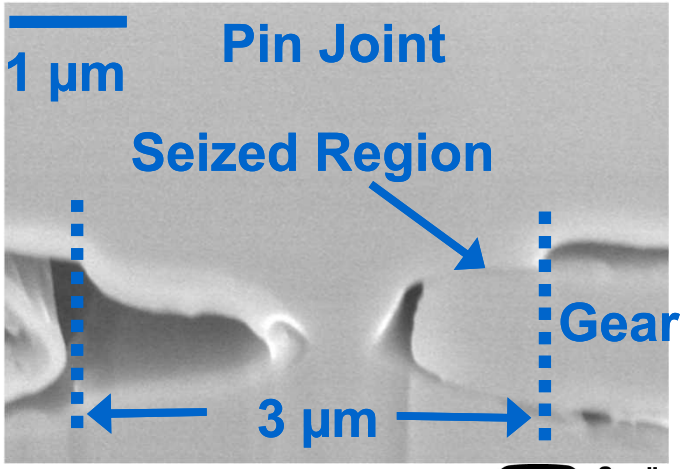
MEMS and VCSEL Failure Analysis

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Focused Ion Beam

- FIB is used for cross-sectional analysis or to repair/modify structures with sub-micron accuracy
  - Imaging
    - Precision cuts and trenches
  - Device modification
    - Etch or deposit conductive and/or insulating materials
- Can remove specific components for multi-layer analysis
- Pros - Allows localized analysis and removal of strategic structures
- Cons - Destructive, material is removed rendering a portion of the device inoperable





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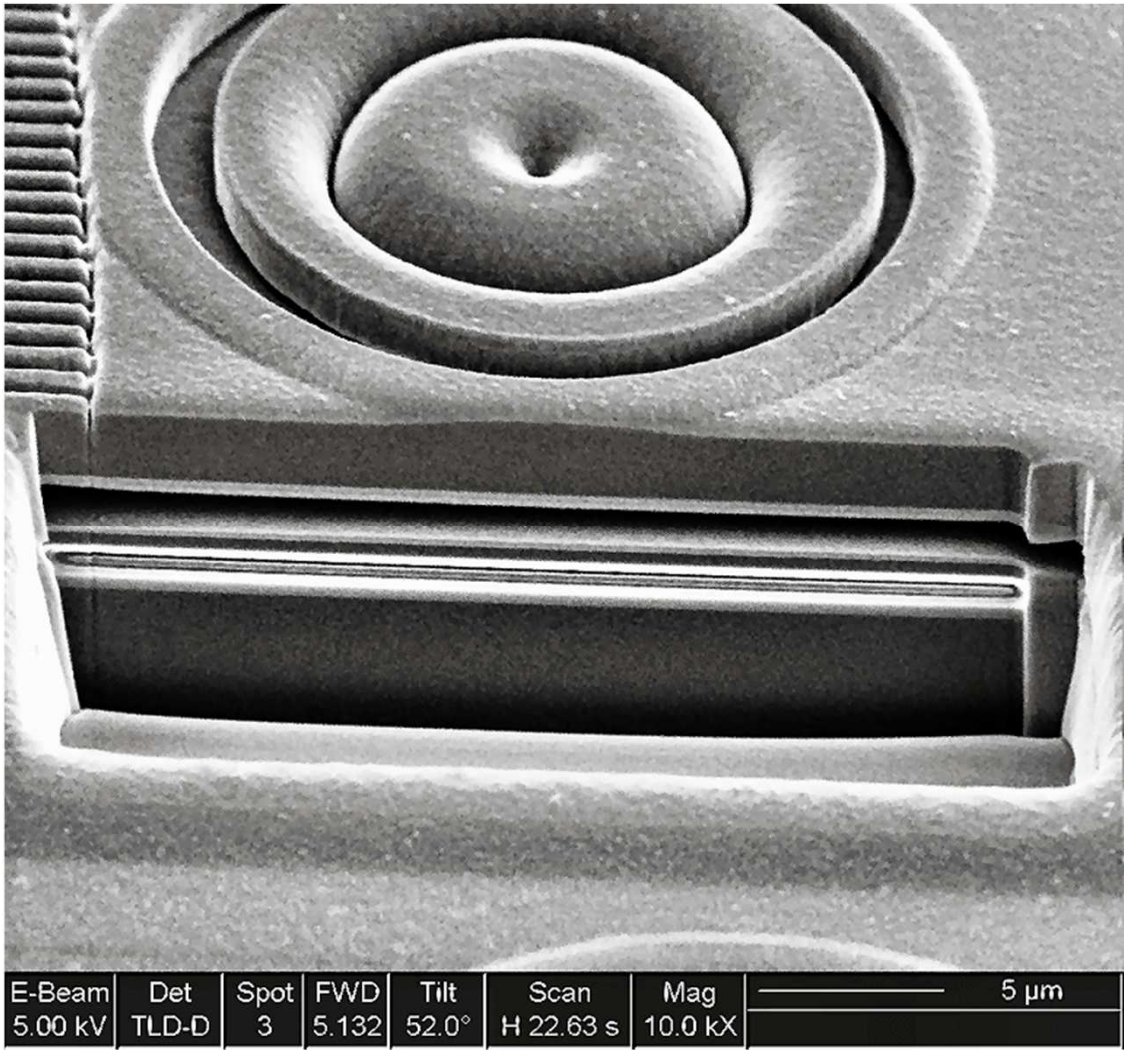
Focused Ion Beam Analysis of a Stuck Hub



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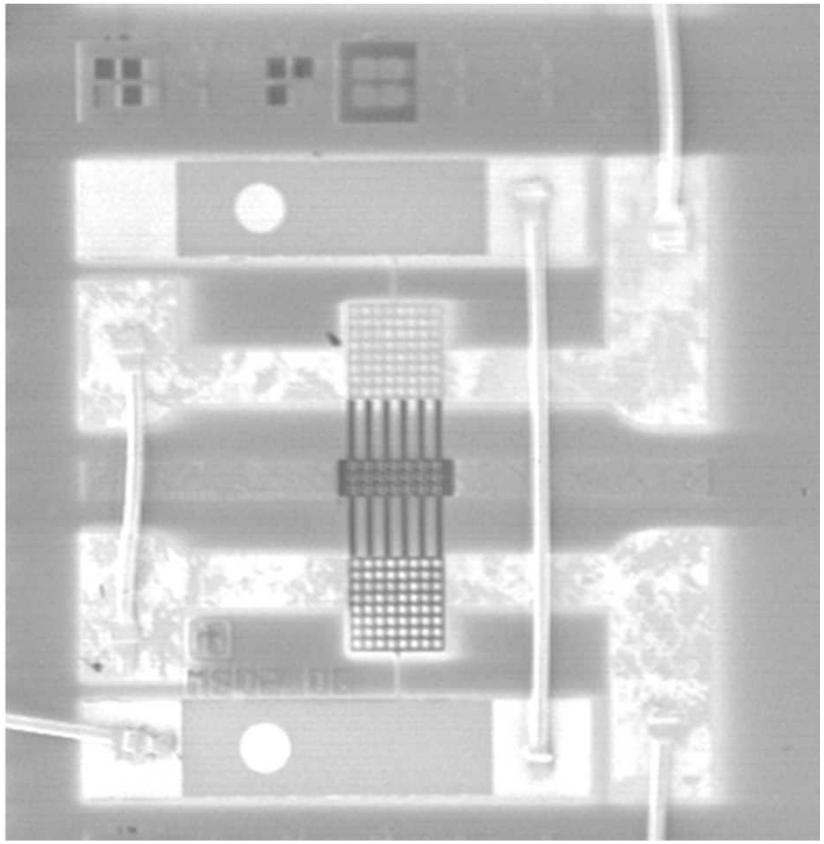
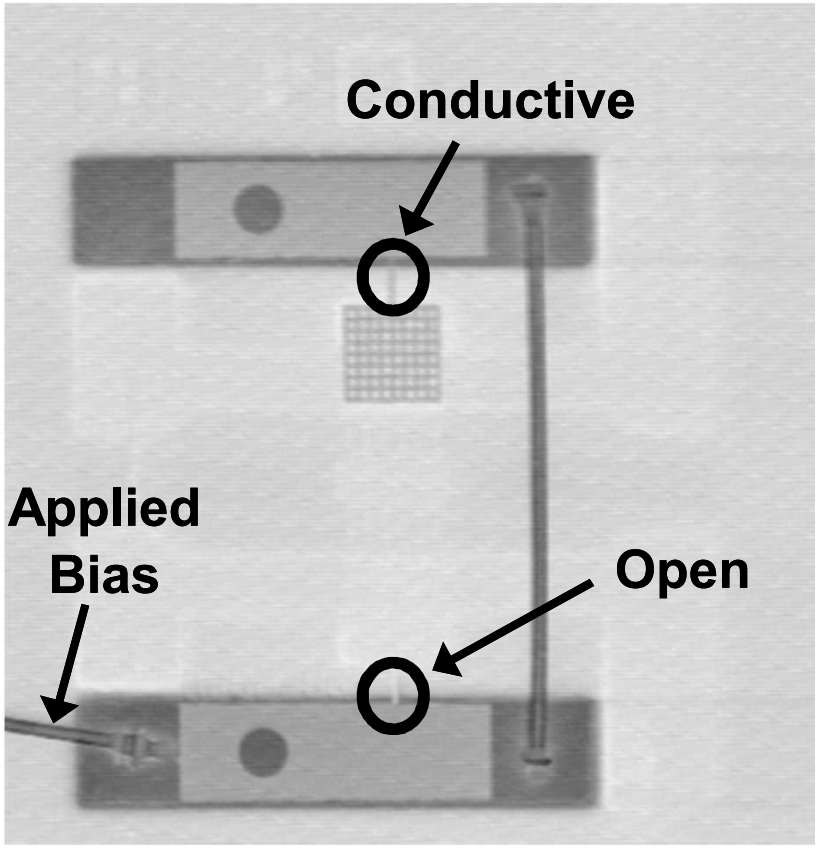
RF MEMS failure analysis: part identified as an open



Secondary Electron Image

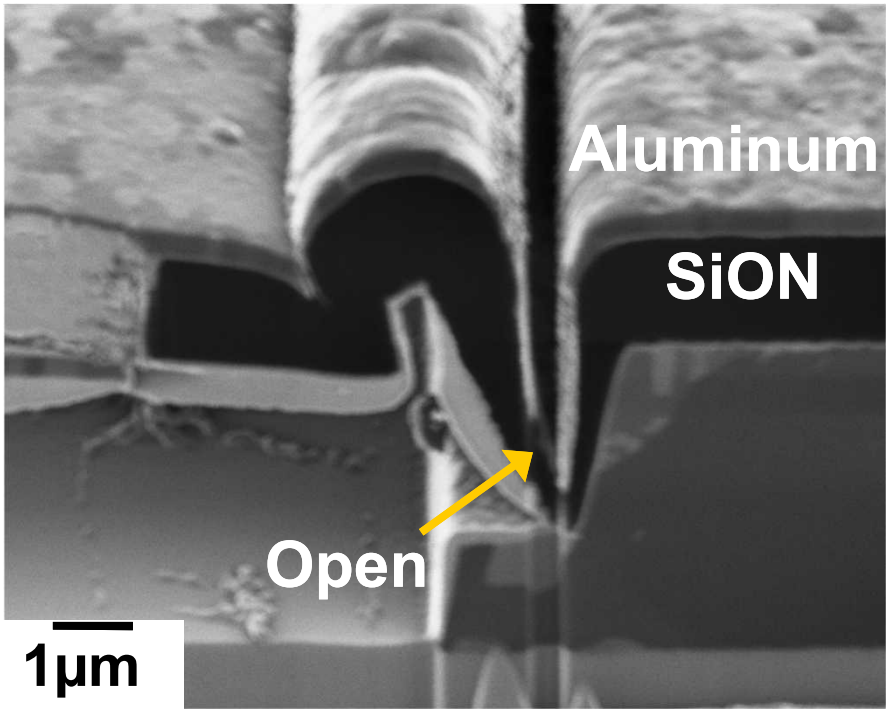


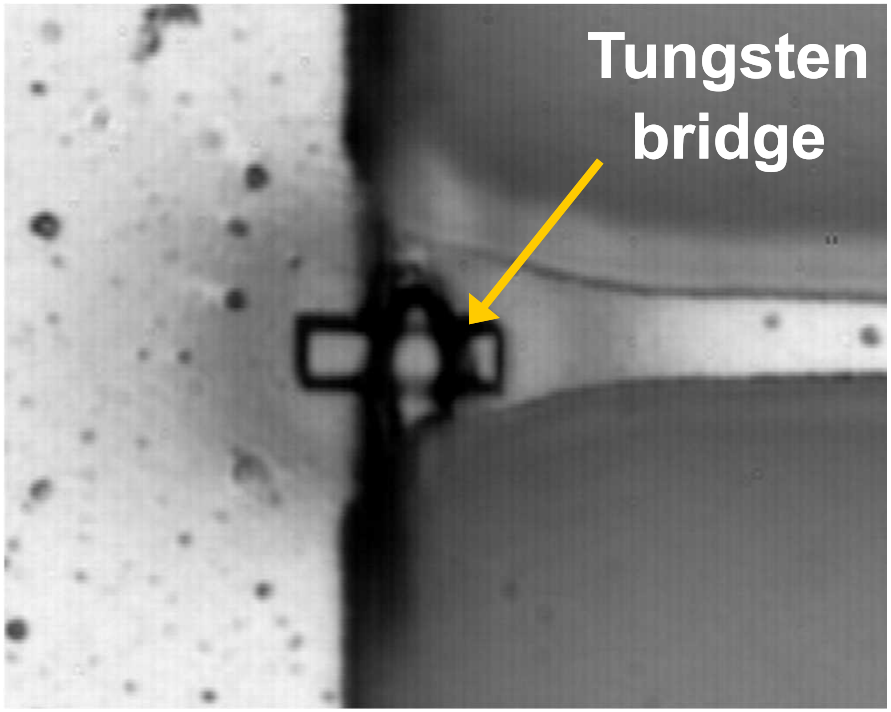
10 keV Resistive Contrast Image

Top pad is observed with applied bias

Bottom pad is not observed indicating an open state

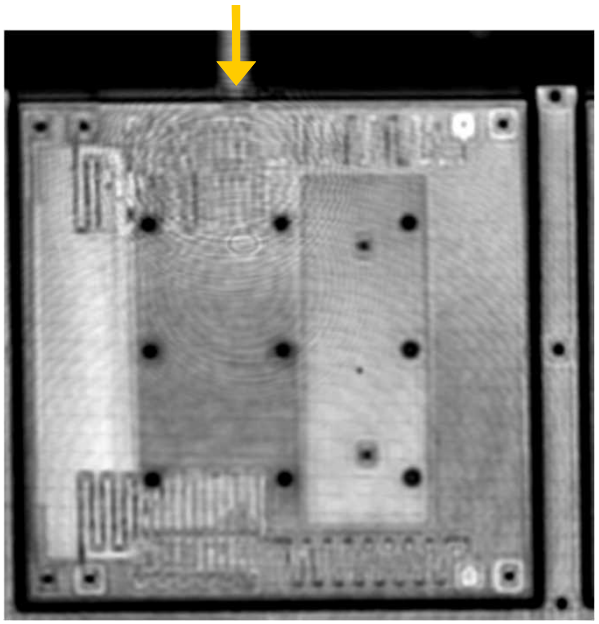
Device Repair/Modification Using the FIB: RF MEMS device now functional

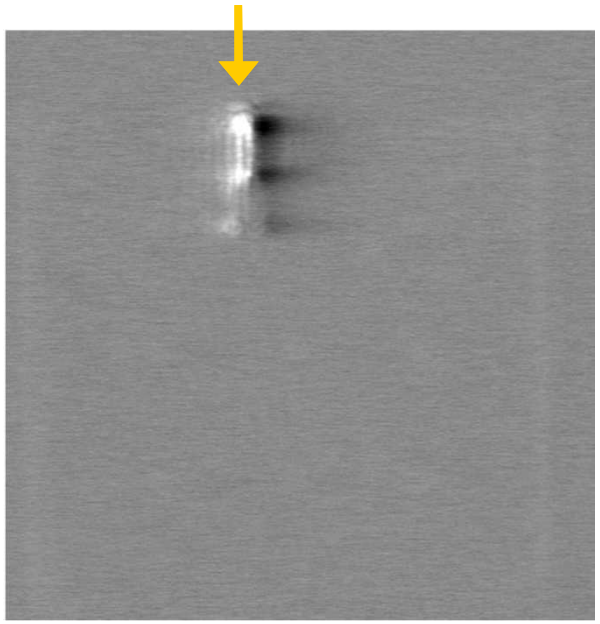


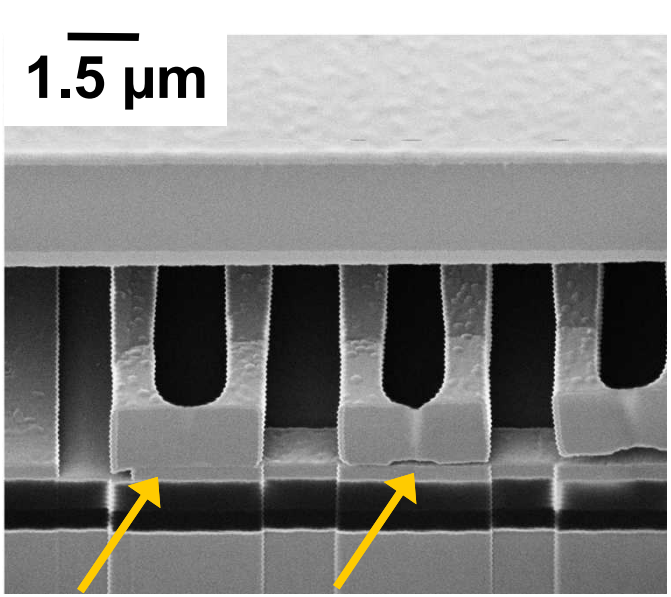


- **Non-uniform metal deposition along the cut region resulted in an open during testing**
- **FIB deposited metal provided bridged the cut**
  - **Switch functioned**

Optical and Ion beam based techniques identified a shorted support spring







Reflected light image

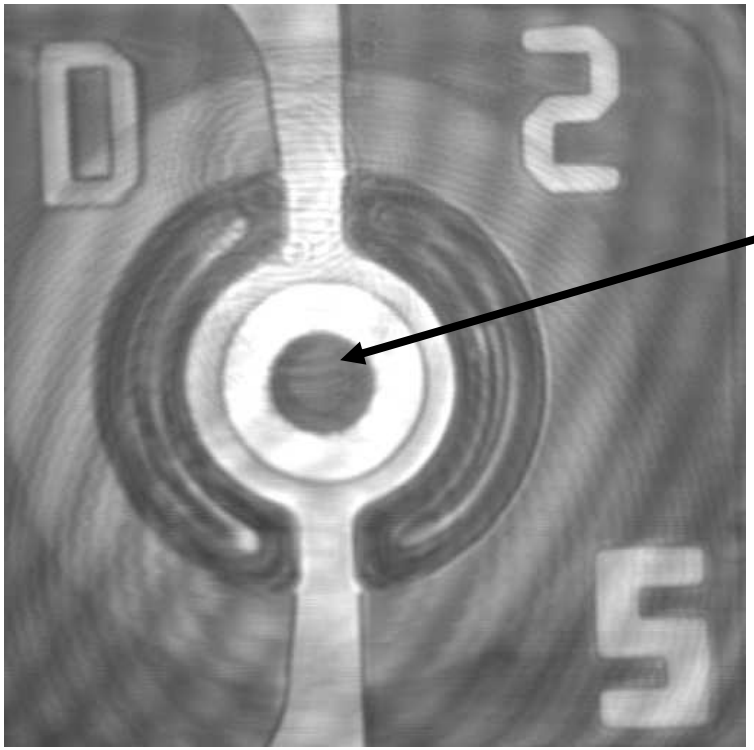
Thermally Induced Voltage Alteration (TIVA) image

FIB cross section

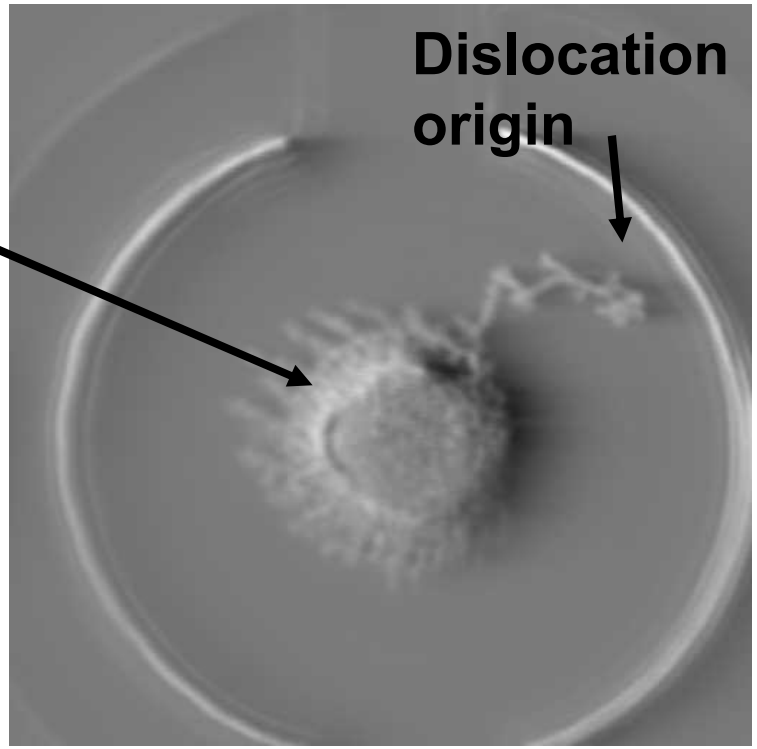
- Applied voltage pulled the spring into contact with the poly 0 power line prior to mirror actuation
- Short was diagnosed *through* the polysilicon mirror

VCSEL Analysis

- VCSEL failure analysis using TIVA shows the origin of a dislocation along the MESA edge from ESD testing and its propagation into the active area through subsequent operation



VCSEL active area



Reflected Light Image

TIVA Image

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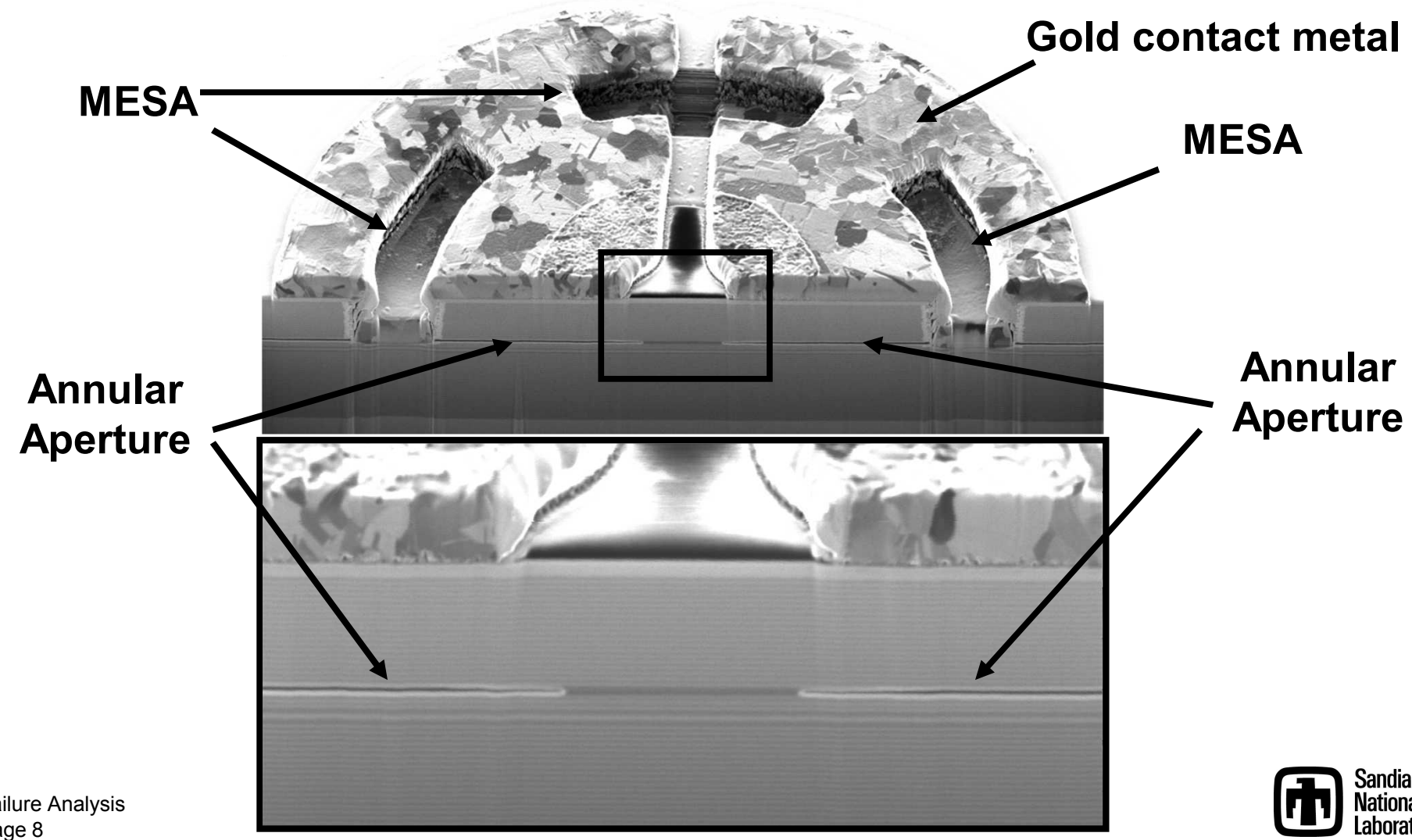
VCSEL Analysis

- FIB cross-section revealing the MESA and annular aperture



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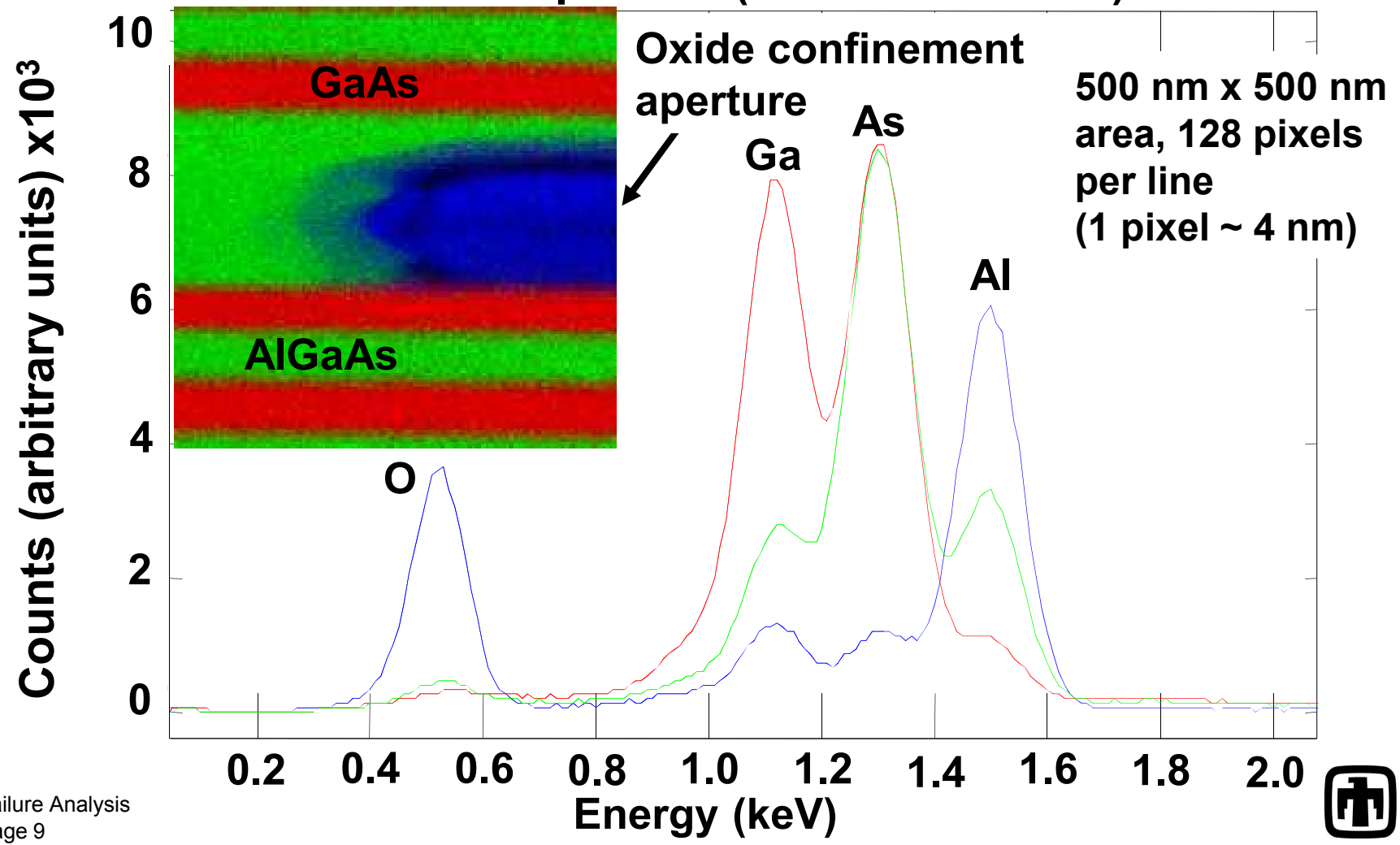
VCSEL Analysis

- EDS analysis shows an Al rich AlGaAs layer used to form the annular confinement aperture (aluminum oxide)



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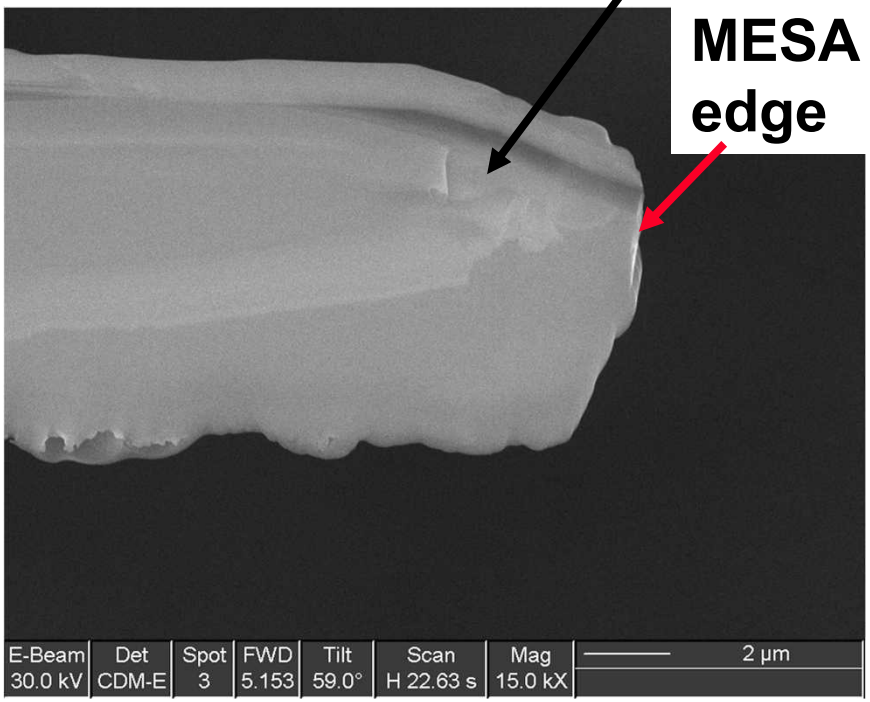
VCSEL Analysis

- **FIB lamella and TEM cross-section of the VCSEL active area showing the dislocation network**

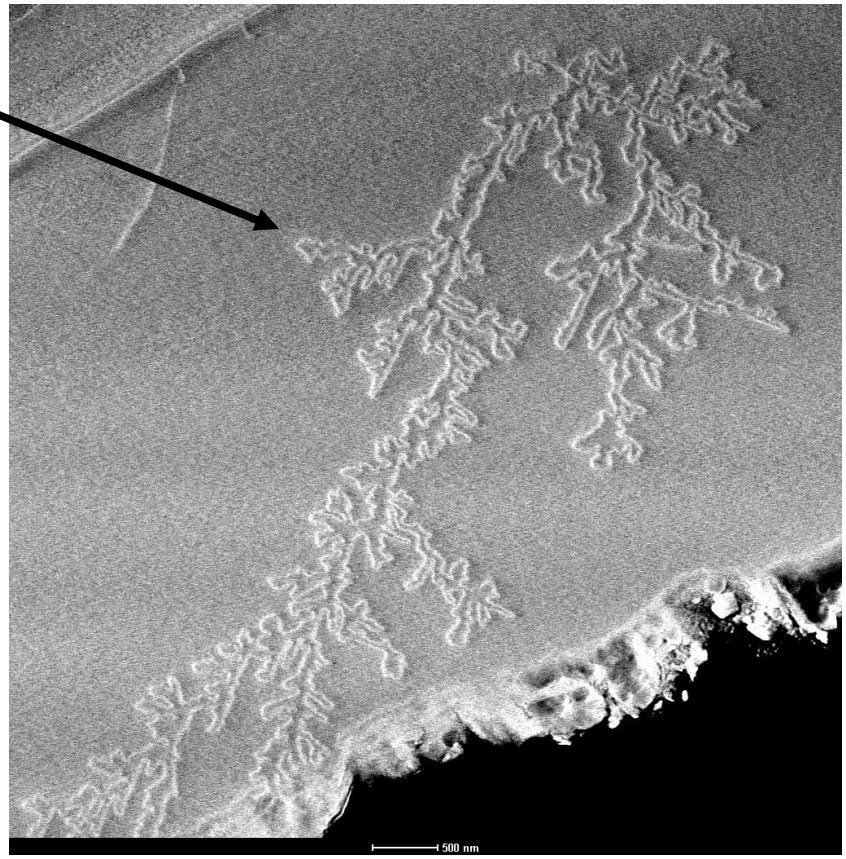
FIB Lamella

Dislocation network

MESA edge



STEM cross-section



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