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Direct-Write Laser Micropatterning Techniques for Polymer Circuits, MEMS Interconnects and Ceramic Thick-Film Devices

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**ElectroScientific Industries, Inc.

What is UV Laser Direct Write Patterning?

"Using a vector-translated single laser beam to create a pattern"

Exposure
(Lower Fluence)

Ablation
(Higher Fluence)

Photodefinable Dielectric or Conductor
(Additive or subtractive)

Non-photodefinable Dielectric or Conductor
(Subtractive)

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Why Use Direct-write?

- Fine-line patterning without expensive photolithography equipment
- “Virtual” pattern can be scaled to match part geometry based on fiducial alignment
- Direct transfer from “software” to “hardware” without intervening process steps
- Can be used in combination with or to replace conventional patterning methods
- Deep aspect ratio patterning

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Applications for Direct Write Processing:

- Exposure:
  - Patterning positive and negative resists
  - Patterning photosensitive thick film conductive inks
  - Additive patterning of UV sensitive epoxies (desktop manufacturing)
- Ablation:
  - Patterning positive and negative resists
  - Patterning non-photosensitive dielectrics (solder masks, etc.)
  - Patterning metals, ceramics, glass, polymers and other materials (subtractive)
  - Via drilling of dielectrics

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Direct Write Exposure Tool:

- Pulsed UV-laser drill used as direct write imager
- ESI 5330 UV laser machining station
  - 355 nm wavelength (tripled-YAG)
  - Vector control of beam position
  - Automatic control of laser fluence down to 30mJ/cm^2 (1-5 mW average power) in range required for ink exposure or ablation
  - Serves dual purpose of drilling and patterning
  - Alternative beam geometries available

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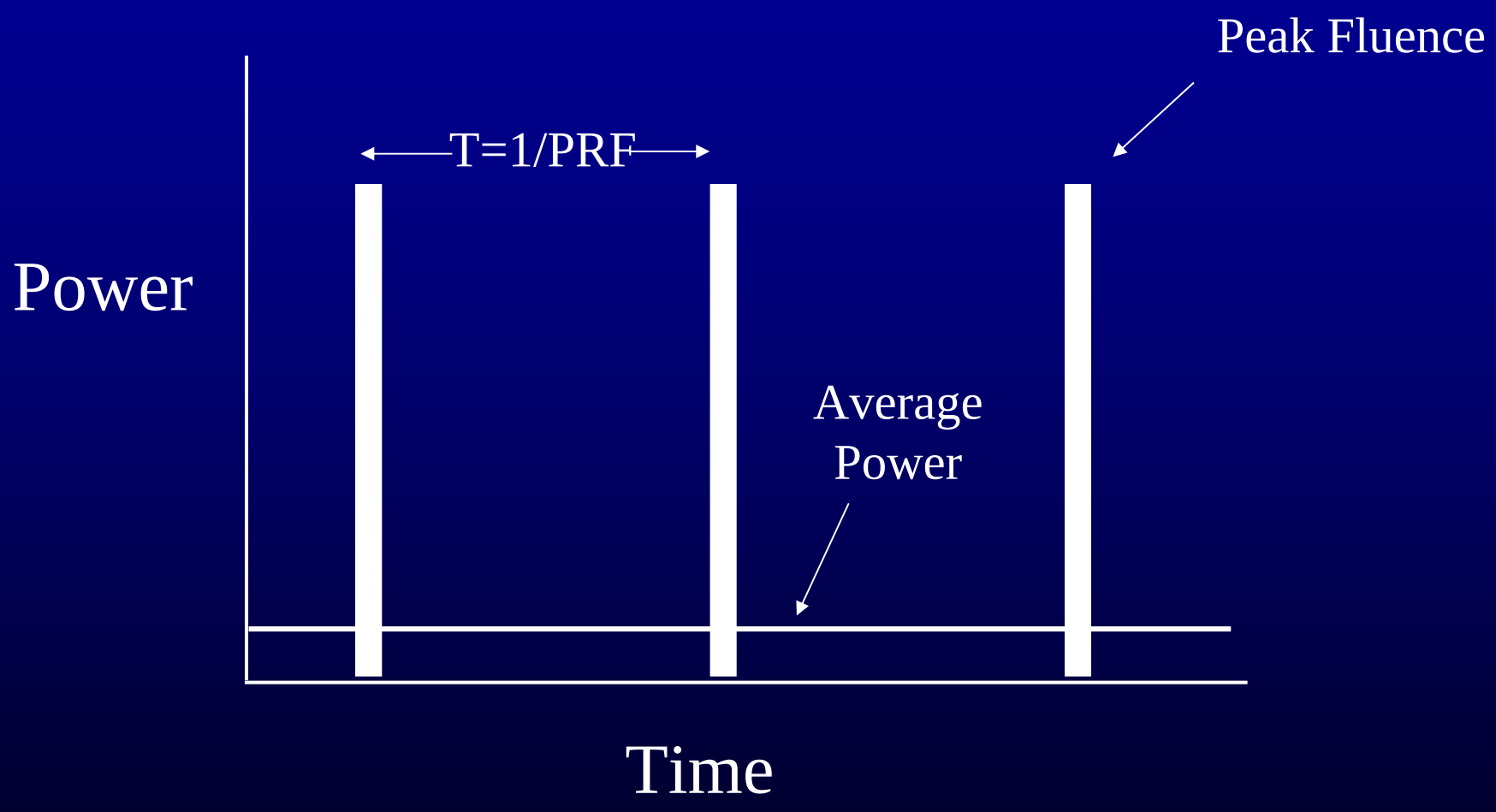
Pulsed Laser Exposure Parameters (Time)



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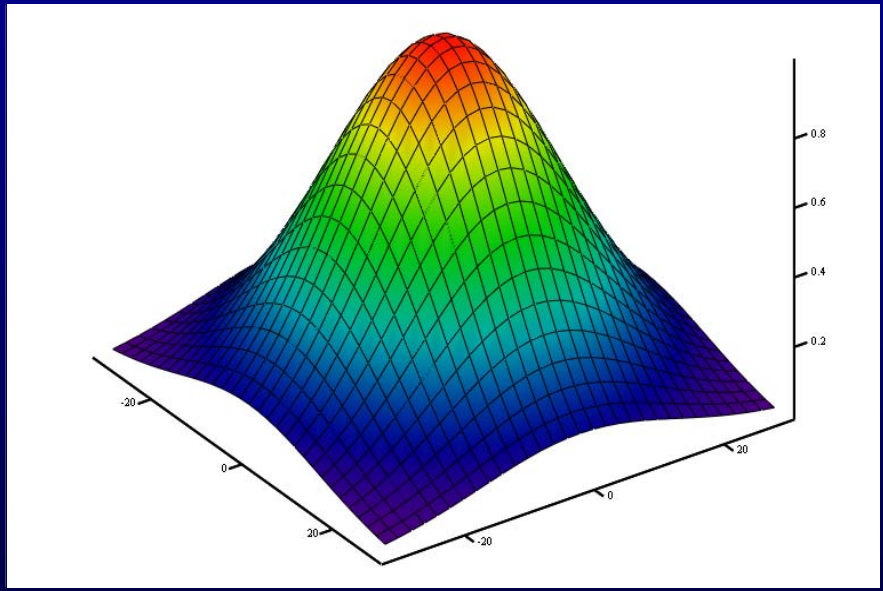
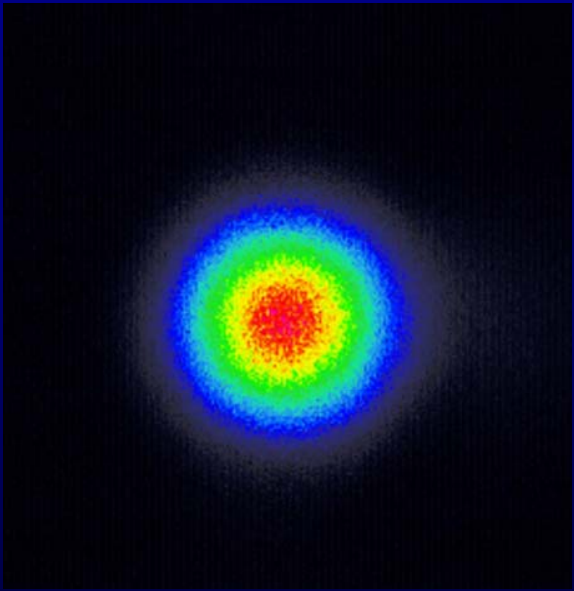
Beam/Exposure Parameters (Spatial)

Gaussian Beam





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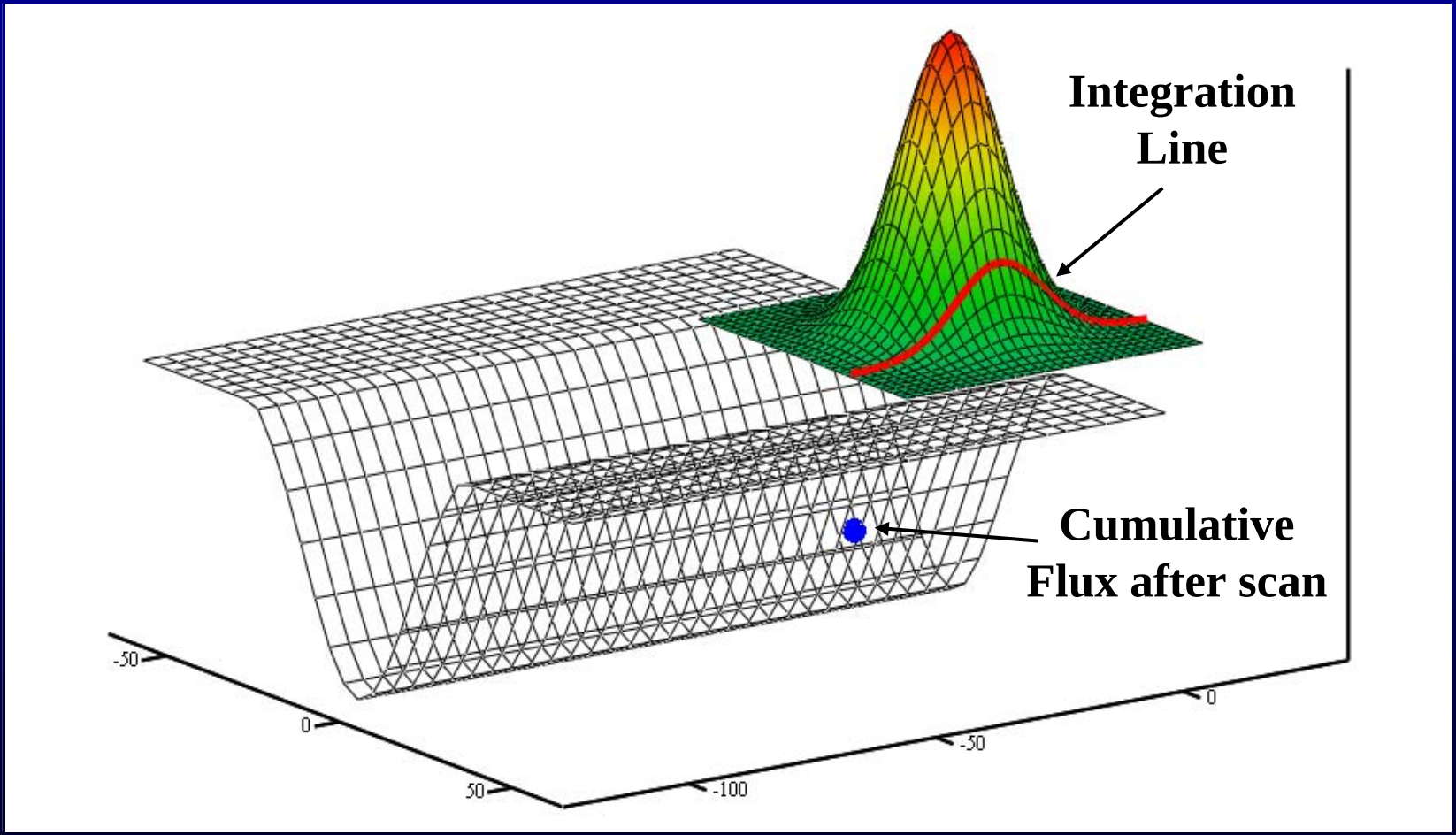
Scanned Gaussian Beam
(Produces tapered cumulative flux pattern)



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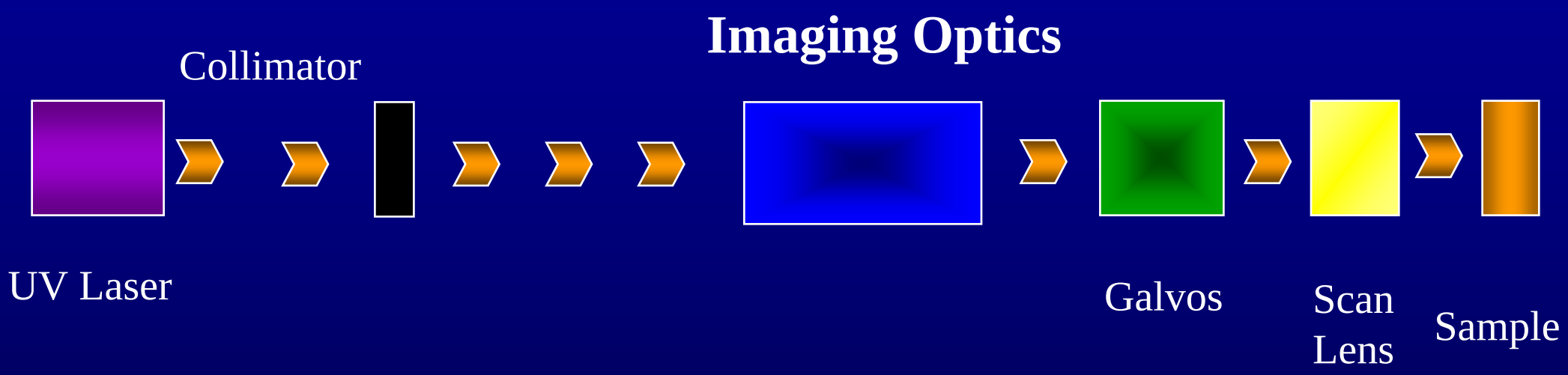
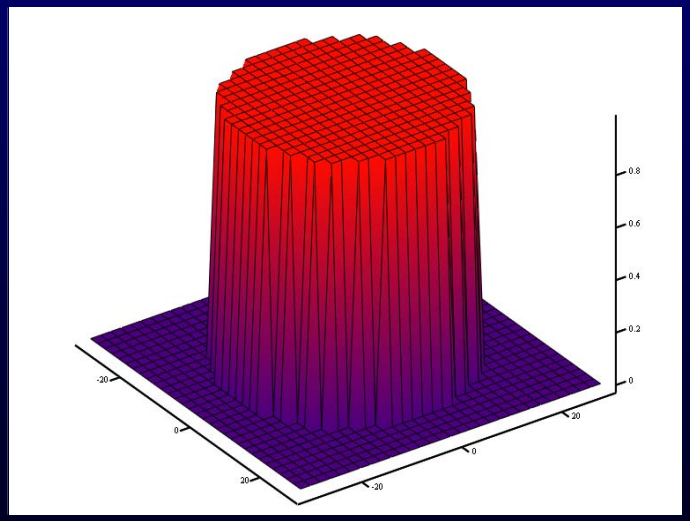
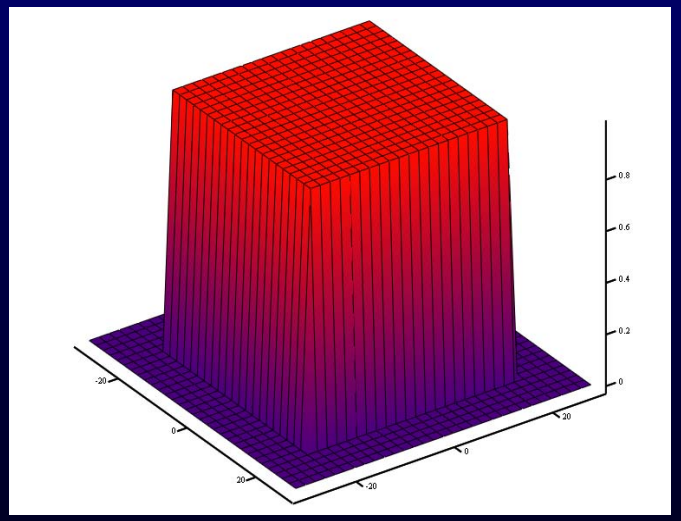
Shaped Beam Optics
"Top Hat" Beams



Round Top Hat





Square Top Hat

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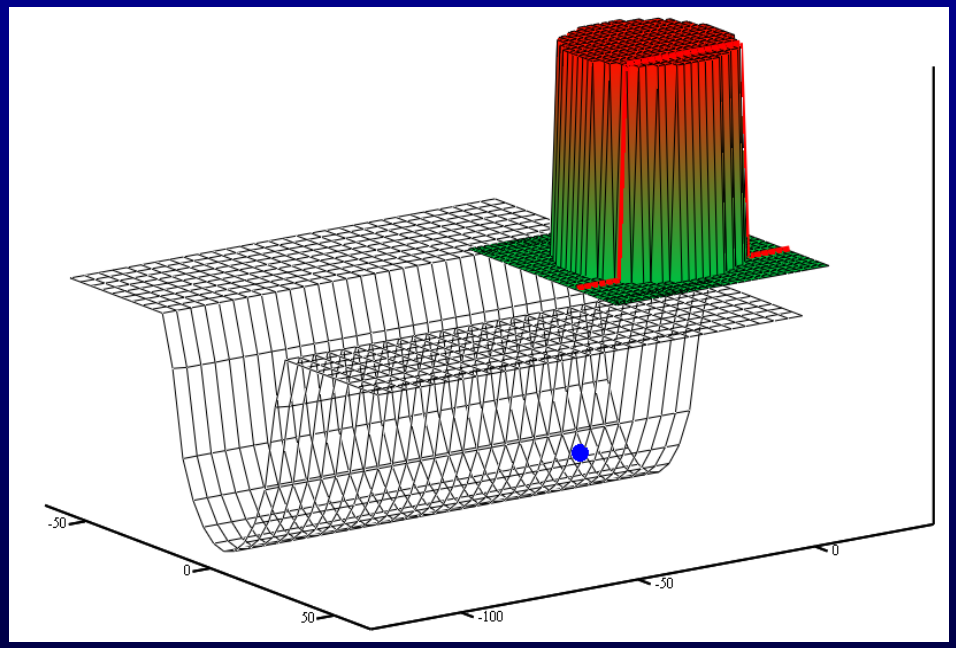
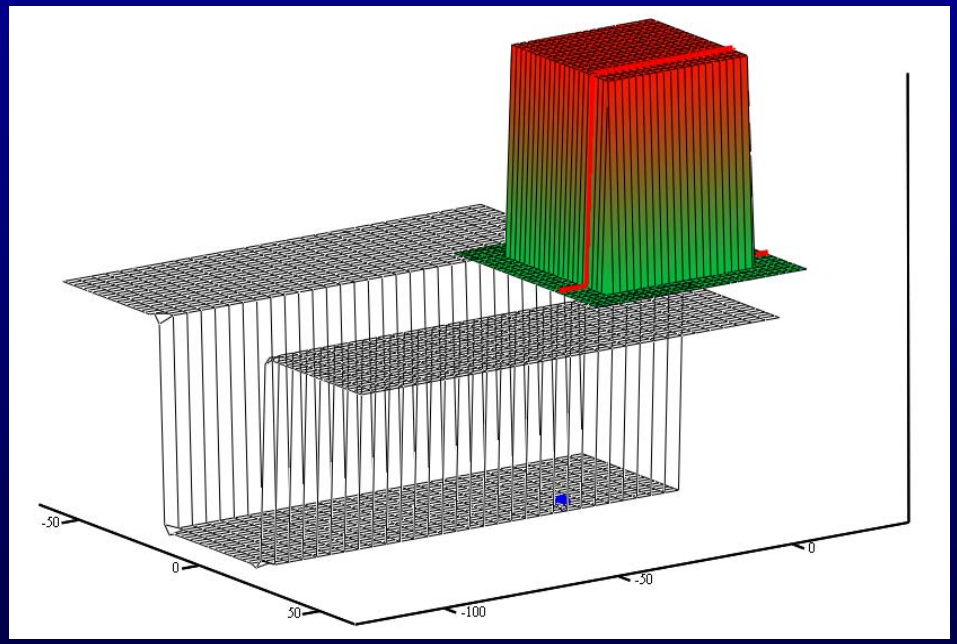
Round versus Square Shaped Beam
(Line-Scan Cumulative Fluence)





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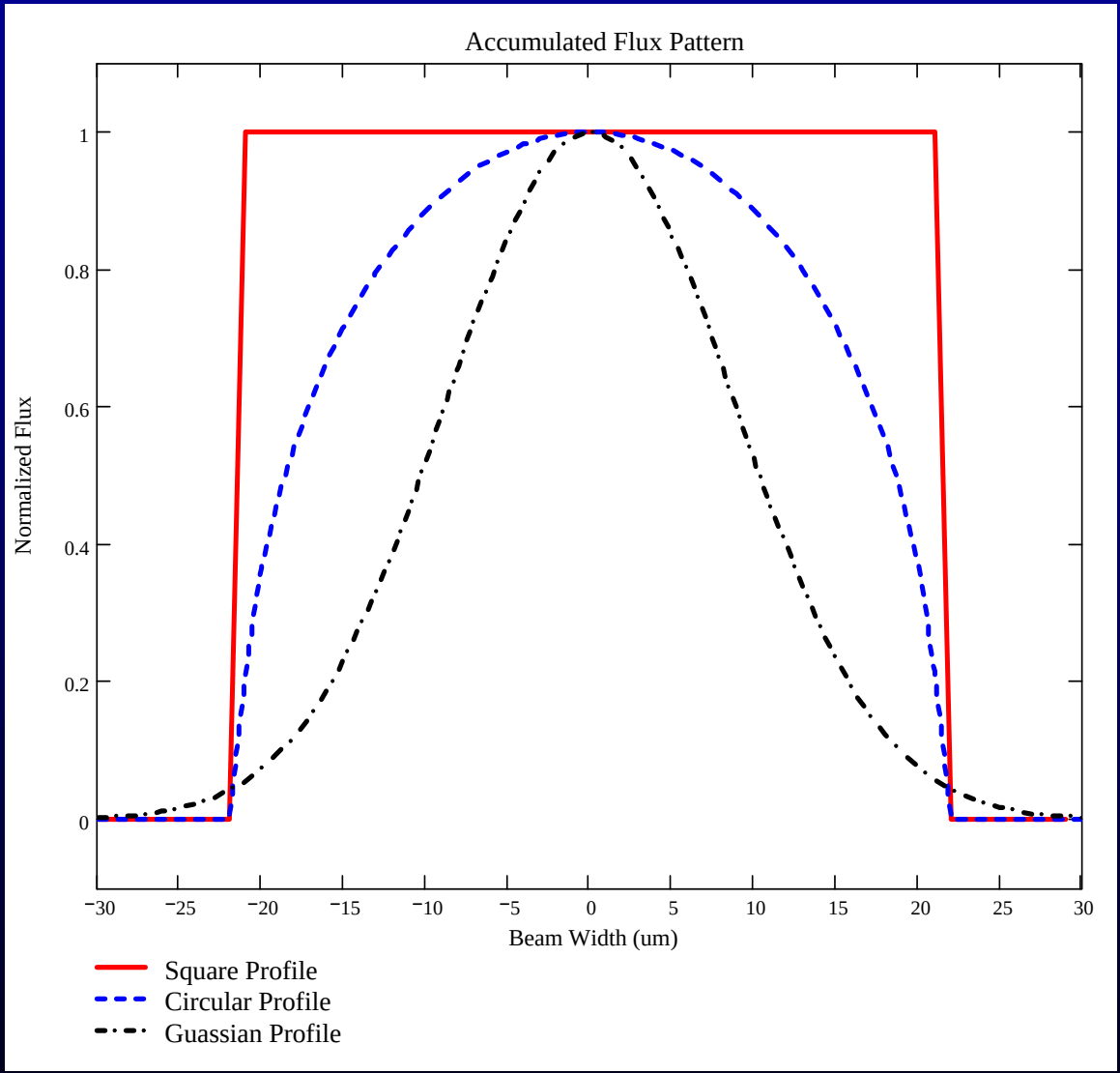
Fluence Comparison (Line Scan)

(Gaussian, Round Top Hat Round, Square Top Hat)



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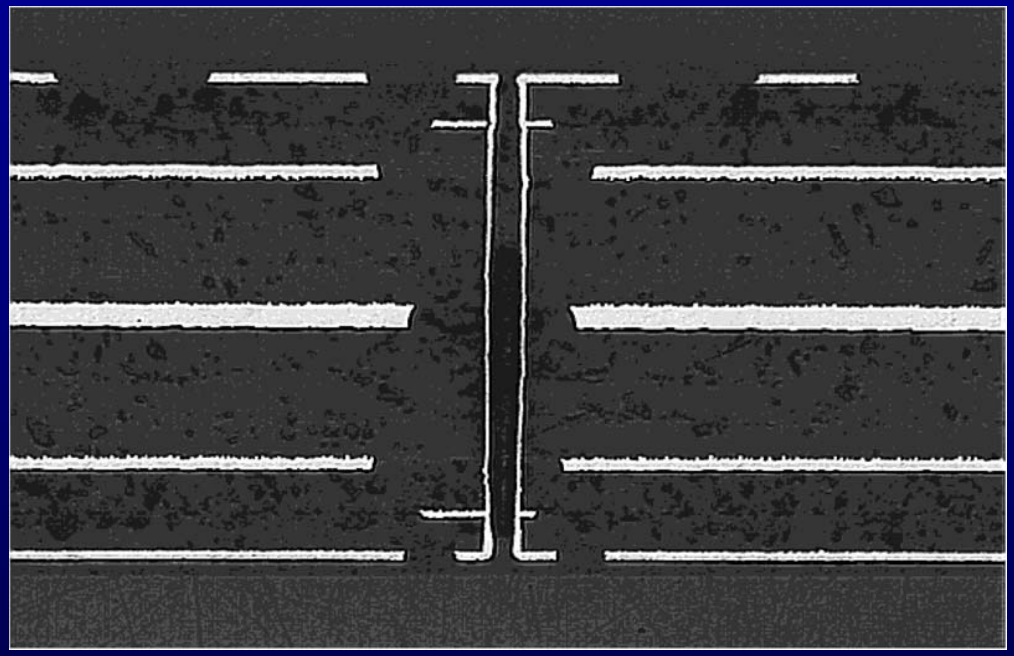
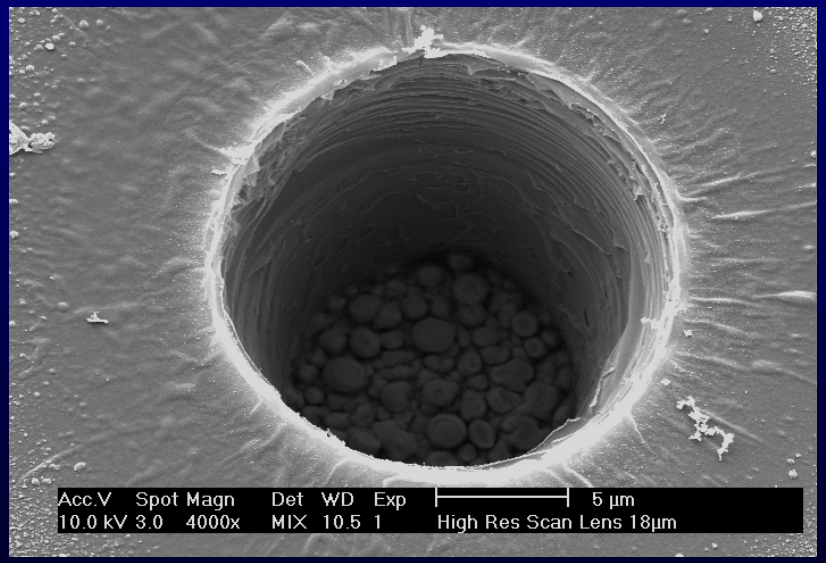
Deep Aspect Via Drilling using Shaped Optics Laser Beam





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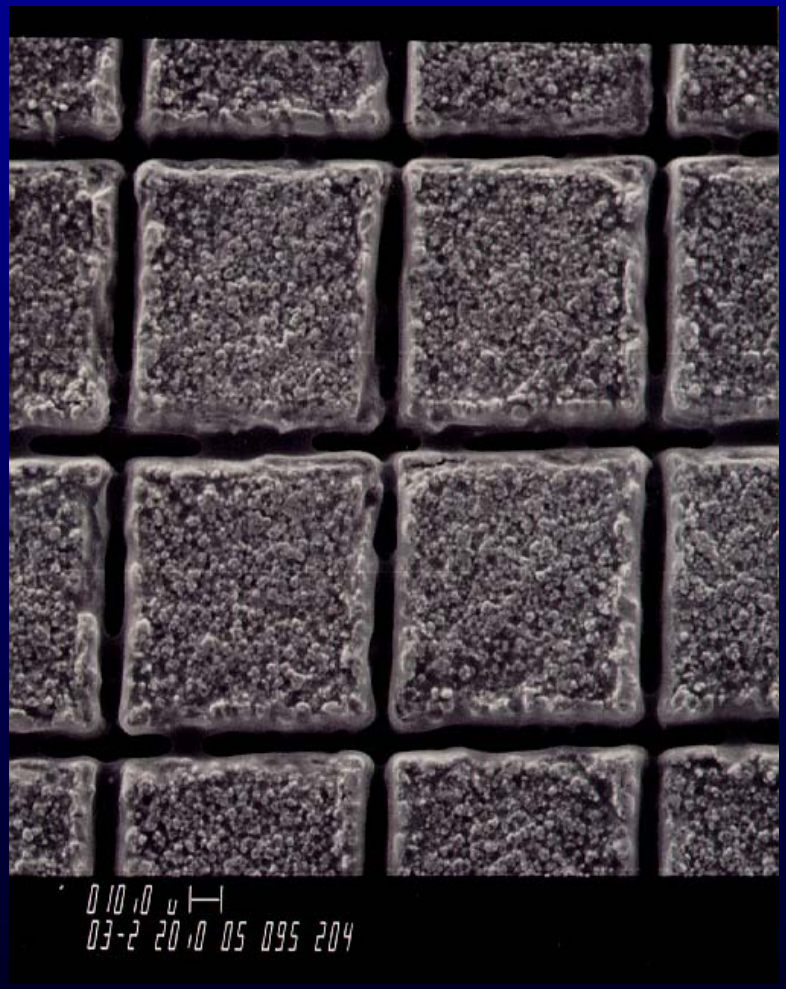
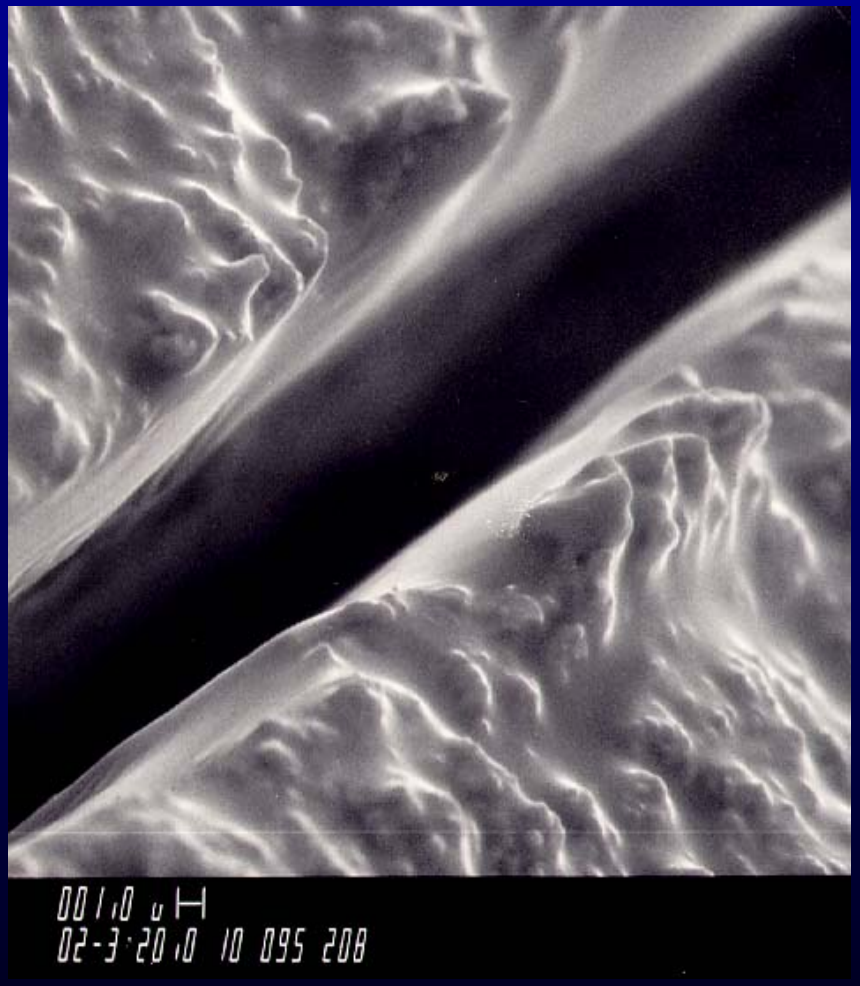
UV Laser-machined PZT Ceramic Die





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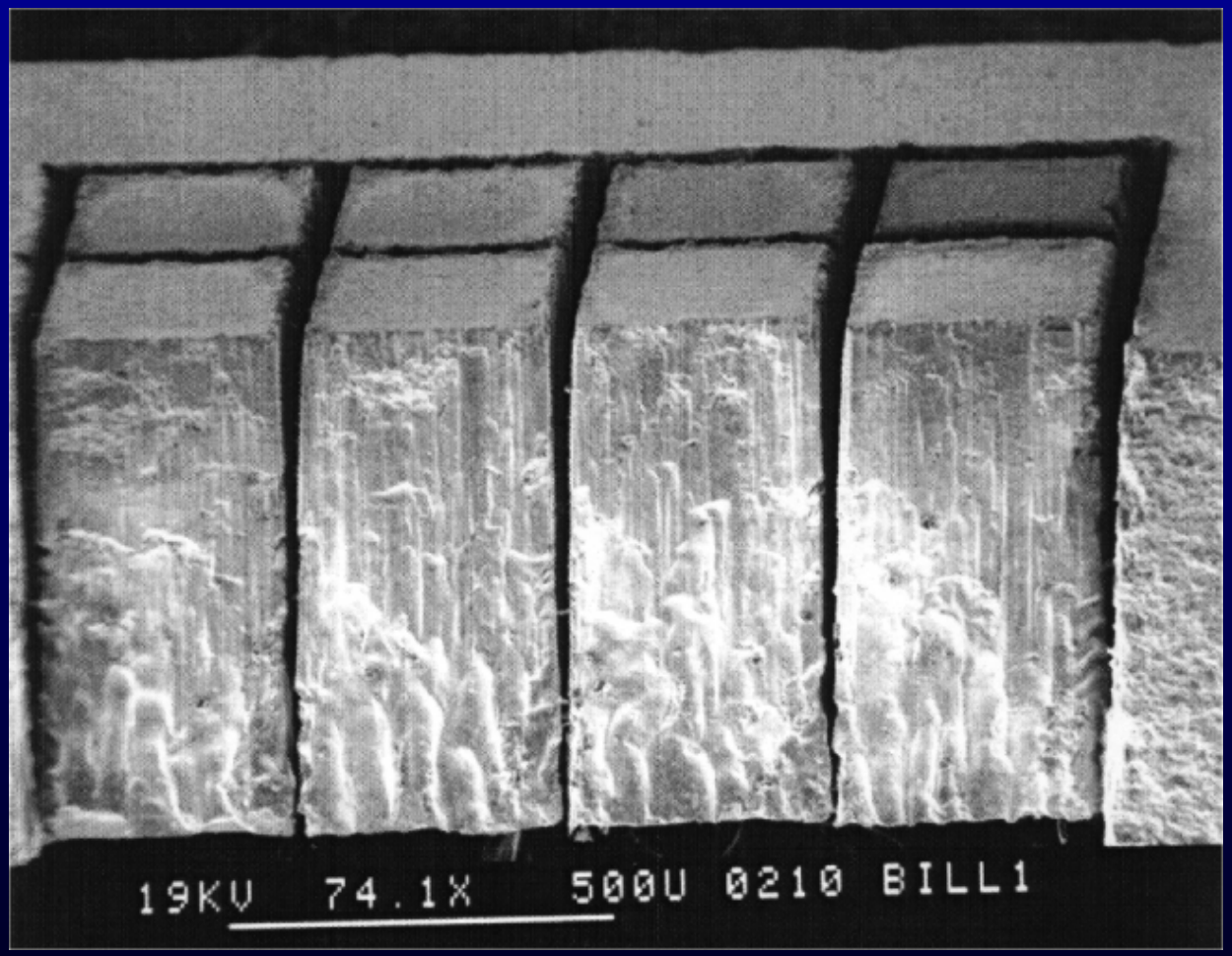
Laser machining of PZN PT Sensor Array



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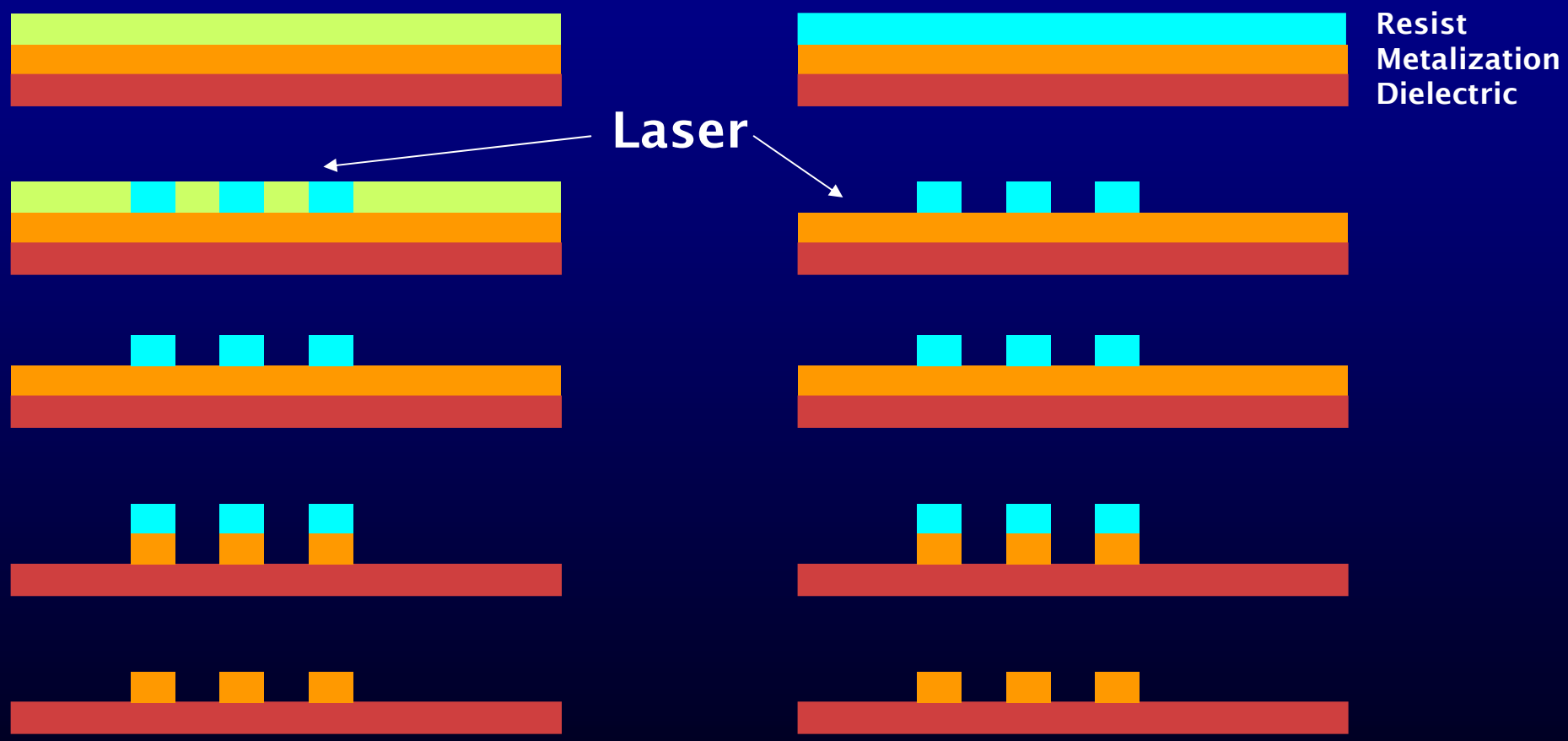
Laser Exposure/Ablation of Resist

(Negative Resist/Subtractive Process Example)

Laser Exposure
(Pattern traces)

Laser Ablation
(Pattern spaces)



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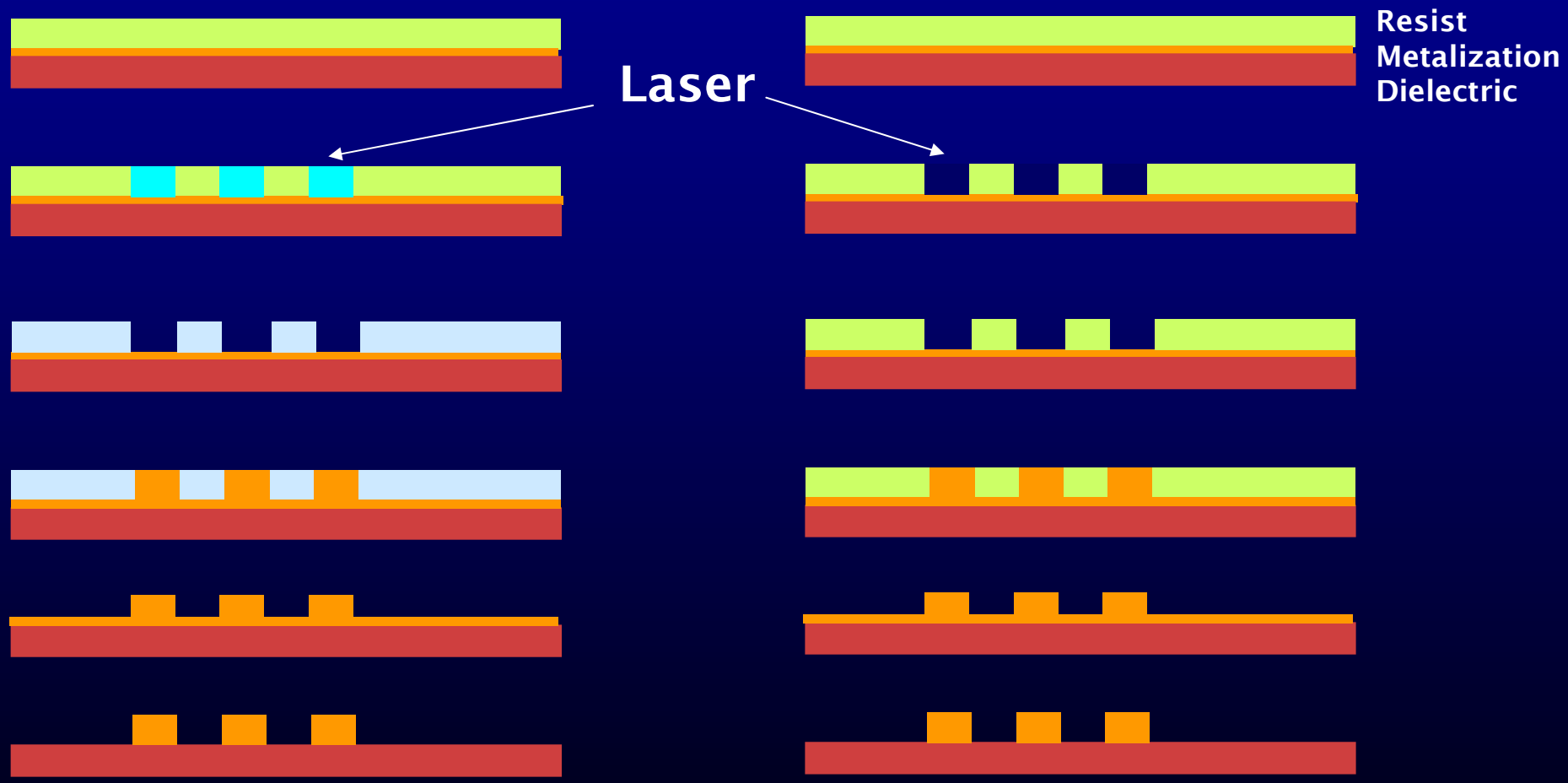
Laser Exposure versus Ablation

(Positive Resist/Additive Process Example)

Laser Exposure
(Pattern traces)

Laser Ablation
(Pattern spaces)



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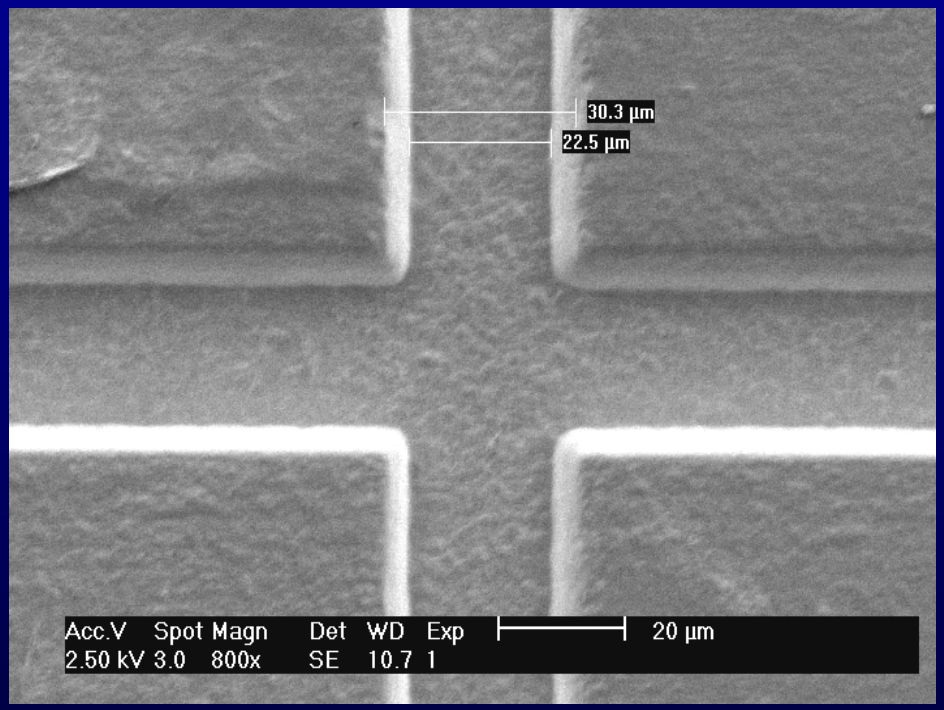
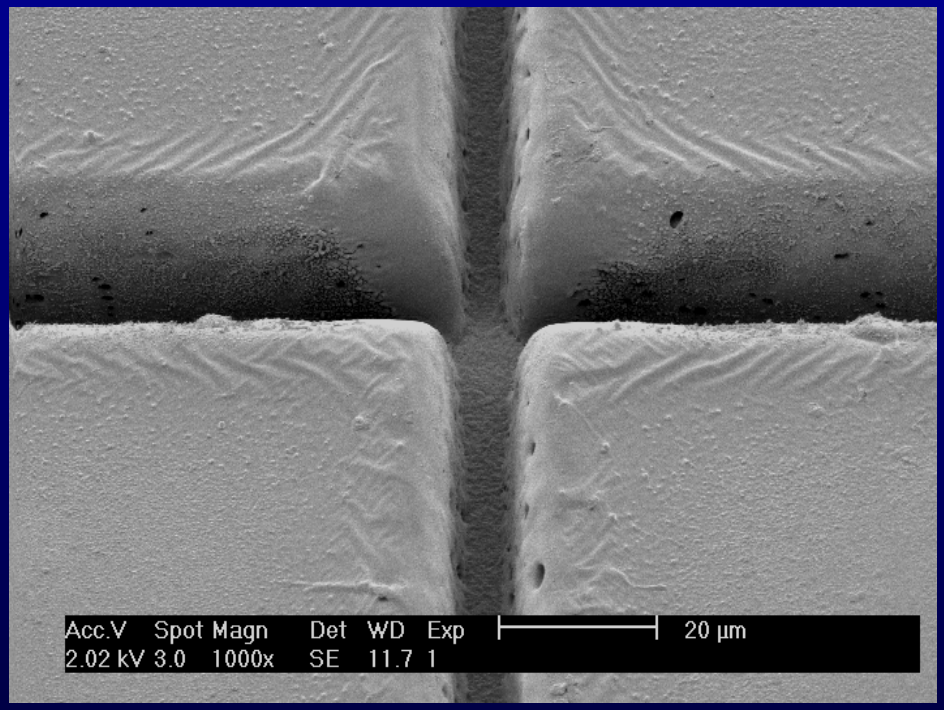
Laser Exposure or Ablation of Resist for Etch Mask
(Positive Resist)



Exposure



Ablation

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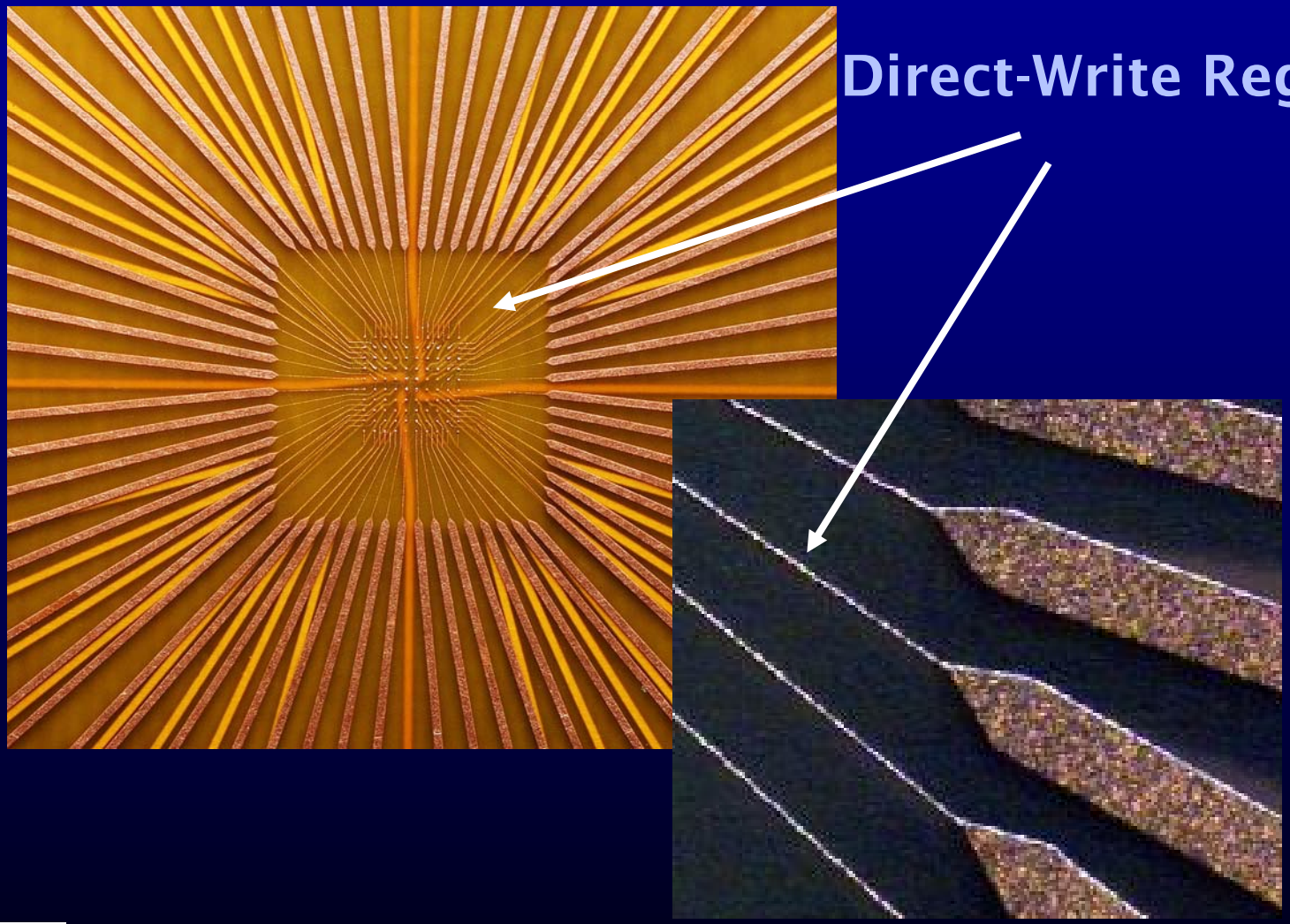
Example of Patterned Flex Circuit
(Combining Mask Photolithography with Laser-exposure of Resist)



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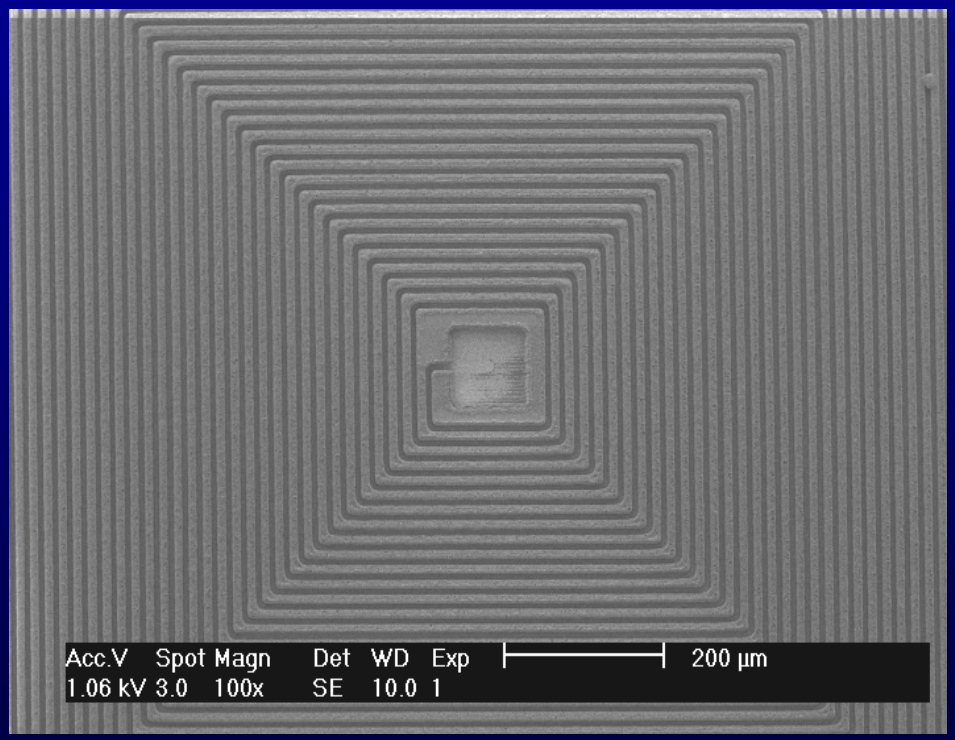
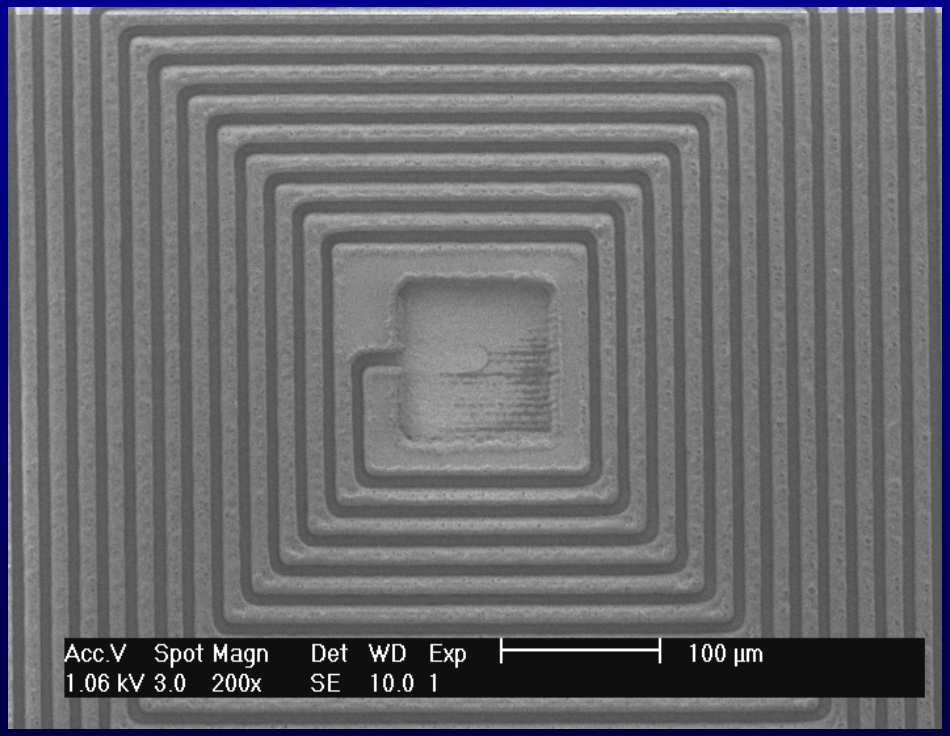
SEM of Fine Line Inductor Pattern in Resist





10µ Lines, 20µ Pitch, 15µ Thick Resist

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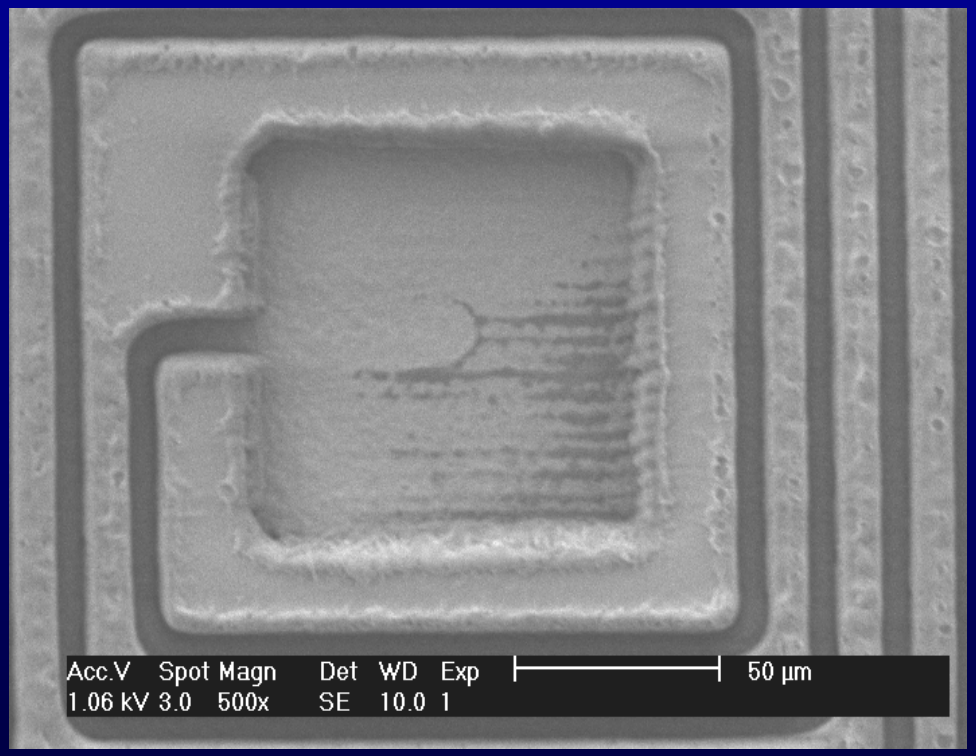
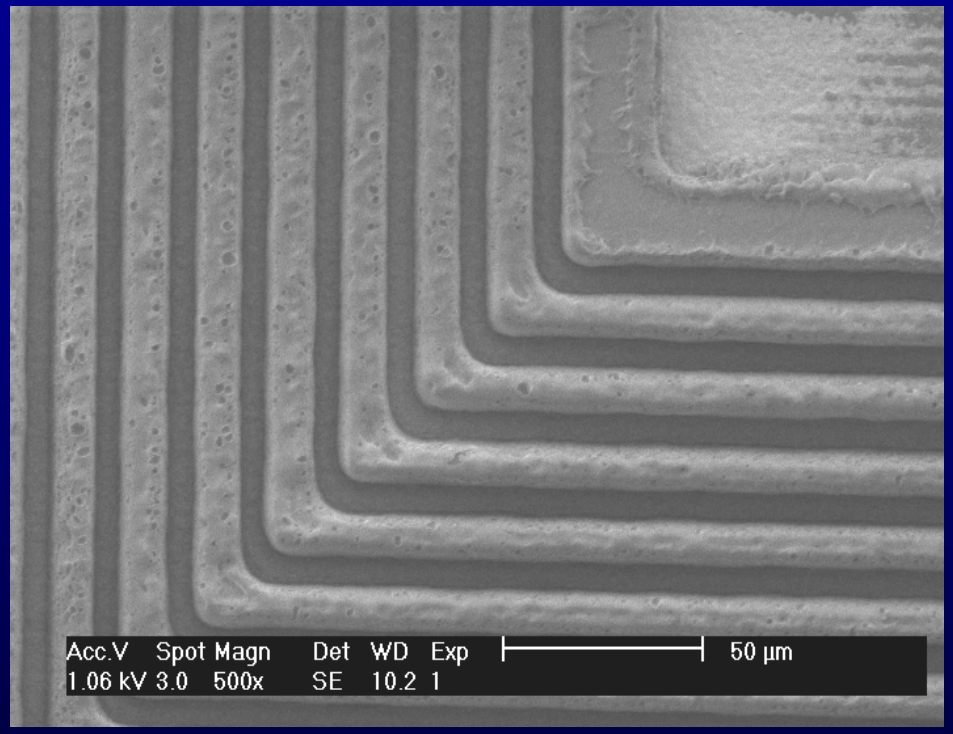
Fine Line Inductor Pattern (Detail)





10µ Lines, 20µ Pitch, 15µ Thick Resist

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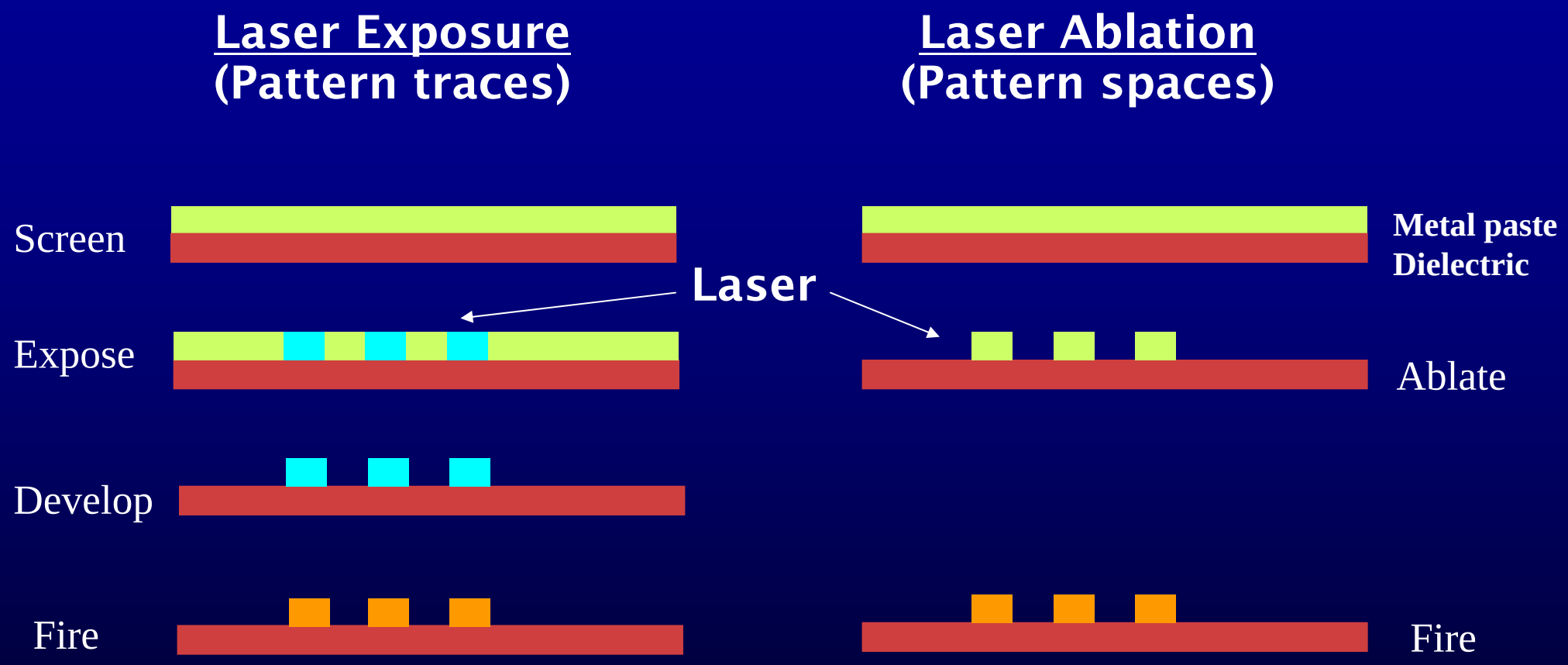
Photoimagable Thick-Film Paste Example

(i.e Fodel® 6778)



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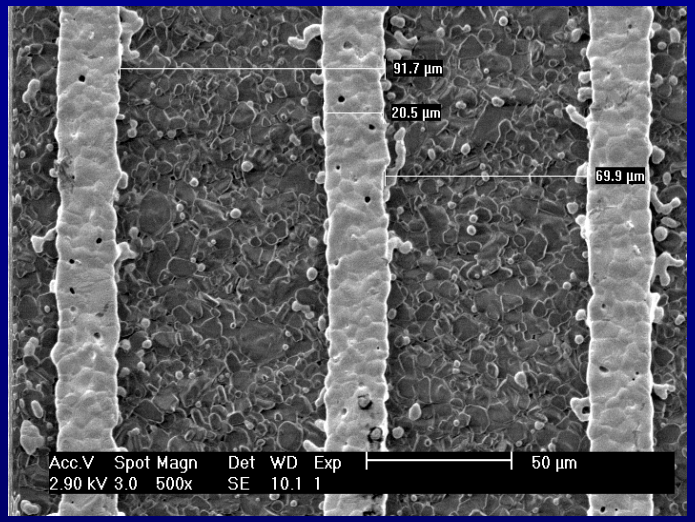
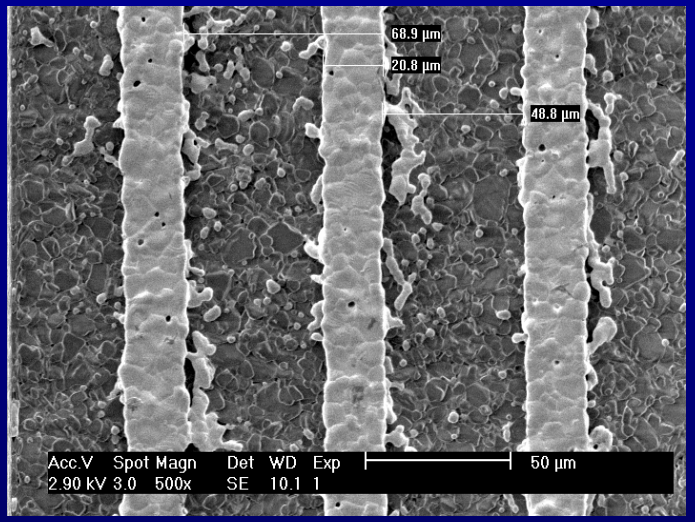
Laser Imaging Fodel® 6778

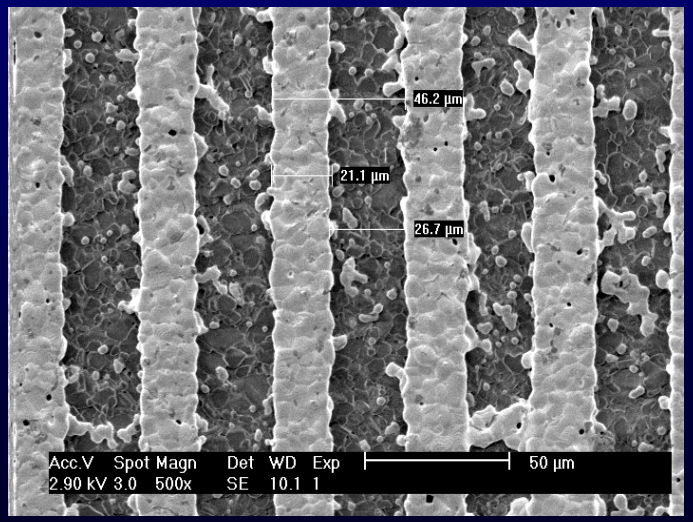
100 µm pitch



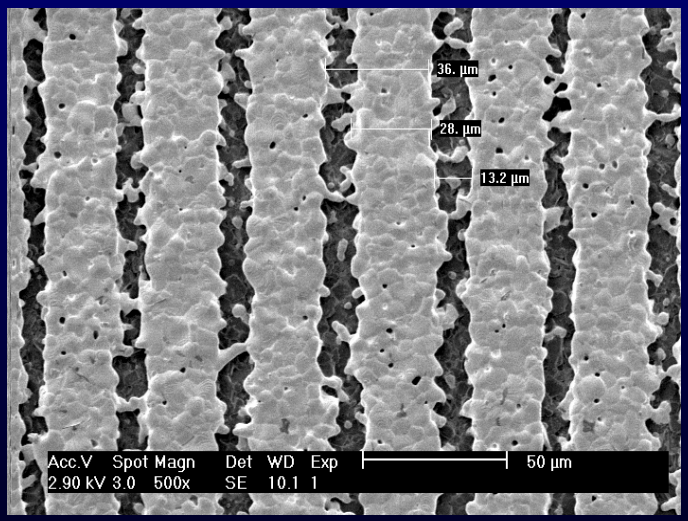
75 µm pitch



50 µm pitch



40 µm pitch



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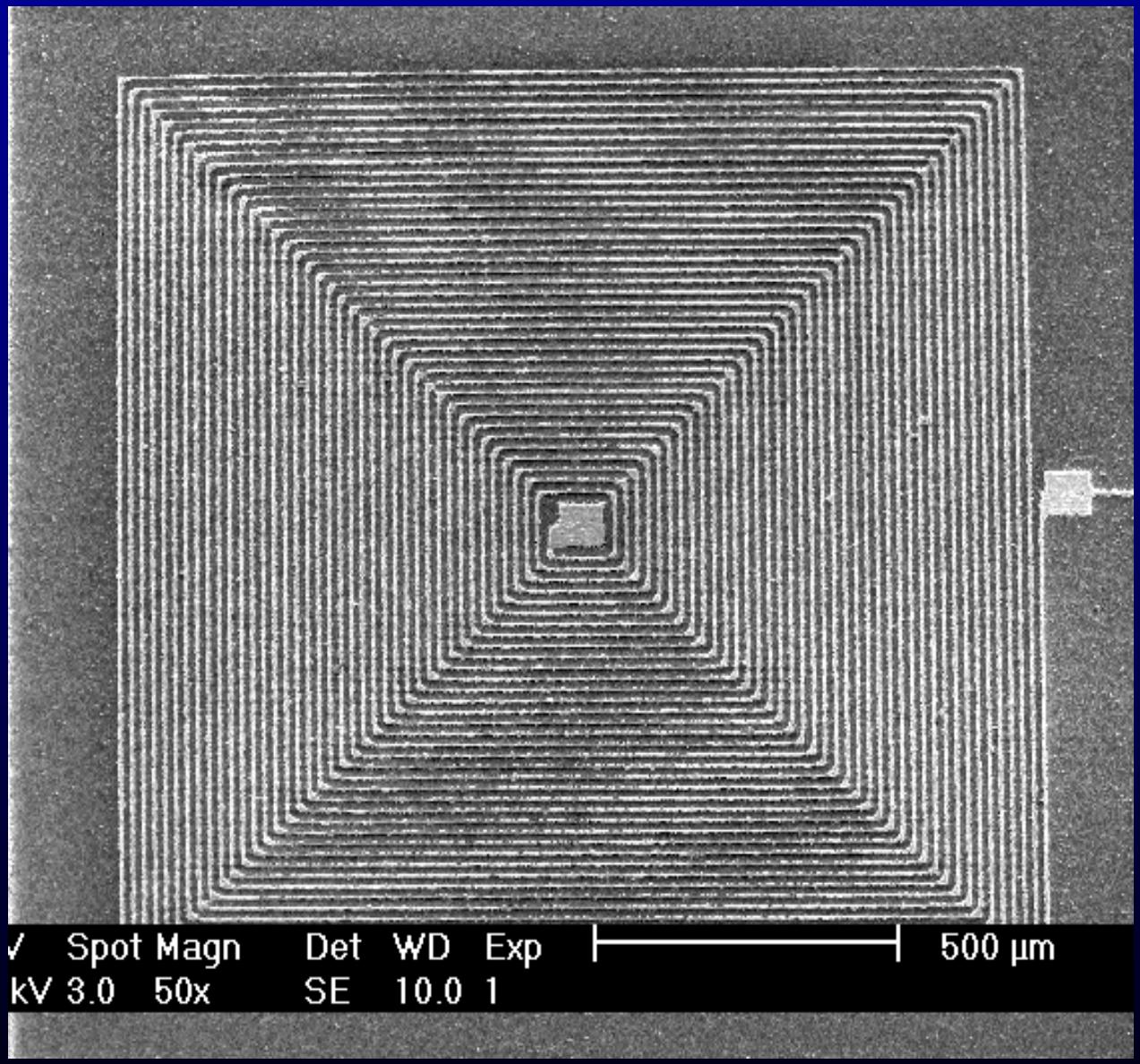
Small Inductor Pattern in Fodel®
(Ablation Process)



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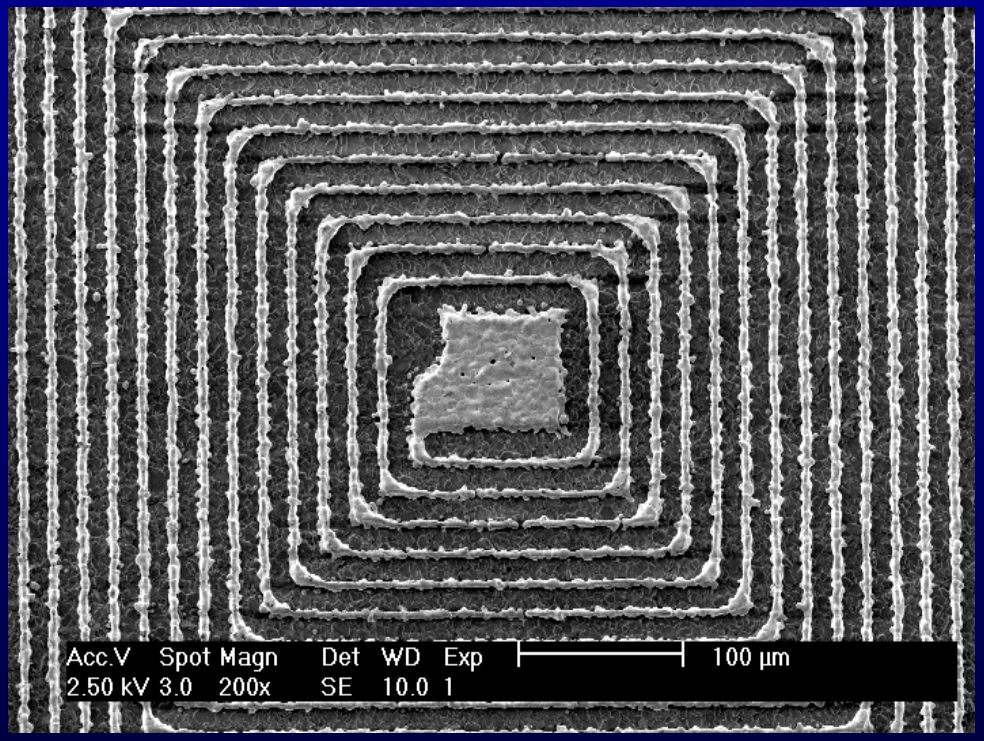
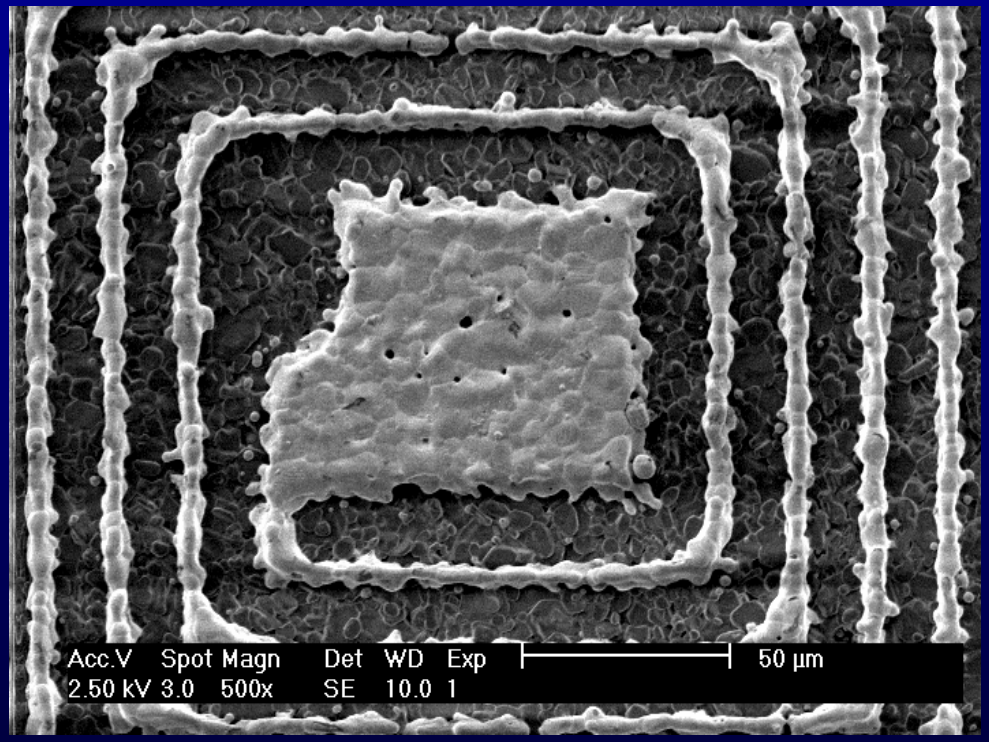
Inductor Pattern Detail





20 µm line pitch

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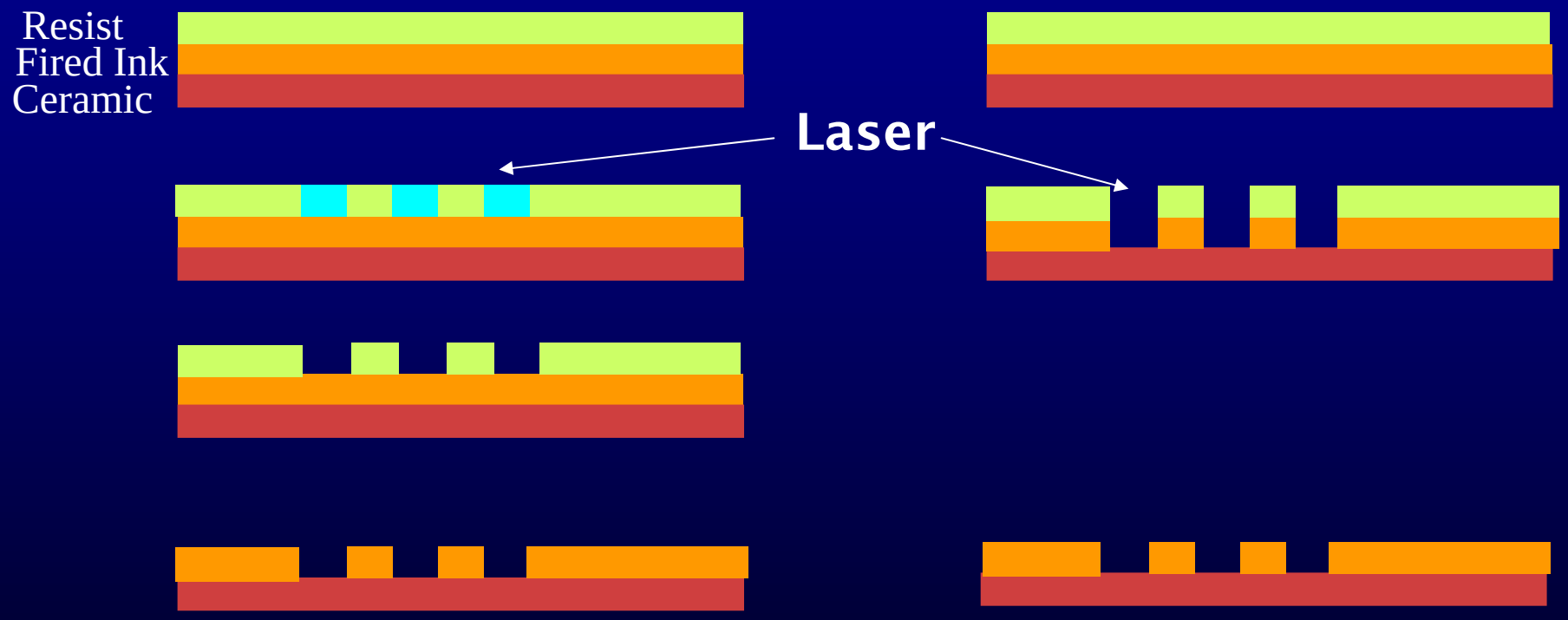
Etchable Thick-Film Ink Example

(Positive Resist/Subtractive Process
(i.e. Heraeus KQ500)

Laser Exposure
(Pattern spaces)

Laser Ablation
(Pattern spaces)



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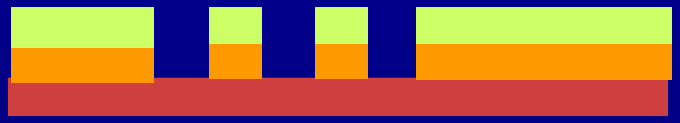
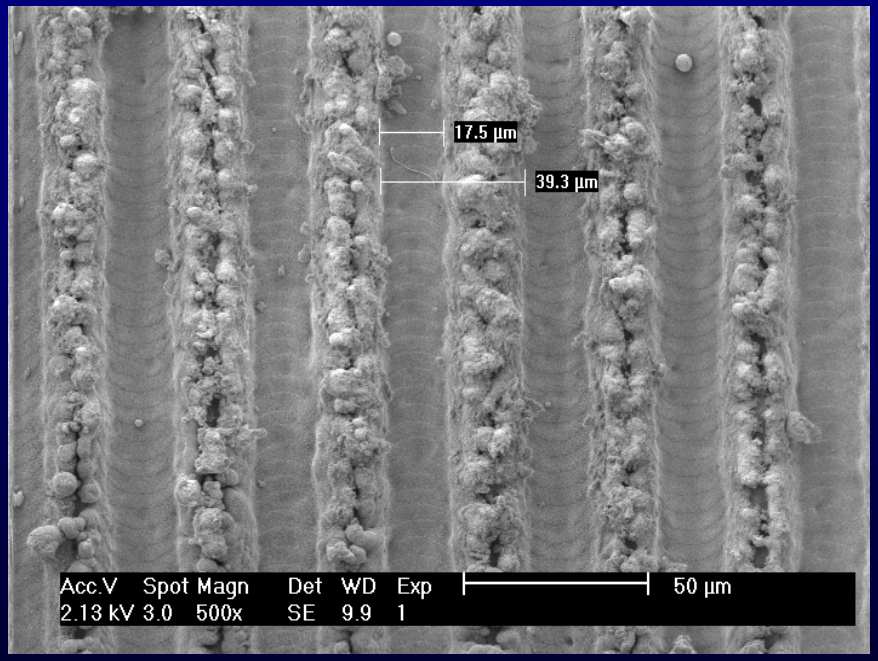
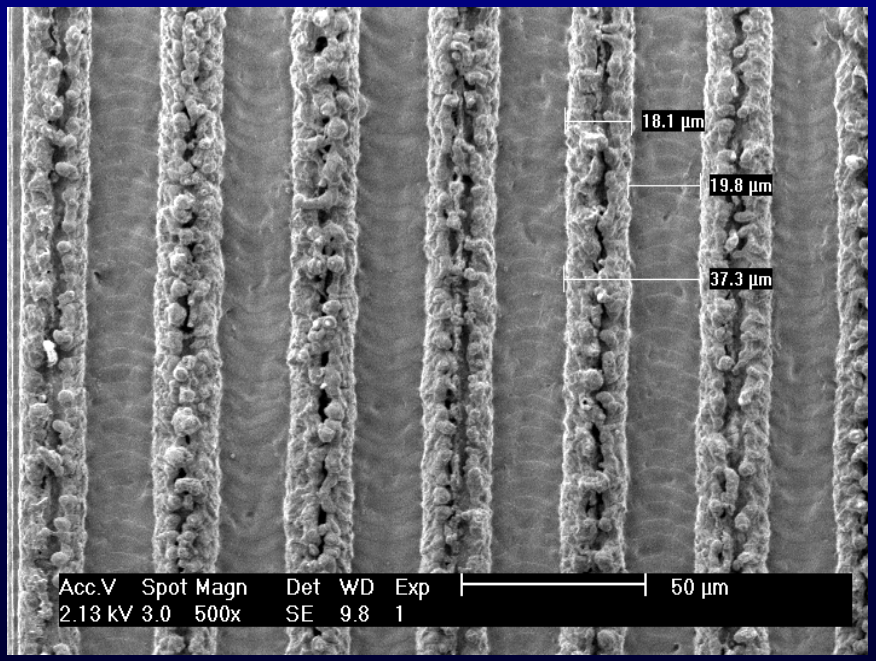
Laser Ablation of Fired Ink
(Heraeus KQ500)







40 µm pitch

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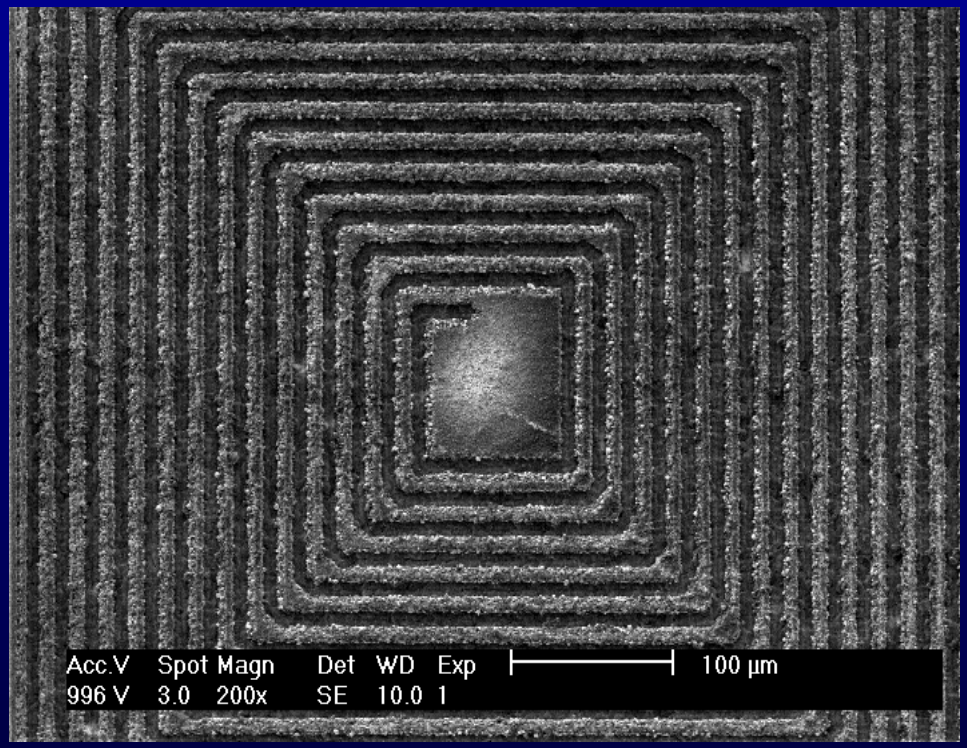
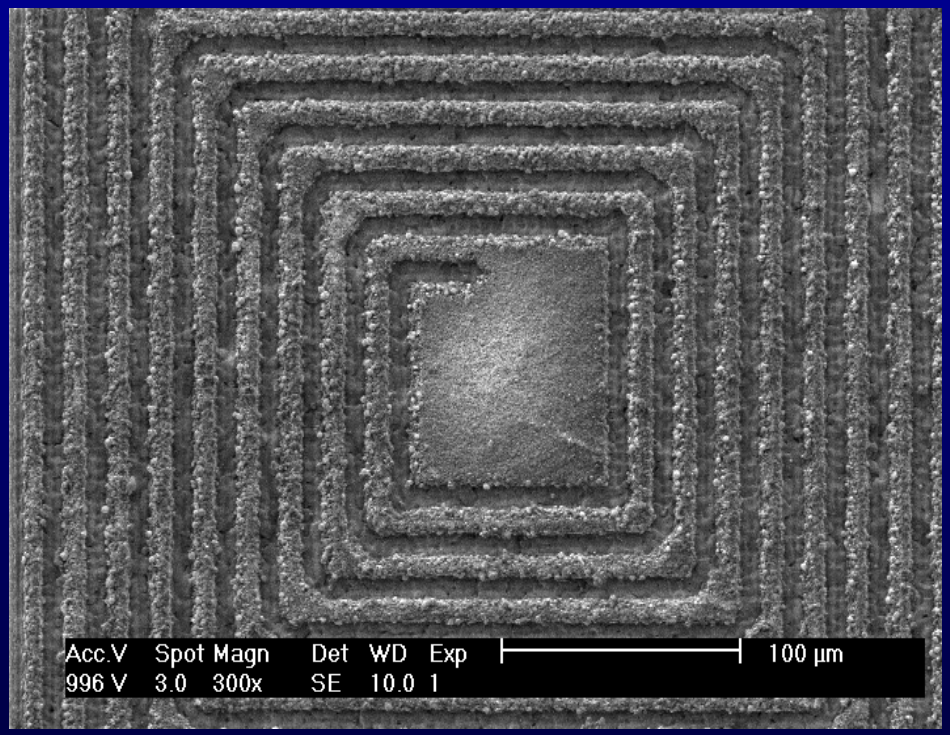
SEM of Unfired Heraeus KQ500 Gold Conductor (Ablation Process)





10µ Square Spot Ablation, 20µ Pitch

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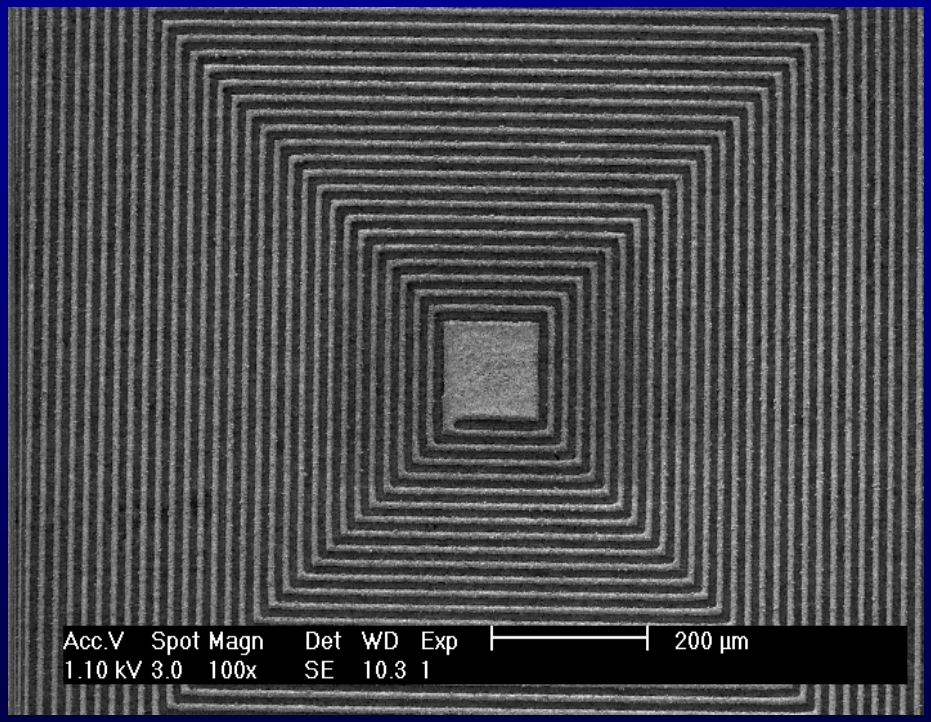
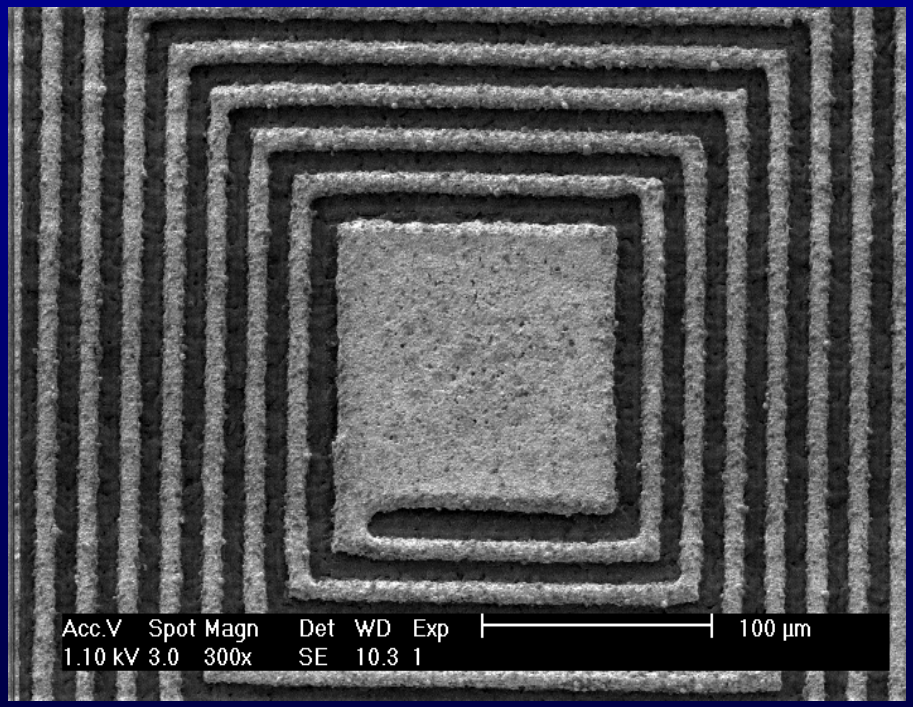
SEM Picture of Fired Heraeus KQ500 Gold Conductor





10µ Square Spot Ablation, 20µ Pitch, 8µ Thick

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Conclusions

- Vector UV laser direct write is a versatile tool for a variety of patterning requirements.
- Applications include:
  - Trace patterning of circuit boards, flex circuits, thick-film ceramic circuits
  - Machining of a wide variety of materials including metals and dielectrics
- The process can be additive (exposure) or subtractive (ablation)
- Shaped beam optics improve the aspect ratio of the machining process
- We have demonstrated circuit features as small as 10 μm
- Key advantage of direct conversion from file to patterned circuit

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