Making Light Go Through Tiny Holes

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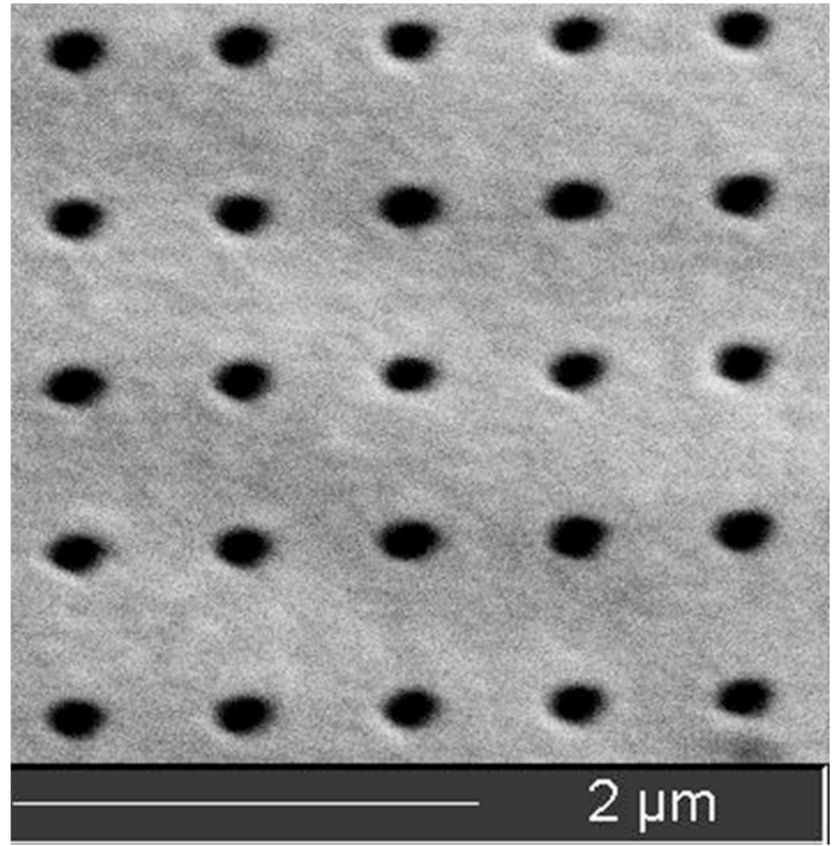

TRIUMF Saturday Morning Lecture Series, Nov. 14, 2009

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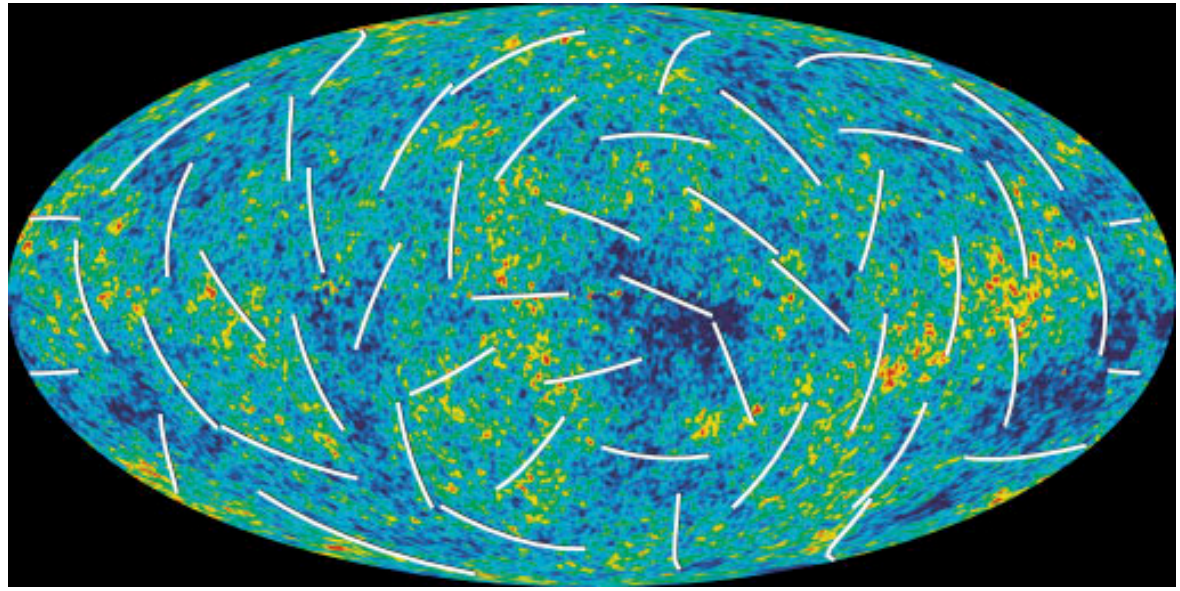
This is BiG

- Infant universe from microwave background

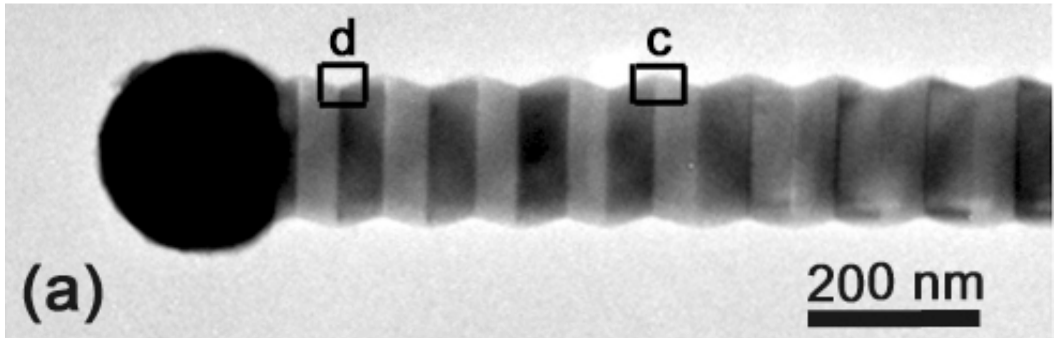


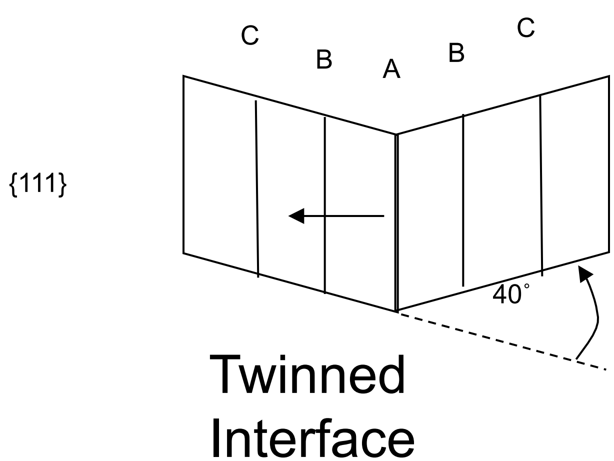
Credit: NASA/WMAP Science Team

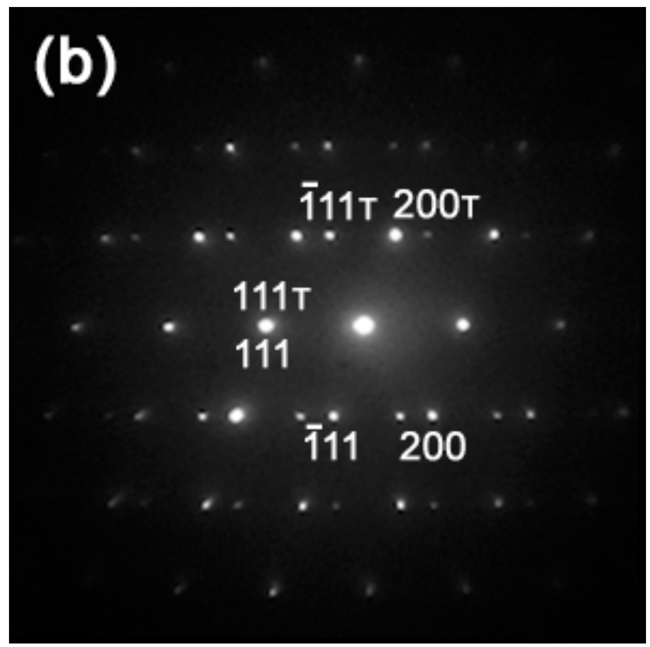
10^{26} nm

Twinning modulation in ZnSe nanowires,
Y.Q. Wang, U. Philipose, H.E. Ruda, and K.L. Kavanagh, *Semicond. Sci. Technol.* 22 (2007) 175

Au/ZnSe/Si

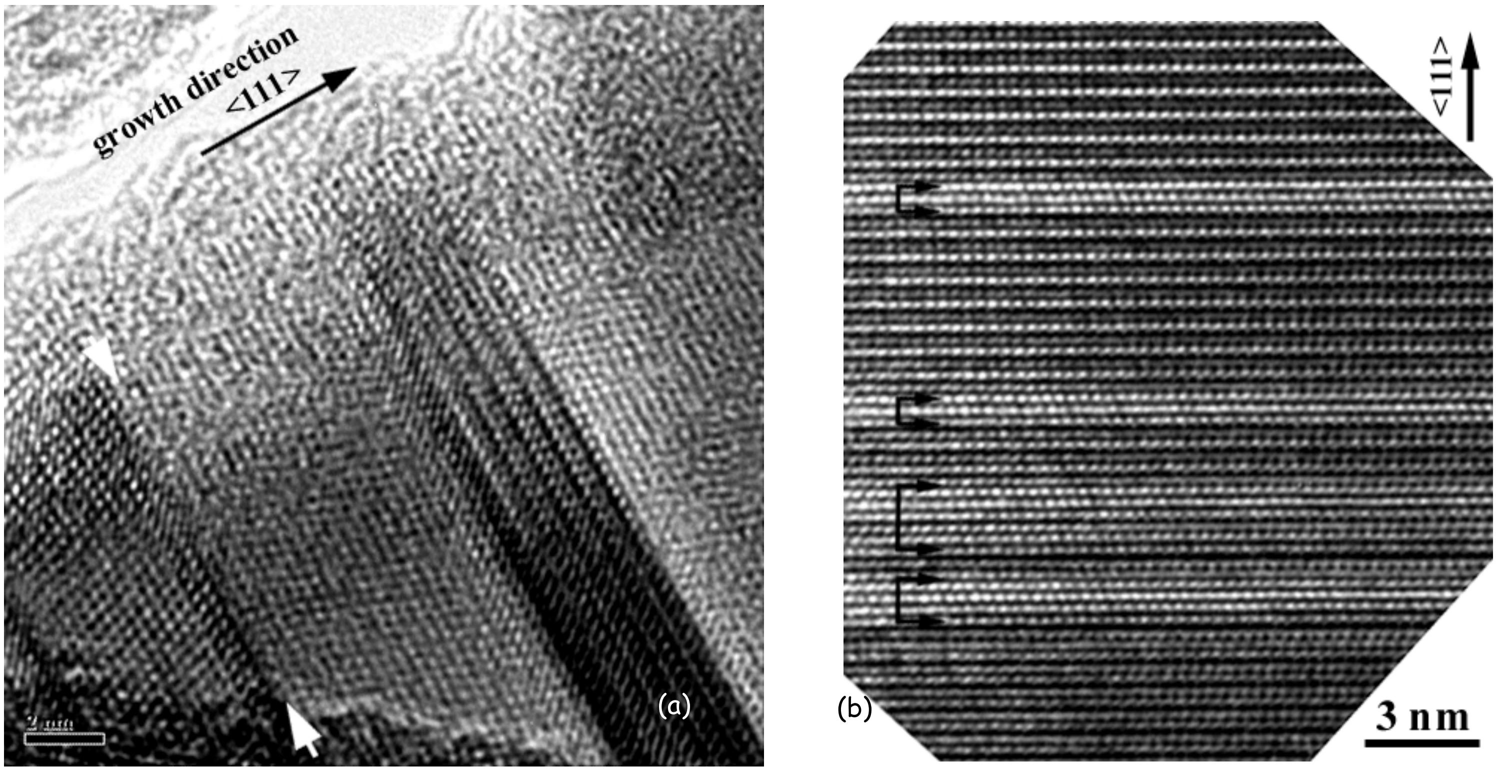






Growth, branching, and kinking of molecular beam epitaxial <110> GaAs nanowires, Z. H. Wu, J. Q., Liu, X. Mei, D. Kim, M. Blumin, K. L. Kavanagh, and H. E. Ruda, *APL* 83 (2003) 3368.

Planar defects in <111> GaAs nanowires

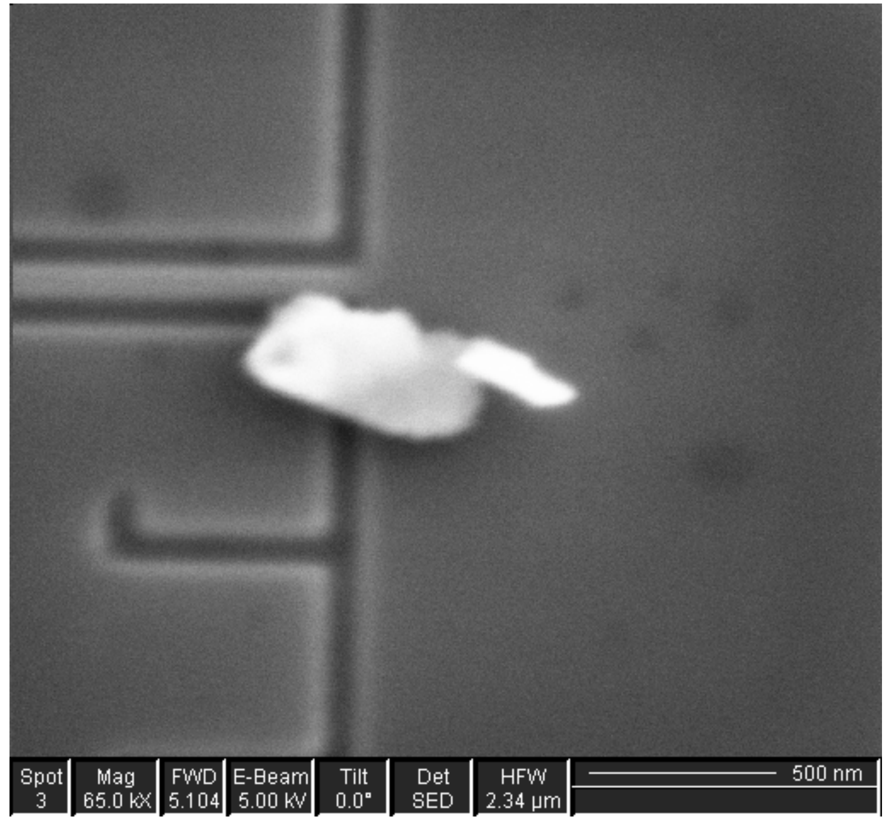


- ❑ (111) planar twin boundary: Faulted stacking sequence (b).
- ❑ The density of planar defects varies. The broader the nanowire, the higher the possibility for finding these defects.

Nanometers

are small.

- Dust on Si wafer
- SEM image
- contrast based on the emission of surface electrons



500 nm

- 1 nanometer (nm) = 1×10^{-9} m

(= 1/1,000,000 mm = 1/1000 micron)

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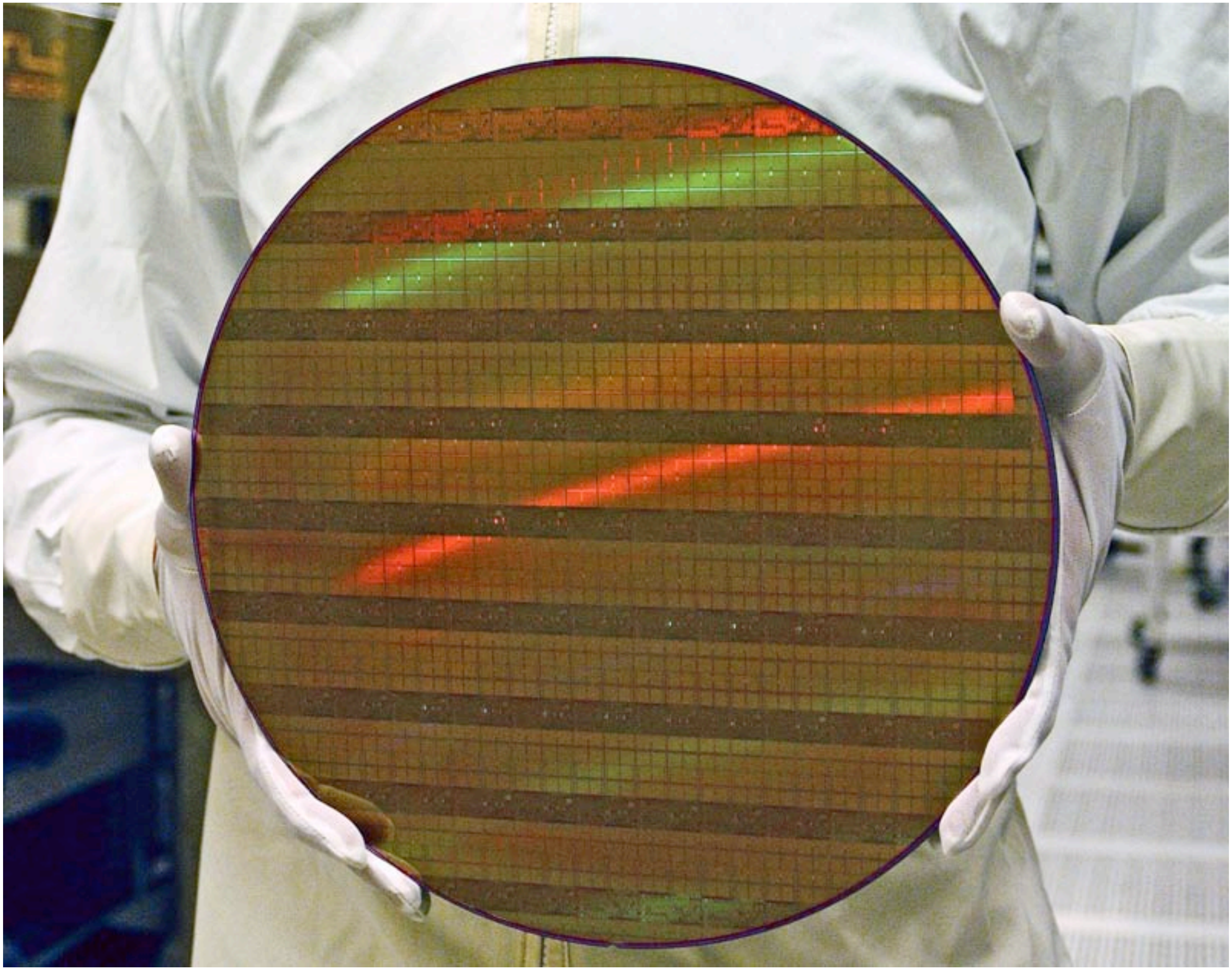
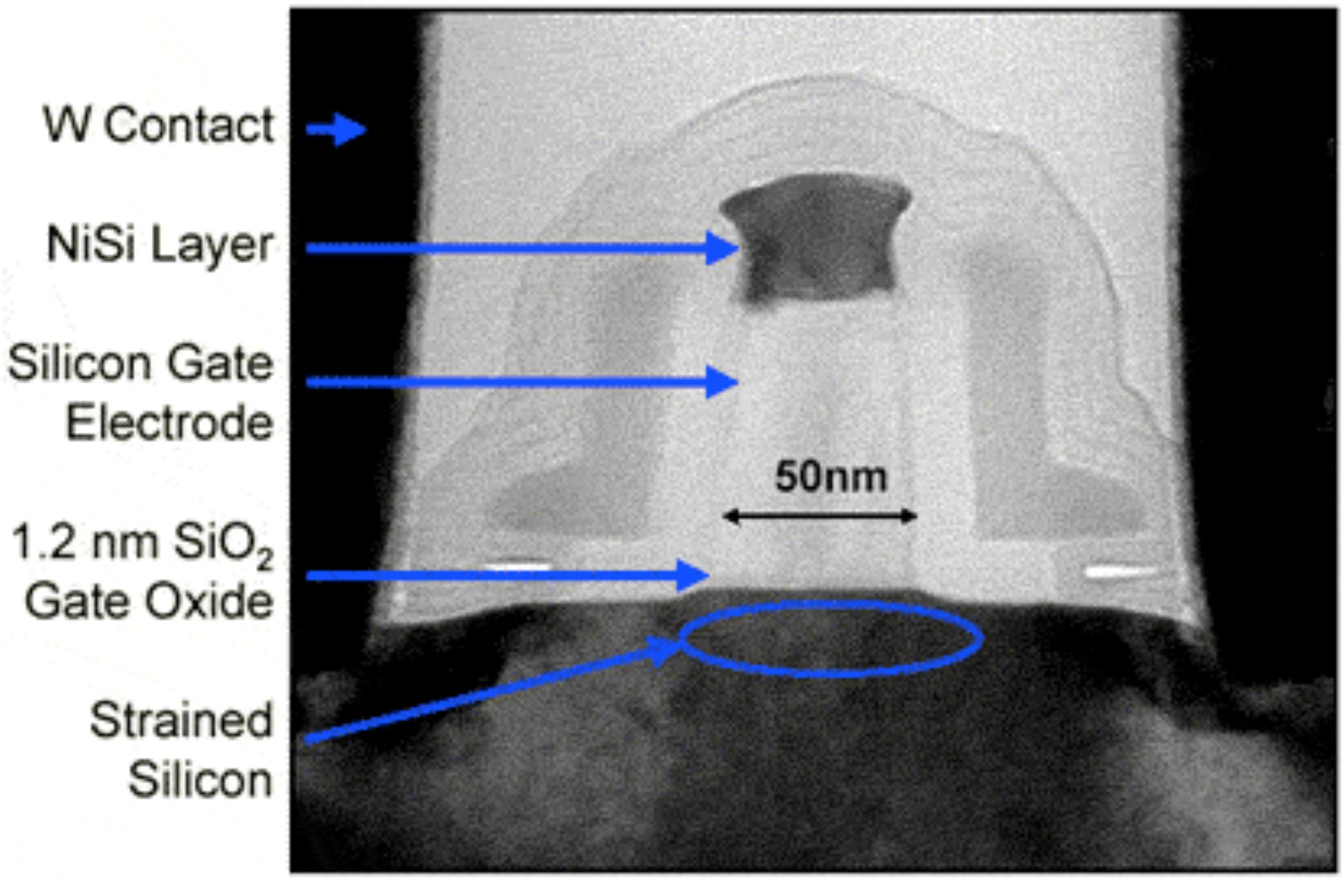
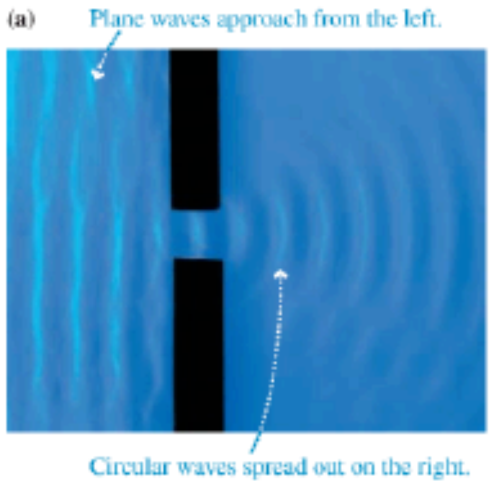


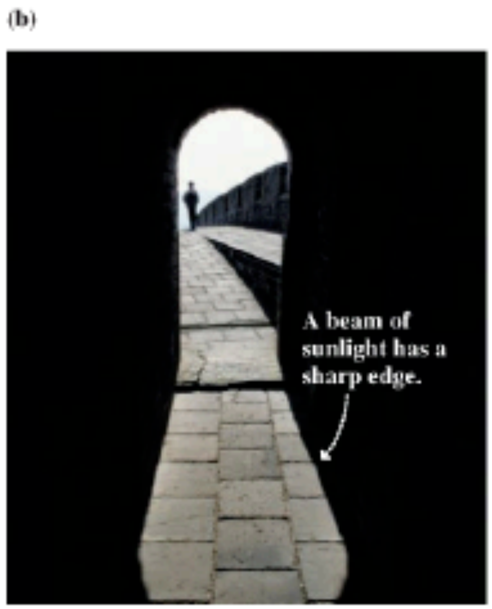
Latest Intel product line

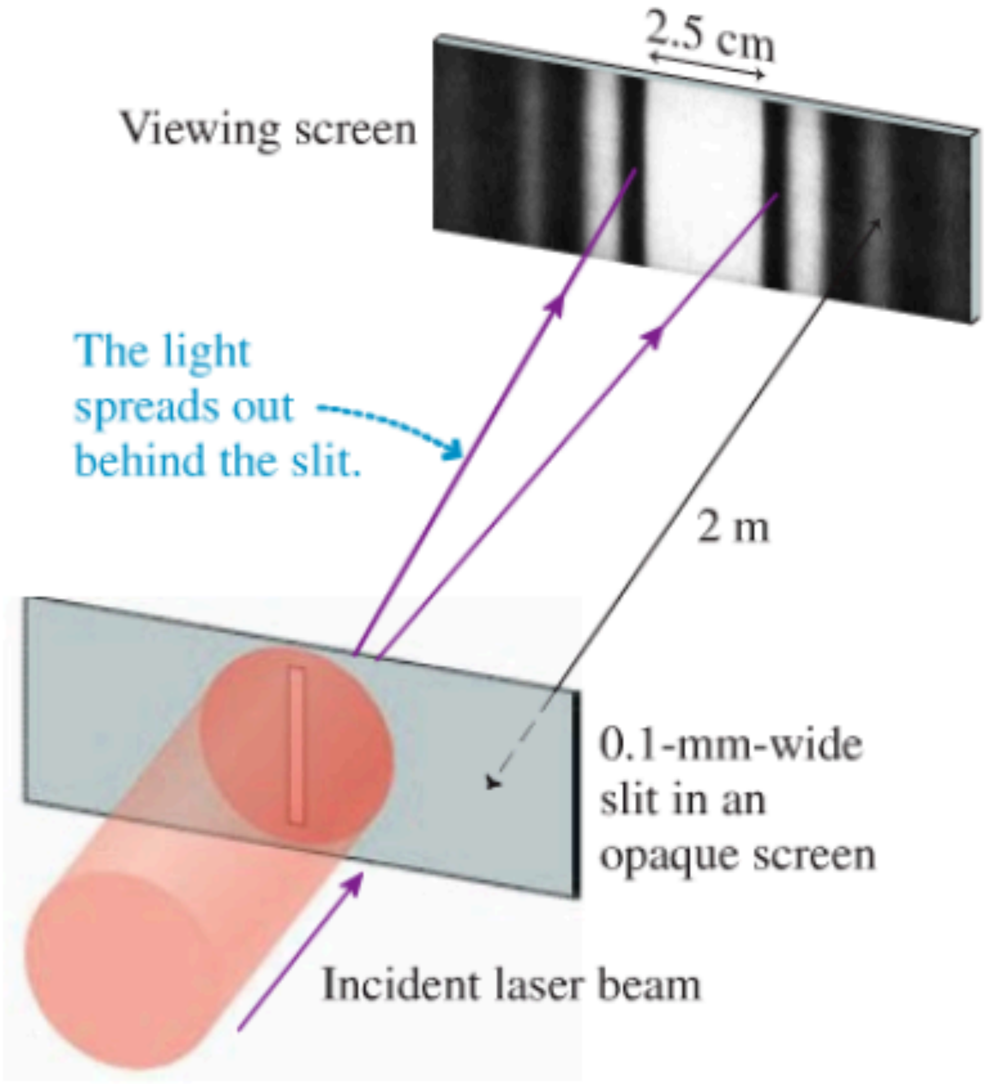
Transmission Electron Micrograph of Intel's
90 nm Generation Transistor



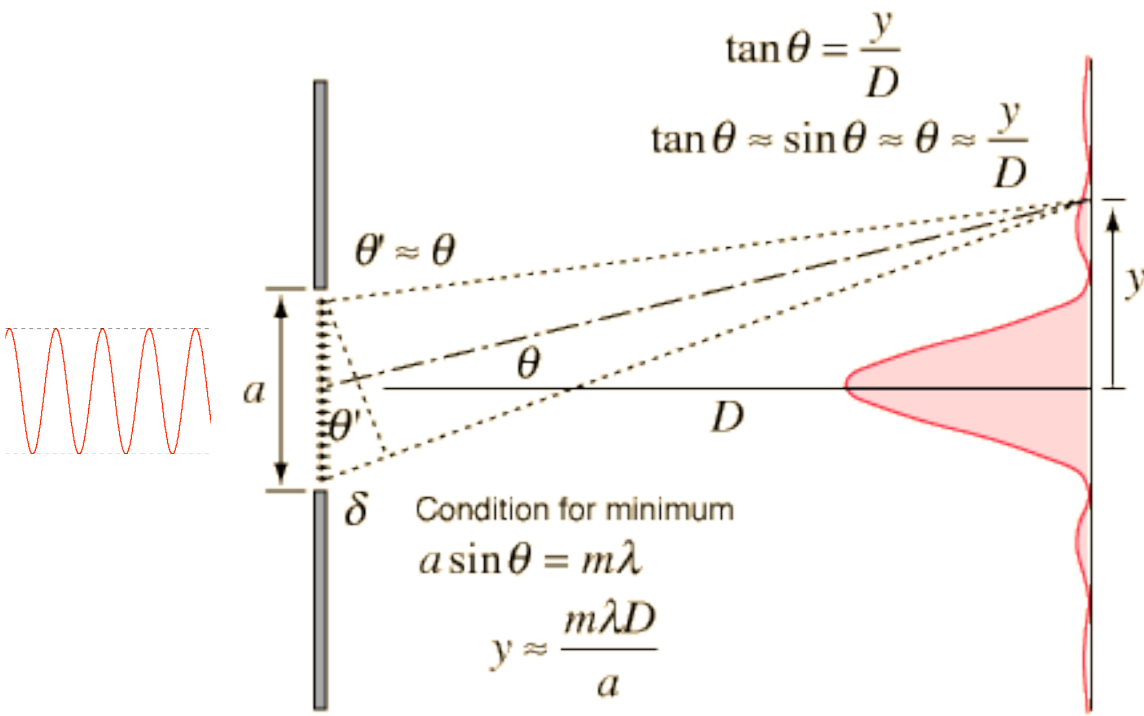
Diffraction - Single Slit

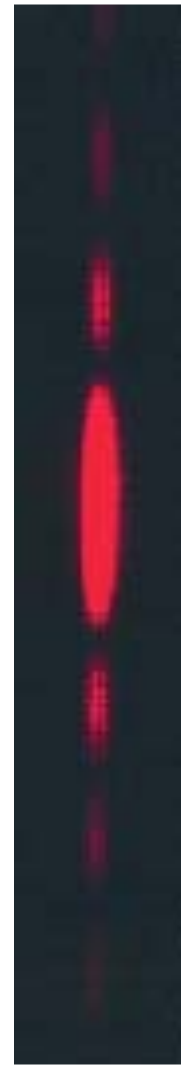






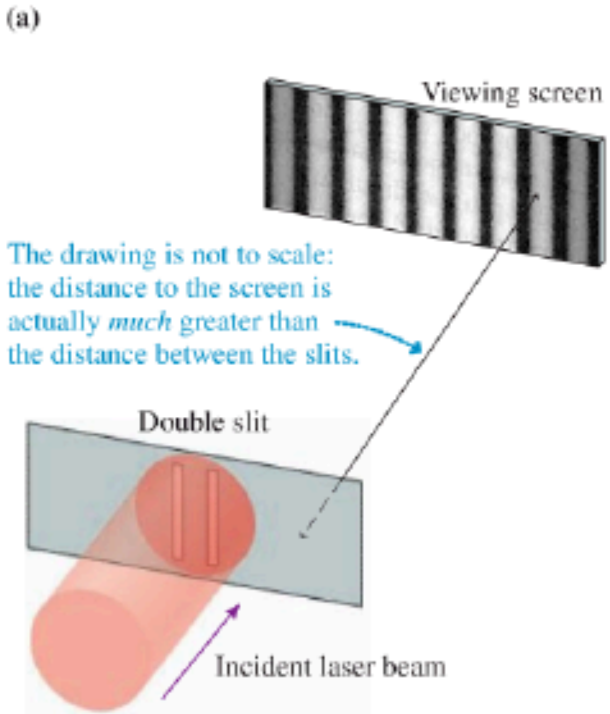
Single Slit Experiment

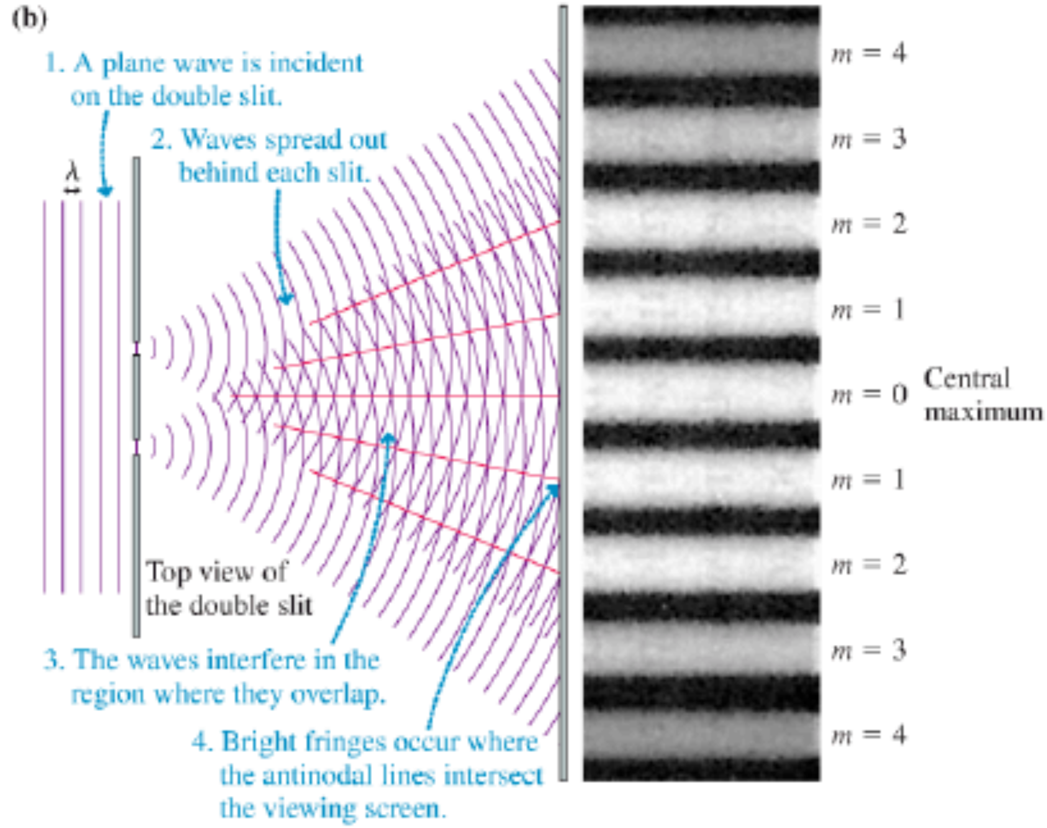




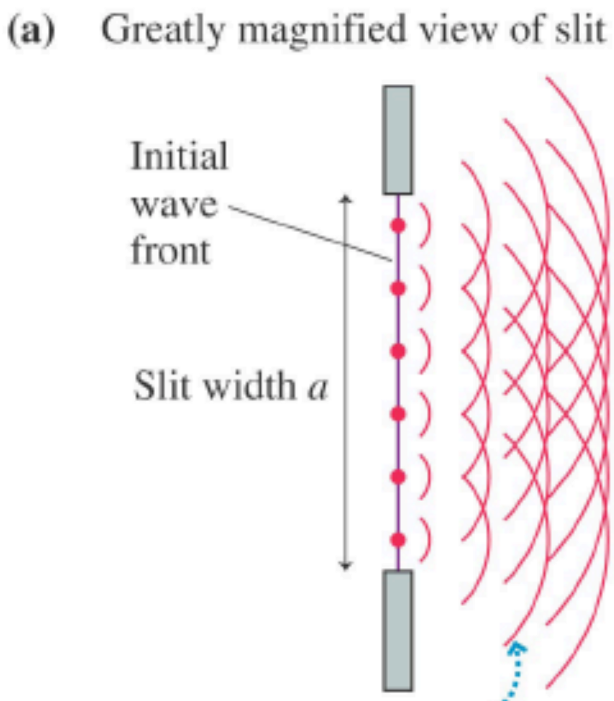
hyperphysics.phy-astr.gsu.edu/.../sinslit.gif

Young's Double-Slit Experiment





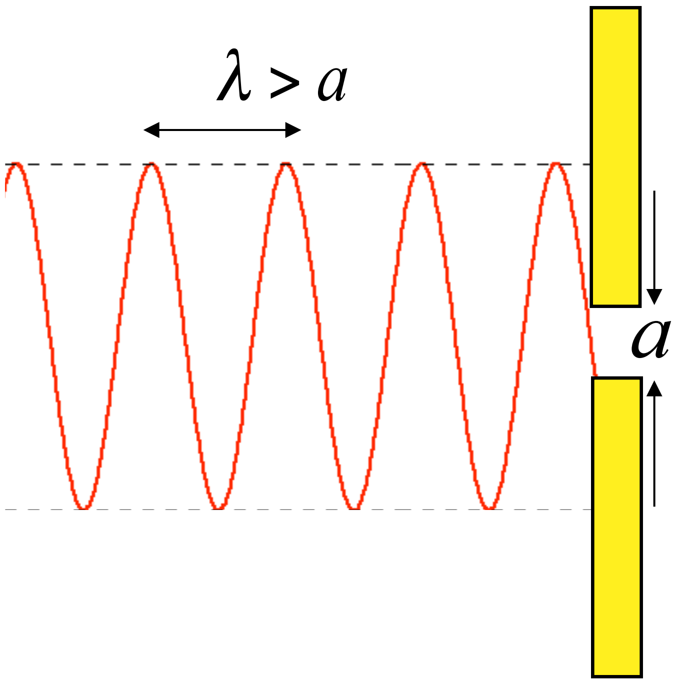
Single Slit Diffraction



The wavelets from each point on the initial wave front overlap and interfere, creating a diffraction pattern on the screen.

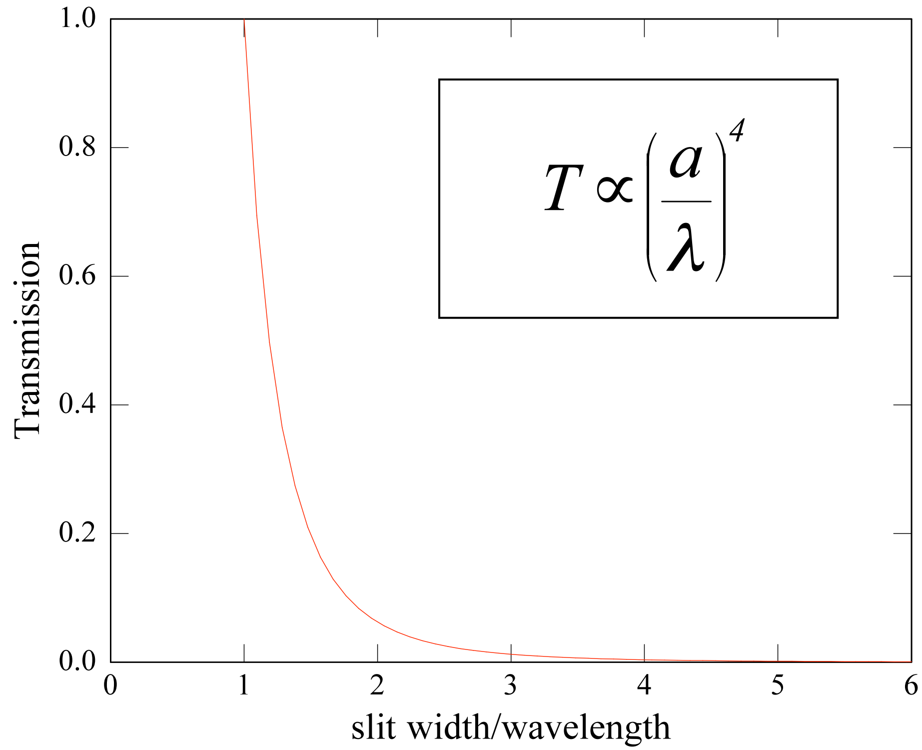
- A wave front passes through a narrow slit (width a). Note that narrow is important.
- Each point on the wave-front emits a spherical wave
- One slit becomes the source of many interfering wavelets.
- A single slit creates a diffraction pattern on the screen.

H. Bethe (1944) Theory of Diffraction through small holes:



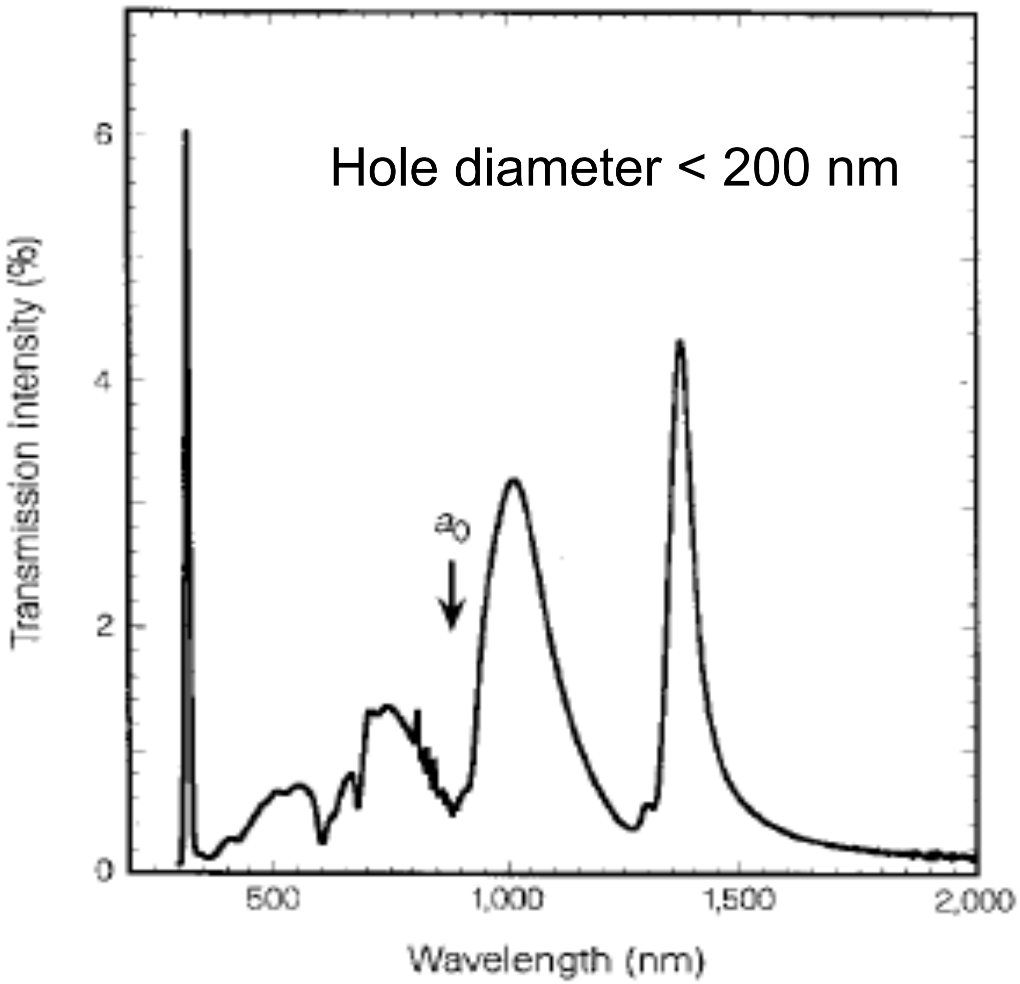
Perfect Electric Conductor

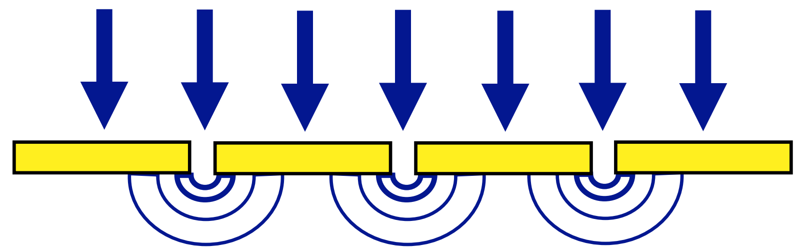
Transmission, T(a/λ)



Ebbesen et al. (Nature, 391, 1998)

"Extraordinary optical transmission through sub-wavelength hole arrays"





Enhanced transmission attributed to surface plasmons

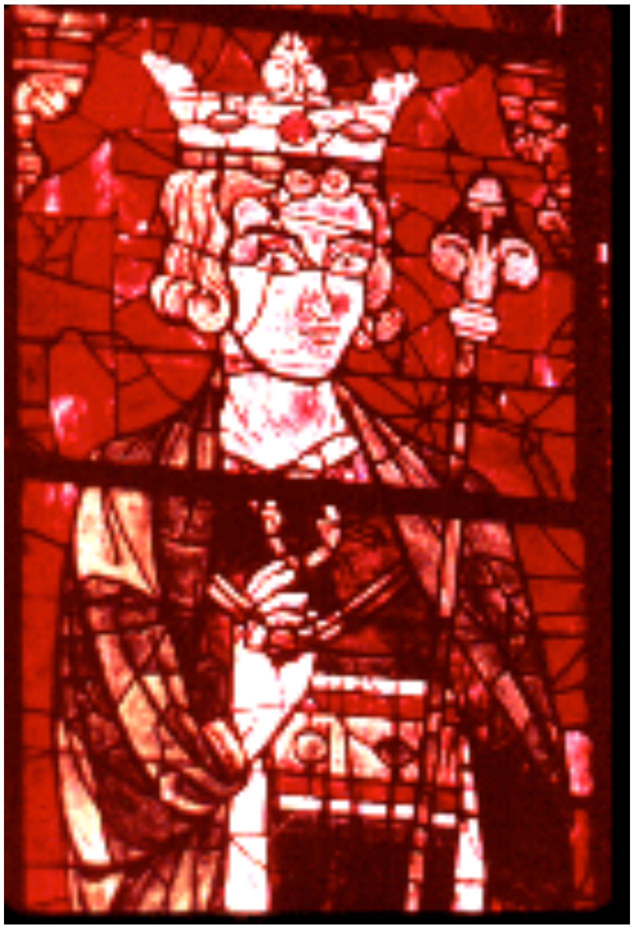
What's a surface plasmon?

- light that propagates along the interface between a metal (ε_1) and an insulator (ε_2)
- wavevector:

$$k_{sp} = \frac{\omega}{c}\sqrt{\frac{\varepsilon_1 \varepsilon_2}{\varepsilon_1 + \varepsilon_2}}$$

- $\therefore$ wavelength is smaller than regular light of the same frequency

Early plasmonics research (1100's)
glass stained with metallic salts and oxides



Text Courtesy of the Art Glass Association _
Pictures courtesy of SGAA Slide Library
http://www.stainedglass.org/

Jeff Burnette

Joe Blow Glassworks, Vancouver

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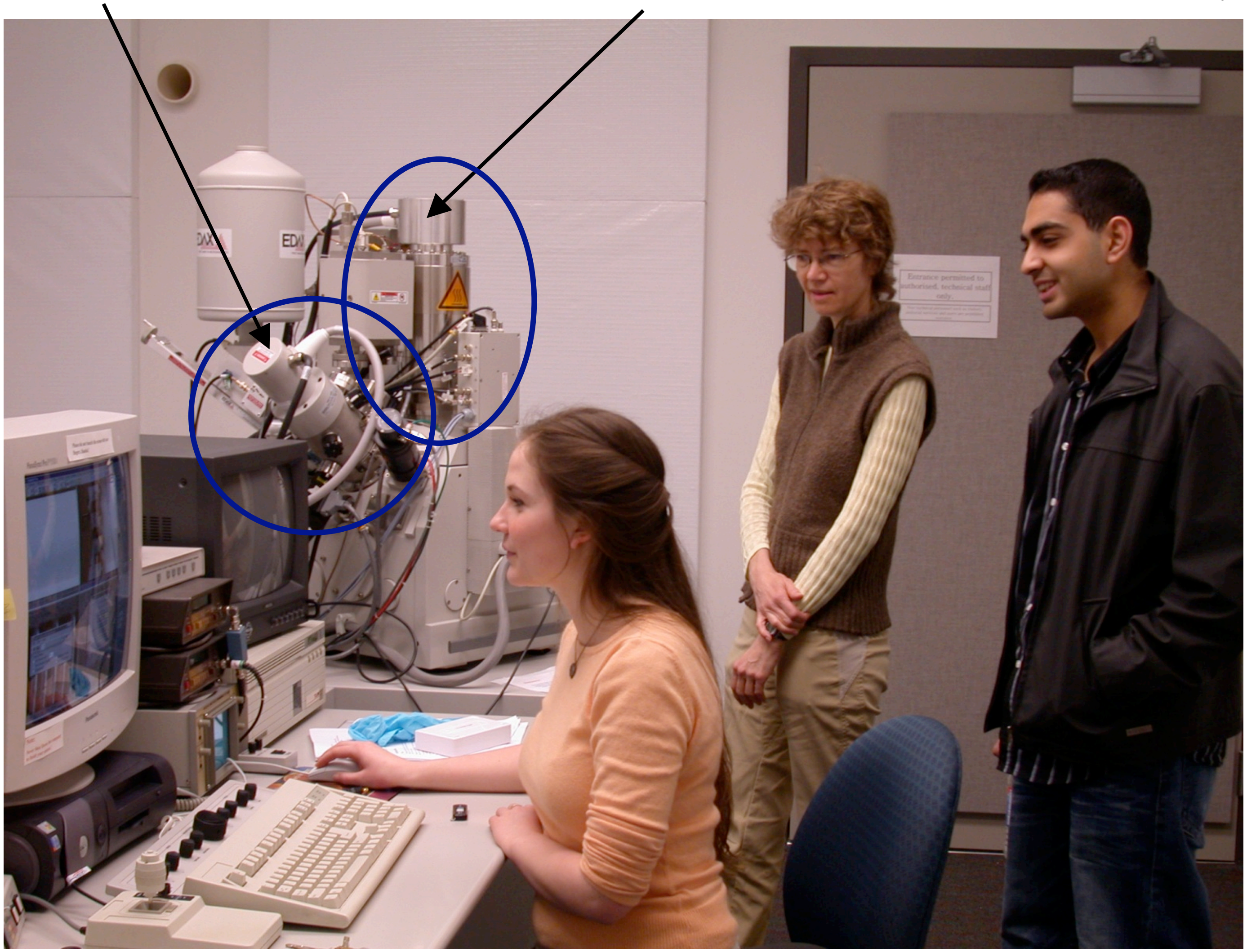
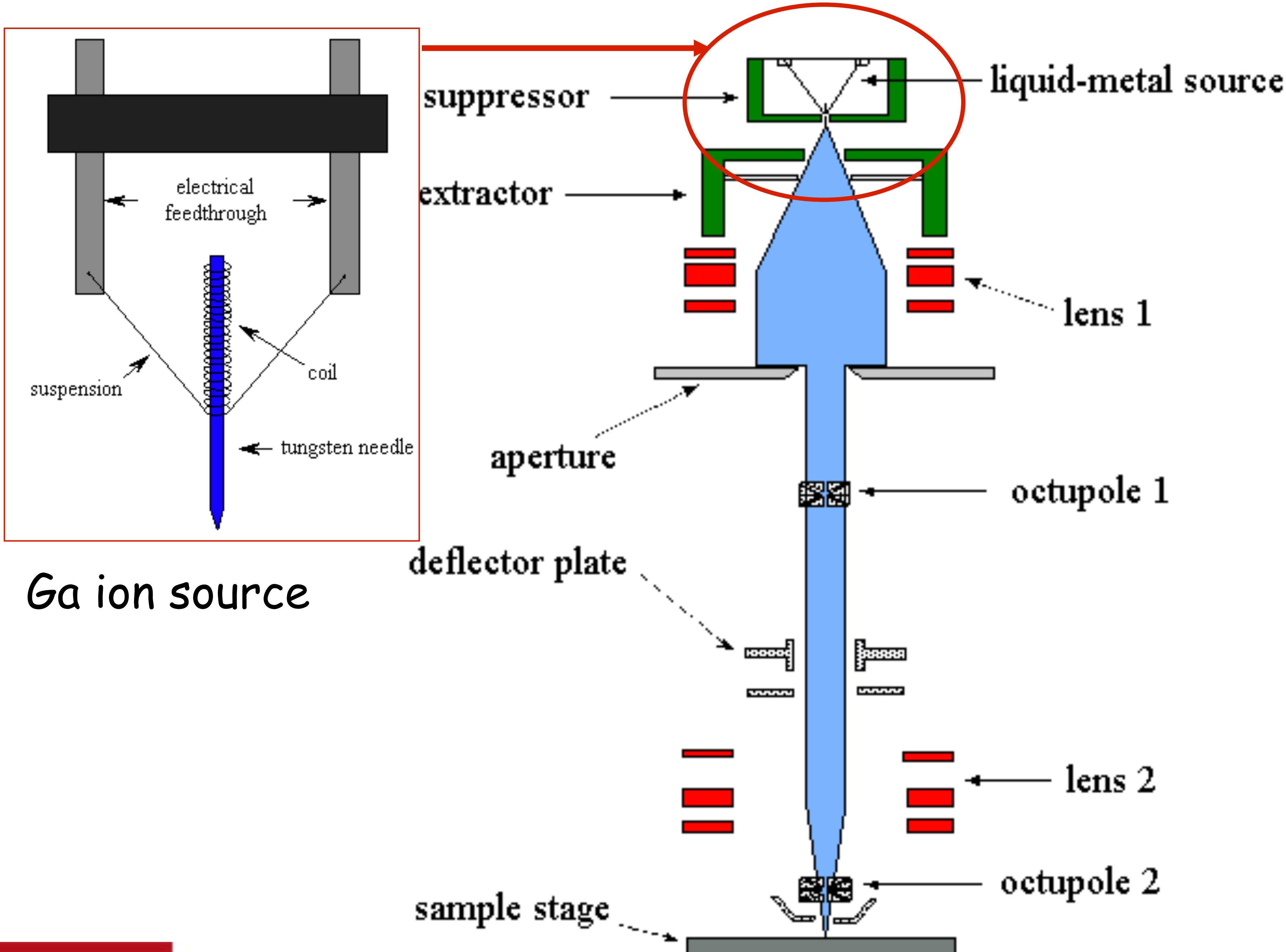
Focussed Ion Beam with a Scanning Electron Microscope



Nauman
Methani
SFU
Chemistry

Samantha Grist, SFU Physics



Ga ion source

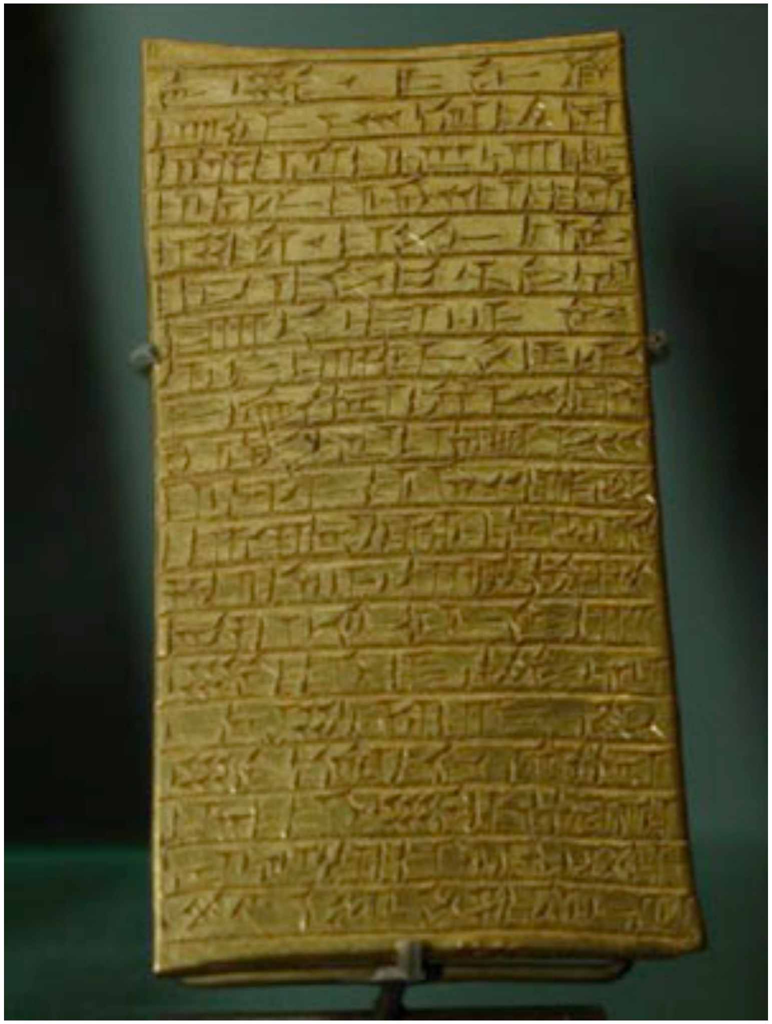
Alma Lee's Ball:

Written, sculpted, and published by Robert Chaplin

ISBN O968818374

Cuneiform Tablets:

Persepolis (in Louvre)
(ancient Iran 500 BC)



Sumerian,
(ancient Iraq)
(2000 BC)
British
Museum

Cuneiforms were written on clay tablets, on which symbols were drawn with a blunt reed called a stylus. The impressions left by the stylus were wedge shaped, thus giving rise to the name cuneiform ("wedge shaped").

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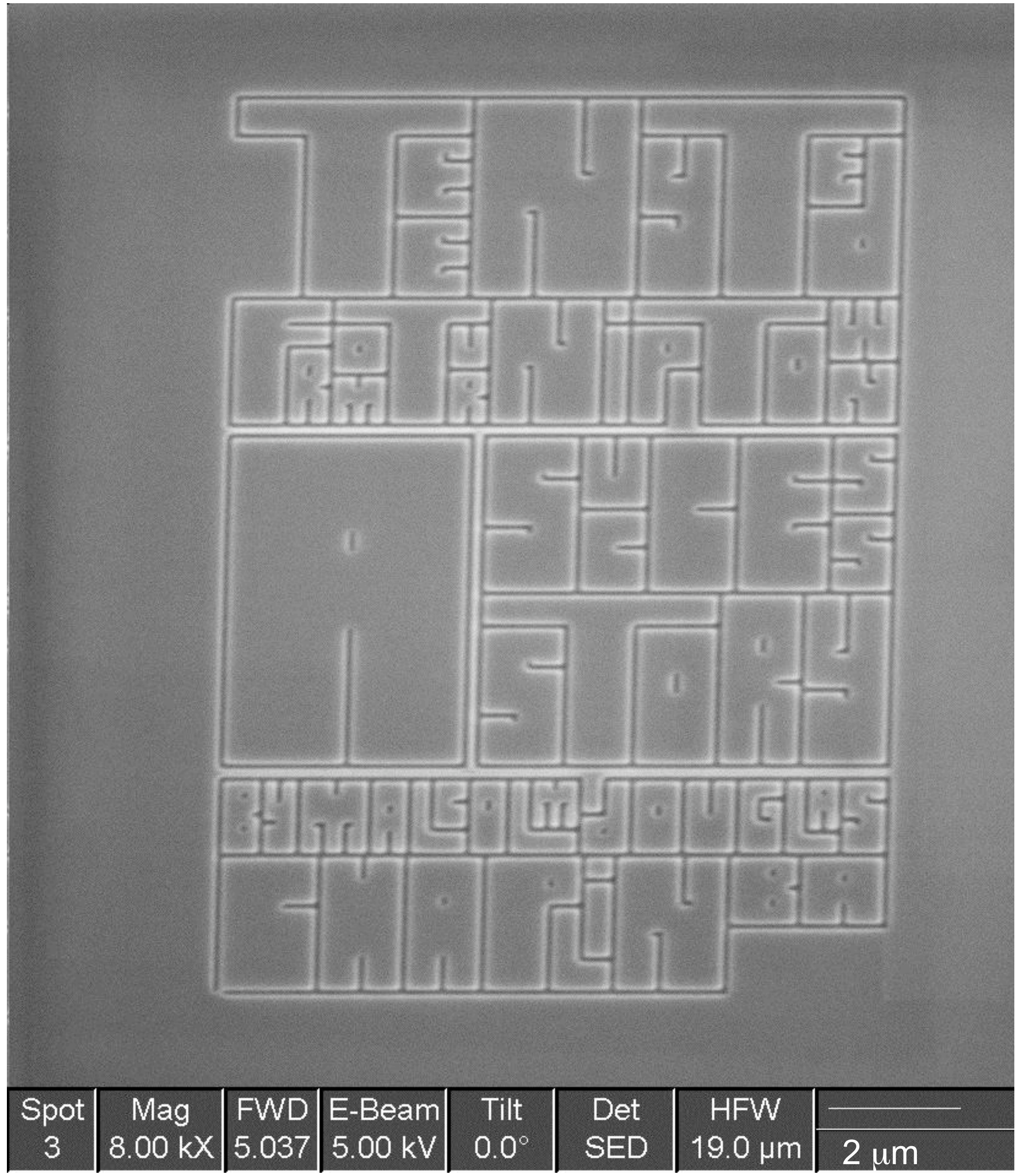
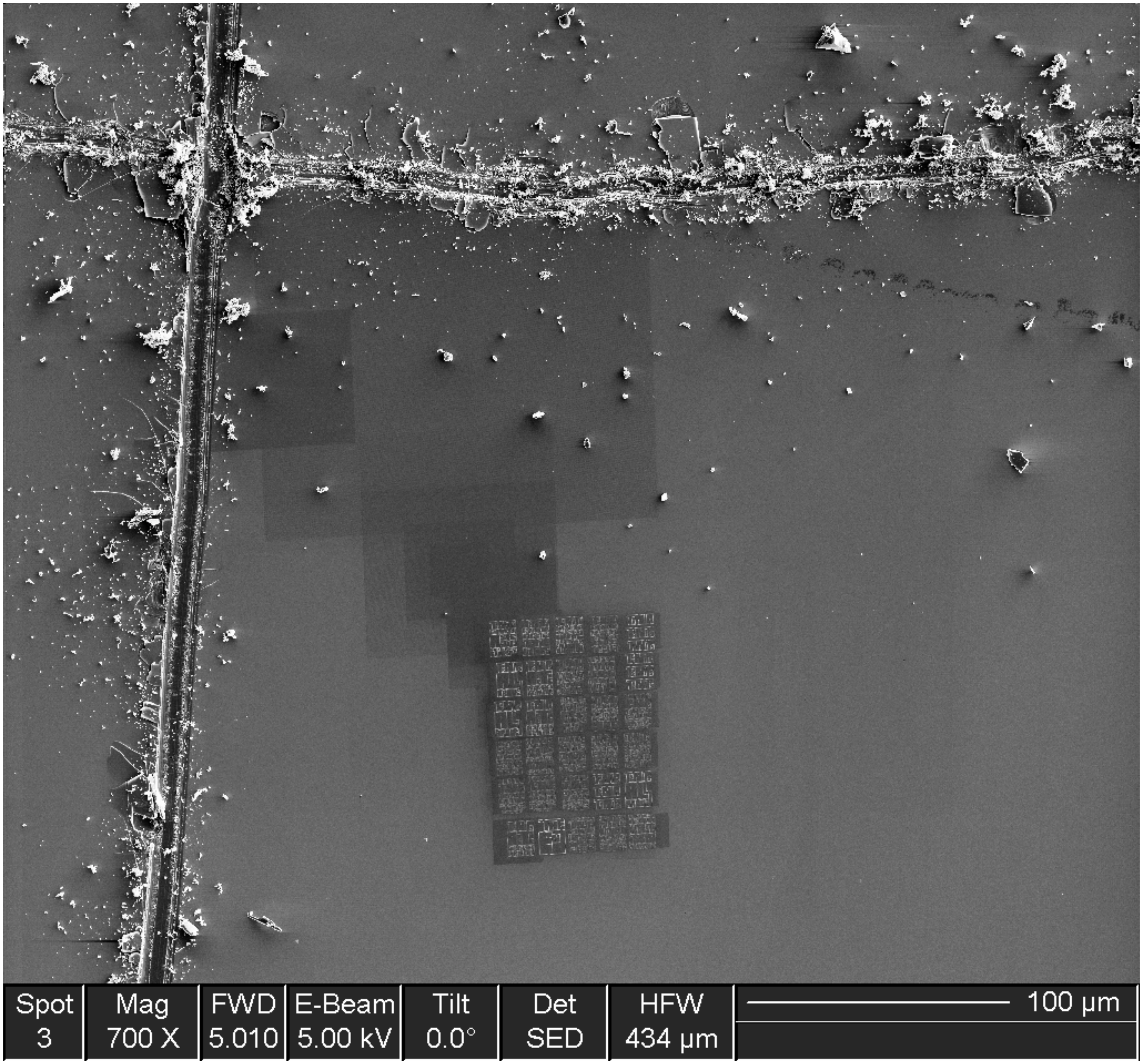
Persepolis (ancient city 500 BC, ruins located 30 km north of Shiraz, Iran)

Thursday, April 12, 2007.
8:48am (AEST)
Teeny Ted's tale is world's smallest book
-Reuters
http://www.abc.net.au/news/newsitems/200704/s1895022.htm



SEM photo of the entire book located close to a cross scratched in the Si wafer.



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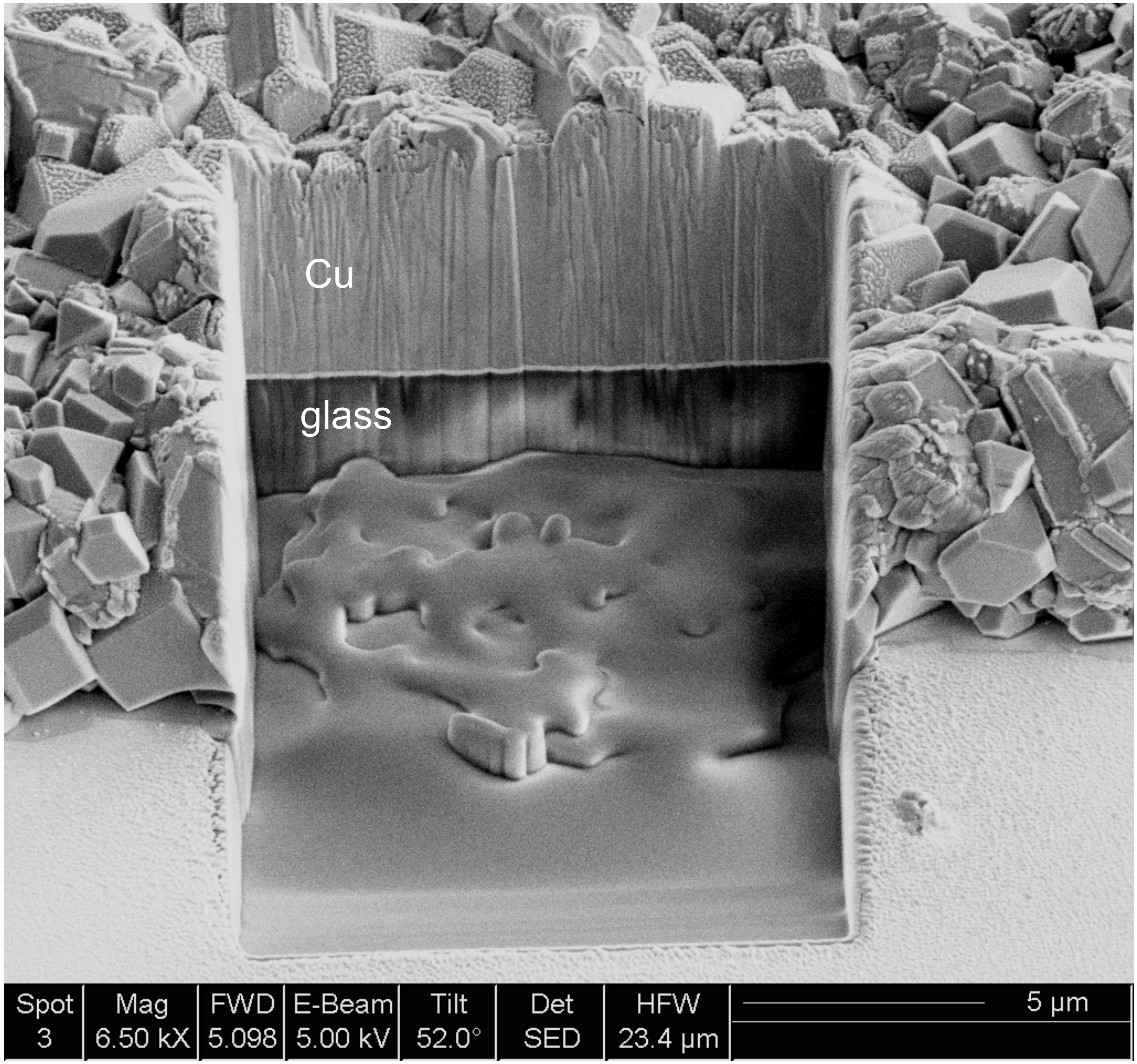
SEM image of a fibbed cross-section of electrodeposited Cu/Au/Ti/glass

Samantha Grist



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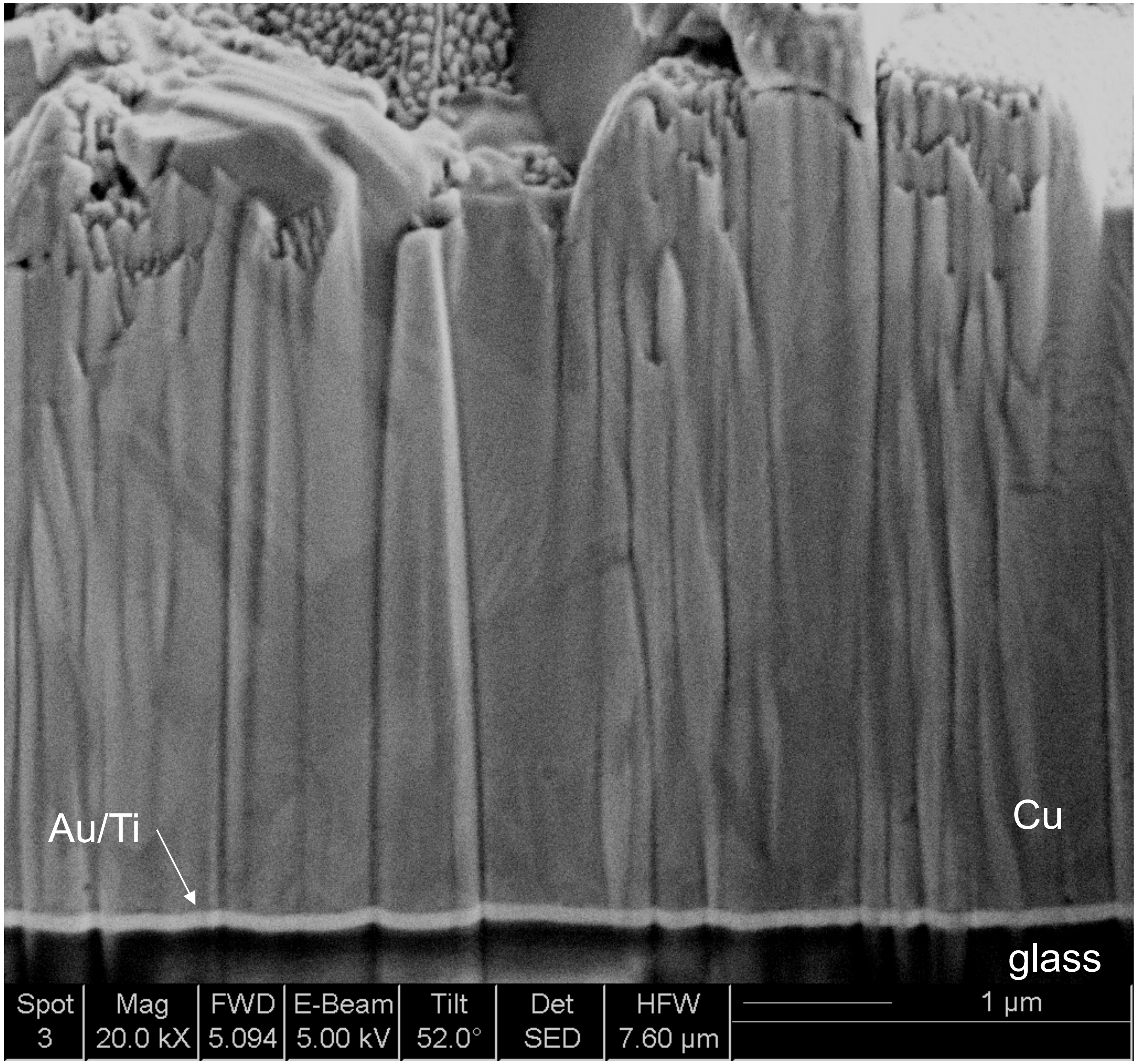
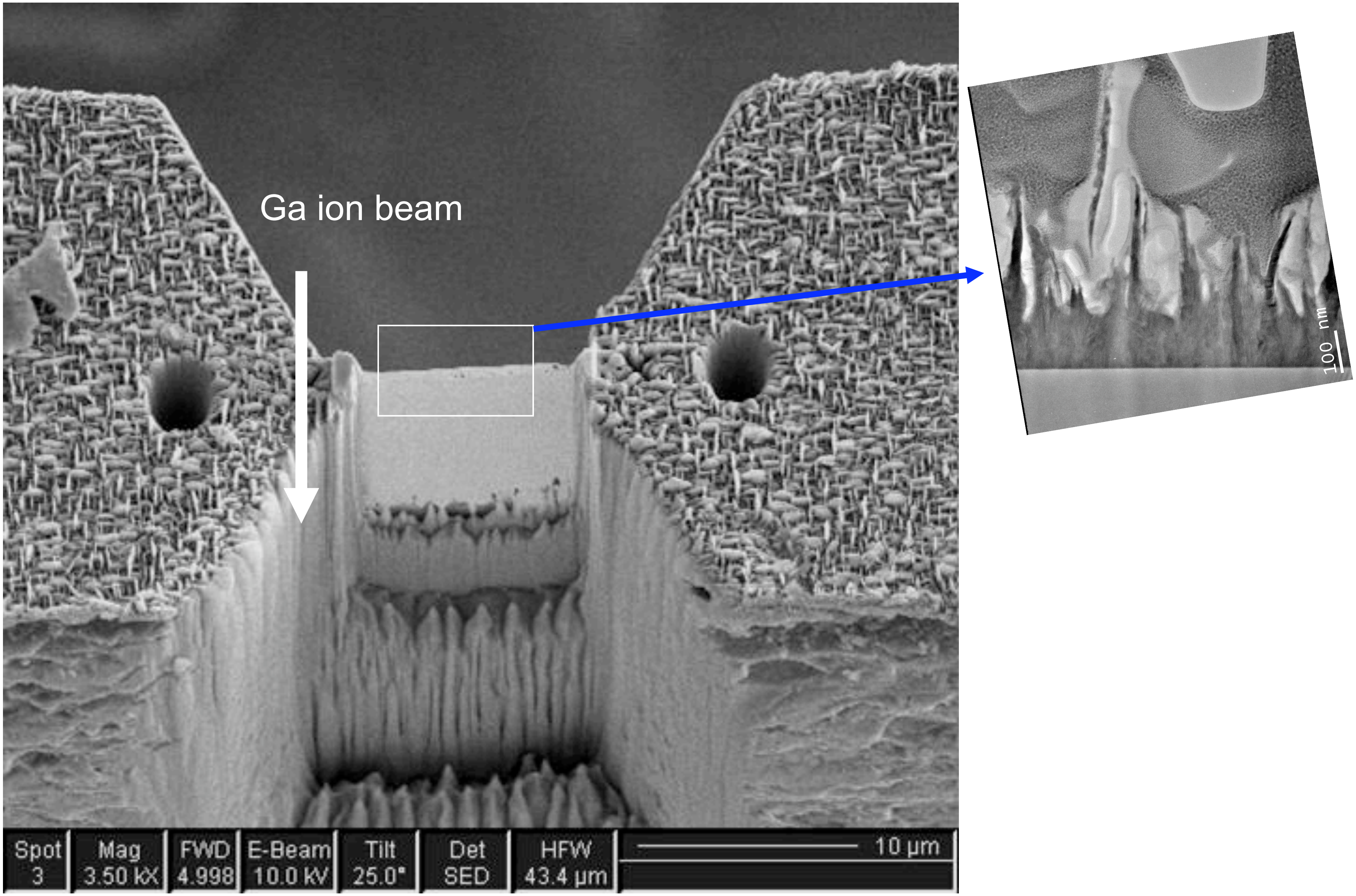
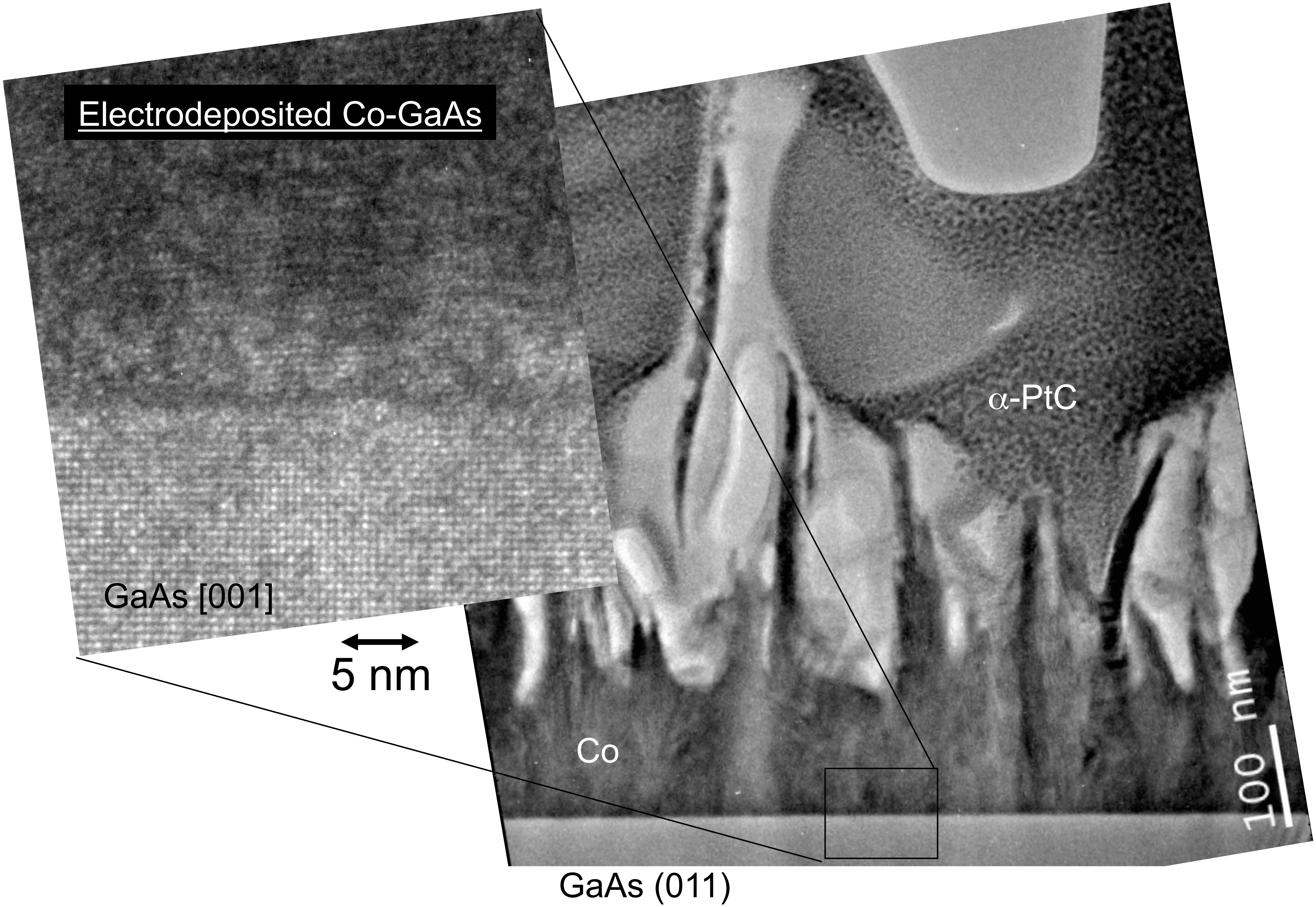

Au/Ti
Cu
glass
Spot 3
Mag 20.0 kX
FWD 5.094
E-Beam 5.00 kV
Tilt 52.0°
Det SED
HFW 7.60 µm
1 µm


Ga ion beam
Spot
3
Mag
3.50 kX
FWD
4.998
E-Beam
10.0 kV
Tilt
25.0°
Det
SED
HFW
43.4 µm
10 µm
100 nm



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Array fibbed by Brian Leathem, M.Sc. 2004

Array C

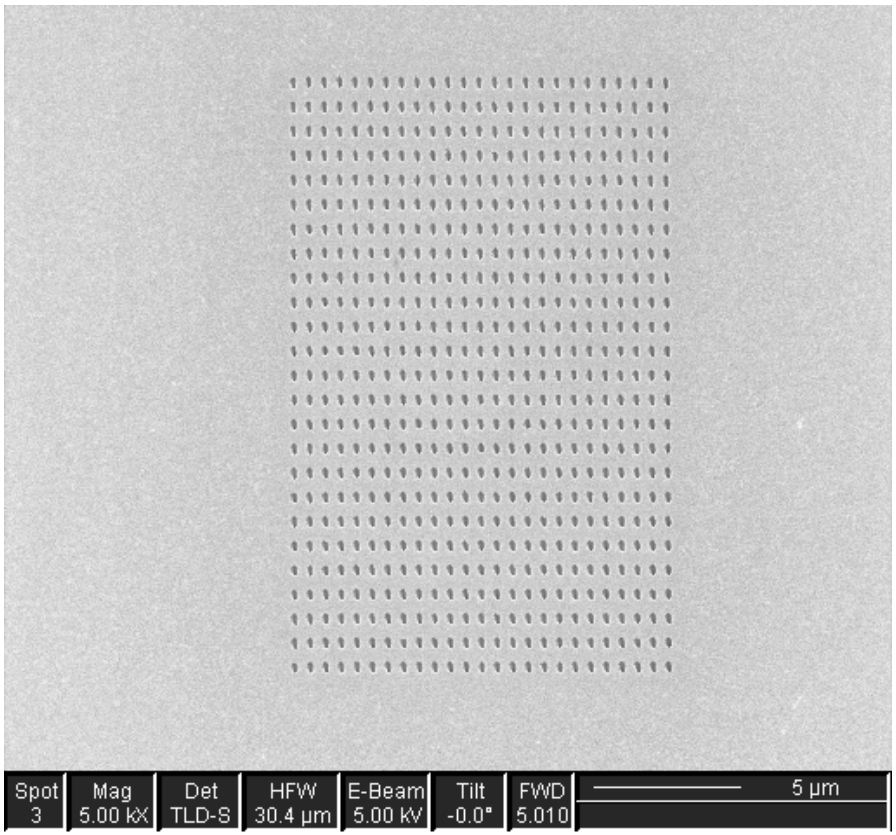
Target spacing: 550 nm   Measured spacing: 760 nm

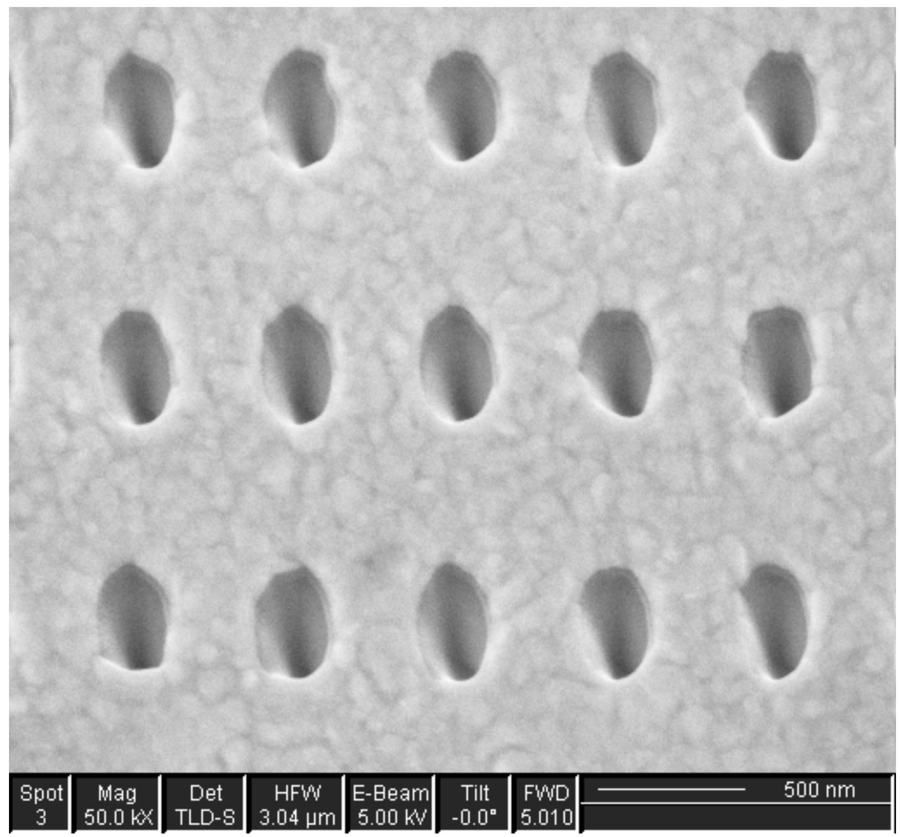
Target diameter: 71 nm   Measured diameter: 380x260 nm

Dwelltime: 300 ns

Ion current: pA ??

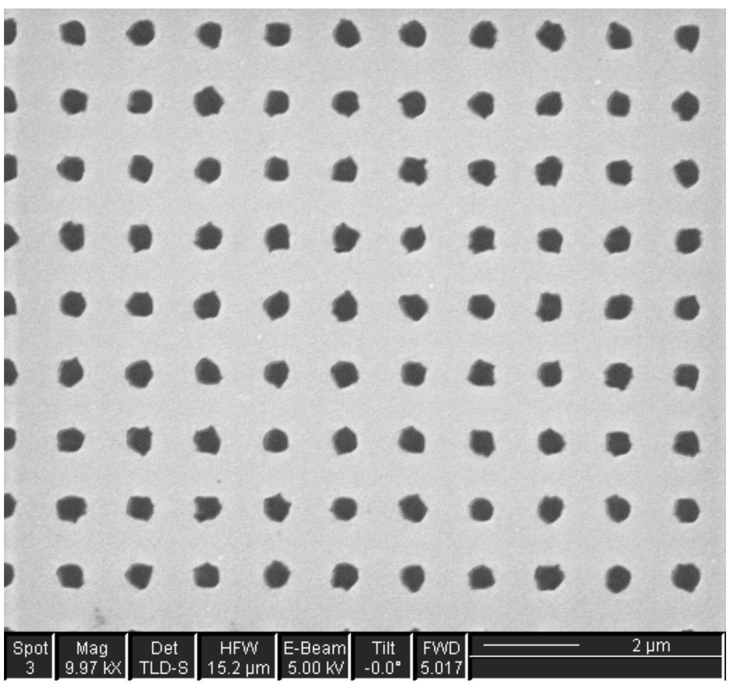
Magnification: 10k

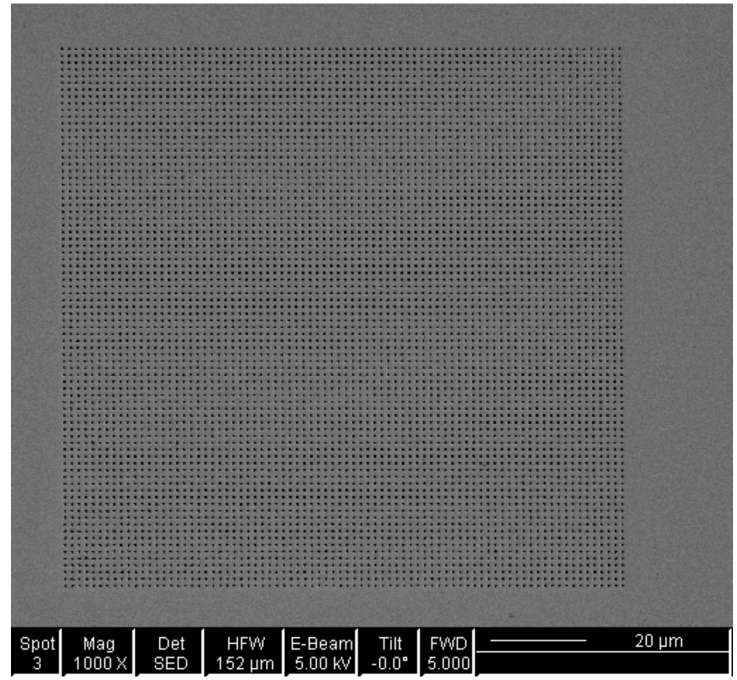


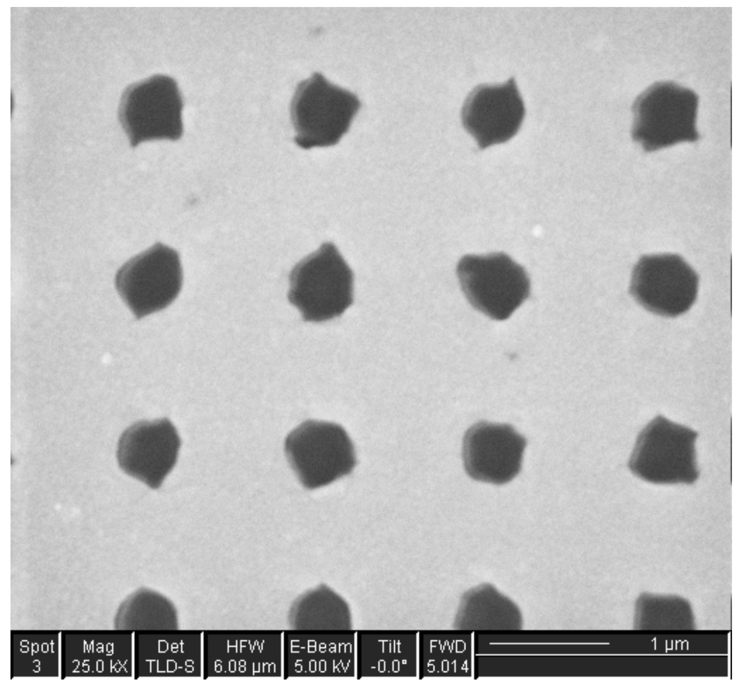


Array B

Target spacing: ~ 1480 nm
Measured spacing: 1380 nm
Target diameter: ~ 500 nm
Measured diameter: 510 nm
Dwell time: ns ??
Ion current: 300 pA
Magnification: 1.2k







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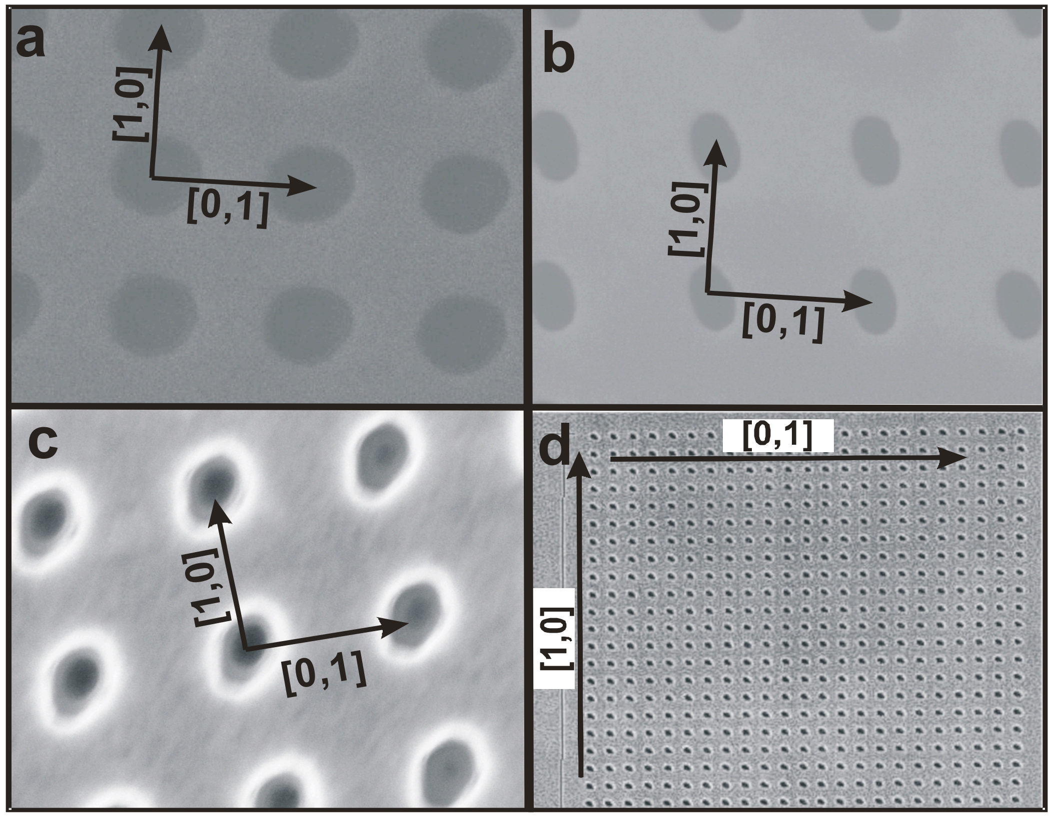
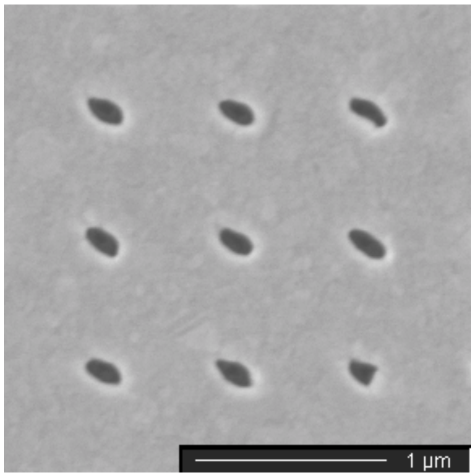
Strong Polarization in the Optical Transmission through Elliptical Nanohole Arrays,

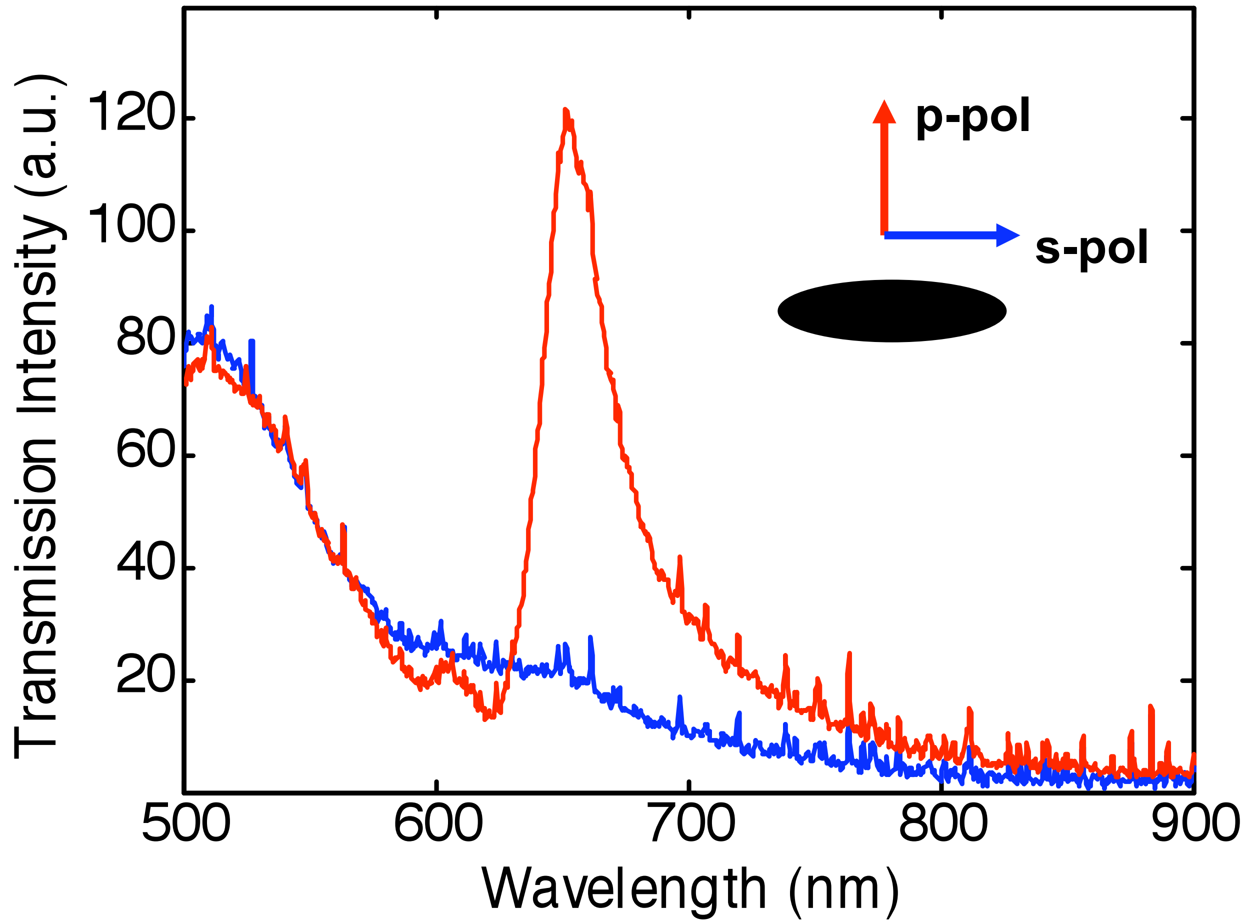
R. Gordon, A. G. Brolo, (U. Victoria) and
A. McKinnon, A. Rajora, B. Leathem, and K. L. Kavanagh (SFU)
Phys. Rev. Letts. 92 (2004).

23 × 23 arrays of ~200-nm holes in gold with variation in ellipticity and orientation of the holes



Enhanced polarization selectivity





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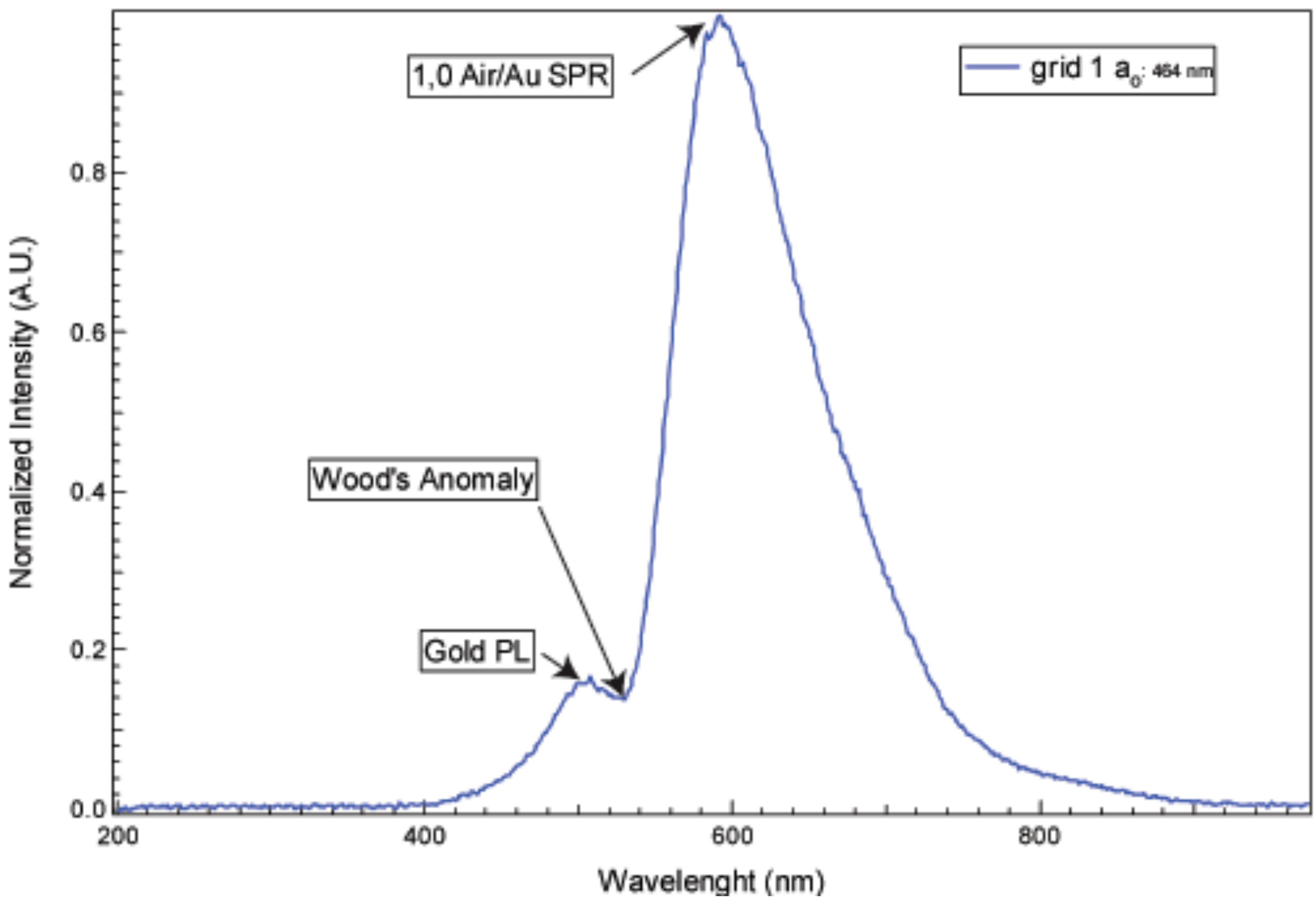
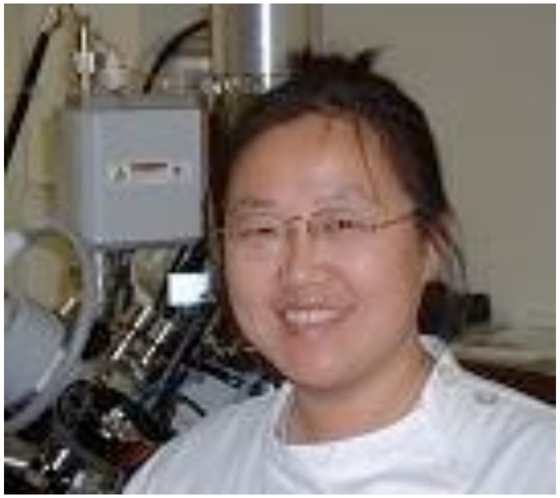

1,0 Air/Au SPR
grid 1 a_0: 464 nm
Wood's Anomaly
Gold PL
Normalized Intensity (A.U.)
0.0
0.2
0.4
0.6
0.8
200
400
600
800
Wavelenght (nm)

Acknowedgements



Big thanks to:

- Nanoimaging Lab Manager: Dr. Li Yang
- Graduate Students: Brian Leathem, Yan Zhang, Bob Bao, Mahshid Karimi, Donna Hohertz
- Undergraduates: Aron Mckinnon, A. Rajora, Samantha Grist, Nauman Methani, Eric Jensen, Kyle Huffman, and Francois Castonguey
- Funding: NSERC, CIPI, CFI, and BCKDF