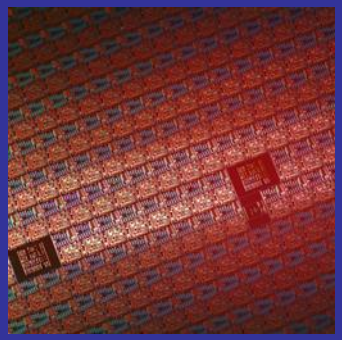
SEMATECH

Accelerating the next technology revolution

# R&D in the Semiconductor Industry What does the Future Hold?



Bryan J. Rice, Ph.D.
Director of Lithography
SEMATECH / Intel Corporation

# Semiconductor Technology

is how computer chips are made

**1977**


At 1976 transistor

prices:

sizes:


an iPod would

cost $3.4B

be as big as a football field

Computer www.apple.com/ipod/u2

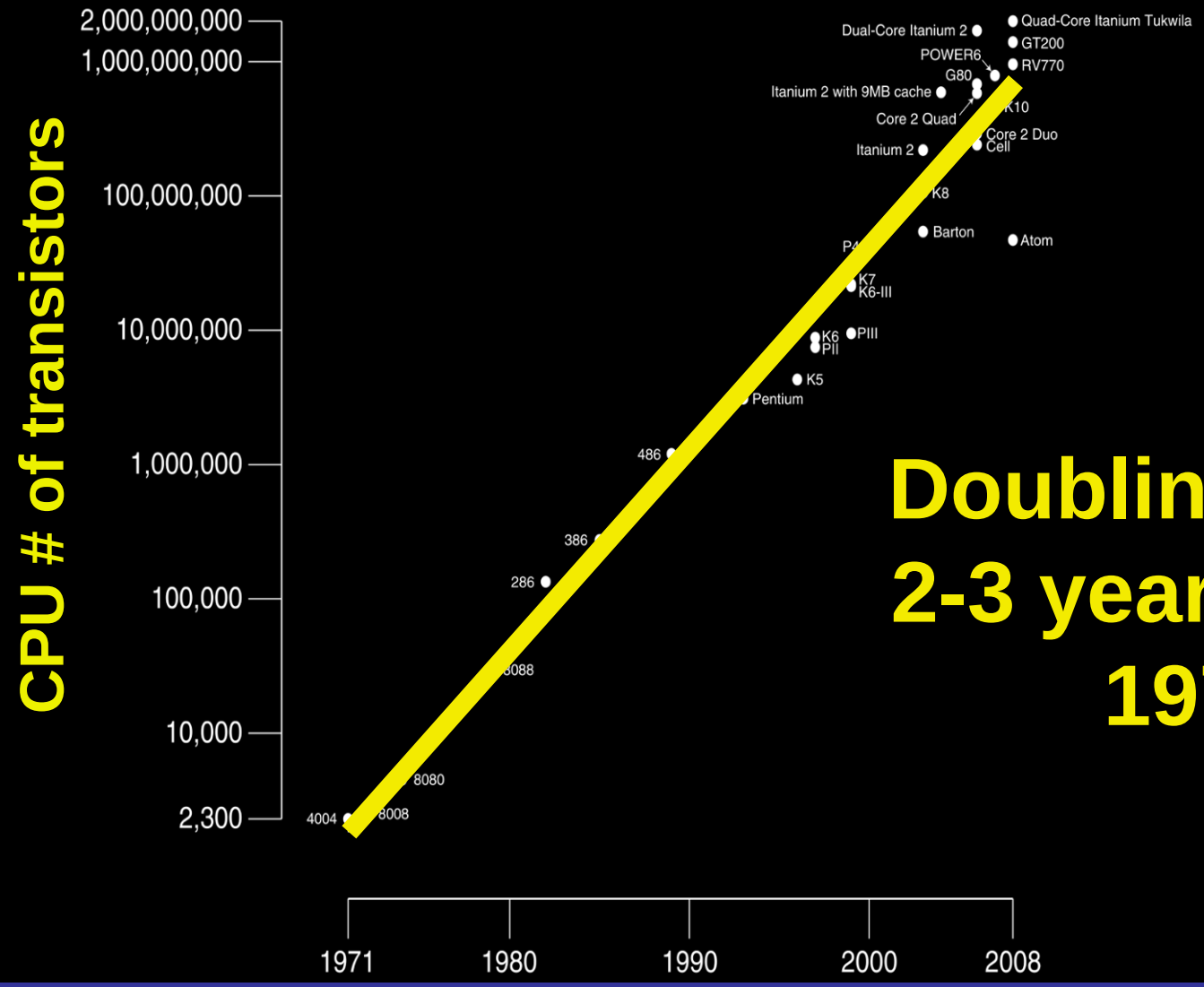
*Applied Materials

# How small are transistors today?

**2010**:
1/3000$^{th}$
of a human hair
(32 nm)

. . . and shrinking

# Moore’s Law sets the pace




**Doubling every 2-3 years since 1970**

http://www.wikipedia.org

# The SIA Roadmap

Semiconductor Industry Association

The pace of computer advancement will continue:

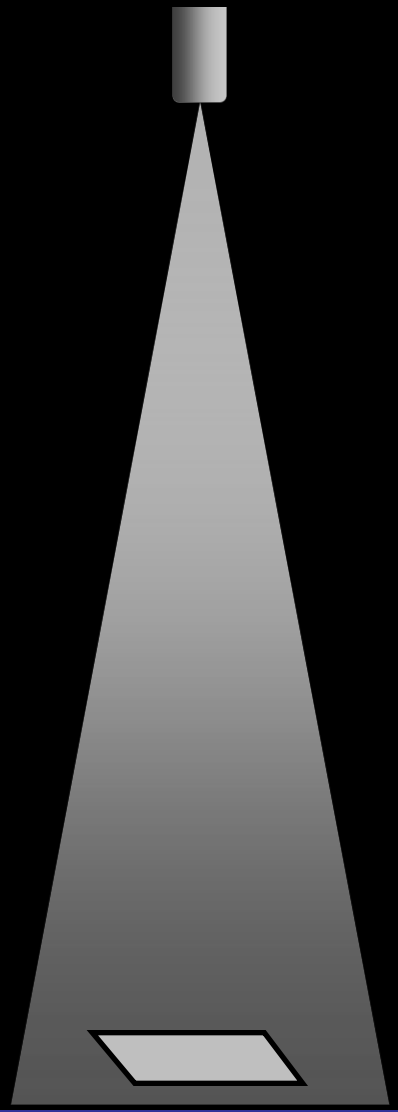
| Year of Production | 2010 | 2013 (EUV) | 2016 | 2019 | 2022 |
|---|---|---|---|---|---|
| **Memory** | | | | | |
| Feature Size [nm] | 45 | 32 | 23 | 16 | 11 |
| Memory Chip Size | 4 G | 8 G | 16 G | 32 G | 64 G |
| **Microprocessors** | | | | | |
| Transistors per chip | 2.2 B | 4.4 B | 9 B | 18 B | 35 B |

# How can this rate of progress be sustained???

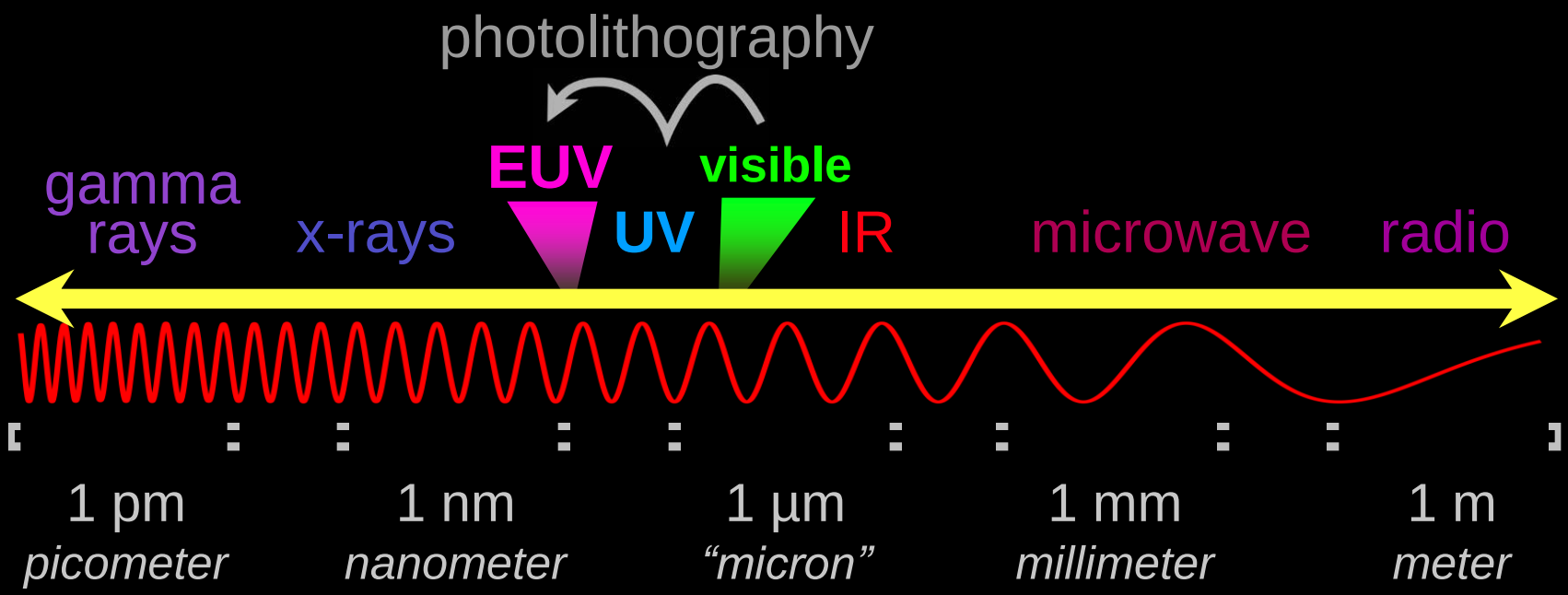
# Part 1:
# The Technology

# How does it work?

*Photolithography is the technique for creating circuit patterns and is very similar to darkroom photography*



# ***Smaller wavelengths*** of light create ***smaller patterns*** on the chip



***EUV photolithography*** *enables another decade of progress for computer chips*

*A great place to do advanced EUV research is at a* ***Synchrotron****, like the* ***ALS at Lawrence Berkeley National Lab*** *a DOE Office of Science-supported lab.*

*This research supports the commercialization of* **nanotechnology**


Ernest Orlando Lawrence


Melvin Calvin


Owen Chamberlain


Steven Chu


Donald A. Glaser


Luis W. Alvarez


Yuan T. Lee


Edwin M. McMillan


Glenn T. Seaborg


Emilio G. Segrè


George F. Smoot

## Eleven Nobel Laureates

# Serving the National Scientific Community – Industry and Academic: Berkeley Lab's Major Scientific Facilities

Advanced Light Source

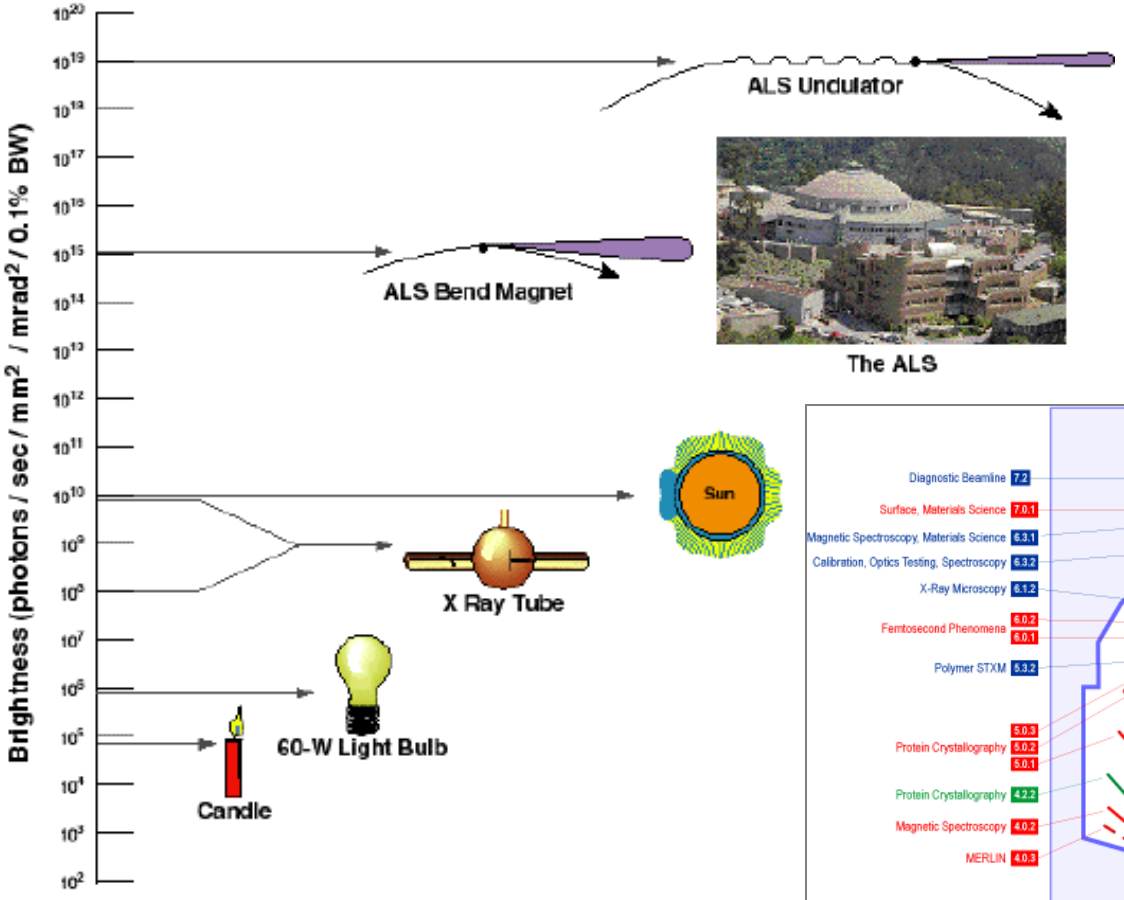
National Energy Research Scientific Computing Center

National Center for Electron Microscopy

Molecular Foundry

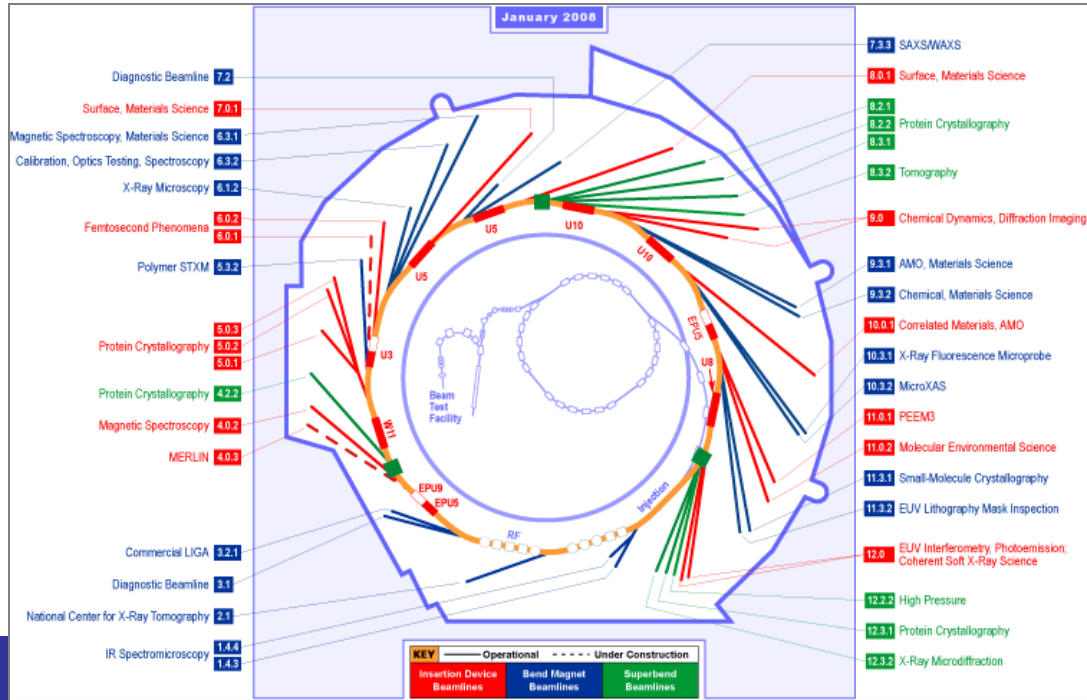

Joint Genome Institute

# The Advanced Light Source

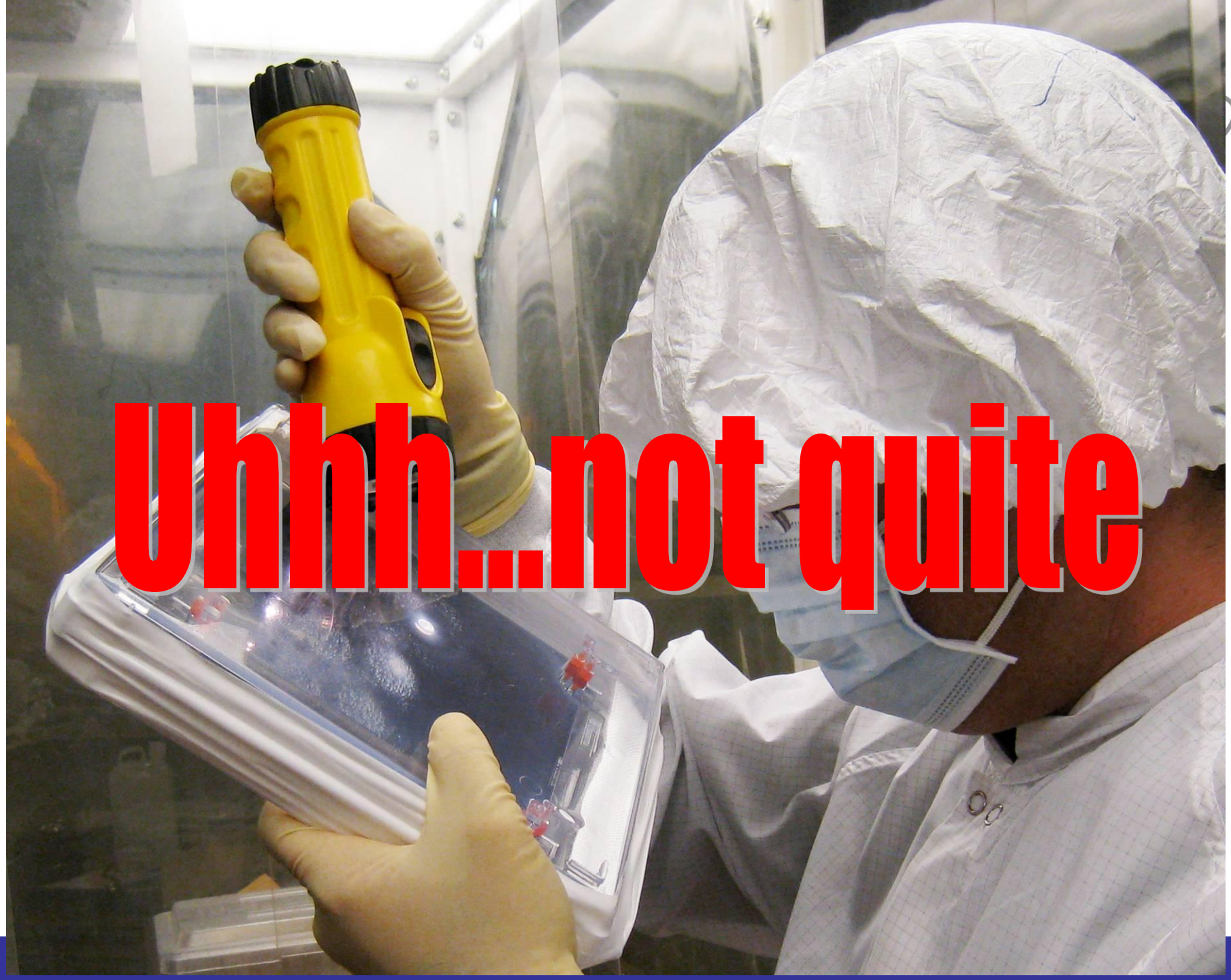





The ALS

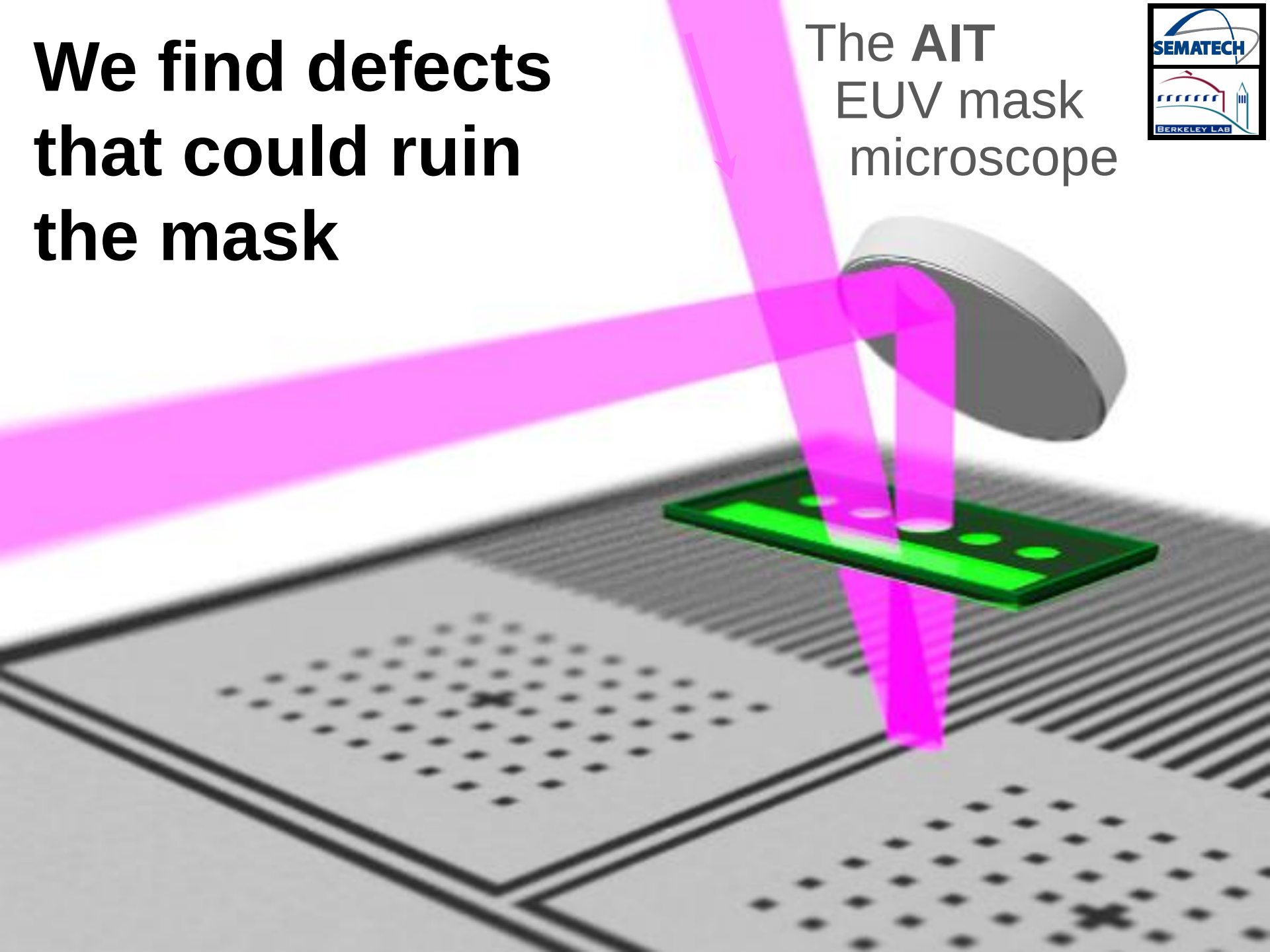



Chipmaking starts with a mask
You have to hunt for defects. . .

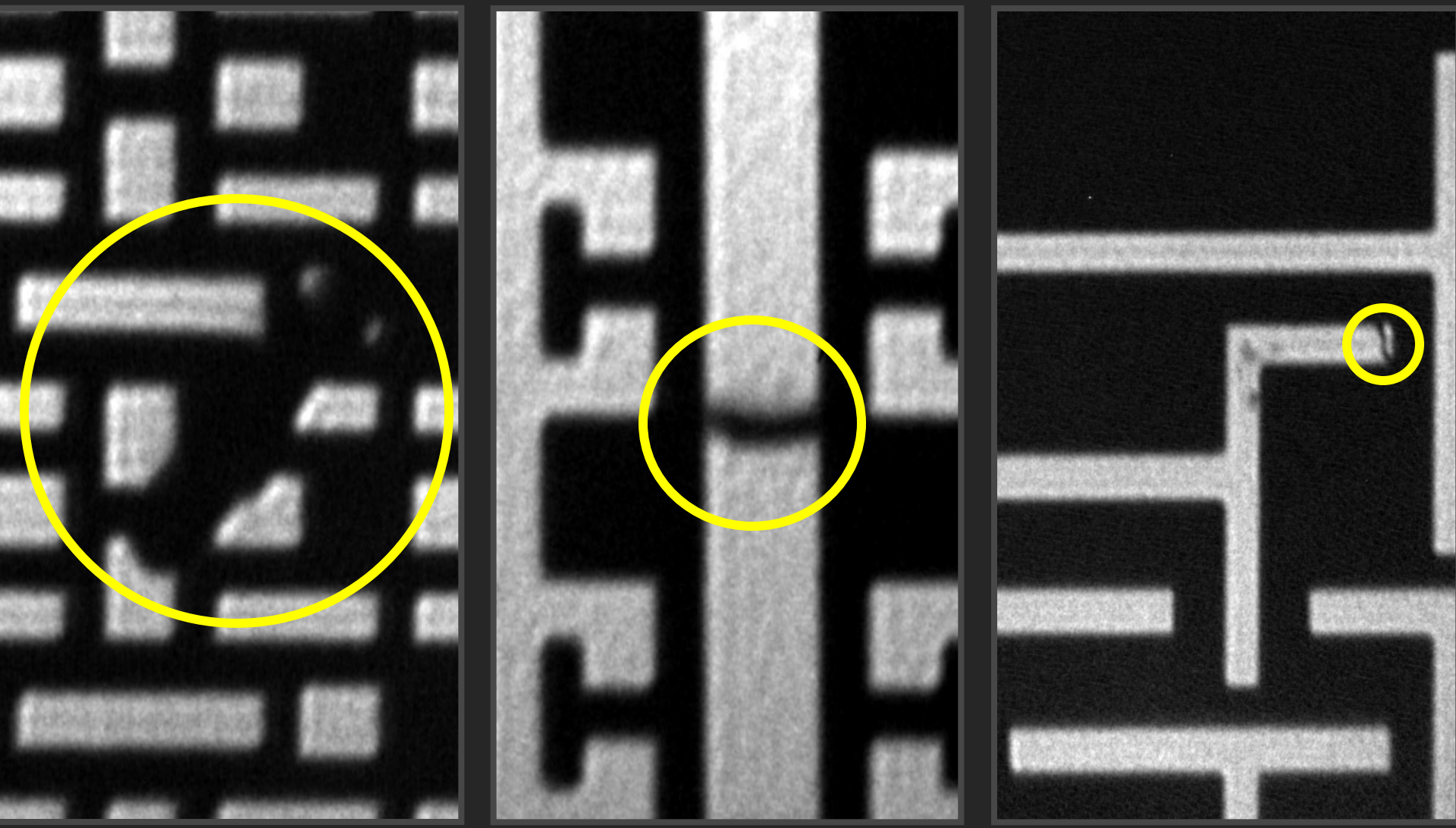

Uhhh...not quite

# We find defects that could ruin the mask

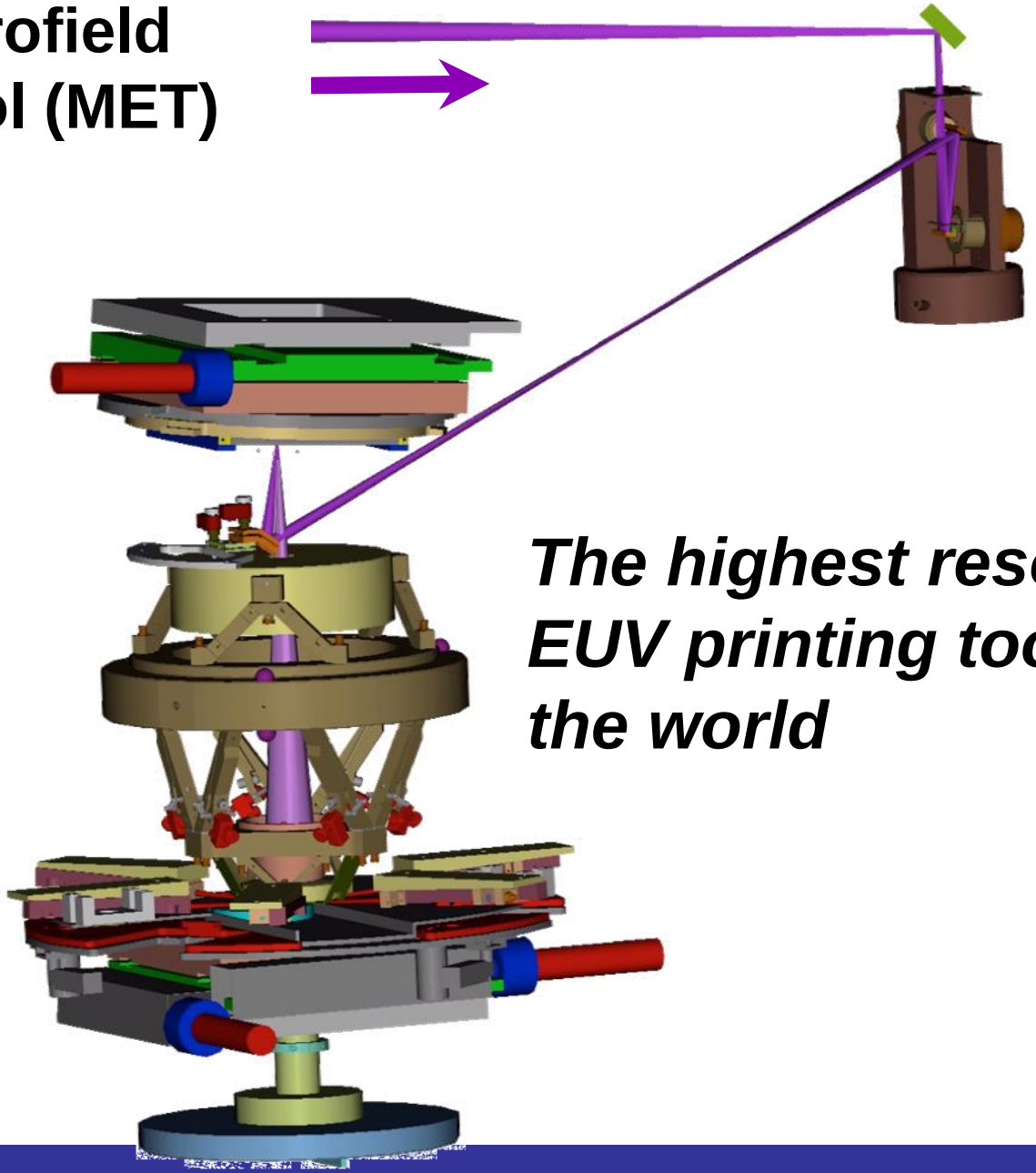
The **AIT** EUV mask microscope



# Defects detected with the EUV microscope

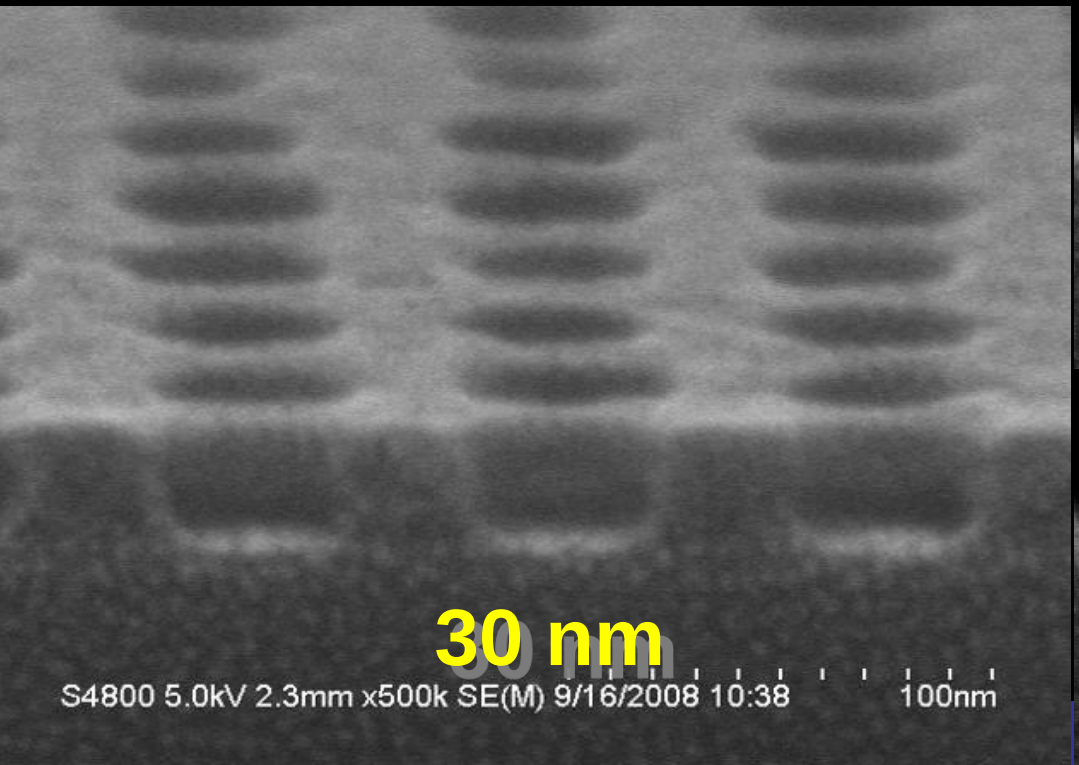


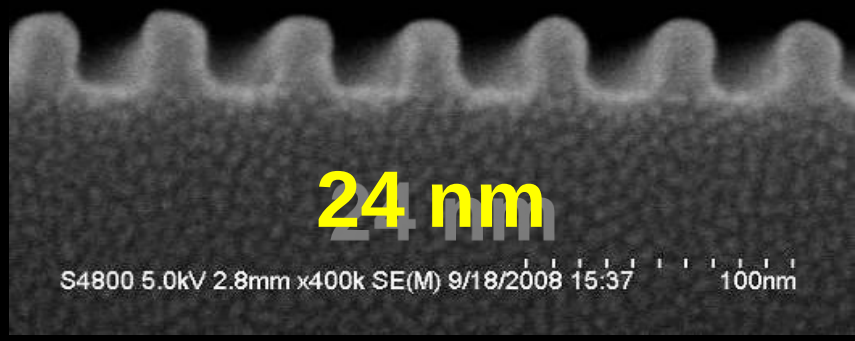
# The SEMATECH Berkeley Microfield Exposure Tool (MET)

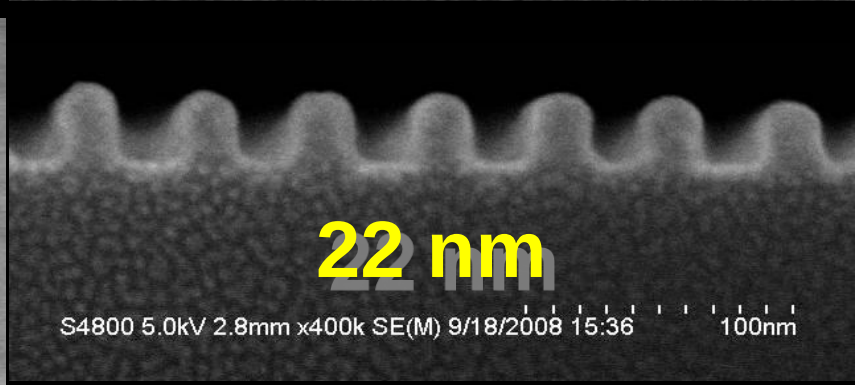


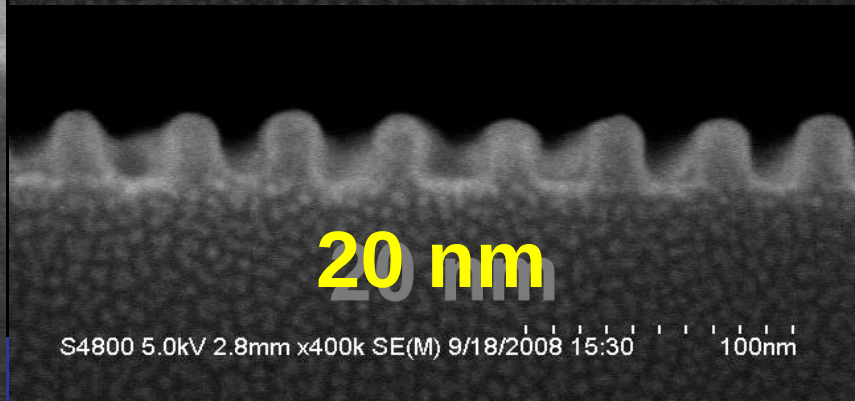
***The highest resolution EUV printing tool in the world***

# *World-record patterning* demonstrates the future of lithography

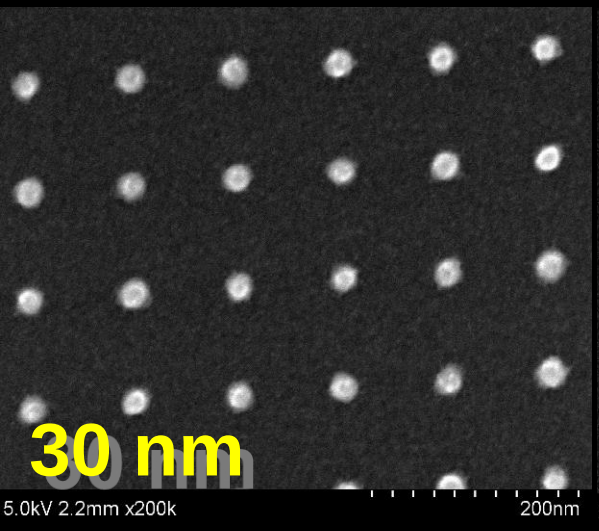


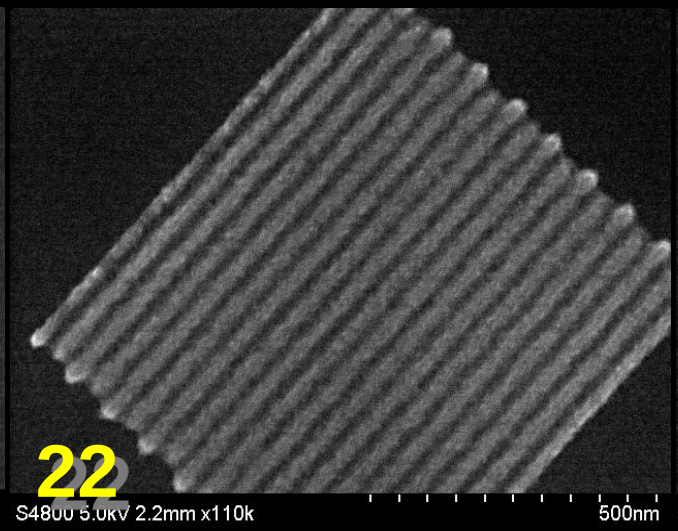



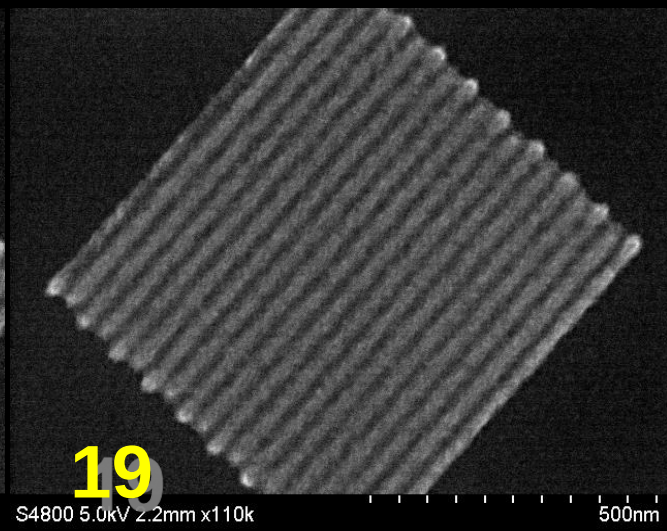



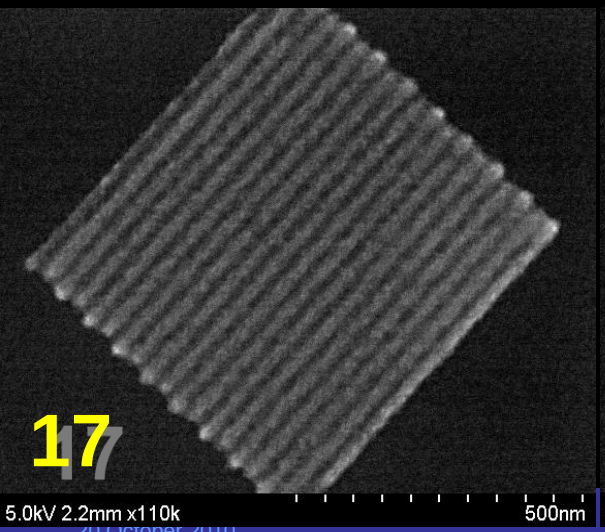



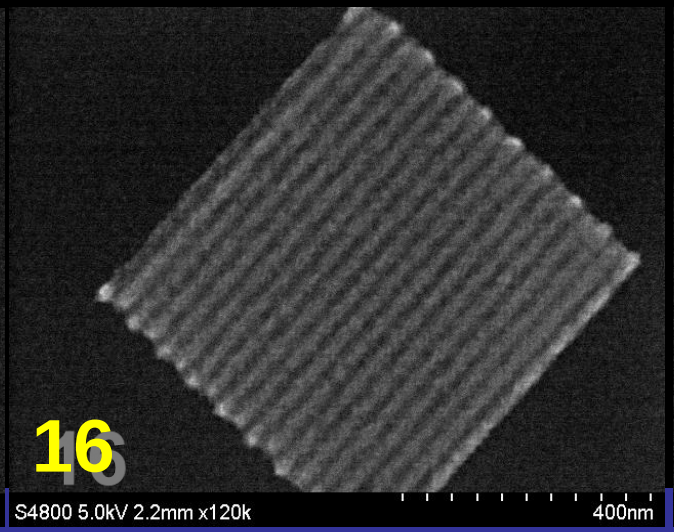
# *World-record patterning* demonstrates the future of lithography

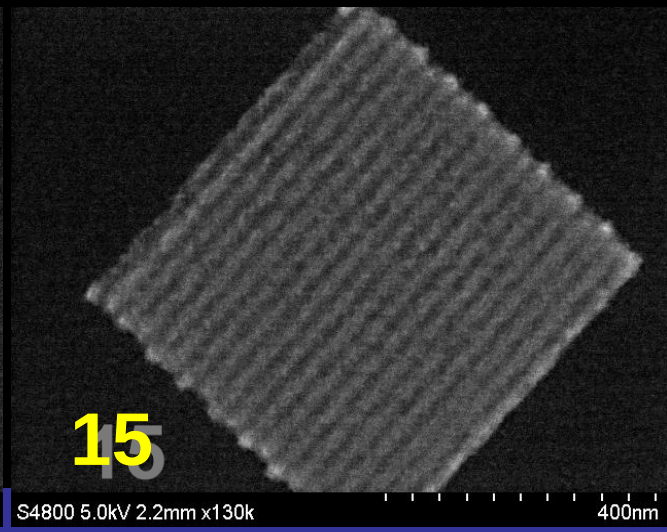


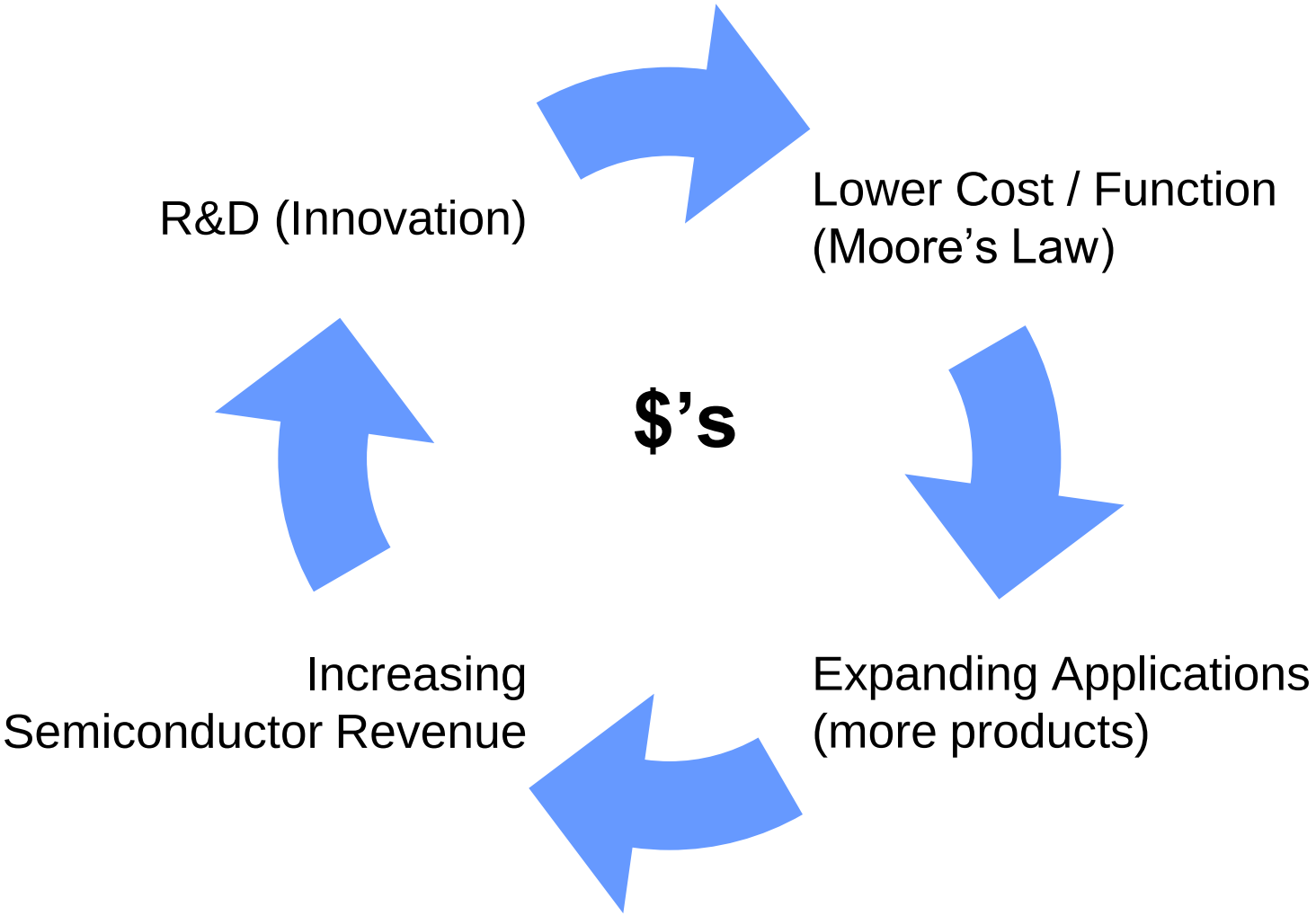



# Part 2:
# The Economics

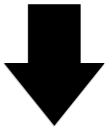
# Why Moore's Law?
# The Virtuous Cycle



# Innovation is Key to Semiconductor Industry Revenue

**$10-20 Billion**

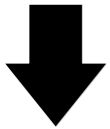
R&D investment



***Technology innovation is the driver***

**$250 Billion**

semiconductor devices revenue



**$2 Trillion**

consumer electronics + related services

SIA, IBM


# Companies work together for pre-competitive research

# One Example: SEMATECH and Lawrence Berkeley Lab (LBNL)

SEMATECH invested over **$20M** in equipment placed at LBNL to support semiconductor industry R&D

SEMATECH funds EUV research at LBNL **over $4M/year**

SEMATECH plans another round (**$15M**) of investment in LBNL from 2010-12

# Semiconductor Technology: A United States Strength

Semiconductor devices are the second largest export good in the US

US based companies have 51% of the world market share in semiconductors

The semiconductor/electronic component industry (manufacturing, research, and development) employed ***493,000 people*** in the United States in '08

That number dropped to ***430,000*** in '09

SIA and Bureau of Labor Statistics

# Industry-Government Partnerships

- Funding research and partnerships with industry boosts US companies and promotes our unique competitive edge
- The DOE Labs, like Lawrence Berkeley, are a national resource
- Industry partnerships with government apply the expertise resident in the DOE labs to today's problems
- What's at stake?
  - If DOE funding is cut or these relationships are not encouraged, jobs can easily go elsewhere
  - US dominance in semiconductor technology
- What is required?
  - Increase DOE and other funding for basic research with ***industry partners***

# Acknowledgements


- LBNL Team: Kenneth Goldberg, Patrick Naulleau, Donald Medley
- SEMATECH Lithography Division