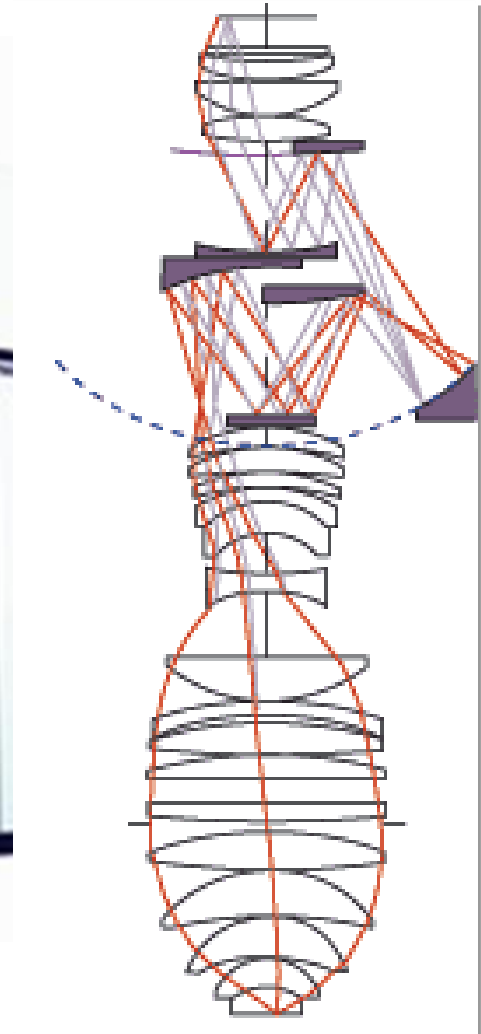


Lecture 2

Chemical Engineering for Micro/Nano Fabrication



Hubble Telescope



Cost \$1.5 Billion



Grinding the Primary Mirror for Hubble



<http://people.tamu.edu/~v-buenger/658/Hubble.pdf>



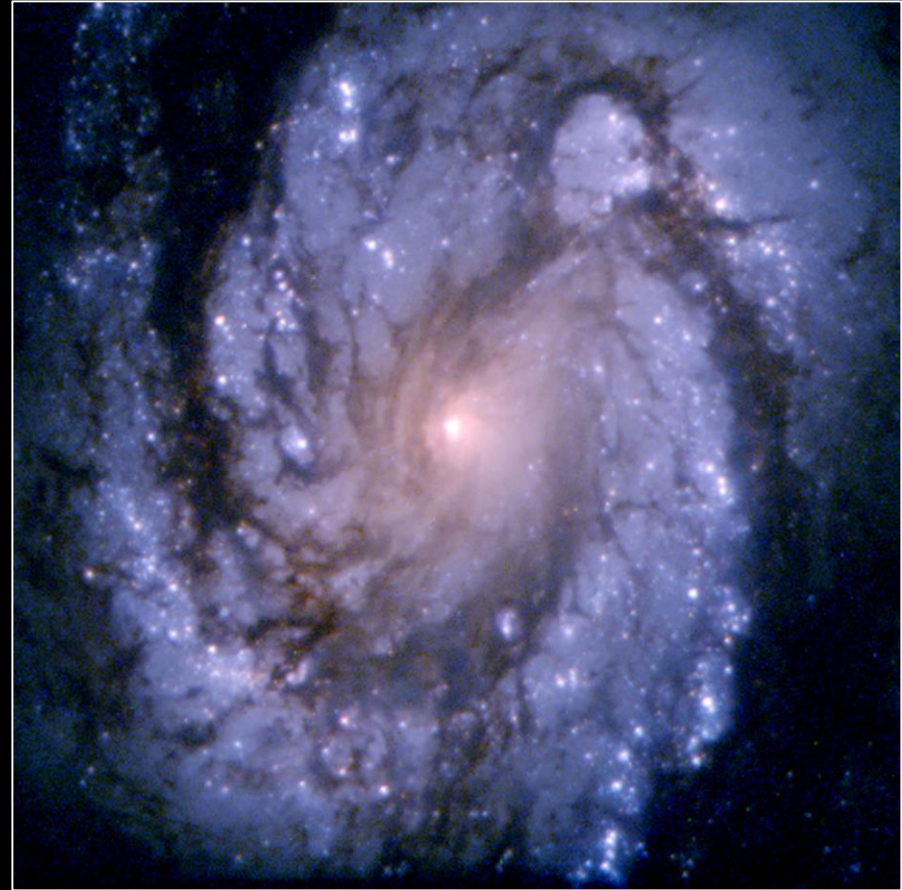
Repairing the Telescope



Repairing the Telescope



Spiral Galaxy Before and After



Eagle Nebula



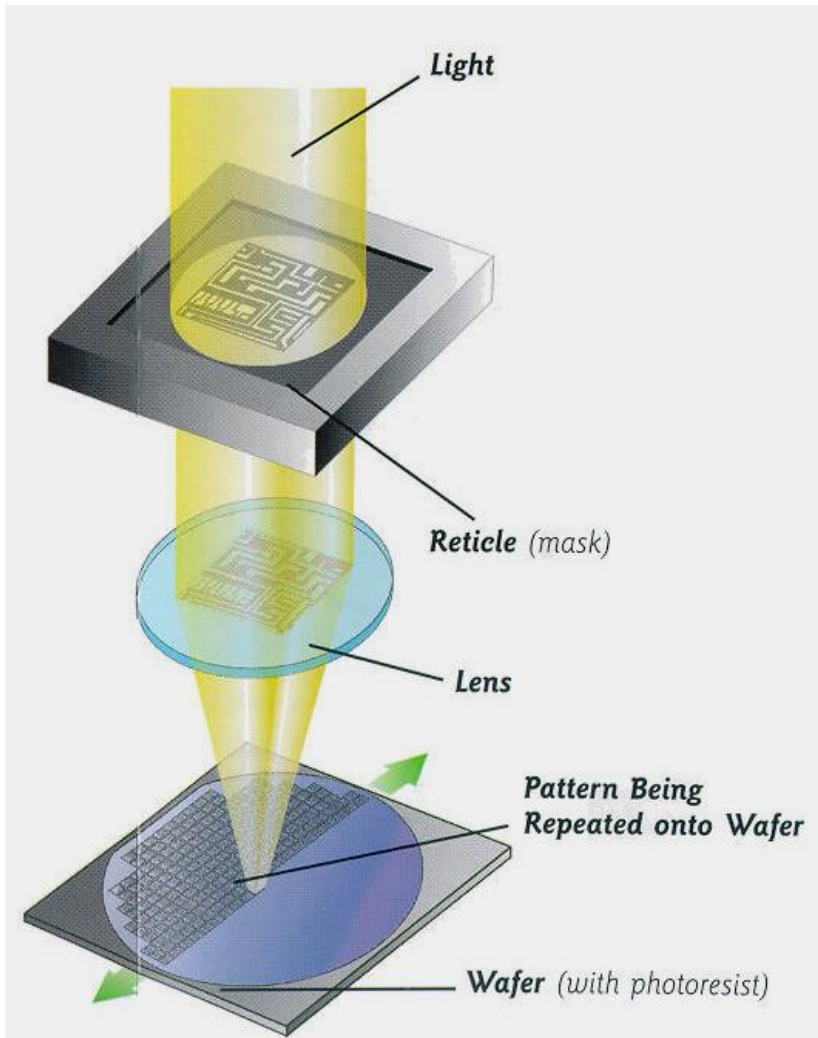
Horse Head Nebula



25th Anniversary Image



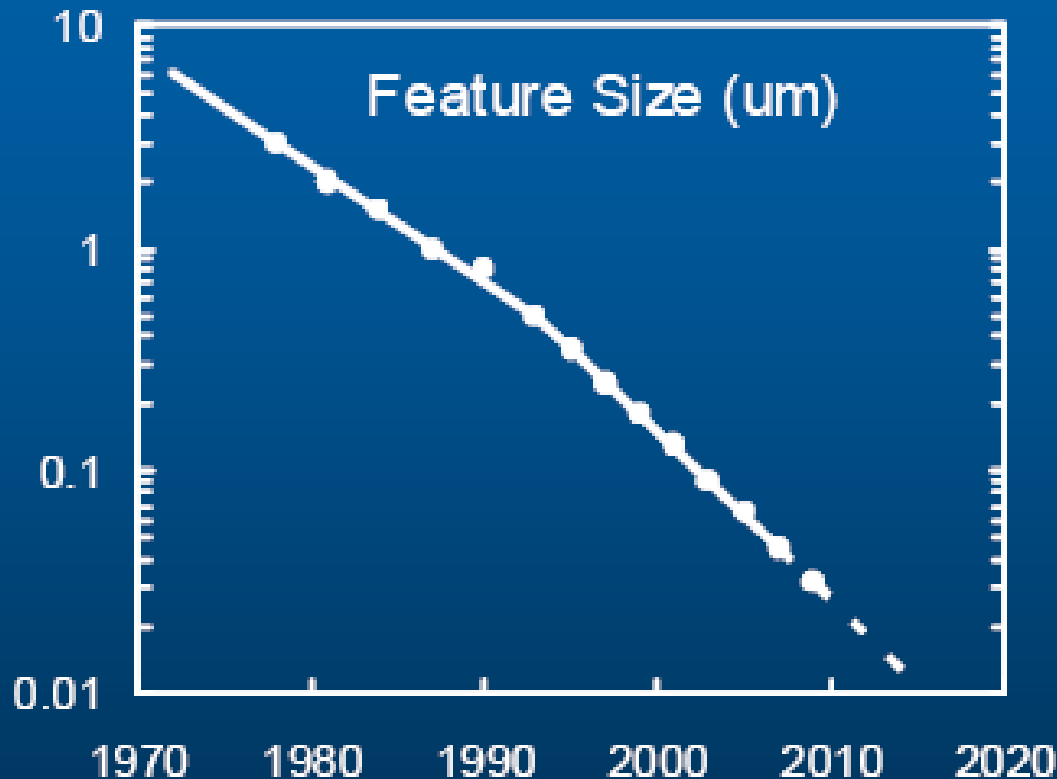
Exposure Systems



$$R = k \frac{\lambda}{NA}$$



Moore's Law at Intel



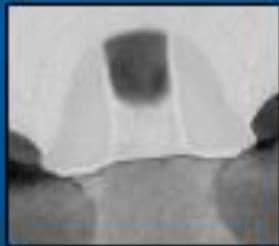
The trend is expected to continue into the future

On-time 2 Year Cycles

90 nm
2003



65 nm
2005



45 nm
2007



32 nm
2009



22 nm
2011

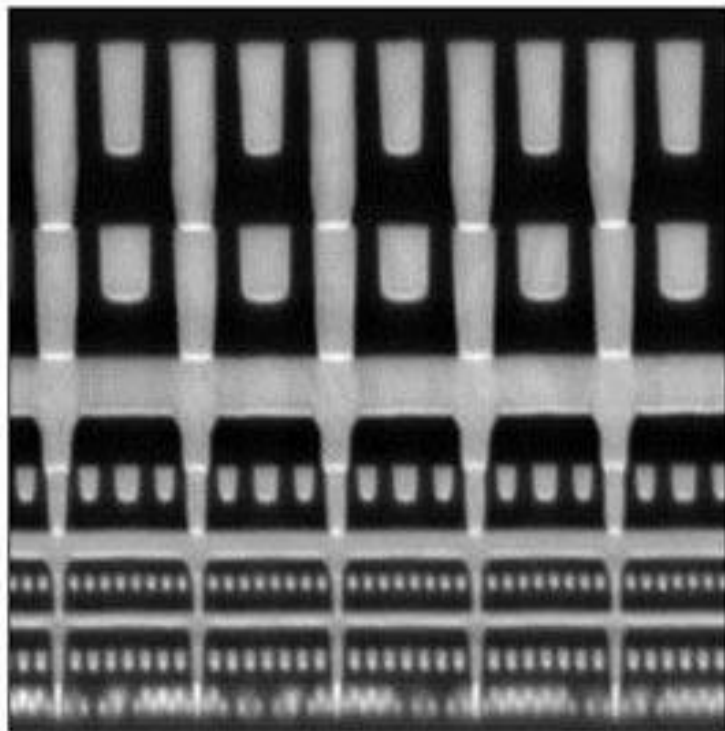


In
development

From M. Bohr
IDF 2009

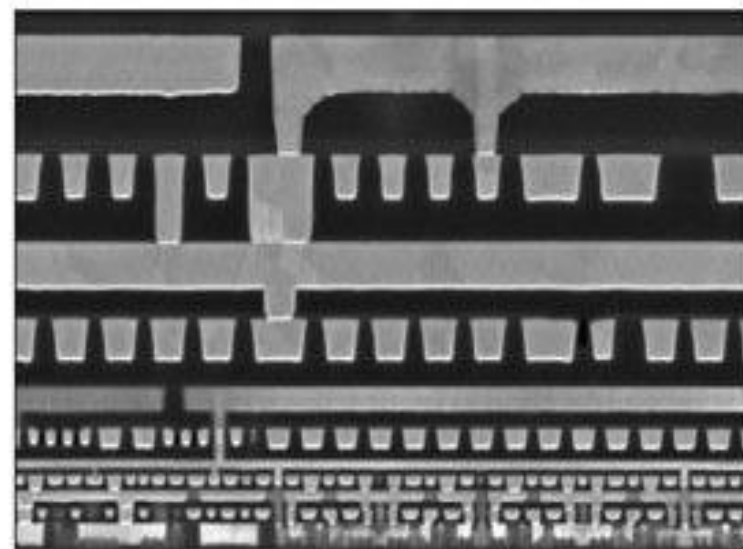
Continuing Progress at Intel

22 nm Process



80 nm minimum pitch

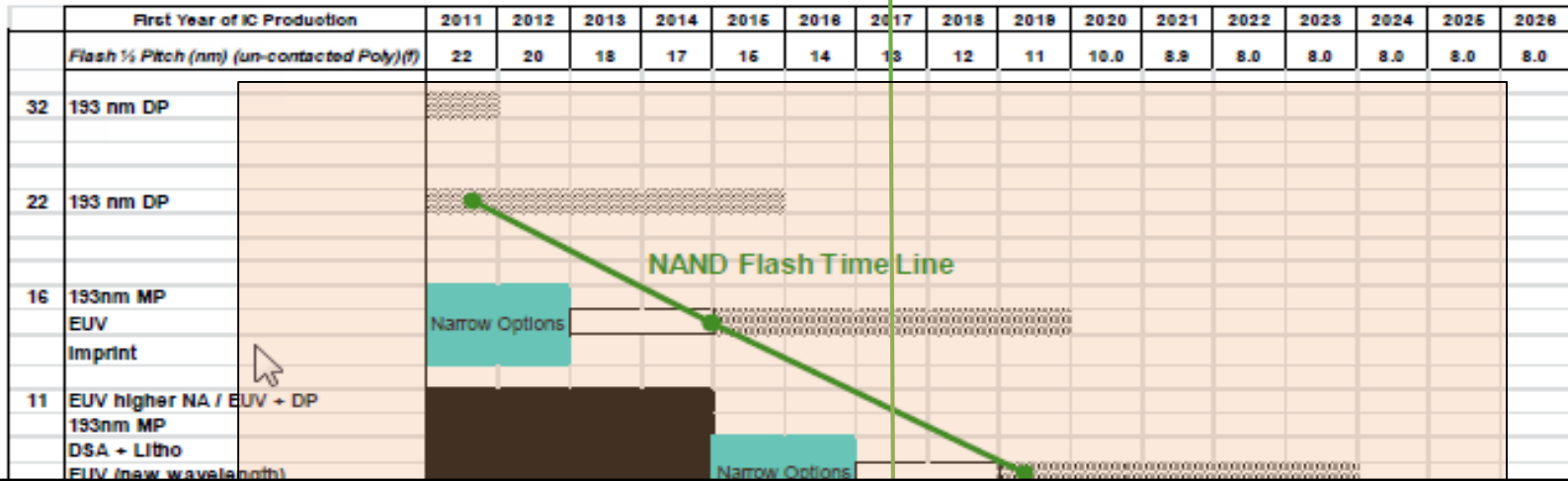
14 nm Process



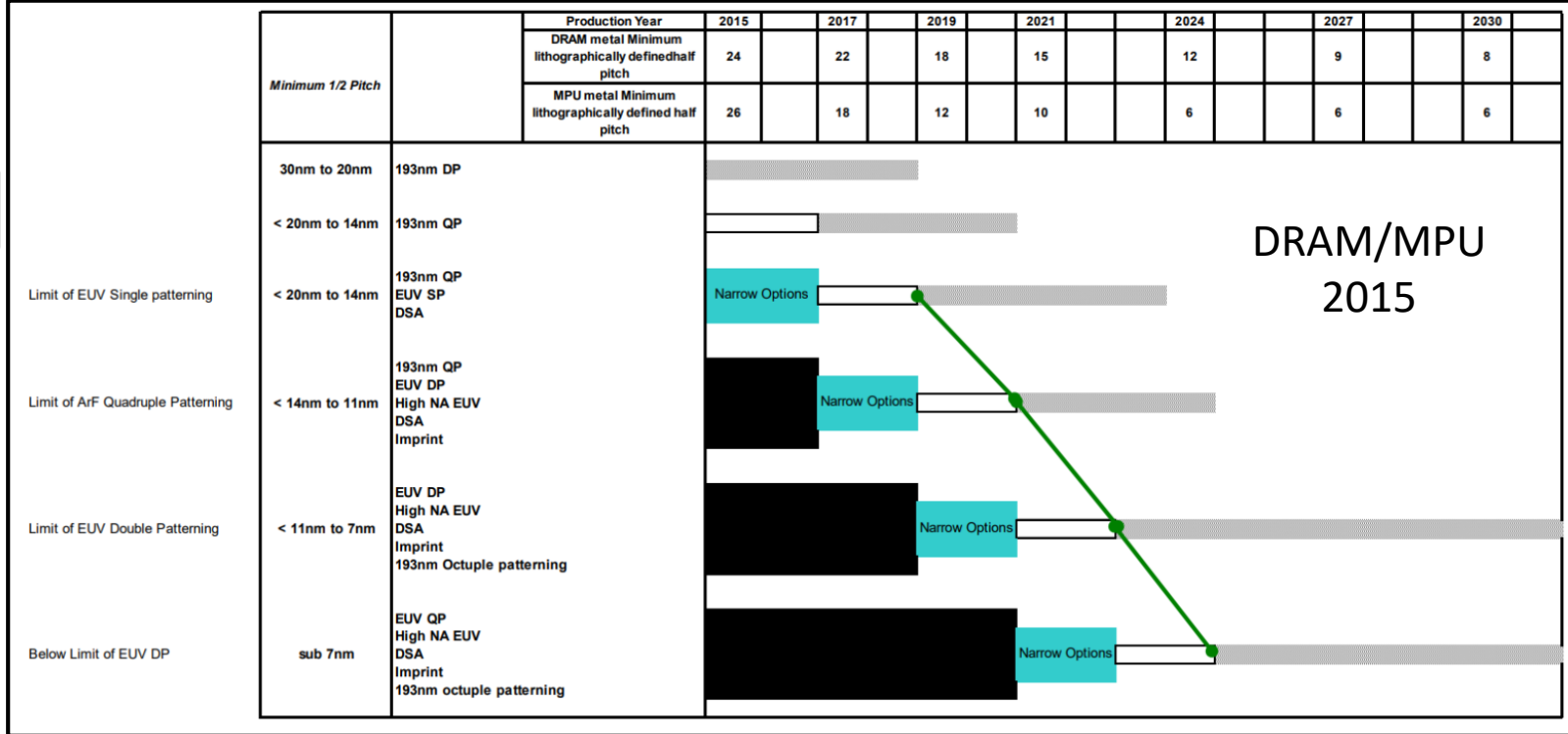
52 nm (0.65x) minimum pitch

ITRS Lithography Roadmap 2011

Flash

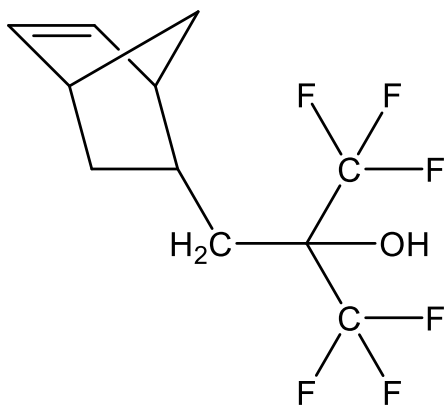


DRAM/MPU

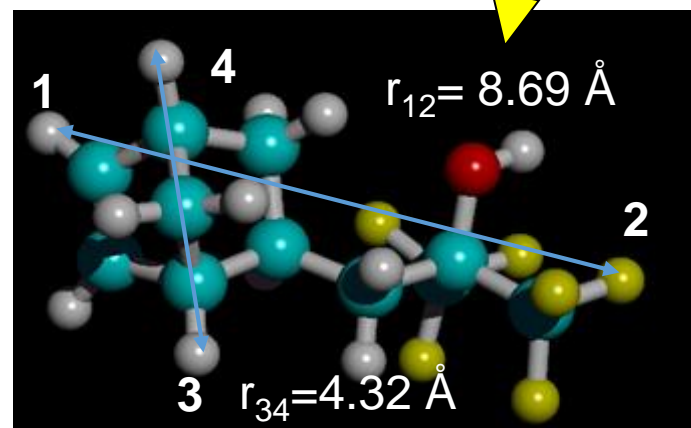


From the NTRS

	2010	2013	2016	2018
<i>MPU 1/2 Pitch (nm) (uncontacted gate)</i>	45	32	22	18
<i>Overlay (nm)</i>	18	12.8	8.8	7.2
<i>MPU gate in resist (nm)</i>	25	18	13	10
<i>MPU gate length after etch (nm)</i>	18	13	9	7
<i>Gate CD control (nm, 3-sigma)</i>	1.6	1.2	0.8	0.6

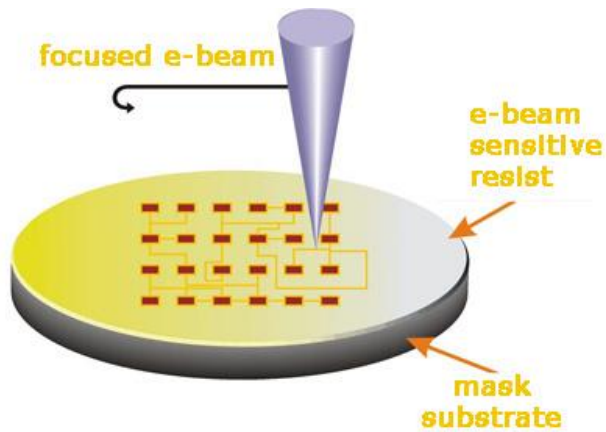


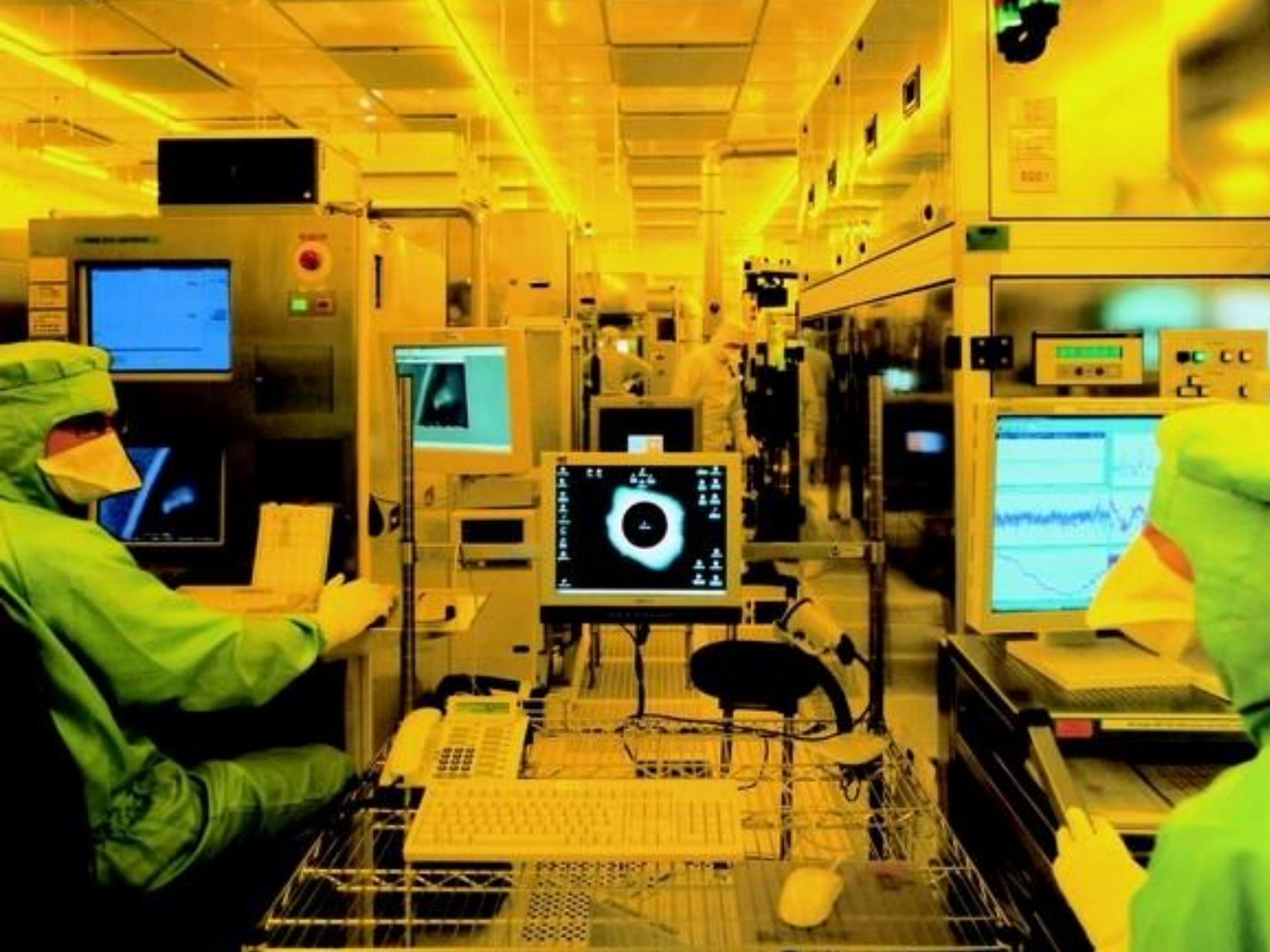
NBHFA



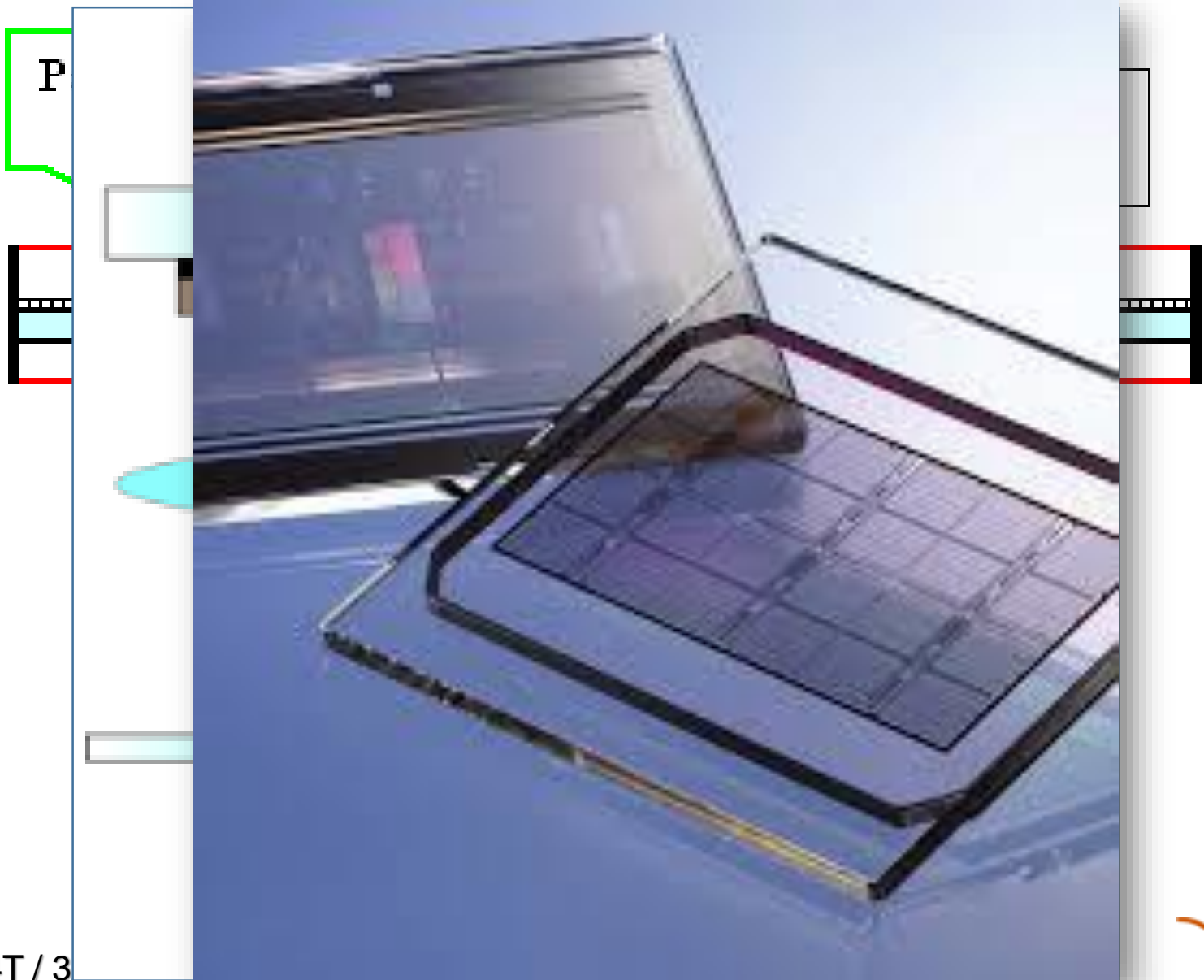
Electron Beam Lithography for Masks

- Converts Computer patterns into Masks
- High resolution but slow and very expensive!

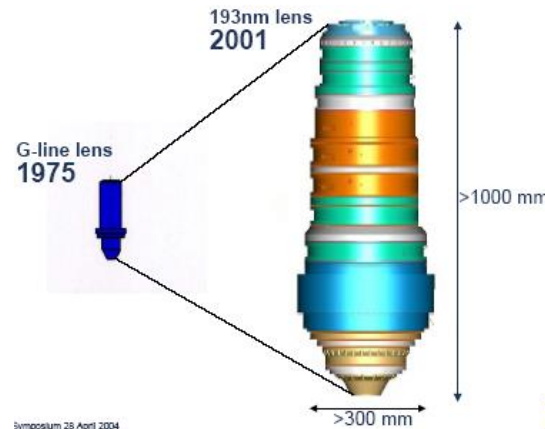
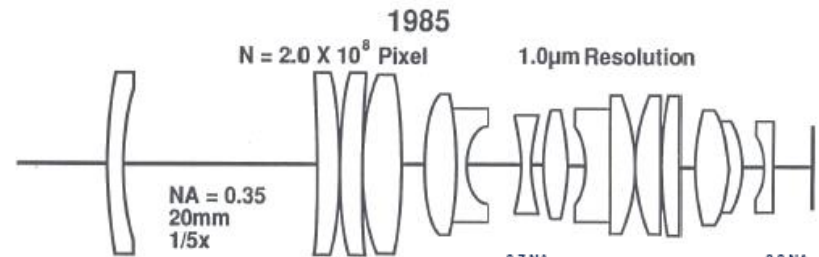
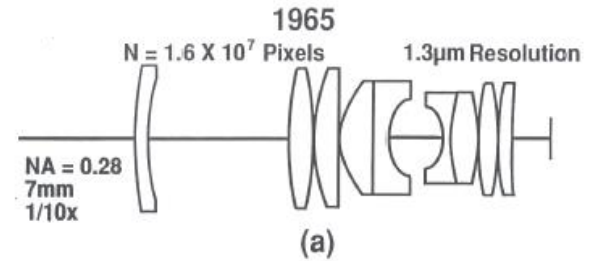
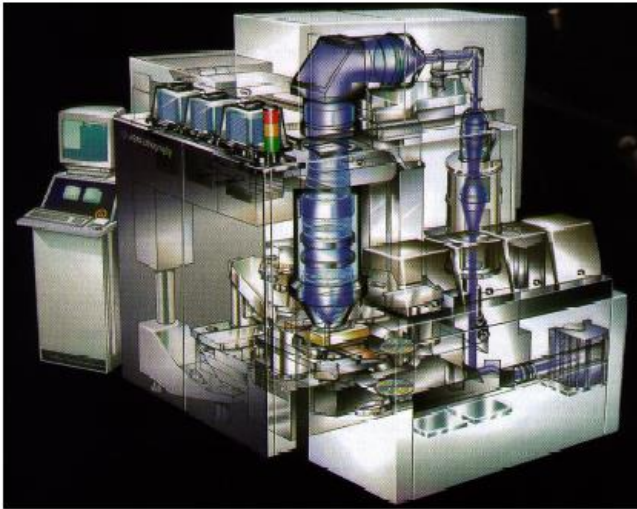




The Pellicle

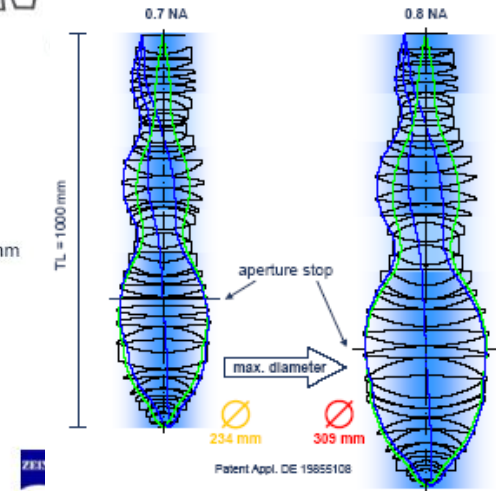


Lithographic Lens Evolution



Symposium 28 April 2004

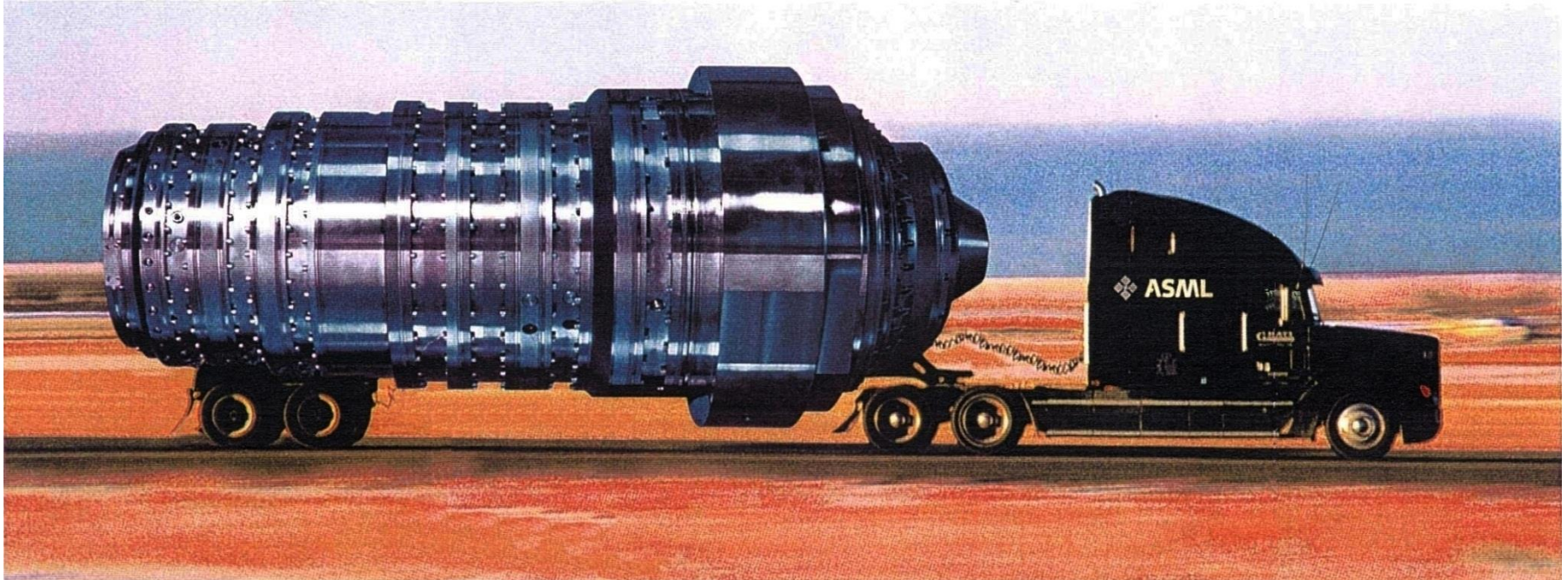
Starlith 500 Lens
(Zeiss)



Brewer Symposium 28 April 2004



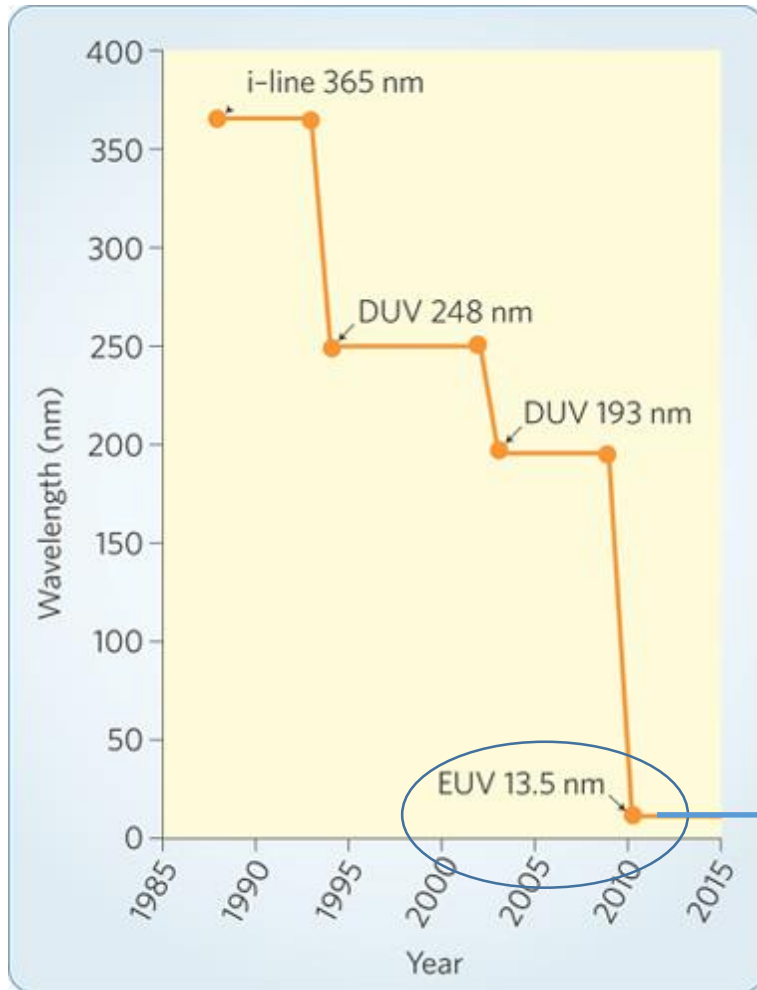
A Prophetic Advertisement??



Size Matters????



Reducing wavelength



$$W = \frac{k_1 \lambda}{NA}$$

W = Resolution (nm)

k_1 = Process-dependent constant ($k_1 > 0.25$)

λ = Wavelength

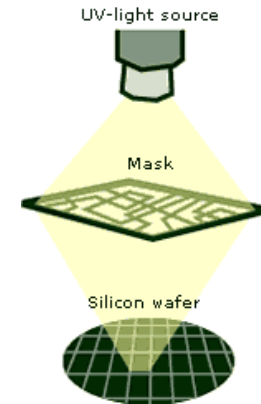
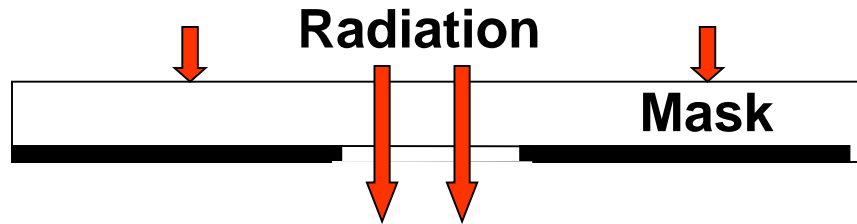
NA = Numerical aperture = $n \sin(\theta)$

Cost: >\$250M/tool ?

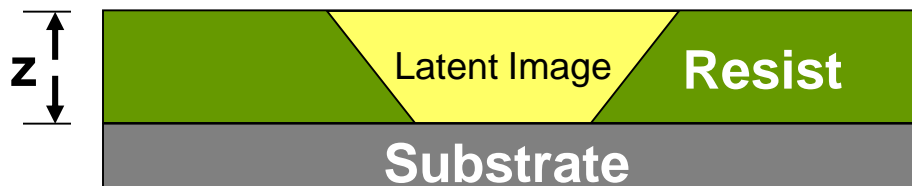
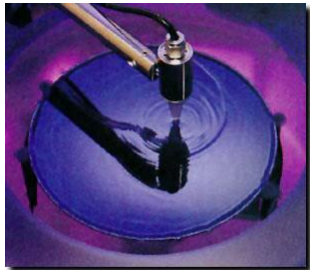
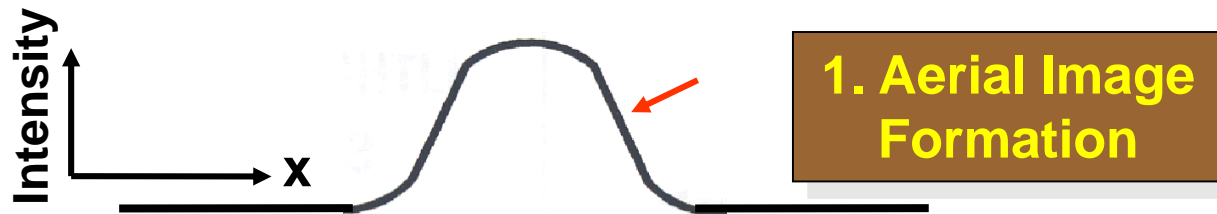
Wagner, C.; Harned, N., EUV lithography: Lithography gets extreme. *Nat Photon* **2010**, 4 (1), 24-26.



Lithographic Pattern Definition

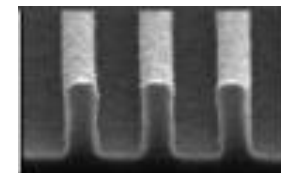
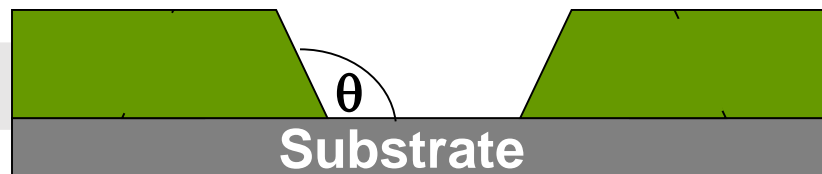


Lithographic Exposure Tool

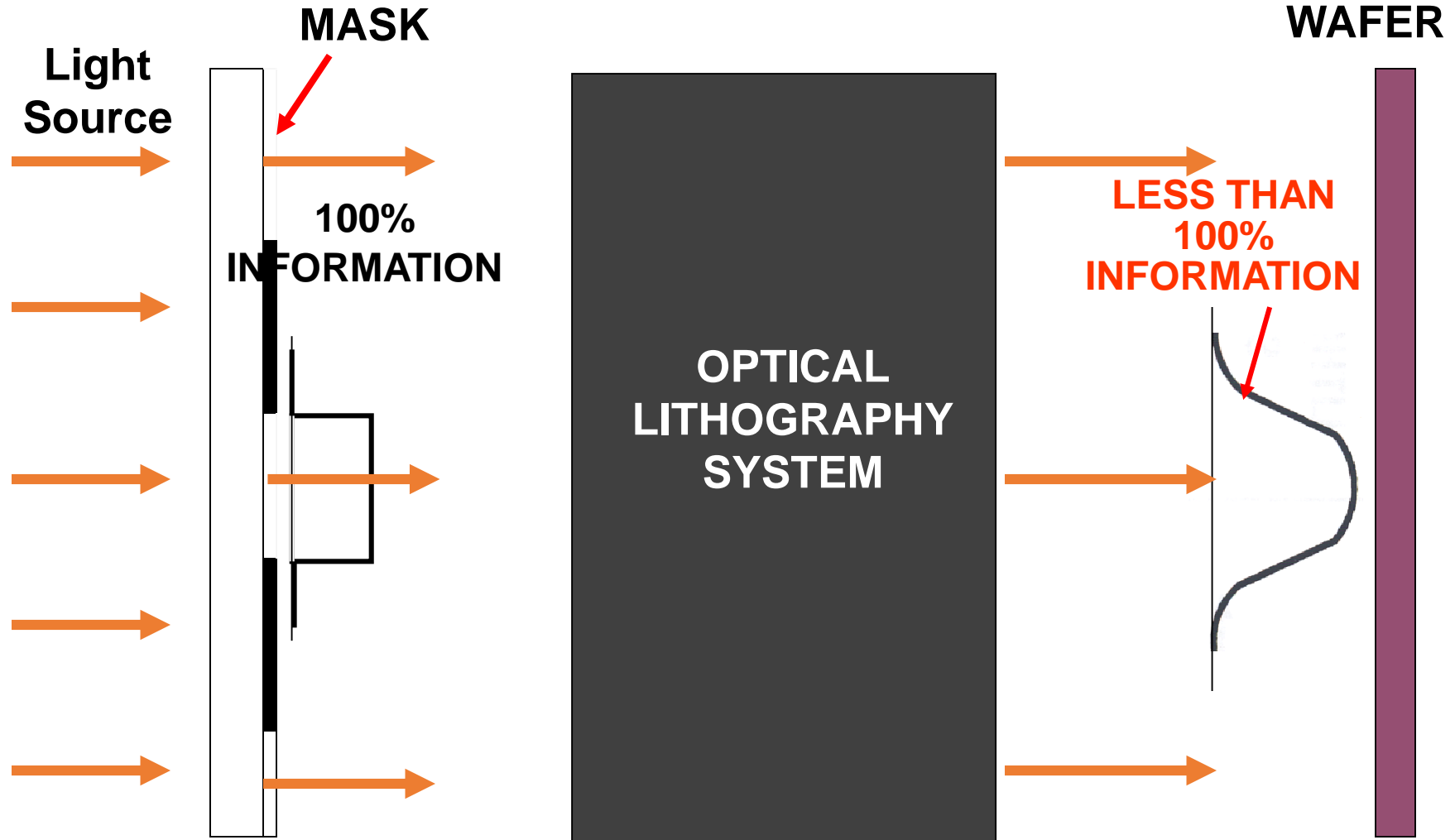


2. Exposure

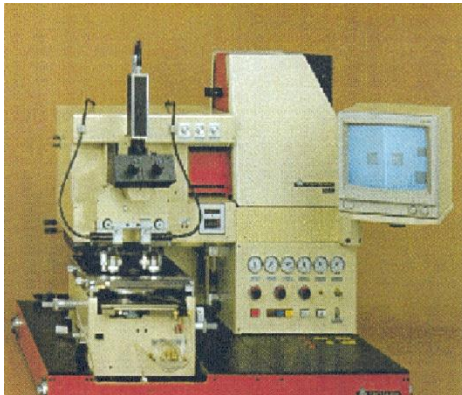
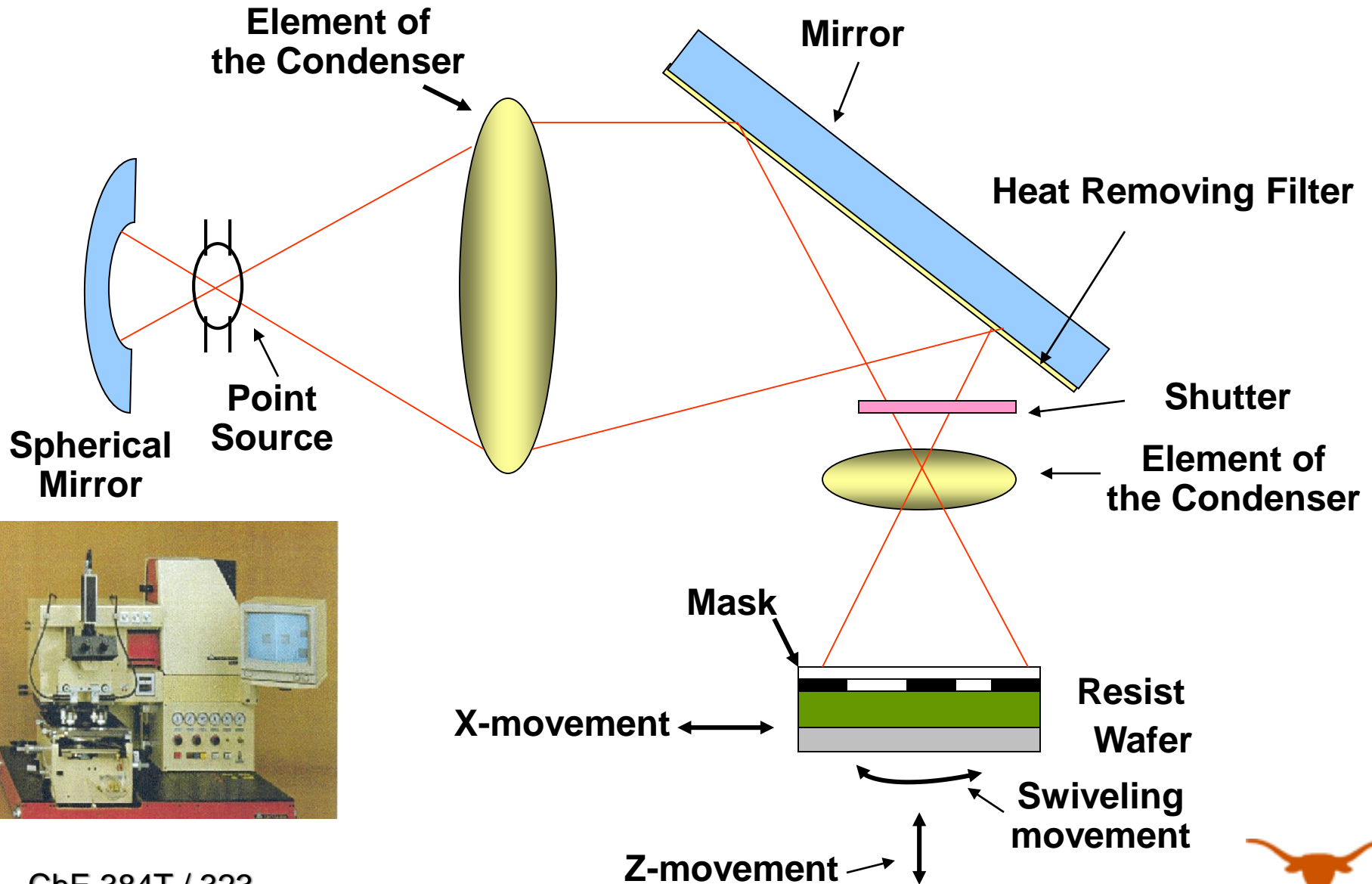
3. Development



The Fundamental Issue – Information Transfer



We Started With Contact Printing



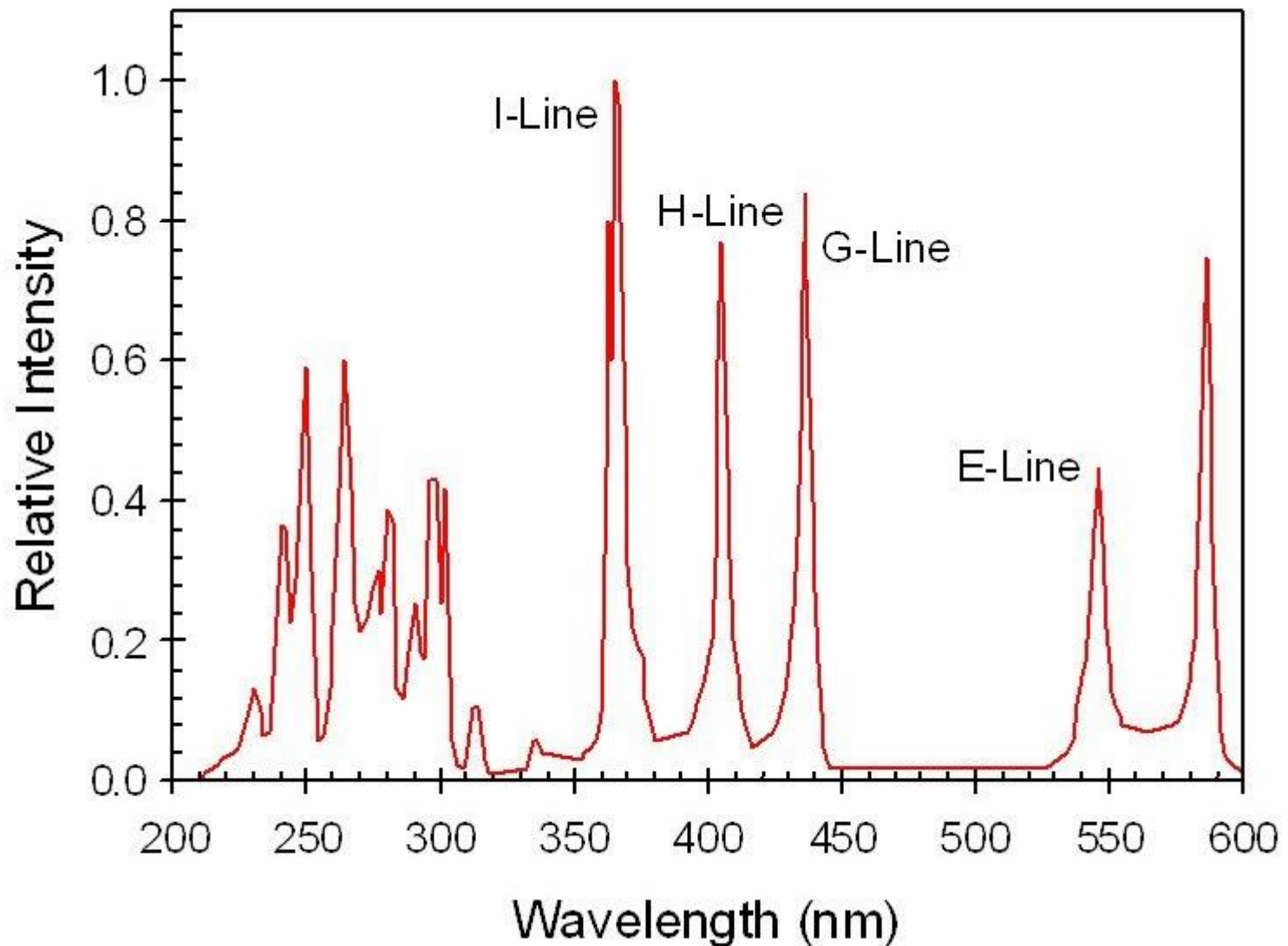
ChE 384T / 323



High Pressure Hg Lamp



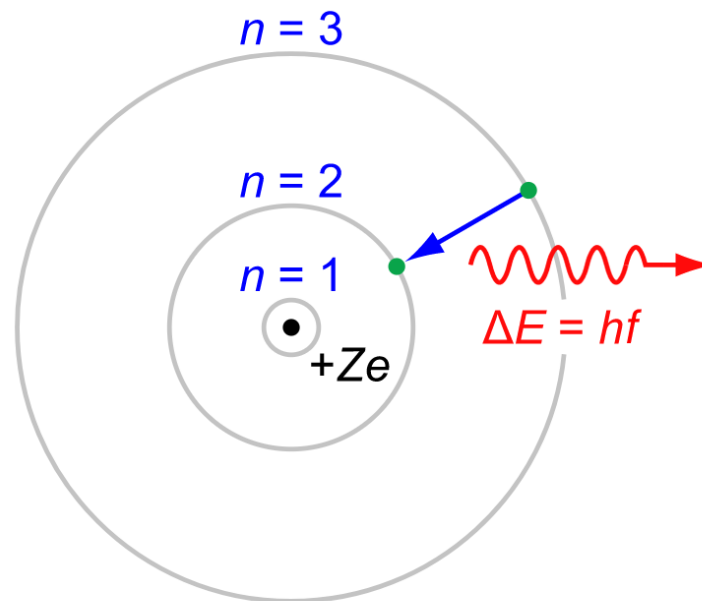
High Pressure Hg Lamp Output



The Balmer Series



Hydrogen Emission Lines



High and Low Pressure Hg Lamps

