

미시세계와 거시세계

8. 양자의 세계

유재준

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2016/2학기

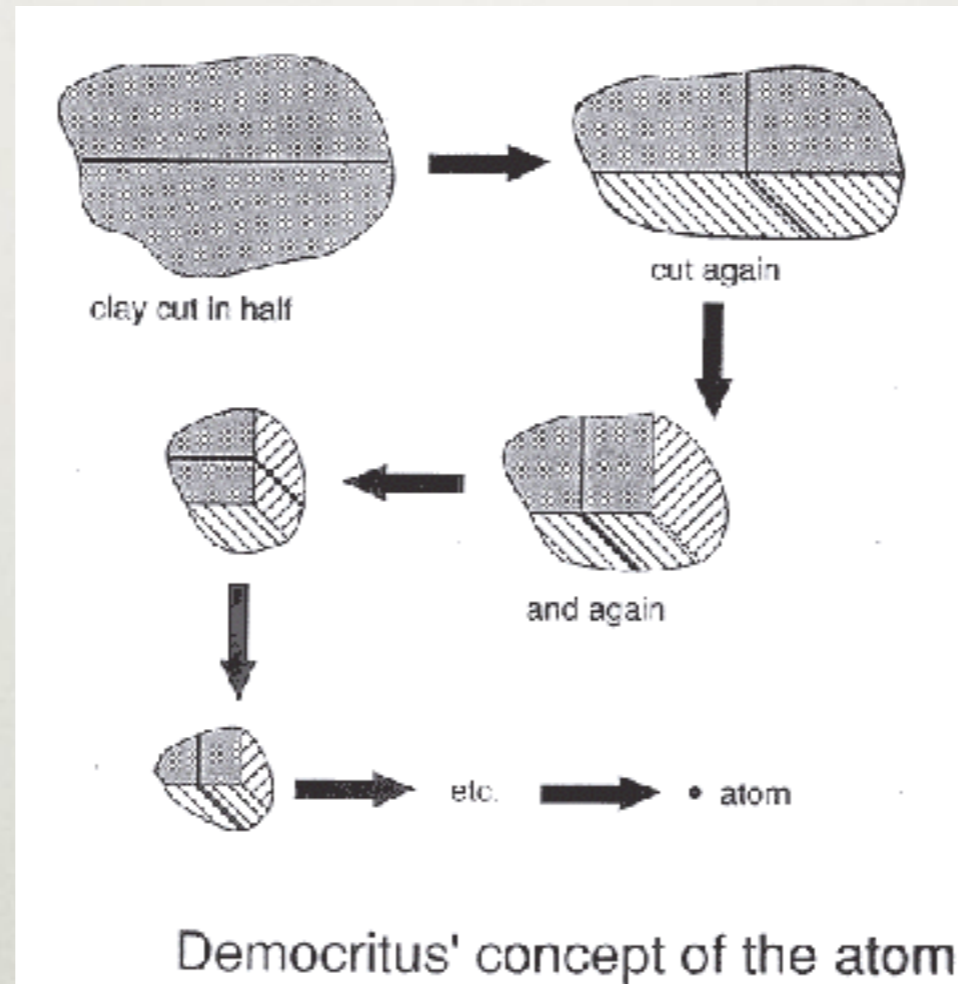
만물의 근원



- Thales: water (水)
- Anaximandros: apeiron (무한자)
- Anaximenes: air (空氣)
- Anaxagoras: 스페르마타 (種子)
- Herakleitos: fire (火)
- Pythagoras: number (數)
- Democritus/Lucippus: Atom (原子)



atoms = indivisible particles



"Any substance could be subdivided until an indivisible *atomos* was reached"



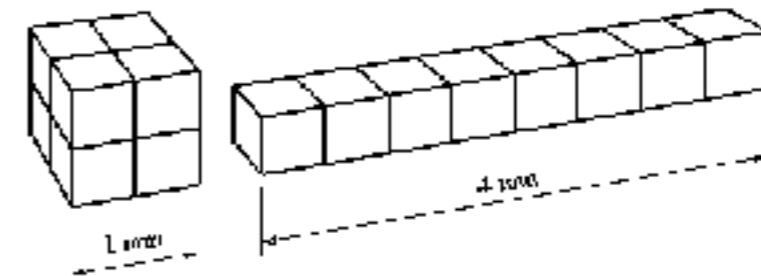
데모크리토스의 목걸이

- PROBLEM

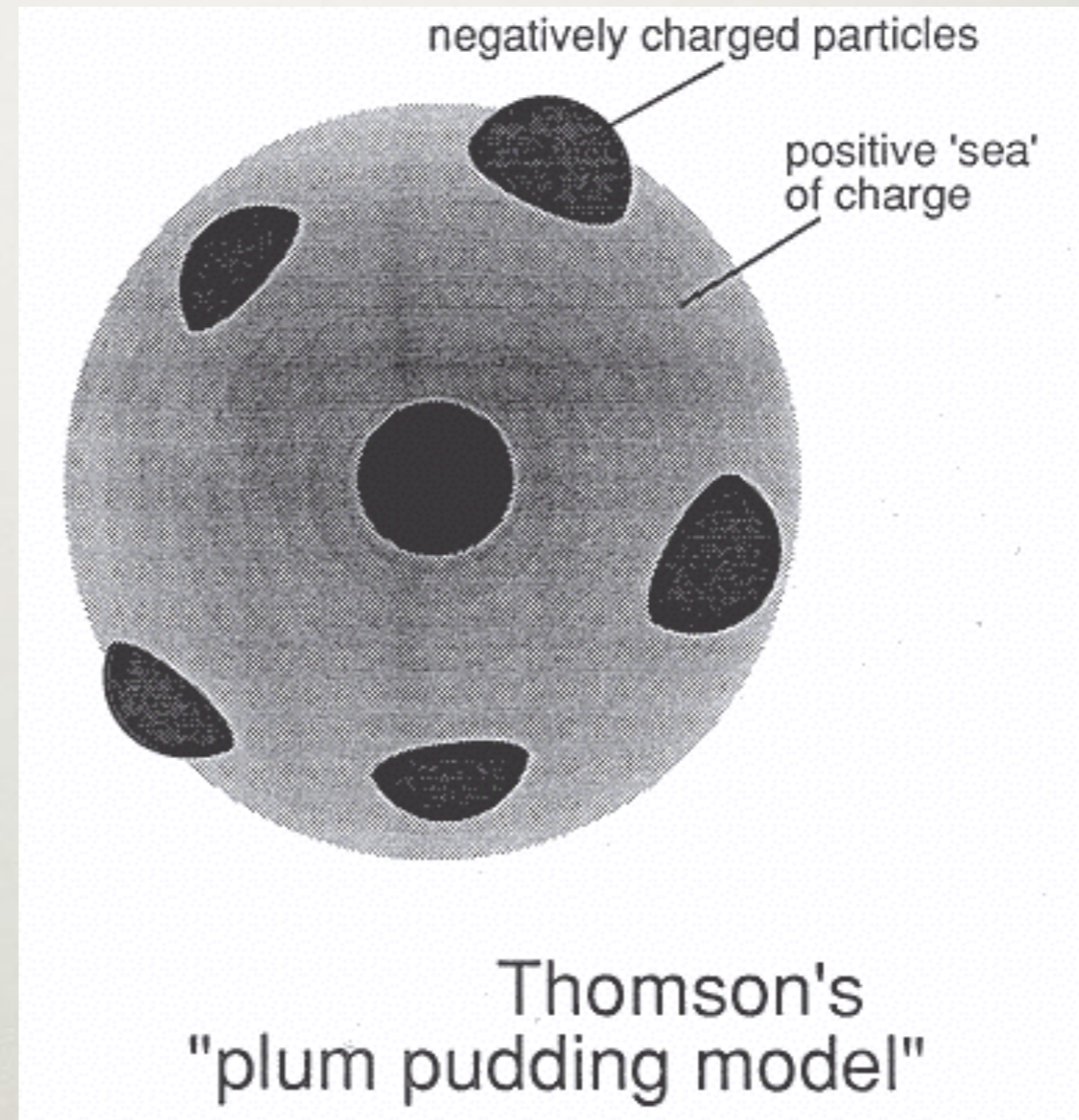
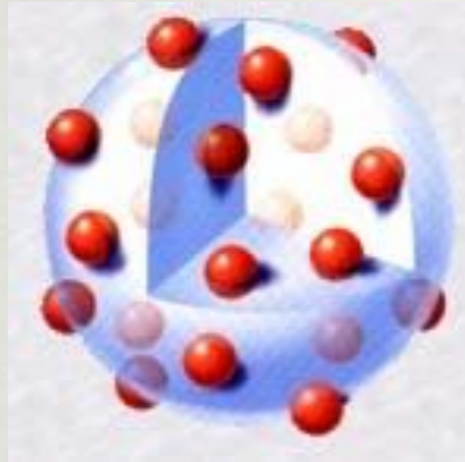
Determine the length of the row that is obtained when the atoms in a 1 mm^3 grain of table salt are placed one next to the other.

- DATA (from the CRC Handbook of Chemistry and Physics)

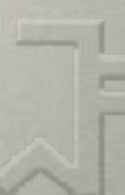
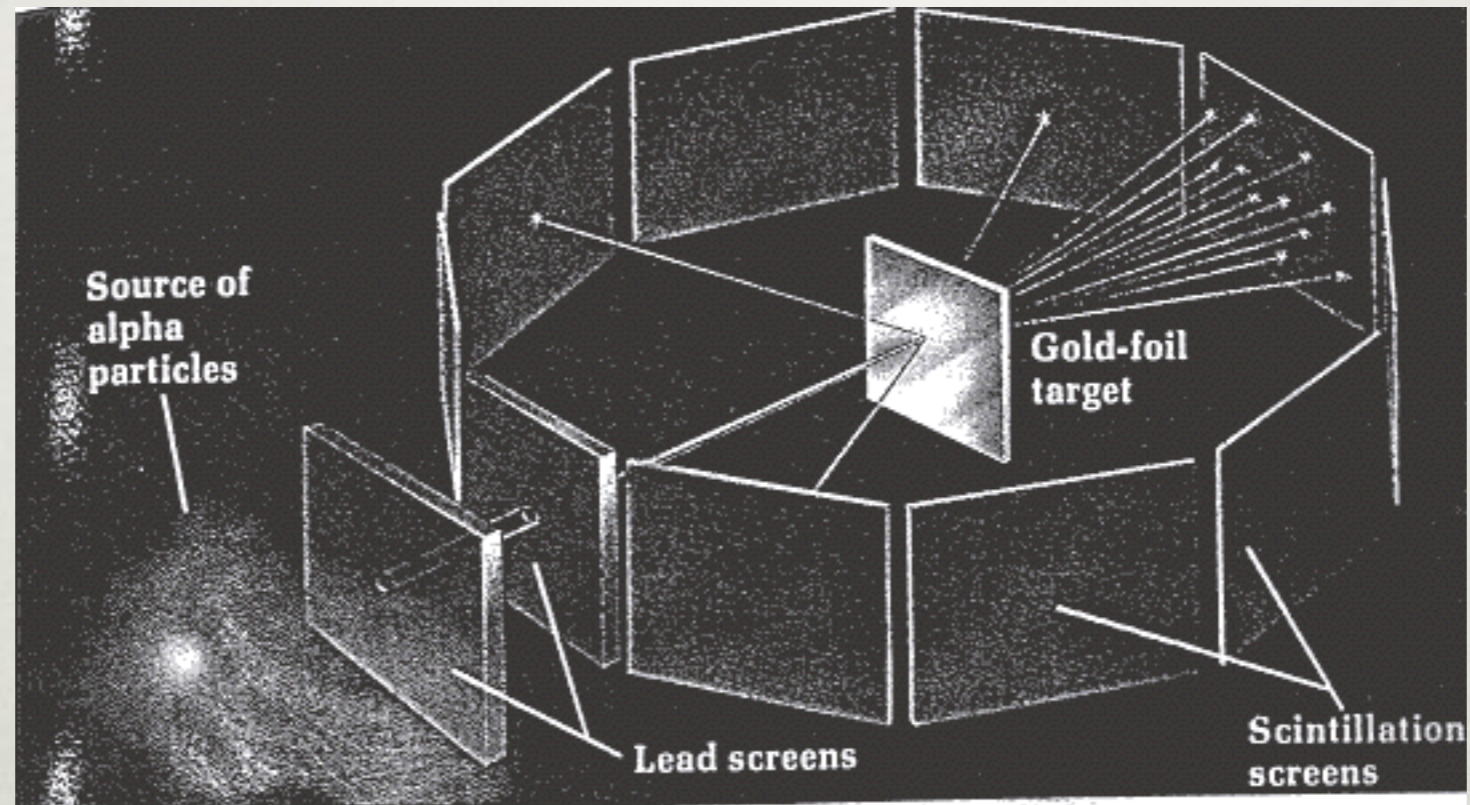
- Density of salt: $d(\text{NaCl}) = 2,165 \text{ g/cm}^3$
- Ionic radius of sodium: $r(\text{Na}) = 0.97 \text{ \AA} = 0.97 \times 10^{-10} \text{ m}$
- Ionic radius of chlorine: $r(\text{Cl}) = 1.81 \text{ \AA} = 1.81 \times 10^{-10} \text{ m}$
- Atomic weight of sodium: $M(\text{Na}) = 22.9898 \text{ g}$
- Atomic weight of chlorine: $M(\text{Cl}) = 35.453 \text{ g}$
- Avogadro's number: $N_A = 6.02252 \times 10^{23}$

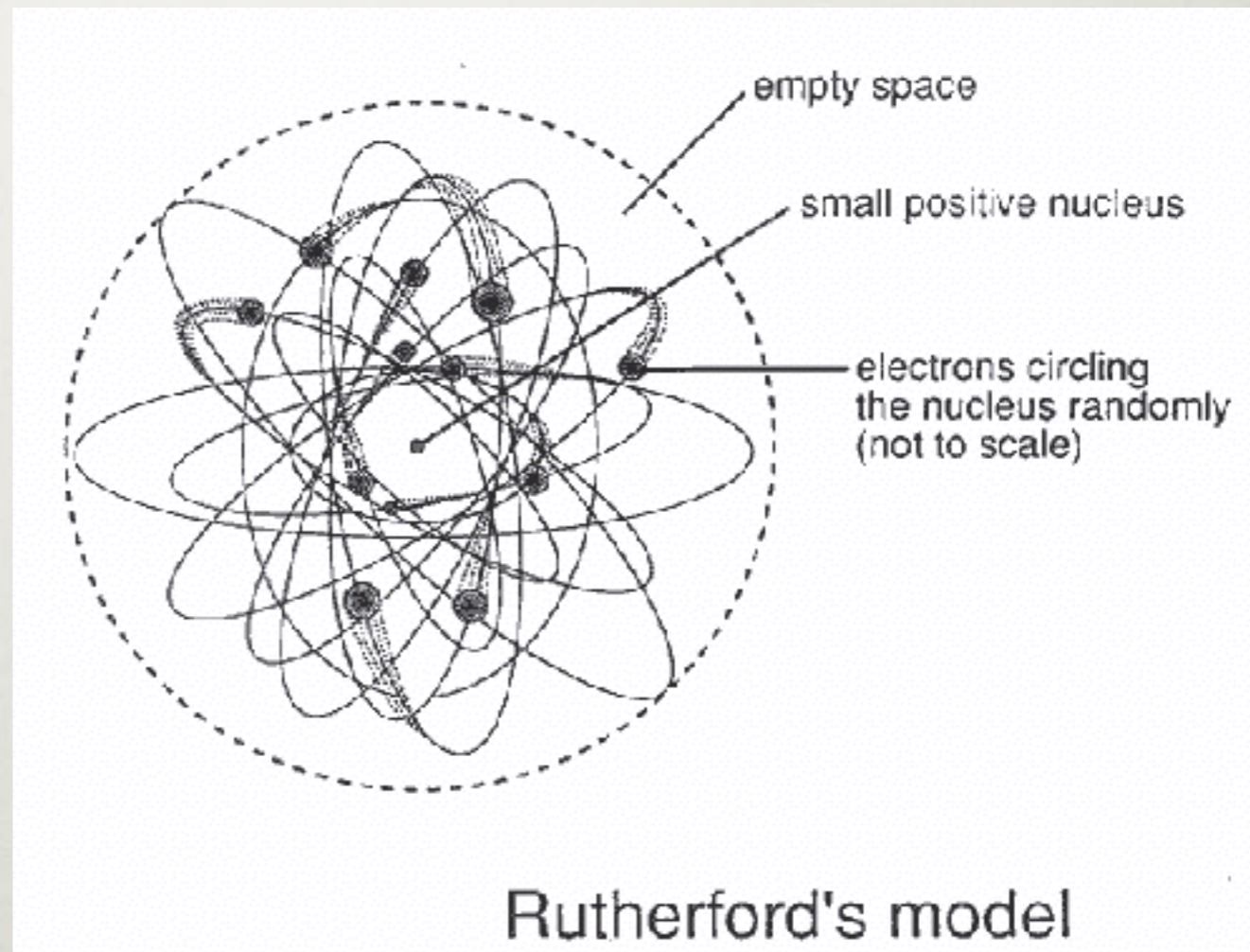
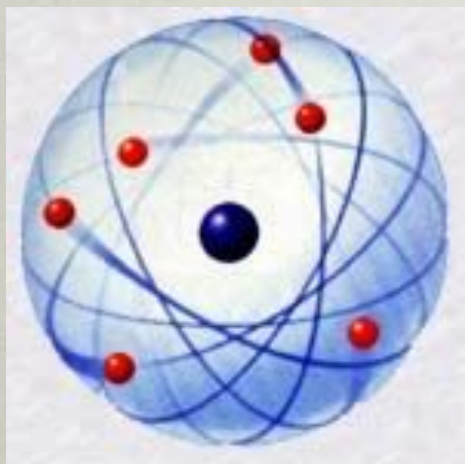
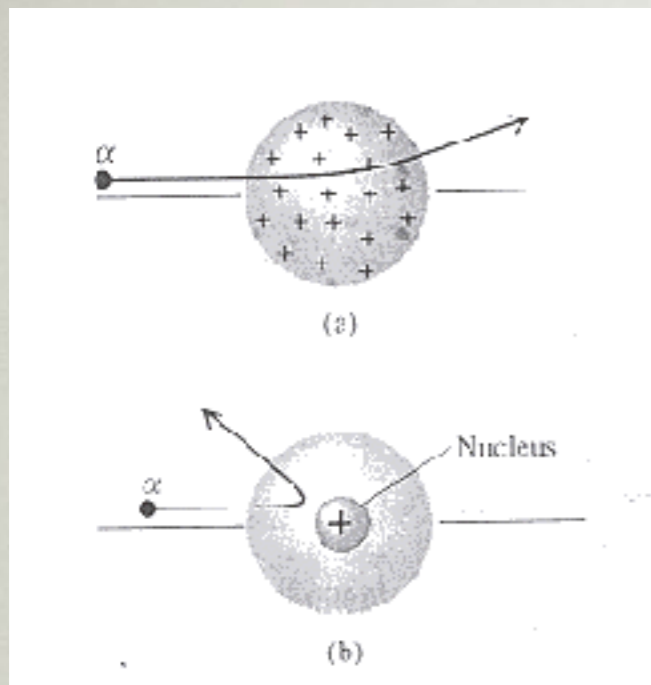


From a cube whose side is 1mm, you obtain 8 little cubes whose sides are 1/2mm. Setting these little cubes in a row side by side, you cover a distance 4 times the length of the side of the starting cube.

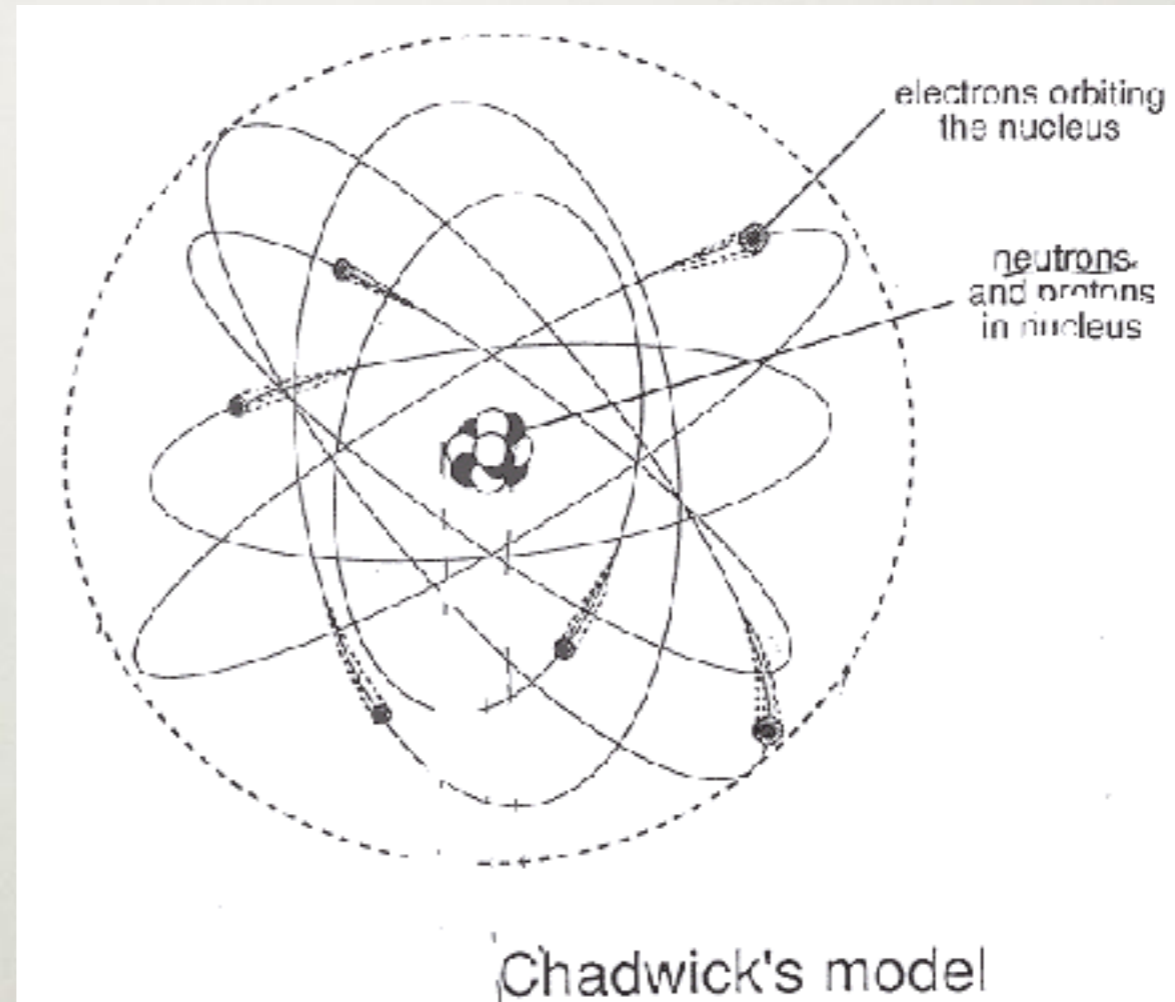
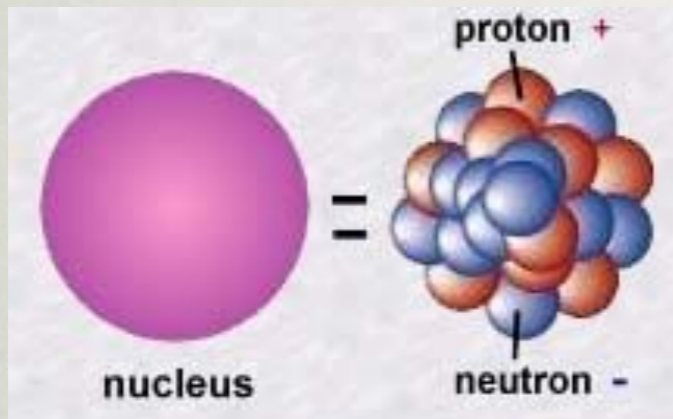


Rutherford Experiment (1911)

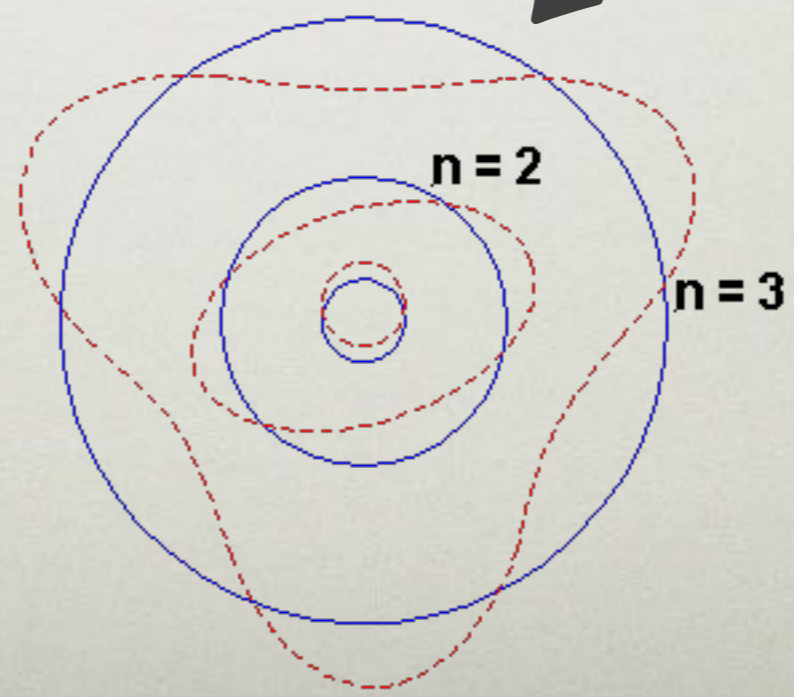
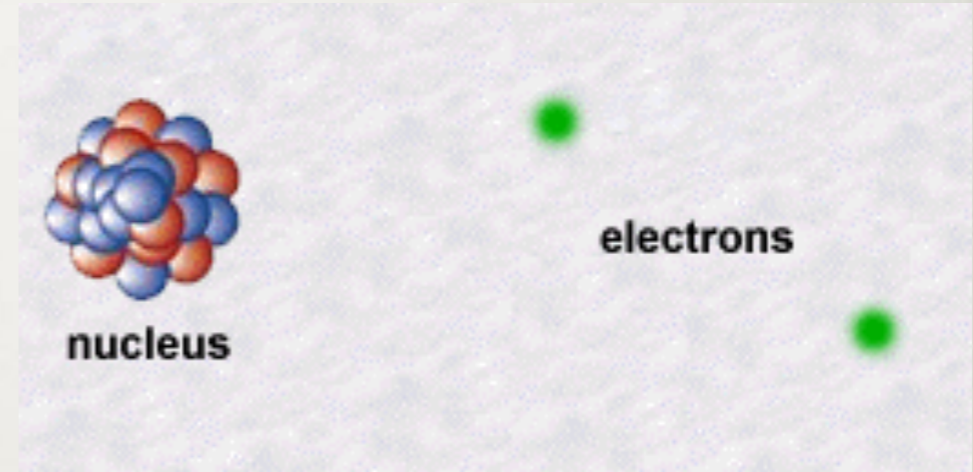
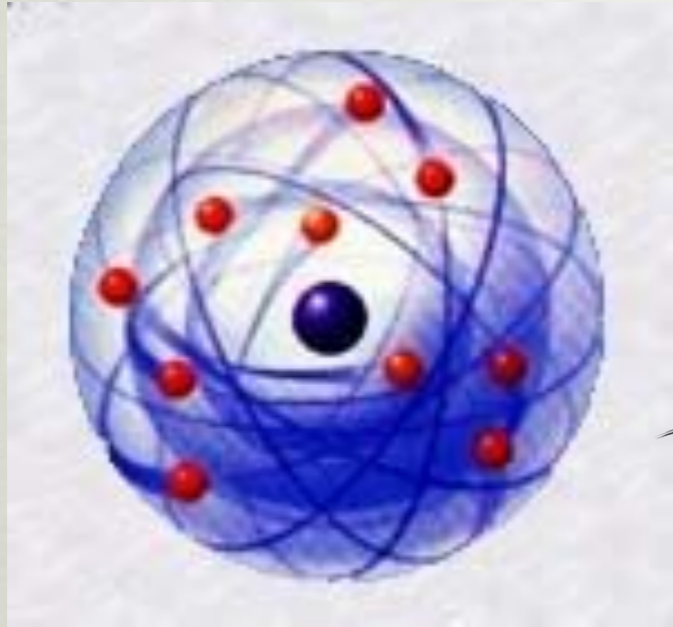




Chadwick (1932)



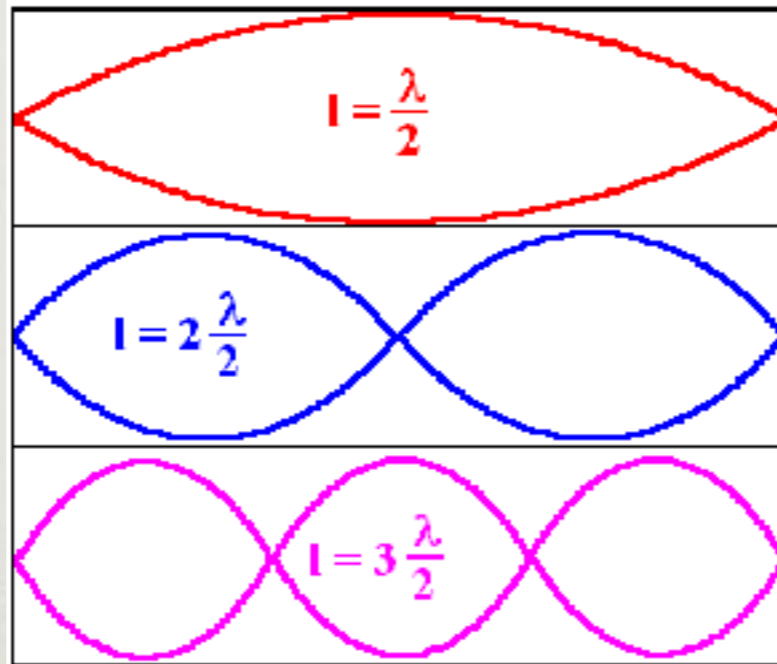
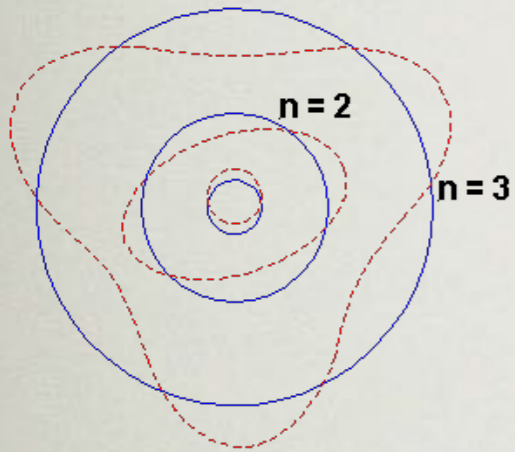
Bohr's atom



“Quantum Physics”



"Quantized" States?

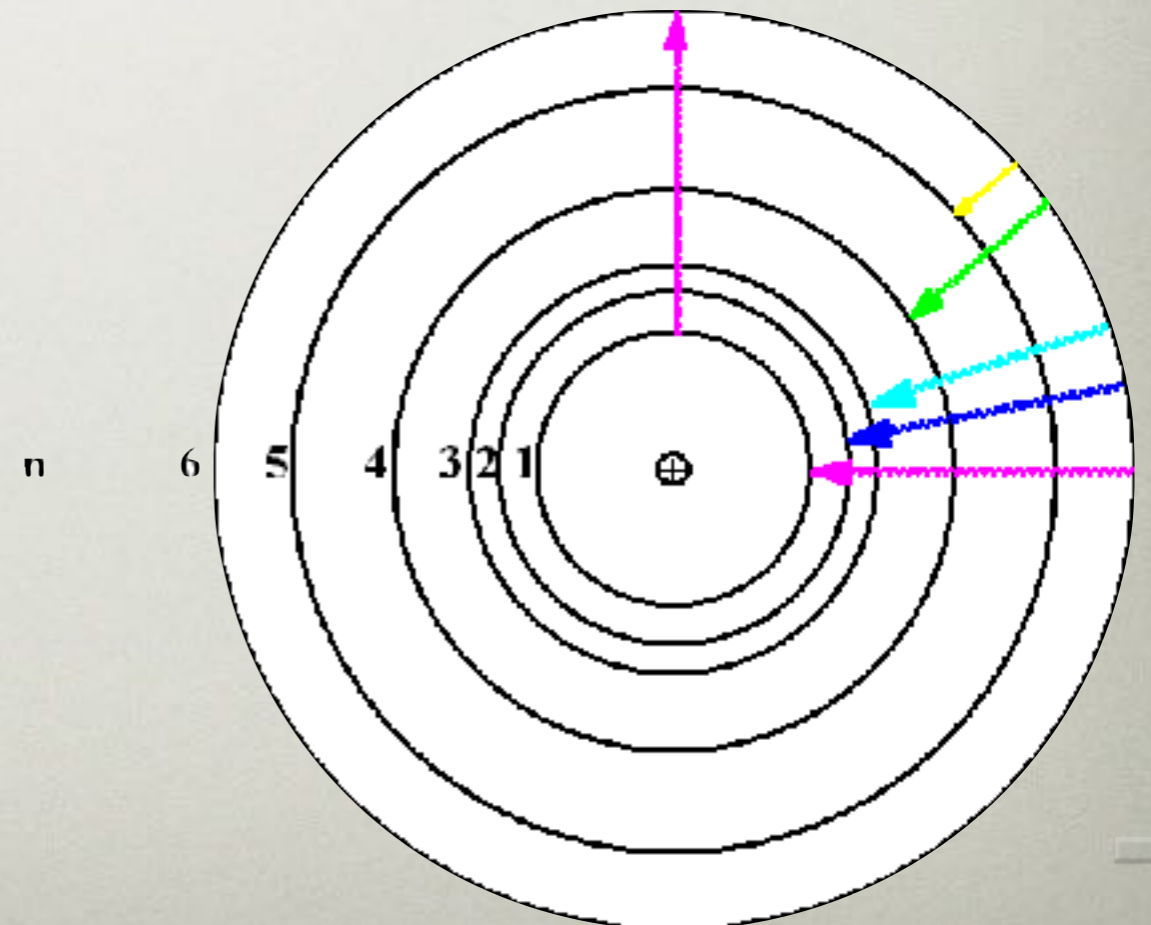


Electron energy level:

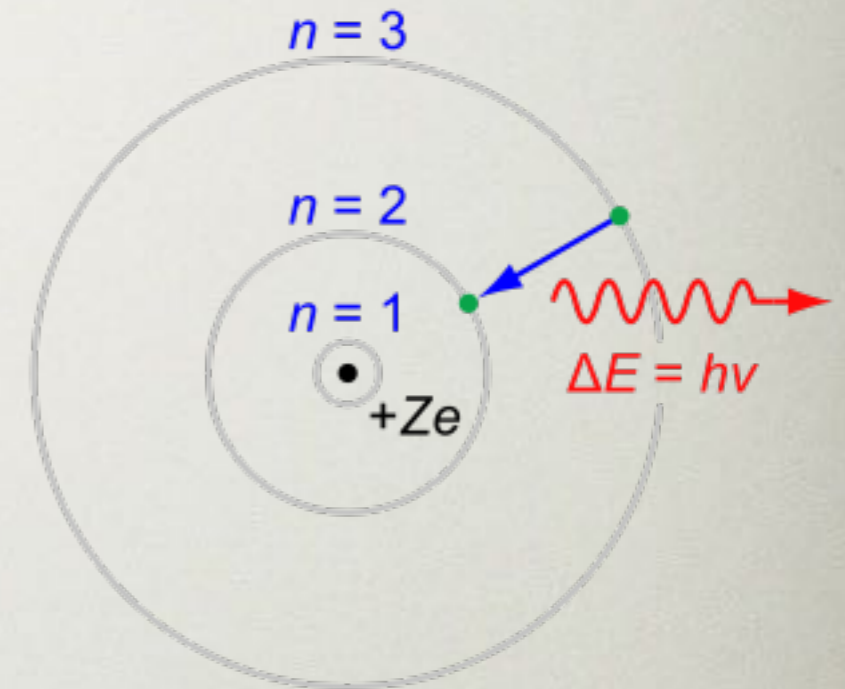
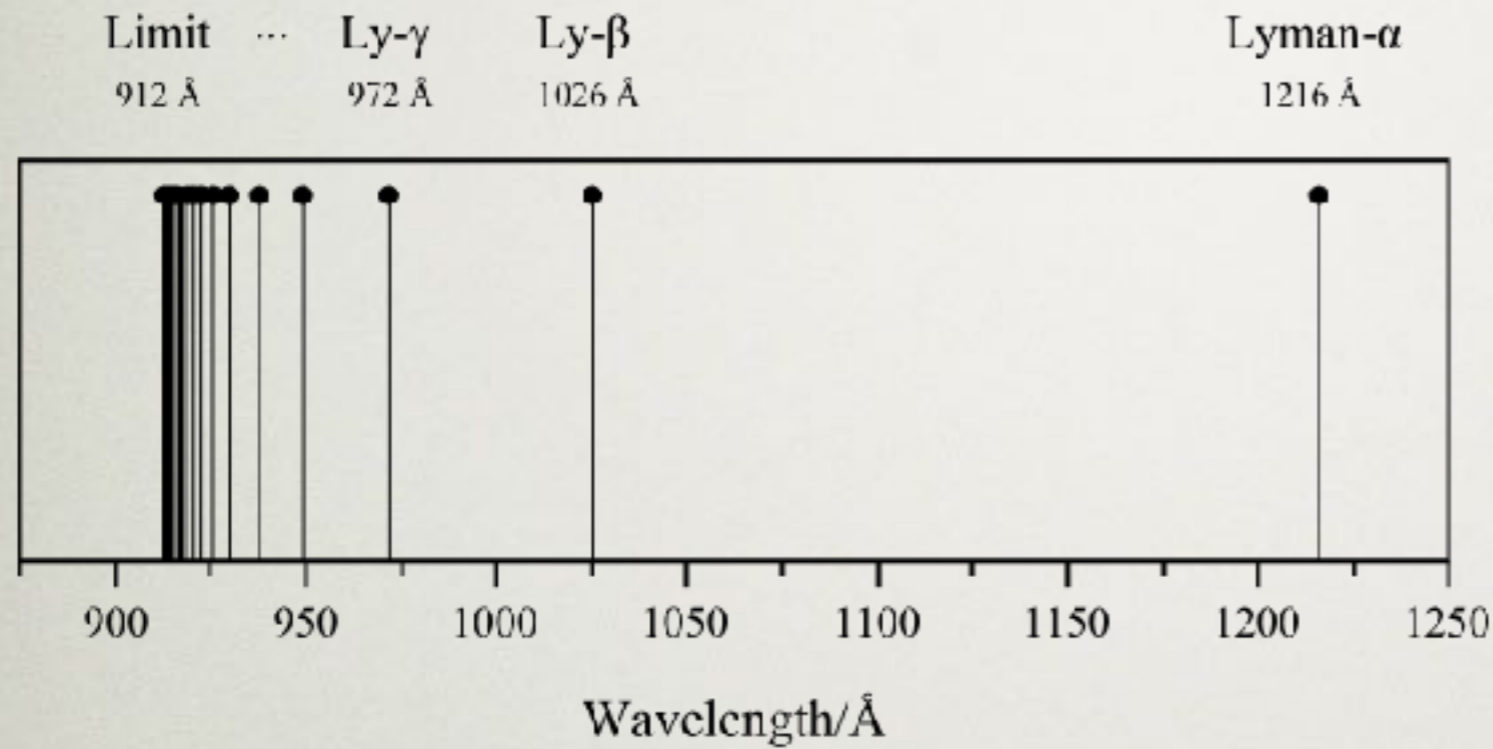
$$E_n = -\frac{R_H}{n^2}$$

$$R_H = 13.6 \times (1.6 \times 10^{-19}) \text{ J} = 13.6 \text{ eV}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$



Lyman series

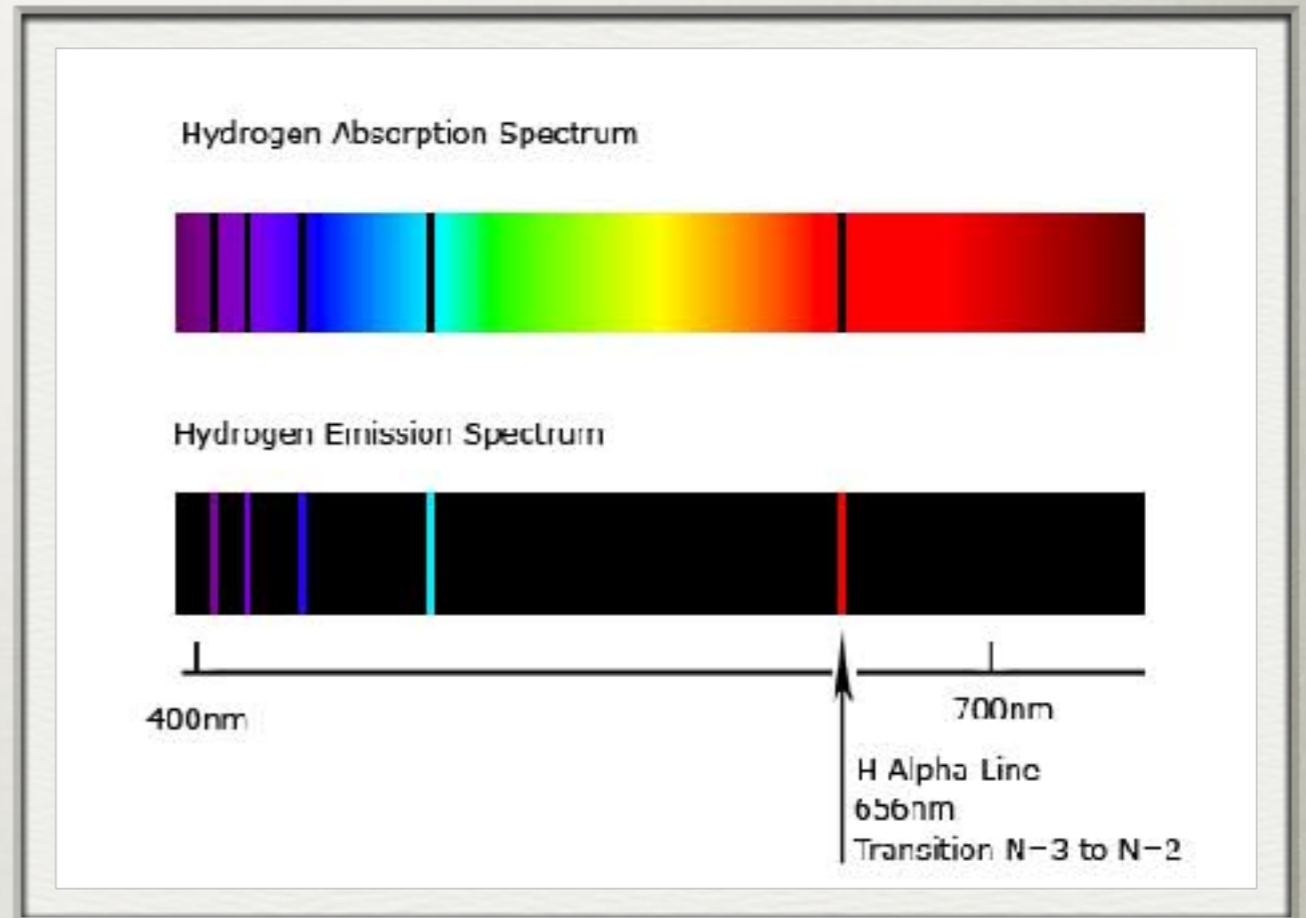
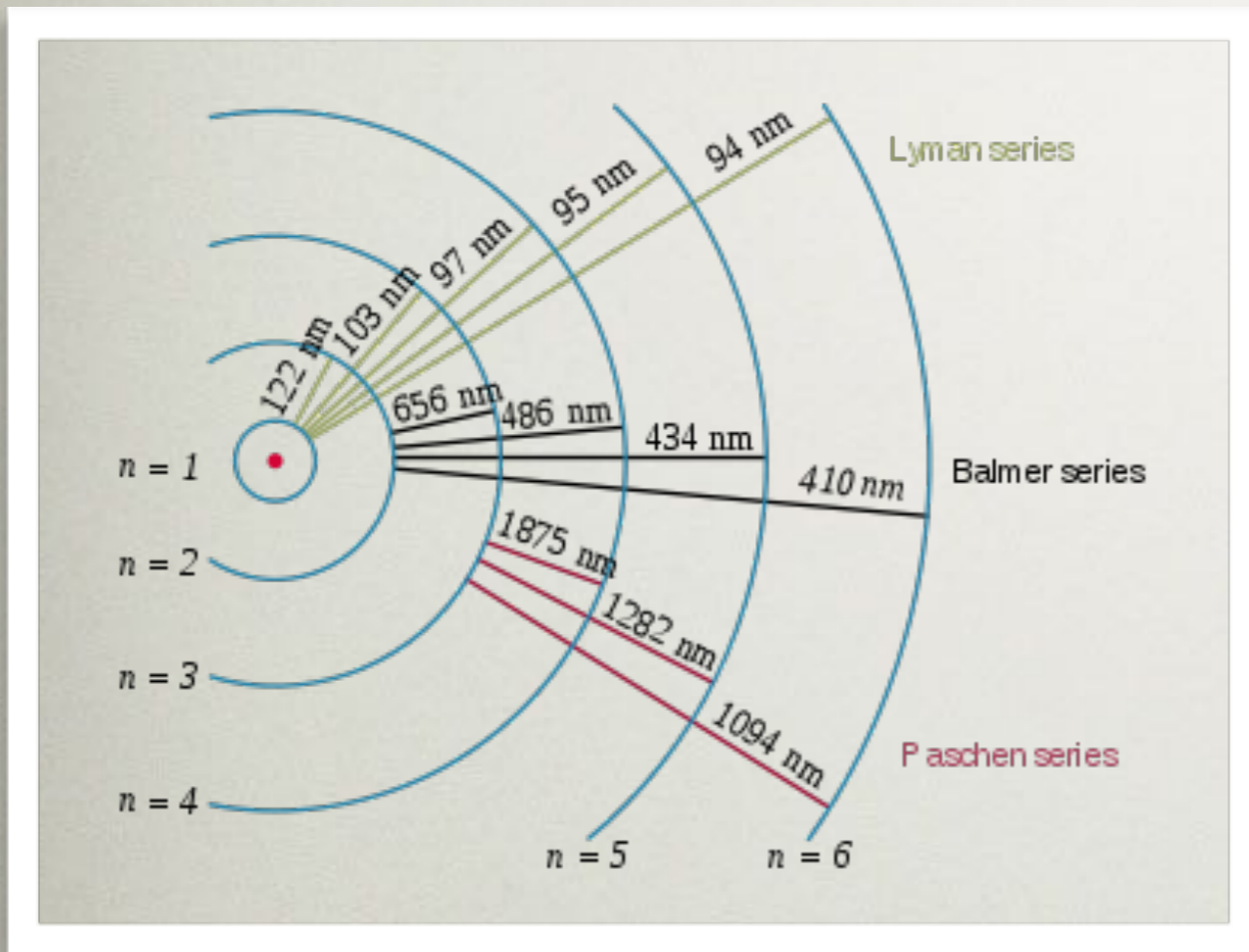


$$\frac{1}{\lambda} = R_H \left(1 - \frac{1}{n^2} \right)$$

$$\Delta E = E_2 - E_1 = h\nu$$

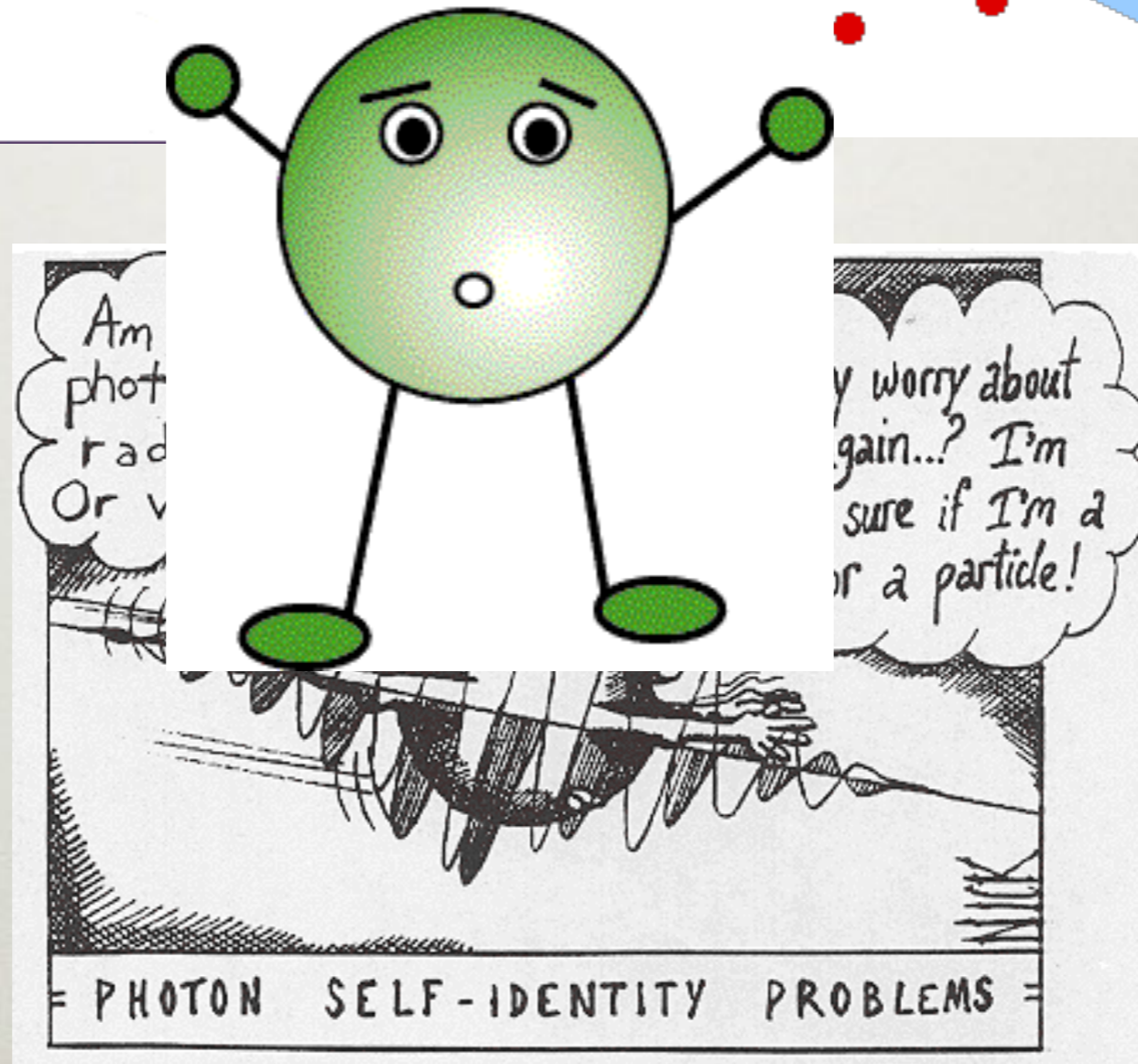
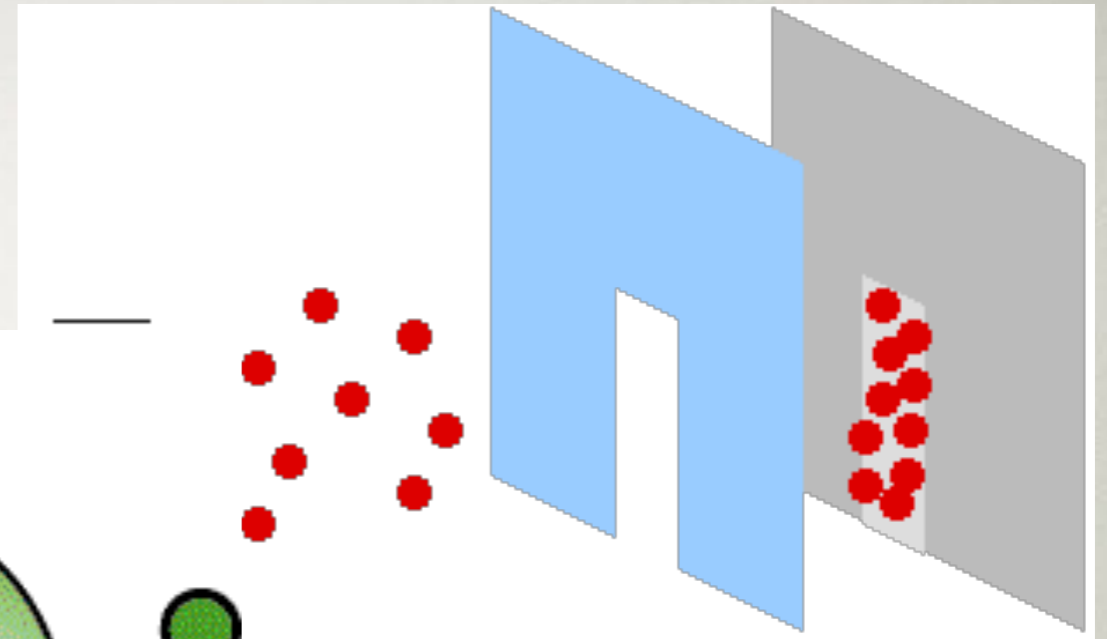
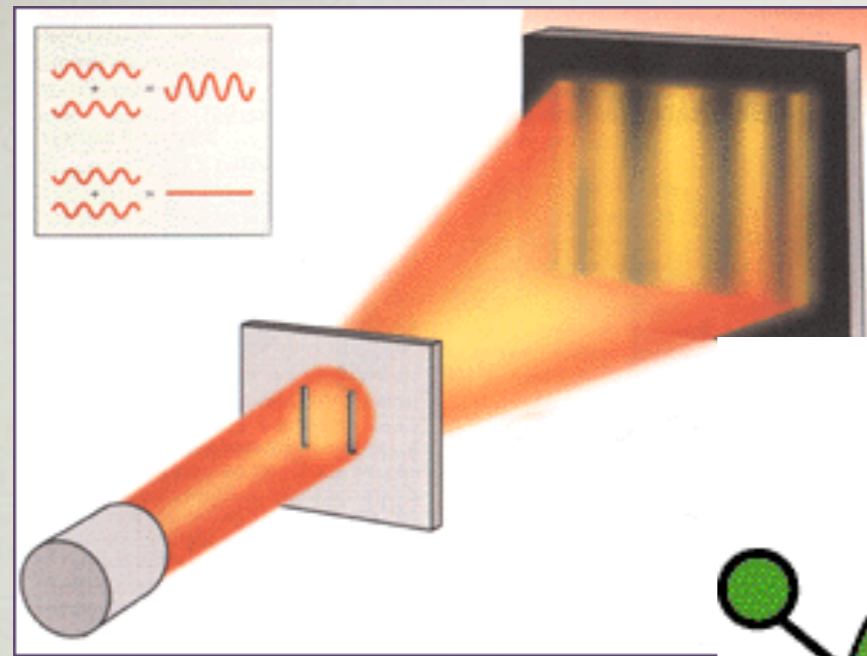


빛의 근원

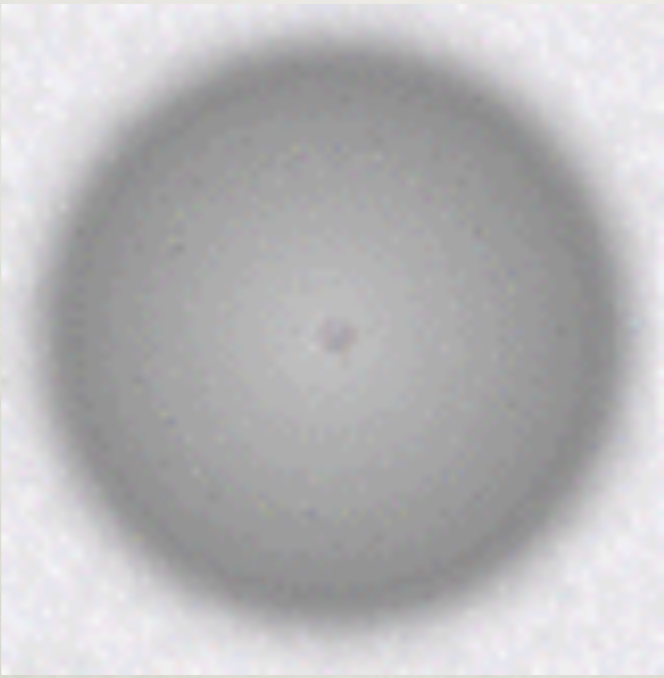



"Classical" vs. "Quantum"



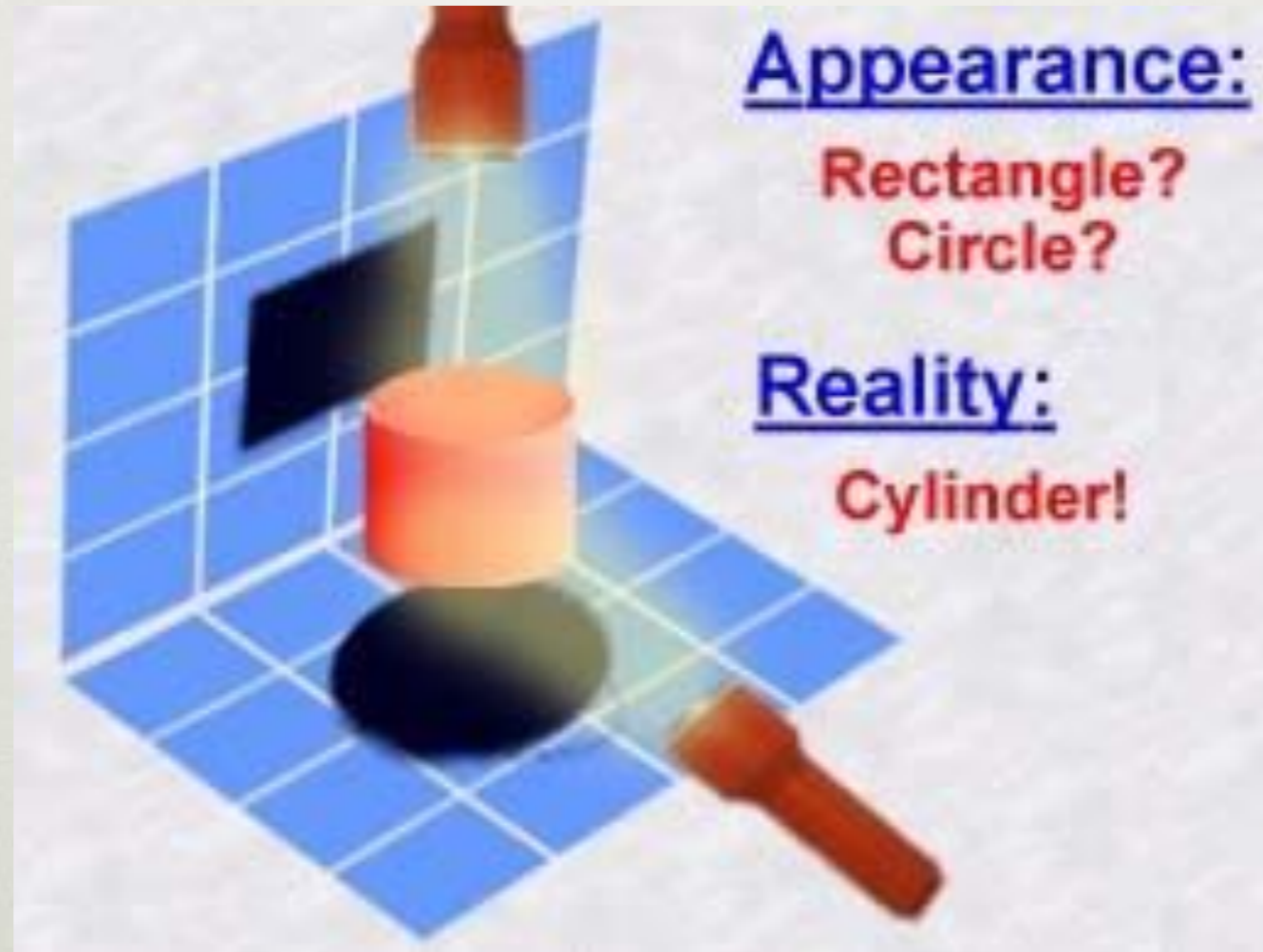


Uncertainty (불확정성)

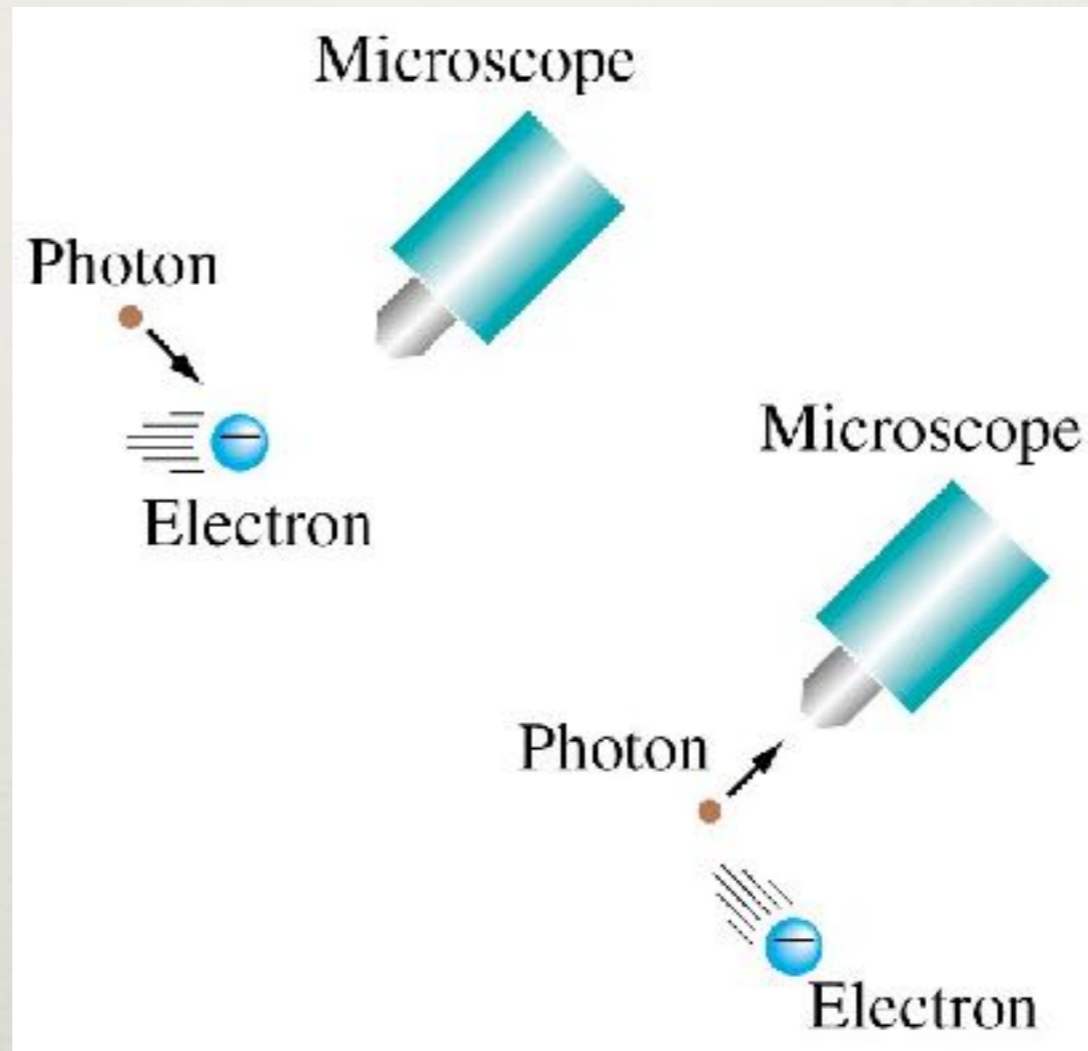
electronic orbital	observed electron
wave like nature	particle like nature
	



Particle-Wave Duality



Before collision



After collision



불확정성의 원리 (Uncertainty Principle)



$$\Delta x \Delta p \geq \hbar/2$$

$$\Delta E \Delta t \geq \hbar/2$$

"The more precisely
the **POSITION** is determined,
the less precisely
the **MOMENTUM** is known"

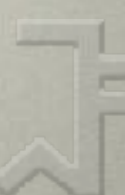
Heisenberg (1927)



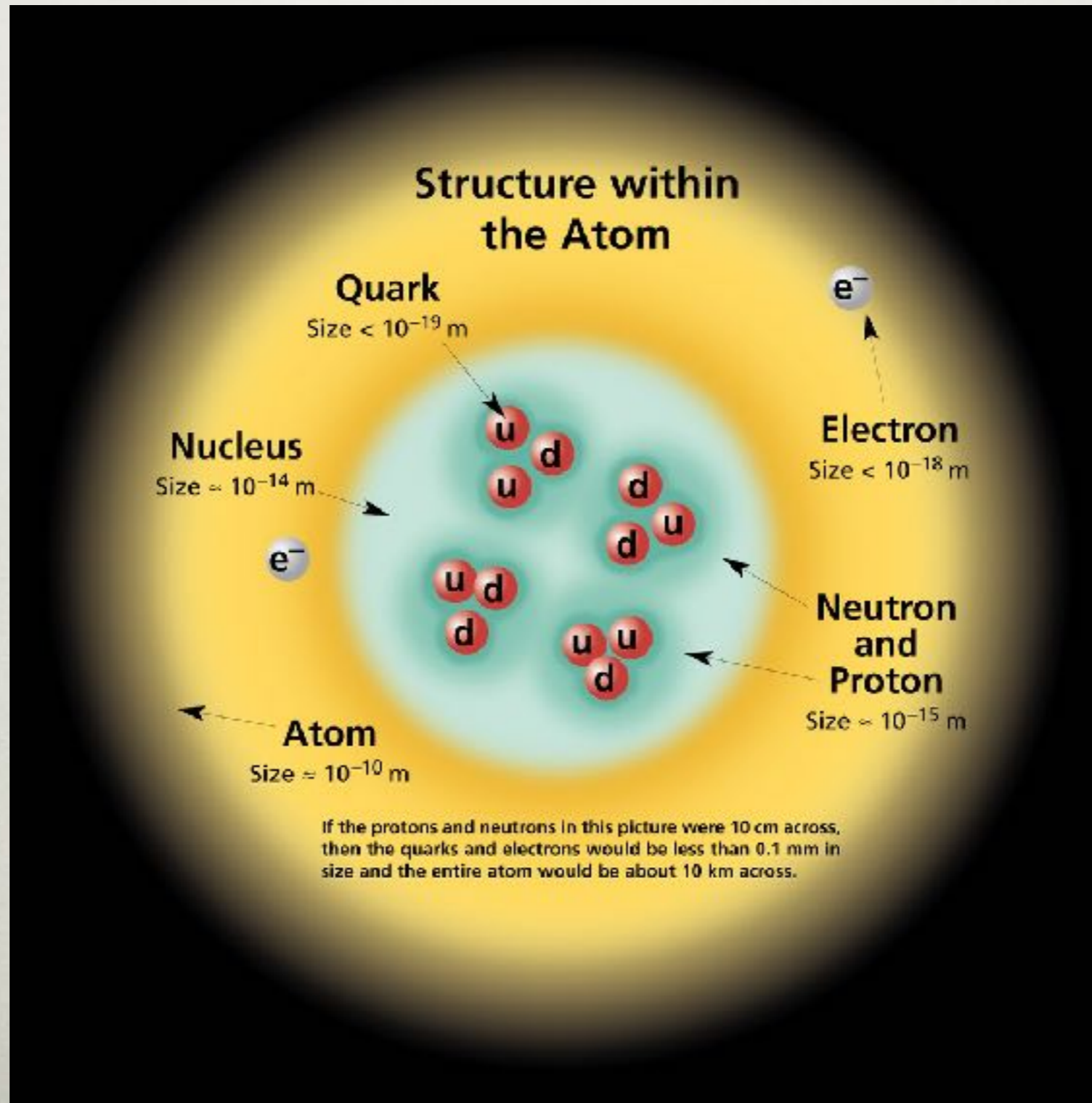
양자 올빼미

**HOUOU
HOUOU !** 👁️👁️

**I can't see him,
but I can hear him!**



원자 핵보다 더 작은 입자?



FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge	Flavor	Approx. Mass GeV/c ²	Electric charge
ν_e electron neutrino	$<1 \times 10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	-1	d down	0.006	-1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	-1	s strange	0.1	-1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	-1	b bottom	4.3	-1/3

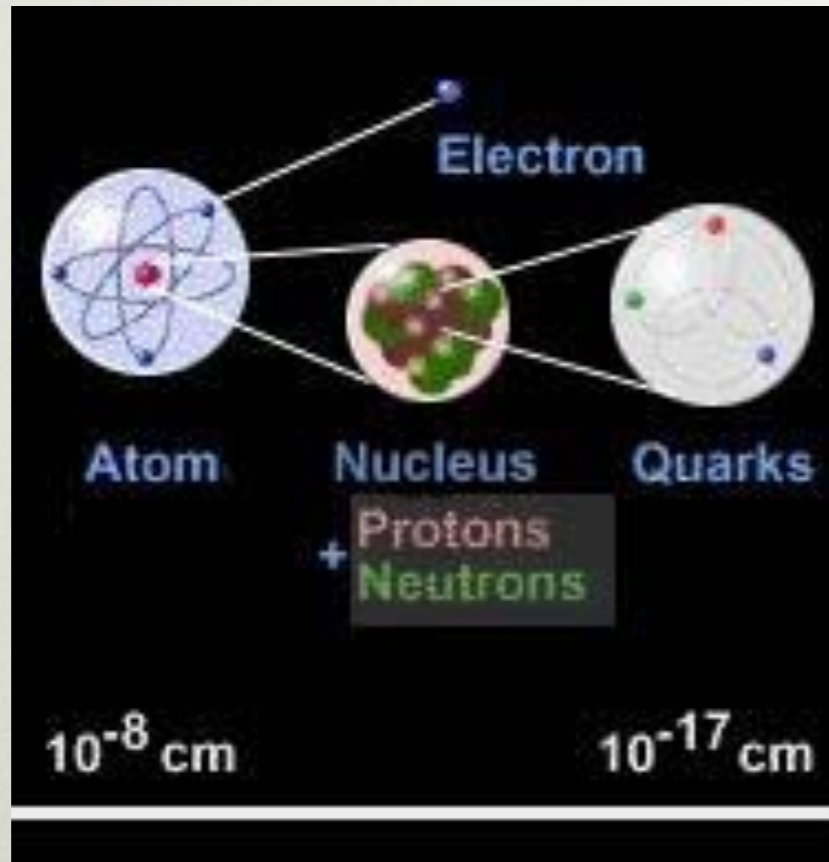
BOSONS

force carriers
spin = 0, 1, 2, ...

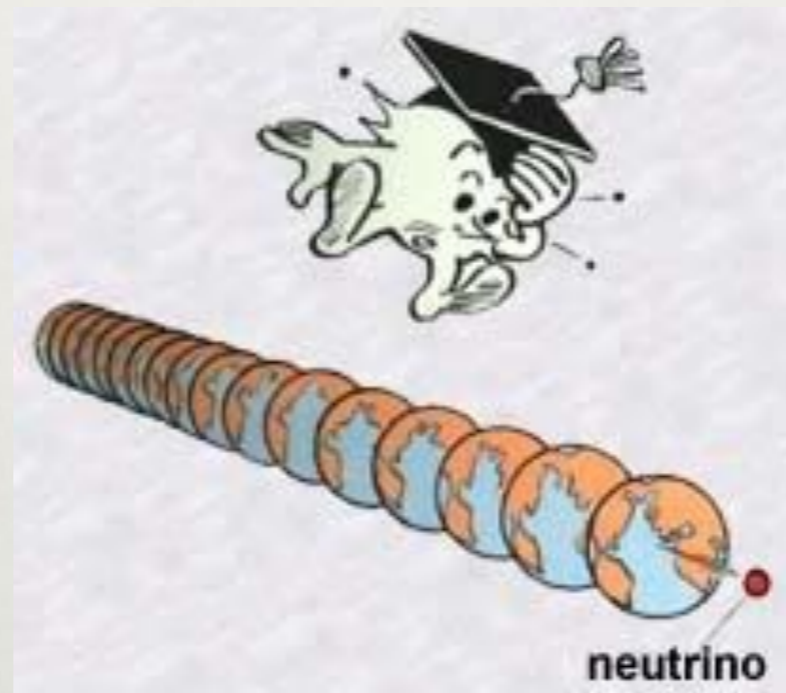
Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass GeV/c ²	Electric charge	Name	Mass GeV/c ²	Electric charge
γ photon	0	0	g gluon	0	0
W⁻	80.4	-1			
W⁺	80.4	+1			
Z⁰	91.187	0			



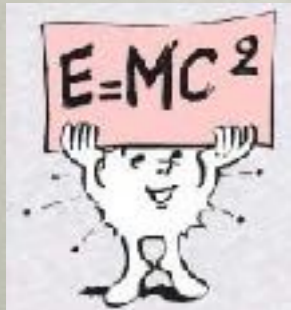
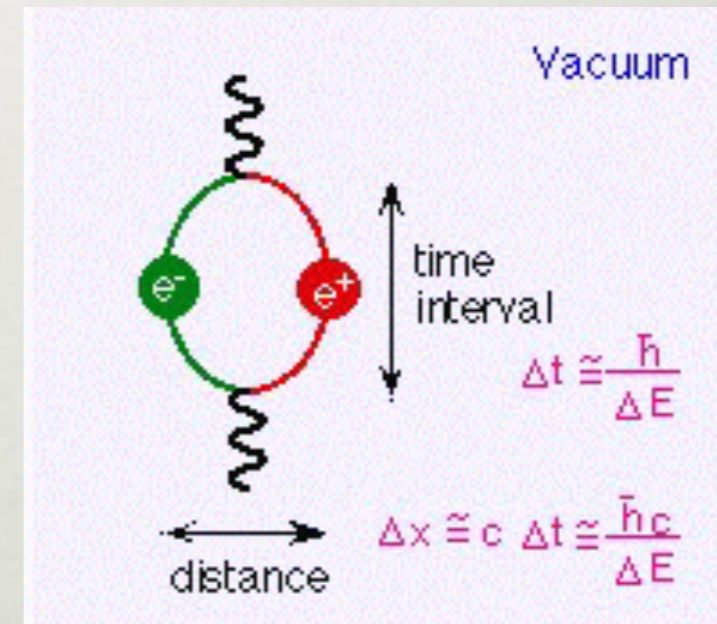
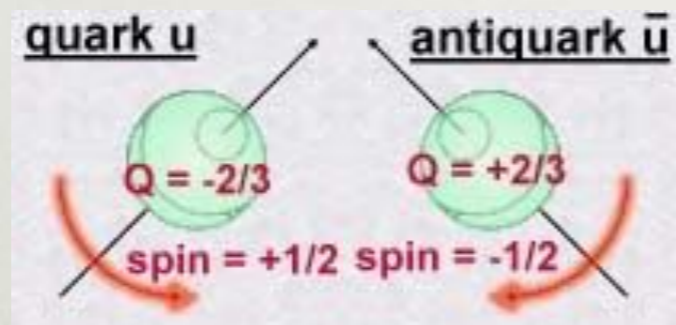
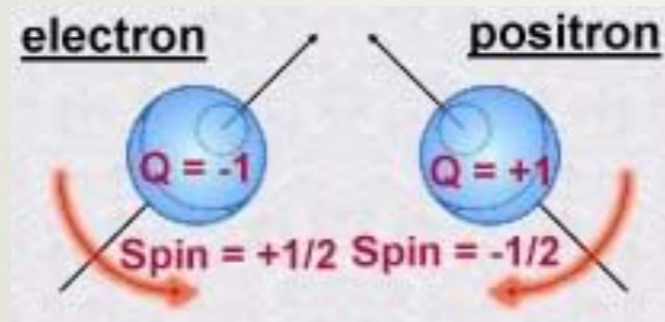
쿼크 (핵자)



중성미자



반입자 (anti-particle)



불확정성의 원리 (Uncertainty Principle)

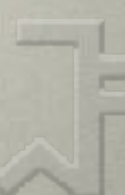
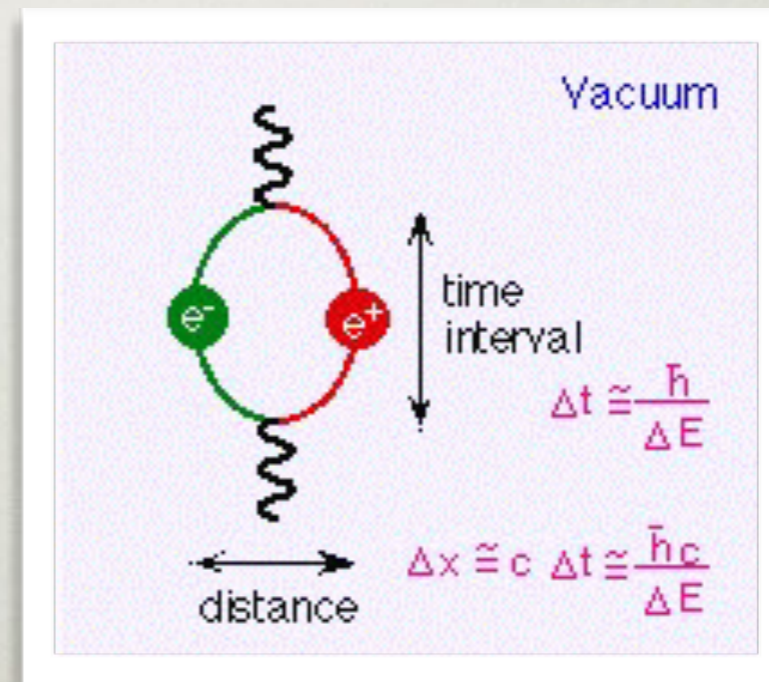


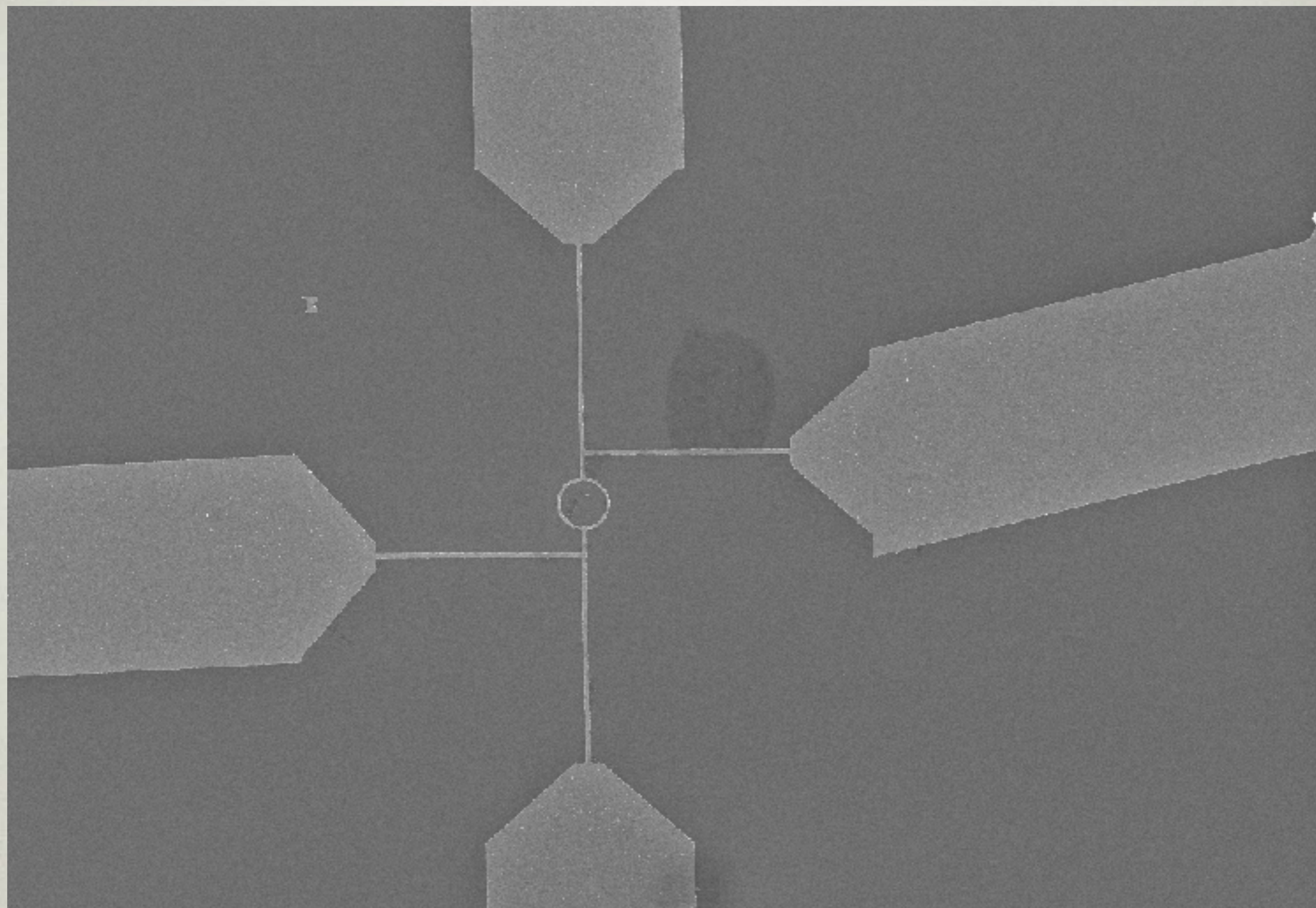
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Heisenberg (1927)

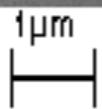
$$\Delta x \Delta p \geq \hbar/2$$

$$\Delta E \Delta t \geq \hbar/2$$





Mag = 10.00 K X

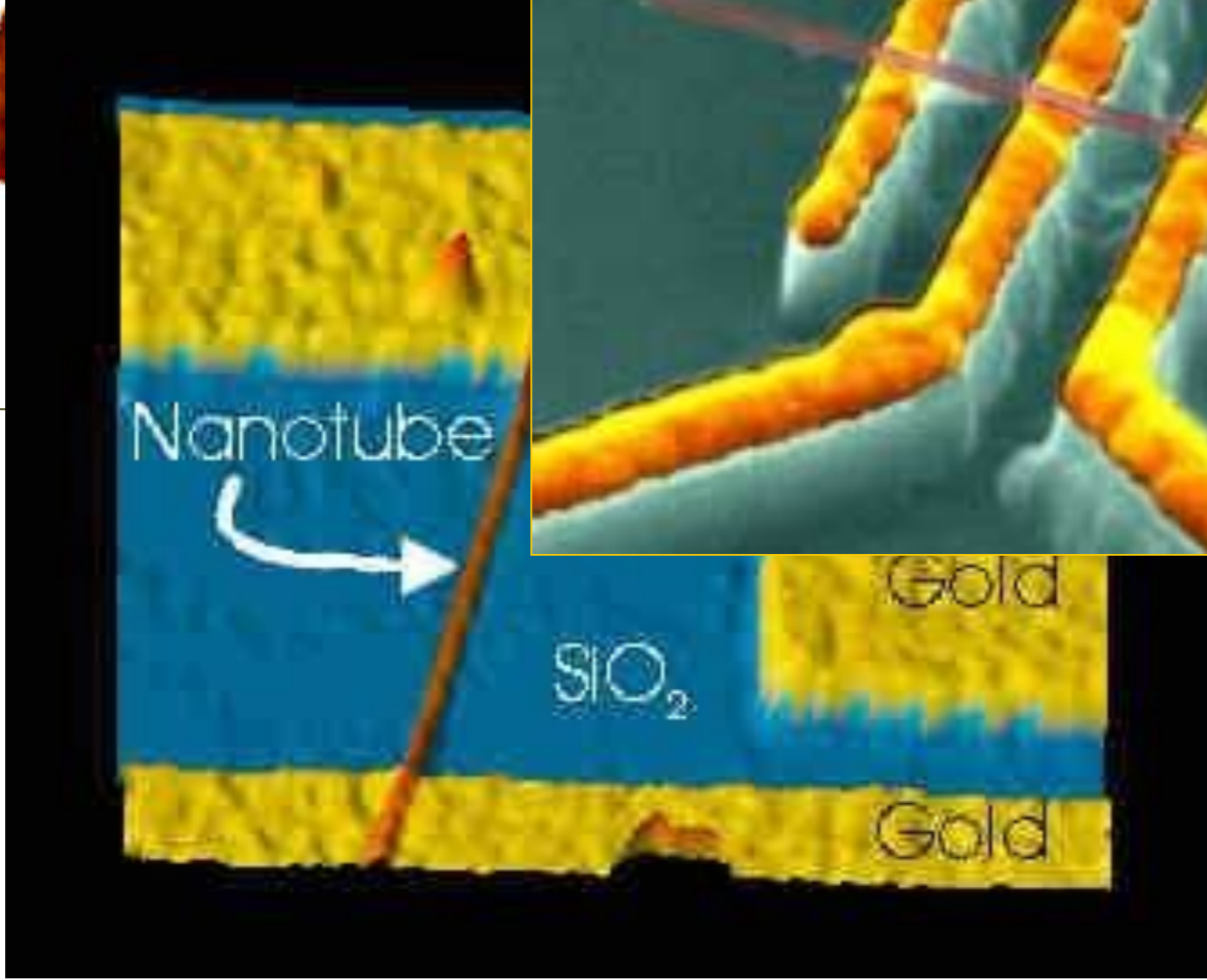
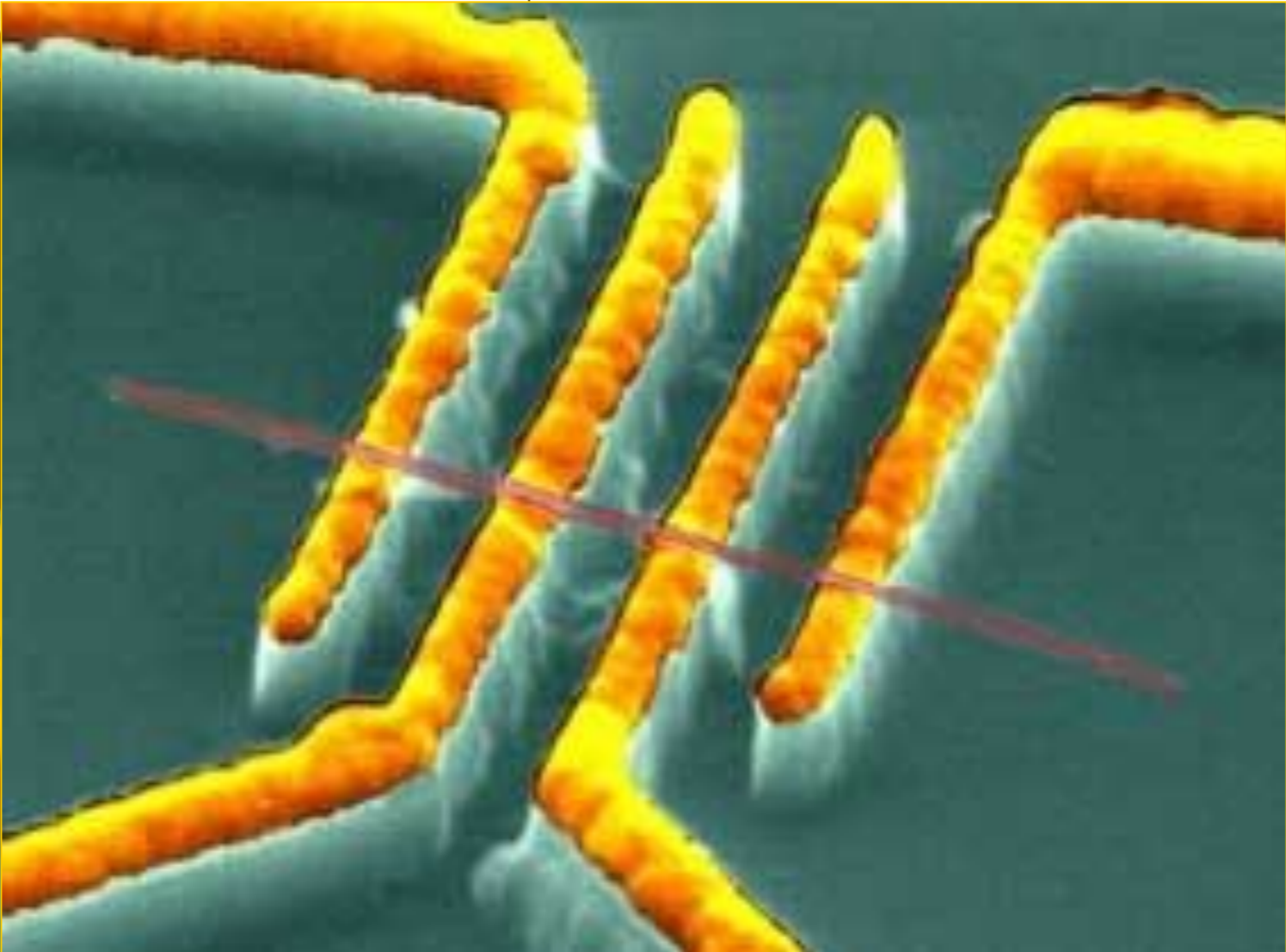
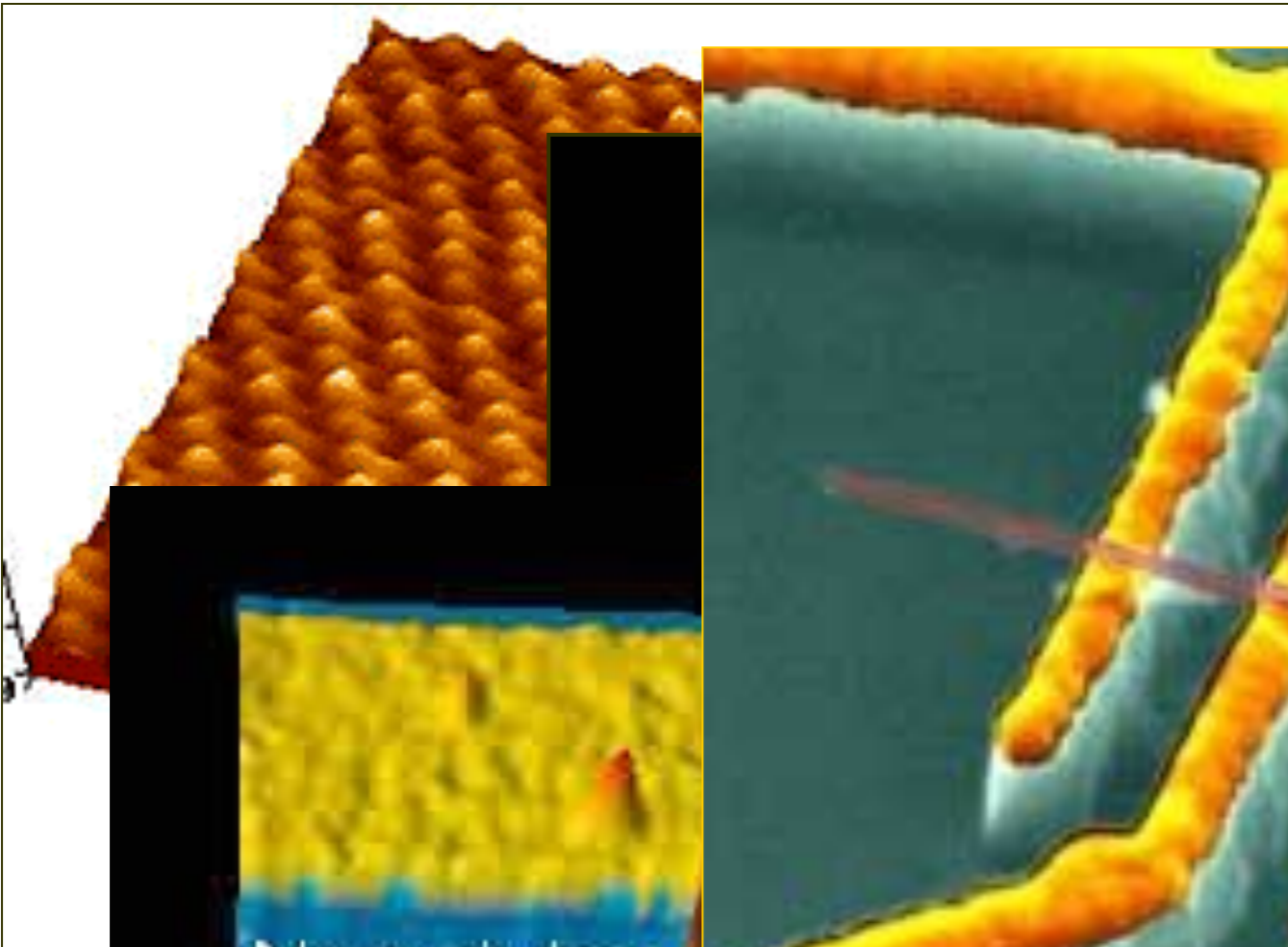


EHT = 10.00 kV
WD = 4 mm

Signal A = InLens
Date :10 Sep 1998

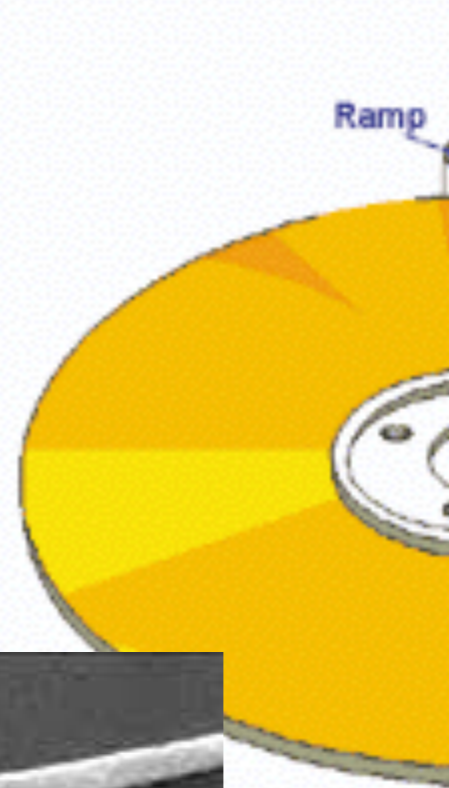
UNI KARLSRUHE LEM:pp







Ramp Load/Unload Technology

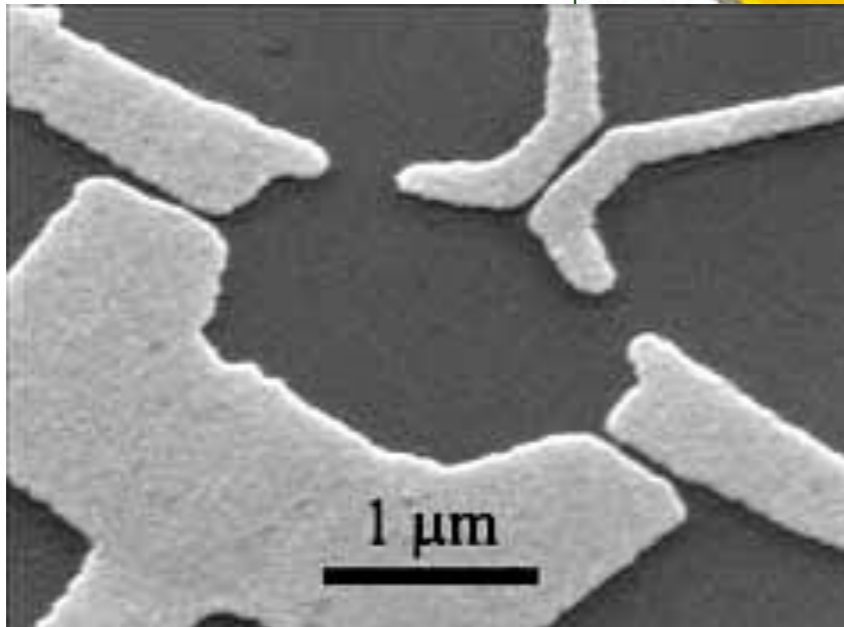
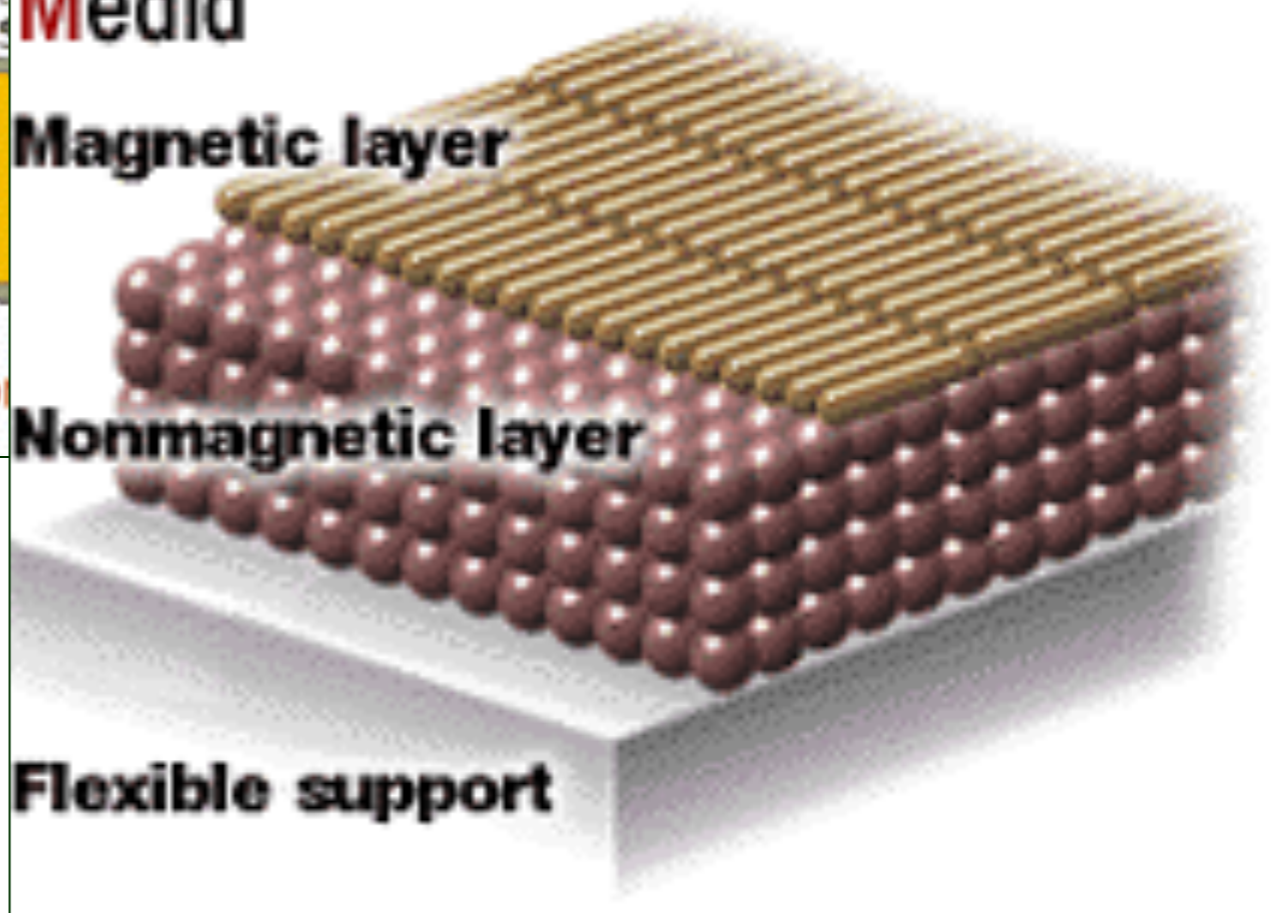


**Advanced super
Thin layer and high-
Output
Metal
Media**

Magnetic layer

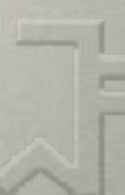
Nonmagnetic layer

Flexible support



**“양자 현상을
원자 크기보다
큰 세계에서는
볼 수 없나요?”**







MRI (Magnetic Resonance Imaging)

