



heute!

Weihnachtskolloquium
des Instituts für Physik
gemeinsam mit dem Doktorandenkolloquium



mit **Glühwein und Stollen**

Am Donnerstag, dem 15. Dezember 2011
spricht um 15 Uhr
im Großen Hörsaal des Instituts für Physik

Dr. Gerhard Knies
DESERTEC Foundation, Hamburg

zu dem Thema

***DESERTEC – Wüstenstrom für eine
lebenswerte Welt mit 10 Milliarden Menschen***

Die Menschheit steuert auf die 10 Milliarden zu, doch schon 5 Milliarden Menschen haben die Versorgungskapazität der Erde überzogen. Der Schlüssel für ein umweltverträgliches und dauerhaftes Versorgungssystem mit Land, Nahrung, Wasser und Zivilisation ist mehr Energie.

Die fossilen Energien sind Chemiewaffen gegen die Lebensbedingungen kommender Generationen und müssen aus dem Markt genommen werden. Die Erneuerbaren Energien dagegen sind sauber, sicher, schadfrei, und satt vorhanden. Insbesondere die Ressource Sonnenenergie der Wüsten erlaubt den zügigen Aufbau einer globalen Energieversorgung ohne Selbstzerstörungsebenenwirkungen. Die Technologien sind vorhanden, doch die nationalstaatliche Selbstorganisation der Menschheit blockiert die Lösung des globalen Klimaproblems. Der Vortrag erläutert, wie das DESERTEC Konzept einen Ausweg eröffnet.

lecture 15.12.2011

we had so far:

- correlated processes in photoionization

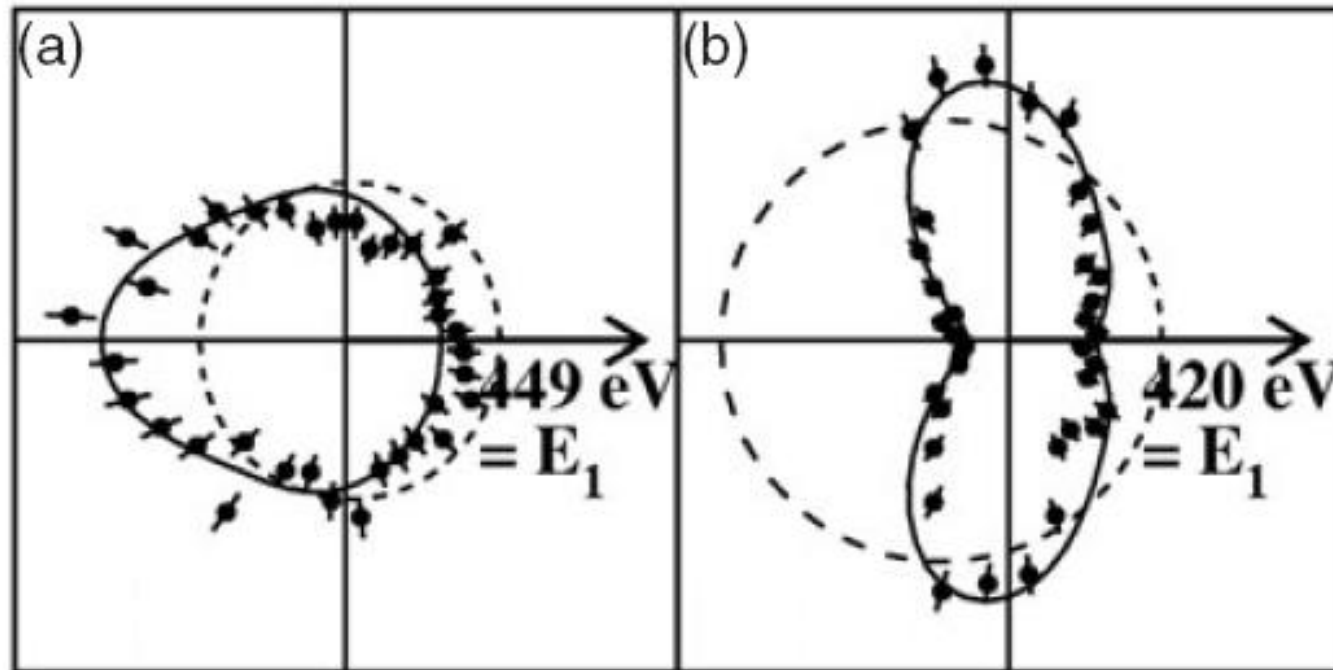
now: cluster physics

- cluster production
- detection by mass spectroscopy and microscopy

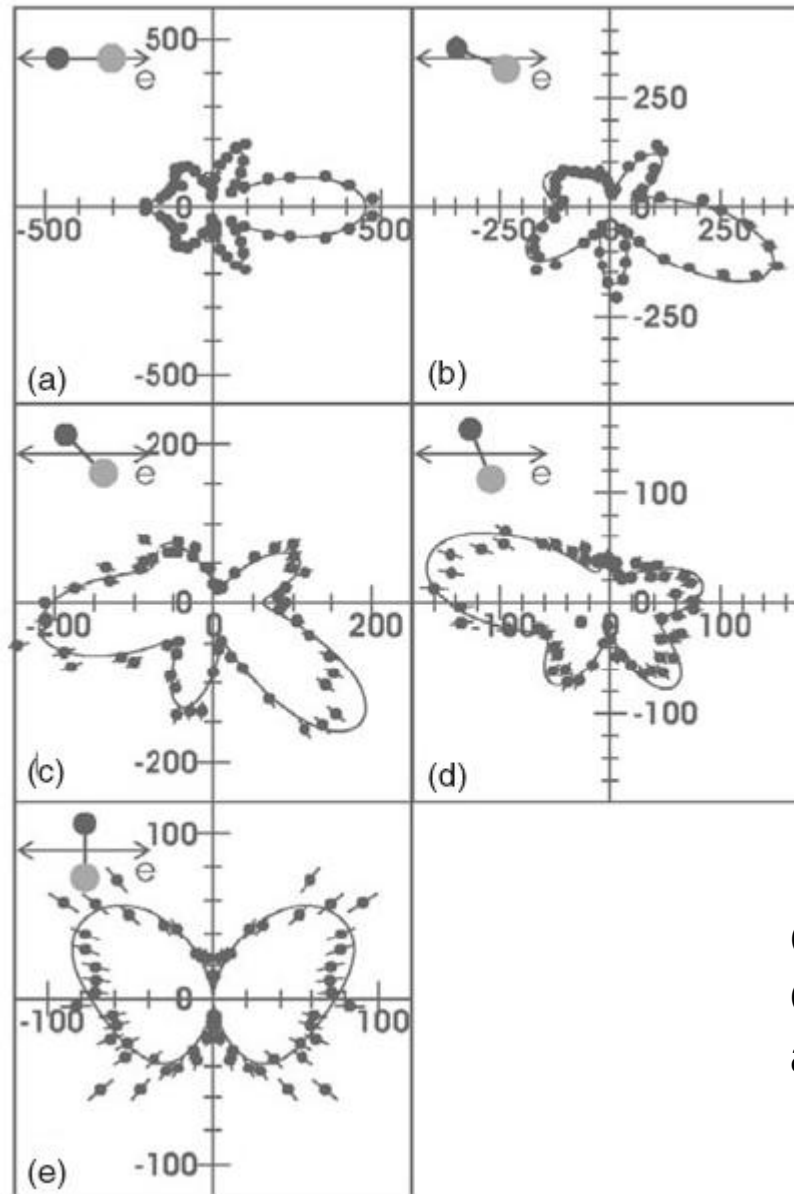
He photo double ionization at 529 eV photon energy

Arrow: direction of electron 1 (with given energy)

symbols: emission of electron 2 (at 2 eV, left, and 30 eV)



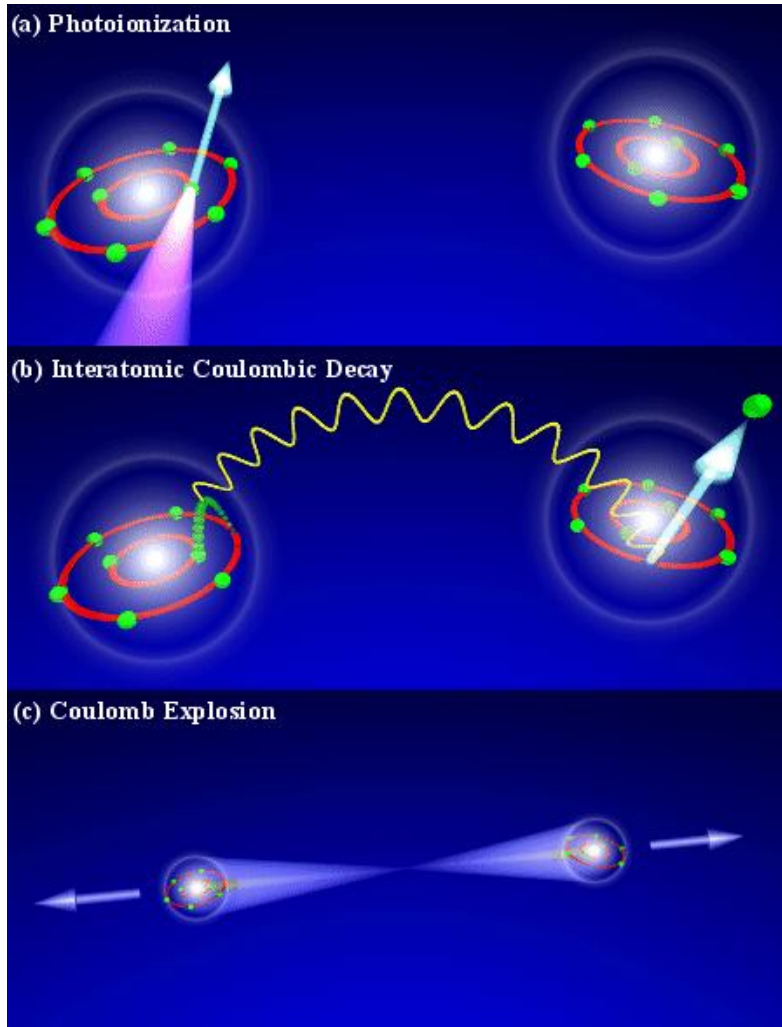
Carbon k-shell photoelectrons from CO at 10 eV energy



C : black
O: grey
arrow: light polarization

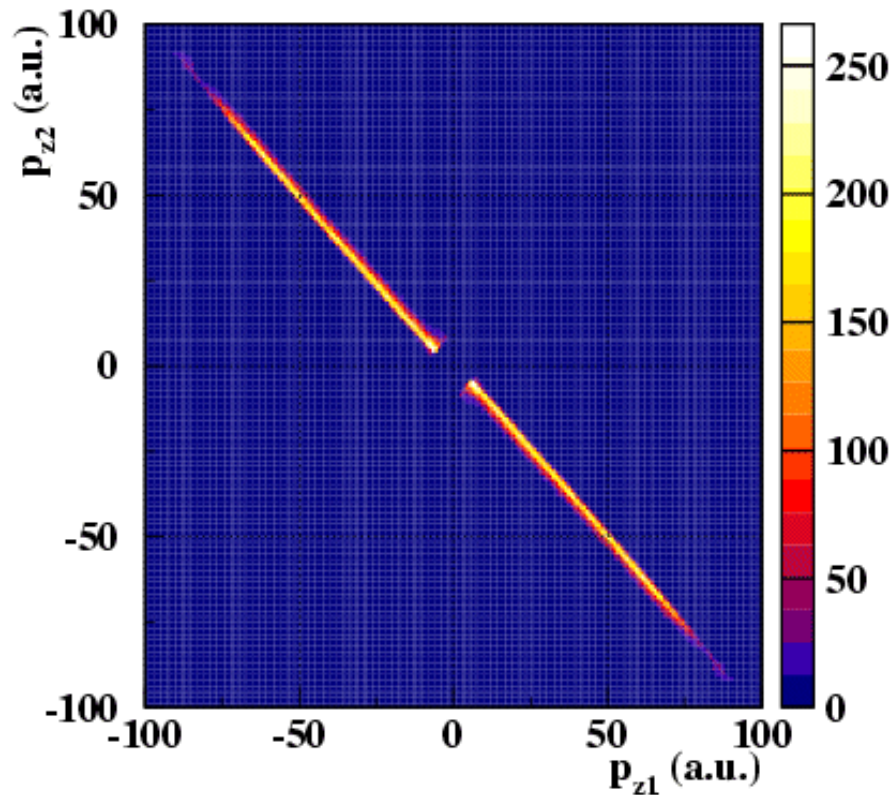
Interatomic Coulombic Decay (ICD) in Neon Dimers

well known: Auger emission, which is always from the same atom (1925)
new effect: Auger-like electron can come from a neighboring atom (1997)



- a) Creation of a 2s hole in a neon dimer by photoionization
- b) Successive Interatomic Coulombic Decay: the 2s hole is filled by a 2p electron, the excess energy is transferred to the neighboring neon atom causing the ejection of one of its 2p electrons.
- c) Back-to-back emission of the fragments after **Coulomb explosion** of the Ne-dimer

momenta of the emitted particles are measured in coincidence

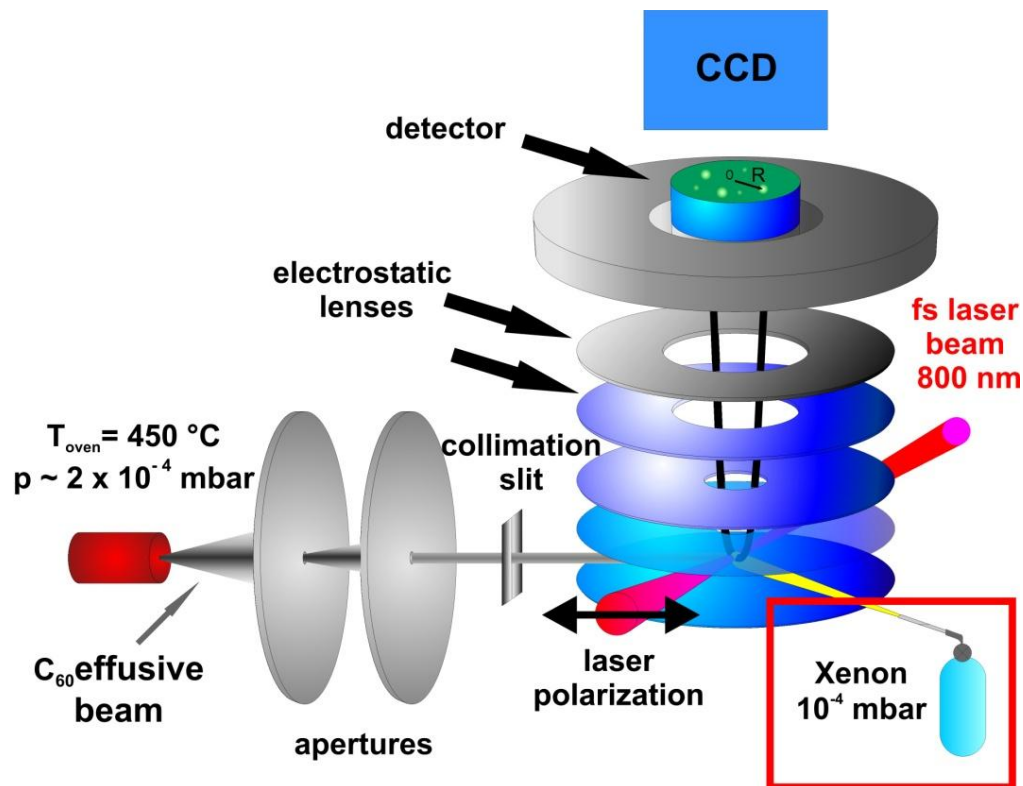
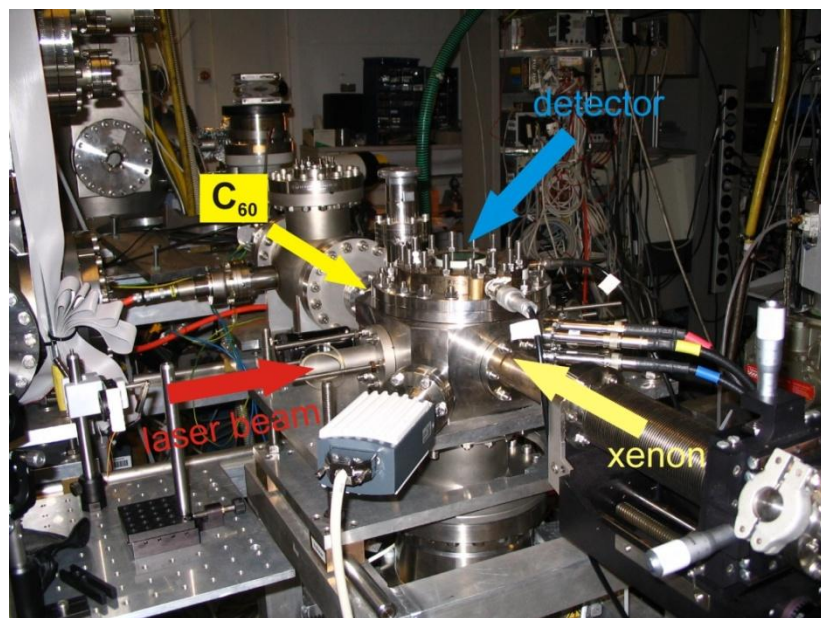


Coincidentally measured momenta of the two Ne1+ ions. The events are found along a diagonal line $p_{z1} = -p_{z2}$, where $p_{z1;2}$ is the momentum component of ion 1 and 2. This proves directly that the two ions result from a Coulomb explosion of a dimer, i.e. it unambiguously identifies step (c)

last method: velocity map imaging spectrometer VMI

work by Slawomir Skruszewicz

Instrumental resolution $\Delta E_{\text{instr.}} / E = 0.07$ at 1 eV



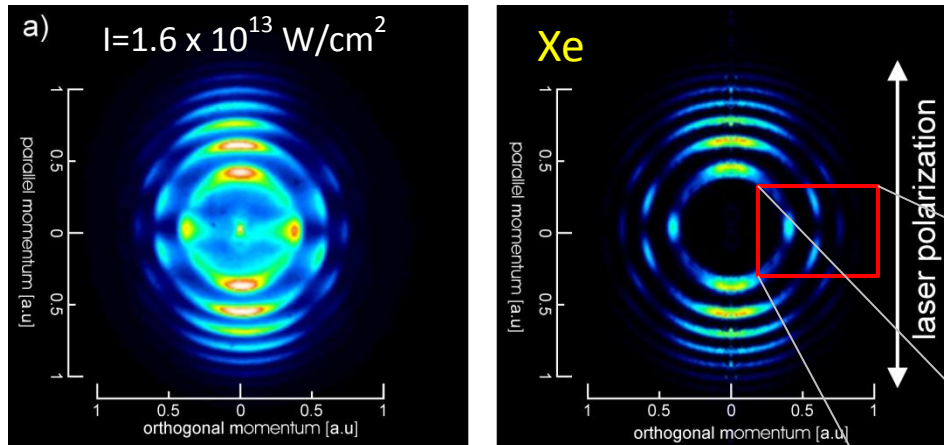
Laser parameters:

$$\lambda = 800 \text{ nm}, \tau_{\text{pulse}} = 80 \text{ fs},$$
$$\Delta E_{\text{laser}} = 70 \text{ meV}$$
$$I = 10^{12} \dots 10^{14} \text{ W/cm}^2$$

- brightness $\Rightarrow$ photoelectron yield
- spot position R $\Rightarrow$ photoelectron momentum
- adjustable kinetic energy detection range

above-threshold ionization in Xenon atoms

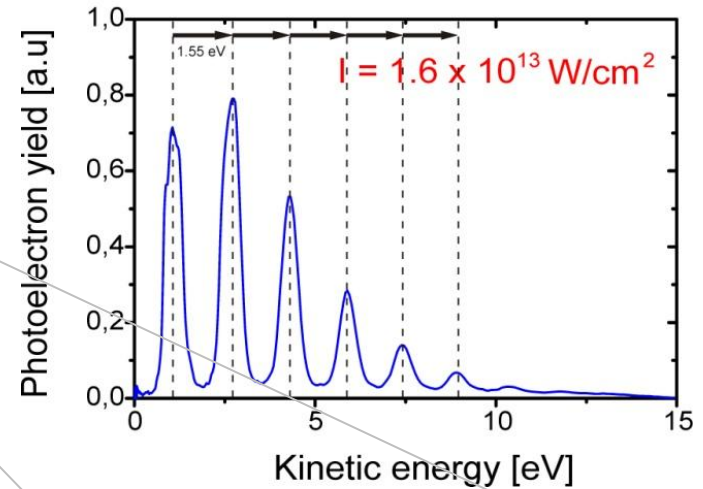
Imaging Spectra



raw

deconvoluted by an
onion peeling algorithm

Angle-Integrated Spectra



Energy spectrum shows signatures of above threshold ionization

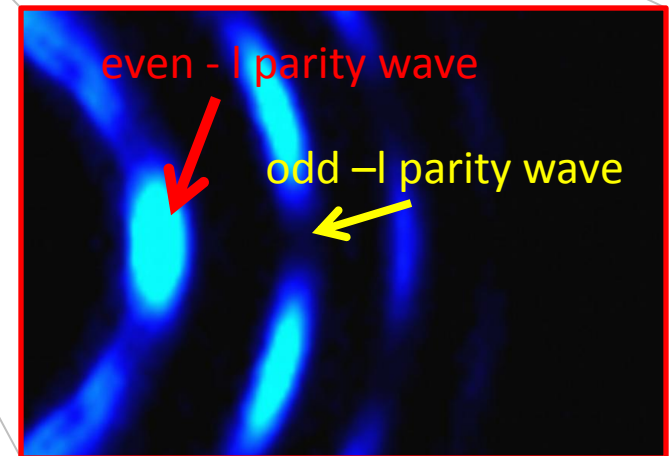
Peaks are spaced by photon energy

Rich structure in **angular-resolved spectrum**

Enhanced emission in direction of laser polarization axis

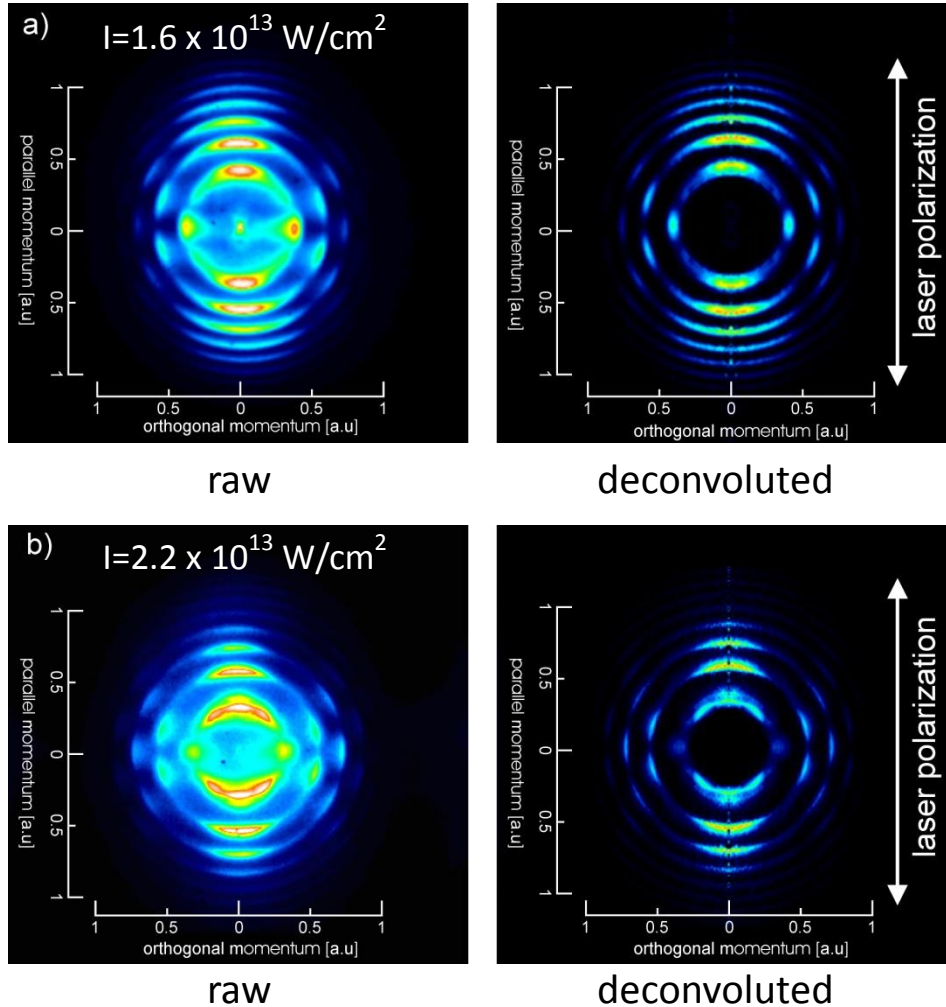
Each ring has own fingerprint

Change in parity of outgoing electron wave

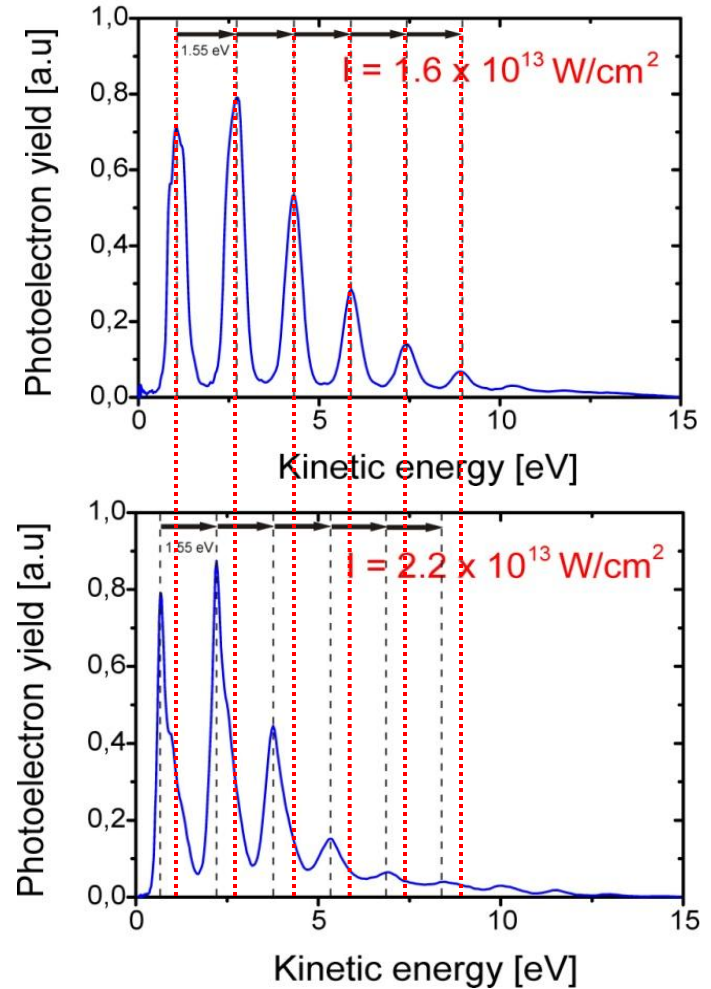


above-threshold ionization in Xenon

Imaging Spectra



Angle-Integrated Spectra

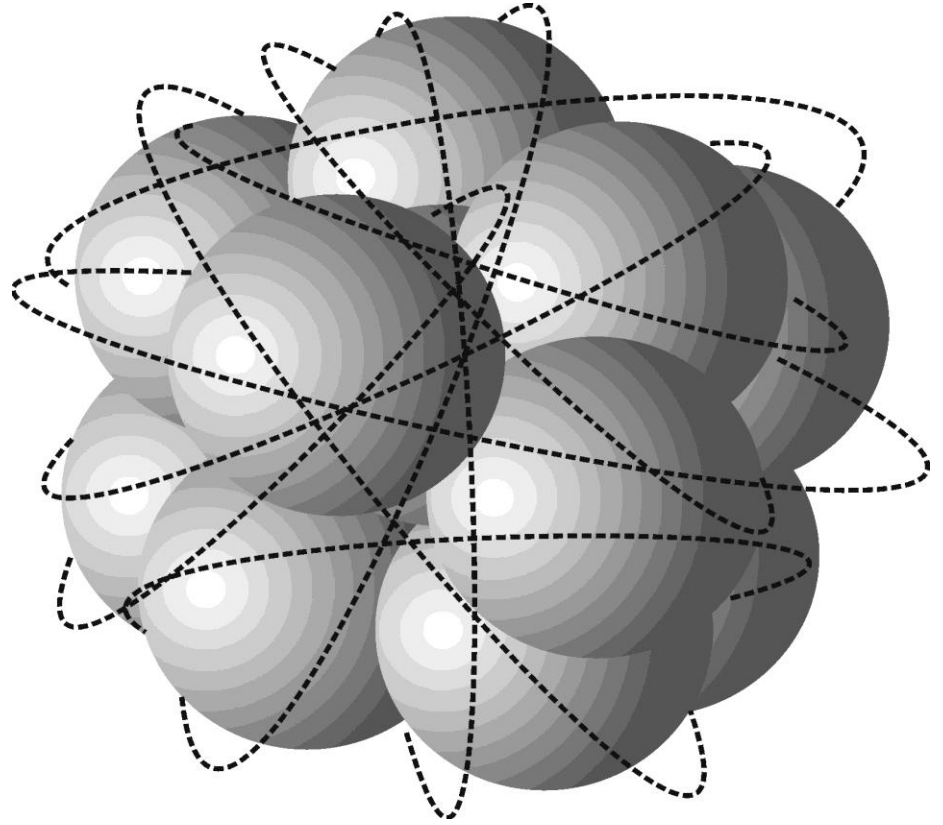


Peak position changes as function of laser intensity

really the end of atomic physics

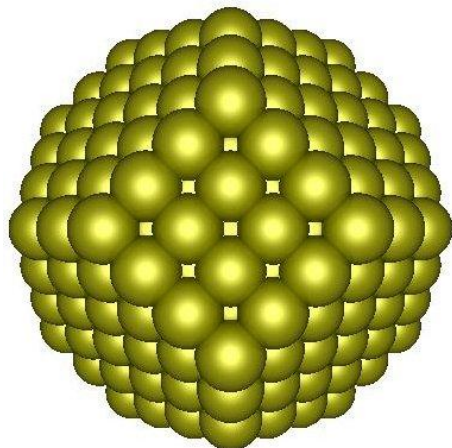
now: cluster physics

in some respect
clusters can be considered
as giant atoms

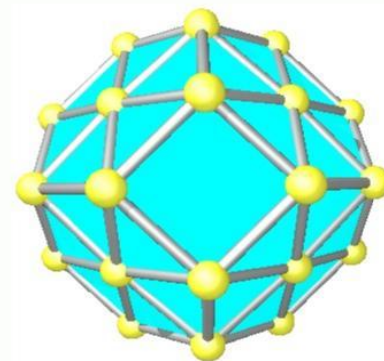
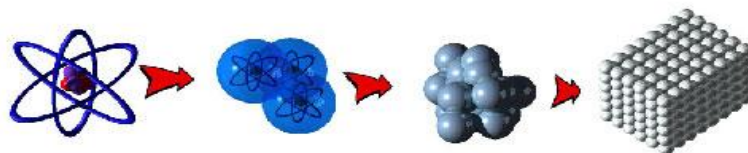


Introduction – What is a cluster ?

Clusters – Intermediate range between atoms and bulk matter



Aggregates of $2\text{--}10^n$ particles
($n \rightarrow 6$ or 7)

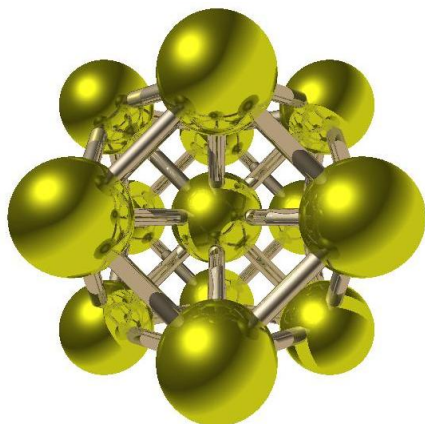


Cluster Size	N	Diameter / nm(Na_N)
Small	$\leq 10^2$	≤ 1.9
Medium	$10^2\text{--}10^4$	$1.9\text{--}8.6$
Large	$> 10^4$	> 8.6

Types of Clusters - 1

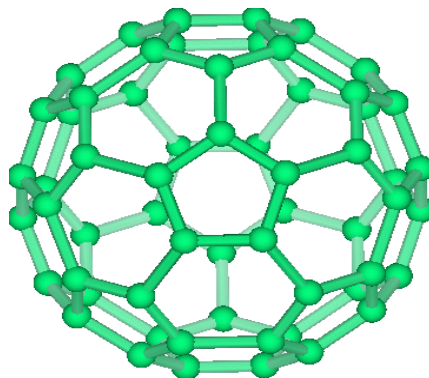
Based on the type of constituent particles & type of bonding

Metal Clusters



S block – Metallic bond
(e.g. alkali & alkaline earth)
SP metals – Covalent bond
(e.g. Al)

Semiconductor Clusters



Bonding – **Covalent**
e.g. C, Si & Ge

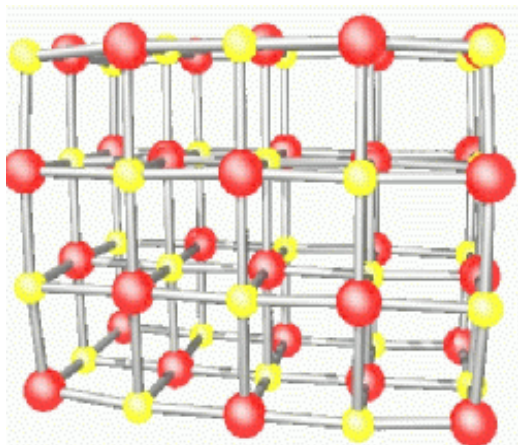
Rare gas Clusters



Bonding - **Van der Waals**
Inter-atomic attraction
increases with increasing
atomic mass (**He→Rn**).

Types of Clusters - 2

Ionic Clusters

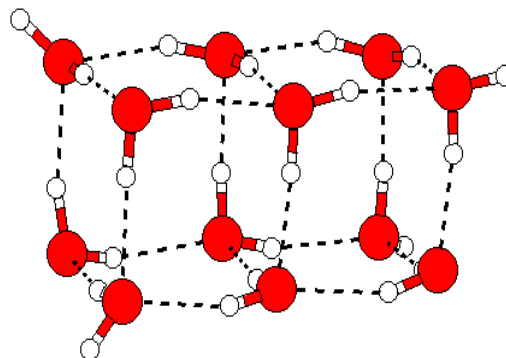


atoms with large difference
in electronegativity

Bonding – **Ionic**

e.g. $(\text{NaCl})_n$, $[\text{Mg}_x\text{O}_y]^{2(x-y)+}$

Molecular Clusters

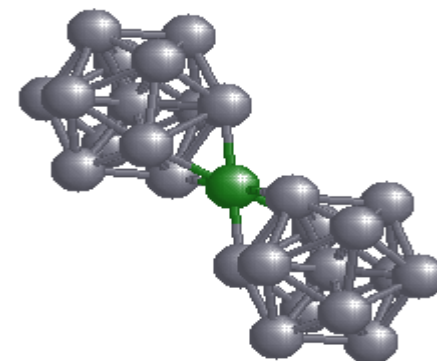


van der Waals,

dipole-dipole interactions,
and hydrogen bonding

e.g. $(\text{N}_2)_n$, $(\text{C}_6\text{H}_6)_n$, $(\text{H}_2\text{O})_n$

Cluster molecules

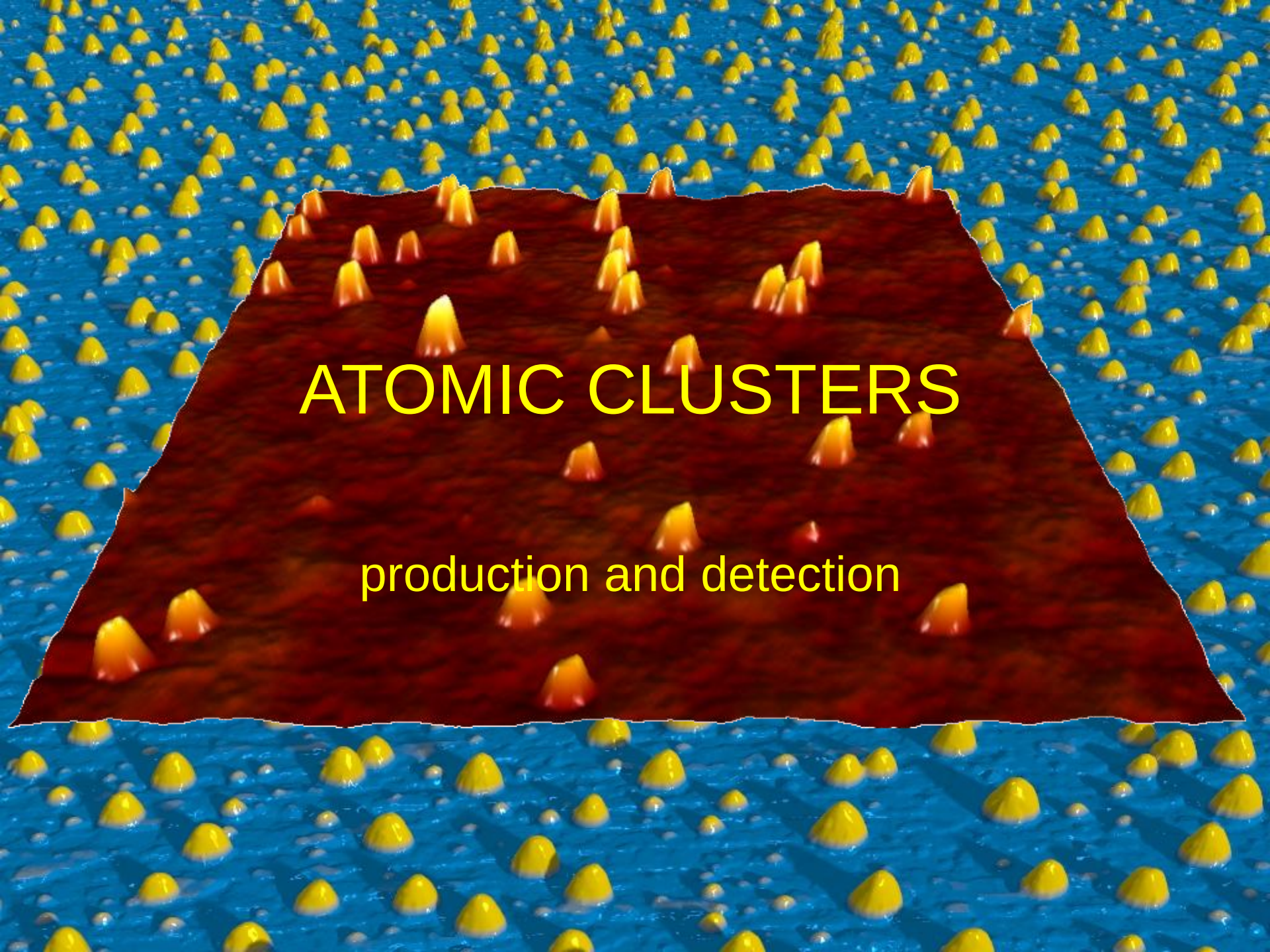


thermodynamically
and/or kinetically
stable with respect
to coalescence
e.g. $\text{Al}_{13}\text{MgAl}_{13}$

examples of binding strenghts

Table 2.1. Classification of clusters according to their binding [Jortner (1984)]

Cluster type	Type of binding	Binding energy [eV]	Examples
van der Waals	Dispersive forces	≤ 0.3	$(\text{Ar})_N$, $(\text{N}_2)_N$, $(\text{CO}_2)_N$
Molecular	Dispersive forces, weak electrostatic forces	$0.3 - 1$	$(\text{org.molecules})_N$, $(\text{I}_2)_N$
Hydrogen-bonded	Intermolecular hydrogen bridges	$0.3 - 0.5$	$(\text{HF})_N$, $(\text{H}_2\text{O})_N$
Ionic	Heteropolar bonding	$2 - 4$	$(\text{NaCl})_N$, $(\text{CaF}_2)_N$
Valence	Covalent bonding	$1 - 4$	C_N , S_8 , As_4
Metal	Metallic bonding	$0.5 - 3$	Na_N , Al_N , Cu_N , W_N

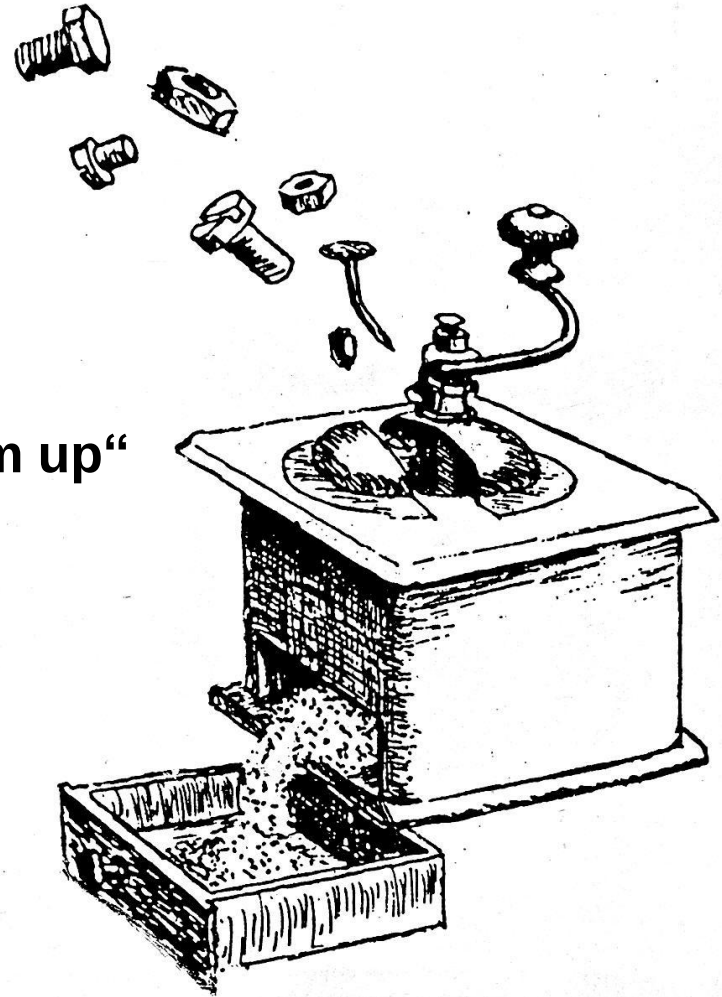


ATOMIC CLUSTERS

production and detection

nanofabrication

- big → small: „top down“
- atoms → nanostructures: „bottom up“



cluster production by atom condensation:

a) cooling a gas by adiabatic expansion

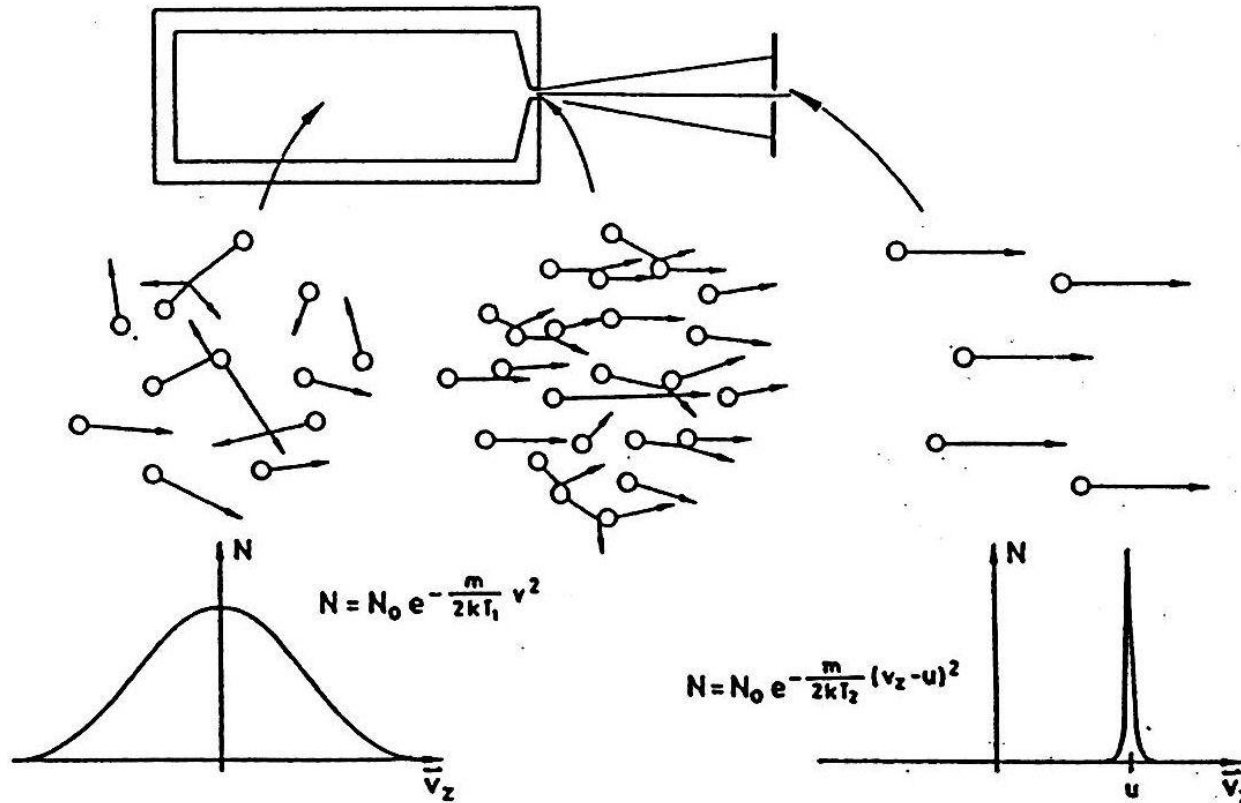
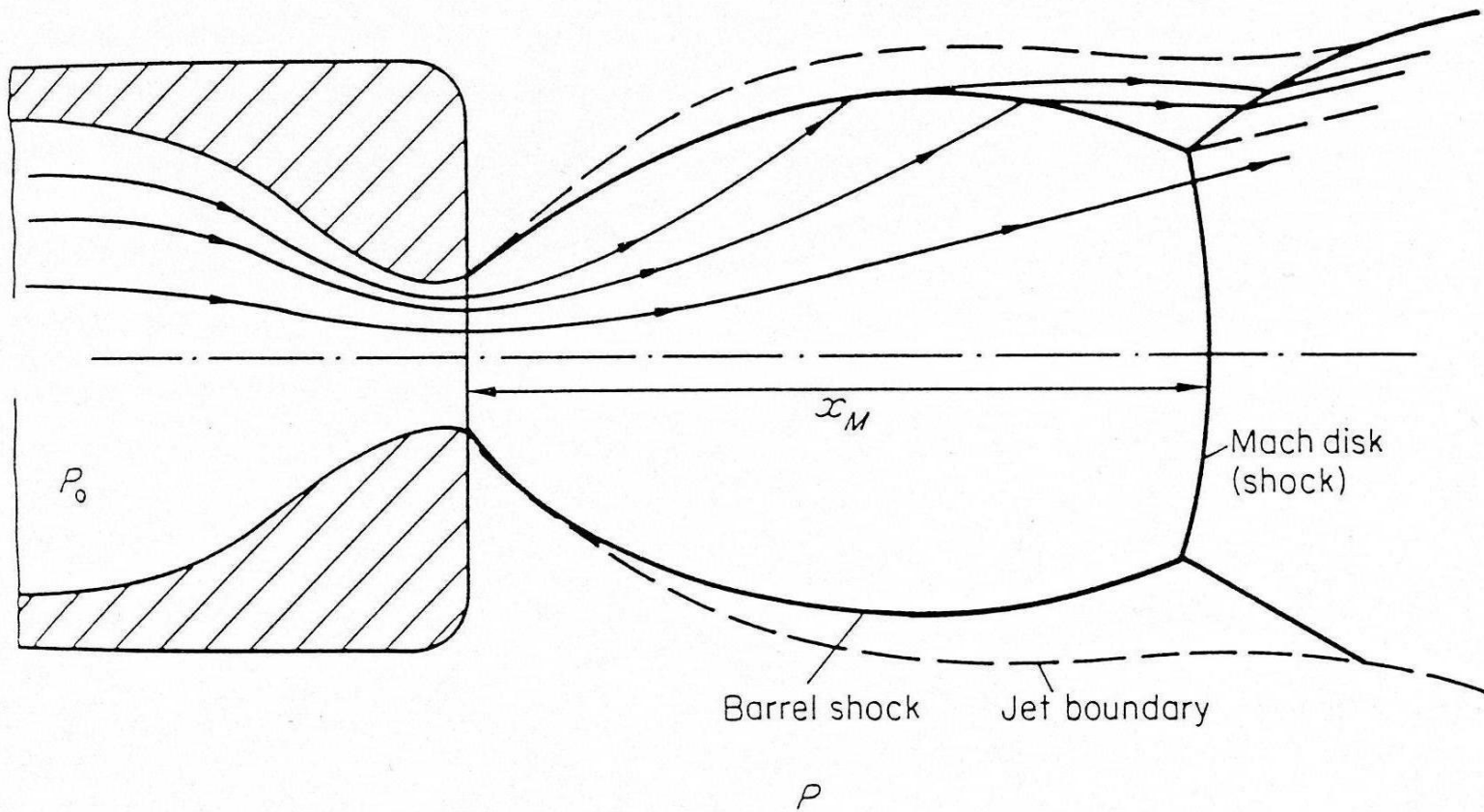
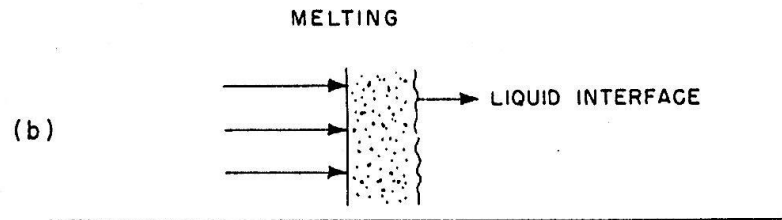
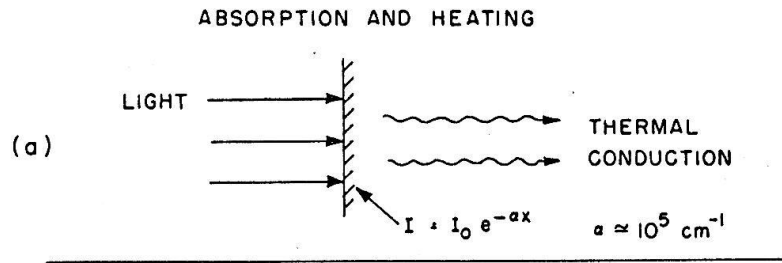


Fig. 8: Die mikroskopische Ursache für die Temperaturerniedrigung und Clusterbildung bei der adiabatischen Expansion [13]. Im Ausgangsbehälter herrscht vor der Expansion thermisches Gleichgewicht. Die ungerichtete Geschwindigkeitsverteilung der Teilchen ist durch die Maxwellverteilung bestimmt. Bei der Expansion des Gases durch eine Düse kommt es durch Stöße mit den anderen Gasparkeln zu Abnahme der inneren Energie zu Gunsten der Expansionsgeschwindigkeit u . Die Relativgeschwindigkeit im kalten Molekularstrahl nimmt stark ab, wodurch die "kalten" Atome zu Clustern zusammenlagern.

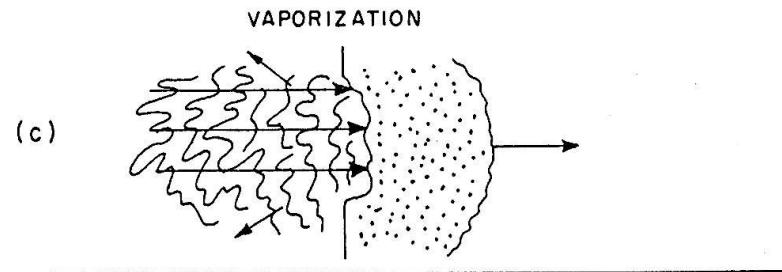
Supersonic jet expansion



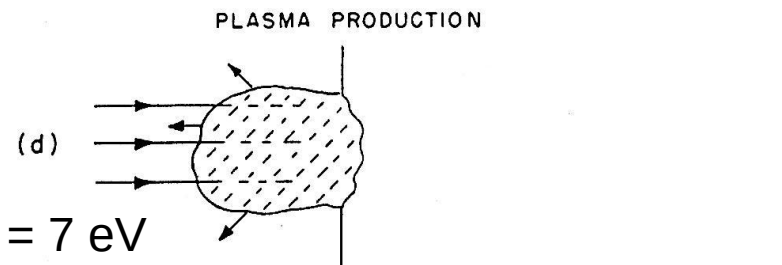
b) laser vaporization followed by expansion



10^5 W/cm^2



$10^6\text{-}10^8 \text{ W/cm}^2$

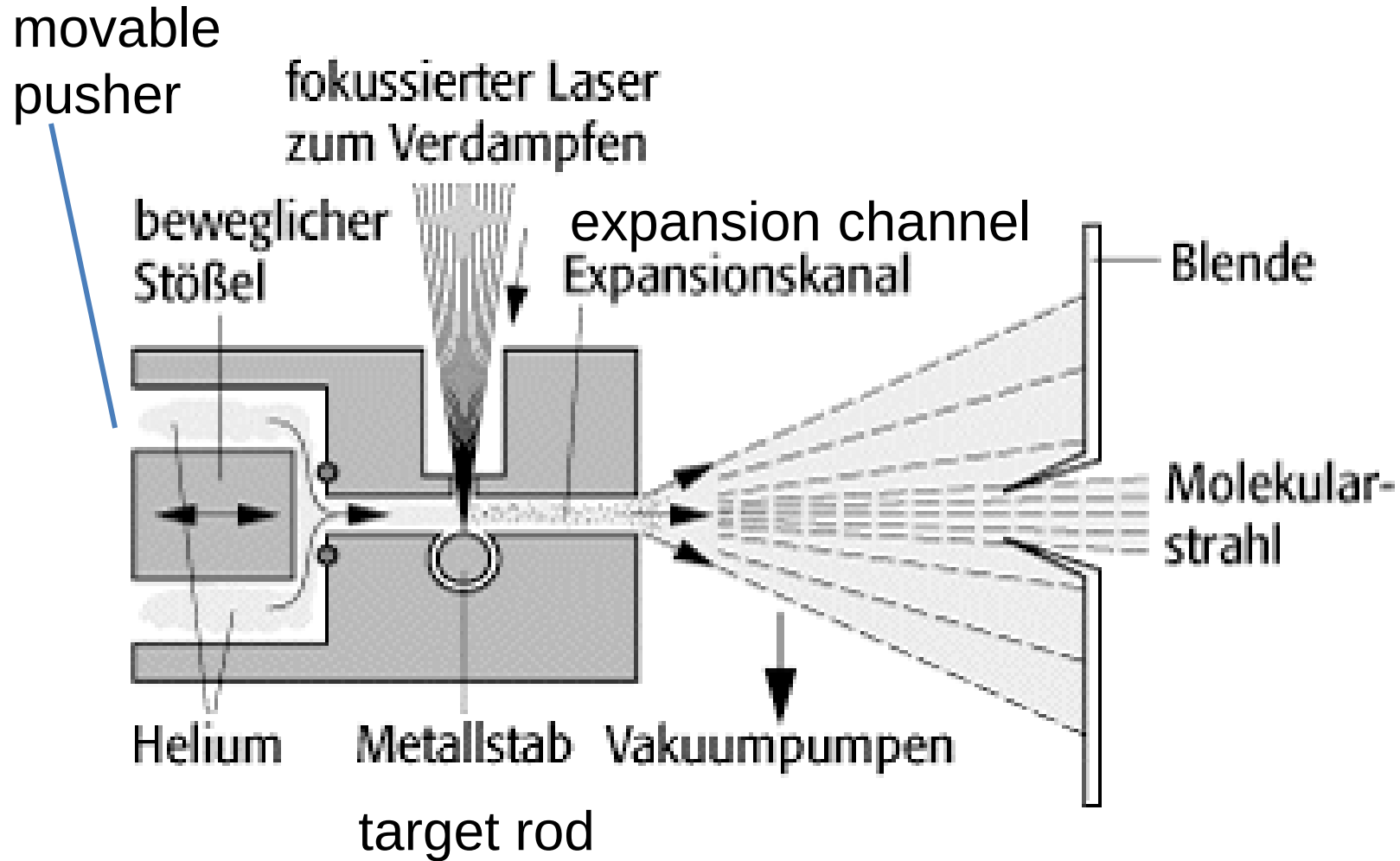


over 10^8 W/cm^2

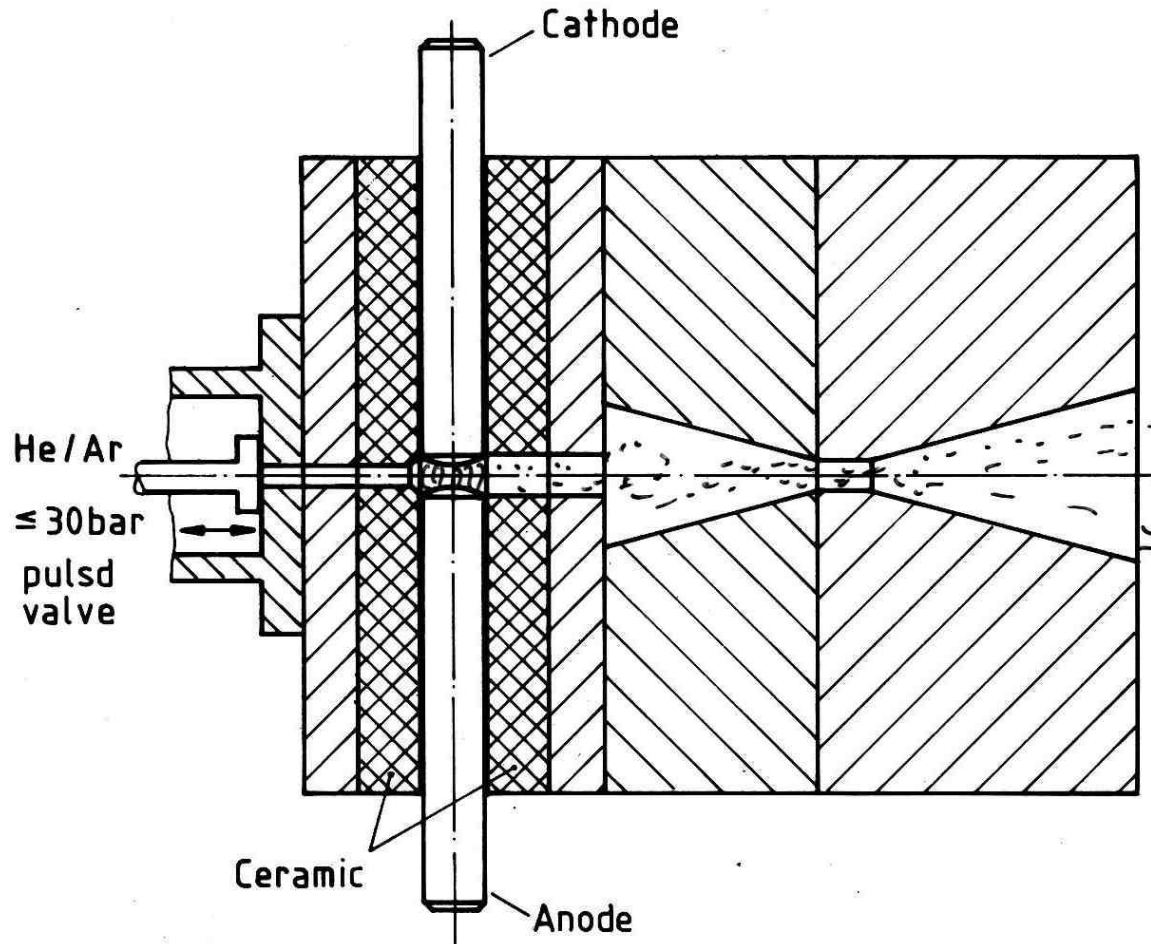
$$E_{\text{kin}} (\text{Cu}^+) = 7 \text{ eV}$$

Fig. 13-13 Schematic diagrams of physical processes occurring when a high-power laser beam strikes an absorbing surface.

Laser vaporization cluster source



c) plasma generation by an arc discharge: the pulsed arc cluster source PACIS

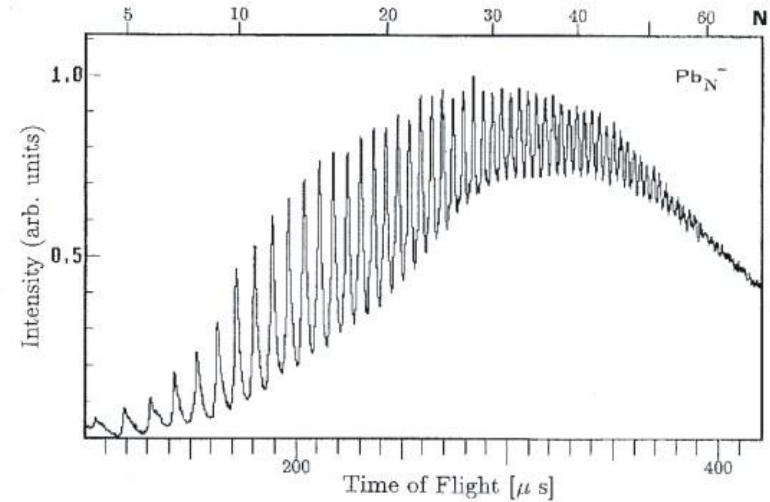


the arc has to burn in the metal and not in the seeding gas

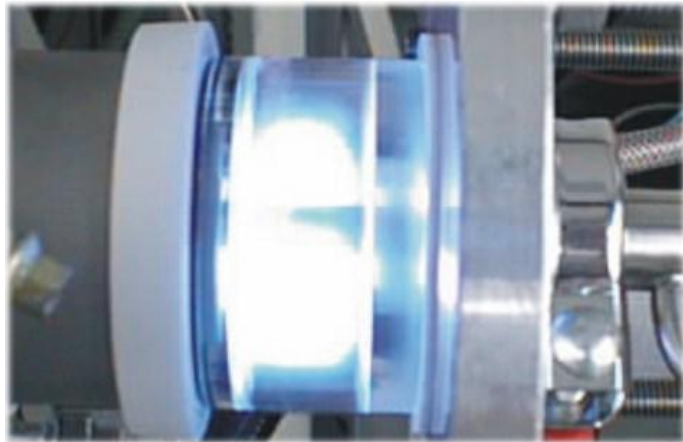
PACIS



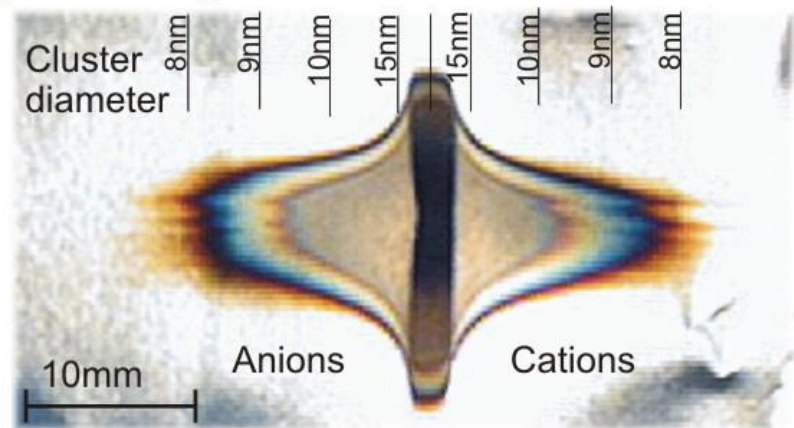
Siekmann/Ganteför



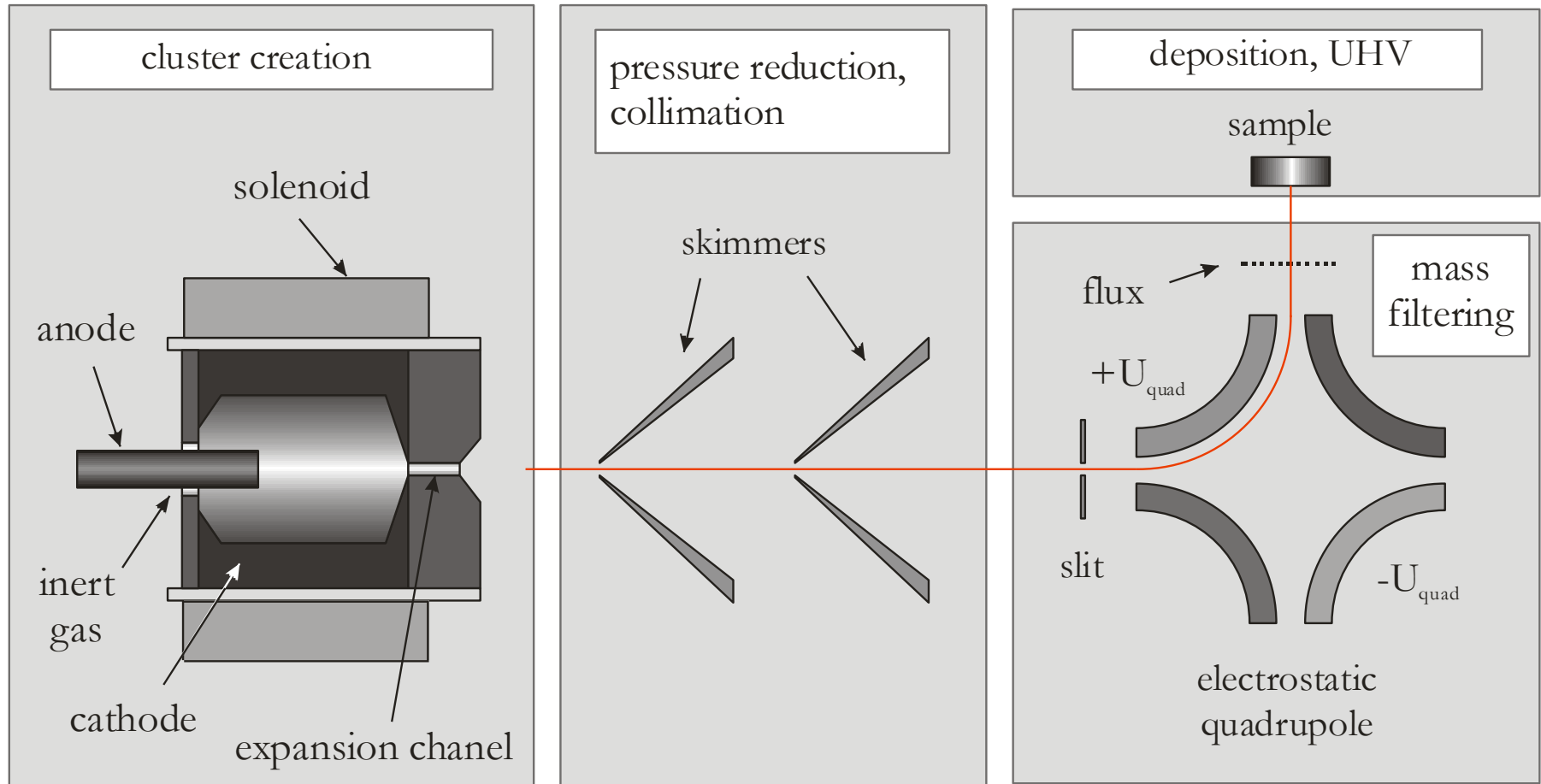
Arc cluster ion source (ACIS)



Klinkenberg/Mayer



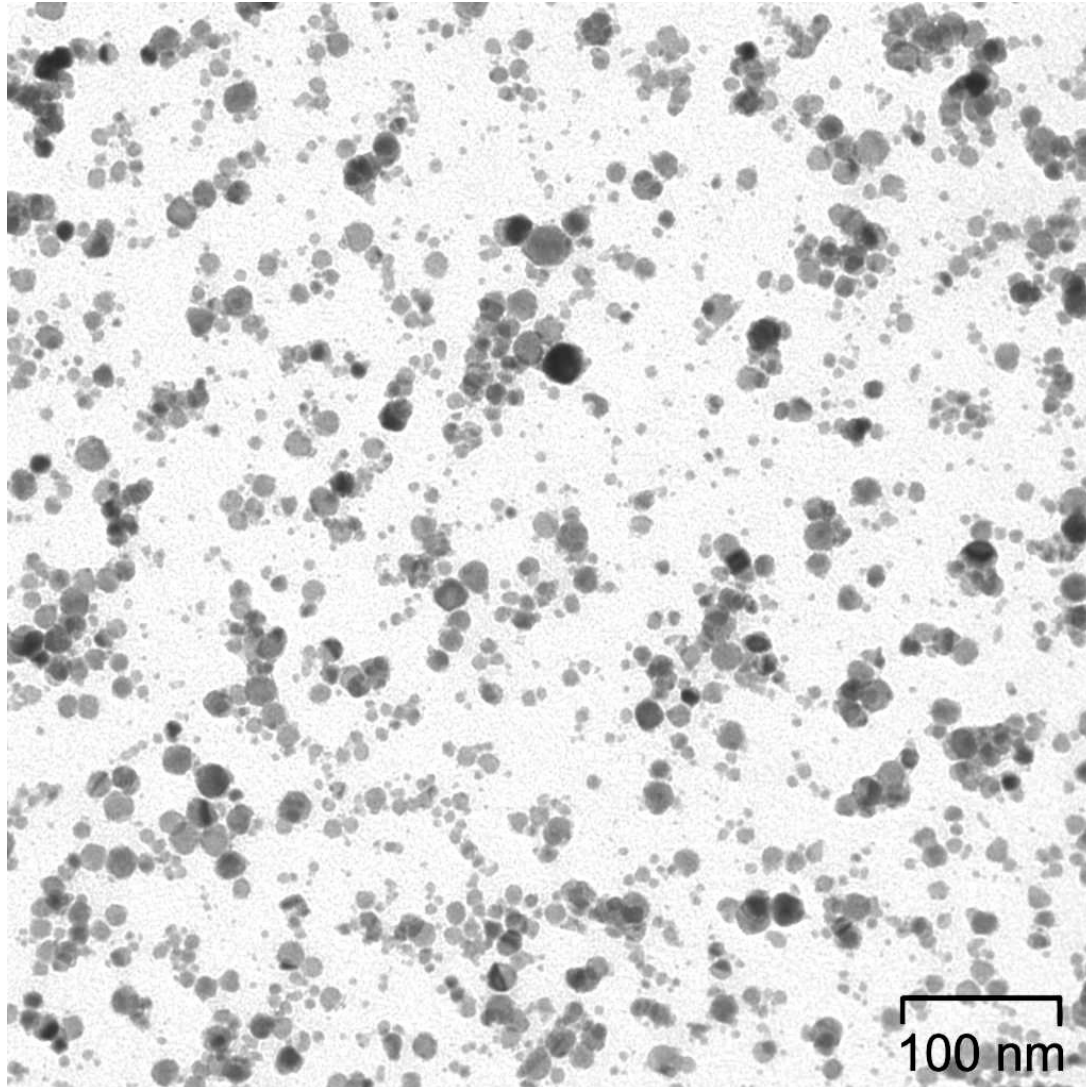
Arc Cluster Ion Source (ACIS), latest version



Methling et al., EPJD 16, 173 (2001)

Cu_N from the ACIS deposited onto a TEM grid

without mass filter, TEM picture

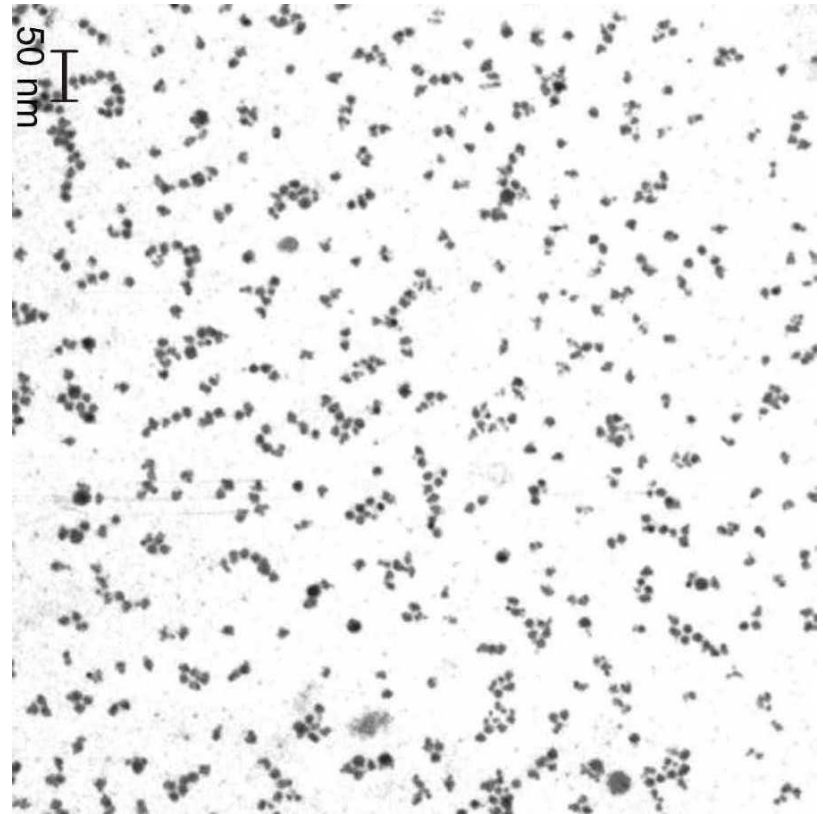
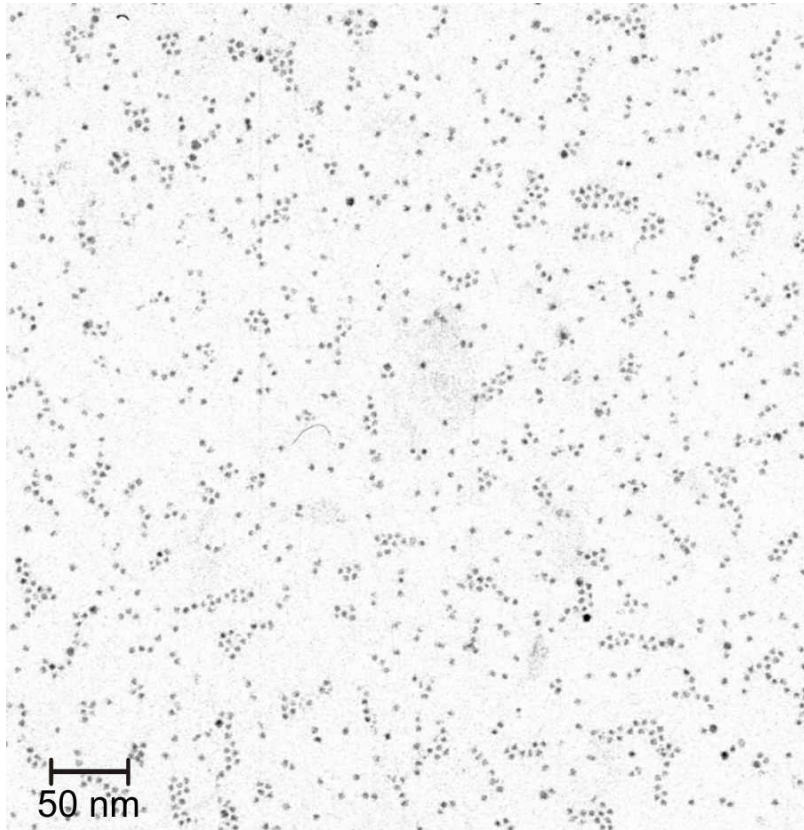


Cu_N from the ACIS

with mass filter

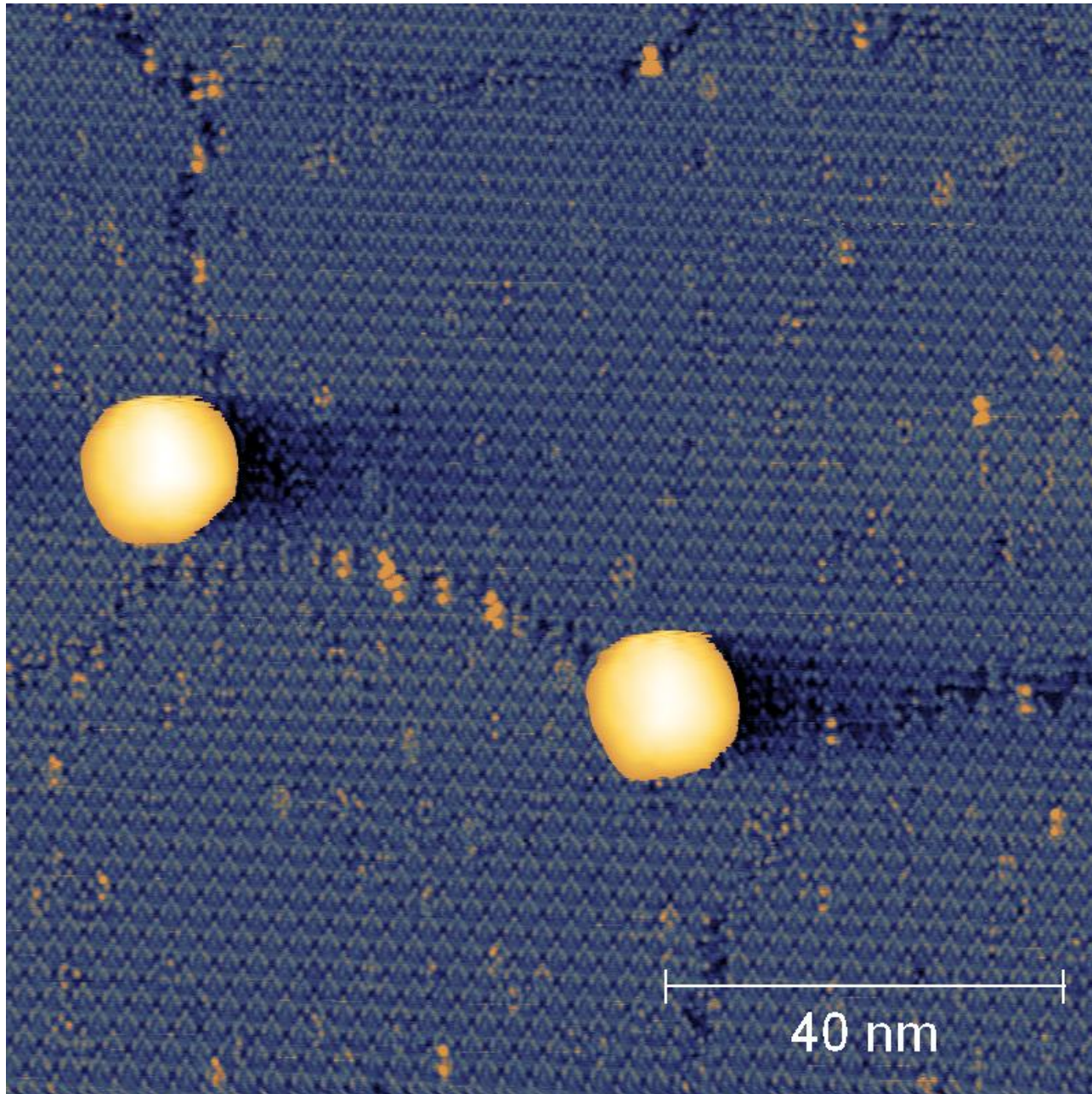
80 V

250 V

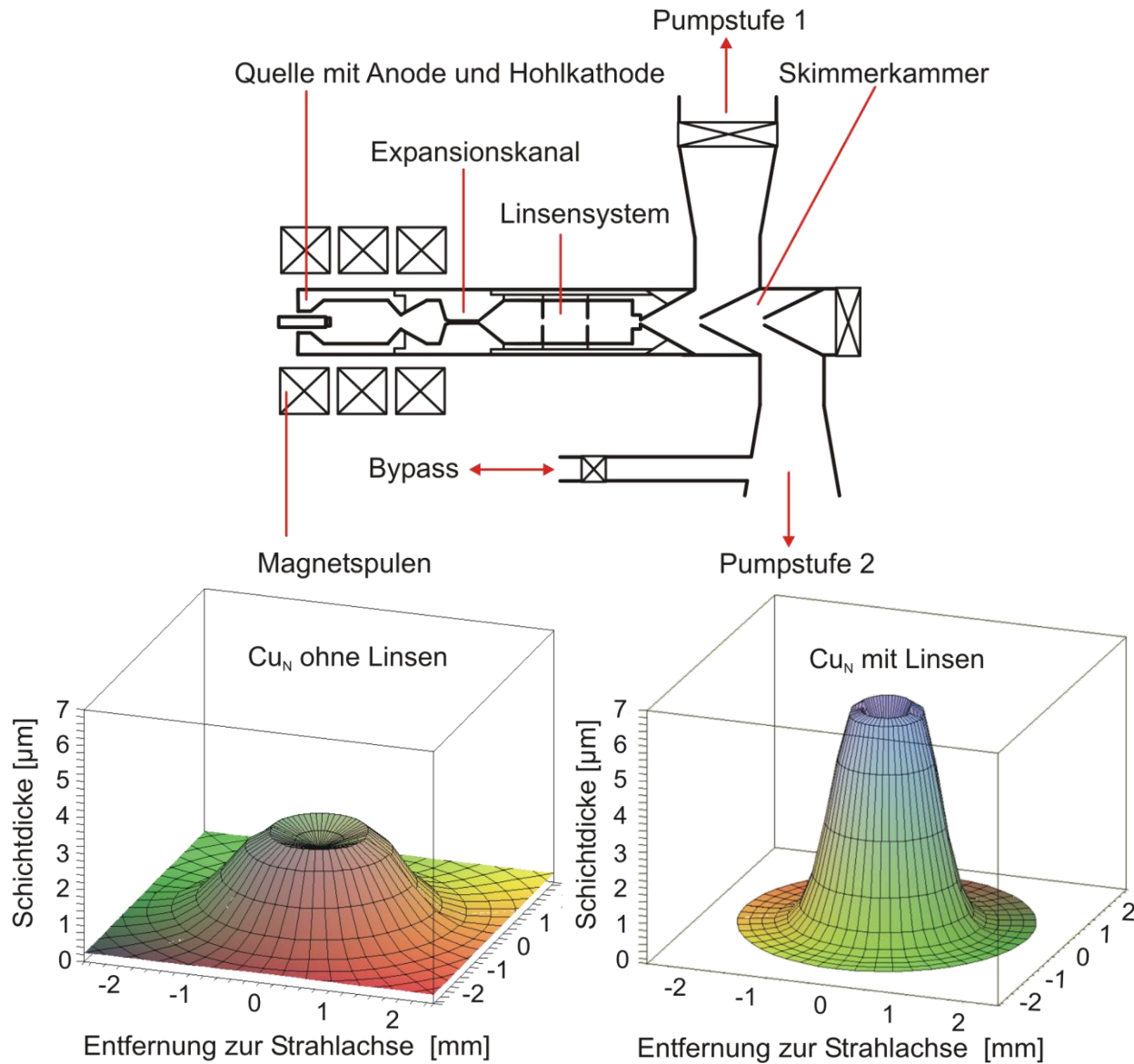


Ag_N on Si (111) from the ACIS

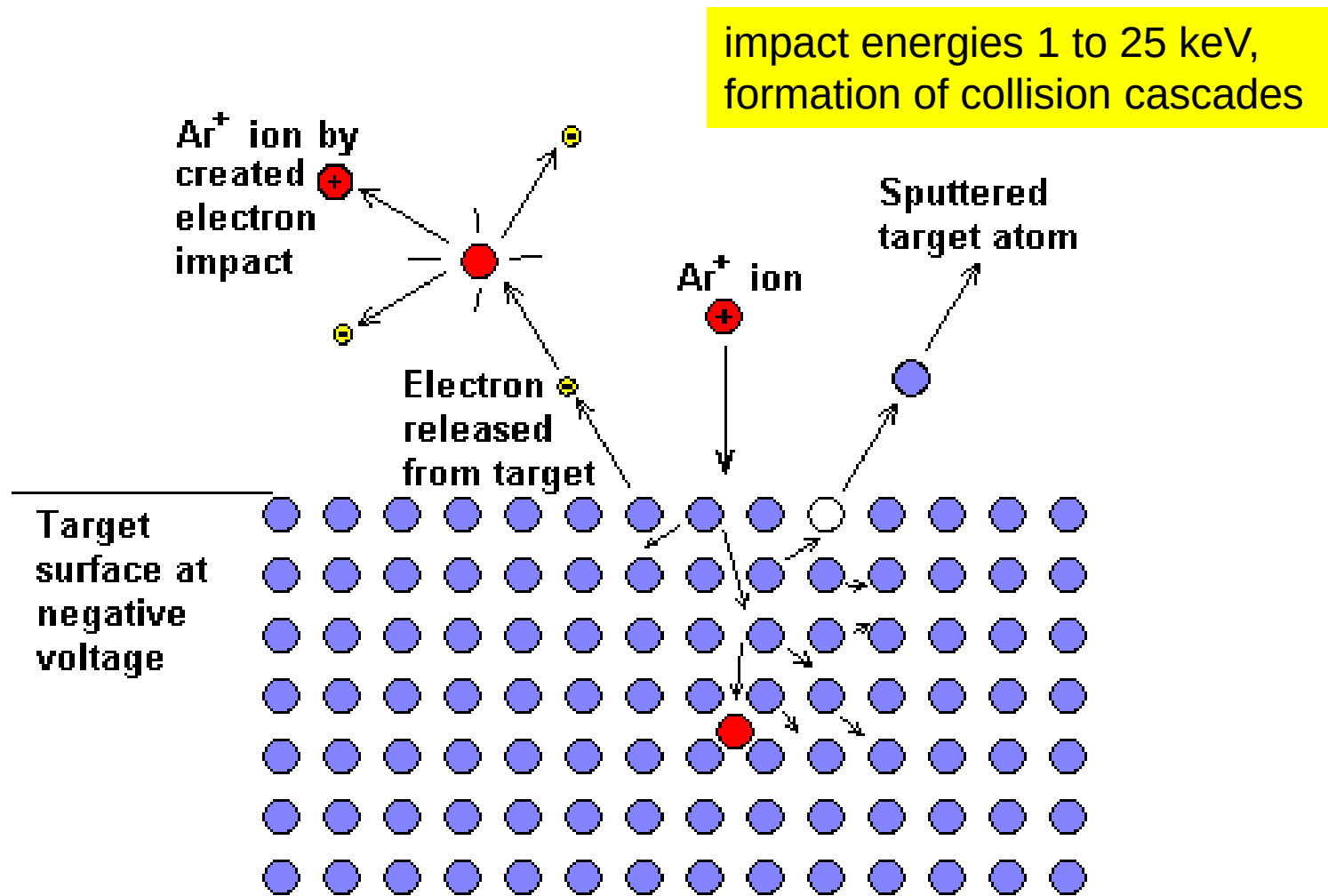
STM image
 $d_{\text{cluster}} = 2 \text{ nm}$



aerodynamic focussing



d) ion sputtering (Zerstäuben)



simulation of the ion sputtering process

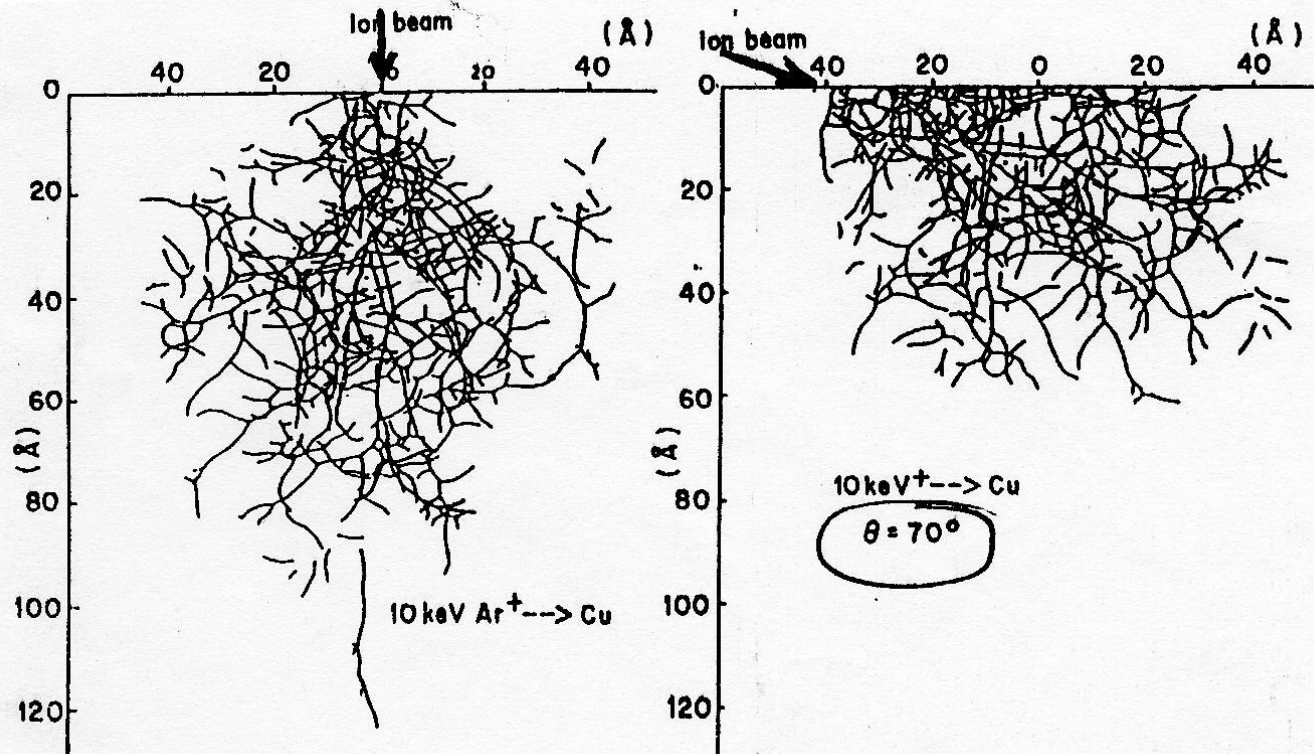
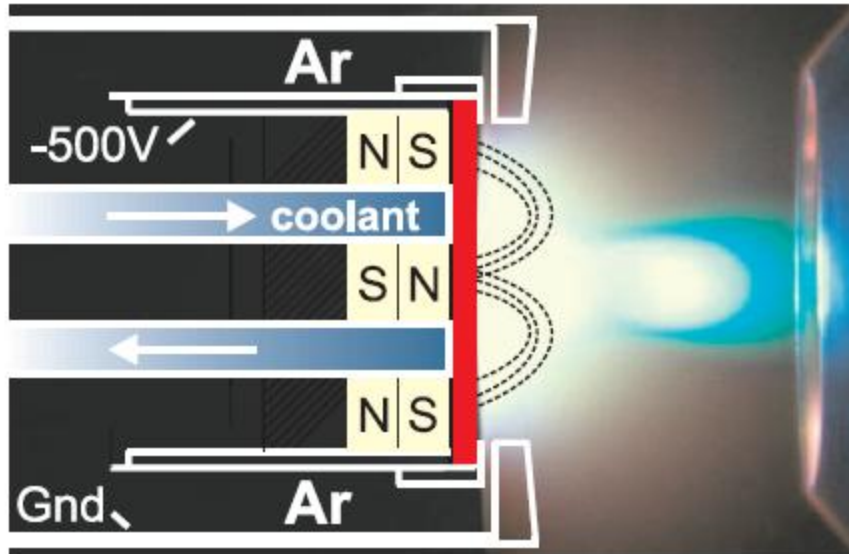


Fig. 1. Monte Carlo simulation of the trajectories of recoiling Cu atoms bombarded by 10 keV Ar^+ ions at (a) normal incidence and (b) 70° (from ref. [5]).

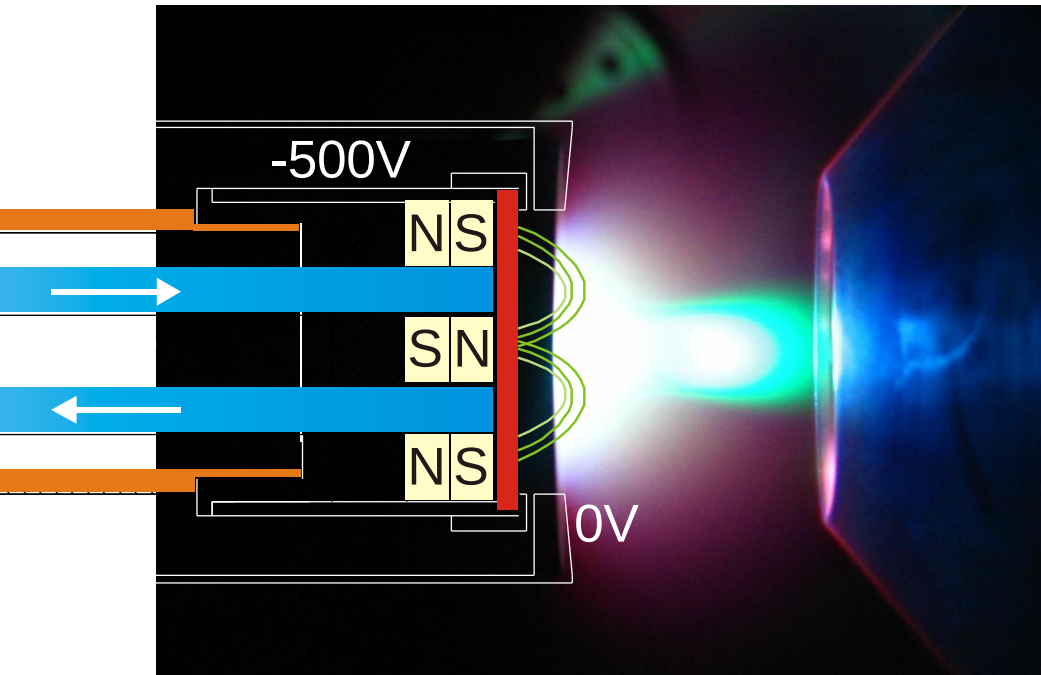
The recoil trajectories are due to first-, second-, and higher-order collisions within the cascade. While the volume of the cascade caused by a single incident particle is quite large and extends nearly 100 Å into the solid, the area on the surface from which sputtered atoms are ejected about the impact site is only on the order of 40 Å in diameter.

magnetron sputtering source

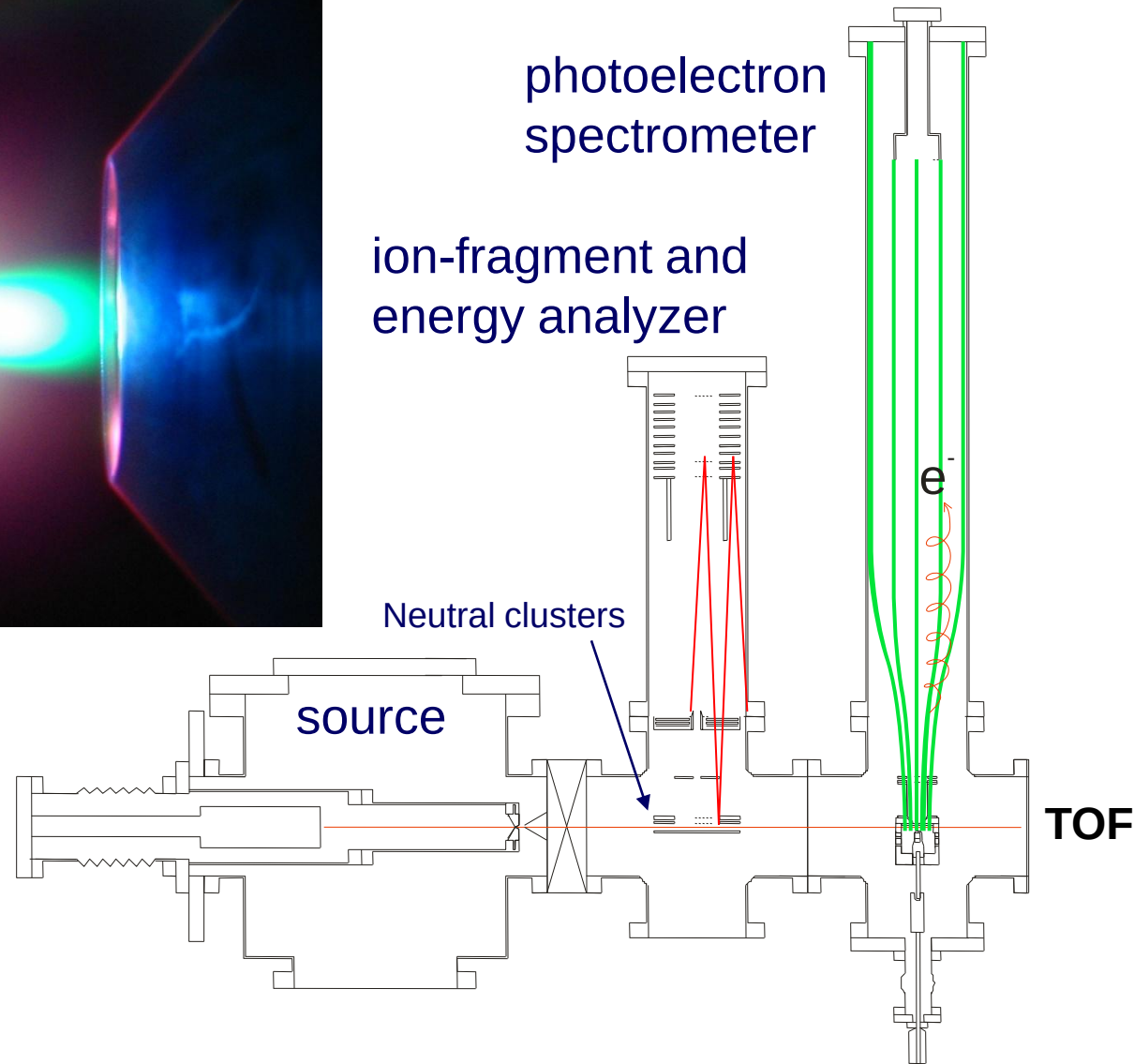


**Magnetron sputtering
(Haberland type)**

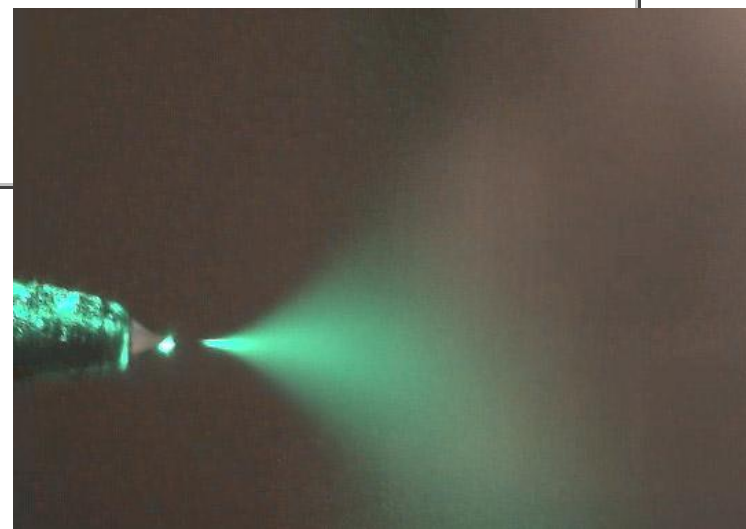
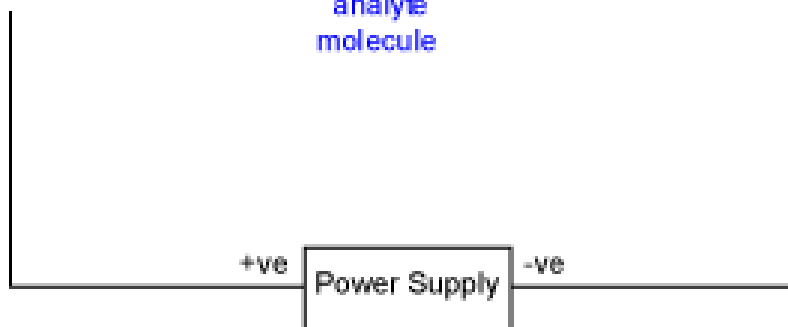
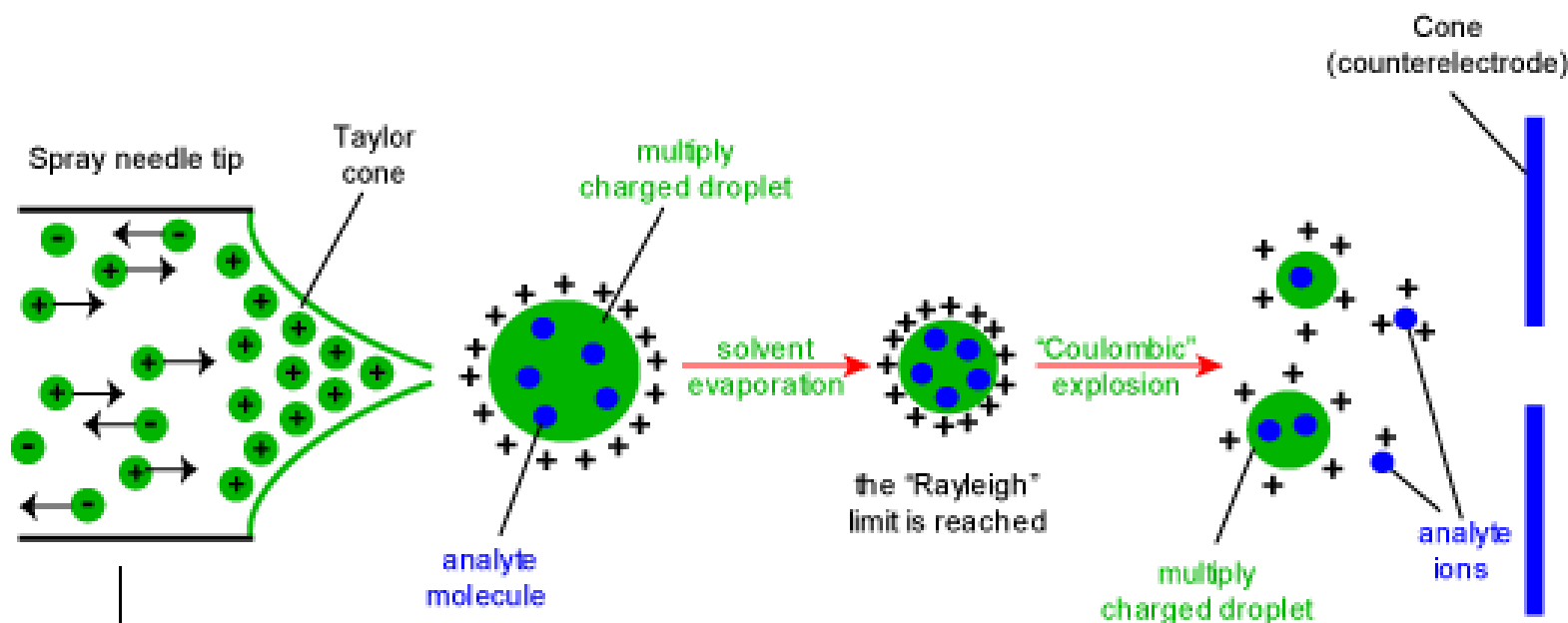
magnetron sputtering source with spectrometers



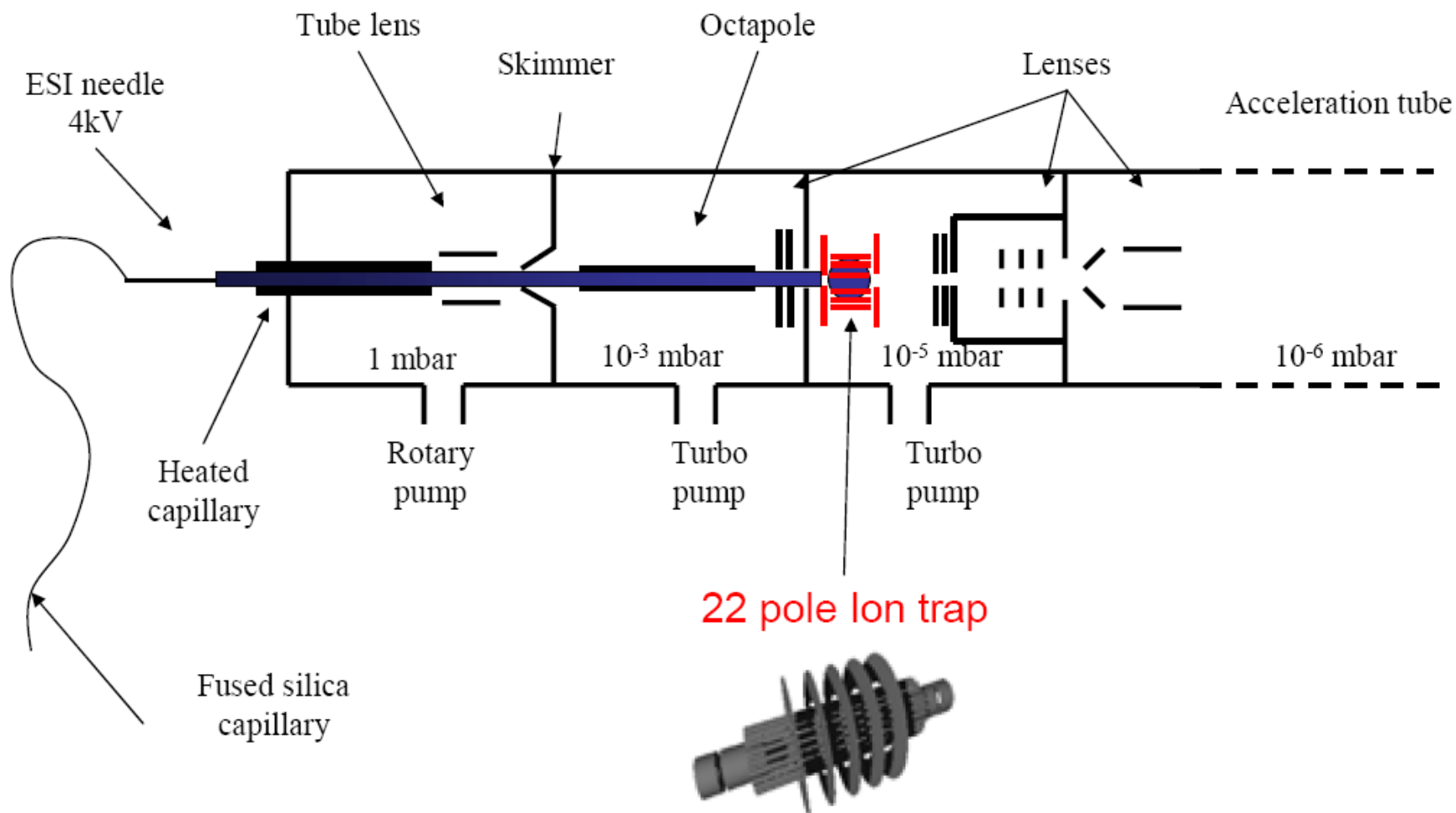
**Magnetron sputtering
(Haberland type)**



e) Electrospray Ion Source



Electrospray Ion Source (EIS) apparatus



M. Yamashita and J. B. Fenn, Electrospray ion source. Another variation on the free-jet theme, *J. Ph. Chem.* **88**, 4451 (1984)

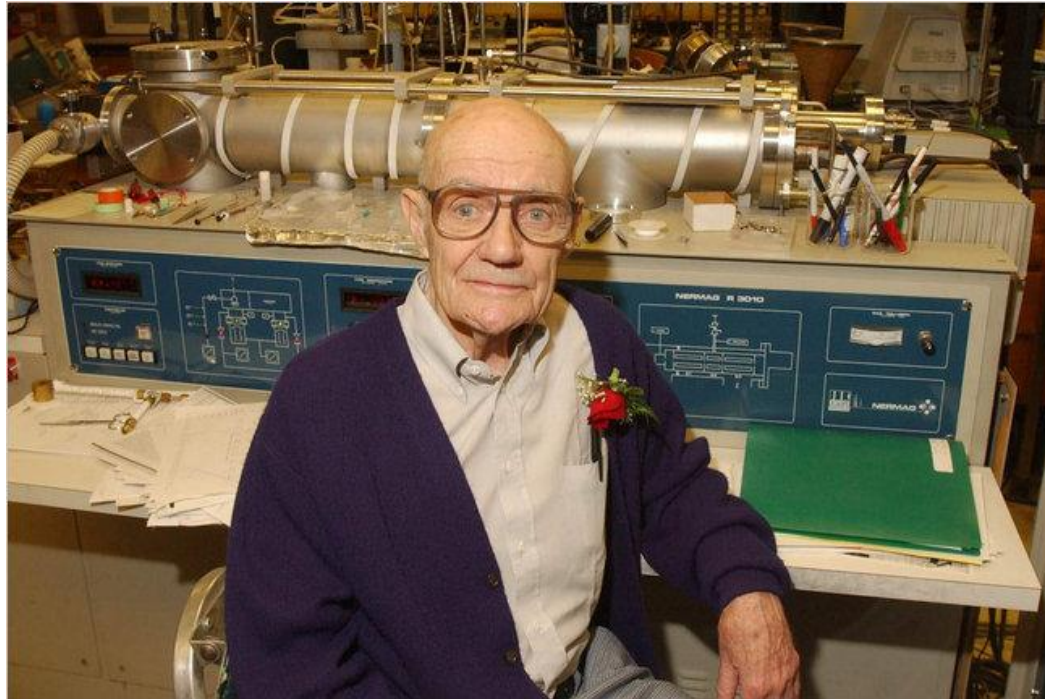
J. B. Fenn, *et al.* Electrospray ionization for mass spectrometry of large Biomolecules. *Science*. **246**, 64 (1989)

S. Brøndsted Nielsen *et al.*, Biomolecular ions in accelerators and storage rings, *J. Ph. B: At. Mol. Opt.Phys.* **37**, R25 (2004)

Prof. John Fenn, inventor of the electrospray ion source

Nobel price 2002

We learned to make elephants fly

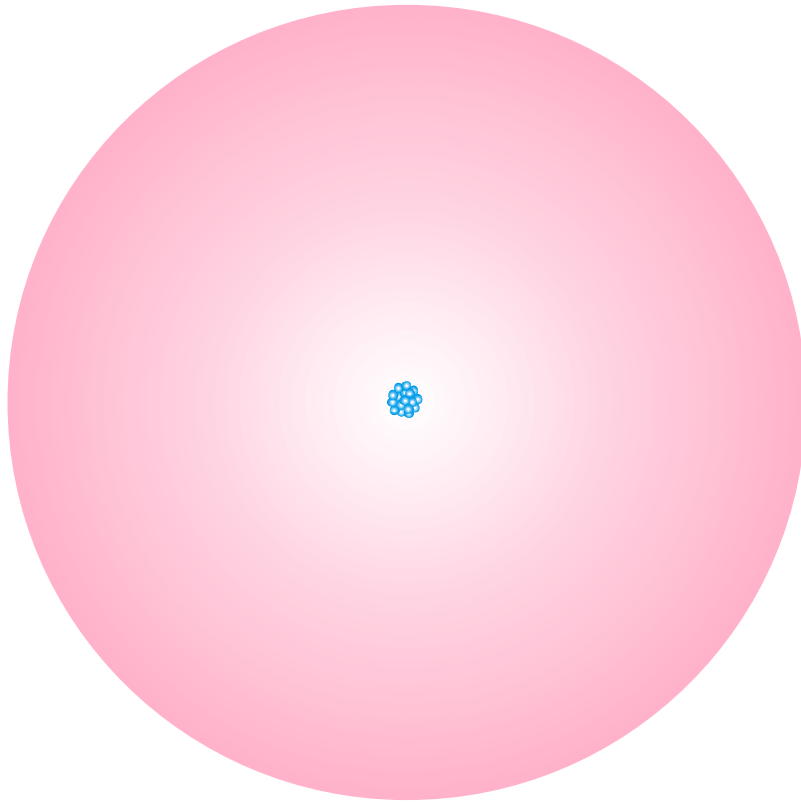


The New York Times 12.12.2010 Prof. Fenn died at the age of 93

Dr. Fenn personally patented it and then licensed the patent to a company he had co-founded. A federal judge ruled in 2005 that Dr. Fenn was guilty of “civil theft,” assigned the patent to Yale and ordered Dr. Fenn to pay Yale more than \$1 million. He appealed the ruling but lost.

f) Helium droplet pick-up source

atom pick-up in superfluid and 0.4 K cold helium droplets

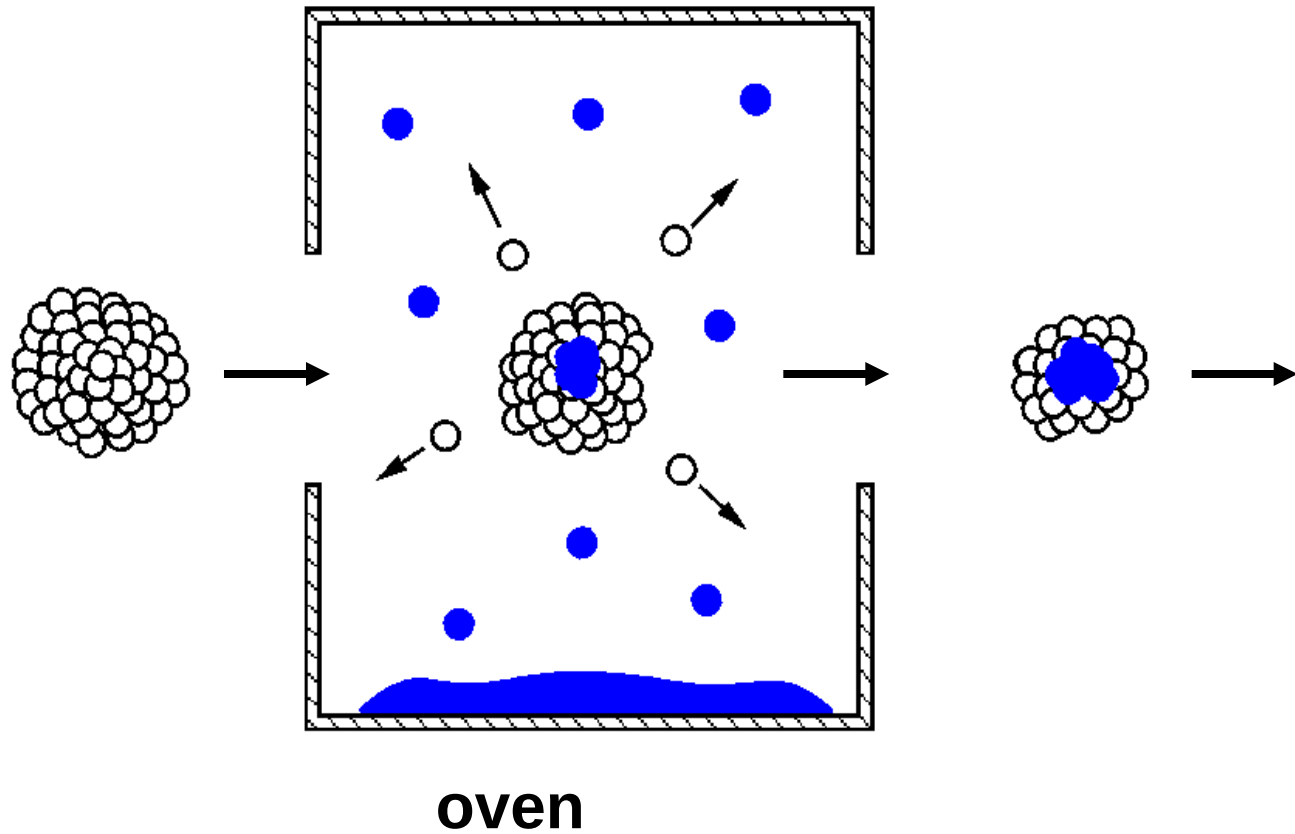


**Binding energy $\text{He@He}_N = 7 \text{ K}$
1 eV BE > 1000 Atoms
stabilization at 0.375 K**

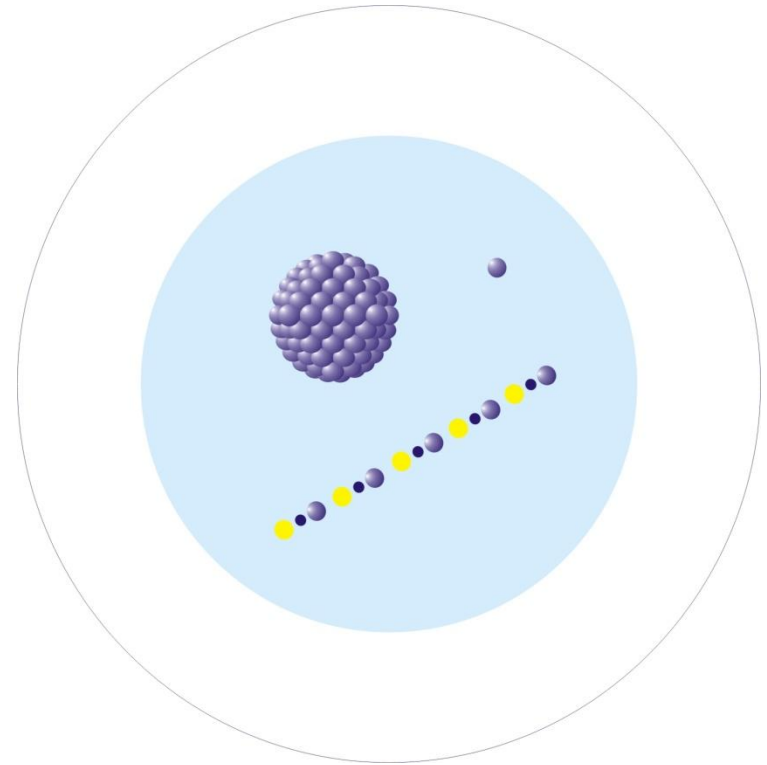
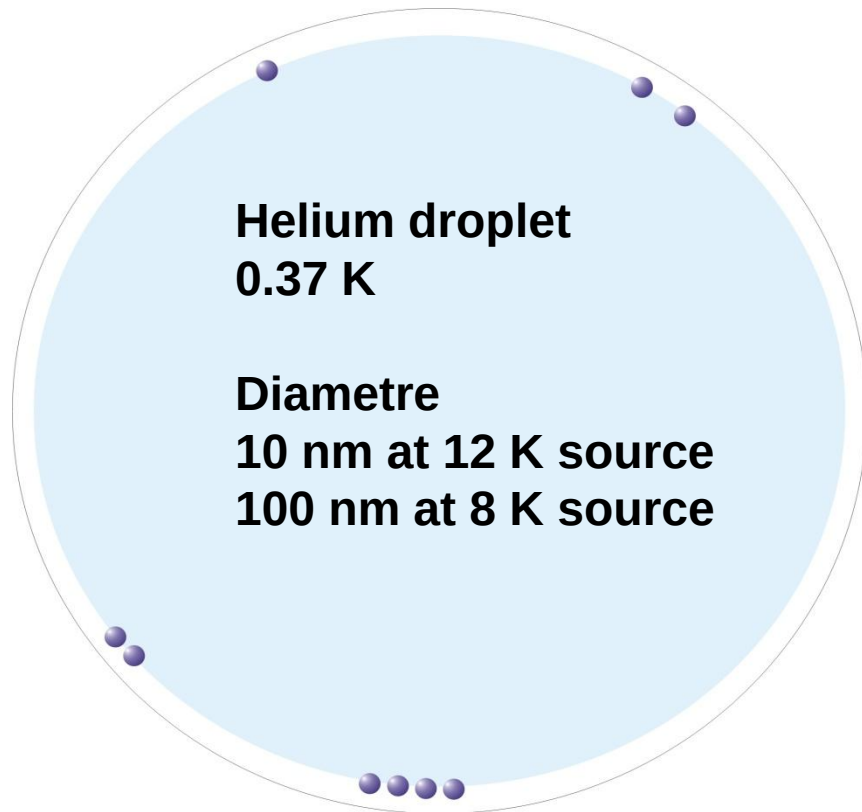
**Schematics of a Ag_{147}
silver cluster inside a
Helium droplet with
 10^6 atoms**

low-temperature physics

atom pick-up in Helium droplets



exotic systems in and on He droplets (will be discussed in the new year)



compilation of cluster sources:

a) aggregation of a gas by supersonic expansion

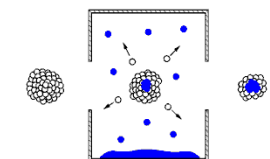
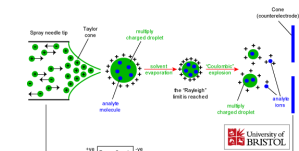
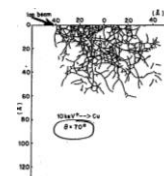
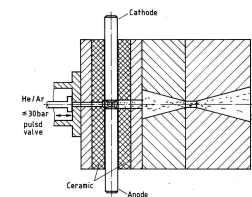
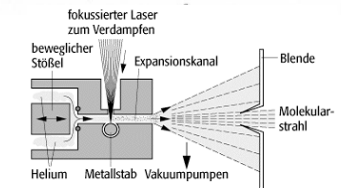
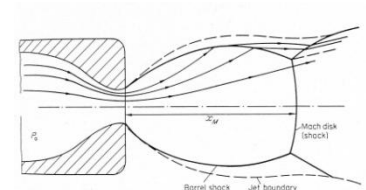
b) laser vaporization followed by expansion

c) plasma generation by arc discharge

d) sputtering, or magnetron sputtering

e) electrospray ion source

f) Helium droplet pick-up source





FROHE WEIHNACHTEN

