HIGH INTENSITY PLASMONICS

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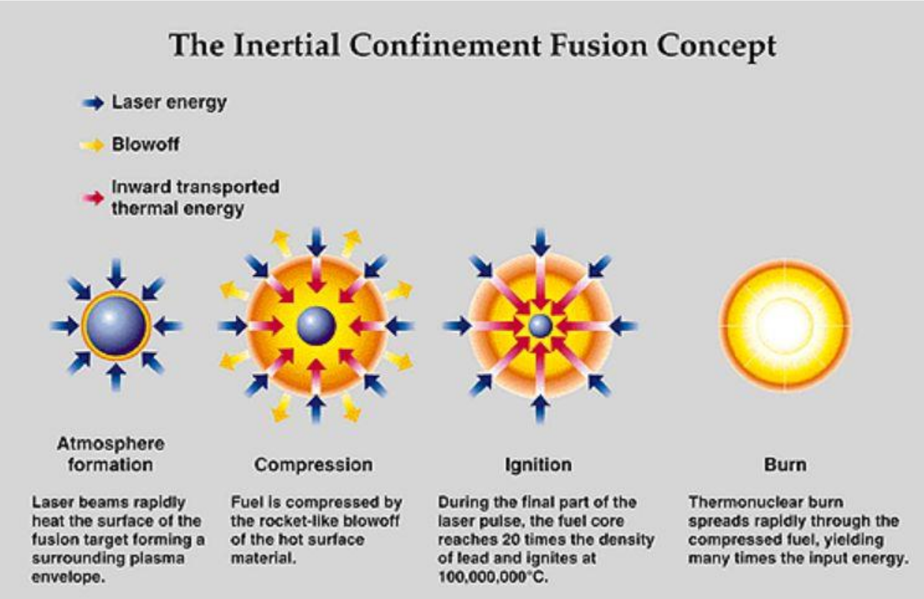
For the NAPLIFE collaboration
Wigner Physics Research Center

Motto: Only those, who are prepared to go too far, can know how far they may go.

KOLYMBARI, 2021.08.30

1.Many of the breakthroughts are the results of combining different technologies



The Inertial Confinement Fusion Concept

Atmosphere formation

Laser beams rapidly heat the surface of the fusion target forming a surrounding plasma envelope.

Compression

Fuel is compressed by the rocket-like blowoff of the hot surface material.

Ignition

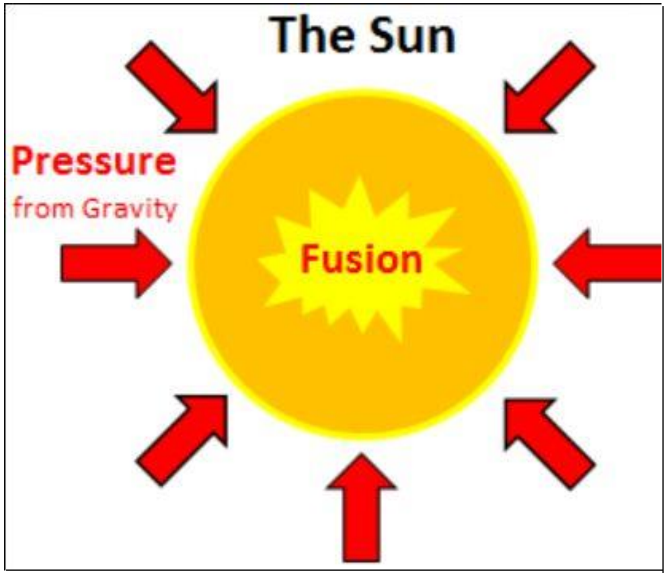
During the final part of the laser pulse, the fuel core reaches 20 times the density of lead and ignites at 100,000,000°C.

Burn

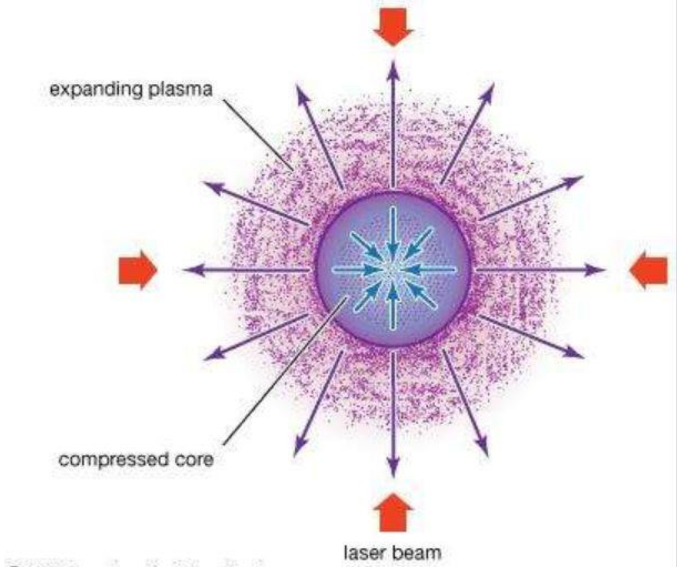
Thermonuclear burn spreads rapidly through the compressed fuel, yielding many times the input energy.

2.The most succesful technologies imitate nature

$$E = mc^2$$



Laserbeams



THE NIF (LASER SOLUTION)

192 laser, 400MJ, on the target 1.8MJ. Pulse length: 10-50ns, 1 imp/day

PROBLEMS WITH THE INERTIAL (NIF) FUSION:

Enormous energy needed to pump the lasers energy and many beams, (low laser efficiency, rare shots)

„Slow” compression , long laser pulses (a few times 10ns)

Rayleigh-Taylor instability

Plasma mirror at the surface of the target

Ignition only at the center of the spherical target, not time-like

OUR BASIC IDEAS:

1. **Nanoparticles in the target (fast process, plasmonic amplification, volume compression, only two beams)**
   Much smaller target, lower energy need, frequent fs pulses
2. Time-like ignition of the target (the presentation of L.P.Csernai)

SURFACE PLASMON POLARITONS are a „NEW TYPE OF LIGHT”, they are

1.BOUND TO THE (METAL) SURFACE,

2.HAVE SPECIFIC DISPERSION PROPERTIES,

3.THE DIFFRACTION LIMIT DOES NOT APPLY,

4. MAY BE GUIDED,

5.MAY HAVE A BANDGAP,

6. MAY INTERFERE,

7.REPRESENT VERY HIGH ELECTRIC FIELDS,

8.MAY BE LOCALIZED (e.g. to nanorods or nanoshells)

9.MAY BE THE SUBJECT OF NONLINEAR PROCESSES

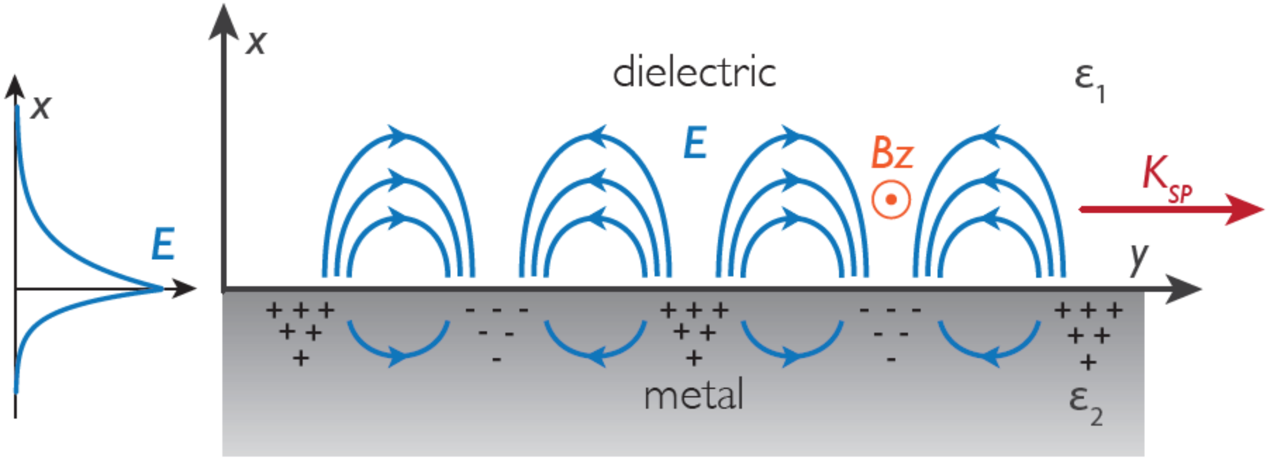
10.SPO „LASER–LIKE” PROPERTIES: SPASER

11.SHOW NON-CLASSICAL PROPERTIES

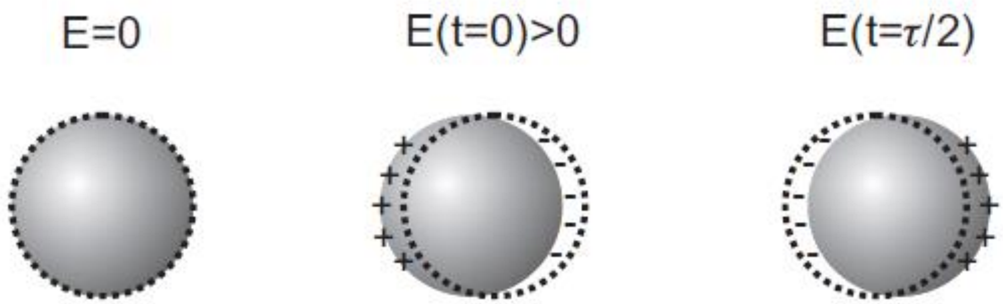
12.SOURCES OF SHORT, ENERGETIC ELECTRON BEAMS

PLASMONICS AND HIGH EM FIELDS

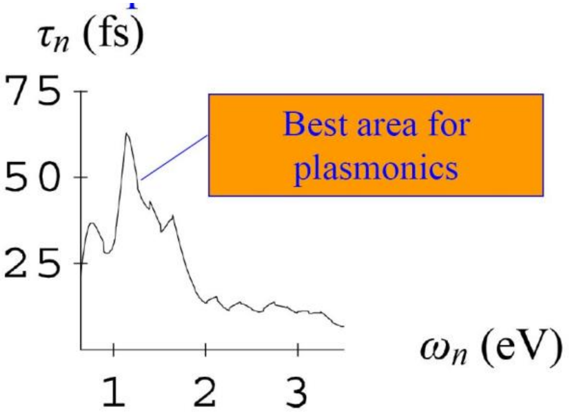
Five examples to explore special plasmonic properties



SPP



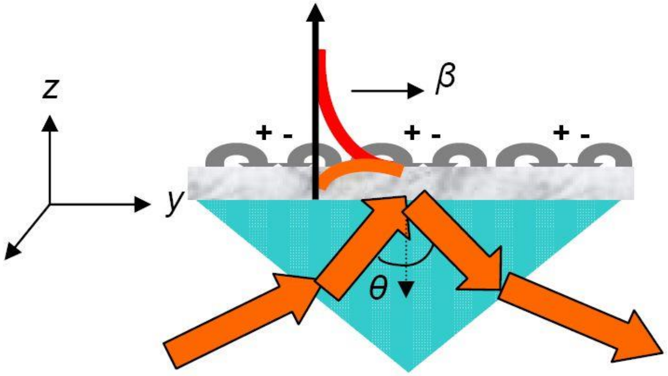
LSPP

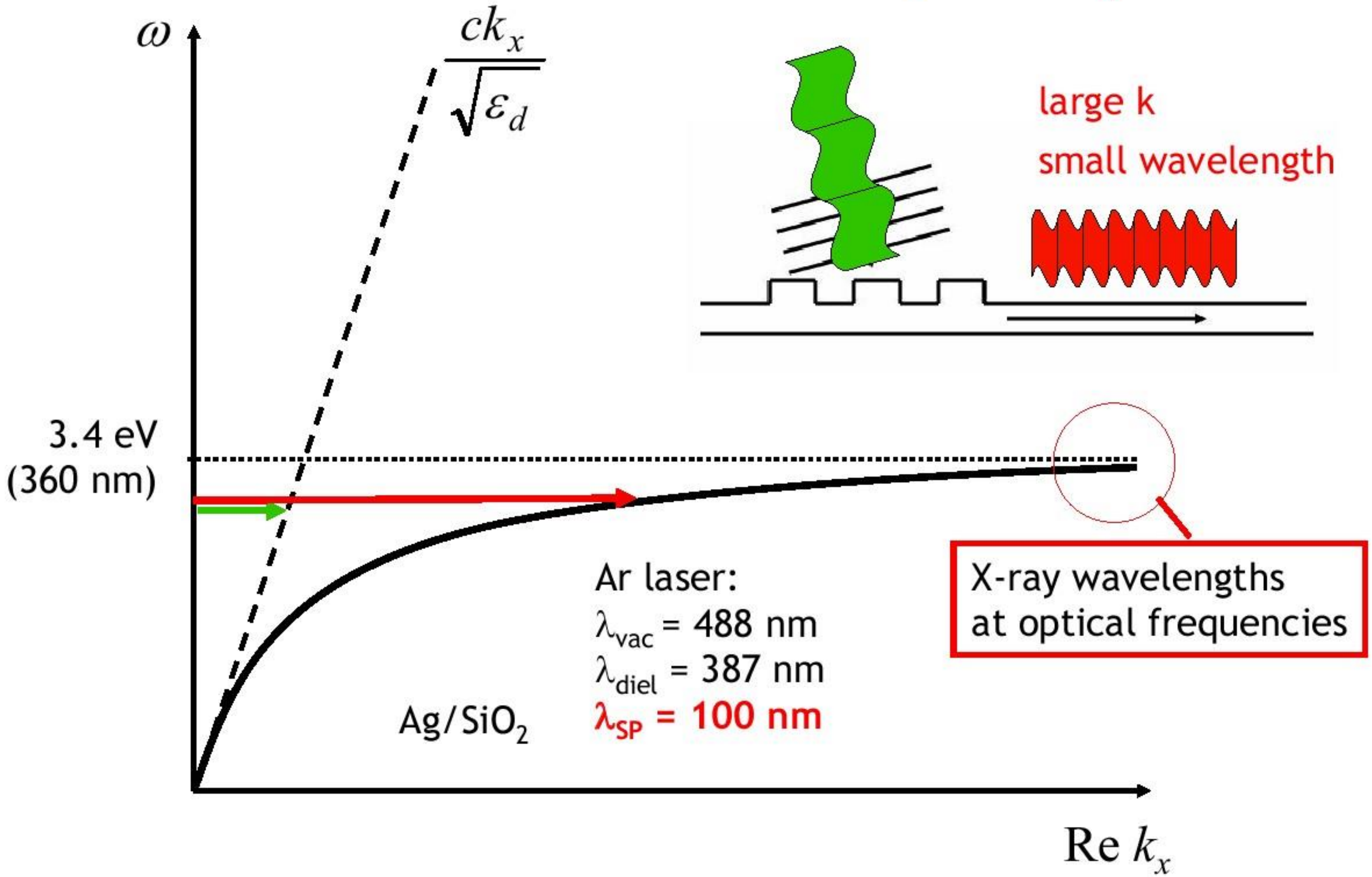


Ti:Sa laser: Λ=800nm (~1.55eV) ; $t_{(SPP)}$~30fs

SPP

Surface plasmons dispersion





large k

small wavelength

Ar laser:

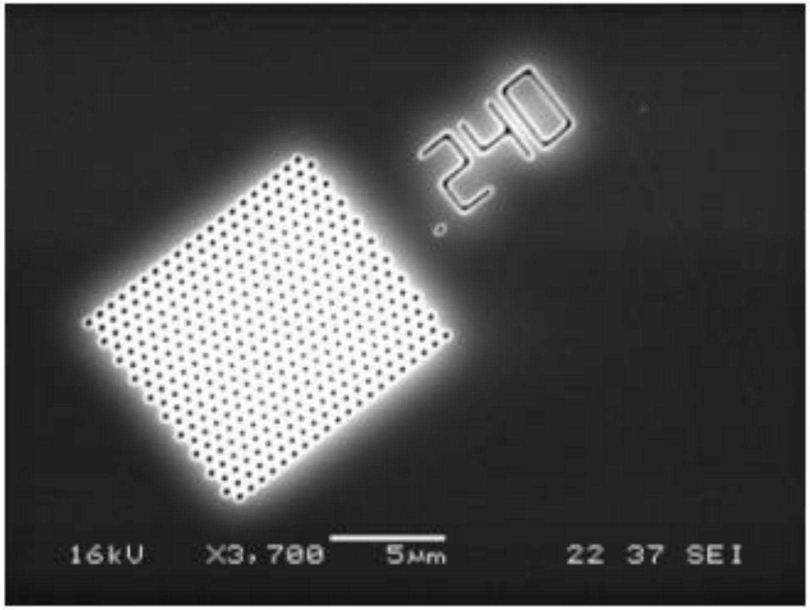
λ_{vac} = 488 nm

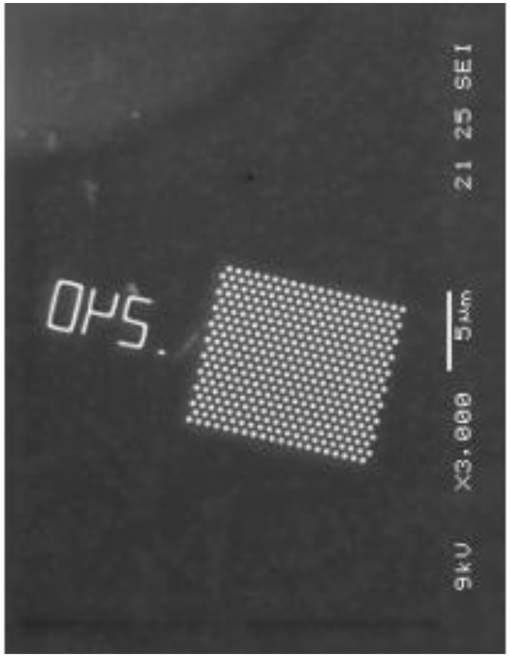
λ_{diel} = 387 nm

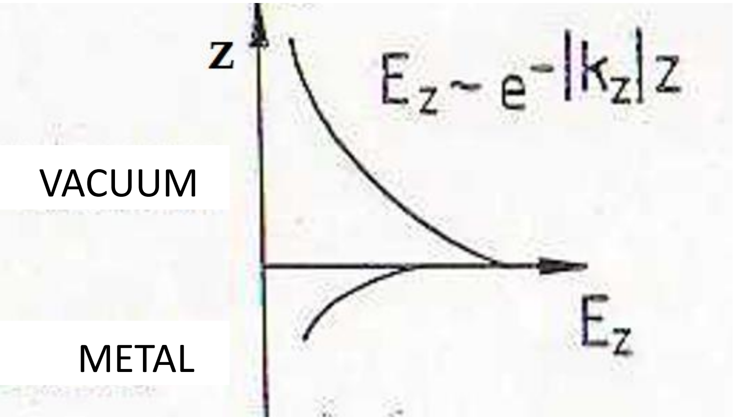
λ_{SP} = 100 nm

X-ray wavelengths at optical frequencies

1. Light gets through the holes much smaller, than the wavelength of applied light.

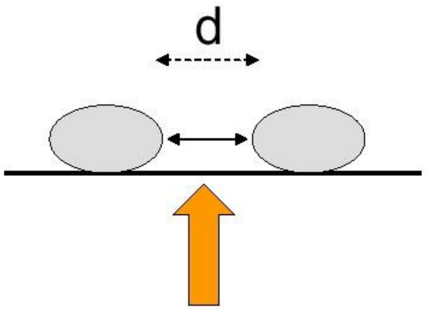






MOST OF THE ENERGY IS CONCENTRATED AT THE SURFACE: GIANT FIELD ENHANCEMENT!

LSPP



d << λ

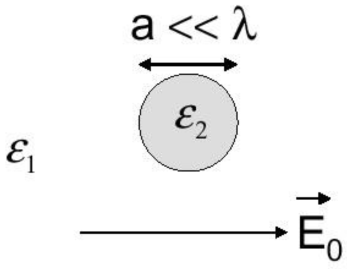
"Near-field coupling"

⇒ Resonator coupling

d >> λ

"Dipole-dipole coupling"

⇒ Interferences



If $a << \lambda \Rightarrow$ dipole :

$$p = \varepsilon_2 \, \alpha \, E_0$$

with:

$$\alpha = 4\pi \, a^3 \frac{\varepsilon_2 - \varepsilon_1}{\varepsilon_2 + 2\varepsilon_1}$$

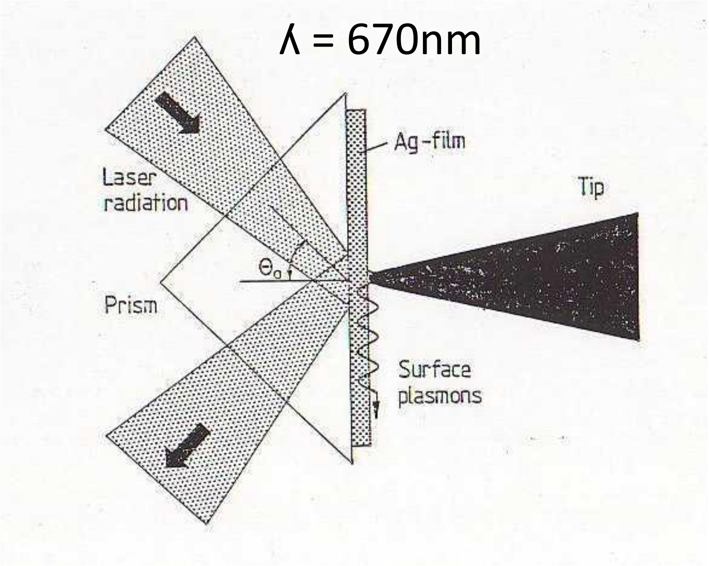
Resonance when $\varepsilon_2 (\omega) = - 2 \times \varepsilon_1 (\omega)$

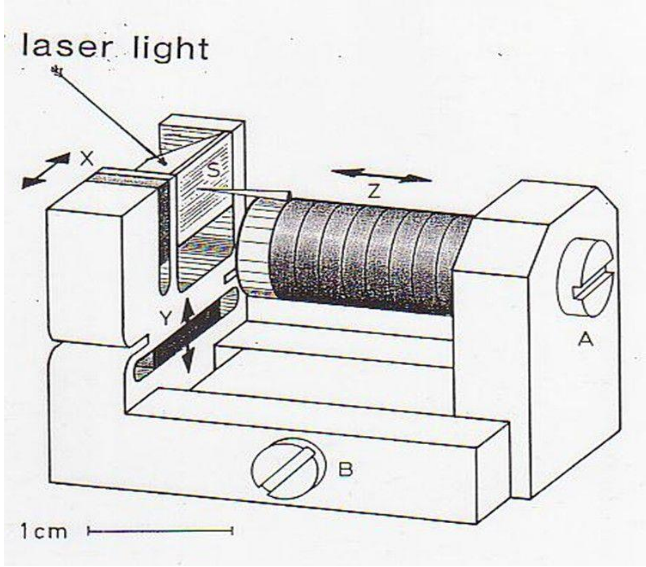
- Enhanced absorption
- Enhancement of the near-field & scattering

2.NEAR FIELD STM (NODIFFRAKCIÓS LIMIT)

NEAR FIELD:LASER EXCITED SPP-s GIANT EM FIELDS

(Kretschmann geometry)

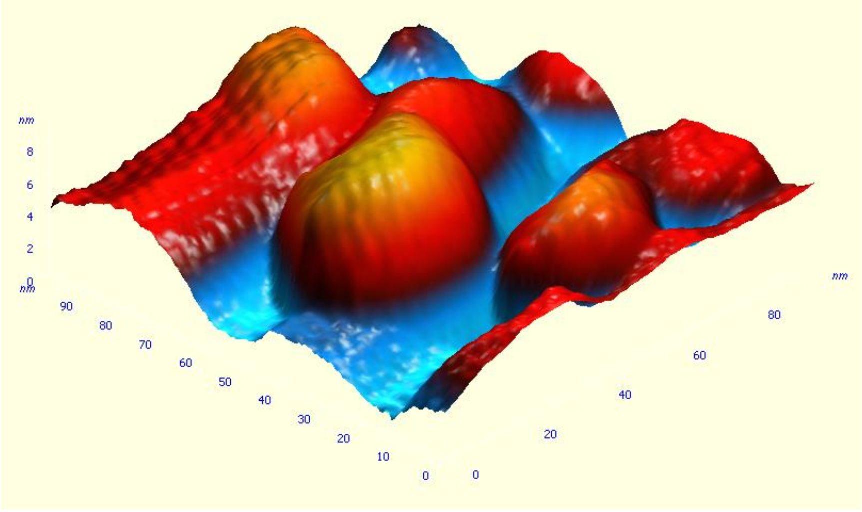


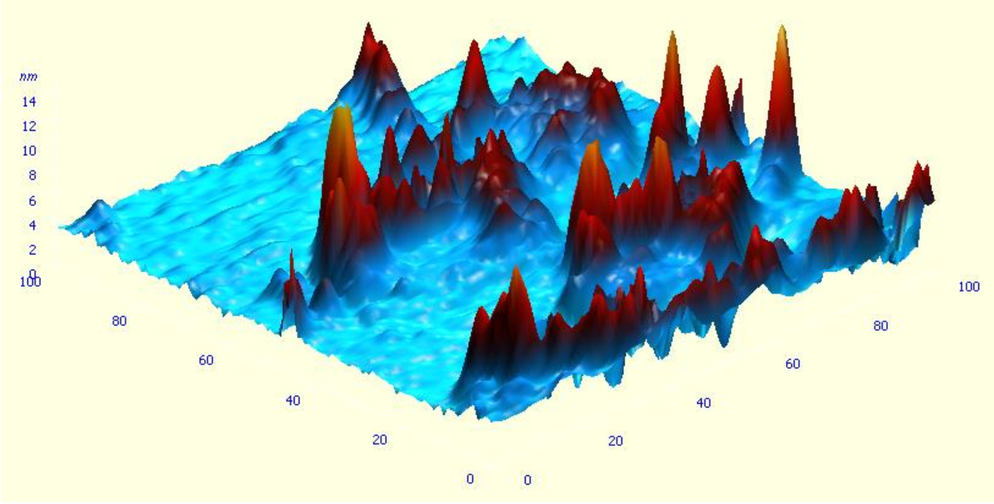


Surface topology

100x100nm

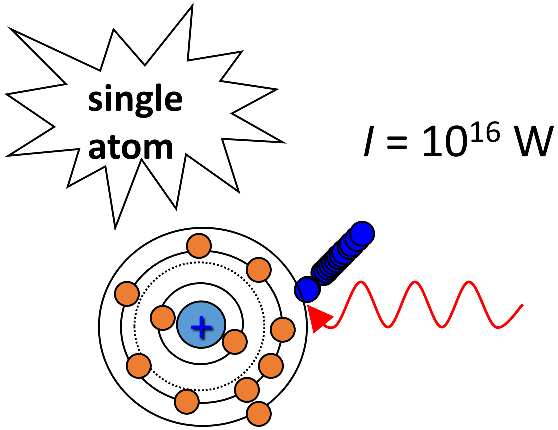
Localized SPP field





3.Matter under extreme conditions

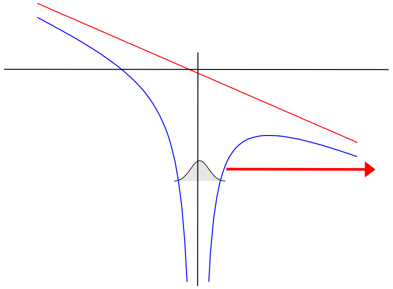
(extremely high intensities)



I = 10^{16} W cm^{-2} → E ~ 10^{9} V/cm

High intensity
Photoeletric Effect

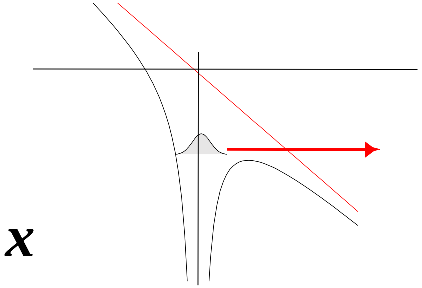
Rapid ionization of valence electrons



Tunnelling

10^{14} - 10^{15} W cm^{-2}

$$V = -\frac{q}{x} \pm E.x$$

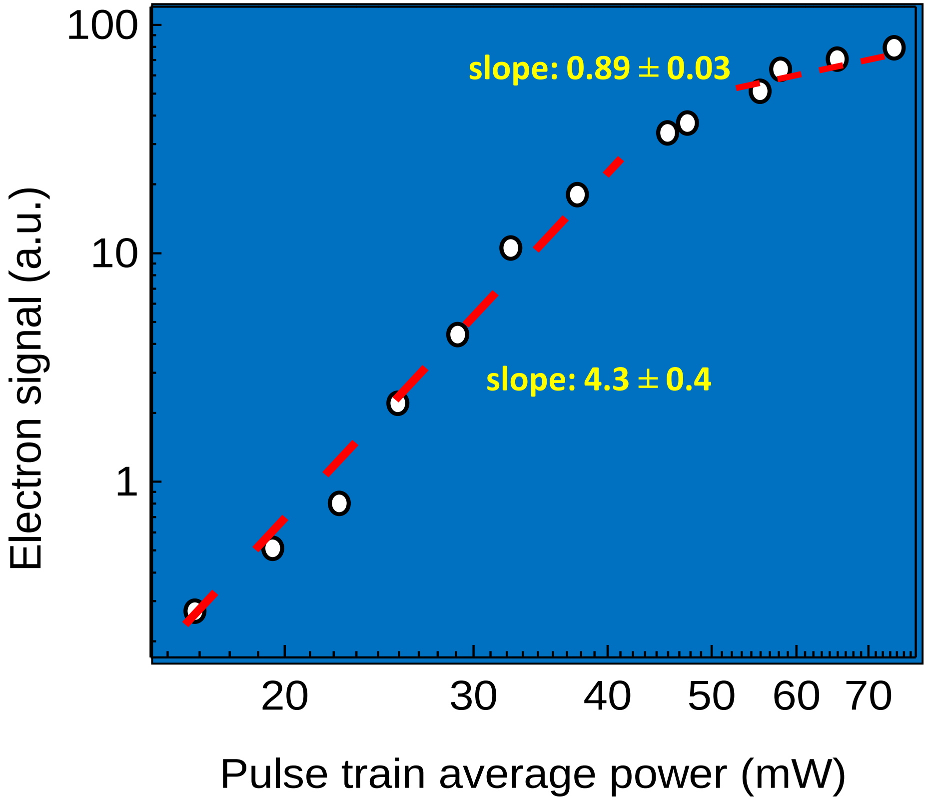


Over the barrier

> 10^{15} W cm^{-2}

Each atom loses at least one electron. Some can lose as many as 6 !

MULTIPHOTON ELECTRON EMISSION FROM GOLD



PLASMONIC ENHANCEMENT!

Multiphoton ⟹ tunneling transition at ~4x10^{10} W/cm^{2} incident intensity, ~5.5x10^{8} V/m field

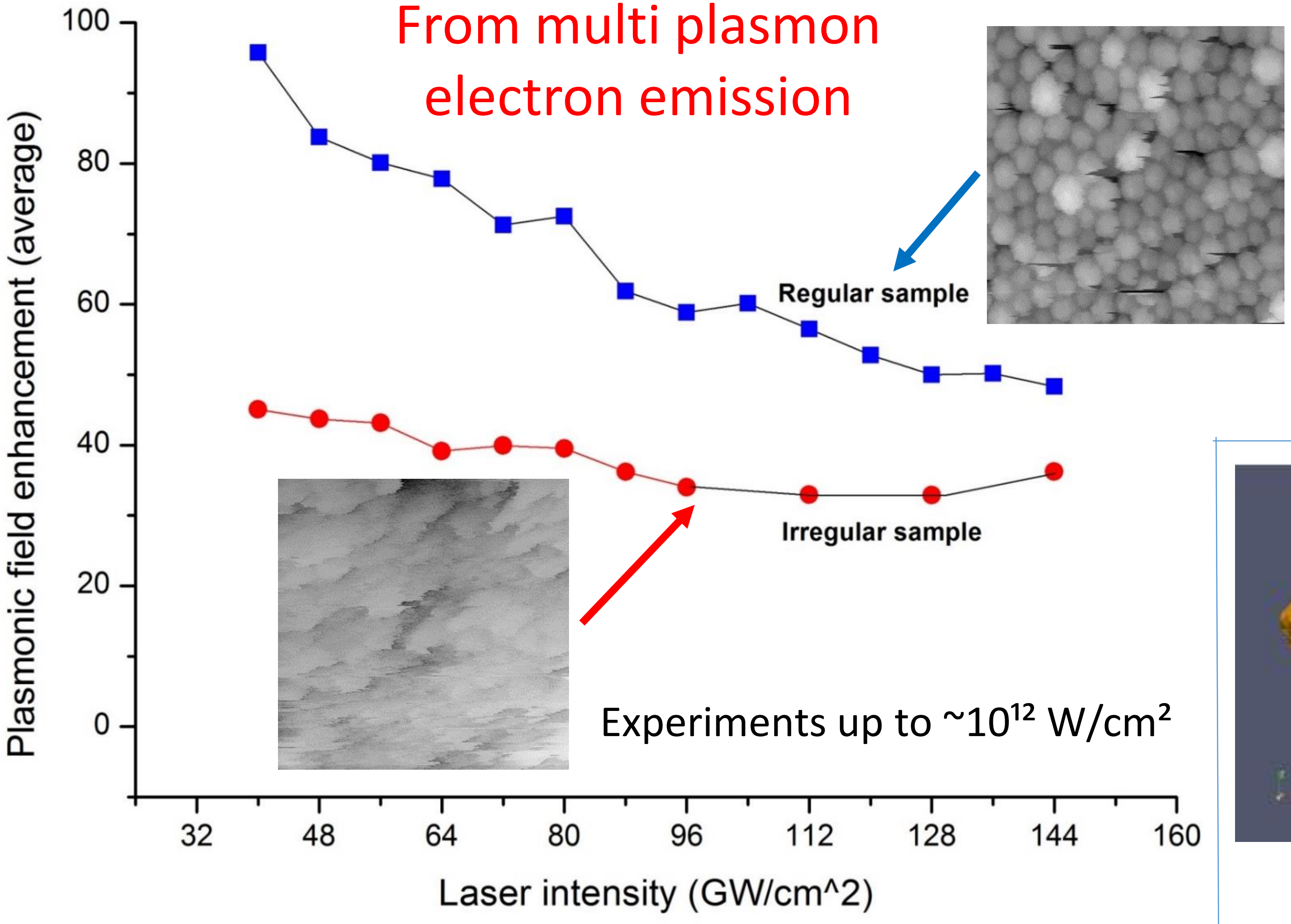
Keldysh-gamma γ=31

→ indication of well-known field enhancement of surface plasmonic fields

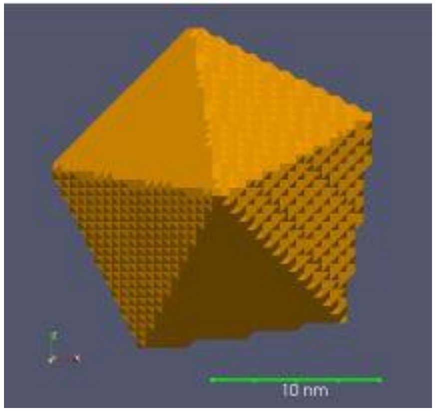
$$\gamma^2 = \frac{W}{2U_p} = \left(\frac{\omega \sqrt{2mW}}{eE_l} \right)^2$$

W: work function, E_l: laser field strength

From multi plasmon electron emission



Experiments up to ~10^{12} W/cm²

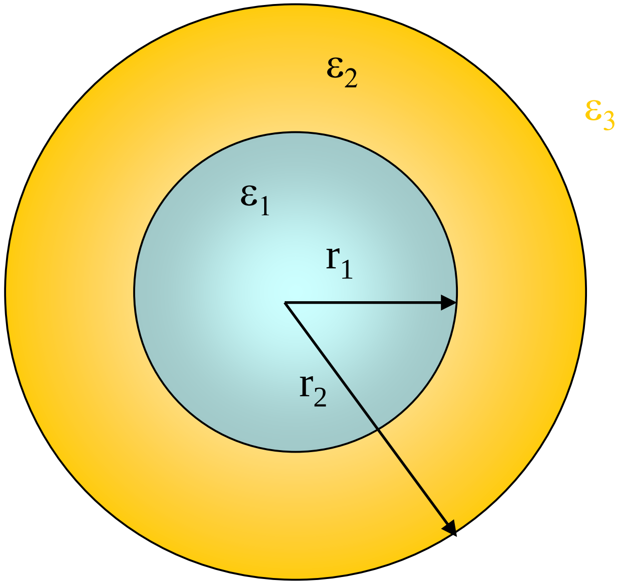


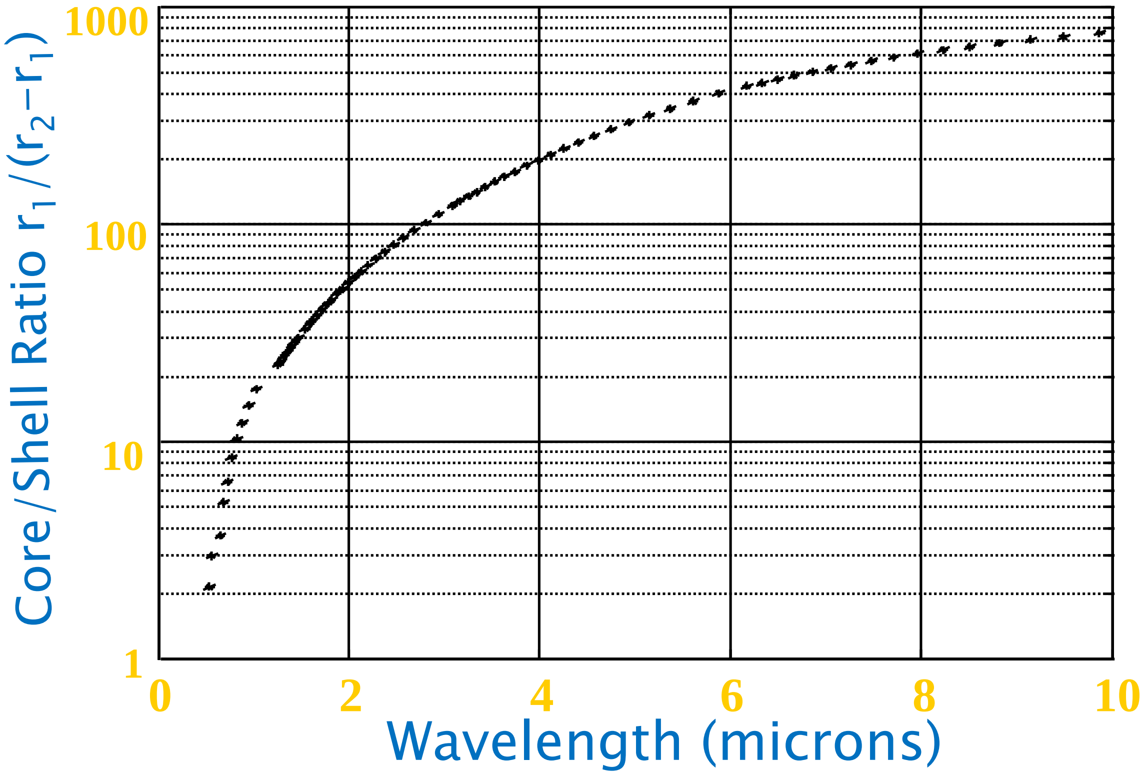
Nanopyramide:
Field enhancement
up to 200 at the tip

Born-Openheimer: >10^{15} W/cm²; Relativistic processes: >10^{18}W/cm²

DOES PLASMONICS WORK AT THESE HIGH INTENSITIES ?

Spectral tunability of the nanoshell plasmon rezonance





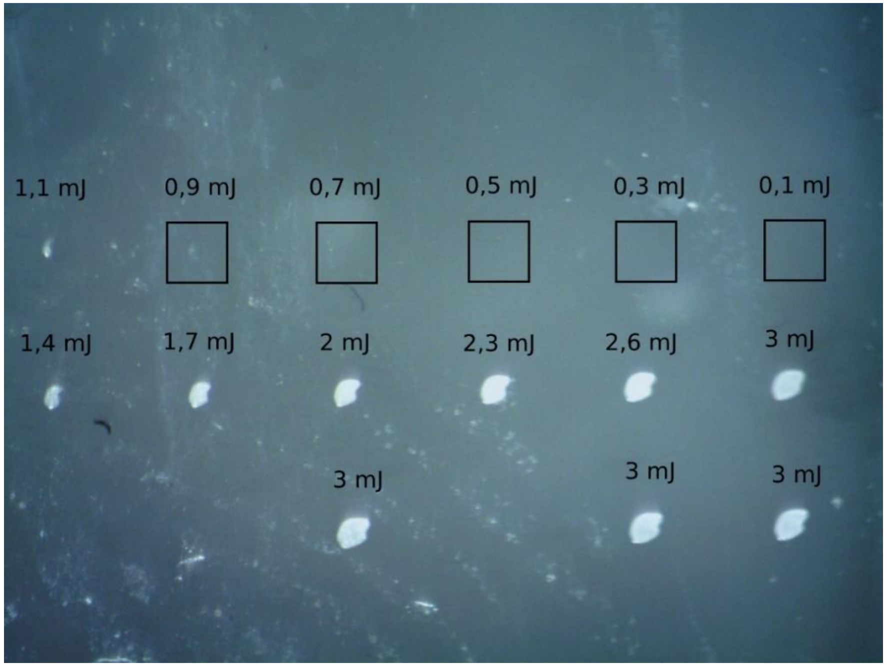
1.24 ← electron volts → 0.124

300 ← THz → 30

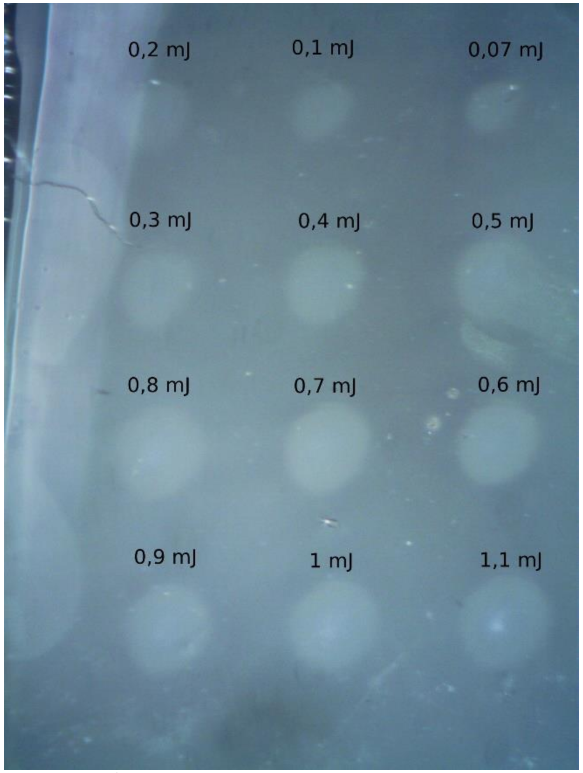
10,000 ← cm^{-1} → 1,000

4. PLASMONIC EFFECTS OF SHORT PULSES IN THE MATERIAL

Not doped (enlarged: 30x)

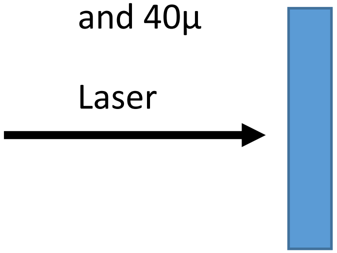


Doped (enlarged: 40x)



A few per mill gold particles

Thickness: ~30µ
and 40µ



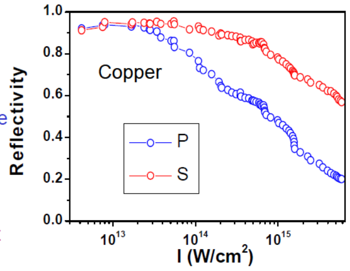
300 fs laser pulses

Focal spot: 85µ diameter
Pulse length: 300fs
Intensity: max. ~4.10^{14}W/cm^2

- A = 1-R

I < 3 x 10^{13} W cm^{-2}, A is almost polarization independent & obeys Fresnel laws, as IB is dominant

- at higher intensities, there is a clear polarization dependence of absorption
- the difference in absorption should account for extra absorption mechanisms, which are polarization dependent

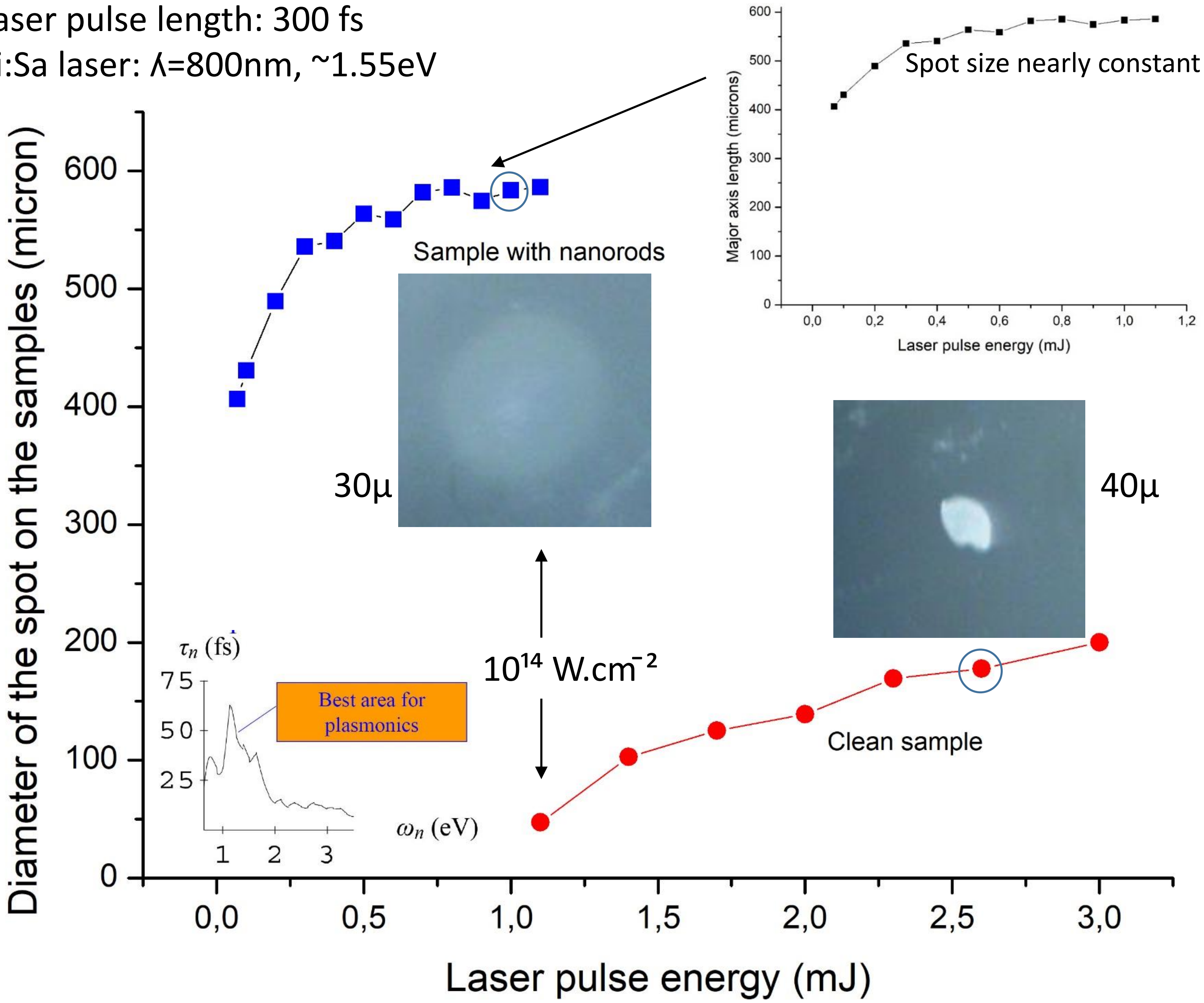


R vs I at 45°

TIFR data

Kumar

Laser pulse length: 300 fs
Ti:Sa laser: Λ=800nm, ~1.55eV



Giant plasmonic amplification; the laserlight reaches the nanoantennas;

HIGH EM FIELDS

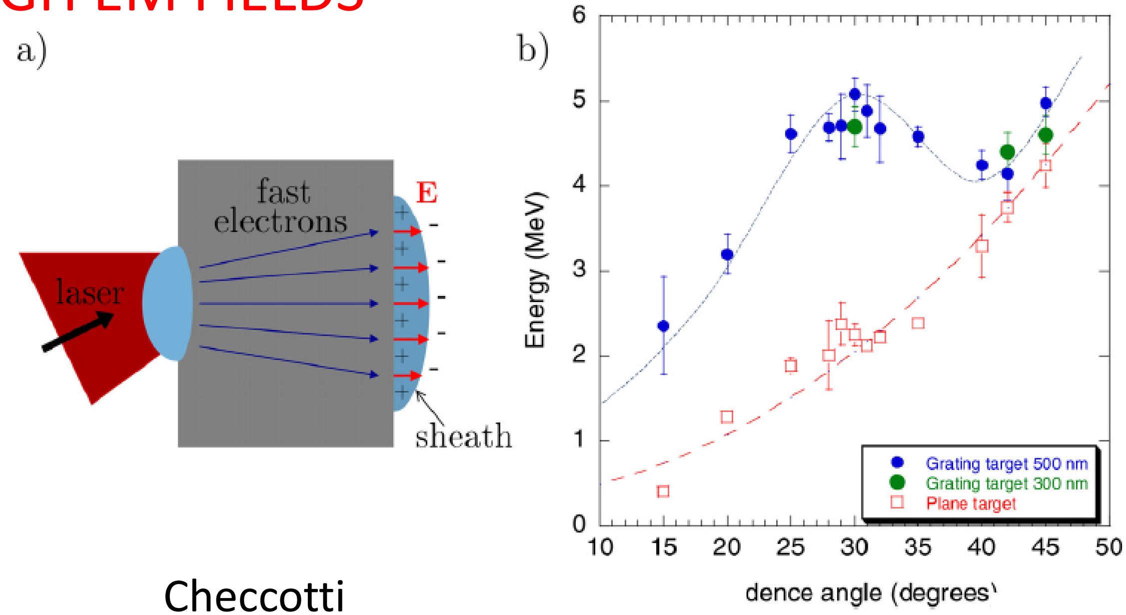


FIG. 5. Plasmon-enhanced TNSA of protons.[95] (a) Schematic of TNSA. The fast electrons produced by the interaction at the front side cross the target and produce a sheath at the rear side, where ions are accelerated. (b) Experimental data from the interactions of a high-contrast 25 fs, 2.5×10^{19} W cm^{-2} laser pulse with solid plastic targets. The cut-off energy of protons emitted from the rear measured as a function of the incidence angle from both flat and grating targets (for two different values of the grating depth). An up to 2.5-fold energy increase is observed for gratings, with a broad maximum around the resonant angle for SP excitation (30°). Data from Ref. 95.

Checcotti

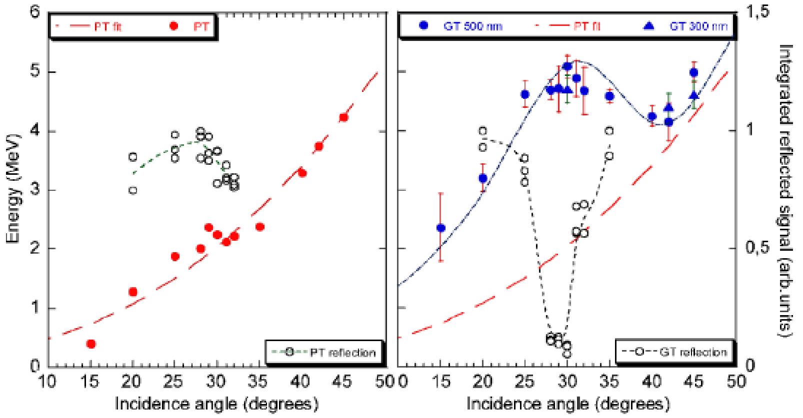


FIG. 3 (color online). Maximum proton energy (filled data points) and reflected light signal (empty data points) as a function of incidence angle α. Left and right frames correspond to 20 μm thick plane targets and to 23 μm thick grating targets, respectively. Filled circles and triangles correspond to 0.5 and 0.3 μm deep gratings, respectively. The (red) dashed line is proportional to $\sin^2\alpha/\cos\alpha$. The other lines are guides for the eye.

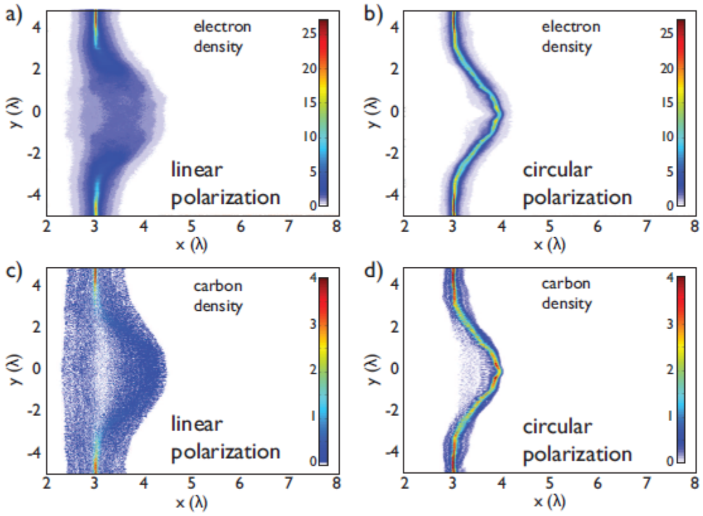
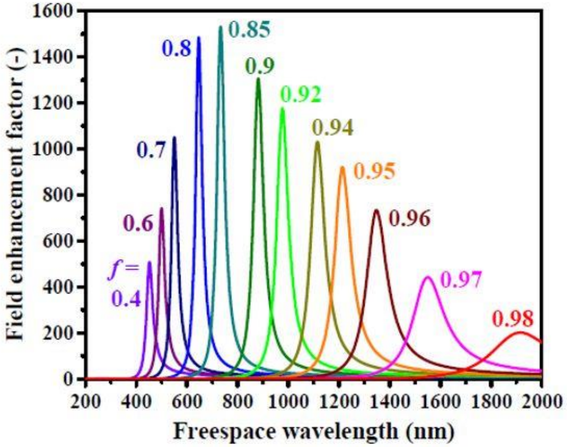


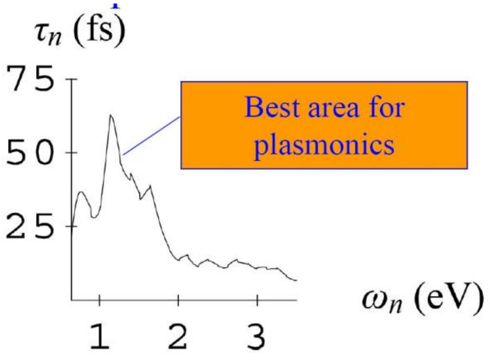
FIG. 4: (color). Cycle-averaged electron (a,b) and carbon ion (c,d) density at $t = 61$ fs after the peak of the laser pulse reached the 5.3 nm target initially located at $x = 3\lambda$. While linear polarization results in strong expansion of the target caused by hot electrons, for circularly polarized irradiation the foil is accelerated as a dense, quasi-neutral plasma bunch.

OUR PROPOSAL:

NANOSHELL
(nx10nm)

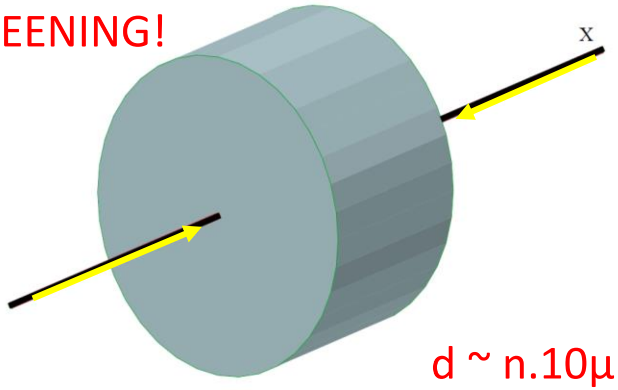


λ = 800nm

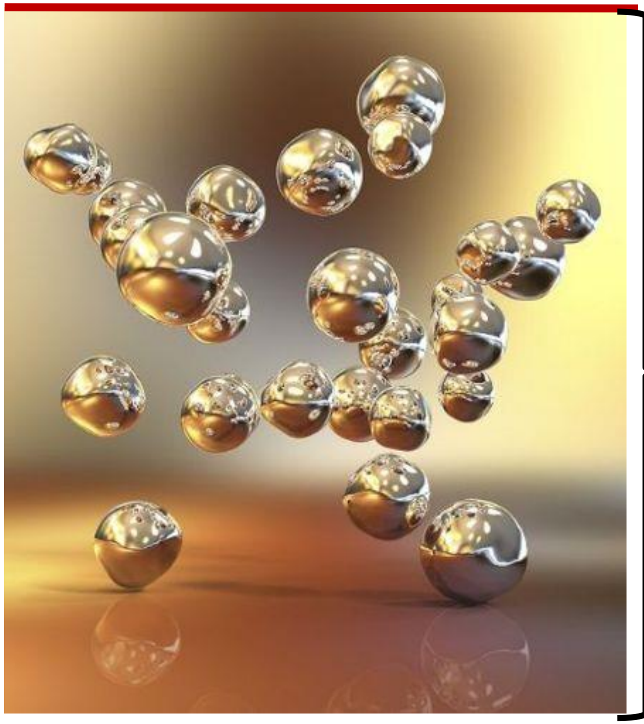


NANOROD (~85x25nm)

PLASMONIC ELECTRON
COHERENCE AND SCREENING!



d ~ n.10μ



n.10μ

NANOPARTICLES IN THE
FUSION MATERIAL

FEMTOSECOND LASER PULSES
HIGH REPETITION FREQUENCY
LIGHT SPEED: NO TIME FOR
INSTABILITIES
ONLY TWO BEAMS
VOLUME IGNITION

Potential SPP assisted LENR reactions

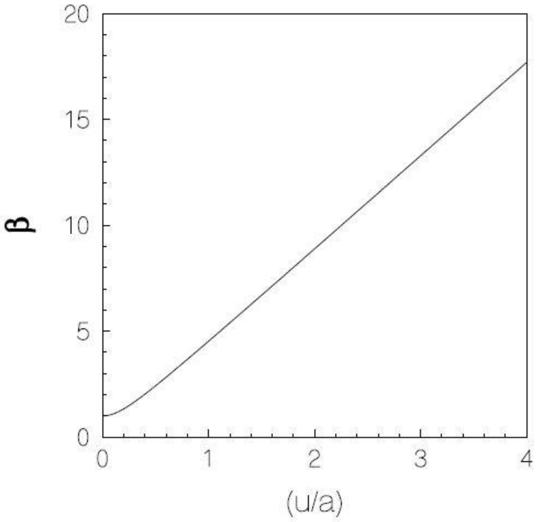
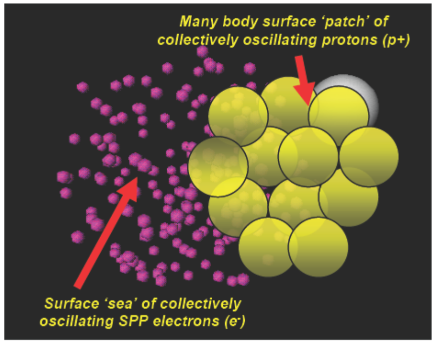
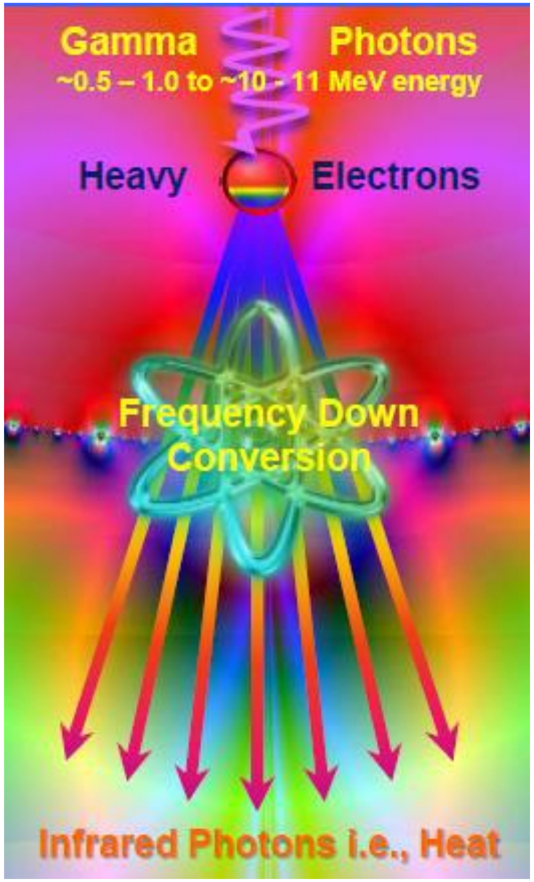


FIG. 4: The predicted electron mass enhacemnt $\beta = \tilde{m}/m$ when protons are absorbed into palladium is plotted as a function of the root mean square proton displacement u where $u^2 = \overline{|\mathbf{u}|^2}$ and the Bohr radius $a \approx 0.5291772108 \times 10^{-8}$ cm.

$$\tilde{e}^- + p^+ \longrightarrow n_{ulm} + \nu_e$$

Now add collective rearrangements from condensed matter effects. It is not just a two body collision !!!





Also proton plasmons above10^{15}W/cm^2

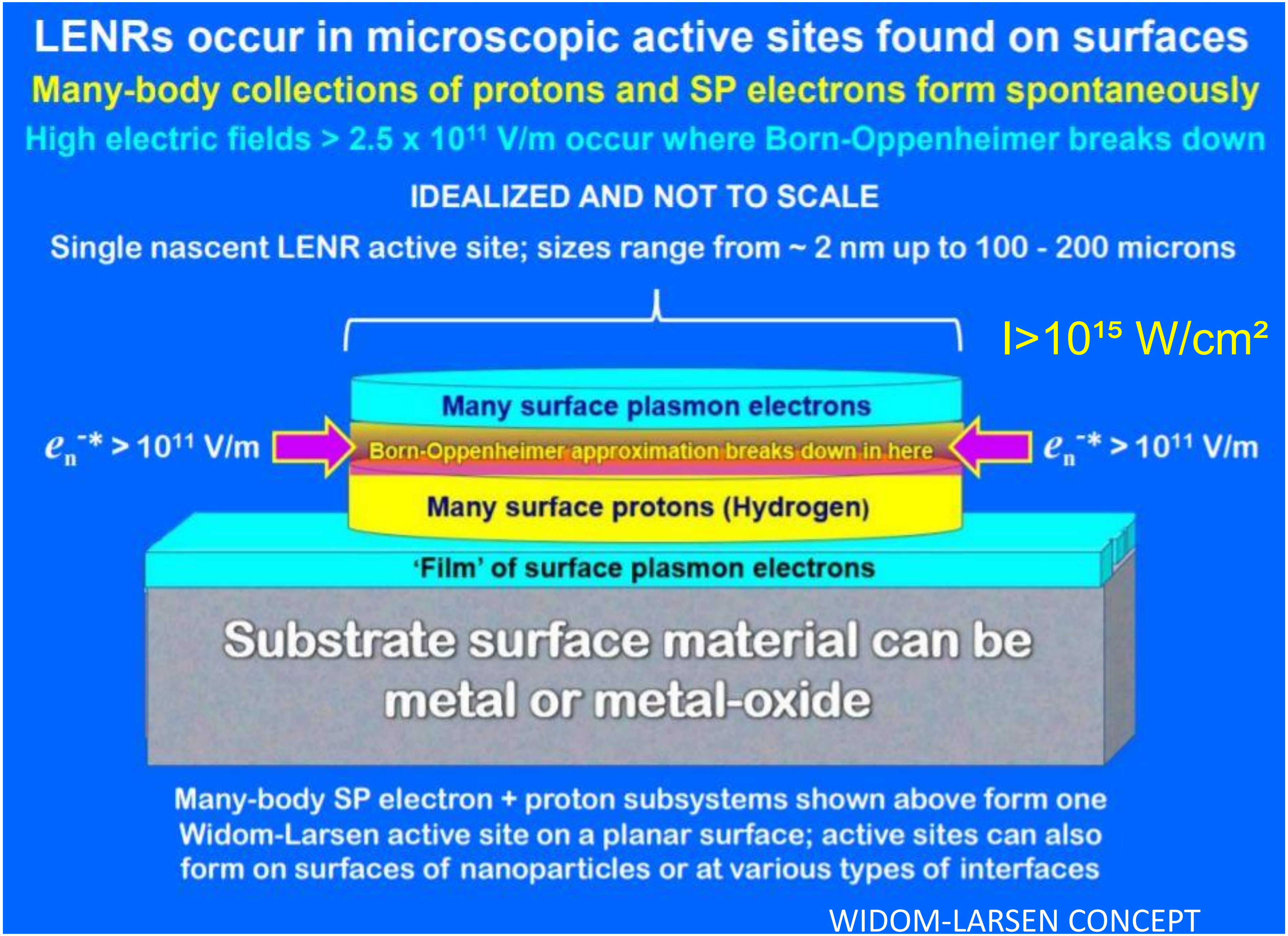
Pl. : Since coherent motion not N (proton number), but N^2 dependence

DEUTERIUM and TRICIUM production?

A + n = (A+1) + ɣ

ɣ → heat

5. IN HUGE EM FIELDS ALSO PROTON PLASMONS



LENRs occur in microscopic active sites found on surfaces

Many-body collections of protons and SP electrons form spontaneously

High electric fields > 2.5 x 10^{11} V/m occur where Born-Oppenheimer breaks down

IDEALIZED AND NOT TO SCALE

Single nascent LENR active site; sizes range from ~ 2 nm up to 100 - 200 microns

$I > 10^{15}$ W/cm²

Many surface plasmon electrons

$e_n^{-*} > 10^{11}$ V/m

Born-Oppenheimer approximation breaks down in here

$e_n^{-*} > 10^{11}$ V/m

Many surface protons (Hydrogen)

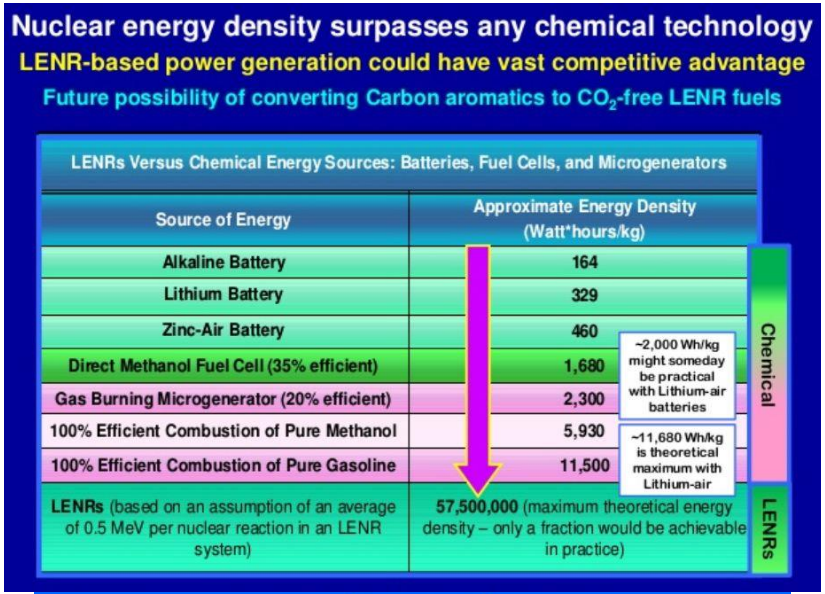
'Film' of surface plasmon electrons

Substrate surface material can be metal or metal-oxide

Many-body SP electron + proton subsystems shown above form one Widom-Larsen active site on a planar surface; active sites can also form on surfaces of nanoparticles or at various types of interfaces

WIDOM-LARSEN CONCEPT

LENR: THE DOWN OF A BASICALLY NEW WORLD?



Nuclear energy density surpasses any chemical technology

LENR-based power generation could have vast competitive advantage

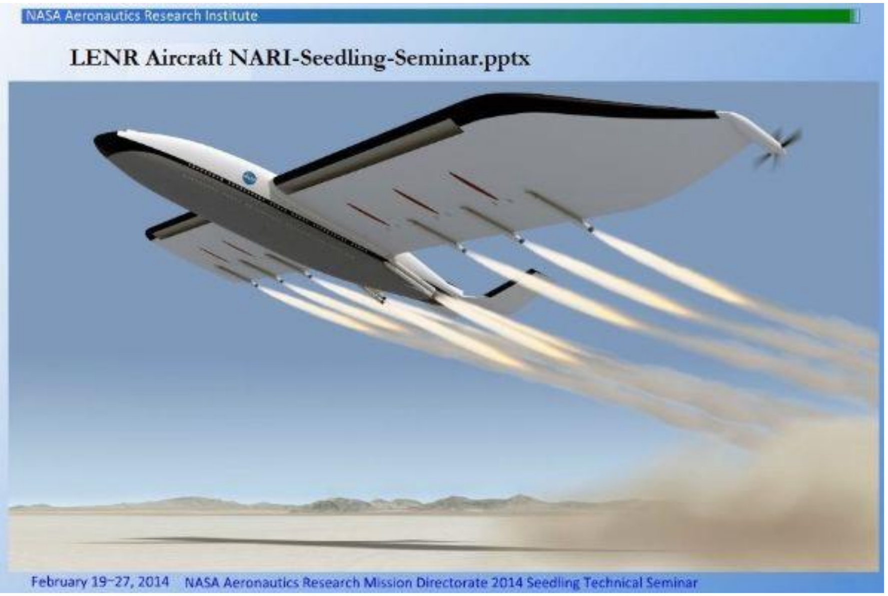
Future possibility of converting Carbon aromatics to CO_2-free LENR fuels

LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators

Source of Energy	Approximate Energy Density (Watt*hours/kg)
Alkaline Battery	164
Lithium Battery	329
Zinc-Air Battery	460
Direct Methanol Fuel Cell (35% efficient)	1,680
Gas Burning Microgenerator (20% efficient)	2,300
100% Efficient Combustion of Pure Methanol	5,930
100% Efficient Combustion of Pure Gasoline	11,500
LENRs (based on an assumption of an average of 0.5 MeV per nuclear reaction in an LENR system)	**57,500,000** (maximum theoretical energy density – only a fraction would be achievable in practice)

~2,000 Wh/kg might someday be practical with Lithium-air batteries

~11,680 Wh/kg is theoretical maximum with Lithium-air



NASA Aeronautics Research Institute

LENR Aircraft NARI-Seedling-Seminar.pptx

February 19–27, 2014 NASA Aeronautics Research Mission Directorate 2014 Seedling Technical Seminar

Research management company

Toyota controls the organization

Mitsubishi H.I.: very deep experience in U^{235} nuclear fission reactor technology

Also designed and produces XASM-3 supersonic ramjet anti-ship missile

Toyota: world's 2nd largest automobile manufacturer; #1 in hybrid e-vehicles

Also doing 3G R&D in humanoid robots: latest is T-HR3 (like avatar of a human)

SECRECY AND DOUBTS!!

1 MW energy for 1.5M$, and 106 E-CAT–s in a container

HIGH ENERGY PARTICLE BEAMS

Mourou, Tadjima,…

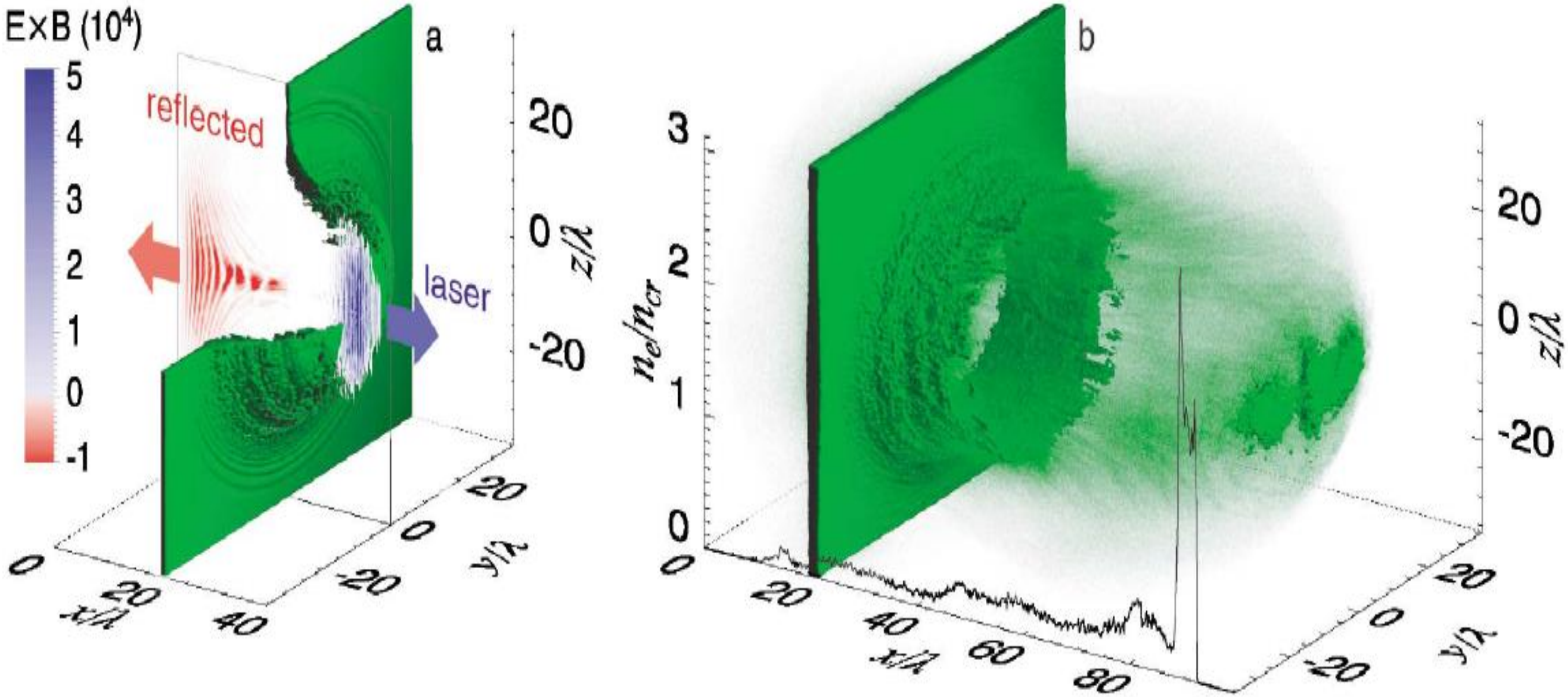
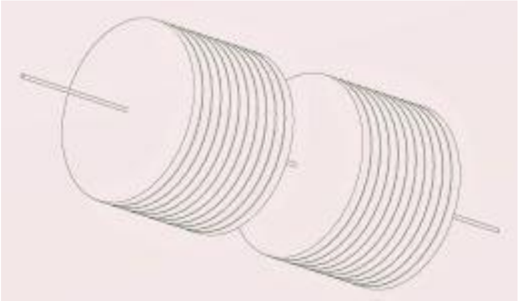
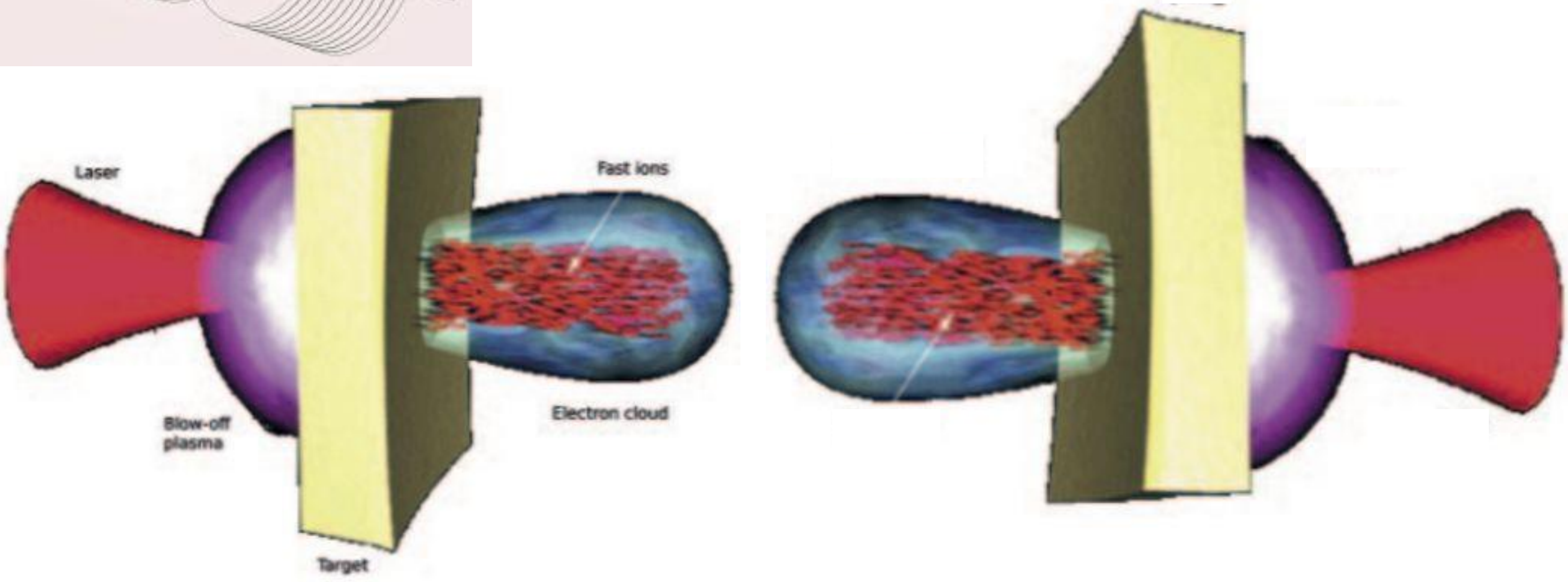
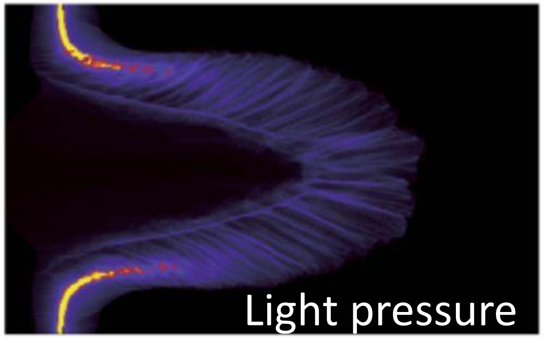


FIG. 1 (color). (a) The ion density isosurface for $n = 8n_{cr}$ (a quarter removed to reveal the interior) and the x component of the normalized Poynting vector $(e/m_e\omega c)^2\,\mathbf{E}\times\mathbf{B}$ in the $(x, y = 0, z)$ plane at $t = 40 \times 2\pi/\omega$. (b) The isosurface for $n = 2n_{cr}$, green gas for lower density at $t = 100 \times 2\pi/\omega$; the black curve shows the ion density along the laser pulse axis.

COLLIDING PARTICLE BEAMS



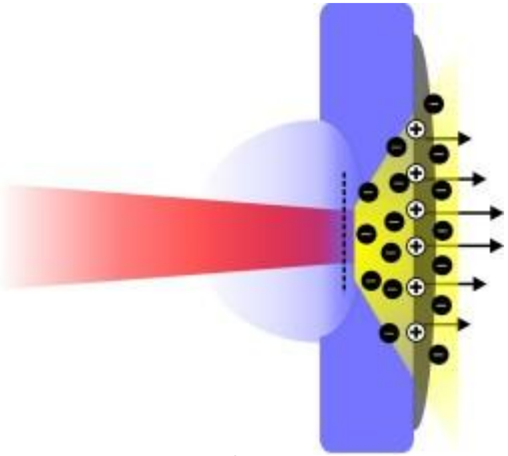




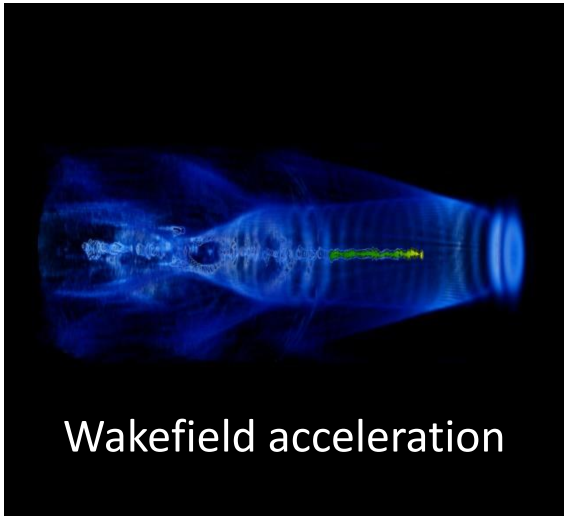
Light pressure

Proton acceleration by radiation pressure (100 MeV)

Nanoparticles: also volume contraction



TNSA (target normal sheath acceleration)



Wakefield acceleration

Technology Readiness Levels

TRL 0: **Idea**. Unproven concept, no testing has been performed.

TRL 1: **Basic research.** Principles postulated and observed but no experimental proof available.

TRL 2: **Technology formulation**. Concept and application have been formulated.

TRL 3: **Applied research**. First laboratory tests completed; proof of concept.

TRL 4: **Small scale prototype** built in a laboratory environment ("ugly" prototype).

TRL 5: **Large scale prototype** tested in intended environment.

TRL 6: **Prototype system** tested in intended environment close to expected performance.

TRL 7: **Demonstration system** operating in operational environment at pre-commercial scale.

TRL 8: **First of a kind commercial system**. Manufacturing issues solved.

TRL 9: **Full commercial application**, technology available for consumers.

NAPLIFE PROJECT ↗

THANKS FOR YOUR ATTENTION!