Plasmonics at ultra-high laser intensities?

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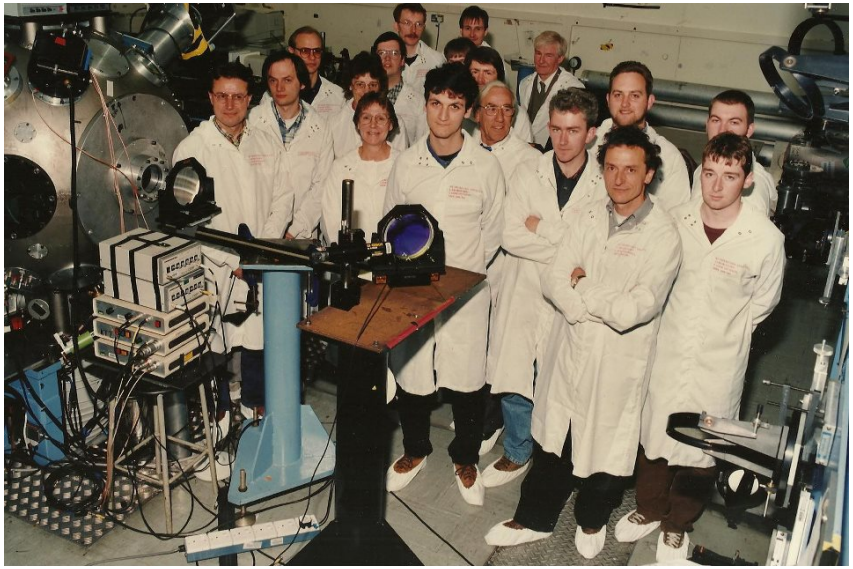
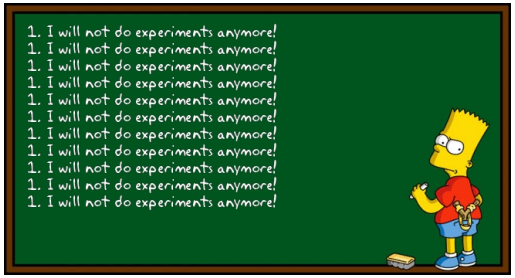
Science with High Power Lasers – “Tony70” day
Monday, June 9, 2014, Pisa

It was 20 years ago today (The way we were)

Picture taken at IFAM, Pisa, for Tonino's 50th birthday (1994)

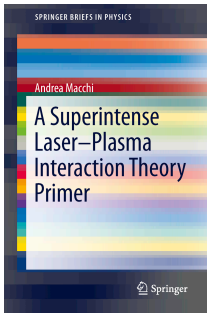
Lessons from my thesis at IFAM

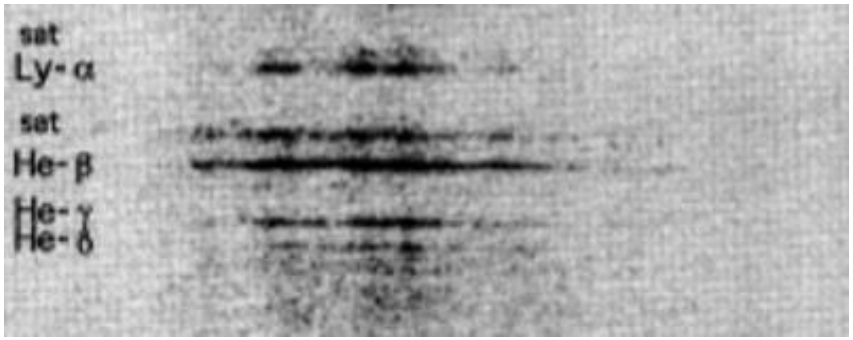




1: I should not try do to experiments anymore (for Physics' sake)

theory book $\longrightarrow$





2: Spectral lines are real (and thus also quantum mechanics)

...

N: ...

Changes (and New Life) through 20 years

- laser intensity: from 10^{13} W cm^{-2} (on lucky days) to $> 10^{18}$ W cm^{-2}, fully in the relativistic plasma regime of interaction
- pulse duration: from $> 10^{-9}$ s (*nanoseconds*) to $\sim 10^{-14}$ s (tens of femtoseconds)
- pulse contrast: from . . . *undefined* to better than 10^{10}
- target manufacturing: from thin plastic foils (hand-)made at IFAM to ultrathin "Diamond" foil and surface structures controlled on the sub-micron scale

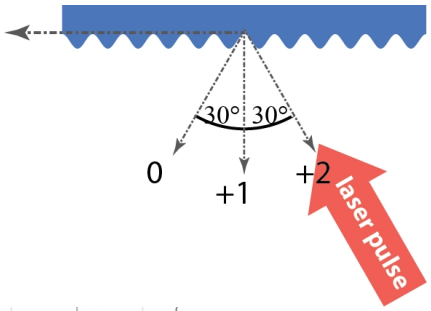
$\rightarrow$ it is possible to exploit target structuring in order to absorb, confine, and manipulate intense laser light

Plasmonics at high fields?

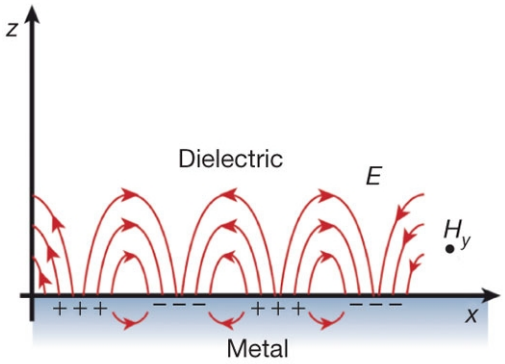
(*From Small Things Big Things One Day Come*)

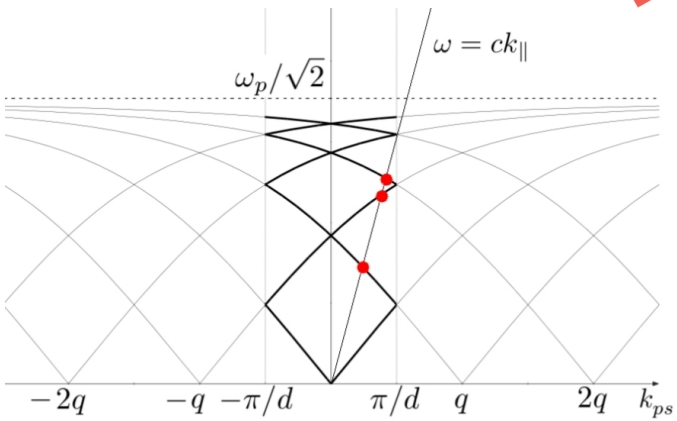
Concept: exploit collective electron excitation in sub-wavelength structures to manipulate light

A building block: excitation of surface waves in periodic structures ("light caught by a grating")



Matching possible at a plasma-vacuum interface if the grating is preserved!



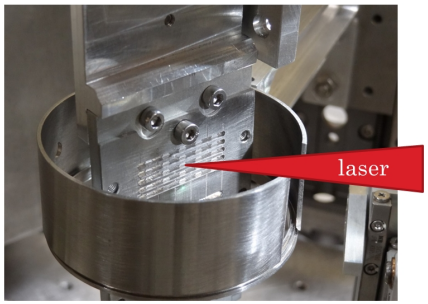


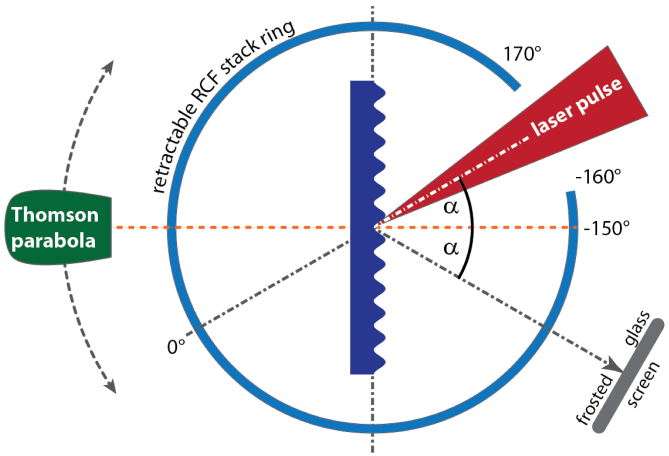
It could work! (first evidence in relativistic regime)

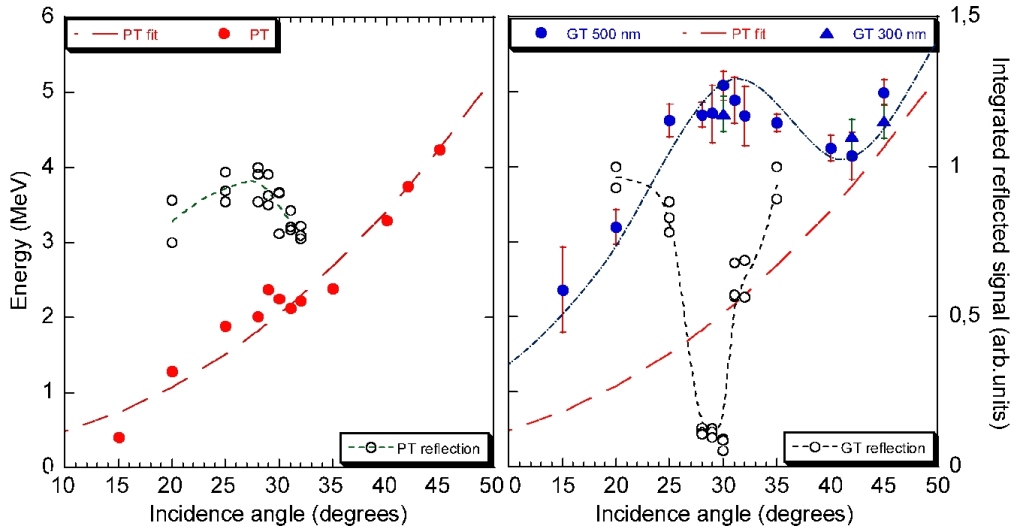
LaserLAB experiment at SLIC

laser UHI, 28 fs, 5×10^{19} W cm^{-2}

contrast $\sim 10^{12}$





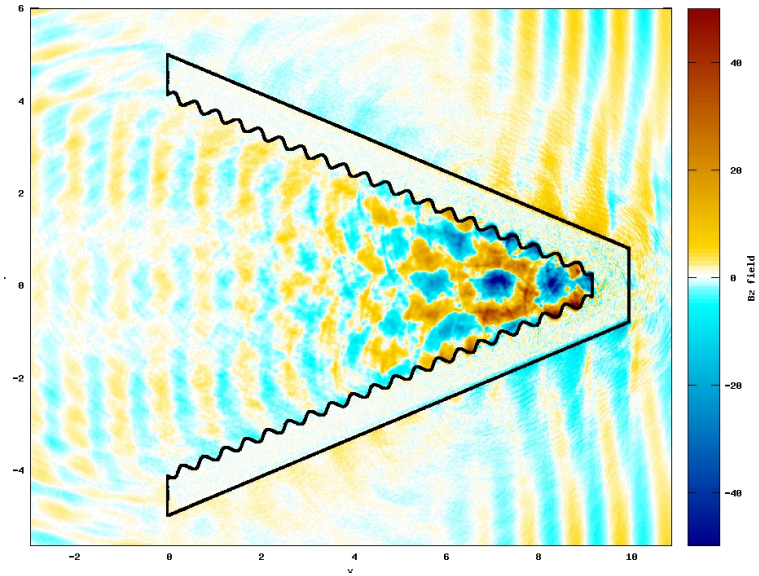


Resonant enhancement observed in proton energy

T.Ceccotti et al, PRL **111** (2013) 185001

Computer games: simulating plasmonics

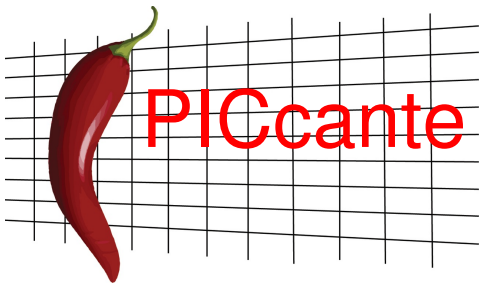
First PIC simulations of a tapered waveguide for light nano-focusing and amplification



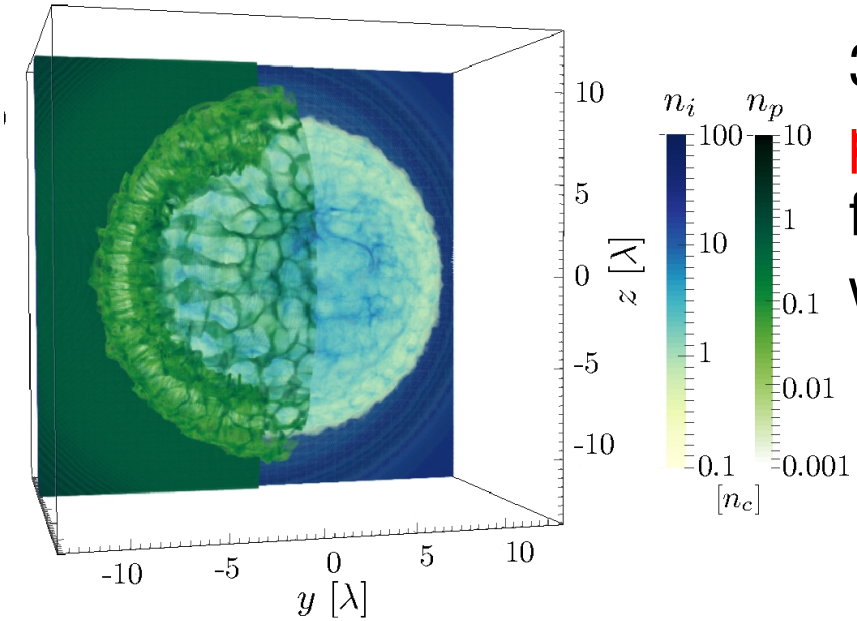
If 100X field amplification confirmed for ultraintense lasers, 10^{25} W cm^{-2} intensity is reached!

Simulations performed on FERMI supercomputer with the Open Source Particle-In-Cell code PICcante originally developed by L.Fedeli, A.Sgattoni, S.Sinigardi

`github.com/ALaDyn/piccante`



Rayleigh-Taylor Instability revisited (plasmonically)

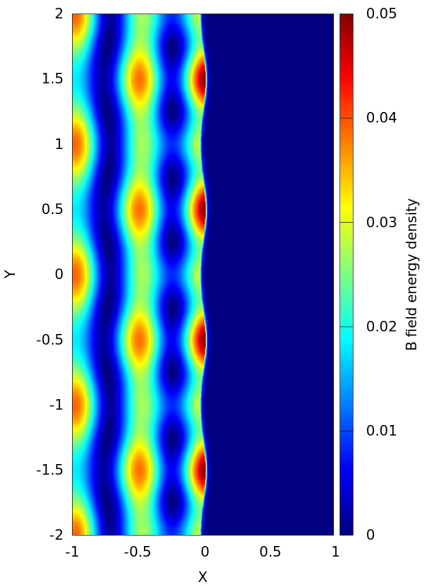


3D simulations of radiation pressure acceleration show formation of net-like structures with size $\sim \lambda$ (laser wavelength)

Model: Rayleigh-Taylor Instability with spatial seed from plasmonic field enhancement at the rippled surface

A.Sgattoni et al, arXiv:physics/1403.2709

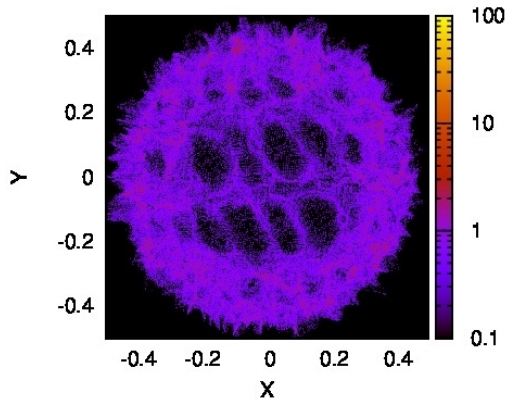
A.Macchi et al, arXiv:physics/1404.1260



RTI impact: from ion acceleration to wallpapers

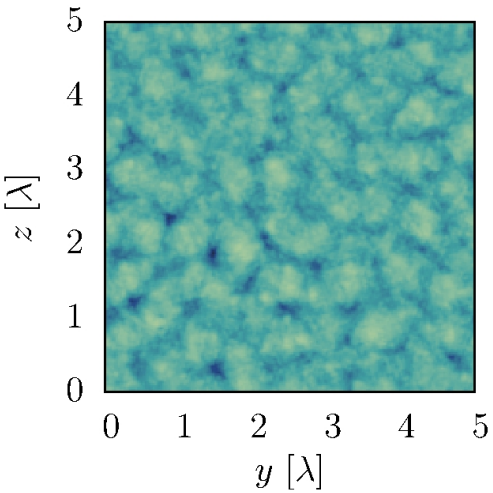
Applications: possible detrimental effect on radiation pressure acceleration of ions

Expt. (GEMINI)

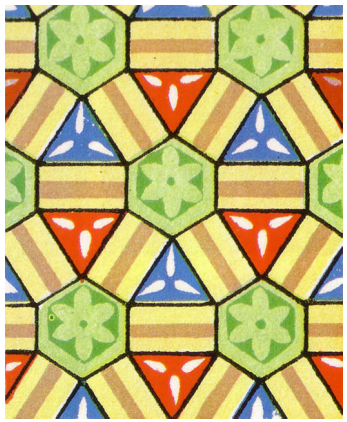


3D sim.

Beauty: nonlinear structures generated by RTI are an example of spontaneous symmetry breaking in a classical system (hexagonal pattern belongs to the "wallpaper" p6m symmetry group)



3D sim. (plane wave)



Persian glazed tile

Conclusions: high field plasmonics, why?

- exploit plasmonic effects for enhanced laser-plasma coupling

→ new perspectives for sources, focusing of fields, etc.

← many examples to test from “ordinary” plasmonics

- understand role of small structures (pre-imposed or self-generated) on laser-plasma interaction (example: Rayleigh-Taylor instability)
- find several examples of interesting nonlinear (relativistic) physics
- *Is this inspiring?* “Ai posteri l’ardua sentenza”