

Plasmonic nanoparticles for the protection of the final optics in inertial confinement fusion facilities: Capabilities and limitations

Ovidio Y. Peña Rodríguez
 Instituto de Fusión Nuclear, Universidad Politécnica de Madrid

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Logos: CSIC, CMAM, UAM, Instituto de Fusión Nuclear, International Programme for ATTRACTING TALENT

INDUSTRIALES People involved
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Simulations and experiments of damage in optical elements

Antonio Rivera, Alejandro Prada, Raquel González-Arrabal, José Manuel Perlado
 Instituto de Fusión Nuclear, Universidad Politécnica de Madrid

Miguel L. Crespillo, José Olivares, Fernando Agulló-López
 Centro de Micro-Análisis de Materiales, Universidad Autónoma de Madrid

María José Caturla
 Departamento de Física Aplicada, Universidad de Alicante




INDUSTRIALES Outline
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- Final lenses in laser fusion plants
 - Challenges for the protection of the final lenses
- Plasmonic nanoparticles
 - Radiation resistance
- Conclusions

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INDUSTRIALES Nuclear Fusion
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Gravity	Magnetic fields	Inertia
 <p>Plasmas de formación de las estrellas</p>	 <p>Tokamak</p>	 <p>Fusion por haces de láseres</p>

Lawson criterion must be fulfilled. This implies reaching a high compression to reach ignition

INDUSTRIALES HiPER, LIFE and NIF
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- High Power laser Energy Research facility
 - European project for laser fusion
- Laser Inertial Fusion Energy
 - USA project for laser fusion
- National Ignition Facility
 - Experimental facility (USA)



INDUSTRIALES ETSII | UPM **Pellet**

0.03 μm -thick Gold on 1 μm -thick Polymer
 289 μm -thick DT-filled Polymer Foam Ablator
 190 μm -thick DT Ice
 1500 μm radius DT Vapour
 3.96 mm

INDUSTRIALES ETSII | UPM **Indirect vs. direct target**

Indirect target

Hohlraum Pellet
 Laser Beams x-rays

- Used in NIF and LIFE
- Easier for obtaining an homogeneous compression
- Providing high enough gain for pure fusion energy is challenging

Direct target

Pellet
 Laser Beams

- Projected for HiPER
- More efficient use of laser light, and greater flexibility in applying drive provides potential for much higher gains

INDUSTRIALES ETSII | UPM **Laser fusion**

Direct target

Central ignition

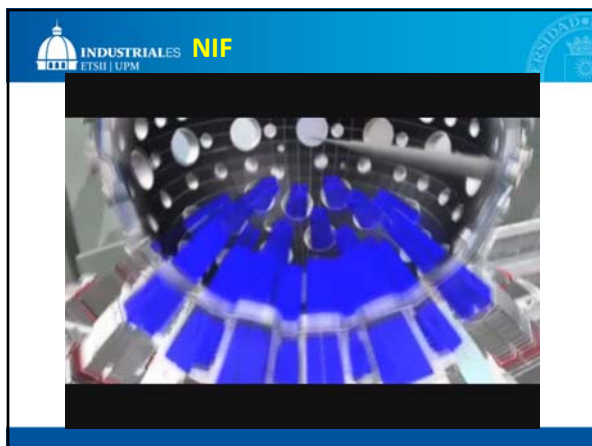
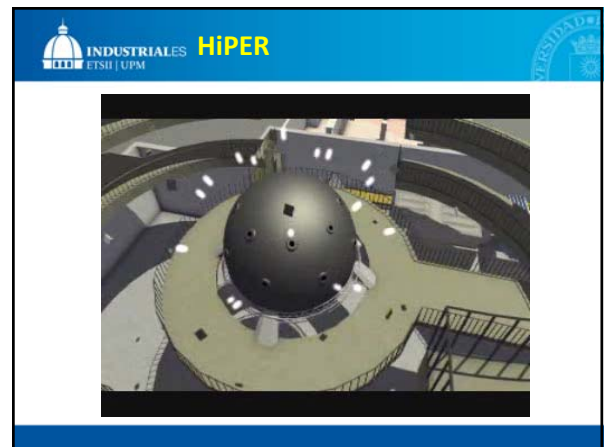
Laser irradiation
 Compression Ignition
 Burn

$\approx 10^{15} \text{ W.cm}^{-2}$
 $\approx 5-10 \text{ MJ}$

$\approx 2-3 \times 10^7 \text{ cm.s}^{-1}$
 100-1000 Mbar

$\approx 100-150 \text{ MJ}$

Repeating this process by injecting targets at a rates 5-20 Hz \approx 1000 MWe



INDUSTRIALES ETSII | UPM **Final optics in HiPER**

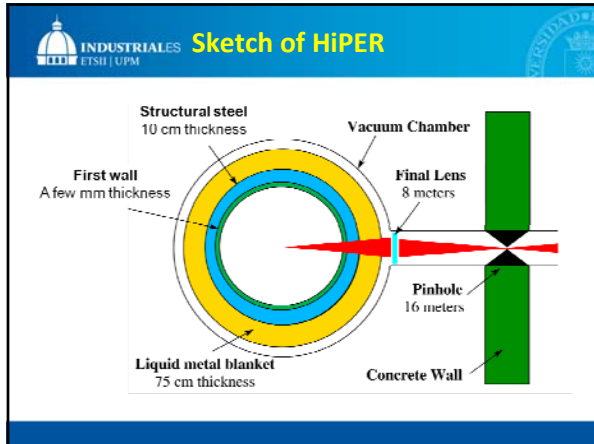
A = Disposable Lens
 B = Pinhole
 C = 1st Bending Mirror

5.0m Rad
 0.4m thick borated polyethylene or GdCl₃

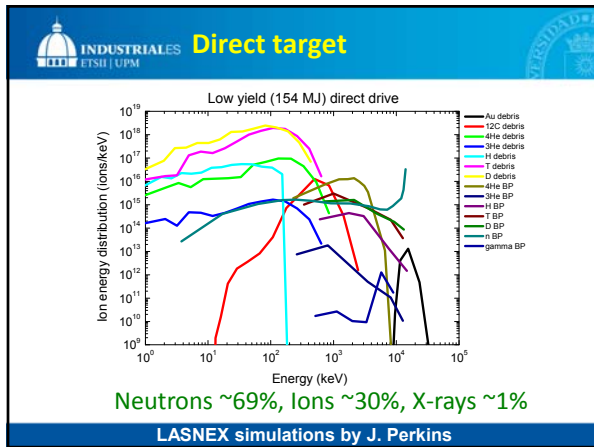
HiPER Concept Layout - SECTION
 Sheet 2

26/04/2010

Oxford Technologies



- ### Final lenses
- They must face the target explosions during operation, being only a few meters away
 - Moreover, they must have:
 - Low laser absorption
 - Good thermo-mechanical properties
 - High radiation resistance
 - Silica is proposed as the best candidate due to its good properties and low cost



HiPER

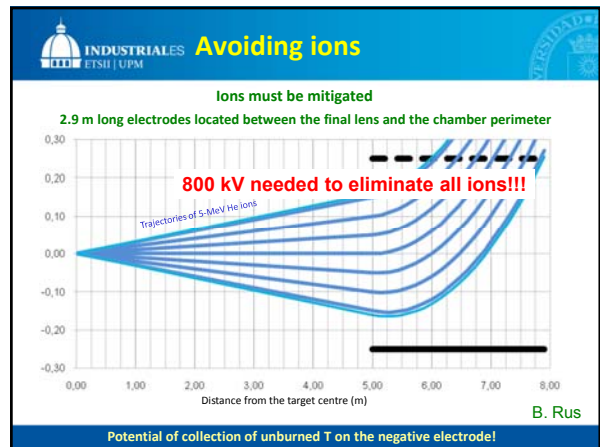
	HiPER Prototype	HiPER Demo
Operation	Continuous (24/7)	Continuous (24/7)
Yield (MJ)	<50	>100
Rep. rate (Hz)	1-10	10-20
Power (GWt)	< 0.5	1-3
T cycle	Yes	Yes
Blanket	Yes	Yes

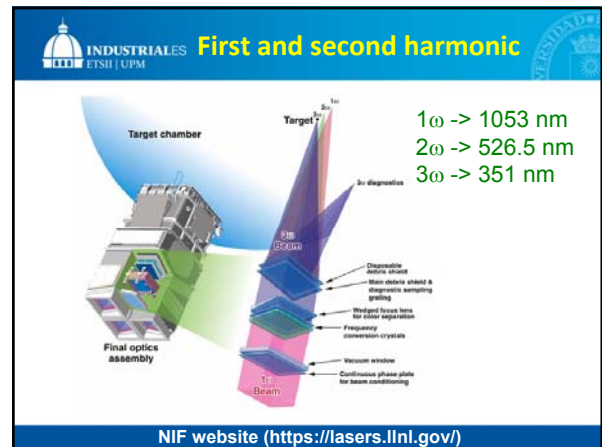
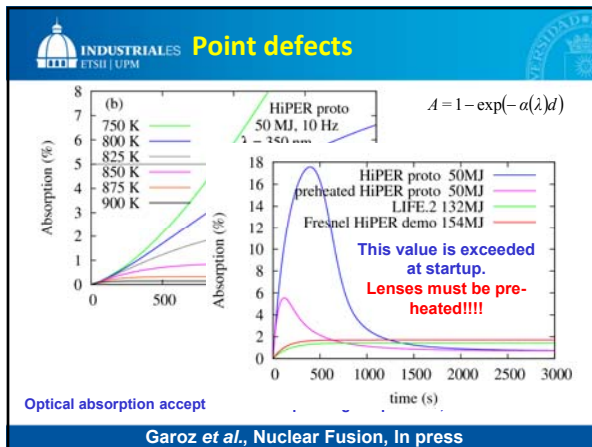
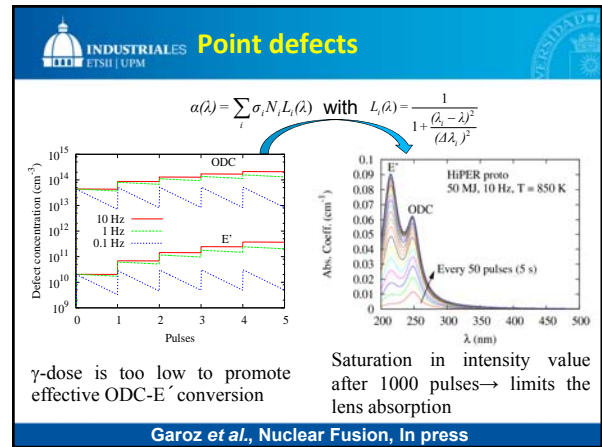
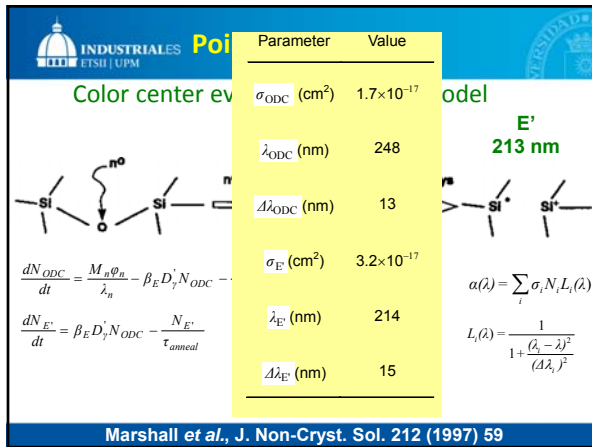
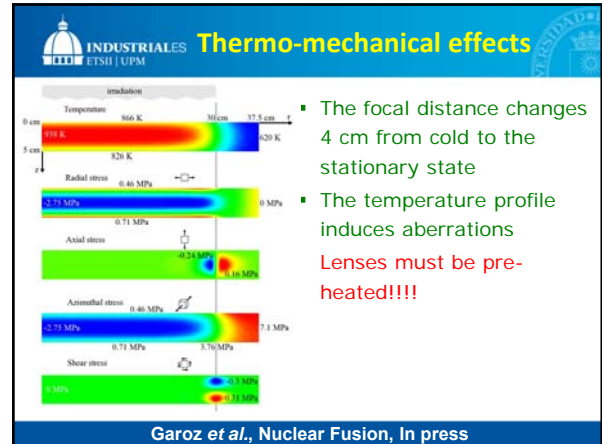
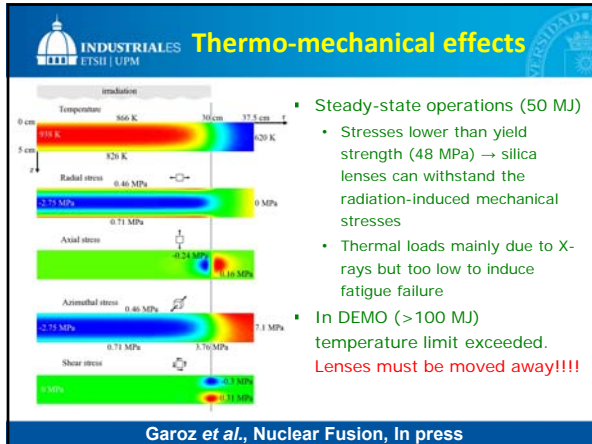
Neutrons ~69%, Ions ~30%, X-rays ~1%

Energy deposited

	HiPER				
	<E> (MeV)	Pulse width (ns)	Pen-depth (mm)	ED demo (J/cm ³)	ED prot. (J/cm ³)
Burnt products (⁴ He)	2.1	400	6.4	3788.48	1230.03
Debris ions (D)	0.15	2200	1.4	19627.93	6372.7
X-rays	0.007	0.17	few10 ³	261.11	84.78
Neutrons	12.4	60	-	0.142	0.046
Indirect gammas	-	»60	-	0.051	0.017

Ions must be mitigated somehow!!!





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Avoiding first and second harmonic

S. H. Glenzer

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In summary

- In HiPER's operating conditions:
 - The energy deposited by the ions is able to **instantly** (and locally) melt the final lenses
 - Ions must be mitigated!!
 - The energy deposited by the neutrons can lead to a hot stationary state where the final lenses melt
 - Lenses must be moved away!!

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Moreover...

- In HiPER's operating conditions:
 - The heating of the lenses during the startup can shift the focus, produce aberrations and create unacceptable quantities of point defects
 - Lenses must be pre-heated!!
 - Some quantities of 1ω and 2ω light can reach the Hohlraum, preheating the Pellet and producing unwanted effects
 - First and second harmonic should be eliminated!!

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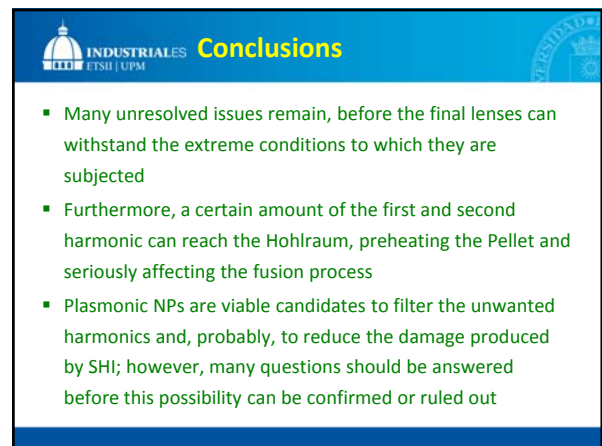
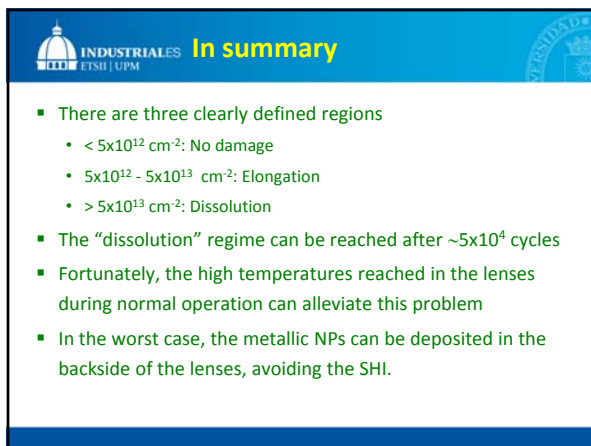
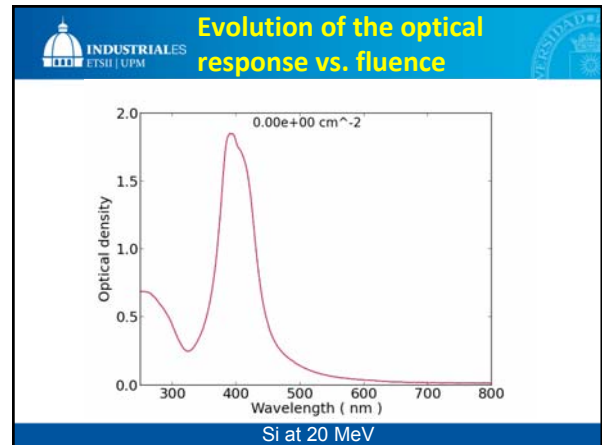
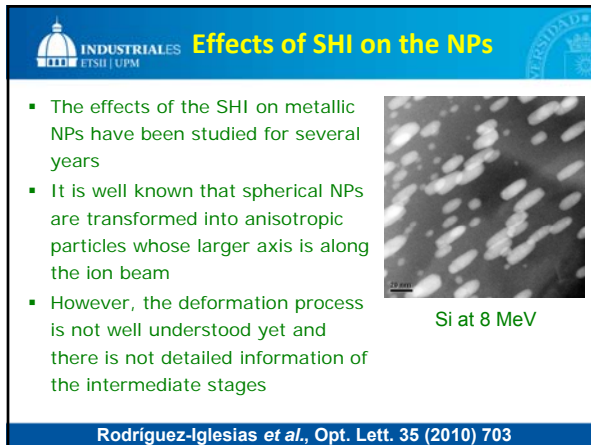
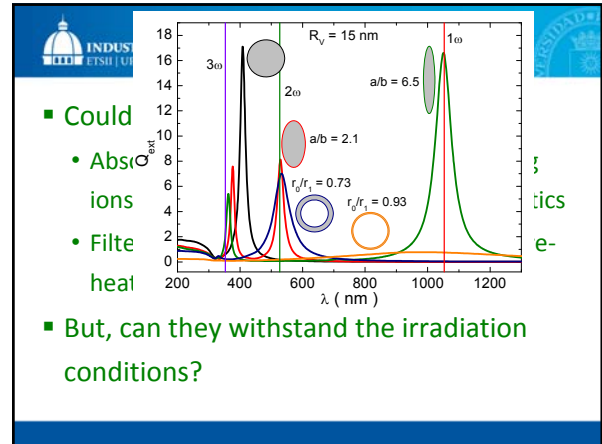
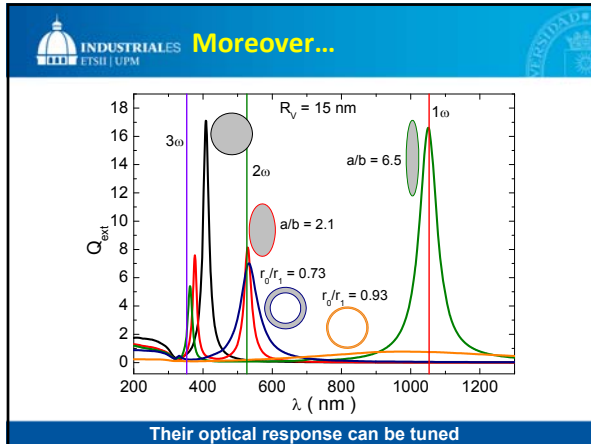
Plasmonic nanoparticles

- The defining feature of nanoparticles is **resonance** (LSPR)
- The position and intensity of the LSPR mainly depends on the size, shape and composition
 - This opens up the possibility of tuning the optical response
- They have important applications in fields ranging from biology and medicine to optoelectronics
- But, also in nuclear fusion?

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Why not?

Silver NPs are highly transparent at 3ω (353 nm)



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Thank you
for your attention

INDUSTRIALES ETSII | UPM **Switch to the green?**

Ultimately, yields well in excess of 100 MJ may be possible on NIF

E. Moses, MR1.00001

INDUSTRIALES ETSII | UPM **Direct target**

LASNEX simulations by J. Perkins

INDUSTRIALES ETSII | UPM **Direct target**

Neutrons ~69%, Ions ~30%, X-rays ~1%

LASNEX simulations by J. Perkins

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INDUSTRIALES ETSII | UPM **ODC**

