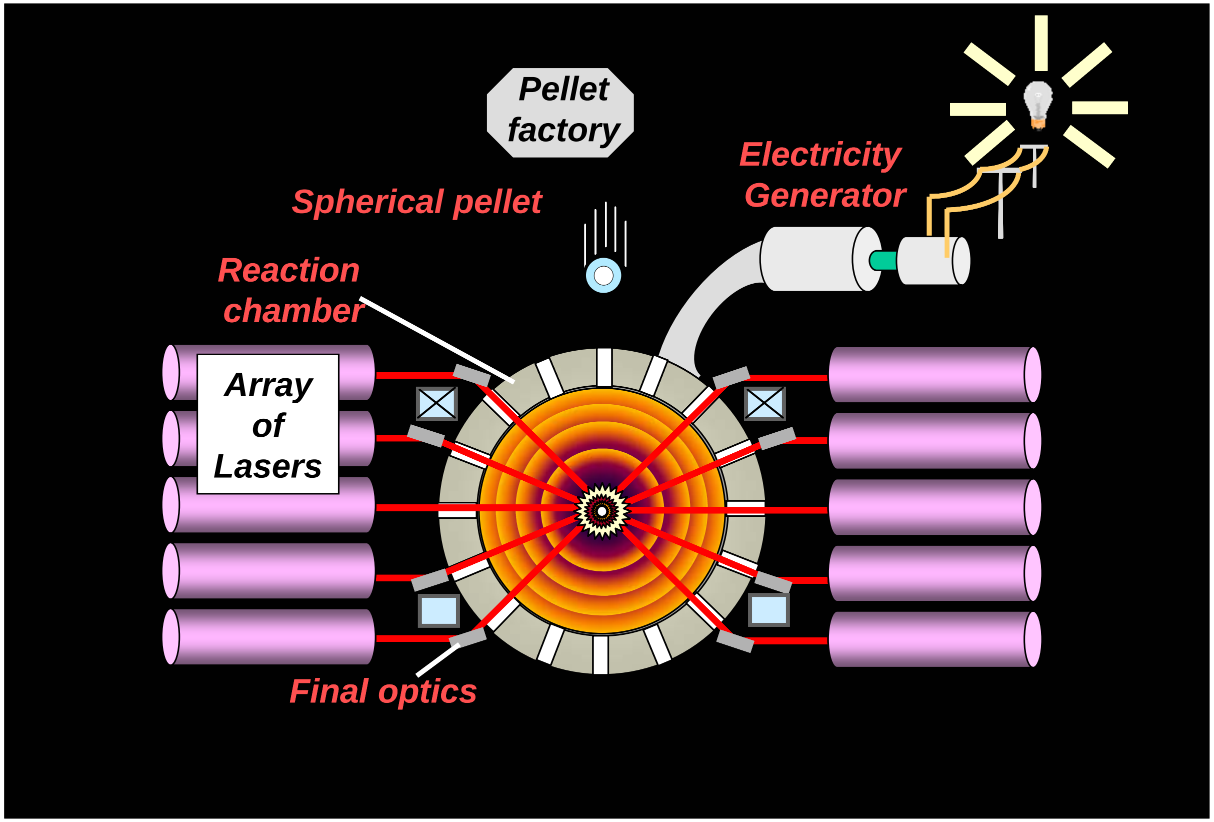
The High Average Power Laser Program

15th HAPL meeting
Aug 8 & 9, 2006
General Atomics/UCSD

presented by
John Sethian
Naval Research Laboratory, Plasma Physics Division, Washington DC
September 27, 2006

The HAPL team is developing the science, technology and architecture needed for a laser fusion power plant... *as if we will be called upon to build one*



Government Labs

1. NRL
2. LLNL
3. SNL
4. LANL
5. ORNL
6. PPPL
7. SRNL
8. INEL

Universities

1. UCSD
2. Wisconsin
3. Georgia Tech
4. UCLA
5. U Rochester, LLE
6. UC Santa Barbara
7. UC Berkeley
8. UNC
9. Penn State Electro-optics

Industry

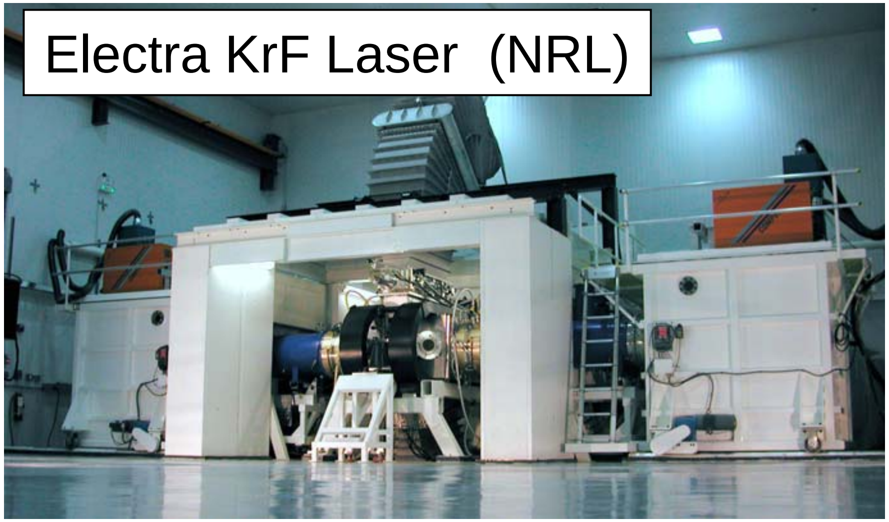
1. General Atomics
2. L3/PSD
3. Schafer Corp
4. SAIC
5. Commonwealth Tech
6. Coherent
7. Onyx
8. DEI

9. Voss Scientific
10. Northrup
11. Ultramet, Inc
12. Plasma Processes, Inc
13. PLEX Corporation
14. FTF Corporation
15. Research Scientific Inst
16. Optiswitch Technology
17. ESLI

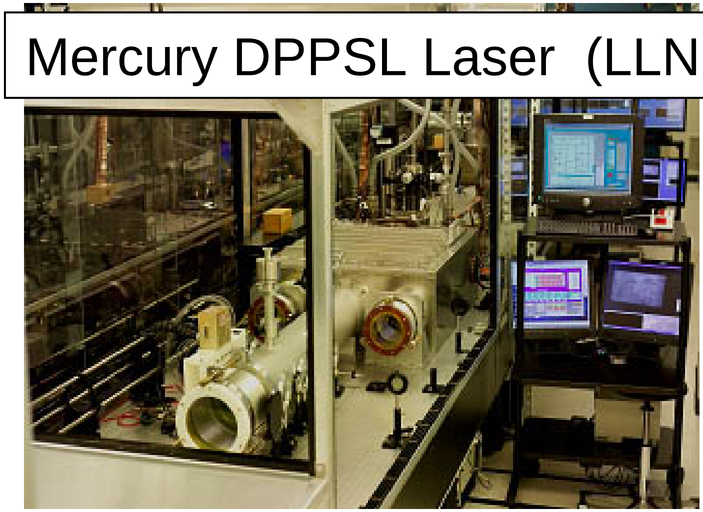
The HAPL program is developing two lasers:

- Diode Pumped Solid State Laser (DPPSL)
- Electron beam pumped Krypton Fluoride Laser (KrF)

Both have run at rep rates (1-10 Hz), for > 10,000 shots
Both have the potential for meeting all the requirements for fusion energy



Electra KrF Laser (NRL)



Mercury DPPSL Laser (LLNL)

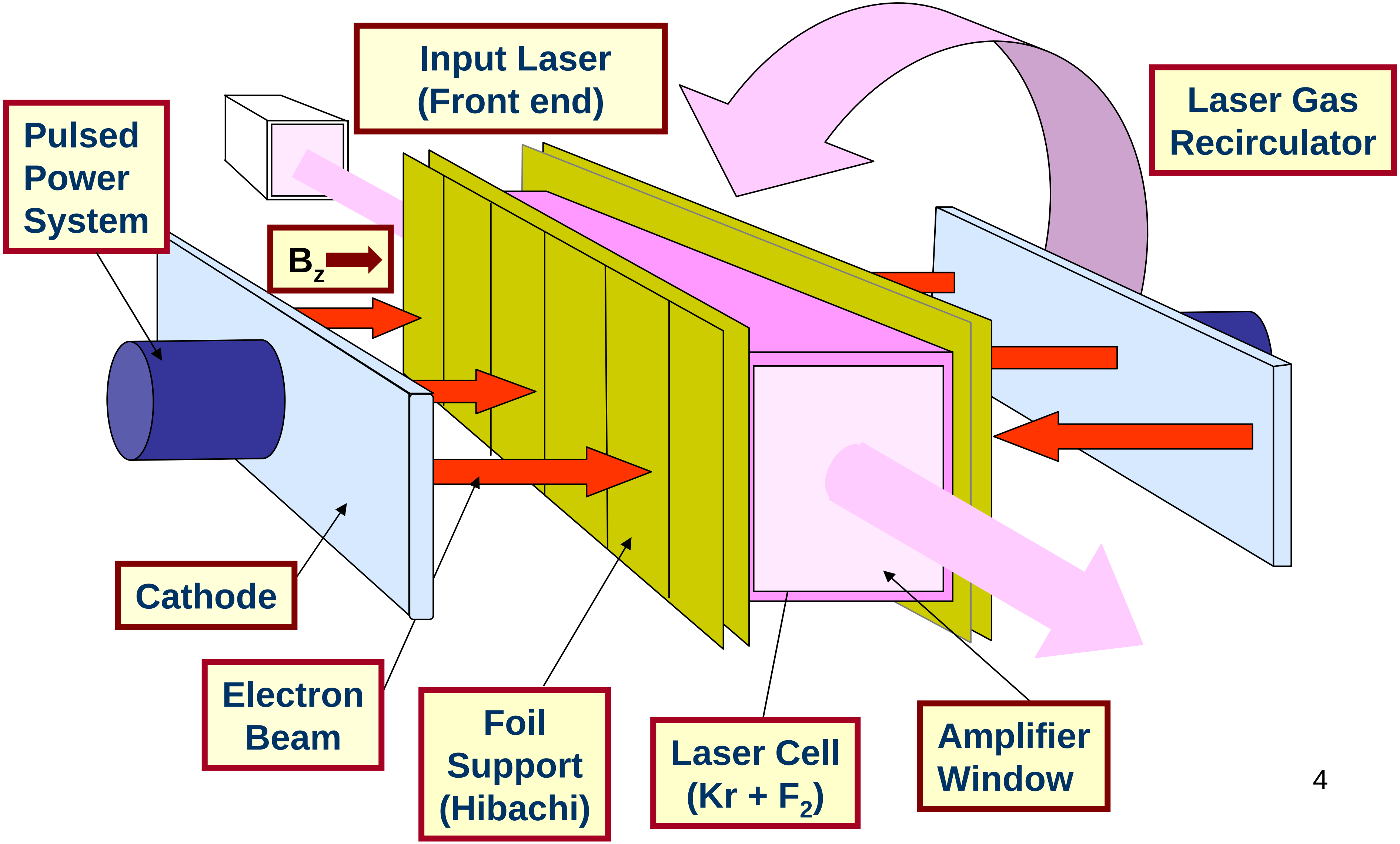
300-700 J @ 248 nm
120 nsec pulse
1 - 5 Hz
25 k shots continuous at 2.5 Hz
Predict 7% efficiency

55 J @ 1051 nm*
15 nsec pulse
10 Hz
100 k shots continuous @ 10 Hz
* Recently demo 73% conversion at 2ω

see talk by John Caird

Key components of a KrF Laser

$$\text{Energy} + (\text{Kr} + \text{F}_2) \Rightarrow (\text{KrF})^* + \text{F} \Rightarrow \text{Kr} + \text{F}_2 + h\nu\ (\lambda = 248\ \text{nm})$$



KrF Lasers- summary of progress

Last FPA meeting 10/2005

Demonstrated long term continuous operation at 1-5 Hz

300 J,	1 Hz	@ 10,000 shots
700 J,	1 Hz	@ 400 shots
250 J,	5 Hz	@ 7,700 shots (total of four runs)

Limited by cathode failure and/or released gasses

Predict Overall efficiency of IFE system ~ 7% (meets goal)

Based on Electra R & D of the individual components

KrF Lasers- summary of progress since last FPA meeting

New carbon electron emitter dramatically increases durability

25,000 laser shots at 2.5 Hz (continuous)

Much less evolved gas (> 10 x)

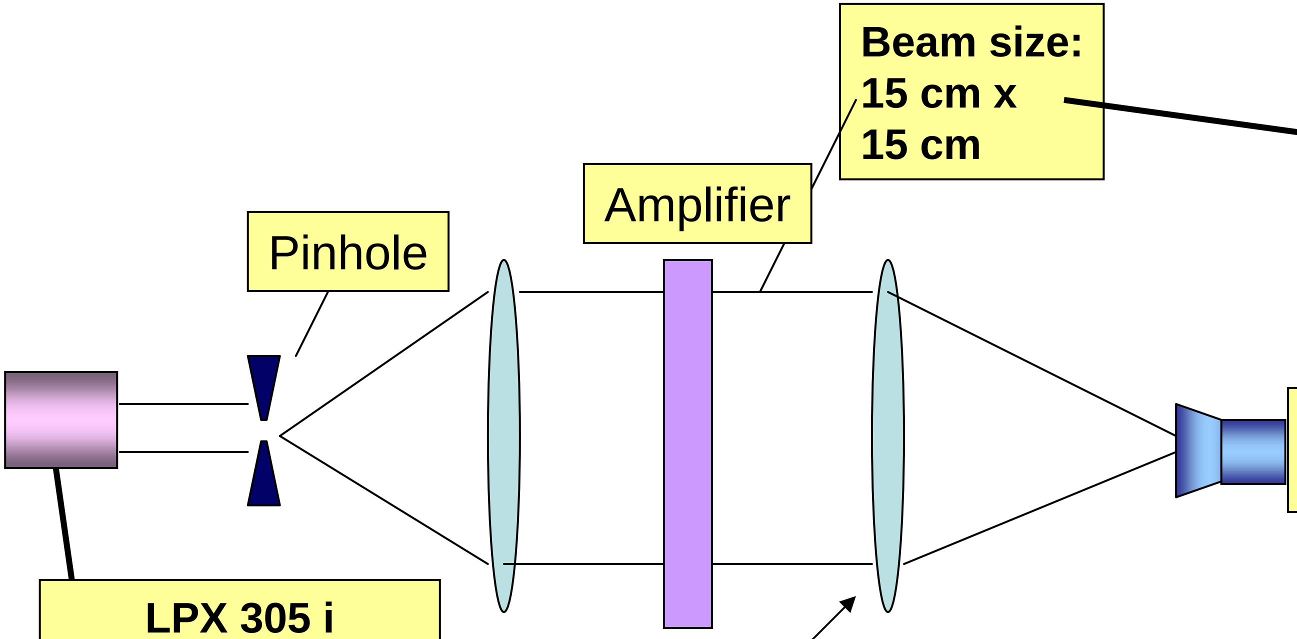
First rep-rate focal profile measurements

Focal profile "recovers" < 200 msec (i.e. 5 Hz)

"First Light" on Electra Pre-Amplifier (input to main amplifier)

23 J laser output

First rep-rate focal profile measurements:
Experimental set up using "Pseudo ISI"



Beam size:
15 cm x
15 cm

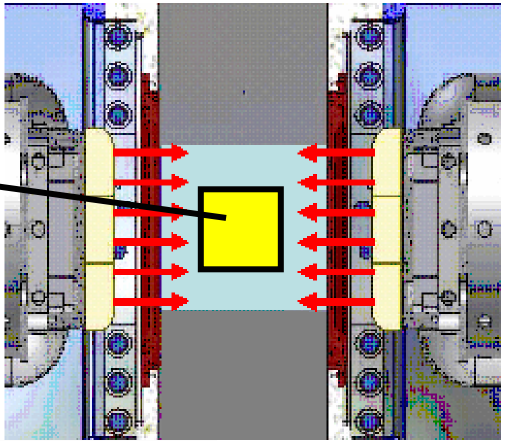
Amplifier

Pinhole

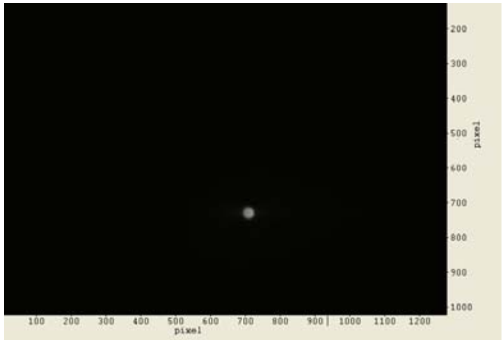
NanoStar
Camera

LPX 305 i
Not ISI Source

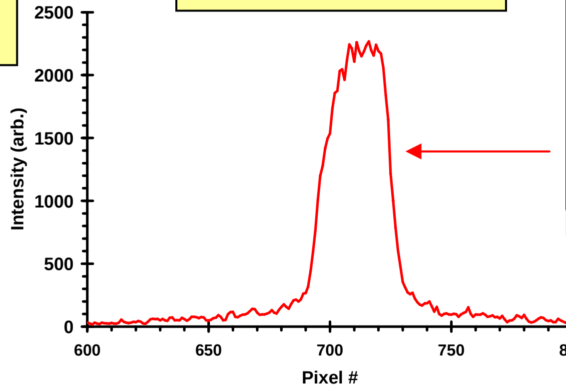
6 meter focal length lens 248 nm



Recorded Image

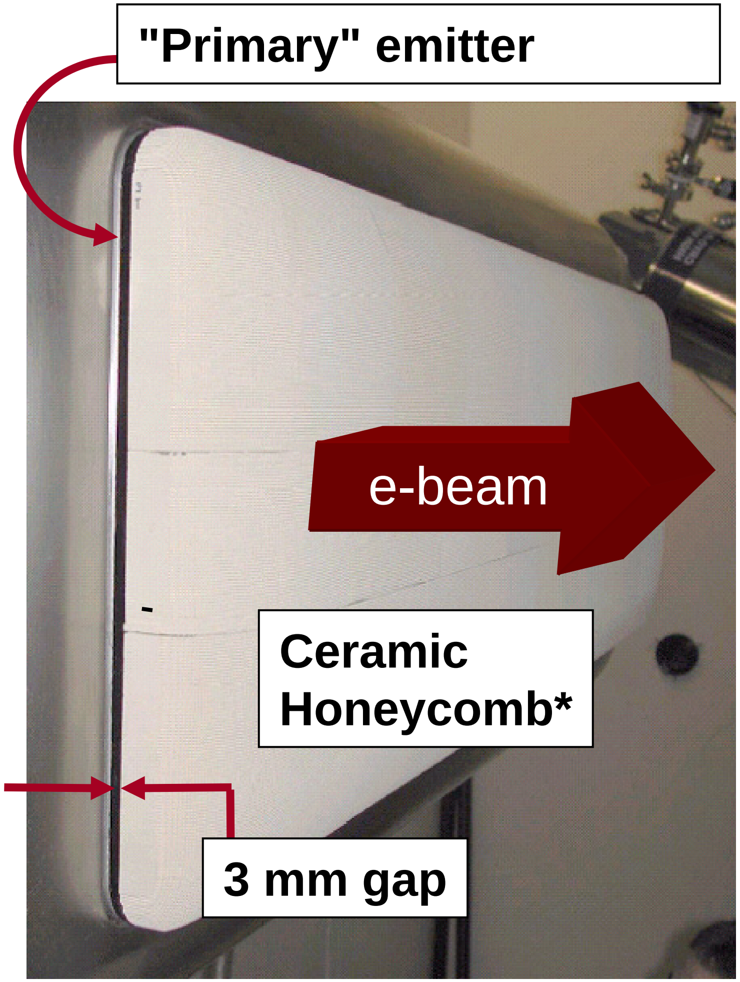


Lineout Image



New carbon electron emitter significantly increases durability

See no change after > 31,000 shots (~25 k continuous)



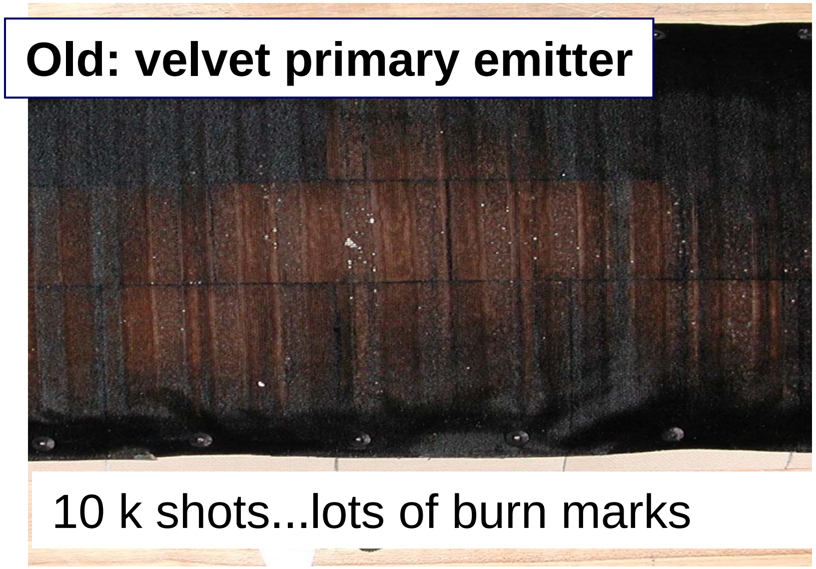
"Primary" emitter

e-beam

Ceramic Honeycomb*

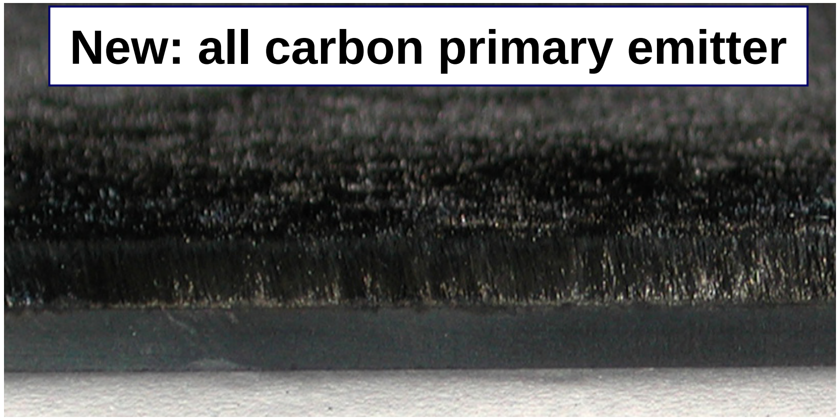
3 mm gap

*325 ppi cordierite honeycomb with gamma-alumina wash coat



Old: velvet primary emitter

10 k shots...lots of burn marks

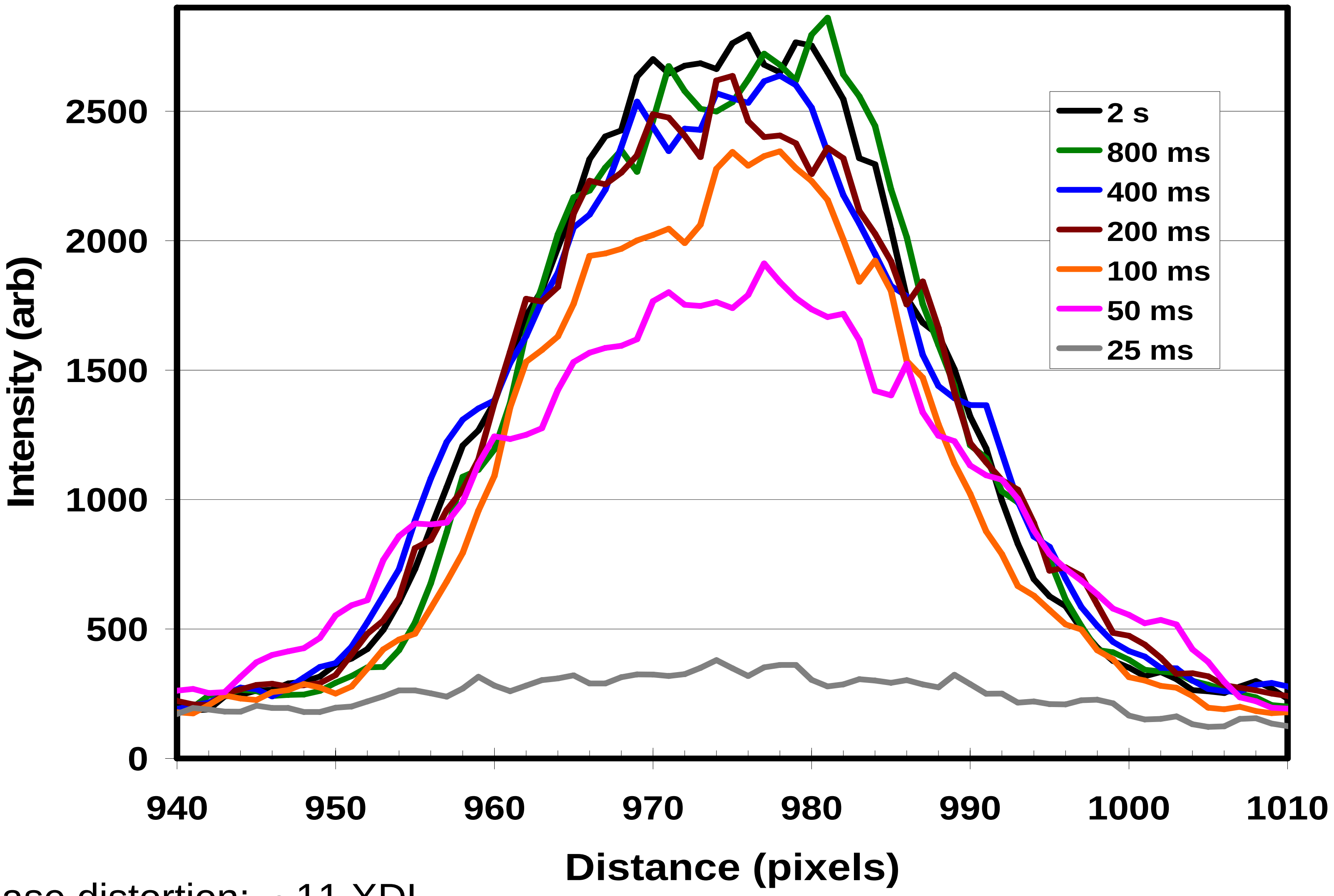


New: all carbon primary emitter

31 k shots...no change

First rep-rate focal profile measurements:

Focal profile "recovers" < 200 msec after e-beam fires



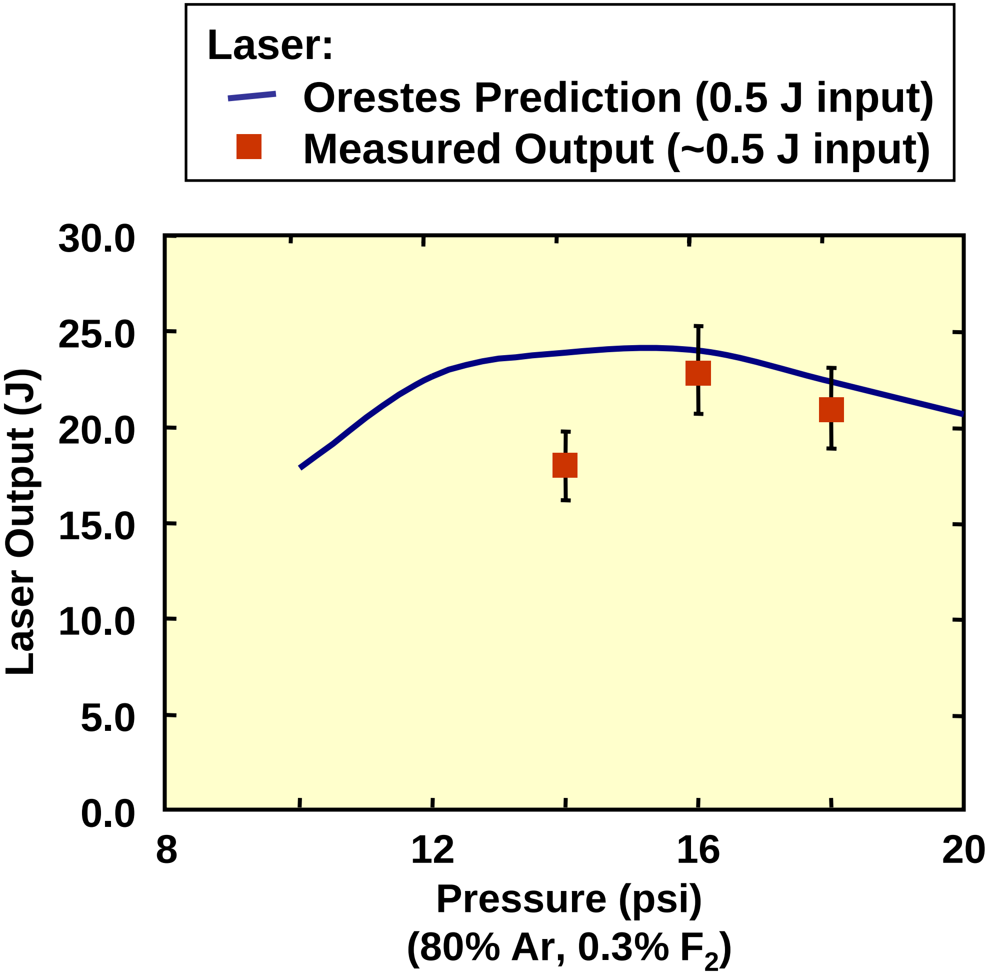
Phase distortion: ~11 XDL

Spot Size: ~50 XDL

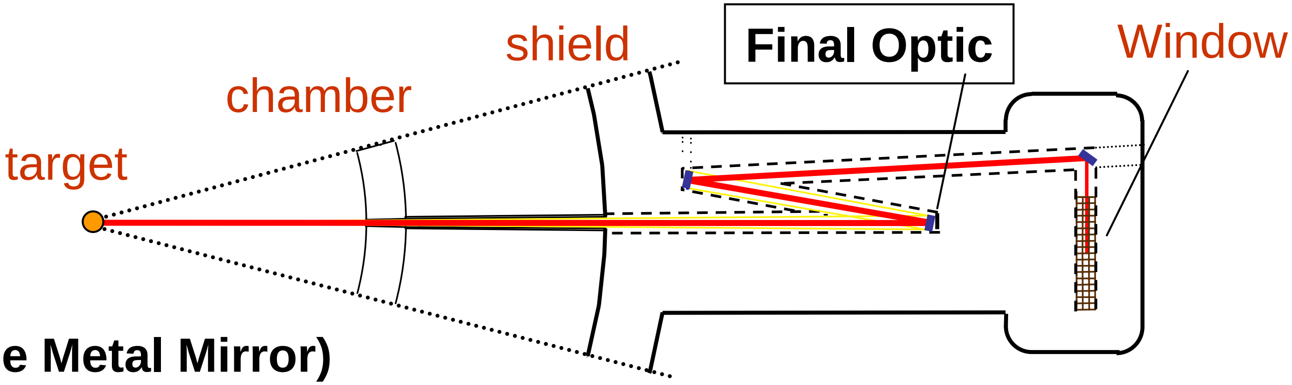
"First Light" on Electra Pre-Amplifier

23 J laser output

Pulsed power:
100,000 shots @ 5 Hz continuous
< 800 psec jitter
Test bed for advanced pulsed power



We are evaluating several types of final optics



GIMM (Grazing Incidence Metal Mirror)

- More resistant to neutrons

but...

- Large
- More neutrons on window

Dielectric Mirror

- Highest damage threshold
- Less neutrons on window

but...

- Less resistant to neutrons

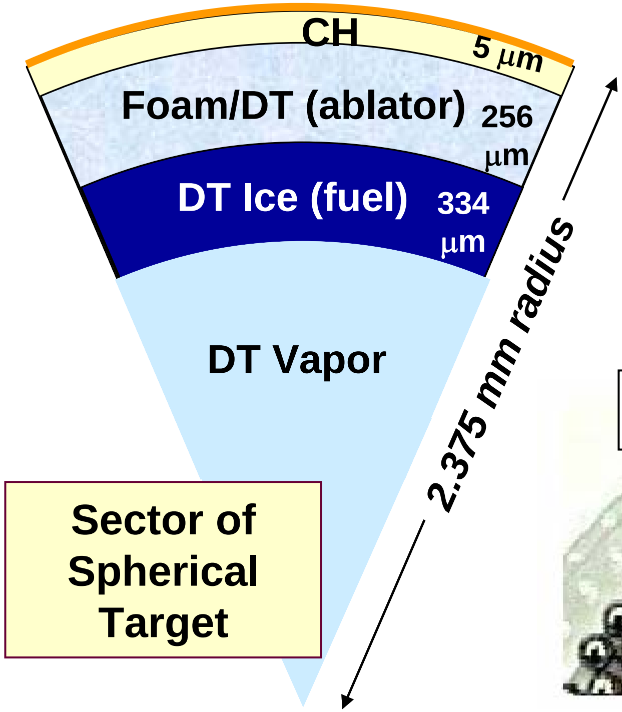
Fresnel lens

- Must be thin and run hot to anneal neutron damage
- May not work for 248 nm (KrF)

UCSD
PLEX Corp
Wisconsin
Penn State
LLNL

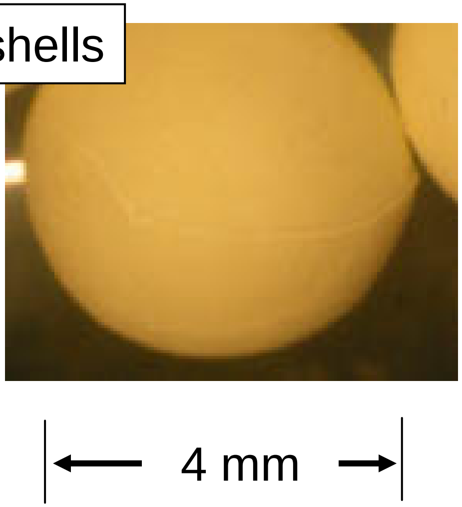
Target fabrication progress (1 of 2):

- Made foam capsules that meet all specifications
- Produced gas tight overcoats
- Demonstrated smooth Au-Pd layer

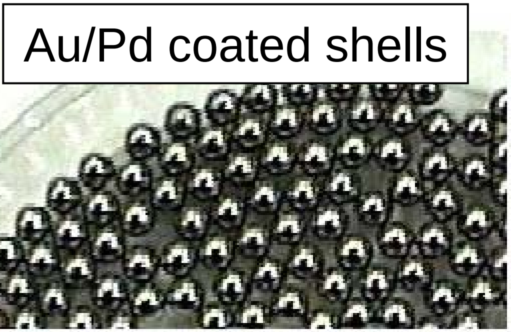


Sector of Spherical Target

foam shells



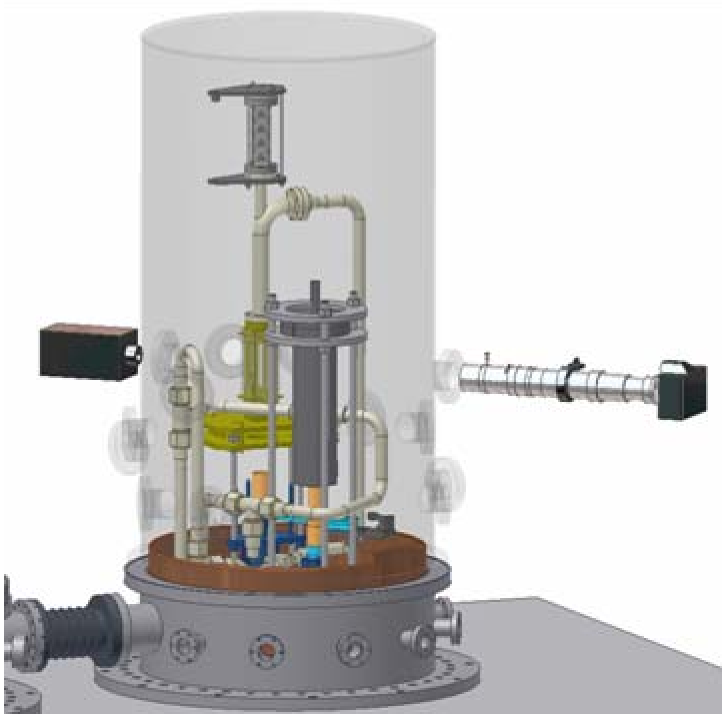
Au/Pd coated shells



GDP coater
to apply overcoat

General Atomics
Schaffer
LANL

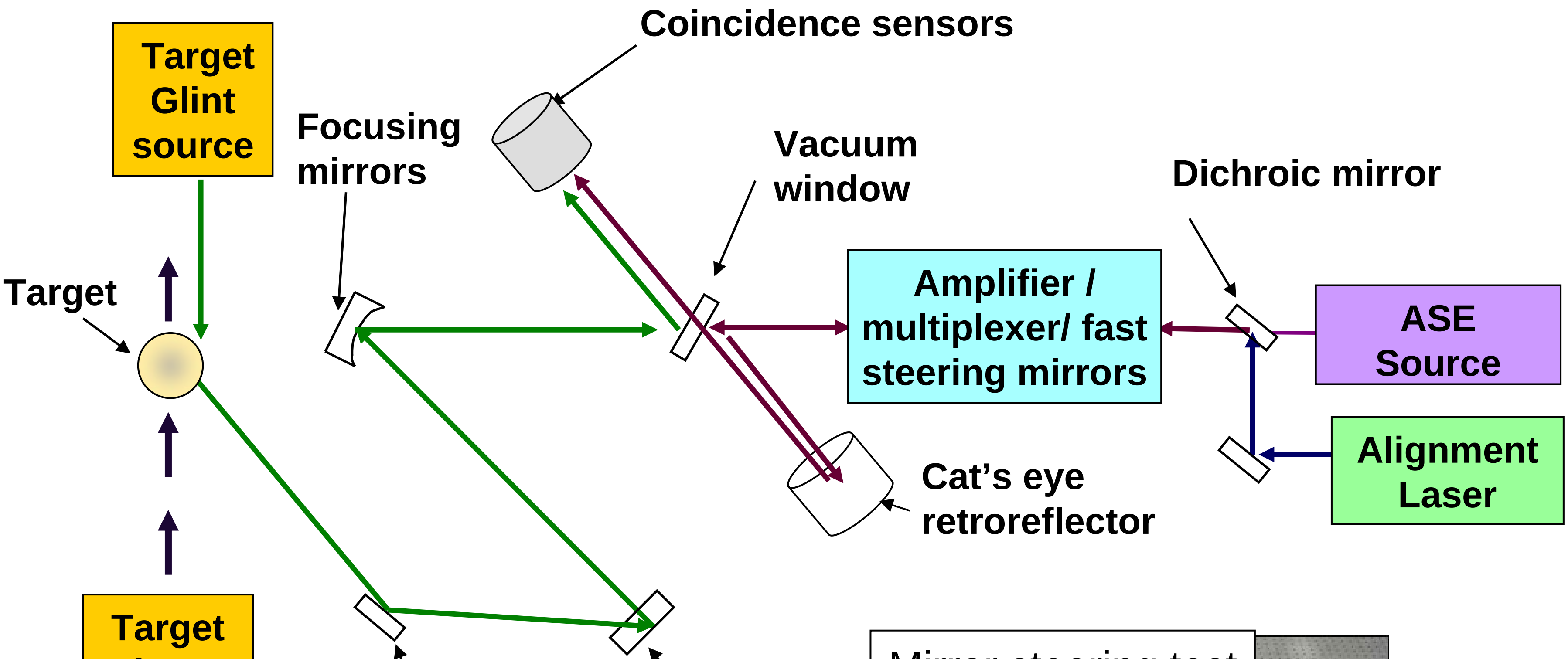
Target fabrication progress (2 of 2):
Nearing completion of MPLX Fluidized Bed
Will demonstrate mass production layering of cryo targets



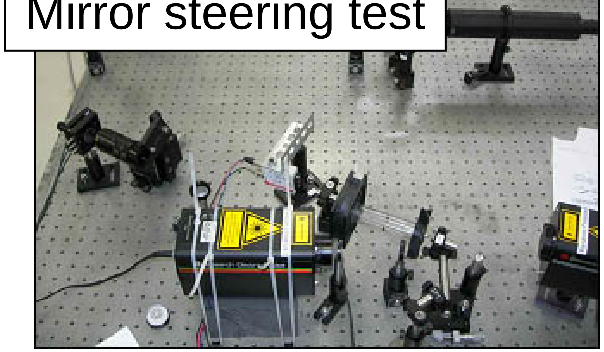
Key features:

- Permeation cell to fill targets with D_2
- Target manipulator
- Fluidized bed with IR layering

We have a concept to "engage" the target
Key principles demonstrated in bench tests
("engage" = tracking the target and steering the laser mirrors)



Mirror steering test



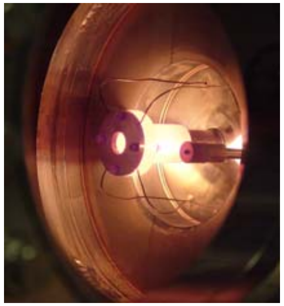
General Atomics
UCSD
Penn State
A.E. Robson

We use many experimental / computational tools to develop a first wall that can resist the "threats" from the target

Thermo-mechanical (ions & x-rays)

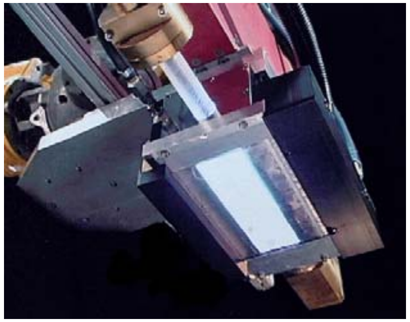
Ions:
RHEPP
(SNL)

Laser:
Dragonfire
(UCSD)



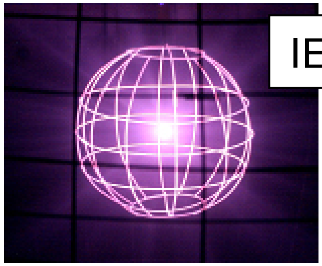
X-rays:
XAPPER
(LLNL)

Armor/substrate interface stress

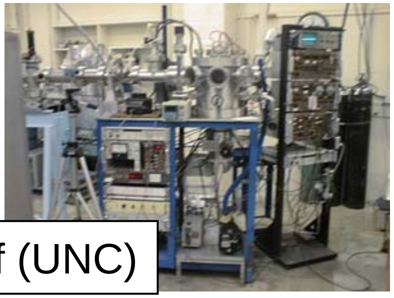


Plasma Arc Lamp
(ORNL)

Helium Retention

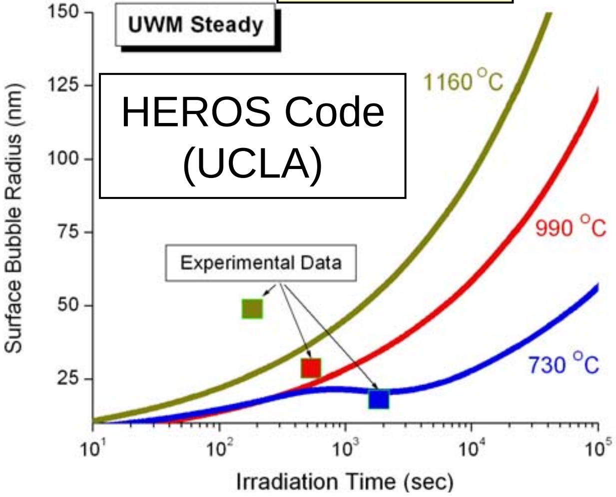


IEC (Wisconsin)



Van de Graff (UNC)

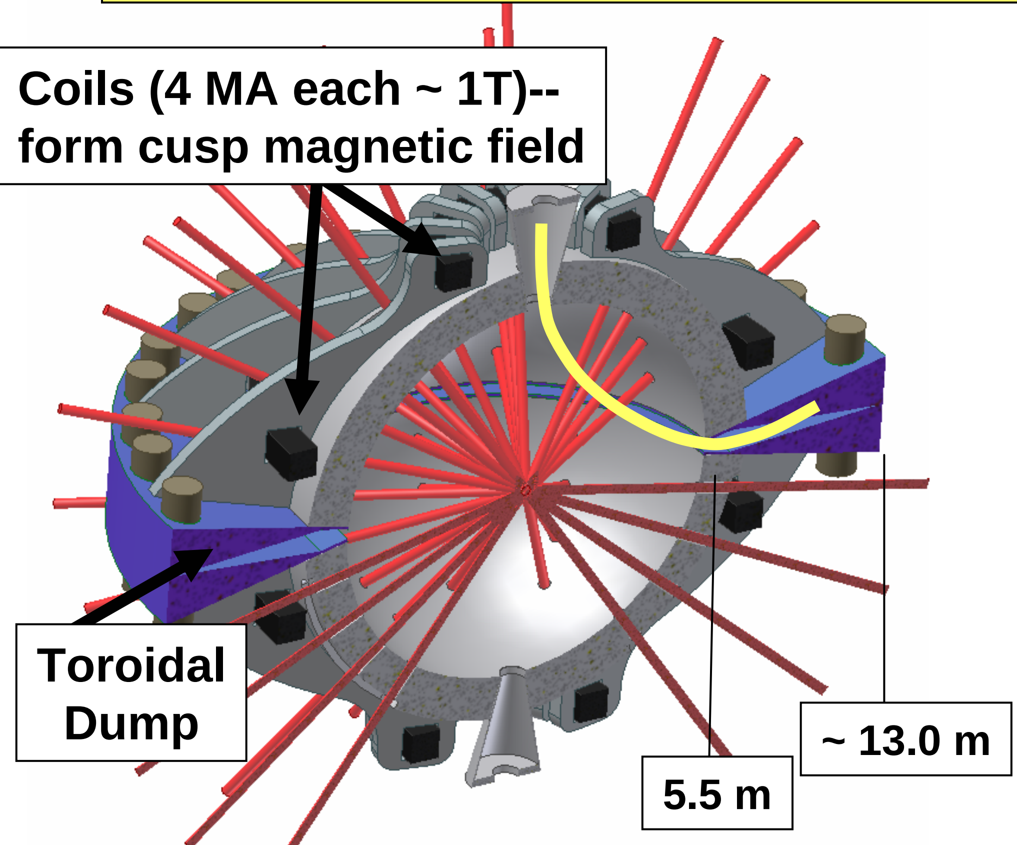
Modeling



HEROS Code
(UCLA)

"Magnetic Intervention" offers a way to keep the ions off the wall

1. Cusp magnetic field stops expanding ion shell.
2. Ions never get to wall.
3. Field is resistively dissipated in wall
4. Ions, at reduced energy *and power*, escape through cusp poles and belt
5. Ions at reduced power, are absorbed in toroidal dump



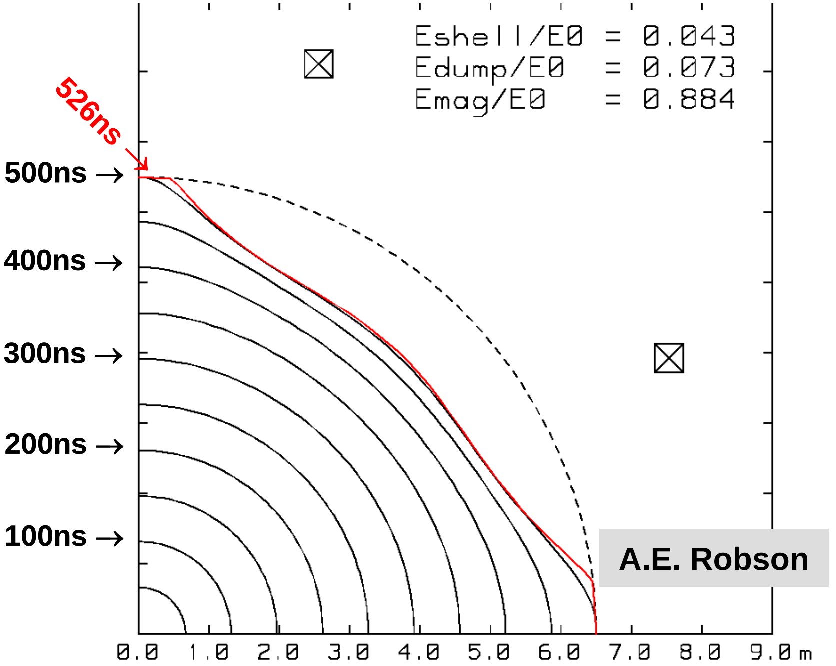
Coils (4 MA each ~ 1T)-- form cusp magnetic field

Toroidal Dump

5.5 m

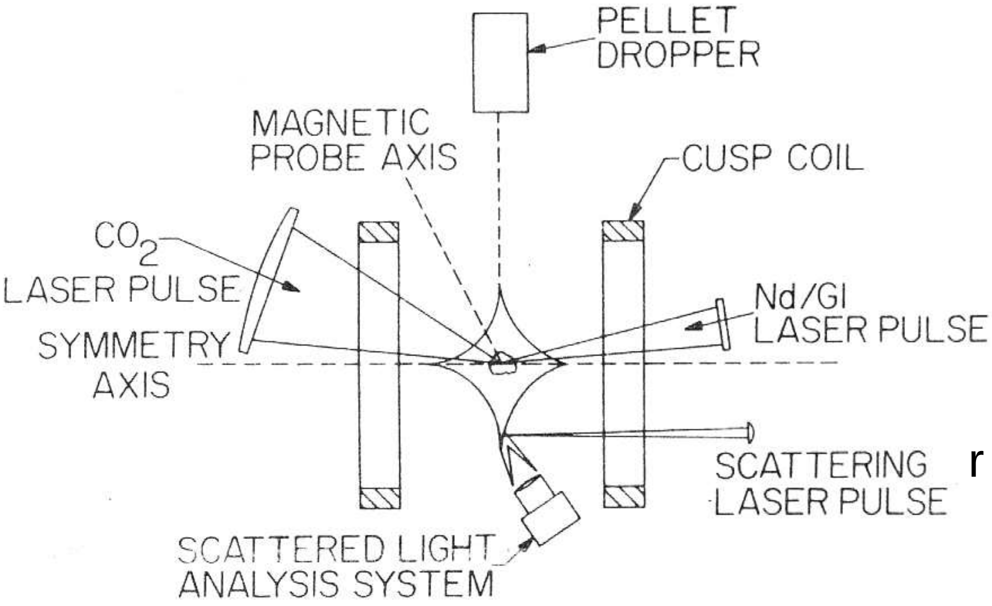
~ 13.0 m

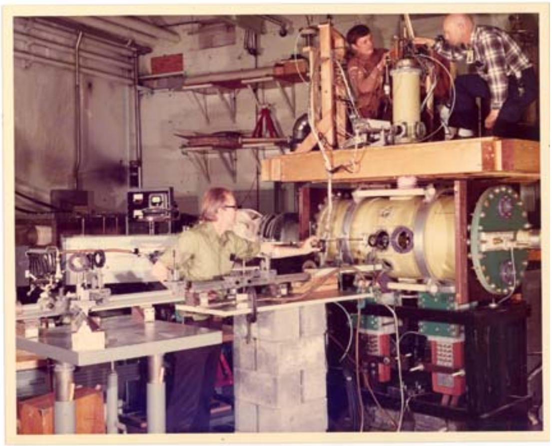
Expansion of plasma in cusp field: 2-D shell model

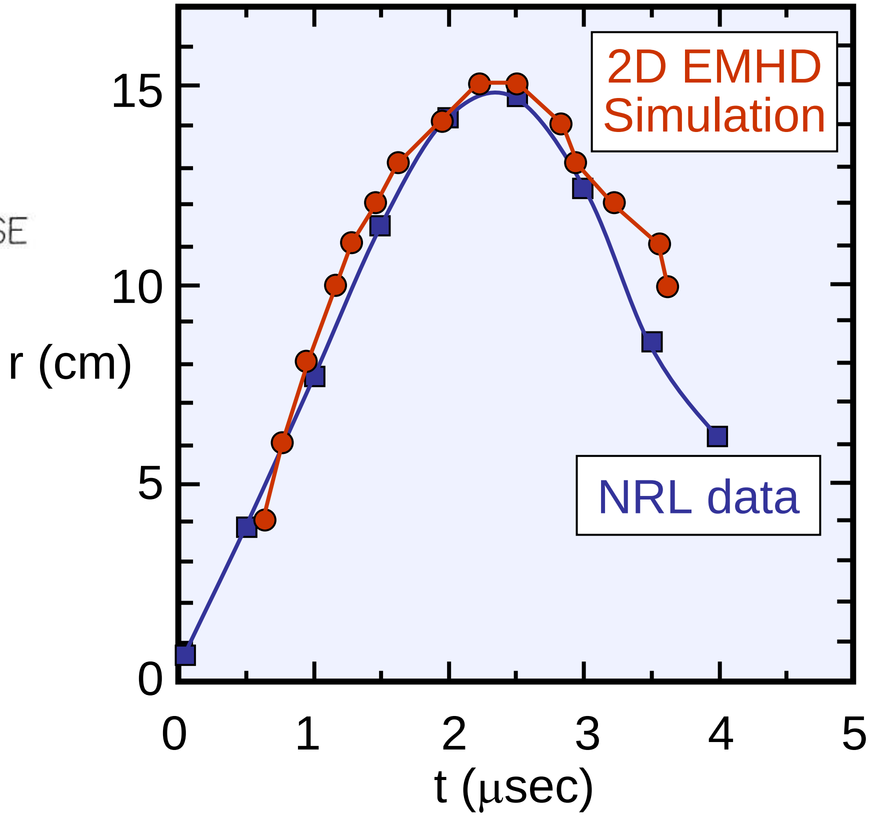


A.E. Robson

♦ 1979 NRL experiment demonstrated principal of MI.
♦ Recent simulations predict plasma & ion motion



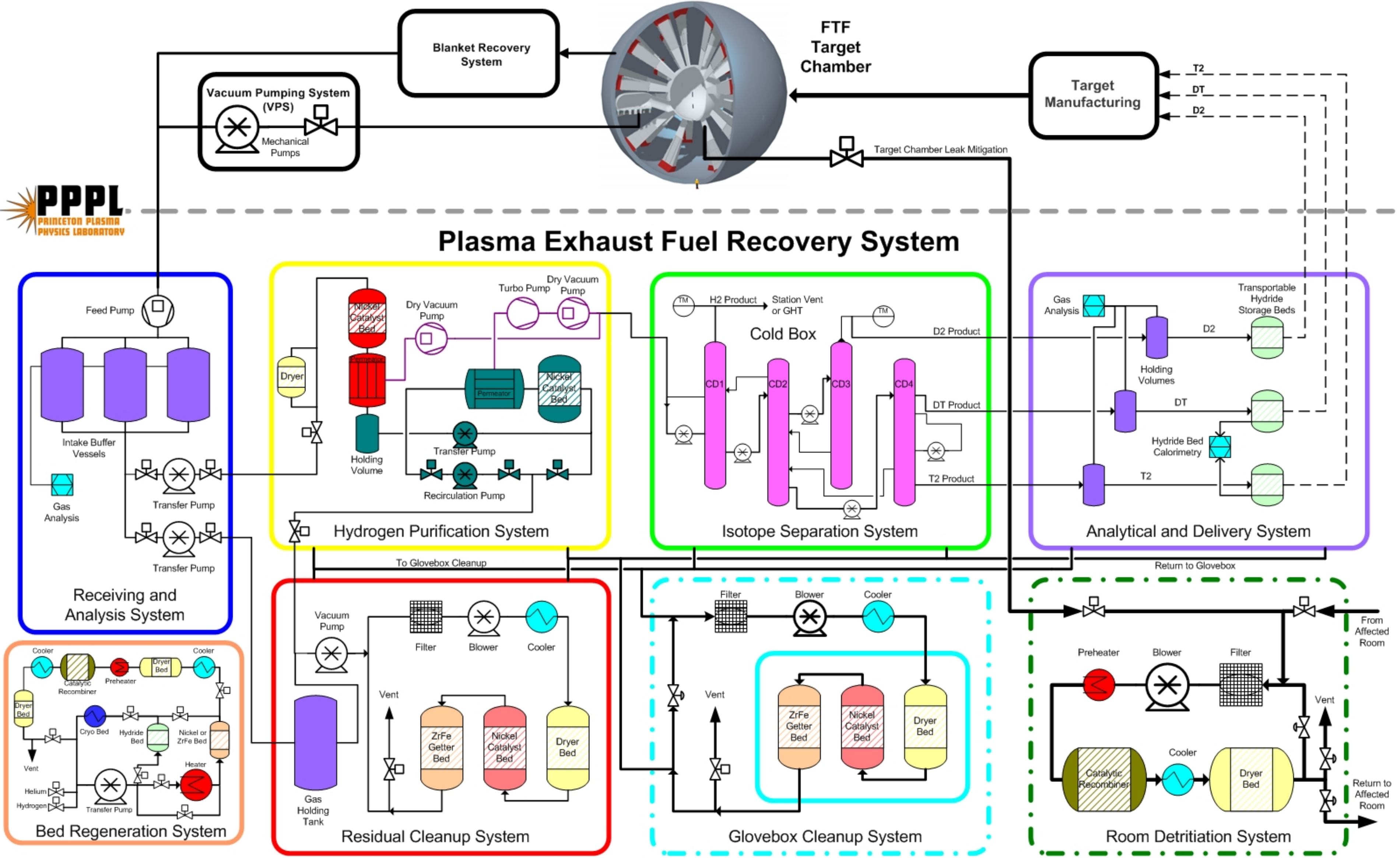




NRL
Voss Scientific (D. Rose)
A.E. Robson

*R. E. Pechacek, *et al.*, Phys. Rev. Lett. **45**, 256 (1980).

We have a conceptual design for as system to recover, process, refine and supply Tritium



Many students are getting advanced degrees through the HAPL program

UCSD
UCLA
Wisconsin
Georgia Tech
U Rochester
U North Carolina
Duke
Princeton