Present and Future Fast Ignition Relevant Experiments on the JLF/NIF Facility

Farhat Beg

University of California, San Diego

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NIF/Jupiter User Meeting
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Collaborators

T. Ma, D. Higginson, B. Westover, S. Chawla, T. Bartal, N. Nakanii, L. Jarrot, D. Mariscal, C. Murphy, T. Yabuuchi, H. Sawada and M.S. Wei — UCSD

C. Chen, D. Hey, S. Le Pape, P. Patel, H. Mclean, A. Mackinnon, A. Macphee, Y. Ping, H. Chen, R. Town, A. Kemp, S. Wilks and M. Key

K. Akli and R. B. Stephens — GENERAL ATOMICS

A. Link, G.E. Kemp, V. Ovchinnikov, L. Van Woerkom and R. Freeman — THE OHIO STATE UNIVERSITY DEPARTMENT OF PHYSICS

H. Friesen, Y. Tsui, R. Fedosejevs — UNIVERSITY OF ALBERTA, EDMONTON, ALBERTA, CANADA

A. Morace, D. Batani — UNIVERSITÀ DEGLI STUDI DI MILANO

Peter Norreys — CCLRC Rutherford Appleton Laboratory

J. Pasley — THE UNIVERSITY of York, A WORLD TOP 100 UNIVERSITY

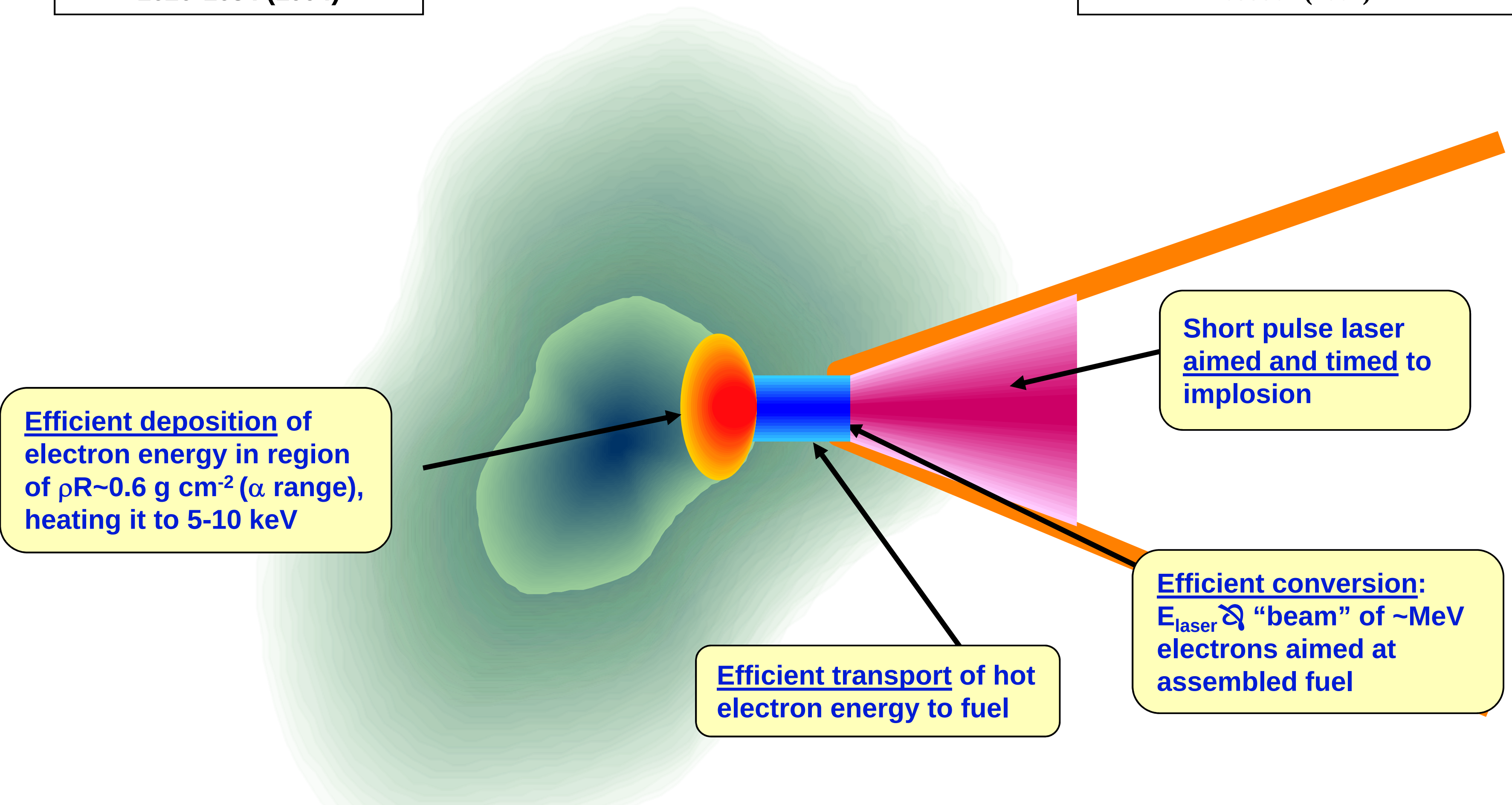
Outline

- Ultimate goal & critical issues
- UCSD research team
- Experiments on the Titan laser
- Future experiments on NIF and JLF
- NIF/JLF as a user facility
- Summary

Our ultimate goal is to test Fast Ignition on NIF

M. Tabak Phys of Plasmas 1 1626-1634 (1994)

M. Key et al. Phys of Plasmas 14 055502 (2007)



Coupling efficiency is one crucial parameters for fast ignition

There are four key issues

– Laser conversion to electrons

– Energy spectrum of electrons

– Angular distribution of electrons

– Transport from cone tip to the core

A number of experiments have been performed on the Titan laser of the Jupiter Laser Facility to address these issues.

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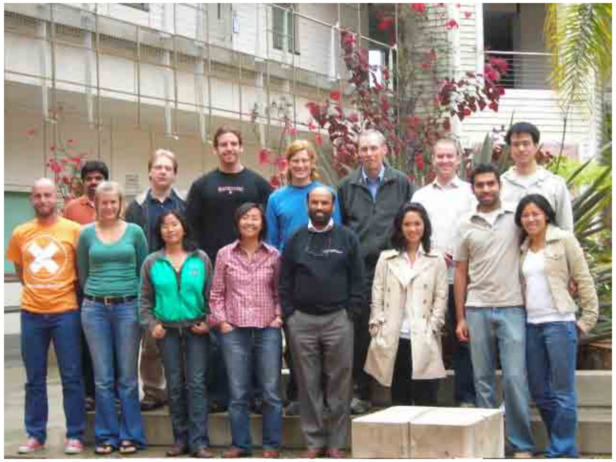
UCSD has a large team participating on experiments at JLF

- **Research Scientists and Post docs**
  - Dr. Mingsheng Wei
  - Dr. Toshinori Yabuuchi
  - Dr. Hiroshi Sawada

- **Graduate Students**
  - Tammy Ma
  - Teresa Bartal
  - Drew Higginson
  - Brad Westover
  - Sugreev Chawla
  - Charlie Jarrot
  - Chris Murphy
  - Derek Marsical
  - Nobu Nakanii (visiting student)



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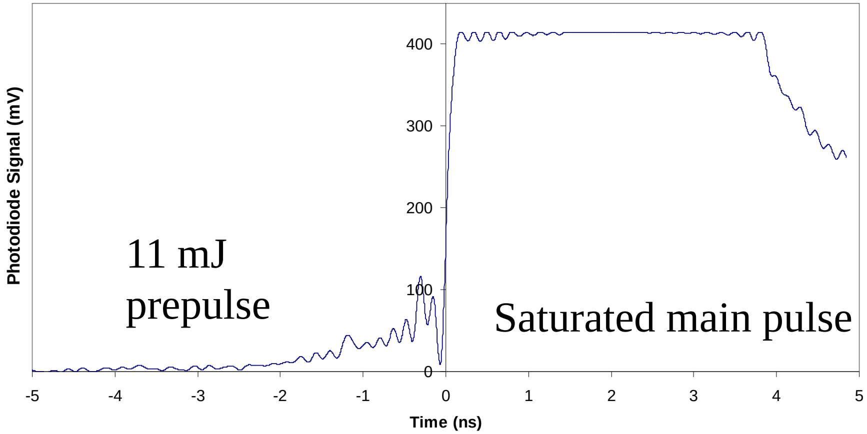
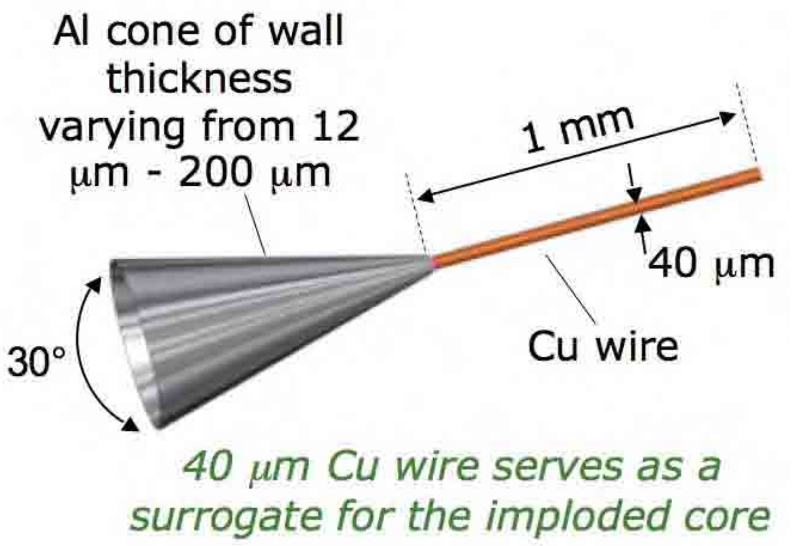
Titan Laser is a well characterized platform for FI relevant experiments

- **Titan laser parameters are monitored every shot**
  - energy
  - intensity distribution in the laser spot
  - pulse length
  - contrast
- **Short Pulse Laser**
  - Energy ~ 150 J
  - Pulse length ~ 0.4 – 10 ps
  - Spot size ~ 8 µm
  - λ ~ 1.054 µm
  - Intensity ~ 10^{20} W/cm^2
- **Long Pulse Laser**
  - Pulse energy ~ 1 kJ, 1 ω, 3ns
    ~ 350 J, 2ω, 3ns



Wire attached to a cone provides an excellent surrogate to compressed fuel



- Wire geometry allows to extract information about forward going electrons for close examination.

- Laser prepulse and cone wall thickness were varied to study coupling into the wire.

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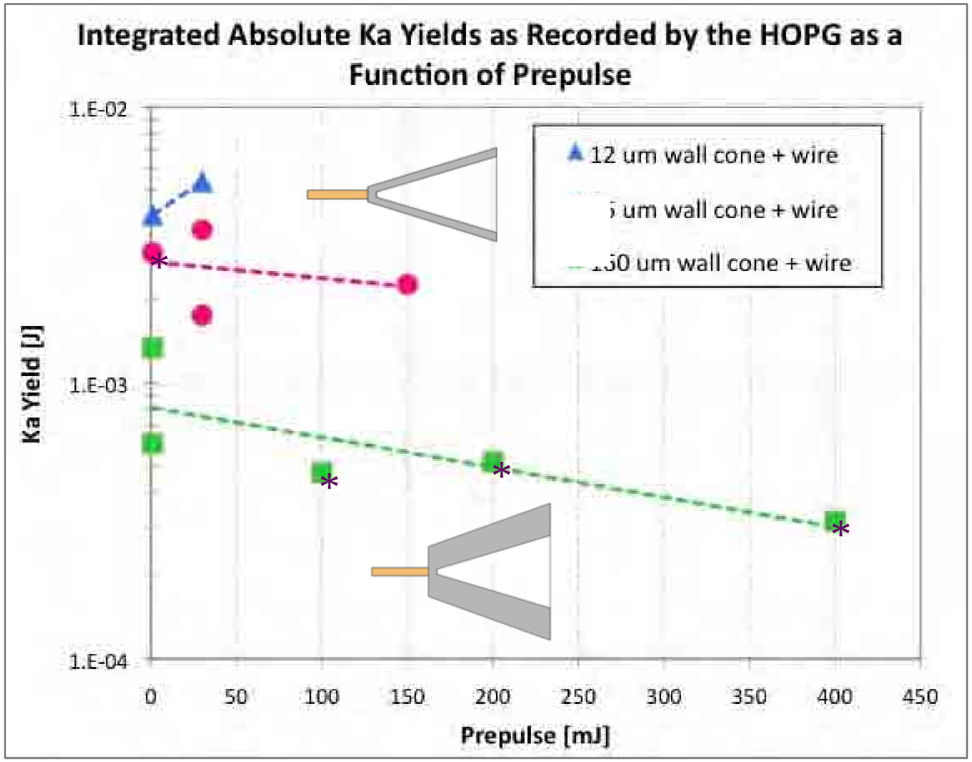
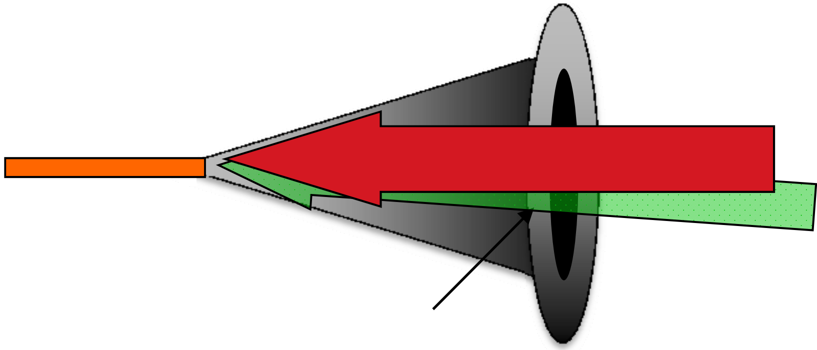
Coupling into the wire is sensitive to both cone-wall thickness and prepulse levels



Titan Laser
150J, 0.7ps
I = 0.5-1x10^{20} W cm^{-2}



Prepulse: 10 mJ - 1J,
527nm, 3 ns

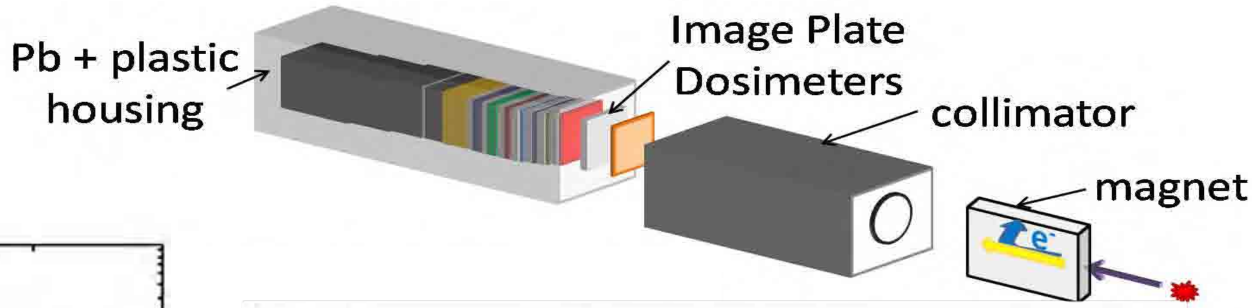
- 1J,3ns prepulse, consistent with 10^{-4} energy contrast for >10kJ integrated experiments

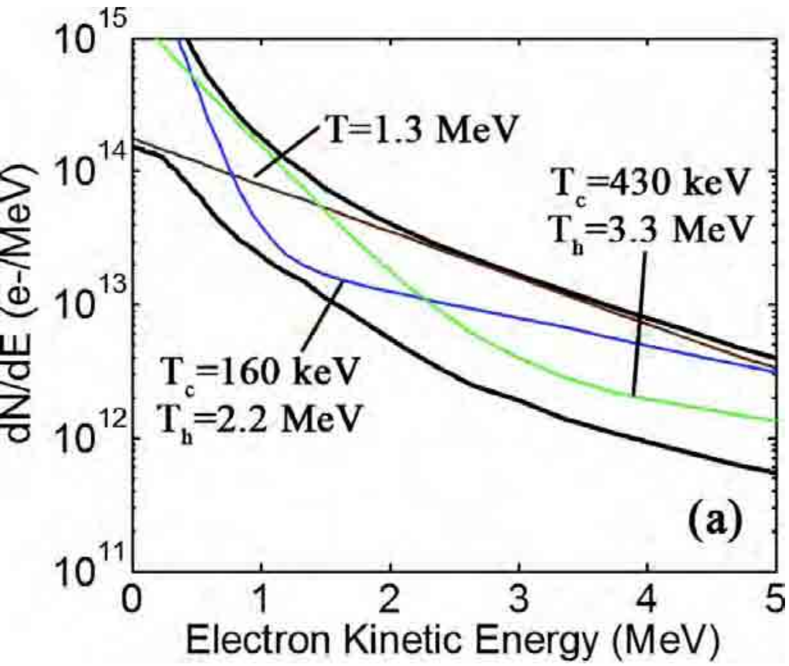
- **Coupling falls off by a factor of**
  - **3.5 from 12 μm wall to 160 μm wall cone,**
  - **3 from intrinsic to 400 mJ prepulse**

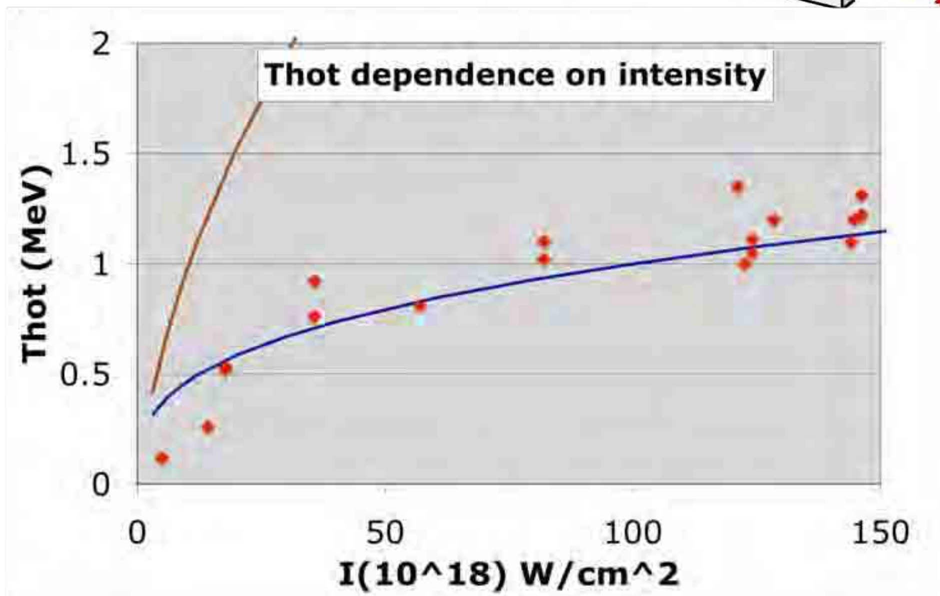
It is important to know the tolerable level of prepulse for integrated experiments.

Hot electron temperature is favorable to FI

C.D. Chen, Phys. Plasmas **16**, 082705 (2009)



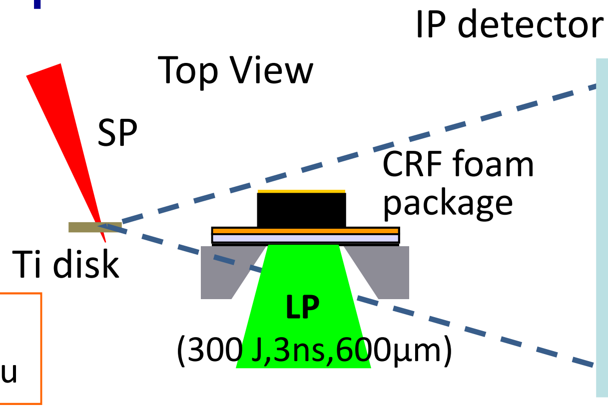




- First in situ measurement of bremsstrahlung and vacuum hot electrons.
- Hot electron temperature is lower than predicted by ponderomotive scaling.

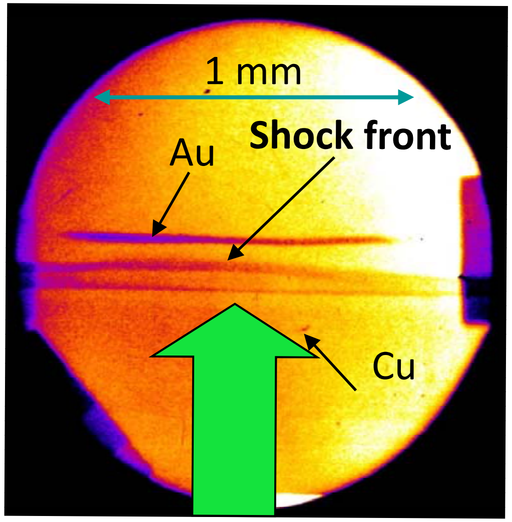
K_α images show a large divergence of electron beam through shocked foam

Ti X-ray radiography provides information on the shock propagation and compression of CRF foam

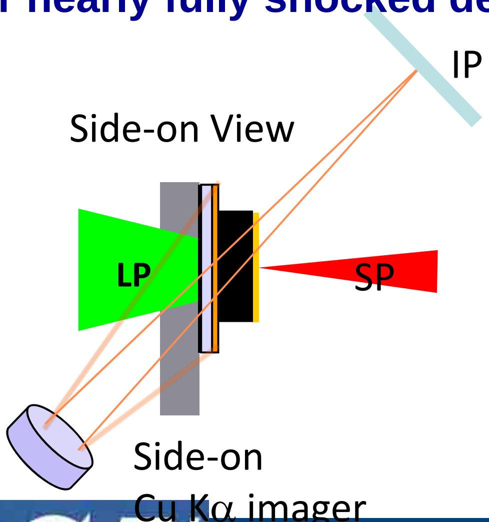


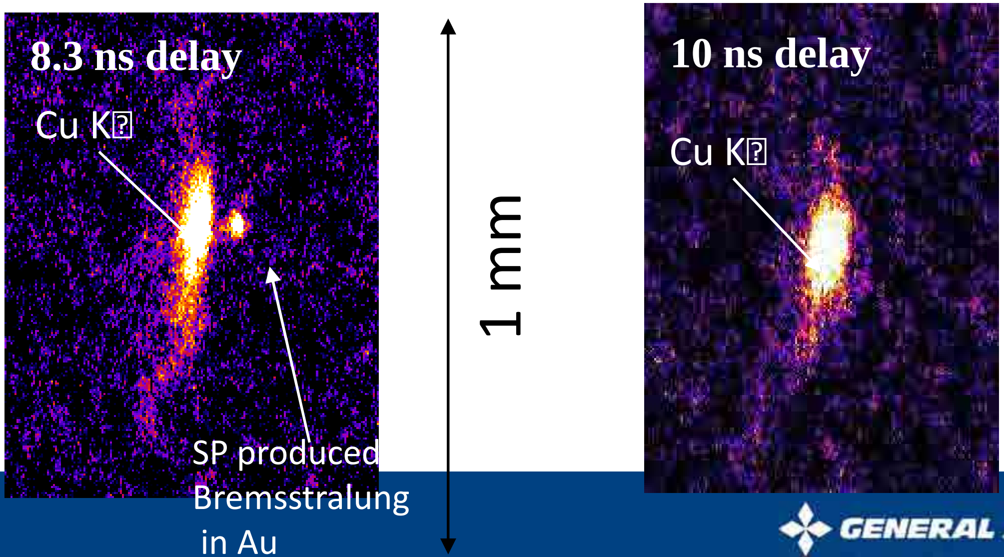
Foam package target:
0.1Al/25CH/5Cu/138CRF/3.9Au

SP with 5 ns delay



A large Kα emission spot is observed only for transport in fully or nearly fully shocked dense CRF foam plasmas





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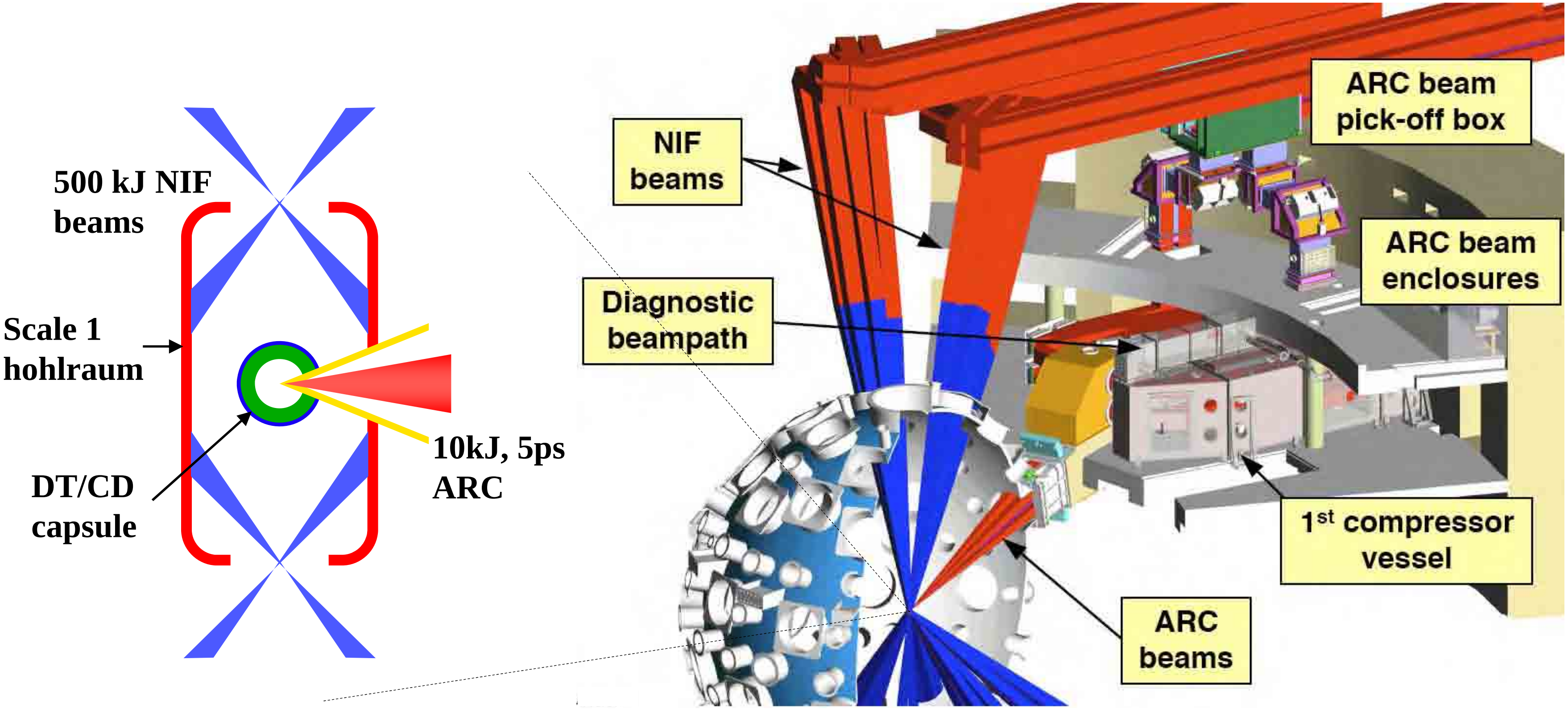
NIF will enable integrated FI experiments with the actual full-scale fuel assembly required for high gain

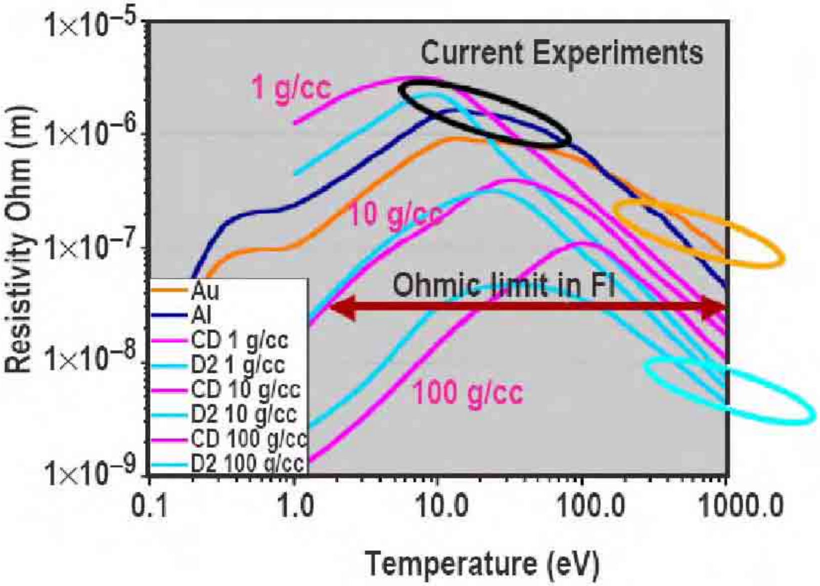


- Pravesh Patel's project team to measure & optimize coupling efficiency of an 10 kJ ignitor pulse to a full-scale fuel assembly ➔ **to determine laser, physics, and target requirements for high gain FI**

NIF and NIF-ARC provide an excellent opportunity to test new physics regimes

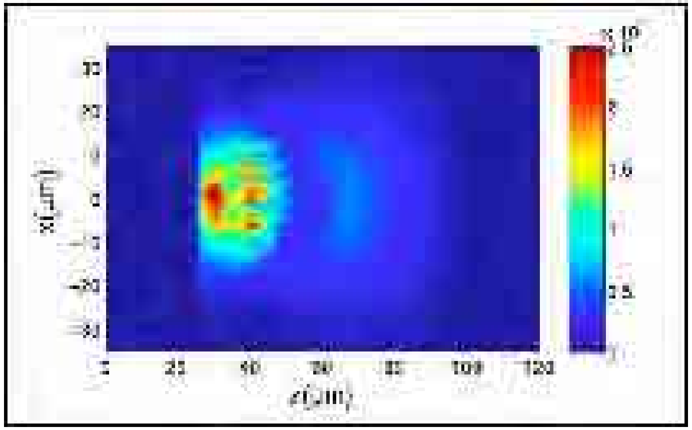
- **Relevant parameter range with NIF**
  - **Cone tip conditions: 1-20g/cc, 1-20eV - shocked cone tip**
  - **Entry to dense fuel: CD or DT at 1-100g/cc and 50-200 eV**

- **Electron energy deposition and divergence NIF-ARC (5 ps, 10 kJ)**
  - **As a function of well defined plasma density and temperature**

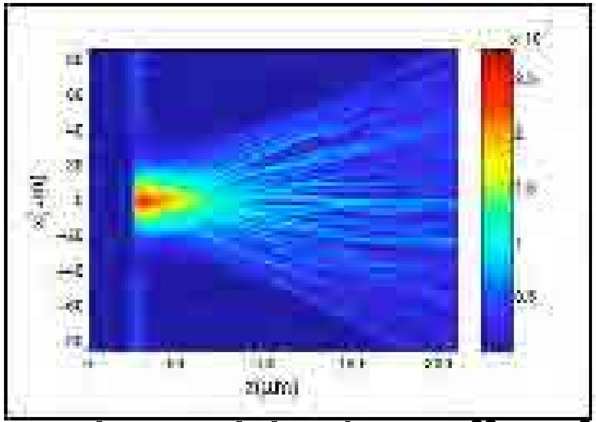


Courtesy of A. Solodov

0.25 ps



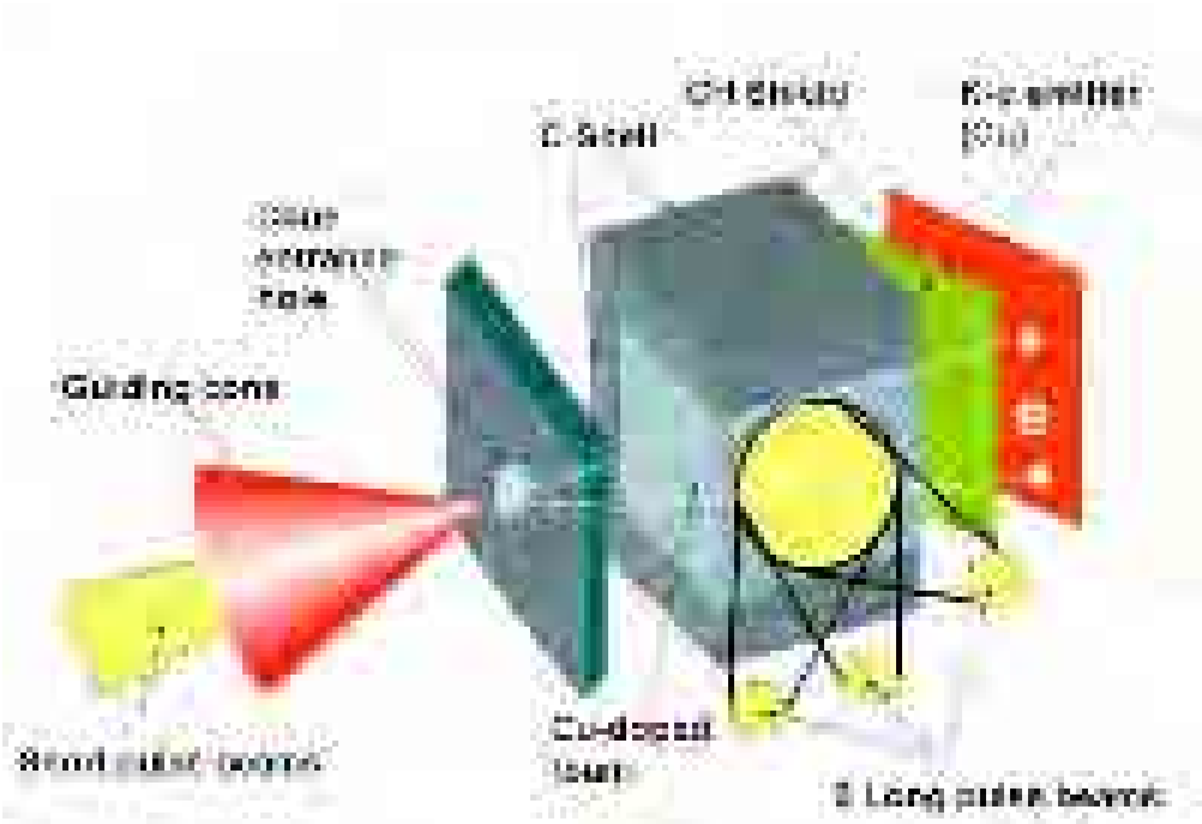
Background density ~ 1.5 x 10^{21} cm^{-3}



2 ps

Background density ~ 10^{23} cm^{-3}

Controlled experiments will facilitate understanding of electron transport and coupling crucial to FI

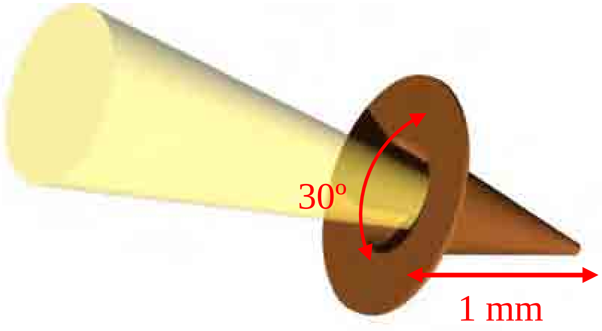


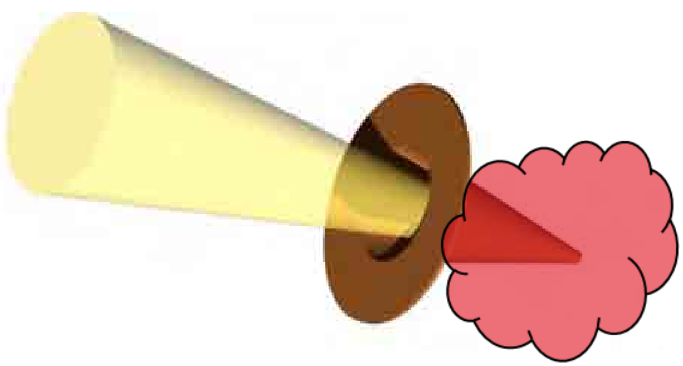
- NIF can create conditions of the matter that have not been possible before for electron transport studies.

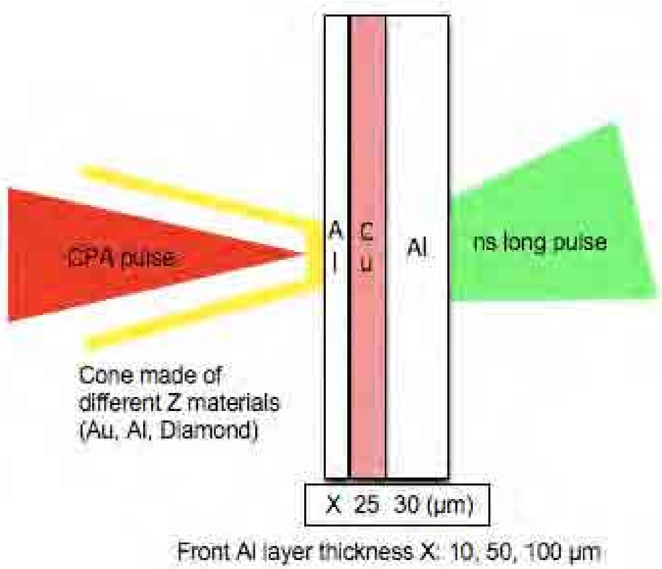
Basic Science experiments on electron source characterization are extremely important for integrated FI

- **Following issues will be tested on the Titan laser and then culminated on NIF-ARC**

  - Tolerable prepulse
  - Survivability of cone tip
  - Effect of environment around cone on coupling
  - Cone tip material for better coupling
  - Cone tip width to reduce divergence







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Enhanced capability at JLF may provide a platform to explore new regimes

- **Two long pulse lasers with energy in kJ range (λ ~ 532 nm)**
  - to tailor plasma to a desired density and temperature

- **Two short pulse high intensity lasers**
  - one short pulse laser at 2ω
  - second short pulse laser to produce particles for probing

- **Rep. rate high energy/intensity laser**
  - to study variance

- **Laser diagnostics**
  - Details of laser parameters are crucial to understanding of target physics

Suggestions

- Liaison office to deal with administrative issues
- Technical contact to deal with the target area issues
- Web page for users with protected data archive
- Relaxed computer use policy (for diagnostics and lasers)
- Long term funding plan for facilities
- User group

Summary

- Significant understanding has been made about the electron source and transport using JLF.
- More experiments are needed on JLF
- NIF and NIF-ARC provide a great opportunity of physics study in unexplored regime.

UCSD FI related presentations at IFSA

Poster 3.10.047	Toshinori	Yabuuchi	FAST ELECTRON TRANSPORT IN FOIL TARGETS WITH A PRE-PLASMA CREATED BY A LONG PULSE LASER
Poster 3.10.048	Bhooshan	Paradkar	NUMERICAL MODELING OF PRE-FORMED PLASMA PRODUCED BY LONG PULSE LASER IN FOIL TARGET AND IT"S EFFECT ON FAST ELECTRON TRANSPORT
Poster 3.10.049	Drew	Higginson	STUDY OF RESISTIVE AND COLLISIONAL STOPPING OF FAST ELECTRONS RELEVANT TO FAST IGNITION
Poster 3.10.050	Mingsheng	Wei	INVESTIGATION OF RESISTIVE EFFECTS IN FAST ELECTRON TRANSPORT IN SOLID DENSE PLASMAS
Poster 3.10.051	Sugreev	Chawla	TEMPERATURE MEASUREMENT OF A THIN FOIL HEATED WITH AN INTENSE PROTON BEAM
Poster 3.10.052	Farhat	Beg	STUDY OF FAST ELECTRON GENERATION AND TRANSPORT IN SOLID TARGETS RELEVANT TO FAST IGNITION
Poster 3.10.053	Teresa	Bartal	PROTON FOCUSING FROM HEMISPHERICAL TARGETS
Poster 3.10.054	Hiroshi	Sawada	INVESTIGATION OF FAST ELECTRON TRANSPORT IN SOLID AND SHOCK HEATED TARGETS
Poster 3.10.055	Bradley	Westover	FAST ELECTRON TEMPERATURE AND CONVERSION EFFICIENCY SCALING IN SOLID TARGETS IRRADIATED BY SHORT-PULSE LASERS
Poster 3.10.015	Tammy	Ma	LASER TO FAST ELECTRON CONVERSION EFFICIENCY SCALING WITH PREPULSE IN CONE TARGETS