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

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This work was performed under the auspices of the U.S. DOE under contracts No.DE-FG02-05ER54834, DE-FC0204ER54789 and DE-AC52-07NA27344. We greatly acknowledge support of Institute for Laser Science Applications, LLNL.
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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

Efficient deposition of electron energy in region of \( \rho R \sim 0.6 \text{ g cm}^{-2} \) (\( \alpha \) range), heating it to 5-10 keV

Efficient transport of hot electron energy to fuel

Efficient conversion: \( E_{\text{laser}} \) “beam” of ~MeV electrons aimed at assembled fuel

Short pulse laser aimed and timed to implosion

Coupling efficiency is one crucial parameter for fast ignition

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

M. Key et al. Phys of Plasmas 14
055502 (2007)
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
  - $\lambda$ ~ 1.054 µm
  - Intensity ~ $10^{20}$ W/cm²

- **Long Pulse Laser**
  - Pulse energy ~ 1 kJ, 1 $\omega$, 3ns
  - ~ 350 J, 2$\omega$, 3ns

![Photodiode Signal (mV)](image)

- 11 mJ prepulse
- Saturated main pulse
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.
Coupling into the wire is sensitive to both cone-wall thickness and prepulse levels.

- Coupling falls off by a factor of
  - 3.5 from 12 \( \mu \)m wall to 160 \( \mu \)m wall cone,
  - 3 from intrinsic to 400 mJ prepulse

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

Titan Laser
150J, 0.7ps
I = 0.5-1\( \times 10^{20} \) W cm\(^{-2} \)

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

• 1J,3ns prepulse, consistent with 10\(^{-4}\) energy contrast for >10kJ integrated experiments
Hot electron temperature is favorable to FI


- 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**

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

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

**Cu K_α** images show a large divergence of electron beam through shocked foam.
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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: 1-20 g/cc, 1-20 eV - shocked cone tip
  - Entry to dense fuel: CD or DT at 1-100 g/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
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

Plasma
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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 ($\lambda \sim 532$ nm)
  - to tailor plasma to a desired density and temperature

- Two short pulse high intensity lasers
  - one short pulse laser at $2\omega$
  - 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.
| 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 |