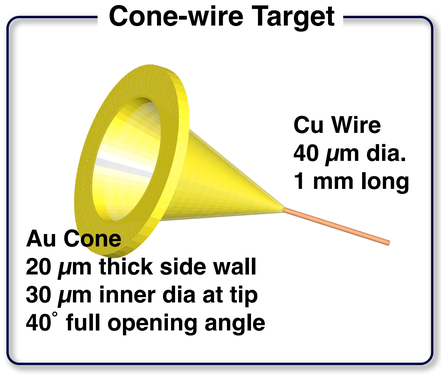
Fast Electron Generation and Transport in Cone-wire Targets

T. Yabuuchi[1], H. Sawada[1], R. B. Stephens[2], M. H. Key[3], T. Bartal[1], K.U. Akli[2], D. Batani[4], S. D. Baton[5], L. A. Gizzi[6], T. Ma[1,3], A. J. Mackinnon[3], P. A. Norreys[7], P. K. Patel[3], C. Spindloe[6], M. Schneider[3], W. Theobald[8], M. S. Wei[1], L. Van Woerkom[9], and F. N. Beg[1]

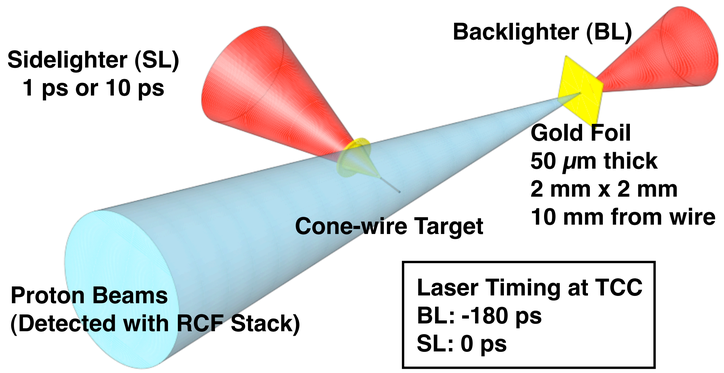
[1] University of California, San Diego, USA, [2] General Atomics, USA, [3] Lawrence Livermore National Laboratory, USA, [4] Università di Milano-Bicocca, Italy, [5] Laboratoire pour l'Utilisation des Lasers Intenses, France, , [6] Intense Laser Irradiation Laboratory, IPCF-CNR, Italy, [7] STFC Rutherford Appleton Laboratory, UK, [8] Laboratory for Laser Energetics, University of Rochester, USA, [9] Ohio State University, USA

Motivation

- Detailed understanding of fast electron generation and transport is crucial for the success of cone-guided fast ignition laser fusion.
- Cone-wire targets (shown in the right figure) can provide information of a temperature and a coupling efficiency of fast electrons into the wire through a cone.
- Coming experiment at OMEGA EP using a pulse with energy of 1 kJ in 10 ps duration is an extension of past experiments performed with shorter pulses (~ 1 ps).



Scheduled Experiments at OMEGA EP



These shots are scheduled on April 30, 2009.

BL Parameters

Pulse	Energy	Intensity
1 ps	~ 350 J	> 10^{19} W/cm^2

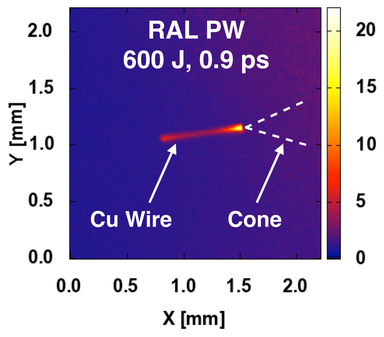
SL Parameters

Pulse	Energy	Intensity
1 ps	~ 100 J	5x10^{18} W/cm^2
10 ps	~ 1 kJ	5x10^{18} W/cm2

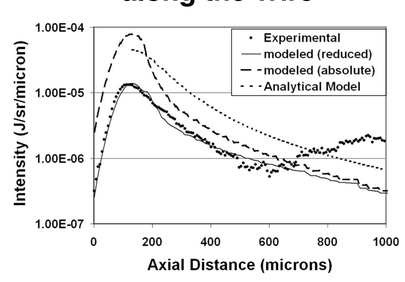
Past Experiments at LLNL and RAL

- Cone-wire targets have been used for the fast electron characterization under several laser conditions.
  - Titan Laser at Lawrence Livermore National Lab.
    ~ 150 J/0.7 ps
  - Vulcan PW Laser at Rutherford Appleton Lab.
    ~ 300-600 J/1 ps

Kα X-ray Image of Cu Wire



Kα X-ray Profile along the Wire†



RAL PW Al cone
345 J, 1 ps

- The fast electron temperature was inferred in the range of 600-750 keV at the laser intensity of 3x10^{20} W/cm^2. The coupling efficiency were 1%, 5%, and 15% for the 10, 20, and 40 μm dia, Cu wire, respectively†.
- The peak temperatures of the wire were predicted to be ~100 eV for all diameter cases†.

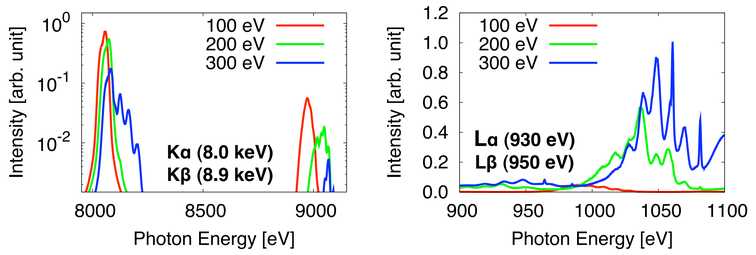
†Ref: J.A. King et al., Phys. Plasmas 16, 020701 (2009).

Cu K-shell/L-shell X-ray Spectroscopy

- HOPG* crystal spectrometer measures x-rays in the energy range of Cu Kα and Kβ to estimate the efficiency.
- The temperature profile along the wire is measured with spatially resolved spectroscopy of Cu L-shell x-ray.

*Highly Oriented Pyrolytic Graphite

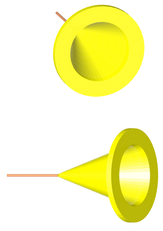
X-ray Spectra from solid Cu at Various Temperatures
(with Fast Electrons of T_h = 1 MeV, N_h = 1% of background)



*FLYCHK results

X-ray PHCs

- One of two X-ray PHCs on EP target chamber is used to see the plasma emission inside the cone.
- Another camera is used to obtain the image of Cu Kα from the wire using Cu filter.



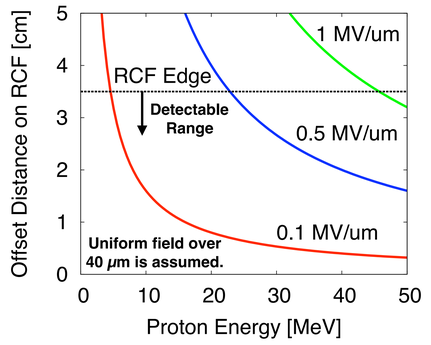
Fast Electron Measurements

- Fast electron energy spectra (0.1-100 MeV) is measured in vacuum on the wire axis with a magnetic spectrometer.

Proton Backlighting

- Protons generated by BL-Foil interactions are used for the measurement of transient electric fields around the cone-wire target.

Proton Deflection



Detection Timing

RCF Layer	Min. Proton Energy [MeV]	Timing Passing through Wire [ps]
1	5.1	97
2	7.3	46
3	9.1	19
4	10.6	2
5	14.9	-32
6	18.3	-50
7	23.8	-70
8	28.4	-82
9	36.0	-97
10	42.4	-106

Summary

- Cone-wire targets have been used to characterize the fast electron generation and transport in intense-laser and cone target interactions.
- Scheduled experiment at OMEGA EP is the first to study the electron source and energy coupling with laser parameters closer to the full-scale fast ignition.

Acknowledgements

This work is supported by U.S. Department of Energy under contracts DE-FC02-04ER54789 and DE-FG02-05ER54834.