Using $K_\alpha$ images to characterize pre-plasma and electron refluxing in intense laser experiments

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Motivation

- Angular distribution of laser generated hot electrons is crucial.
- Recent experimental measures of the divergence vary widely.
- $K_\alpha$ imaging is a primary experimental measure.
- PIC simulations tend to indicate a large \textit{intrinsic} divergence in the LPI region ($\alpha_{1/2} = 50-60^\circ$).

This talk will show how a large intrinsic electron divergence can result in varying divergences as measured by $K_\alpha$ imaging.
We’ve shot slabs and buried cone targets.

Cone-guided Fast Ignition:

**Bragg crystal**

**Buried cone target with a Get-Lost Layer (GLL)**

**Kα image of a buried cone target**
Recent Titan Results: $K_\alpha$ imaging

2009 Run: Buried Cone Results. \( \omega_{1/2} = 40-45^\circ \)

- **20090826 s02**
  - 30 \( \mu \)m tip, fluor depth: 10 \( \mu \)m
- **20090826 s04**
  - 30 \( \mu \)m tip, fluor depth: 100 \( \mu \)m
- **20090826 s05**
  - 90 \( \mu \)m tip, fluor depth: 10 \( \mu \)m
- **20090826 s06**
  - 90 \( \mu \)m tip, fluor depth: 10 \( \mu \)m

Detector used: X-ray CCD

2010 Run: Buried Cones Results. \( \omega_{1/2} = 12-15^\circ \)

- **20100726 s02**
  - 30 \( \mu \)m tip, fluor depth: 10 \( \mu \)m
- **20100726 s04**
  - 90 \( \mu \)m tip, fluor depth: 10 \( \mu \)m
- **20100726 s06**
  - 30 \( \mu \)m tip, fluor depth: 100 \( \mu \)m

Detector used: Image Plates
Simulation setup for the 2009 experiment

Fully kinetic simulations, using modified PIC code LSP

(1) TARGET
Buried cone target
(30° cone angle)
Exponential preplasma

(2) GRID
2D Cartesian (XZ)
Cell size: from $\lambda/8$ to $\lambda$

(3) LASER
$\lambda = 1 \mu m$
$I = 1 \times 10^{20} \text{ W/cm}^2$
$w_o = 7 \mu m$
sine$^2$ envelope w/
$\tau = 700 \text{ fs}$
propagates along $+x$
z-polarized

(4) RUN DURATION
~20 ps
with $\Delta t = 30$ timesteps/optical cycle

Preplasma scale length is the only free parameter
Simulation vs. 2009 Experiment: \( L = 5 \, \mu m \)

Red – simulation
Grey - experiment

a) fluor depth: 10 \( \mu m \)

Preplasma scale length \( L=5 \, \mu m \)
Simulation vs. 2009 Experiment: $L = 2.5 \, \mu m$

Red – simulation
Grey - experiment

a) fluor depth: 10 \, \mu m

b) fluor depth: 100 \, \mu m

Preplasma scale length $L=2.5 \, \mu m$
Preplasma scale length $L = 3.75 \, \mu m$
Effect of the Get Lost Layer

Red – simulation
Grey - experiment

Preplasma scale length L=3.75 μm (no GLL)
Simulation vs. experiment for a slab with no GLL

Slab target, no GLL
Experimental results for 2010 experiment

\[ \sqrt{\frac{1}{2}} = 12-15^\circ \]

- **a)** 15 µm fluor depth
- **b)** 100 µm fluor depth
- **c)** 200 µm fluor depth
Noise issue in IP-based images

This is what we would have measured in 2009, had we had used image plates.

Note, the pedestal is hidden!
Simulations for 2010 experiment

Preplasma scale length: \( L = 2.5 \, \mu m \)

Red – simulation
Grey - experiment
Slab targets with GLL
Slab results

Preplasma scale length: \( L = 1.75 \, \mu m \)

Red – simulation
Grey - experiment
Summary

- Good match between experiment and simulation.
- Wide range of targets using data collected with 2 different detector types over 2 years.

We find that $K_\alpha$ images
- provide a poor measure of intrinsic divergence.
- yield a bulk divergence angle that is low compared to intrinsic.
- can characterize the pre-plasma near the critical surface.
- can be used to check the performance of GLL’s.

$K_\alpha$ images can still be used to benchmark PIC codes from which the intrinsic divergence can be determined.
Thank you!