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Exploring the Fast Ignition Approach to Fusion Energy

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CENTENNIAL OF A MIRACULOUS YEAR
ALBERT EINSTEIN
1905 2005

Abstract

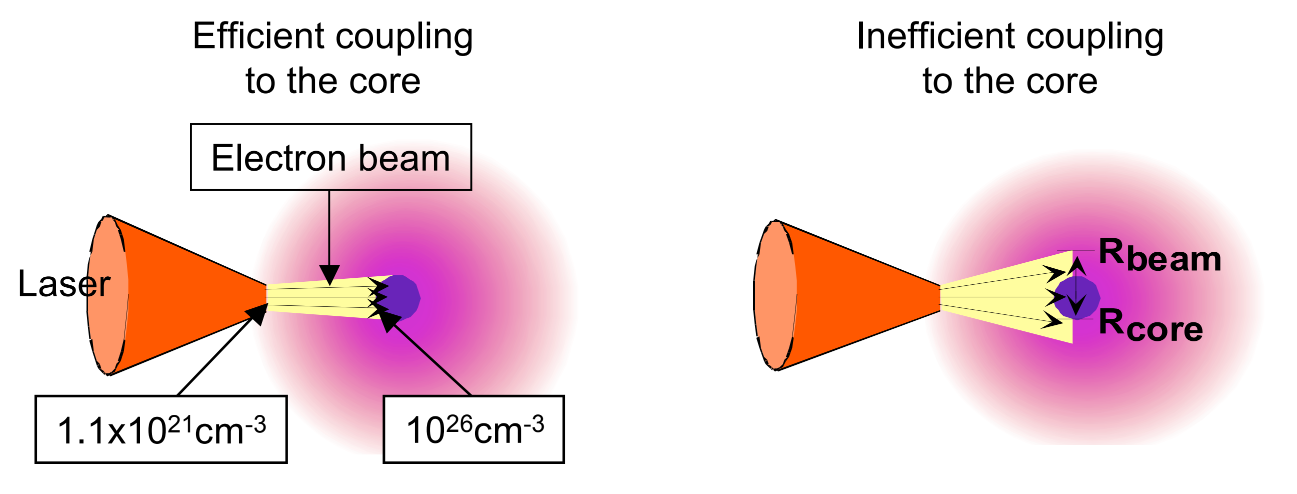
Probably the most famous equation in physics is Einstein's *E=mc²*, which was contained within his fifth and final paper that was published in 1905 [1]. It is this relationship between energy (*E*) and mass (*m*) that the fusion process exploits to generate energy. When two isotopes of hydrogen (normally Deuterium and Tritium (DT)) fuse they form helium and a neutron. In this process some of the mass of the hydrogen is converted into energy.

In the fast ignition approach to fusion [2] a large driver (such as the NIF laser) is used to compress the DT fuel to extremely high densities and then is "sparked" by a high intensity, short-pulse laser. The short-pulse laser energy is converted to an electron beam, which then deposits its energy in the DT fuel. The energy of the electrons in this beam is so large that the electron's mass is increased according to Einstein theory of relativity [3]. Understanding the transport of this relativistic electron beam is critical to the success of fast ignition and is the subject of this poster.

Introduction

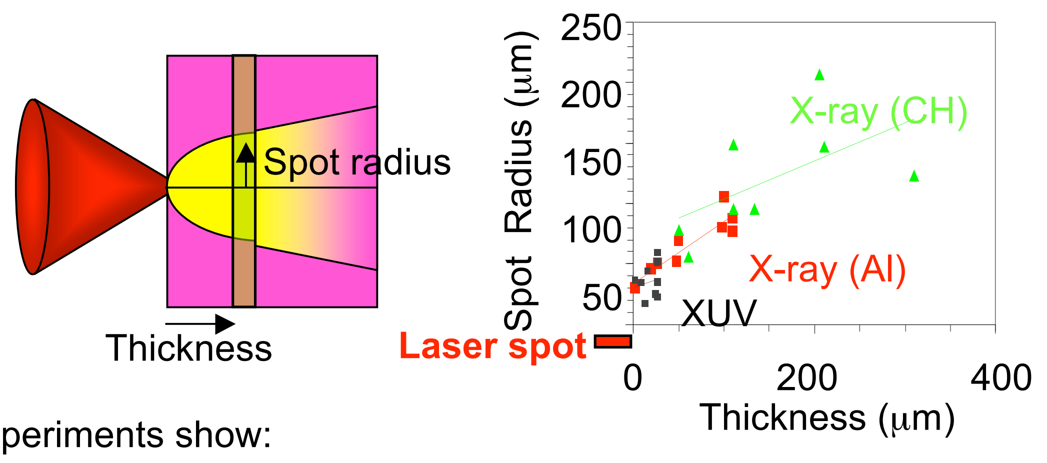
- A critical issue for Fast Ignition is understanding the transport of the relativistic electrons to the fuel.
- Experiments have shown a rapid increase in beam width followed by reasonable collimation with a 20° half angle.
- We are using a hybrid particle-in-cell code (called LSP [4]) to:
    - —generate simulated Kα images; and
    - —model XUV images.

A critical issue for fast ignition is understanding the transport of the relativistic electrons to the fuel



$$E_{laser} \approx E_{\min}\left(\frac{R_{beam}}{R_{core}}\right)^2 \text{ for } R_{beam} \geq R_{core}$$

Experiments on relativistic electron transport have been performed by researchers around the world [5]



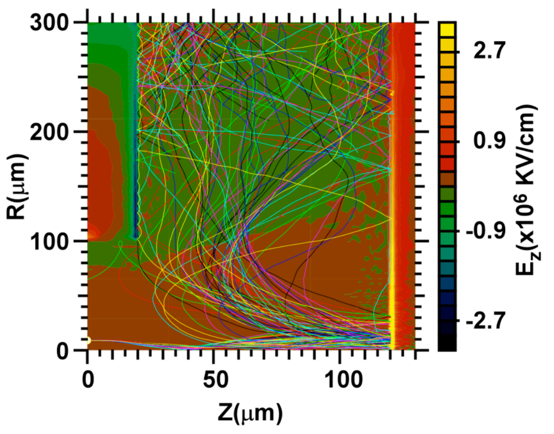
Experiments show:

- a rapid increase in beam size in the first few microns; and
- a fairly collimated (20° half angle) beam in the bulk of the material.

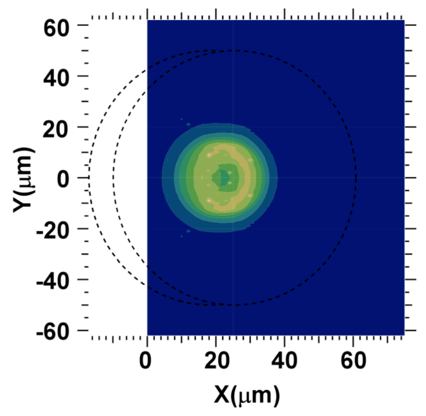
We are using a hybrid particle-in-cell code (called LSP) to model these experiments [6]

The LSP code self-consistently models the transport of the relativistic electrons through the target and generates Kα photons that can be directly compared to experiments.

Electron trajectories

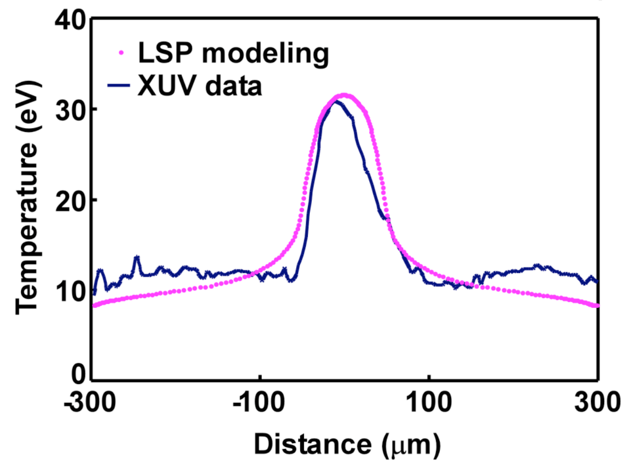


Kα image from rear of target



The LSP calculation matches the measured temperature pattern at the rear surface of the target

- 27J of hot electrons, in a 1-ps pulse, with Beg scaling and a thermal spread of 300keV injected into a 100μm Al^{3+} plasma.
- The temperature was obtained by post-processing the LSP energy data at the rear surface with a realistic equation of state.



Conclusions/Discussion

Our LSP calculations show:

- good agreement with the experimentally measured rear surface heating; and
- a smaller initial Kα spot size than experimentally observed.

However, our calculations use an initial electron distribution function based on experimental observations.

We are currently working to couple our laser-matter interaction code, radiation hydrodynamics code, and LSP together into one virtual code to enable us to perform an integrated fast ignition simulation.

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