

FAST IGNITON: PROPAGATION OF FAST ELECTRONS IN COMPRESSED MATTER

J. J. Santos¹, B. Vauzour¹, D. Batani², S. D. Baton³, M. Koenig³, Ph. Nicolai¹, F. Perez³,
F. N. Beg⁴, C. Benedetti⁵, E. Brambrink³, P. Carpeggiani², S. Chawla⁴, M. Coury⁶, A. Debayle⁷,
F. Dorchie¹, A. Dubrouil¹, C. Fourment¹, M. Galimberti⁸, L. A. Gizzi⁹, L. Gremillet¹⁰,
R. Heathcote⁸, D. P. Higginson⁴, J. J. Honrubia⁷, S. Hulin¹, E. d'Humières¹, L. Huret¹, R. Jafer², L. C.
Jarrot⁴, L. Labate⁹, K. Lancaster⁸, L. Leconte³, P. Köster⁹, A. J. MacKinnon¹¹, P. McKenna⁶,
A. G. McPhee¹¹, W. Nazarov¹², J. Pasley¹³, M. N. Quinn⁶, R. Ramis⁷, Y. Rhee¹⁴,
M. Rabec Le Glohaec³, A. Ravasio³, C. Regan¹, X. Ribeyre¹, M. Richetta¹⁵, F. Serres³,
H.-P. Schlenvoigt³, G. Schurtz¹, A. Sgattoni⁵, C. Spindloe⁸, V. T. Tikhonchuk¹, M. Tolley⁸,
X. Vaisseau¹, M. Veltcheva², L. Volpe²

¹ Université de Bordeaux, CELIA, Talence, France, santos@celia.u-bordeaux1.fr

² Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy

³ LULI, Ecole Polytechnique-CNRS-CEA-UPMC, Palaiseau, France

⁴ University of California, San Diego, La Jolla, USA

⁵ Dipartimento di Fisica, Università di Bologna, Italy

⁶ SUPA, Department of Physics, University of Strathclyde, Glasgow, UK

⁷ ETSI Aeronauticos, Universidad Politécnica de Madrid, Madrid, Spain

⁸ Central Laser Facility, Rutherford Appleton Laboratory, Didcot, UK

⁹ Intense Laser Irradiation Laboratory at INO, CNR, Pisa, Italy

¹⁰ CEA-DAM, Bruyères-le-Châtel, France

¹¹ Lawrence Livermore National Laboratory, Livermore, USA

¹² University of St. Andrews, Fife, UK

¹³ Department of Physics, University of York, UK

¹⁴ KAERI, South Korea

¹⁵ Dipartimento di Ingegneria Meccanica, Università di Roma Tor Vergata, Italy

The fast ignition approach to inertial confinement fusion is based on a detailed understanding of the relativistic laser pulse interaction with dense plasmas capable of generating fast and collimated electron beams, as well as of the propagation of these beams in dense plasmas including the way they transport and deposit their energy from the source, near the critical density surface where the laser energy absorption is maximum, till the core of nuclear fuel, compressed to $\sim 300 n_c$.

We report on experimental results and their interpretation of the fast electron transport in compressed plasmas, created by laser-induced shock propagation in both planar and cylindrical geometry. Depending on the compression geometry and on the target initial density (ρ_0), we created plasmas with densities ranging from 2 to 11 g/cc and temperatures ranging from 4 to 120 eV. While not reproducing the density and temperatures of the core of a compressed fusion target, we studied the propagation and the stopping power of the fast electrons in warm and dense plasmas that represent either the degeneracy and/or the coupling levels of the compressed nuclear fuel core, or the density and temperature values expected in the shell plasma surrounding the core in the region close to the electron source.

In the adopted planar geometry compression, with counter-propagating compressing shock and fast electron beam, the areal density as seen by the electrons is not varied upon compression. Consequently, the changes in the hot electrons range are ascribed to variations in collective transport mechanisms. We had the special concern of reducing the fast electron refluxing in the targets (spurious for the interpretation of the results) and of using detectors based on high-energy (>20 keV) X-ray fluorescence, optimizing the sensibility to the electrons in the range of interest for fast ignition. An increased resistive stopping power has been inferred in warm (~ 5 eV) and dense (~ 5.5 g/cc) Al compared to solid Al.

In cylindrical compression of CH foams the fraction of electrons with a range of 200 μm decreases with increasing compression, independently of the foam ρ_0 . The collimation of the fast electron beam depends on the target density and temperature gradients (varying according to ρ_0 and to the compression stage) producing different resistivity structures inside the targets. By imaging the $K\alpha$ fluorescence of dopant atoms in the target, we observed for the first time fast electron jets propagating inside laser-compressed targets. In some identified conditions a collimated electron jet is propagating through the all length of the cylinder targets.

Numerical simulations of the fast electron transport using hybrid and particle-in-cell codes will be presented. They support the interpretation of the fast electron transport features presented above, including energy losses and divergence.

The work presented in this report constitutes a part of the experimental validation program within the Inertial Fusion Energy European project HiPER.