Equilibrium charge state distribution measurement in warm dense matter

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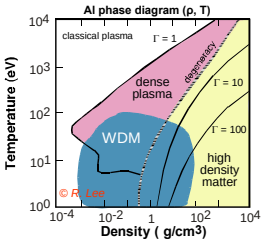
Definition and interests

Warm Dense Matter is a state of matter characterized by its temperature from 1-100 eV and its density from 0.1-10 times the solid density.

At the boundary between condensed matter and plasma physics, this regime attracts considerable interest and can be found in many subjects like inertial confinement fusion, HEDP, astrophysical studies …

In this regime classical theories fail. The only way to discriminate between different models of WDM or validate them is to confront theoretical results to experimental data.

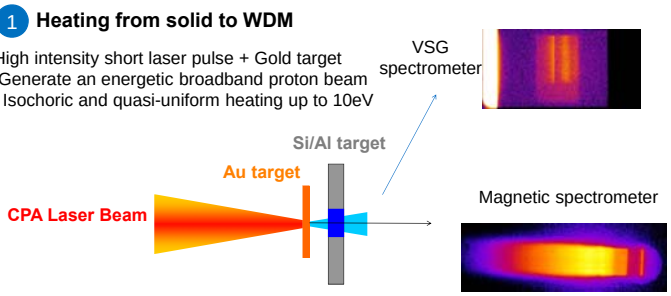


*R. W. Lee, J. Opt. Soc. Am. B **20**, 770 (2003)*

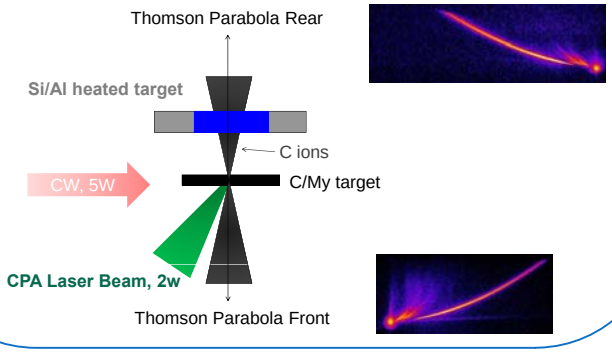
Experimental set up

1 Heating from solid to WDM

High intensity short laser pulse + Gold target
Generate an energetic broadband proton beam
Isochoric and quasi-uniform heating up to 10eV



2 Characterization and ion probing



Conclusion and Perspectives

With this experiment , we have demonstrated the feasibility of the experiment dispositive. The geometry used, as well as the two beams configuration, one to generated the proton beam heating the secondary target, the other one to generate the carbon probing source. No space charging or perturbation has been encountered yet between the two beams .

The data analysis is still in progress, the exact calibration of all the diagnostics used during the experiment remains to be done.

Future experiments using other ion probe beam and/or other target material are conceivable.

Main goals of the experiment

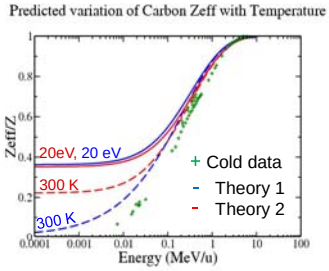
Heat isochorically and quasi-uniformly a solid target with a broadband proton beam.

Measure the incident proton beam and the temperature reached to characterize the generated plasma.

Measure, at several projectile energies, the charge-state distribution and equilibrium of heavy ion beams after passing through either cold or isochorically-heated WDM.

Compare projectile effective charge (Z_{eff}) with the current existing theories. This term plays a central role in the computation of the stopping power.

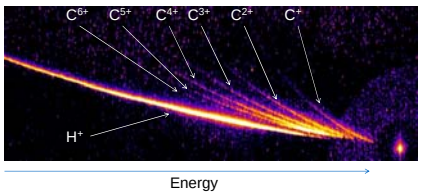
$$Z_S^{eff} = \frac{\sum_i n_{S^{i+}} i}{\sum_i n_{S^{i+}}}$$



Several expressions trying to describe its evolution with the temperature exist
with <u>strong disagreement between each other</u>

Diagnostics

<u>Ion probing:</u>
A **Thomson Parabola** measures the C ion charge state distribution as a function of energy. We used two of them, one was to measure front ion beam, i.e., to get some idea of the incident beam, the other was for the transmitted beam (Rear side).



<u>Temperature measurement:</u>
A **magnetic spectrometer** measures quantitatively the proton source as a function of energy. This is used as an input in a hydrocode (Esther[1]) that incorporates stopping power routines allowing to obtain the temporal evolution of the heated target. The result obtained are correlated with VSG results.

Variable line Space Grating (VSG[2]) spectrometer measures the integrated emitted X-ray spectrum from 6 to 60 Å. Knowing the dispersion function of the grating, one can compute the electron temperature and density of the target.

[1] *J.-P. Colombier, P. Combis, F. Bonneau, R. Le Harzic, and E. Audouard,. Phys. Rev. B **71**, 165406 (2005)*

[2] *J. Park ,G. V. Brown, M. B. Schneider, H. A. Baldis,et al , Rev. Sci. Instrum. 81, 10E319 (2010)*