Magnetic reconnection in high energy density plasmas [*]

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Context

Magnetic reconnection is a long standing problem in astrophysics (and more specifically in the Earth magnetosphere), characterized by a β parameter (ratio of kinetic pressure to magnetic pressure) around unity and a large Lundquist number (ratio of Alfven time to resistive time). In HED plasmas, such as those generated by the interaction of an intense laser beam with a solid target, the β parameter is at least about several hundreds, and the Lundquist number is as small as a few hundreds. Despite these large discrepancies, reconnection occurs in HED and astrophysical plasmas in a similar manner, as observed in numerical simulations. Laboratory experiments provide a valuable way to investigate reconnection mechanisms, but experimental studies have been limited in the past, because large and expensive plasma machines (as the MRX machine) were needed. HED laser experiments offer however smaller and affordable setups. [1]

During the irradiation of a solid target by a nanosecond laser pulse, a MegaGauss magnetic field loop is self generated by non-colinear gradients of density and temperature, around the plasma bubble. This magnetic field loop then increases in size with the expanding plasma. Thus in the case of two close-by laser irradiation spots, as illustrated on Fig.1 the magnetic field of each spot will be pushed toward each other. This will lead to compressed anti-parallel field lines and then trigger a reconnection process, converting magnetic energy into kinetic energy.

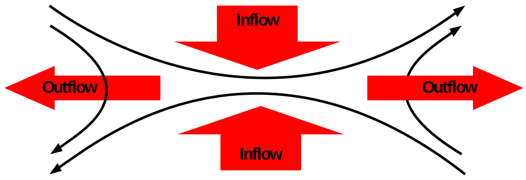

Figure 1: Scheme of the reconnection process.

Setup

We performed an experiment on the PHELIX laser facility in the femtosecond - nanosecond configuration (Exp. P088). The two beams entered the chamber on top of each other. The 50 J, 2 ns pulse at the bottom was separated in two using a 50 % beamsplitter and then focused using $f = 300$ mm lenses on a 23 μm thick Mylar target, driving the plasmas with their fields. The use of random phase plates gave us third order super-gaussians focal spot, with 120 μm Full Width at Half Maximum (FWHM). The 50 J, 500 fs beam was focused on a secondary target (10 μm thick gold) to produce an energy broadband proton beam through the TNSA mechanism. This proton beam probed the main target by the rear and a stack of Radiochromic Films recorded the proton dose modulations due to the deflection of the protons in the magnetic field.

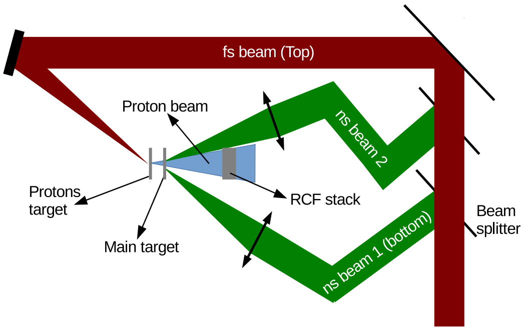

Figure 2: Setup of the experiment.

Preliminary results

In order to look a the dynamic of the system, we changed the delay between the ns and fs laser beams. Fig. 3 shows the results of the proton radiography for different delay (t_0 being the foot of the laser pulse rising slope). These results are presently being analyzed with the help of 3D numerical simulations performed using the code HECKLE [2].

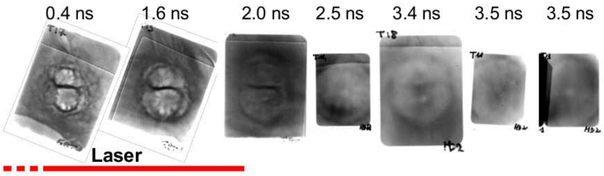

Figure 3: results of the proton radiagraphy.

References

[1] P. M. Nilson et al., PRL 97, 255001 (2006).

[2] R. Smets, N. Aunai, G. Belmont, C. Boniface, and J. Fuchs, Phys. Plasmas 21, 062111 (2014).

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