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Experimental method for preparing necessary conditions for laser fusion without radioactivity based on nonlinear force driven laser acceleration

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Abstract: Picosecond(ps)-petawatt(PW) laser-pulse interaction with solid targets for block ignition of fusion need suppression of relativistic self-focusing by very high contrast irradiation. A simple x-ray diagnostic method is described how this relativistic self-focusing can be detected for studies of the plasma-block ignition for laser-fusion.

The now available laser pulses of pisocecond duration and more than petawatt power permit side-on ignition of solid density fuel (Hora 2009). Fuel of hydrogen and boron isotope 11 (HB11) (Hora et al. 2010) produces less radioactivity than burning coal per generated energy. It is necessary that this ignition of a fusion flame is produced by plasma acceleration due to direct conversion of laser energy into plasma based on dielectric optical properties (Hora 1969, Hora et al 2007, Sadighi et al 2010) as measured first by Sauerbrey (1996). This acceleration is hundred-thousand times higher than the acceleration by thermal plasma interaction. The nonlinear force acceleration is within picoseconds while the thermal collision delayed acceleration is by nanosecond interaction.

In contrast to all the similar experiments with ps laser pulses, Sauerbrey's experiments with several TW power were very exceptional. Pre-pulses were cut off by a contrast ratio of 10^8 such that the usually occurring relativistic self-focusing could be avoided. Only under these conditions it was possible to produce plasma fronts for the ignition of fusion flames. This suppression of self-focusing with high contrast ratio interaction was observed also by Zhang et a. (1998) and by Badziak et al. (1999) and is the basis for the plasma block generation (2007) leading to the new scheme of laser fusion about which Steve Haan from Livermore said in an interview in London by the Royal Society of Chemistry that "this has the potential to be the best route to fusion energy" (Li 2010).

The essential problem for experiments to study these mechanisms is that the PW-ps laser plasma interaction avoids relativistic self-focusing. Only very few lasers in the range of PW-pulses have this extreme quality. There is a rather direct way to confirm the high quality. It is not necessary to establish the sophisticated Doppler measurements of Sauerbrey (1996) or the measurement of the energy and direction of the emitted ions (Badziak et al. 1999, Badziak et al. 2005). A straight-forward experimental check follows the experiments by Zhang et al (1998) by measuring the x-ray emission. This is very intense and of short wave length in all the usually usual experiments where relativistic self-focusing occurs. However, with the clan pulses with 10^8 contrast ratio, the x-ray emission was of low intensity and increased only after controlled prepulses were irradiated for generating relativistic self-focusing channels as usual.

Measurements for the block generation by >TW-ps laser pulses need to be checked only by the x-ray emission from an irradiated target. If this as exceptionally low as in the experiment by Zhang et al (1998), the condition for avoiding relativistic self-focusing is fulfilled.

Furthermore, this needs to be checked whether is remains as low x-rays when the laser beam diameter at the target is varied. As known for the block ignition (Hora 2009, Hora et al 2010), the laser intensity does not need record values with a smallest possible focus. The optimum intensity of the laser beams may be only 10^{18} W/cm^2 or even less. This is of advantage for the aim that the plasma block for igniting the fusion flame should be a wide spread “pancake”. If the x-ray chek is performed at an appropriate target where oxidation and hydrogen emission is under control, one may begin with highest focusing and the gradual increasing of the interaction area by increasing the focus diameter. Only if then the x-ray emission is still remaining at the low level, these conditions are sufficient for generation of the pancakes. It was noticed (Flippo 2010) that this check is necessary to keep the lateral uniformity of the laser pulses without hot spots and other undesired properties under control or at a sufficiently low level to provide the conditions of plasma block generation (Sauerbrey 1996, Zhang et al. 1998, Badziak et al 1999, Hora et al. 2007).

Only after this confirmation of sufficient suppression of the relativistic self-focusing it will be possible to perform the further experiments for studying the plasma block generation and plasma interaction in view of fusion energy generation.

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