Report of visit to the HILL (High Intensity Laser Laboratory)

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Periode of visit: 1st Dec. – 10Th Dec. 2009

I-Purpose of the Visit:

1-The main purpose of the visit is to provide the preliminary requirments fot the investigation of high-harmonics on the steep density gradient of the plasma generated by the ultrashort laser pulse. The mechanism of the high-harmonics generation gives important information about absorption mechanisms. The low prepulse laser allows the heating of the solid by electron transport. It is inturn preliminary for isochoric heating.

2-To enhance the Hungarian-Italian bilateral scientific program.

3- To enhance knowledge of the three institutions, Milano – Bicocca Laser produced plasmas group, KFKI Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Science and the HILL laboratory at the

University of Szeged, Department of Experimental Physics, Hungary. This facilitates the use of the diffrent laser system available at each facility.

II-Further Collaboration with Host Institution:

It has been agreed by both sides that near future collaborations are of immence importance. Preparations are underway for a one month experiments by both sides at the Host Institution. This will make it possible to continue the present experiments. Visit is planned for early 2010.

III-Projected Publications/Articles to result from the grant:

Using the sussesfully focused laser beam by using off-axis parabola mirrore to ~ 2.5micron diametear, corresponding to 10^{18} Wcm^{-2} Intensity, it is expected to achieve new research results in plasma harmonice which deserves to be published.

IV-Description to the HILL facility, its interests and activities:

The main interest of the HILL is directed on Laser plasma researches which is related to the physics of fast ignitors

The main activities of the HILL laboratory is to conduct research on the following interrelated m by using off-axis

- nonlinear interactions, high harmonics generation
- Spectroscopy, isochoric heating.

Collaboration with The **MPQ (MAX-PLANCK-INSTITUT FÜR QUANTENOPTIK) Germany:**

HILL has a program of collaboration with MPQ on the following topics:
- fast electron generation in a preformed plasma
- propagation of fast electrons in solid matter

Description of the HILL (High Intensity Laser laboratory)

HILL is a joint project of the Department of Physics of the University of Szeged (Sándor Szatmári, J. Bohus, short pulse ultraviolet lasers) and the Plasma Physics Department (Association EURATOM) of the KFKI-Research Institute for Particle and Nuclear Physics (Plasma Physics Department) in Budapest (István B. Földes, G. Kocsis, E. Rácz, G. Veres Laser plasma interactions, plasma diagnostics)

The KrF laser system parameters
The laser has the following parameters
- λ = 248 nm
- τ = 600 fs
- E = 15 mJ upgraded now to 70mJ

prepulses only from ASE (ns duration)
ASE intensity: 10^7 W/cm^2

Planned upgrade: 100 mJ

Main use of the laser: It is mainly used for laser plasma experiments
Other applications: ablation of solid surfaces
also with nanosecond pulses (1 J, 10-20 ns)

High-intensity experiments with tight focusing

the short wavelength of the diffraction-limited beam allows focusing to a small spot by a Janos Inc. off-axis parabola mirror. The diameter of the focal spot is 2 µm. Approximately 55% of the laser intensity was found inside this focal spot which corresponds to $5 \cdot 10^{17}$ W/cm^2 intensity. The intensity of theASE prepulse remained as low as 10^7 W/cm^2 .

Diagnostics:
- x-ray diodes
- VUV grating for 10-150 nm.

Single-shot spectra onthe MCP detector.
The main purpose of these experiments is the investigation of high-harmonics on the steep density gradient of the plasma generated by the ultrashort laser pulse. The mechanism of the high-harmonics generation gives important information about absorption mechanisms. The low prepulse laser allows the heating of the solid by electron transport.

Harmonics to 62 nm wavelength

Second, third and fourth harmonics were observed in Al, B and C targets. The appearance of 4ω radiation at these intensities is crucial for clearing the generating mechanism, because even harmonics cannot be generated in a preplasma.

Similarly to previous experiments with lens-focusing harmonics were observed both for p- and s-polarized incidence of the laser beam. The study of the polarization of the harmonics is in progress at HILL. These results are probably caused by the ponderomotive force at the critical surface and the v×B force in the evanescent wave in the overdense plasma even for the still nonrelativistic laser intensity.

Preliminaries for the investigation of isochoric heating

Fast ignition is based on isochoric heating by fast electrons. In the experiments target (C) layers of 0.5 µm thickness were on glass plate. According to MULTI-fs simulations of K. Eidmann temperatures of several 100 eV are expected in these depths. The observed Si V features from glass refer to temperatures of at at least 50-150eV, much higher than shock wave heating can give. The solid body is thus heated by the (fast) electrons from the corona. Experiments are in preparation with crystal spectrometer for higher x-ray energies.

Collaboration in the MPQ.Fast electrons inpreplasmas.

The experiments of M. Kaluza, G. Tsakiris and M. Santala showed fast electrons at the rear side of the target with atemperature of 2 MeV.
The group of HILL have investigated the preformed plasma at the front side with an x-ray pinhole camera.

Filamentary structure in the preplasma:

Previous experiments of Tanaka et. al (2000) showed a filament in the x-ray pinhole image. They claimed that it is a result of self-focusing. The scattered 2ω light shows filament, referring to self-focusing. HILL x-ray pinhole photograph for energies > 1keV shows intense radiation along the short laser pulse but no narrow filament. Although self-focusing is probably important in this case,the estimated plasma density of 10^{19} cm^{-3} is low, it is optically thin for the x rays generated in the filaments. Only the radiation caused by the ionizing effect of the main beam is seen.

Target rear side diagnostics:

x-ray pinhole camera for energies above 1keV viewed the rear side of the target when no prepulse was present. The results show no significant divergence of the electron beam in the target, the angle of divergence is less than 12° in agreement with V. Malka et al. (LULI) and M. Tatarakis et al.(RAL).
X-ray diffraction on a razor blade shows no significant divergence, too. The measured spot diameter in this case is 18 µm, too. In the same times energetic proton beams were observed originating from the rear side of the target (M. Kaluza, G.D. Tsakiris). the experiments showed that in the previous strong

prepulse-case the heat wave reaches the rear side, thus inhibiting the formation of the double layer, the source of proton acceleration.

Optimization proton energy for low ASE prepulses (M. Kaluza et al., MPQ) in the case of low intensity prepulse and sufficiently thick targets, the heating does not reach the rear side. However, in the preplasma, a sufficient number of fast electrons are generated which can reach the rear side, there establishing the double layer for the proton acceleration. Varying the pulse duration of the prepulse and the thickness of the target allows one to optimize the energy of the proton beam.

Cutoff-Energies for Different Thicknesses and Prepulse Durations:

For longer prepulses maximal proton energy is achieved with thicker foils.
If foil burns through, backside acceleration is suppressed. Clear indication, that high energy protons come from target backside!(from M. Kaluza)

Trends in fast ignitor physics:

Reasons for fast ignitor:
- reduces required driver energy
- reduces symmetry requirements

the original scheme of Tabak et al. (1994)
- central spark ignition
- isobaric compression
- 3kJ energy

Fast ignition occurs in a uniform fuel:
Isochoric scheme of S. Atzeni (1995, 1999)
2.4 times larger energy is needed.

Parameter range for fast ignitor:
Simulations of S. Atzeni, summarized by
M. Roth et al., 2001

the motivation for studying isochoric heating

Trends in fast ignitor physics
Results of the Fast-Ignitor Consortion (ILE, RAL) ,M. Key, Nature, 2001

R. Kodama et al., Nature 2001

The short pulse is guided with a gold cone to the precompressed DD fuel.

60 J
0.06 pW
1 ps

Trends in fast ignitor physics

Thermal neutrons were oberved from the DD reaction. The 10x increase of neutron numbers corresponds to 1% temperature rise when using 0.1% of required ignitor energy.
R. Kodama et al., 2002: 0.5 pW laser energy resulted 3 orders of magnitude neutron number increase.
2-fold temperature increase: 0.3-0.4 → 0.8 keV.
0.6 ps pulse duration << measured 40 ps stagnation time.

Consequence: Laser pulse duration can be increased, not the power.
It can be scaled.

Ideas in fast ignitor physics

Coronal ignition?
Traditional FI-scheme: Self-focused beam is guided to the overdense matter.
Calculations of S. Hain and P. Mulser (2001):
- Bad news: hole boring does not work to high densities.
- Good news: Fast ignition is possible from the corona with diffusive transport.
Insensitive to precompression symmtry the reason why the Au cone works ?

FI by proton beam? (M. Roth et al., 2001)

Basis: Highly directional proton beam was observed from the target rear side up to 10^{13} protons of 6 MeV temperature. Better focusing, source close to pellet but not directly coupled. But even one more step, more indirect.

Physical issues under investigation for fast ignitors:

Fast electron transport in overdense matter

Simulations (M. Honda, J. Meyer-ter-Vehn, A. Pukhov, M. Tatarakis):

Small scale instabilities of electron beams.
Question: How it affects bulk propagation?

Experiments:
Propagation of fast electrons was measured to be nearly parallel.
G. Malka et al (LULI): 1 J, 30 fs, 2 - 10^{19} W/cm^2 . θ<15°.
M. Tatarakis et al (RAL): 50 J, 1 ps, 5 - 10^{19} W/cm^2 .
HILL's results with MPQ: 1 J, 150 fs, 10^{19} W/cm^2 . θ<12°.

Parallel propagation of the fast electron beams open the possibility both for direct FI applications and for proton beam generation.

Question remains: How far can it be scaled up?

V-What is the outcome of my visit:

In collaboration with the group of HILL we were working in the alignment of the off-axis parabola and measuring the intensity. The objective of the aformentioned experiments is to have a high intensity of ~10^{18}.
Incoclusion, the wok of my visit o HILL is a a preparatorty work of plasma harmonice experiments. The upgraded KrF laser beam (248nm, 610 fs, 60mJ) of HILL was for the first time successfuly focused by using their off-axis parabola mirrore to ~ 2.5micron diametear, corresponding to 10^{18} Wcm^{-2} Intensity.

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