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Investigation of Intense Ion Beams Interaction with Matter and Dynamic Processes in Irradiated Targets.

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Abstract

Penetration of charged particles through matter is accompanied by various processes of interaction with elementary particles, nuclei, ions, atoms. The character and the effect of these interactions depend on the type, energy and intensity of the particle beam and on the type, state, density, composition and size of the target.

The main goal of our investigations during last years is justification of the Hohlraum target design for investigation of ion interaction with hot dense plasma on the *Phelix* (*nhelix*) + *UNILAC* facility [1]. The activity includes experimental, numerical and theoretical investigations:

- Experiments on the *ISKRA-5* (VNIIEF), *nhelix (Phelix)* laser facility (GSI) for the study of laser radiation interactions with matter;
- Experiments on the *Unilac* (GSI*), TWAC*(ITEP*)* and *EGP10* (VNIIEF) accelerators for the study of ion interactions with cold matter;
- Trial experiments on the *nhelix (Phelix) + Unilac* laser-accelerator complex for the study of ion distributions in the targets with different compositions, irradiated by intense laser beam;
- Theoretical investigation and computer simulation of laser and ion beam interactions with different targets;
- Theoretical investigation and computer simulation of hydro and thermo dynamical processes in plasma

Numerical analysis and investigation are performed using 1, 2 and 3D computer codes:

- The spectral X-radiation transfer and its interaction with matter are described with the system of multi group kinetic equations and the equation of energy [2],
- Calculations of the medium gas-dynamic motion are held at the MIMOZA code. At the same time the continuous time connection between two codes, realized in the complex code, takes place [3].

- The Monte-Carlo spectral code is successfully used for experimental data analysis,

All of these codes have possibility to calculate laser and ion beam interaction with plasma [3].

- The TRIR spectral code, based on the view factors method, is used for experimental data analysis at the laser facilities [3].

This report presents the some results of the calculation and theoretical investigations of laser and ion beam interactions with different targets.

1. Gas dynamic processes in spherical target, irradiated by the Co ion beams

Ion beam parameters: E = 200 MeV/A, I = 10^{20} 1/s×cm^2, R = 0.15 cm

Target parameters:

Thick spherical layer

(ρ_0 = 18.7 g/cm^3, *Rint* = 0.08 cm, *Rext*= 0.14 cm);

The enclosure is filled with gas

(ρ_0 = 0.01 g/ cm^3, *Rint* = 0.0 cm, *Rext*= 0.08 cm)

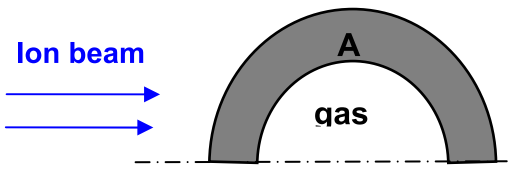

Fig.1. Schema of the 2D calculation

Energy distribution inside target is no uniform (Fig.2). Therefore we have asymmetry compression inner region (Fig.3). Nevertheless, density of the gas region reaches some g/cm^3 (Fig.4)

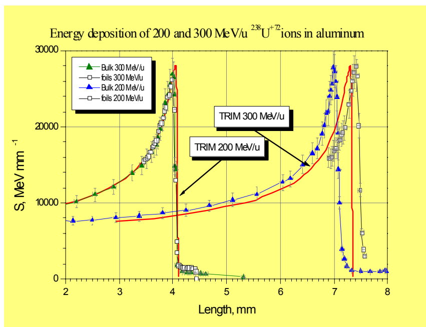

Fig.2. Experimental results of ion beam stopping measurements in condense matter (SIS18 accelerator, VNIIEF, GSI and ITEP groups, “thick target” method [4])

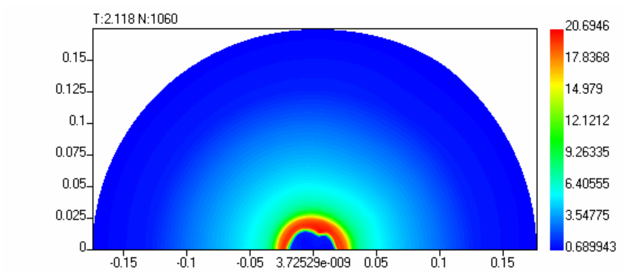

Fig.3. Density (g/cm3) distribution over the target.

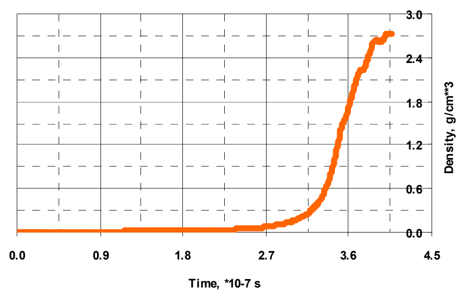

Fig.4. Time dependence density of light region

2. Calculation of inertial fusion converters on heavy-ion driver

Converter design for target is a one of the essential part of the inertial fusion with heavy ion driver investigations. The main aim of this investigation is increasing x-ray flux from converter and decreasing low boundary of the ion beam flux. Converter from hydrogen is a possible candidate for reaching this aim. We have some 2D calculation for investigation his parameters.

Target parameters:

H, d=7mm, ρ=0.0715g/cm^3

Be, d=0.8mm, ρ=1.85g/cm^3

Al, , d=0.63mm, ρ=2.7g/cm^3

Ion beam parameters

U238 , E = 50 MeV/nucleon, R_{beam} = 1.0 cm

Intensity: from 1×10^{23} to 5.4×10^{23} $s^{-1}\times cm^{-2}$

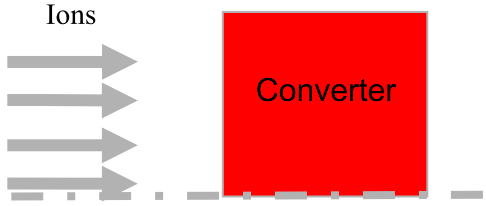

Fig.5 Schema of the 2D calculation

At the Fig.6 and Fig.7 some results of our calculations are presented.

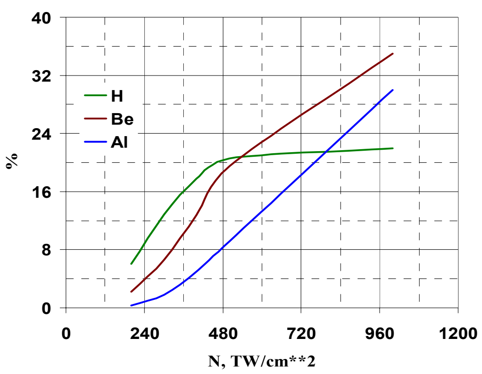

Fig.6. Converter efficiency as a function of ion beam intensity for different materials

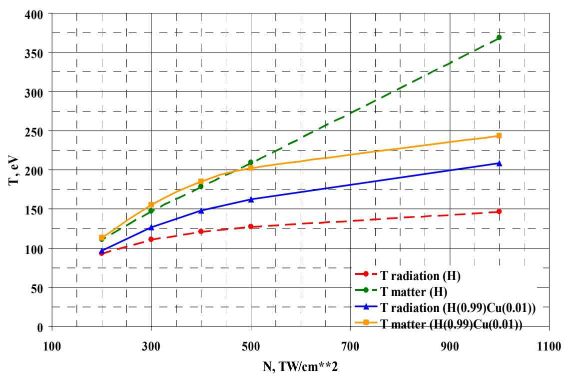

Fig.7. Converter temperature as a function of ion beam intensity for different materials composition

From these pictures we can see that for low ion beam intensity converter with hydrogen (doped by small part of heavy materials) has a higher efficiency.

3. On Possible Research Directions on the FAIR Accelerator + KJ Laser

In 2007 was started building the FAIR power heavy-ion accelerator with the ion beam pulse energy up to 50-100 kJ. During the 28th International Workshop on Physics of High Energy Density in Matter (Hirschegg, Austria, 2008) a meeting was proposed to consider possible research directions for the prospective laser+accelerator facility [5]. We have formulated some possibilities which can be realized if the FAIR accelerator connected with a power pulse laser facility with the pulse energy 1-10 kJ or more and pulse duration about 1-2 ns [6]

1. Study of the interaction of ions with the energy above 50 MeV/A with hot plasma. At present a lot of experimental data on ion interaction with cold matter are available for a wide range of ion energies. The ion energy loss in hot dense plasma in low-Z matters at ion energies up to 10 MeV/A (*nhelix+Unilac* and *Phelix+Unilac* facilities) is studied now. Measurements with ion beams with higher energies are feasible on the FAIR+laser facility only.
2. Gas dynamics studies in thick plasma layers, obtained as the result of laser pulse impact on different targets, by fast ions transmission (method of ionography). The volume of generated plasma and its parameters (temperature, type of matter, etc.) are determined by the laser energy.
3. Study of the shockwave and gas-dynamic flows expansion, generated by a laser pulse (with direct and indirect impact) in the plasma, generated by the FAIR ion beam in irradiated targets with different compositions and designs at plasma temperatures up to several tens of eV.
4. Study of the shockwaves collisions, generated in targets irradiated by synchronized laser pulses and the FAIR ion beams.
5. Studies for the developments of inertial fusion targets with different designs and operation (direct and indirect impact, Fast ignition) with heavy-ion driver.

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