Parameter Margins of Hohlraum Targets for Ion-Plasma Interaction Experiments

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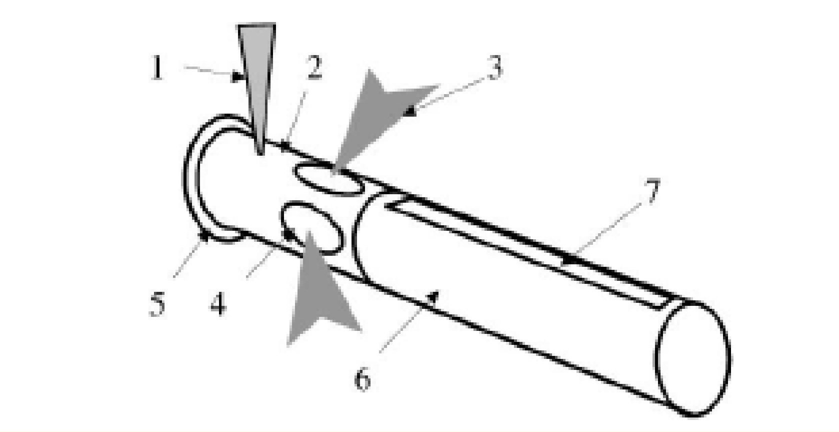
Plasma Target

- Diagnostics of target parameters;
- Homogeneity of density, temperature, and other target parameters :
  - in space,
  - in time;
- Geometric dimensions sufficient for measurements with required precision;
- Target lifetime sufficient for measurements;
- Broadest possible temperature and density ranges (and ion types).

“Converter” Hohlraum Target



VNIIEF (Sarov)

- «ILLUMINATOR»: conversion of laser radiation into X ray source for heating cylindrical channel.
- Cylindrical channel: radiation field initiates evaporation and hydro motion of heated matter and plasma;

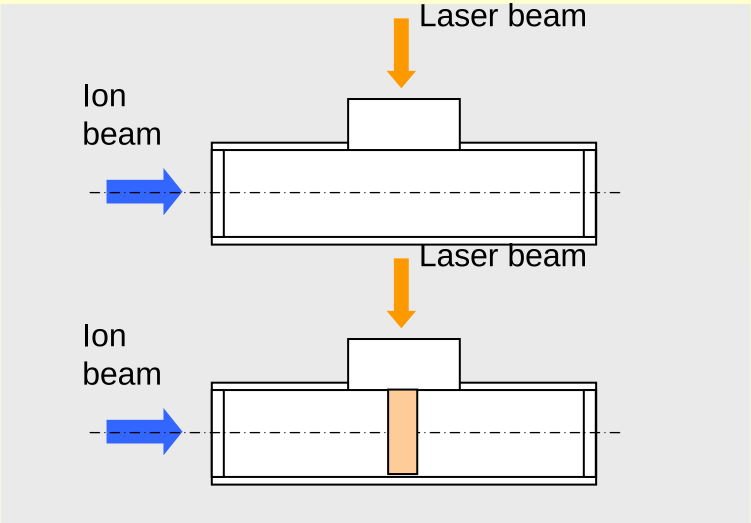
  Local thermodynamic equilibrium of hot plasma; equalization of parameter distributions in the channel.

Hohlraum Target

- «Converter»-type target for hot plasma production and subsequent ion stopping studies.
- Physics to be taken into account:
  - Interaction of nsFE Phelix laser pulse with the wall material,
  - Wall heating and emission of X-rays into the target cavity,
  - Filling the cavity by plasma from hot walls,
  - Heating and ionization of wall material,
  - Hydro motion of hot walls,
  - Heating ad ionization of low-density material in the cavity (option),
  - Radiation absorption ad re-emission by the plasma in the cavity.

«Converter»-type target provides homogeneous equilibrium plasma inside the cavity for measurements of plasma parameters and ion stopping.

Hohlarum Targets for Studies at SIS / unilac + Phelix / nhelix



Vacuum targets:

High-Z material,

T = 50 ÷ 100 eV; $\rho_{el} \sim 10^{20}$ 1/cm^3.

Targets filled with low-Z material:

T = 50 ÷ 80 eV; $\rho_{el} \sim 10^{21}$ 1/cm^3 (CH).

Equilibrium homogeneous radiation field inside the target:

- For T_{rad} = 100 eV and CH target, ρ_{CH} = 0.01 g/cm^3
  average Rosseland path length L_{Ross} ~ 1 mm, i.e., 0.01 g/cm^2;
- For T_{rad} = 100 eV and Au target, ρ_{Au} = 20 g/cm^3
  average Rosseland path length L_{Ross} ~ 0.003 mm, i.e., 0.6 mg/cm^2.

For 10 % ion energy losses

$L_{Ross} \sim L_{ion}$ in low-Z material;

$L_{Ross} << L_{ion}$ in high-Z material.

Processes and Models

- X ray transport in an optically thin cavity:
  - Nonstationary, account of retardation;
  - Precise account of cavity geometry;
  - Account of spatial and angular distributions of radiation field and sources (no so called “ray effect” induced by discrete grid of spatial cells and discrete set of numerical directions).

  Kinetic radiation transport equation; «View Factor» method.
- Hydro equations in heavy (high-Z) material
- Equations of state in a wide range of matter parameters
- X ray transport in optically thick domains:
  - Kinetic nonstationary equation;
  - Spectral transport;

  Radiative hydro equations.
- Stable and balance-preserving boundary and coupling conditions.

MULTI-VF Software for Simulation of Plasma and Ion Stopping Experiments with Hohlraum Targets

MULTI

- Multigroup radiation transport equation:

$$\left(\frac{1}{c}\partial_t + \vec{n}\cdot\nabla\right)I(\vec{r},\vec{n},\nu,t) = \eta(\vec{r},\vec{n},\nu,t) - \chi(\vec{r},\vec{n},\nu,t)I(\vec{r},\vec{n},\nu,t)$$

Local thermodynamic equilibrium, Planck radiation:

$$I_P(T,\nu) = \frac{2h\nu^3}{c^2}\left(\exp\left(\frac{h\nu}{kT}\right)-1\right)^{-1}$$

- Hydrodynamic equations (1D, 2D Lagrangian):

$$D_t = -\rho\nabla\cdot\upsilon \qquad \rho D_t\upsilon = -\nabla P - \vec{R} \qquad \rho D_t e = -P\nabla\cdot\upsilon - \nabla\cdot\vec{q} - Q + S \qquad D_t \equiv \partial_t + \upsilon\cdot\nabla$$

- Boundary conditions: radiation source or reflection conditions; free boundary, for hydrodynamics free surface, rigid wall.

MULTI-VF Software for Simulation of Plasma and Ion Stopping Experiments with Hohlraum Targets

VF

- Integral nonstationary radiation transport equation (multigroup, 2D, 3D):

$$J_\nu^-(P,t) = \int_{S(P)} K(P,Q) J_\nu^+\left(Q, t - \frac{r(P,Q)}{c}\right) dS \qquad K(P,Q) = \cos\left(\vec{n}_P, \overrightarrow{PQ}\right) \cdot \cos\left(\vec{n}_Q, \overrightarrow{QP}\right) / \pi r^2$$

$$J_\nu^-(P,t) = J_\nu^+(P,t) + q_\nu(P,t)$$

Solved using View Factors.

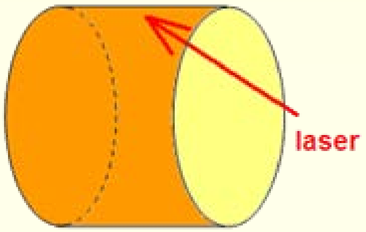
Coupling conditions

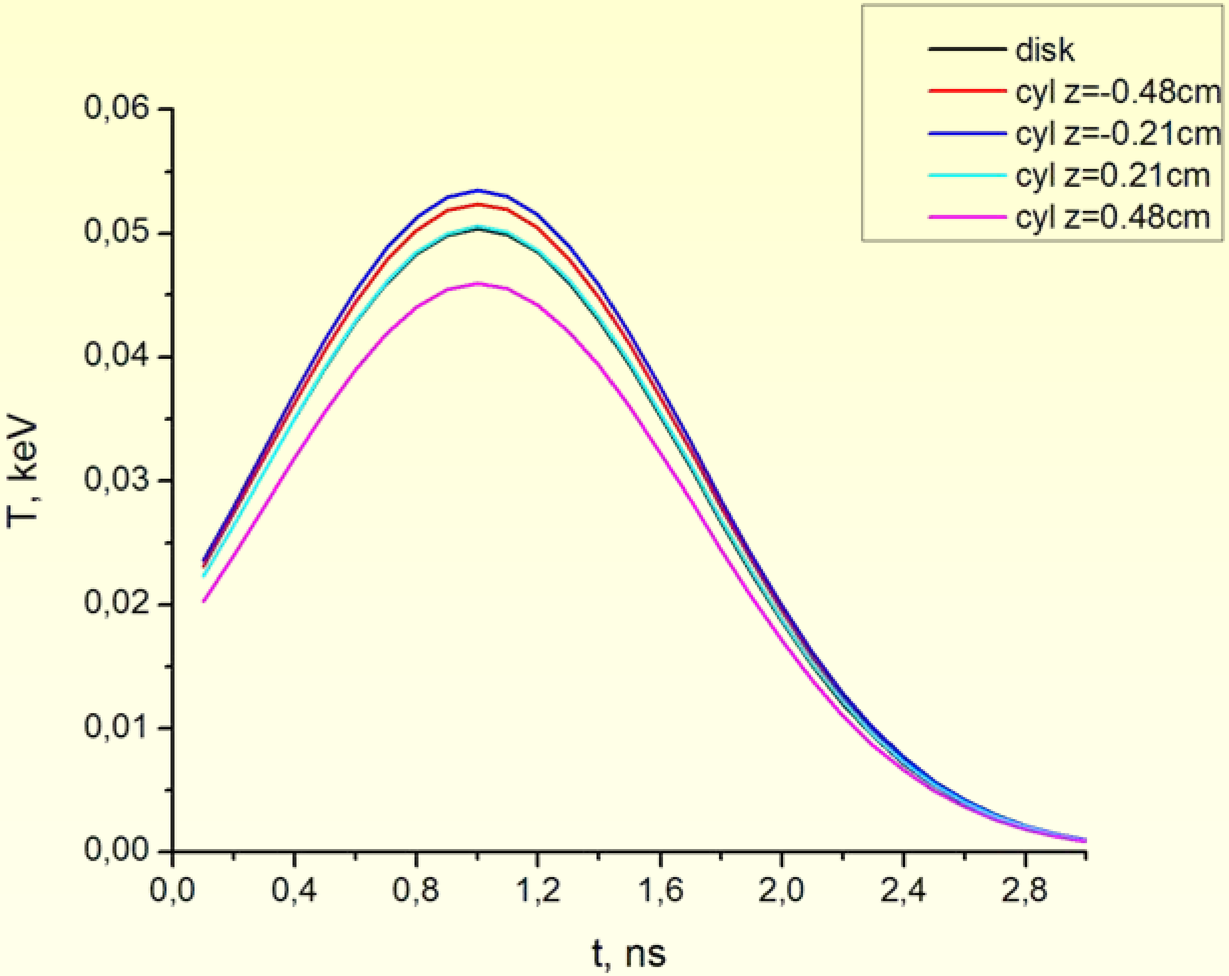
- One-way radiation fluxes between MULTI and VF:

$$\underset{VF}{J_\nu^+}(P,t) = \underset{MULTI}{J_\nu^-}(P, t-\tau) \qquad \underset{MULTI}{J_\nu^+}(P,t) = \int_{S(P)} K(P,Q) \underset{VF}{J_\nu^+}\left(Q, t - \frac{r(P,Q)}{c}\right) dS$$

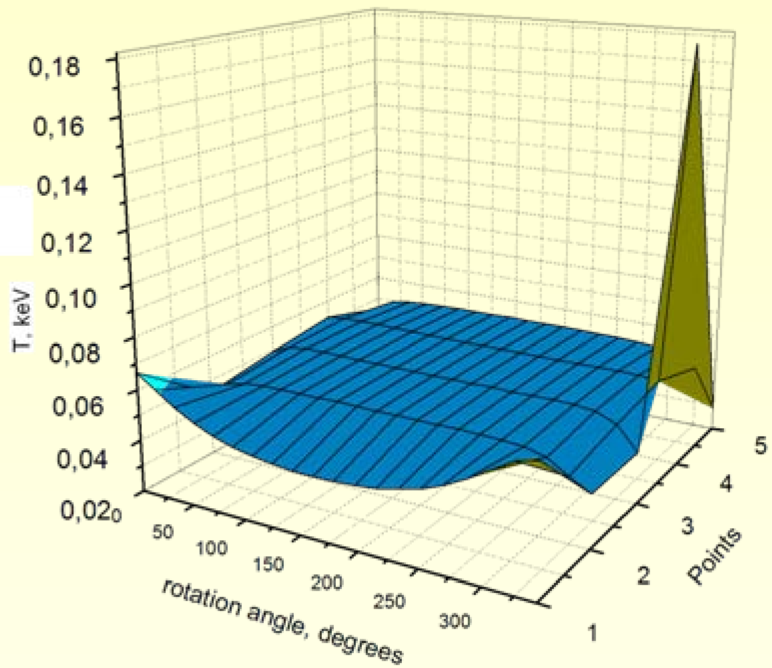
3D VF Simulation

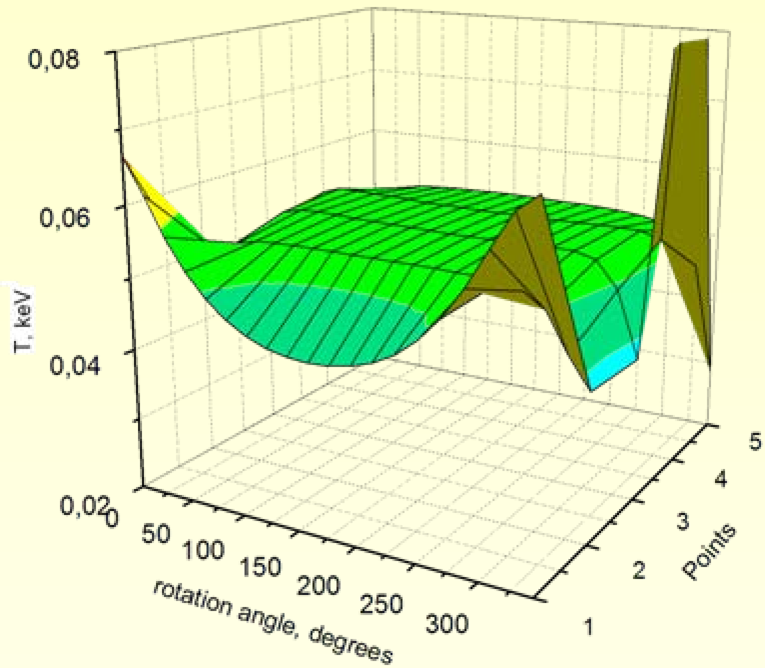
- Target: gold cylinder, diameter 0.15 cm, length 0.11 cm. One end closed by gold foil, other end opened.
- Laser beam: 250 J, Gaussian time profile, FWHM = 1 ns, spot size 200 mkm (center of the cylinder wall). First harmonic (albedo ~ 0.5).

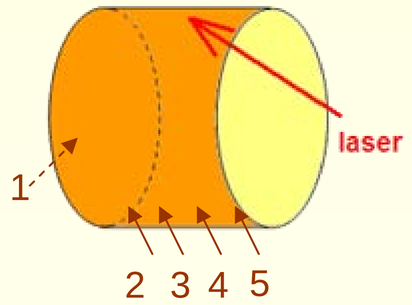




3D VF Simulation







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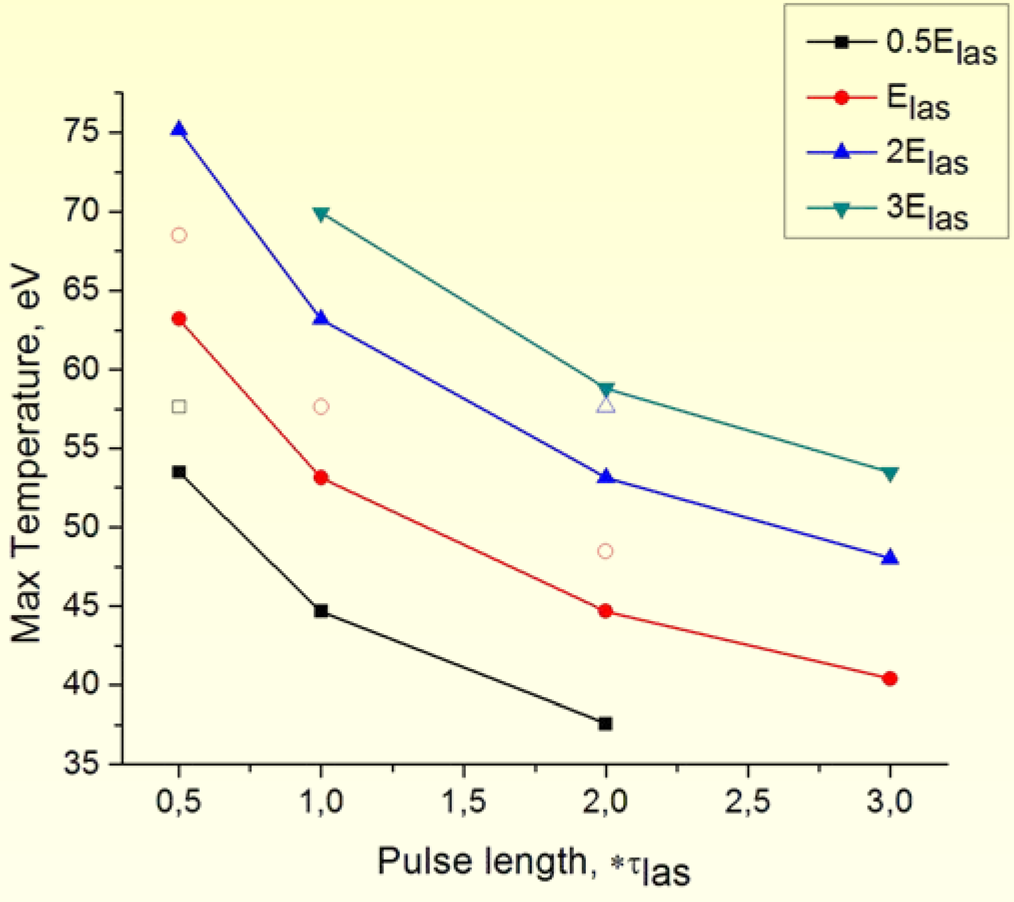

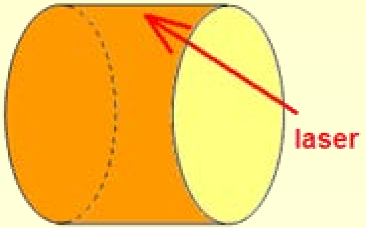

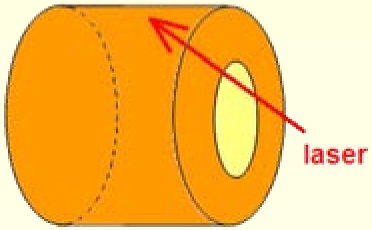

3D VF Simulation