Radiation-hydrodynamic simulations of foams heated by hohlraum radiation*

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Undergoing experiments at GSI use a cylindrical hohlraum target irradiated by the PHELIX laser for the indirect x-ray heating of a carbon foam to create a homogeneously ionized plasma state for measurements of the ion stopping power [1]. Simulations with the newly developed code RALEF-2D [2] have been performed to investigate the dynamics of the hohlraum and of the plasma [3]. Figure 1a shows the lateral cut of the simulated Cartesian (x, y) configuration which extends to infinity along the z-axis.

The RALEF-2D code solves the one-fluid one-temperature hydrodynamic equations in two spatial dimensions on a multi-block structured quadrilateral grid by a second-order Godunov-type numerical scheme using the ALE approach. Thermal conduction, radiation transport, and laser energy deposition by means of inverse bremsstrahlung absorption have been implemented within the unified symmetric semi-implicit approach with respect to time discretization. The applied EOS, thermal conductivity, and spectral opacities were provided by the THERMOS code. In combination with the Planckian source function, this involves that the radiation transport is treated in the LTE approximation.

The frequency-doubled PHELIX laser pulse in the experiment has a pulse duration of 1.4 ns with a total energy of 180 J, which corresponds to 122.8 J/mm after conversion to the simulated 2D case. In the simulation, the radiative transfer equation was solved for 7 spectral opacity groups and for 960 discrete ray directions over the entire 4π solid angle. The spatial laser intensity profile was approximated by a Gaussian curve with a FWHM of 0.2 mm.

The calculated x-ray hohlraum spectrum close to the end of the laser pulse (Figure 1b) shows a highly non-Planckian spectrum, which mimics the spectral opacity profile of carbon. The matter and radiation temperatures at the center of the hohlraum equilibrate to ≈ 31 eV at $t = 3$ ns. For times $t > 7$ ns a thin and dense filament of shock-compressed gold plasma is formed and stays close to the hohlraum center due to the collission of the expanding clouds of the ablated material from both hohlraum walls.

For a large portion of the hohlraum radiation emitted during the laser pulse the carbon foam with the initial mean density $\rho_C = 2.0$ mg/cm^3 has an optical thickness of ≈ 1. For this reason the carbon foam is practically instantaneously heated by a flash of x-rays from the laser spot over the entire foam volume to an average temperature of $T \approx 30$ eV, varying by about a factor 4 across a distance of 1 mm. After the laser pulse, the plasma temperature relaxes while the x-ray heating from the hohlraum continues. At $t = 14$ ns (Figure 1c) the dynamics of the carbon plasma is dominated by lateral expansion and by a shock wave propagating from the Cu-C interface. Nevertheless, the simulations show that the time and space variations of such key parameters as the column mass density along the ion trajectories and the plasma ionization degree ($Z \approx 3.9$ at $T \approx 30$ eV) over the ion beam aperture remain sufficiently small for the measurements in the range 3 ns $\lesssim t \lesssim 10$ ns.

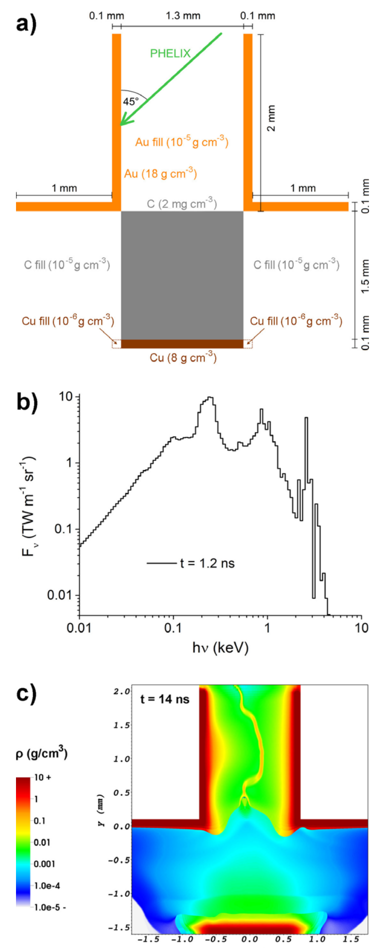

Figure 1: a) 2D lateral cut of the simulated configuration; b) calculated x-ray spectrum as observed through the lower hohlraum hole at $t = 1.2$ ns; c) density ρ at $t = 14$ ns.

References

[1] O. N. Rosmej et al., NIM-A 653 (2011) 52.

[2] M. M. Basko et al., GSI Report 2010-1 410.

[3] S. Faik et al., in preparation.

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