Studies of Uranus and Neptune Interiors in LAPLAS Experiment Simulations*

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Two–dimensional hydrodynamic simulations have been performed using a circular focal spot to compress solid water using a uranium ion beam that will be available at the future FAIR facility at Darmstadt. This work has been done to study the possibility of studying planetary physics by generating extreme states of matter which are expected to exist in the interiors of the giant planets [1].

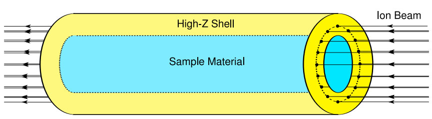

Figure 1: Beam–target geometry for LAPLAS experiment

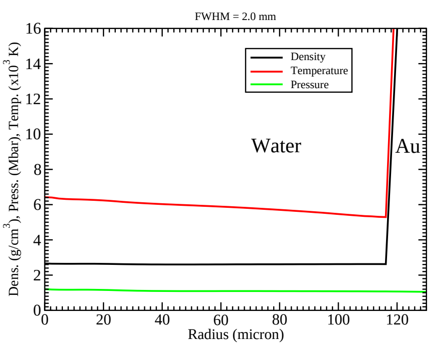

Figure 2: ρ, T and P vs radius in the water layer at the time of maximum compression for a beam FWHM = 2 mm

In this study we consider an intensity of 10^{11} 1 GeV/u uranium ions that are delivered in a single bunch, 50 ns long. A circular focal spot is considered with a Gaussian intensity distribution.The target is a cylinder of frozen water having a radius = 200 μm that is enclosed in a Au shell (see Fig. 1). The target length is 5 mm which is shorter than the length of the projectile particles so that the energy deposition is uniform in the longitudinal direction. In these simulations we use a semi-empirical equation of state model [2] for Au and data based on Quantum Molecular Dynamic (QMD) simulations for water [4].

In Fig. 2 we plot the density, temperature and pressure along the radius (in the water layer) using a beam FWHM = 2 mm at the time of maximum compression. It is seen that a density of 2.6 g/cm^3, a pressure of 1.2 Mbar and a temperature of about 5000 K is achieved.

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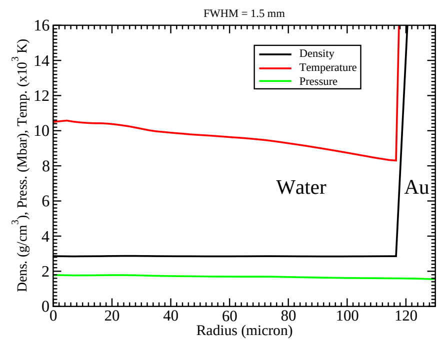

Figure 3: Same as in Fig. 2, but for a beam FWHM = 1.5 mm

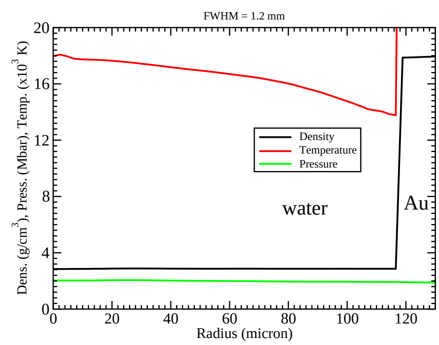

Figure 4: Same as in Fig. 2, but for a beam FWHM = 1.2 mm

Fig. 3 shows the same variables as Fig. 2, but using beam FWHM = 1.5 mm. In this case we achieve a water density of 2.8 g/cm^3, a pressure of 1.8 Mbar and a temperature on the order of 10000 K. Fig. 4 shows the results for a beam FWHM = 1.2 mm and one achieves a density of 3 g/cm^3, a pressure of 2 Mbar and a temperature of about 16000 K. These parameters correspond to the plasma state of water.

Further calculations are planned using higher beam intensities that will allow one to access higher densities corresponding to the superionic state in which the protons become mobile in the oxygen lattice [3, 4].

References

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