# High-temperature plasma of Ge generated by the PHELIX laser *

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Certain nuclear transitions, accompanied by release of large amounts of energy, can be induced by appropriate atomic resonances. One potential candidate is an isomeric state of $^{84}$Rb, whose $\gamma$-decay could be initiated by resonant $ns \rightarrow 2s$ transitions in strongly ($z_{ion} > 27$) ionized Rb atoms [1]. The required degree of ionization could be achieved by heating the medium, where the $^{84}$Rb isomers are created, with the PHELIX laser at GSI. Since the Rb isomers are expected to be created in the $^{76}$Ge(12C,p3n)$^{84}$Rb reaction, i.e. by irradiating Ge with a carbon beam, it is the Ge plasma where one should demonstrate the ability to achieve the necessary temperatures under laser irradiation.

Here we present the results of RALEF-2D [2] simulations of a 4 $\mu$m thick Ge foil, irradiated normally by a $\lambda = 532$ nm laser pulse of 150 J over a focal spot of radius $r_f = 100$ $\mu$m; the 1.4-ns long pulse was ramped with 0.2-ns linear rise and fall intervals. As a preliminary step, spectral opacities and the equation of state of Ge in the approximation of local thermodynamic equilibrium (LTE) were generated with the THERMOS code [3]. The RALEF runs were performed in the newly developed axial $rz$ mode of the radiation transport, which was treated with 22 spectral groups and the $S_{12}$ angular quadrature.
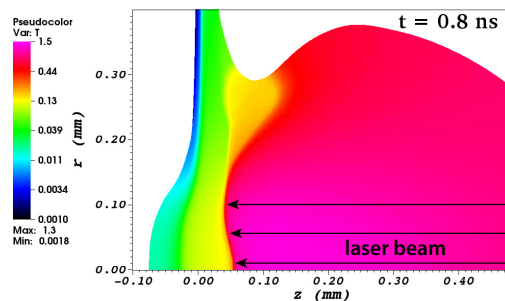


Figure 1: 2D color contour plot of Ge-plasma temperature (in keV) at $t = 0.8$ ns.

The calculated 2D temperature distribution in the Ge plasma shortly after the middle of the laser pulse ($t = 0.8$ ns) is displayed in Fig. 1. The corresponding 1D profiles along the laser-beam axis are shown in Fig. 2. The laser heated plasma consists of two distinct zones: a low-density hot corona behind the critical surface, whose temperature reaches $T_{max} \approx 1.3$ keV, and a radiation-driven heat wave before the critical surface with a relatively high density of $\rho \approx 0.1$–0.2 g/cc, where the matter and radiation temperatures are practically equal and lie in the range $T \approx T_r \approx 100$–150 eV. The whole structure is dominated by x-ray energy transport: our simulation indicates that about 70% of the absorbed laser energy escapes the target in the form of keV-range x-rays. The calculated time- and space-integrated emission spectrum (in the direction opposite to the laser beam) is shown in Fig. 3.
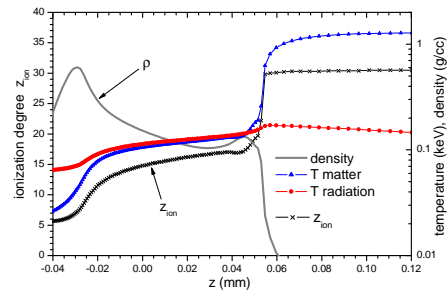


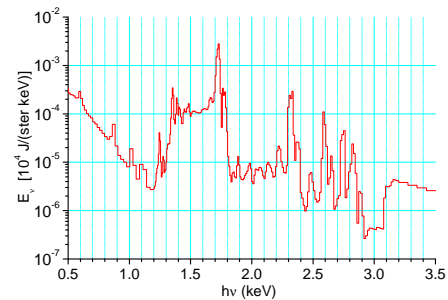Figure 2: Profiles along the laser-beam axis at $t = 0.8$ ns.



Figure 3: Time- and space-integrated emission spectrum.

Of principal interest for studying the nuclear transitions in Rb would be a narrow ablation front, where the matter temperature jumps from $T \lesssim 0.2$ keV to $T > 1$ keV. It is within this layer that, similar to Ge, the admixture Rb atoms should undergo sharp increase in their ionization degree from $z_{ion} \approx 15$–20 up to a helium-like state with $z_{ion} = 35$ assuming LTE.

## References

[1]  F. Gobet et al., Nucl.Instr. and Meth. A **653** (2011) 80.

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[3]  A.F. Nikiforov, V.G. Novikov, V.B. Uvarov, *Quantum-statistical models of hot dense matter: methods for computation of opacity and equation of state*, Birkhäuser, 2005.