Ionization and temperature measurements in warm dense copper using x-ray absorption spectroscopy

T. Cordova[1,2†], E. V. Marley[2], D. Chin[3], T. Döppner[2], R. A. London[2], M. K. G. Kruse[2], H. A. Scott[2], F. N. Beg[1], F. Coppari[2], J. Emig[2], S. B. Hansen[4], C. C. Kuranz[5], M. Millot[2], P. Nilson[3], M. P. Springstead[5], P. Sterne[2], and M. J. MacDonald[2]

[1]*University of California San Diego, San Diego, CA, USA*
[2]*Lawrence Livermore National Laboratory, Livermore, CA, USA*
[3]*Laboratory for Laser Energetics, University of Rochester, Rochester, NY, USA*
[4]*Sandia National Laboratories, Albuquerque, NM, USA*
[5]*University of Michigan, Ann Arbor, MI, USA*

Warm dense matter exists at temperatures of order 10 eV and a few times solid density, where the complex balance of collective and quantum effects precludes standard approximations used in plasma physics or condensed matter physics. Understanding ionization in the warm dense matter regime, in particular, is an active area of research requiring additional experimental data to benchmark and improve current predictive capabilities. In this study, we present the experimental results and analysis of K-shell x-ray absorption spectra to infer temperature and ionization state distribution of copper uniformly heated to temperatures 10–30 eV and compressed to densities of 9–30 g/cm^3. The experiments were conducted at the OMEGA laser facility using a buried layer of copper tamped by plastic on both sides. The two sides were then irradiated by a symmetric laser pulses and probed by a laser-generated x-ray source. Experimental results are compared to collisional-radiative models where we find large discrepancies in the predicted x-ray absorption spectra at these conditions. We also explore the role of including density effects in the underlying atomic data used in the collisional-radiative models and compare the results to our experimental data.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and was supported by the LLNL-LDRD Program under Project No. 22-ERD-005. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

†Corresponding Author Email: tcordova@ucsd.edu