International Conference on X-ray Lasers (ICXRL)

University of York
York, YO10 5DD
United Kingdom
2nd October 2019

Time-of-flight mass spectrometry to determine plasma temperature from ablated target surface

Eduardo Solís Meza[1], Lydia Rush[2], Carmen Menoni[2], Jorge Rocca[2], Gregory Tallents[1], Erik Wagenaars[1]

[1] York Plasma Institute, Department of Physics, University of York, YO10 5DD, United Kingdom

[2] Center for Extreme Ultraviolet Science and Technology and Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado 80523, U.S.A

Extreme Ultraviolet Laser Ablation Time-of-flight Mass Spectrometry (EUV TOF) has recently been introduced as a reliable new technique for chemical analyses at the nanoscale [1]. In this work, we explore a further application of this method as a plasma diagnostic tool by combining the spectral data with post-processing simulations. EUV TOF mass spectrometry was used to measure the distribution of ions resulting from the EUV laser ablation and ionisation of materials with different attenuation lengths. The materials analysed were gold, silver, aluminium and silicon. These materials have attenuation lengths that change from nm to μm. As expected, in materials with shorter attenuation lengths, such as gold and silicon, the ion distributions showed a bigger 2+/1+ ratio, of ~20%. In silver and aluminium, materials with longer attenuation lengths, the same ratio decreases to ~5%. In gold, small amounts of 3+ ions were measured (3+/2+ ~0.6%). These experimental results are combined with a simple analytical adiabatic expansion model to derive the plasma temperature on the target surface, at the end of the laser-solid interaction. The plasma created during the ablation has a relatively low density and it can be studied using a stellar corona plasma approximation [2]. The plasma expansion can be modelled as an adiabatic expansion in vacuum, using two models for the initial conditions of the expanding plasma; an isothermal and isentropic model [3]. The number of ions of different degree of ionisation that reaches the mass spectrometer detector was calculated from the expansion model for a given set of initial conditions. The calculated ion spectrum was then fitted to the measured ion spectrum by changing the initial plasma conditions in the model, giving an estimate for the plasma temperature at the start of the expansion, i.e. at the end of the laser-solid interaction. We explored the scope and limitations of the different gas expansion approximations and their similitude with the expected values.

[1] Kuznetsov, I., Filevich, J., Dong, F., Woolston, M., Chao, W., Anderson, E. H., Bernstein, E. R., Crick, D. C., Rocca, J. J. & Menoni, C. S. (2015). Three-dimensional nanoscale molecular imaging by extreme ultraviolet laser ablation mass spectrometry. Nature Communications, 6(6944), 1-6.

[2] Tallents, G. (2018). An Introduction to the Atomic and Radiation Physics of Plasmas. Cambridge: Cambridge University Press. DOI: 10.1017/9781108303538

[3] Stapleton, M. W., McKiernan, A. P., & Mosnier, J. P. (2005). Expansion dynamics and equilibrium conditions in a laser ablation plume of lithium: Modelling and experiment. Journal of applied physics, 97(6), 064904.