Soft x-ray laser nanoscale molecular imaging: enhanced mass range and sensitivity
I. Kuznetsov, J.J. Rocca and C.S. Menoni
Department of Electrical and Computer Engineering, Colorado State University

Laser ablation and ionization combined with mass spectrometry (MS) forms the basis of one of the most widely exploited analytical tools of the solid state. We have previously reported the first demonstration of soft X-ray laser (SXRL) ablation mass spectrometry [1] using the focused 46.9 nm wavelength output from a compact capillary discharge laser [2]. The focusing of the SXRL beam into 100 nm diameter spots, its high absorption in all materials and efficient photo-ionization contribute to the nanoscale spatial resolution and attomole sensitivity of the method. The high sensitivity and spatial resolution of SXRL time of flight (TOF) MS has enabled 3-D nanoscale composition imaging of a single microorganism. However, due to the high photon energy (26.4 eV) photoionization is often accompanied by extensive fragmentation of analyte molecules. This leads to interferences in mass spectra which complicates analysis.

This paper describes the implementation of post-ablation soft ionization that is aimed at selectively extracting molecular or atomic information from the most abundant neutrals in the SXRL-created plasma. Post-SXRL ablation ionization is implemented using either the 355 nm wavelength output from a frequency tripled Nd:YAG laser or the 9th harmonic (118 nm) obtained by upconversion of the 3rd harmonic in a Xe:Ar mixture. Focusing the vacuum ultraviolet (VUV) light into the sample region allows for softer ionization of intact neutral molecules. Using selected organic solids, it will be shown that the combination with SXRL with post-ablation ionization provides increased imaging resolution, sensitivity and mass detection range in comparison with what is obtained using conventional lasers or ion sources.


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3D nanoscale molecular imaging. Schematics of the EUV laser ablation mass spectral imaging method (left). Iso-lines showing the distribution of the most intense ion in the mass spectra from a single Mycobacterium smegmatis with 70.1 m/z (right).