A Laser Multicharged Niobium Ion Source

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The interaction of multicharged ions (MCIs) with solids releases both kinetic and potential energy.[1] The potential energy of an MCI corresponds to the sum of the ionization potentials of the electrons that are removed. The release of this potential energy induces electronic exchange and excitation. By generating MCIs with varying ionization states, both the kinetic and potential energies of the ions can be adjusted, whereas only the kinetic energy of singly charged ions can be controlled. Surface interaction of slow MCIs can be used to generate surface nanofeatures, as the released potential energy is confined to a depth of a few nanometers from the surface.[2]

A niobium laser multicharged ion source was developed using laser ablation with a 10-ns, 1064-nm pulses with laser fluences ~10−83 Jcm^{-2}. The ions were accelerated and allowed to drift in a transport line containing an electrostatic ion energy analyzer, a retarding field analyzer, and a Faraday cup. A schematic of the laser ion source and transport line is shown in Figure 1. Three distinct groups of Nb ions were detected: ultrafast, fast, and thermal. Analysis of the ion energy (E) and charge (z) showed that each group of ions experienced different acceleration potentials during plasma expansion. The ions are accelerated after they separate from the expanding plasma. Time-of-flight (TOF) signal of the thermal ions showed overlap of the signals from Nb^{1+} and Nb^{2+}. The TOF signal of the fast ions, showed separated peaks, indicating the presence of ion charges up to Nb^{7+}, as shown in Figure 2. The TOF signal showed that the ultrafast ions are composed of higher charge ions.

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[1] M.H.A. Shaim, H.E. Elsayed-Ali, "Aluminum multicharged ion generation from laser plasma," Nucl. Instrum. Meth. B 356–357, 75–80 (2015), https://doi.org/10.1016/j.nimb.2015.04.066.

[2] H. Gnaser, Low-energy ion irradiation of solid surfaces, in: Springer Tracts in Modern Physics, Springer, Berlin, New York, 1999, pp. 1–6, https://doi.org/10.1007/bfb0110693.

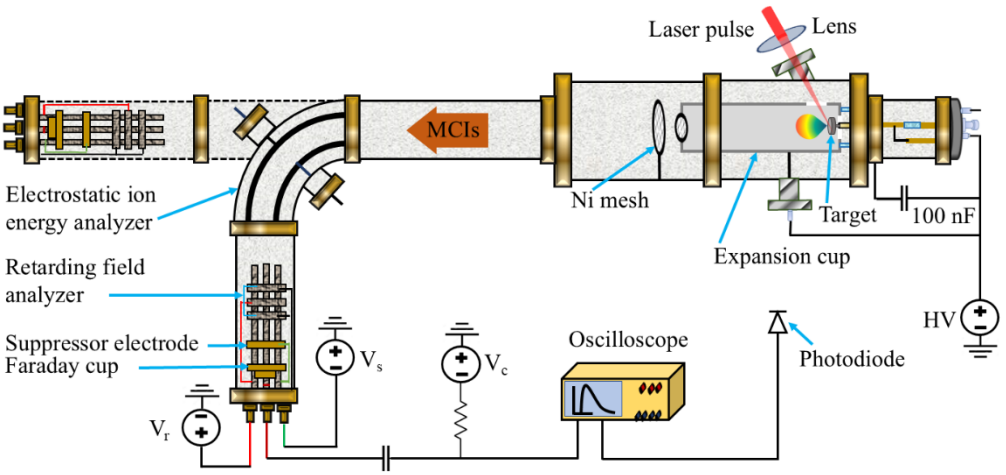

Figure 1: A schematic of the laser ion setup is shown featuring the target chamber, drift tube, expansion cup (EC), electrostatic ion energy analyzer (EIA), three-grid retarding field analyzer (RFA), time-of-flight analyzer containing the Faraday cup (FC), and suppressor electrode (SE). V_r, V_s, and V_c are voltages applied to retarding electrode, SE, and FC, respectively. The ion transport line can be configured with or without the EIA, while maintaining a consistent distance from the target to the FC.

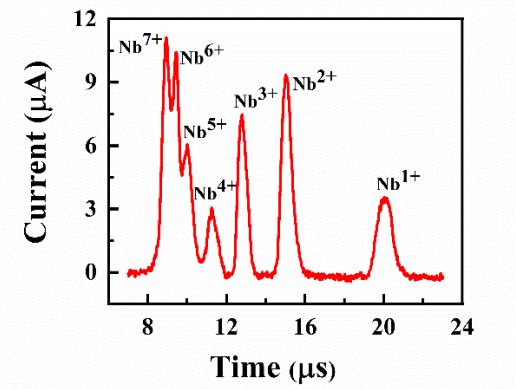

Figure 2: Fast Nb ions TOF detected with a 6000 V voltage applied to the target and EC and using a 4-mm slit at the exit of the EIA. Nb ions from Nb^{1+} to Nb^{7+} are observed.