Evaporative cooling of atomic and molecular ions by autoresonance in an electrostatic ion beam trap

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Translational cooling of atomic and molecular ions is a requisite in several research areas. An Electrostatic Ion Beam Trap (EIBT) can trap any ion with any mass or charge using the same tuning conditions; therefore, it is an ideal ion trap for ion beam cooling. An external chirp sinusoidal electric field is applied on one of the EIBT mirror electrodes. In this procedure, called autoresononace (AR), a bunch of ions is accelerated out of the rest of the ion beam population. Depending upon the chirped field intensity and rate, one can cool such a bunch of ions. A cooling process has been demonstrated in the EIBT that, by using an autoresonance procedure, reduced the temperature of ions from an initial value of ~40 K down to about 0.15 K in 80 ms and with ion-ion interaction [1]. Figure 1 shows the calculated bunch internal temperature as a function of the AR voltage using the measured ion bunch velocity distributions. The AR threshold field for an ion bunch acceleration is about 0.052 V. The arrow in the figure indicates the initial temperature of the ions in the trap before the AR process.

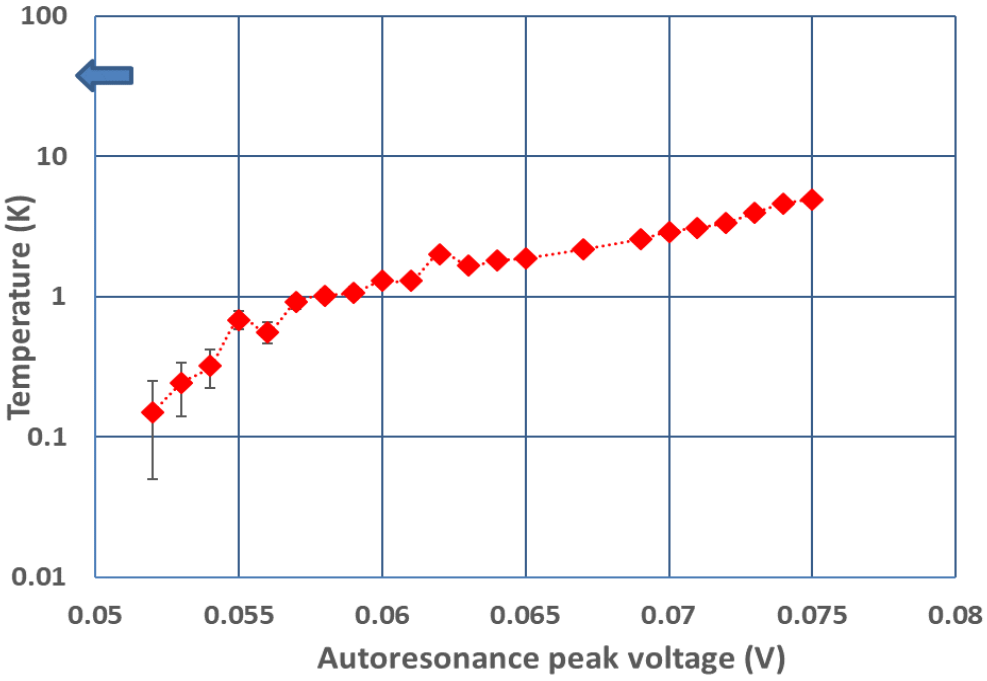

Fig 1: The temperature of the ion bunch after the autoresonance dragging process. The arrow represents the intial temerature of the ions in the EIBT

During the process, it has been shown[1] that the ion-ion collisions transfer kinetic energy from the cold population to the hotter population, which in turn is evaporated from the ion bunch, hence reducing the temperature and increasing the phase-space density. Further experiments and theoretical models are ongoing to improve the cooling efficiency and to achieve lower temperatures.

References

[1] R. K. Gangwar, K. Saha, O. Heber, M. L. Rappaport, and D. Zajfman, Phys. Rev. Lett. 119, 103202 (2017).

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