Sympathetic cooling of mixed ion Coulomb crystals

Hans A Schuessler[1], Kunihiro Okada[2], Aiko Takamine[3], Michiharu Wada[3], Feng Zhu[1], Cade Perkins[1], James Bounds[1], and Hideki Iimura[4]

[1]*Department of Physics & Astronomy, Texas A&M University, MS4242, College Station, USA*
[2]*Department of Physics, Sophia University, 7-1 Kioicho, Chiyoda, Tokyo 102-8554, Japan*
[3]*RIKEN Nishina Center for Accelerator-Based Science, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
[4]*Department of Materials Science, Japan Atomic Energy Institute,Tokai-mura, Naka-gun, Ibaraki 319-1195 Japan*

We demonstrate the application of reliable methods to determine both the average micromotion energies and the number of sympathetically cooled ions (SCIs) embedded in mixed-ion Coulomb crystals in a linear Paul trap. The number of the SCIs and the micromotion energies for the observed mixed-ion crystals are determined by comparing experimentally obtained images with molecular-dynamics simulations, where the kinetic energies of SCIs trapped in rf fields are averaged in cold elastic collisions between the laser-cooled ions and virtual very light atoms. This combined method quickly achieves the quasiequilibrium state of large mixed Coulomb crystals with over 103 ions, regardless of the initial conditions, and shows that the previously used pseudopotential-based adiabatic approximations should be replaced by such molecular-dynamics simulations. In addition, a pattern-matching recognition procedure is introduced which objectively ascertains the number of ions. We also apply the presented characterization method for sympathetic cooling of highly charged ions by laser cooled singly charged ions. This work is financially supported in part by a Grant-in-Aid for Young Scientists from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Robert A. Welch Foundation under Grant No. A1546, and the Matsuo Foundation.