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Stopping power of Coulomb crystals for precision measurements in antimatter and nuclear physics

Laser Doppler cooling, a technique well-established since 1975, exploits laser light to cool atoms. When applied to trapped ions, this method leads to the formation of unique structures known as Coulomb crystals. These organized and cooled ion clouds present promising prospects in spectroscopy, particularly for species inaccessible to laser Doppler cooling via sympathetic cooling. The extension of these techniques beyond atomic physics introduces new avenues for detecting, capturing, and cooling a diverse range of charged objects for precision measurements, encompassing antimatter, highly charged ions, macromolecules, and potentially radioactive ions.

In our ongoing research program ESPRIT (Exploring stopping power in ion traps), we investigate the interactions of various projectile ions through Coulomb crystals within radiofrequency traps, disturbing their thermal equilibrium. Within our experimental setup, GiantMol, a radiofrequency ion trap is utilized to produce laser-cooled calcium ion clouds. This setup is complemented by an external ion source capable of generating projectiles with varying mass and charge states. Additionally, specific ion optics are employed to ensure the precise separation and injection of ions into the radiofrequency trap. Through this configuration, our goal is to explore the feasibility of utilizing Coulomb crystals as detectors and potentially as capture media for heavy ions. These investigations present novel opportunities in nuclear physics, potentially enabling the cooling of radioactive ions to temperatures necessary for high-resolution laser spectroscopy or mass spectrometry. This abstract seeks to emphasize the transformative potential of laser Doppler cooling and sympathetic cooling in ion traps, with broad implications for advancing topics across various fields like antimatter physics, nuclear physics or even analytical chemistry

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