Ion cloud transport between linear RF traps

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Trapping of ions in radiofrequency (RF) ion traps is a topic of great interest for multiple applications [1]. Quantum information processing and frequency metrology are only two possible domains where single ions in RF traps play a key role [2]. Exciting physics can also be found at the other extreme, where a large ion cloud rather than a single ion is trapped [3]. Moreover, by combining different types of RF traps, a large ion cloud can serve as a basis for a microwave clock [4]. This clock needs to store a large sample and to be able to shuttle it between traps without any loss.

In order to investigate these transport processes, a new experimental set-up has been conceived and realised in our group. Our trapping device is composed of two different linear traps, aligned along the z-axis. The first trap consists of a quadrupole trap (r_0=4mm) with two trapping zones (each of a $2z_0$=20mm) separated by an additional central electrode. The second trap is an octupole trap ($2z_0$=100mm) of identical r_0. The geometry of trapping potentials has been optimized numerically [5] to minimize anharmonic terms. In order to allow crystallization of large clouds of Ca^+ ions, trapping voltages of the order of several MHz with amplitudes of several hundred volts are applied.

While the transport of single ions in traps has gained much interested in the last few years (see for example [6]), no study has been done in transporting large clouds. The main reason being that single ion transport is studied in microfabricated traps, which cannot be transposed to large ion clouds. Our experimental system, where the quadruple trap contains two trapping zones, is perfectly suited for studies with large samples. Due to the complexity of the problem, numerical simulations can help to understand such transports. We have therefore developed a FORTRAN90 code which allows to simulate ion cloud transport using the “real” trap potential generated by SIMION8.1. Major differences exist between micro-traps and macroscopic traps, mainly the distances of the transport and the number of control electrodes that can be incorporated in the design. Compared to transport in microtraps, our experiment takes into account additional parameters, as for example the fact that the ion cloud is 3D, and the ratio of transport distance to the number of DC electrodes is several orders of magnitude larger than in micro-traps. The equations governing the dynamics have been obtained and they allow to achieve 100% transport of clouds containing more than 10 thousand ions.

We will present numerical results from 1D and 3D simulations, showing that fast (<1us) transport is in principle possible over large distances (20mm) without ion loss. Experimental results of such transports will also be reported.

References:

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